

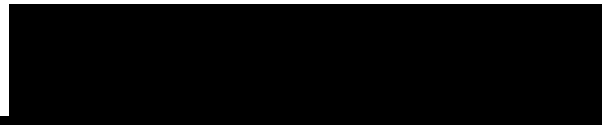
### **Installation, Operation and Maintenance Instructions** 1600°C Coal Ash Fusion Furnace - CAF G5

CAF G5

## Contents

This manual is for guidance on the use of the Carbolite Gero product specified on the front cover. This manual should be read thoroughly before unpacking and using the furnace or oven. The model details and serial number are shown on the back of this manual. Use the product for the purpose for which it is intended.

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## 1.0 Safety Information

### 1.1 General

Please read all of this section first.

Please look through the complete manual before connecting the furnace.

In particular read through the section 3.6.



This furnace must be earthed (grounded).

Do not operate the furnace at temperatures above 815 °C (1500 °F) with the door open.

The furnace door must not be left open longer than is necessary to load and unload samples from the work tube.

The furnace door must be closed and secured using the two swing bolts before commencing a Coal Ash Fusion test. It is important that the swing bolts are tightened evenly to create a gas tight seal between the door flanges. When a coal ash fusion test is running the yellow Test In Progress light illuminates on the control panel and the green Standby Mode light goes out. Do not open the furnace door when the Test In Progress light is illuminated or exposure to carbon monoxide may result. See section 1.2.

During a test only the yellow Test In Progress light should be illuminated. If any of the other three lights are illuminated (see fig 11a) then there is a fault: do not use the furnace until the fault is rectified.

During Standby Mode only the green Standby Mode light should be illuminated. If there are no lights illuminated, or if any of the other three lights are illuminated (see fig 11a) including the green Standby Mode light, then there is a fault: do not use the furnace until the fault is rectified.

Do not operate the furnace with the door or window 'O' ring seals removed or exposure to carbon monoxide may result. See section 1.2.

A regular work tube pressure test must be conducted to ensure integrity of the work tube and 'O' ring seals. See section 3.3.5.

To avoid fire, do not expose combustible materials to heat from the open door.

Do not use the furnace in the presence of inflammable or combustible chemicals: fire or explosion may result. Do not place the furnace on an inflammable surface.

When operating the furnace wear appropriate safety clothing, including eye protection and gloves.

Isolate the furnace from the electrical and gas supply and ensure that the furnace is cold before changing elements, thermocouples or undertaking other routine maintenance.

## 1.2 Carbon Monoxide Warning

Operation of the CAF furnace involves the use of carbon monoxide.



Carbon monoxide is a product of reaction of  $H_2$  and  $CO_2$ .

Carbon monoxide (CO) is a colourless, odourless, tasteless and inflammable gas which is acutely toxic. CO is introduced into the blood stream through the lungs and binds with the haemoglobin preventing it from carrying oxygen around the body. This can result in rapid damage to body tissues due to oxygen starvation. Since CO is an accumulating toxin it can be dangerous even when present in quite low concentrations over long periods of time. Individuals vary considerably in their reactions to concentrations of toxic gases; table 1 shows the typical effects of cumulative CO exposure.

### **Information extracted from Guidance Note EH43 (1996) from the Health and Safety Executive.**

To minimise the risks associated with CO it is most important that the furnace is installed and operated in accordance with this instruction manual. If the furnace operator experiences any of the effects listed above, the furnace must be isolated from the gas and electricity supplies immediately and expert advice sought. For safety guidelines seek the gas manufacturers advice.

**Table 1. Carbon monoxide in air:**

Parts per million	Effect
50	Recommended Exposure Limit (8 hours time weighted average concentration)
200	Headache after approximately 7 hours if resting or after 2 hours exertion
400	Headache with discomfort with possibility of collapse after 2 hours at rest or 45 minutes exertion.
1200	Palpitations after 30 minutes at rest or 10 minutes exertion.
2000	Unconscious after 30 minutes at rest or up to 10 minutes exertion.

For further information refer to:

- Guidance Note EH43 (1996) from the Health and Safety Executive. ISBN 0 11 883597 1
- EH40/ 2005 Workplace Exposure Limits 2011. ISBN 978 0 7176 6446 7

### 1.3 Hydrogen and Carbon Dioxide Warning

Applicable for furnaces constructed to use H<sub>2</sub> and CO<sub>2</sub> test gases with CO<sub>2</sub> 'Purge' gas.



H<sub>2</sub> can form explosive gas mixtures, take precautions to avoid leakage of H<sub>2</sub>.

H<sub>2</sub> and CO<sub>2</sub> can react to form CO.  
see section 1.2.

Carbon dioxide (CO<sub>2</sub>) is a colourless, odourless and tasteless gas that is an asphyxiant. Rapid unconsciousness occurs at levels above 11%, levels of 20 - 30% are immediately hazardous to life.

#### **Information extracted from Croner Publications Ltd. Substances Hazardous To Health.**

To minimise the risks associated with CO<sub>2</sub> it is most important that the product is installed and operated in accordance with this instruction manual. If the product operator experiences any of the effects listed above, the product must be isolated from the gas and electricity supplies immediately and expert advice sought. For safety guidelines seek the gas manufacturers advice.

### 1.4 Safety Warning - Refractory Fibre Insulation



**Insulation made from High Temperature Insulation Wool  
Refractory Ceramic Fibre, better known as (Alumina silicate  
wool - ASW).**

This product contains **alumino silicate wool** products in its thermal insulation. These materials may be in the form of blanket or felt, formed board or shapes, slab or loose fill wool.

Typical use does not result in any significant level of airborne dust from these materials, but much higher levels may be encountered during maintenance or repair.

Whilst there is no evidence of any long term health hazards, it is strongly recommended that safety precautions are taken whenever the materials are handled.

**Exposure to fibre dust may cause respiratory disease.**

**When handling the material, always use approved respiratory protection equipment (RPE-eg. FFP3), eye protection, gloves and long sleeved clothing.**

**Avoid breaking up waste material. Dispose of waste in sealed containers.**

**After handling, rinse exposed skin with water before washing gently with soap (not detergent). Wash work clothing separately.**

Before commencing any major repairs it is recommended to make reference to the European Association representing the High Temperature Insulation Wool industry ([www.ecfia.eu](http://www.ecfia.eu)).

Further information can be provided on request. Alternatively, Carbolite Gero Service can quote for any repairs to be carried out either on site or at the Carbolite Gero factory.

### 1.5 Viton 'O' Rings - Warning

The 'O' ring seals used in the CAF G5 furnace work tube assembly are manufactured from Viton. Viton is combustibile and decomposition occurs at elevated temperatures.



Decomposition products include Hydrogen Fluoride, fluorinated hydrocarbons, Carbon Monoxide and Carbonyl Fluoride. Hydrogen Fluoride is highly corrosive.

Although these seals should not be exposed to elevated temperatures during normal use, the following precautions should be taken:

- Wear neoprene gloves while handling the seals.
- Dispose according to local regulations. Landfill is recommended. Burning is not recommended except by an approved or licensed incineration agent.

## 2.0 Models Covered by this Manual

Three furnace options are available, These differ in the type of gases that are used to create the 'oxidising' and 'reducing' atmosphere and the control of those gases and the option of rear lighting particularly for lower temperature analysis, such as Biomass.

Type 1.	CO/ CO <sub>2</sub> 'reducing' gas and Air 'oxidising' gas with N <sub>2</sub> 'Purge' gas. With no rearlighting. Compatible with both: ASTM D1857 / D1857M – 04 (2010) Standard Test Method for Fusibility of Coal and Coke Ash & BS ISO 540 : 2008 Hard coal and coke. Determination of Ash Fusibility.
Type 2.	Rear Lighting option with CO/CO <sub>2</sub> 'reducing' gas and Air 'oxidising' gas with N <sub>2</sub> 'Purge' gas. Compatible with: DDCEN/TS 15370-1:2006 Solid biofuels-Method for determination of as melting behaviour. & PD CEN/TR 15404:2002 Solid recovered fuels-Methods for the determination of ash melting behaviour by using characteristic temperatures. & ASTM D1857 / D1857M – 04 (2010) Standard Test Method for Fusibility of Coal and Coke Ash & BS ISO 540 : 2008 Hard coal and coke. Determination of Ash Fusibility.
Type 3.	H <sub>2</sub> and CO <sub>2</sub> 'reducing' gases and CO <sub>2</sub> 'oxidising' gas with CO <sub>2</sub> 'Purge' gas. With no rear lighting. Compatible with - BS ISO 540 : 2008 Hard coal and coke. Determination of Ash Fusibility.

## **3.0 Installation**

### **3.1 Unpacking and Handling**

When unpacking and handling the product, always lift it by its base. Do not use the door or any other projecting cover or component to support the equipment when moving it. Use two or more people to carry the product where possible.

Carefully remove any packing material from inside and around the product before use. Avoid damaging the surrounding insulation when removing packing materials.

Avoid applying force to internal components such as the work tube or insulation.

### **3.2 Packing List**

The packaging should contain the following components:

1 off	Furnace Assembly
1 off	Work tube and back seal assembly, see fig 2.
1 off	Work tube front insulating collar.
1 off	Work tube gasket.
1 off	Front tube seal assembly, see fig 3.
1 off	Door arm assembly (without door plug), see fig 4.
1 off	Door plug, see fig 4.
1 off	Flexible gas pipe.
1 off	Camera mounting bracket, see fig 5a.
1 off	Lens and camera assembly, see fig 5b.
6 off	Panel hole blanking plugs.
1 off	Sample Carrier.
1 off	Sample Loading Tool, see fig 21.
100 off	Sample tiles.
1 off	'Window retaining ring' spanner.
1 off	Cone mould.
1 off	1.25 mm Allen key
1 off	150 mm length of Gold wire (1063 °C fuse wire).
1 off	150 mm length of Palladium wire (1554 °C fuse wire).
1 off	Carbon Monoxide monitor
1 off	RS232 Interface cable.
1 off	Ethernet connection cable, Furnace/ Computer.
1 off	Computer.
1 off	Monitor.
1 off	Keyboard.
1 off	Mouse.
1 off	Memory Stick - containing a copy of the software and operation manual.
2 off	Computer power cable.
1 off	Installation, Operation and Maintenance Instructions for the CAF Test Furnace.

### 3.3 Assembly of the Furnace

#### 3.3.1 Element Fitting

Ensure that the furnace is isolated from the mains supply. Remove the back panel from the furnace unit.

**Note:** The heating elements are fitted at the factory to test the furnace but are removed for transit. These elements are extremely fragile, and can be damaged by contamination: handle them with care and keep them clean. Avoid touching the heating part.

Slide one insulating collar over each element, then gently slide the element into its hole in the furnace until the tip of the element locates in the front insulation, see fig 1. If the element does not slide in freely check that you are holding it in line with the hole; it may help to rotate the element whilst sliding it in. Only light finger pressure should be required. When the element is in position slide the insulating collar up against the furnace back insulation.

Use the braids to link the elements and connect them to the terminal posts as shown in fig 1. Make sure the braids do not touch any other component, or each other.

### 3.3.2 Installing the Work Tube and Rear Seal Assembly

Ensure that the furnace is isolated from the mains supply, remove the back panel and front panel from the furnace unit.

Remove the fixing nut and one washer from each of the work tube back support fixing pillars on the back of the furnace. See fig 6a, 6b.

Take the rear insulation assembly. See Fig 2.

Carefully insert the work tube and back seal assembly into the furnace from the back and slide it through the furnace until the work tube is protruding from the front. The work tube is correctly positioned when: the work tube insulating collar is in contact with the back face of the furnace heating chamber, the work tube back support is located over the fixing posts and the thermocouple sheath is at the top above the vent tube fitting. Secure the work tube back support in position using the fixings provided. See fig 6.

**Note:** Take care not to stress the work tube. The work tube back support must be parallel to the back of the furnace heating chamber and it should not be necessary to bend the back support fixing posts to locate it.

Connect the numbered thermocouple leads to the thermocouple connecting terminals mounted on the work tube back support. Ensure correct polarity, compensating cable colour coding is:

thermocouple leg	colour
negative	white
positive	orange

Rear Lighting Option.

If the rear lighting option is fitted connect the 6 way socket and plug that connects the LED lights to the LED Driver positioned in the bottom right of the case looking at the rear of the unit, see fig 23.

Make sure the element braids do not touch any metal components of the back tube seal assembly.

### 3.3.3 Fitting the Work Tube Front Seal Assembly

Slide the work tube front insulating collar over the front protruding part of the work tube until it is in contact with the front face of the heating chamber.

Dismantle the front tube seal assembly by removing the six socket screws. See fig 3.

Slide the work tube ring over the front of the work tube with the internal chamfer facing towards the front. See fig 3 and See fig 7.

Fit the tube 'O' ring over the front of the work tube and position it uniformly 7.0 mm from the front edge of the work tube. See fig 7.

Fit the work tube gasket to the work tube sealing ring as fig 7, position the work tube sealing ring on the front end of the work tube and loosely secure to the work tube ring using the six socket screws provided.

Rotate the front seal assembly so that the swing bolts are positioned horizontally and the gas inlet fixing is at the lower left side of the work tube. See fig 8.

Tighten the six socket screws evenly in the sequence as shown by numbers 1 to 6 in fig 8. Ensure that the work tube sealing ring is held firmly against the end of the work tube and is evenly spaced from the work tube ring about its circumference.

Fit the furnace front panel in position and adjust the work tube front support bracket to support the weight of the work tube assembly. See fig 9.

**Note:** Do not stress the work tube. With the work tube front support correctly adjusted there should be a slight gap around the circumference of the tube within the aperture of the furnace heating chamber. This can be tested for by lifting the work tube upwards from the support bracket, only a slight gap should be observed between the work tube and the support bracket when the work tube is lifted as far as possible.

### 3.3.4 Fitting and Adjusting the Door Arm Assembly

**Note:** the refractory door plug is fragile: handle with care.

The door plug is supplied separate from the door arm assembly to avoid transit damage. Fit the door plug to the door arm assembly before fitting the door assembly to the furnace. Refer to section 5.4.

Pull out the door slide shaft to its full extension and rotate it fully anti clockwise (view from front). The door slide shaft will only rotate when it is fully extended.

Remove the four socket screws from the back of the door arm assembly mounting block only; do not remove the front fixing screws, which are factory set to position the door arm. See fig 10a.

Slide the door arm assembly onto the end of the door slide shaft and secure firmly in the door open position shown in fig 10. using the four socket screws. Take care to tighten the socket screws evenly to avoid any distortion in the door arm assembly.

**Caution:** To allow the door side shaft to slide in and out, some clearance is required in the door mechanism; consequently there is a small radial movement in the door slide arm when the door arm is pushed in towards the work tube. Because of this radial movement it is possible for the door plug to contact the work tube front seal assembly if the door handle is lifted as the door arm is pushed inwards: take care to avoid this happening.

Carefully swing the door arm in a clockwise direction (view from front) to its stop position, ensuring that the door plug does not touch tube end guard. The door plug should be clear of the furnace in its fully withdrawn position. It should not be possible to push the door arm in towards the furnace until the door arm is rotated fully clockwise (view from front) and the door plug is in line with the work tube front aperture.

The door arm assembly has an Ethernet cable running through it for the camera. The cable has a connector at each end. One end of the cable comes out of the conduit cable through the conduit plate and is connected to the Ethernet connector inside the aperture in the left hand side of the furnace case see fig. 22. Once the cable is connected carefully insert the connector into the aperture and fix the conduit plate into position.

**Note:** take care to keep the cable away from sharp edges.

If no other options are to be added to the rear of the unit i.e. rear lighting option, the back panel can be replaced, ensuring that the earth tag and fan connections are securely fitted.

Carefully slide the door plug into the work tube ensuring that it is clear of the front seal assembly. If the door plug is misaligned, adjustment of its position in relation to the work tube can be achieved by loosening the front and back door arm fixing screws and rotating the door arm about the door slide shaft axis. See fig 10a.

### 3.3.5 Pressure Testing of the Work Tube Assembly

**Note:** To ensure that the work tube assembly has been correctly installed it is necessary to pressure test the furnace prior to use.

Due to the high work tube temperatures used during CAF testing the tube 'O' ring seals will deteriorate with time. The furnace work tube also has a finite life and may eventually crack due to normal wear and tear. It is necessary to conduct a pressure test of the work tube assembly at regular intervals during normal use of the furnace to ensure integrity of the work tube and 'O' ring seals. The following procedure applies:

Connect one end of the flexible gas inlet pipe (normally connected between the bulkhead connection on the front of the furnace case and the work tube front seal assembly) to the work tube front seal assembly. See fig 11b. Connect the other end to an adjustable compressed air test line or inert gas supply capable of delivering up to 4 psi. Check all air/ gas connections for leaks, any leakage from the air/ gas supply line may affect the pressure test results.

Close the door assembly and clamp in position using the swing bolts.

Securely block the work tube vent at the back of the furnace using blanking plug.

Pressurise the work tube assembly via the flexible gas inlet pipe to 3 psi  $\pm$  1 psi using compressed air or inert gas.

Once the furnace gas system is pressurised to 3 psi  $\pm$ 1 turn off the air supply, the gas system should stay pressurised to 3 psi  $\pm$ 1 for 5 minutes.

Following successful pressure testing of the work tube assembly, connect the flexible gas inlet pipe to the bulkhead connection on the front of the furnace case. Check all external gas connections and vent tubes for leaks prior to using the furnace.



Under no circumstances should any objects be placed on top of the product. Always ensure that any vents on the top of the product are clear of any obstruction. Always ensure all cooling vents and cooling fans (if fitted) are clear of any obstruction.

### 3.4 Positioning the Furnace

Significant amounts of carbon monoxide may be exhausted from the work tube during the use of this furnace. Carbon monoxide is toxic and inflammable (see section 1.2) and must be ducted out of the building. See also section 3.7.



The furnace is designed to be gas tight during normal operation, but incorrect installation or component failures due to misuse or wear and tear could give rise to a high presence of carbon monoxide. To minimise risk to the operator in the event of a high presence of carbon monoxide the furnace must be installed under a suitable forced air extraction hood. An example is shown in fig 12. The extraction hood must be ducted out of the building and must be operating whenever the furnace is in use. The room must be well ventilated and the 'fresh air in' ventilation should exceed the hood extraction to ensure that fumes do not escape into the room.

As a precaution the furnace is supplied with a carbon monoxide detector. If the CO detector is correctly installed it will alert the furnace operator in the event of a leak of carbon monoxide that is not removed by extraction.

Note: The CO detector must be positioned and installed in accordance with the manufacturer's instructions supplied. In the event of a CO detector alarm evacuate the area immediately and seek expert advice. Isolate the furnace from the gas and electricity supply only if it is safe to do so.

Ensure that the furnace is installed in such a way that the electrical supply and the gas supply can be quickly switched off in the event of an emergency without any danger to the operator.

Ensure that there is a minimum free space of 100 mm around the furnace and do not obstruct any of the vents in the case as these are required to keep internal components cool.



Under no circumstances should any objects be placed on top of the product. Always ensure that any vents on the top of the product are clear of any obstruction. Always ensure all cooling vents and cooling fans (if fitted) are clear of any obstruction.

### 3.5 Electrical Connections



Connection by a qualified electrician is recommended.

The voltage or range of voltages on which the furnace may be operated is given on the furnace rating label. See fig 11a. Check that the electrical supply voltage is compatible with the voltage on the label, and that the current capacity is sufficient for the maximum current on the label before connection to the electrical supply.

The furnace should be permanently connected to the correct supply through a wall mounted isolating switch or an easily removable plug. The switch or plug should be within easy reach of the operator. Unless a supply cable is fitted the electrical supply connections are to be made to terminals mounted inside back of the furnace, accessed by removing the furnace back panel.

The terminals are marked according to the power supply, connect as shown in the table below. The electrical supply must incorporate an earth (ground).

Electrical Connection Details:

Supply	Terminal Label	Cable Colour	Supply Types	
			Live - Neutral	Reversible or Live-Live
1-phase	L1	Brown	to live	to either power conductor (For USA 200-240V, connect L1)
	N / L2	Blue	to neutral	to the other power conductor (For USA 200-240V, connect L2)
	PE	Green/ Yellow	to earth (ground)	to earth (ground)
2-phase	L1	Black	to phase 1	
	L2	Black	to phase 2	
	N	Light Blue	to neutral	
	PE	Green/ Yellow	to earth (ground)	

### 3.6 Voltage Level and Power Limit Settings








Check the furnace rating label voltage. If the actual supply is not the same as the voltage on the label, the controller power limit should be adjusted as follows. The power limit can also be changed through the software if connected, see section 5.3.

If the actual supply voltage is higher than the voltage on the rating label (or the voltage for which the furnace was last set), immediately after switch-on set the temperature setpoint to zero, to prevent heating and drawing excessive current.

First select user level 2. Press and hold the page  until 'Access Goto' is displayed.

Select Level 2 using the down  or up . Access pass code should now be displayed.

Using the down  or up  enter pass code 9. The word 'Pass' should be shown briefly and then the display will revert back to main display screen.

To Select Output high. From the main screen. Press page  twice to display 'Control output High'. Using the down  or up  keys select the correct power setting.

Correct values for the OP.Hi parameter, with new elements, are:

200 V	208 V	220 V	230 V	240 V
		380 V	400 V	415 V
79%	74%	65%	60%	55%

See also the section 5.3

### 3.7 Exhaust Vent Connections

**Note:** Significant amounts of carbon monoxide may be exhausted from the work tube during the use of this furnace. Carbon monoxide is toxic and inflammable (see section 1.2) it is recommended that the vent tube is routed out of the building.



The furnace must always be positioned as recommended in section 3.4.

The furnace has two exhaust vents, the main vent at the back of the heating chamber and a safety pressure relief vent at the side of the furnace. The purpose of the safety vent is to prevent dangerous pressure build up as the furnace warms up if the main vent tube becomes blocked.

The main vent and the safety pressure relief vent must be connected to separate vent runs and routed out of the building.

With the back panel removed access is gained to the main vent tube fitting situated on the work tube back seal assembly below the thermocouples. The main vent tube fitting is a 12 mm x 3/8" BSP adapter suitable for connecting 12 mm diameter copper tube. See fig 6.

The safety pressure relief vent tube fitting is a 6 mm x 1/8" BSP adapter suitable for connecting 6 mm copper tube. See fig 11a.

**Note:** It is important that the vents are not restricted in any way, do not use a tube of less than 6 mm diameter for the safety pressure relief vent connection and 12 mm for the main vent connection.

Check regularly that the main and safety pressure relief vents are clear from obstructions.

### 3.8 Gas Connections

#### 3.8.1 Furnaces for CO/ CO<sub>2</sub> and Air Test Gases with N<sub>2</sub> Purge Gas

*See below if a mixer box for separate CO & CO<sub>2</sub> inputs is supplied.*

**Note:** The gas supply pressure required is 4 psi (0.276 bar) and must not exceed this.

There are three gas connections on the side of the furnace, CO/ CO<sub>2</sub> pre mixed 'reducing' atmosphere gas, Air 'oxidising' gas and N<sub>2</sub> 'Purge' gas. See fig 11a. It is recommended that the gases are supplied to the furnace via separate isolation valves that can be quickly switched off in the event of an emergency or potential hazard without danger to the operator. See section 1.2.

The 'Purge' gas line is pre-set to allow a flow of N<sub>2</sub> into the work tube equal to 6 litre/ minute, the 'oxidising' and 'reducing' atmosphere gases have adjustable flow via the flow meters on the front of the furnace. See fig 11a. The gas supply fittings are 6 mm x 1/8" BSP adaptors suitable for connecting 6 mm copper tube.

Separate CO and CO<sub>2</sub> supplies.

*If a mixer box is supplied, separate input connections of CO and CO<sub>2</sub> may be made to the lower connections at the back of the box. A pipe from the upper connection is to be taken to the CO/ CO<sub>2</sub> inlet on the furnace.*

*The box is fitted with two flow-meters which may be adjusted to ensure that equal mixtures of CO and CO<sub>2</sub> are supplied. The box also contains two non-return valves to ensure that neither gas can flow back out of either inlet connection.*

#### 3.8.2 Furnaces for H<sub>2</sub> and CO<sub>2</sub> Test Gases with CO<sub>2</sub> Purge Gas.

**Note:** The gas supply pressure required is 4 psi (0.276 bar) and must not exceed this.

There are three gas connections on the side of the furnace, CO<sub>2</sub> 'oxidising' atmosphere gas, H<sub>2</sub> (mixed with CO<sub>2</sub> in the work tube) 'reducing' atmosphere gas and CO<sub>2</sub> 'Purge' gas. See fig 11a. It is recommended that the gases are supplied to the furnace via separate isolation valves that can be quickly switched off in the event of an emergency or potential hazard without danger to the operator. See section 1.3.

The 'Purge' gas line is pre-set to allow a flow of CO<sub>2</sub> into the work tube equal to 6 litre/ minute, the 'oxidising' and 'reducing' atmosphere gases have adjustable flow via the flow meters on the front of the furnace. See fig 11a. The gas supply fittings are 6 mm x 1/8" BSP adaptors suitable for connecting 6 mm copper tube.

### 3.9 Camera Mounting and Connections

Fit the camera mounting bracket onto the door arm as shown in fig 5c and 5d. Note that the camera shown in fig 5c and 5d is not fitted for this operation.

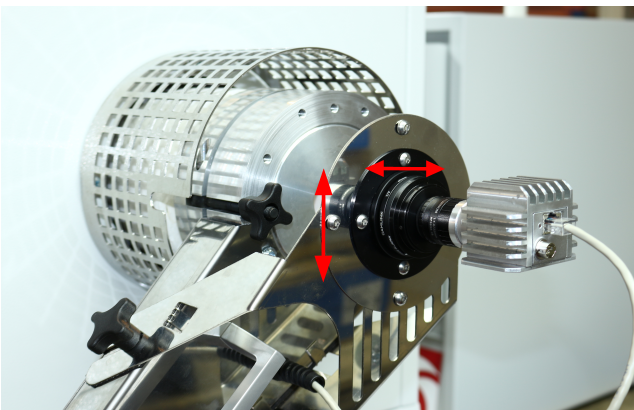
Note: Depending on the age of your furnace, it will have one of two camera mount fittings. Older models will have the type 1 fitting, while newer models will have the type 2 fitting.

### Fitting Type 1 - Bayonet

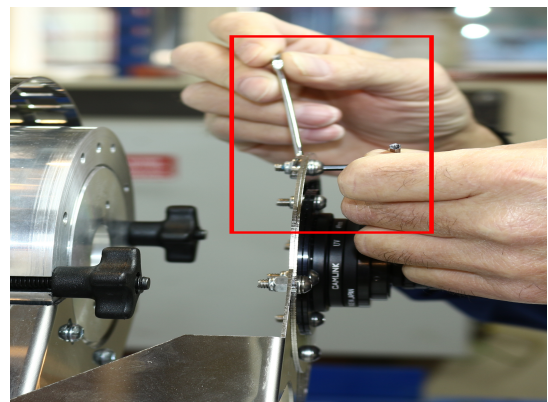
- Mount the lens and camera assembly (fig 5b) onto the camera mounting bracket as shown in fig 5e and 5f.
- Rotate the lens and camera assembly anti-clockwise to locate in position. The socket head screws are fixed in position and do not require tightening.
- Ensure that the camera is in a horizontal position.
- To rotate the camera independently of the lens, hold the camera firmly in position and use a 1.25 mm Allen key to loosen the three grub screws positioned around the adapter ring as shown in fig 5b, and position the camera horizontally.
- Once the camera is in the correct position, tighten the three grub screws and release the camera.
- Connect the Ethernet cable from the front of the door arm to the Ethernet socket on the rear of the camera. See fig 11a.

### Fitting Type 2 - Screw

- Mount the lens and camera assembly onto the camera mounting bracket as shown in fig 5e and 5f.
- Secure the camera assembly in place with the four nuts and socket head screws provided.
- Screw the nuts onto the screw threads by hand, then hold them in place using an 8 mm spanner.
- Tighten the screws using a 3 mm Allen key.
- To adjust the positioning of the camera, loosen the outer screws to allow vertical movement, or the inner screws to allow movement horizontally.



*Horizontal and Vertical Adjustment*



*Securing Camera Assembly*

#### 3.9.1 Camera and Lens Settings

1. The camera settings are pre adjusted in the software to give the best image quality and should not need any additional further adjustment.
2. The lens is manually adjusted to give the best quality picture in the following way:
  - Focusing ring on the front of the lens, see fig 5b.
  - Aperture adjustment, see fig 5b. The ideal position for the aperture is at f16. At this position exposure will be maintained between 450 °C (with rear lighting) and 1600 °C. If a specific test temperature range is to be utilised i.e. maximum temperature set

to 1200 °C, the aperture can be set to a suitable position to maximise the exposure range e.g. f8.

### 3.9.2 Adjusting the Lens.

To adjust the lens for the ideal image quality the furnace and computer must be connected, see section 3.10 and the software must be running in configure mode see section 4.7.2. The image displayed in the image window is a real time image, so the camera focus can easily be adjusted. The camera must be mounted as described above.

Prepare a number of test samples and load into the work tube as described in section 4.5. Close the door and ensure it is securely closed using the swing bolts.

For there to be sufficient light in the work tube to allow image capture the furnace must be either at a standby temperature of 450 °C with rear light activated (if available) or at a standby temperature of 815 °C.

With the lens set at a suitable aperture, ideally f16 an image should now be displayed in the software. Loosen the focus locking screw and with the focusing ring at the front of the lens see fig 5b the image can be focused on the screen. It may be useful to take the weight of the camera in one hand while focusing with the other. Once the image is focused on the screen the focus locking screw can now be tightened (care must be taken not to over-tighten these screws.)

**Note:** As the furnace warms up the work tube will increase slightly in length causing the camera focus to alter, it may be necessary to re-focus the camera during the initial Ash Fusion test run. Once the camera is focused the focus ring can be locked in position using the locking screw, unless the camera is disturbed it should not require re-focusing during subsequent tests.

## 3.10 Computer Connections

Unpack the computer from its transit boxes and assemble in accordance with the manufacturers instructions provided.

Connect the Ethernet cable from the Ethernet socket on the back of the furnace case to the Ethernet socket on the back of the computer.

Connect the comms lead from the 'Comms Port' on the back of the furnace to the comms port on the back of the computer.

Connect the Monitor DVI in lead to the socket on the rear of the computer via the DVI to display port adaptor.

Connect the keyboard and mouse to a USB socket on the rear of the computer.

## 4.0 Operating Instructions

### 4.1 Furnace Start-Up

This furnace is available with either of two gas options (These cannot be converted - see section 2.0 for more details):

Type 1/ Type 2	CO/ CO <sub>2</sub>	Reducing Gas	Rear lighting version available.
	Air	Oxidising Gas	
	N <sub>2</sub>	Purge Gas	
Compatible with both: ASTM D1857/ D1857M - 04 (2010) Standard Test Method for Fusibility of Coal and Coke Ash & BS ISO 540: 2008 Hard coal and coke. Determination of Ash Fusibility. & DDCEN/ TS 15370-1:2006 Solid biofuels - Method for determination of ash melting behaviour. & PD CEN/ TR 15404: 2002 Solid recovered fuels - Methods for the determination of ash melting behaviour by using characteristic temperatures.			
Type 3	H <sub>2</sub> and CO <sub>2</sub>	Reducing Gas	
	CO <sub>2</sub>	Oxidising Gas	
	CO <sub>2</sub>	Purge Gas	
	Compatible with - BS ISO 540: 2008		

The principle of operation is the same for both types. The furnace is normally supplied programmed to operate between a pre-determined setpoint (start temperature) and 1500 °C at a ramp rate of 7 °C/ minute. The target temperature is set to 1500 °C to avoid operating the furnace at high temperatures unnecessarily. See section 4.7.2.2. The following text describes how to use the furnace with this program.

1. Open the furnace door to check that the silica window is clean. Any slight haze should be removed before use. If neglected this haze quickly thickens and becomes impossible to remove. See section 5.5 for instructions on how to remove and clean the viewing window.
2. Turn on the 'oxidising', 'reducing' and 'purge' gas supplies. If the 'purge' gas is not present when the furnace electrical supply and instrument switch are on the control system will activate an alarm buzzer and illuminate a warning light on the

control panel. See fig 11a. This alarm will continue until the furnace is turned off and the 'purge' gas supply is restored. While the alarm is activated the control system will not allow introduction of 'reducing' gas.

3. Switch on the furnace electrical supply, the cooling fans will run. Operate the instrument switch to activate the control system, the furnace will begin to heat up to the start temperature and the work tube will be purged with 'Purge' gas for 5 minutes. The standby temperature is adjustable using the software, see section 4.7.2.2.

**Note:** Initial heat up of the furnace may create a strong odour from the binders in the new insulation materials; it is therefore recommended that the furnace is located where there is adequate extraction during the first heating phase. The fumes from the binders may also cause interference with the internal CO sensor during initial heat up (see fault analysis in section 6.0).

For furnaces constructed to use CO/ CO<sub>2</sub> and Air test gases with N<sub>2</sub> 'Purge' gas, (compatible with ASTM D1857/ D1857M -04 (2010) & BS ISO 540: 2008 & DDCEN/ TS 15370-1:2006 & PD CEN/ TR 15404:2002) the start temperature is adjustable from 400 °C.

For furnaces constructed to use H<sub>2</sub> and CO<sub>2</sub> test gases with CO<sub>2</sub> 'Purge' gas,

(compatible with BS ISO 540: 2008) the start temperature is adjustable from 815 °C.

To switch the furnace off, set the instrument switch to off, see fig 11a. The case cooling fans remain on. Leave the fans on until the furnace cools to below 300 °C. If the furnace is to be left off unattended, isolate it from the electrical supply.

**Note:** It is not recommended to operate the furnace continuously at temperatures above 1500°C. The furnace is designed to operate to a programmed ramp; continuous operation at elevated temperatures will shorten the life of the elements, insulation and tube end seals.

## 4.2 Eurotherm Controller

The Eurotherm controller is configured to control the furnace and provide the other signals necessary to switch gas flows, rear lighting (if fitted) and communicate with the CAF Test Software. All the Eurotherm controls required for ash fusion testing are accessed through the software.

## 4.3 Computer Start-Up

The computer is set up by Carbolite Gero to run the following software:

Microsoft Windows 7 embedded.

Carbolite Gero Ash Fusibility Test Software:

Although the software is already installed, an installation memory stick is supplied for system support.

**Note:** Carbolite Gero accept no responsibility for any damage to software loaded onto the computer by the operator and accept no responsibility for damage to the computer or its software resulting from the use of any software or hardware not supplied by Carbolite Gero.

Switch on the computer and monitor, and double click on the Carbolite Gero icon displayed on the desktop screen. The Carbolite Gero Ash Fusibility Test' software will load and be displayed with an image from the camera if the correct connections have been established.

**Note:** This software is Windows 7 embedded compatible; all normal Windows 7 functions apply.

When running the software the following may occur:

#### 4.3.1 Communication Failure:

The connection between the furnace and the computer can be confirmed by checking the "Camera Status" and "Controller Status" indicator in the lower left of the software window. If the status is highlighted red "disconnected" for either the camera or the controller, check the cable connections, then allow a few seconds for the computer to identify the equipment, after which the software (not the computer) can be restarted. If the correct connections have been made the status indicators should be green indicating "connection".

## 4.4 Gas Set-Up

The gas sequence is started automatically by the furnace controller. The gas sequence is as follows:

When the instrument switch is turned on the control system will open the 'purge' gas solenoid valve and purge the work tube for a duration of 5 minutes, after which the system will go into 'standby' mode and the green 'standby' indicator will illuminate.

**Note:** In the event of a power failure during standby the 'purge' gas will flow continually until the power is restored. When the power is restored the 'purge' gas timer will run for 5 minutes if the system was at the set standby temperature i.e. 815 °C, when the power was interrupted.

If the system had not reached its standby temperature when the power is interrupted the system will not purge again until the program is initiated.

When the controller program is started the 'purge' gas solenoid valve will open and purge the work tube for 5 minutes (during the 5 minute dwell period of the program). After the 5 minute purge period, the 'purge' gas is turned off and the test gas solenoid valve is opened.

**Note:** If the 'purge' gas supply is interrupted at the start of the test or during the test an alarm buzzer will sound and a warning light will illuminate on the control panel. See fig 11a. This alarm will continue until the furnace is turned off and the 'purge' gas supply is restored. While the alarm is activated the control system will not allow introduction of 'reducing' gas. See also section 4.1.

**Note:** During the test the yellow 'test in progress' light will illuminate on the control panel and the green 'Standby Mode' indicator will go out. Do not open the furnace door when the 'test in progress' light is illuminated. See section 1.0.

The desired test gas is selected using the 'oxidising' - 'reducing' gas selector switch on the front of the furnace control panel. See fig 11a. The test gas will flow for the duration of the controller program.

#### 4.4.1 Gas Flow Rates

To set the gas flow rates please refer to the following guidance notes:

##### **BS ISO 540: 2008**

##### **Reducing Atmosphere**

If you are testing to ISO 540: 2008 then this specification states a linear rate of flow past the test pieces of 400 mm/ min, with a note to state that this is not critical provided that it is sufficient to prevent any leakage into the furnace.

If you calculate the volume in a diameter 79 mm tube to give 400 mm linear flow per minute this gives 2.0 litre/ minute. However the gas will expand with the high temperature in the furnace. If the gas ambient temperature was 20 °C and the furnace temperature was 400 °C Boyle's law ( $PV = kT$ ) gives a volume ratio of 2.3. The 400 mm/ min within the work tube equates to 2 L/ min at 400 °C.

Therefore  $2 \text{ L} / 2.3 = 0.87 \text{ L/ min}$  at 20 °C.

Because the CAF G5 work tube has very effective gas seals ('O' rings) Carbolite Gero would recommend that after an initial purge the gas flow rate can be reduced during the test to a very low flow rate. The operator should experiment with this to confirm the flow rates that give them satisfactory and consistent results.

##### **Oxidising atmosphere**

If you are testing to ISO 540: 2008 then this specification states that the flow rate is not critical.

Carbolite Gero would recommend using a low flow rate.

##### **ASTM D1857-04**

##### **Reducing & Oxidising Atmosphere**

If you are testing to ASTM D1857-04 then this specification states a regulated gas stream to provide a flow of 1.3 to 1.5 furnace volumes per minute.

The volume of the CAF G5 work tube is 2.16 litre when the volume of the insulation plugs are taken into account. Therefore a flow rate of 1.3 volumes per minute = 2.8 litre/ minute. However the gas will expand with the high temperature in the furnace. If the gas ambient temperature was 20 °C and the furnace temperature was 400 °C Boyle's law ( $PV=kT$ ) gives a volume ratio of 2.3. The 2.8 litre/ min at 400 °C equates to 1.2 litre/ min at 20 °C.

Because the CAF G5 work tube has very effective gas seals ('O' rings) Carbolite Gero would recommend that after an initial purge the gas flow rate can be reduced during the test to a very low flow rate. The operator should experiment with this to confirm the flow rates that give them satisfactory and consistent results.

At the end of the controller program or if the program is interrupted (manual intervention) the 'reducing' gas is turned off and the 'purge' gas solenoid valve will operate to purge the work tube for a duration of 5 minutes.

**Note:** In the event of a power failure during the program the 'purge' gas will flow continually until the power is restored. When the furnace mains supply is turned off the gas supply must also be turned off.

When the power is restored the 'Purge' gas timer will run for 5 minutes after which the system will go into 'standby' mode and the green 'standby' indicator will illuminate. The program can be restarted at this point.

#### 4.4.2 Carbon Monoxide Sensor

This CAF G5I has a built in carbon monoxide sensor.

In the event of an unsafe level of carbon monoxide being present within the case the sensor will detect this.

If detected the CAF G5 will begin an automated cycle to bring the level of carbon monoxide back to a safe level

The automated cycles will run through the following steps:

- Carbon monoxide sensor will sense a high level of carbon monoxide
- Sensor will sound an alarm
- Process gas will be turned off
- Purge gas will begin and should be left on for a minimum of 5 minutes
- User can turn off/on the unit to reset.

If the alarm has been activated the user should check the following on the unit prior to re starting any testing.

- Gas system for leaks
- Work tube integrity
- Work tube end seals
- Exhaust outlet is not blocked

For further details of what to do if the carbon monoxide sensor is activated please refer to the maintenance section in the manual

### 4.5 Loading Samples into the Work Tube

Use the sample carrier and sample tiles provided. Arrange the samples as shown in fig 13a. It may be useful to spot a small drop of water in the position were the sample will be positioned as this will give the samples slight adhesion to the sample tile in preparation for loading.

1. When the furnace has reached its start temperature open the furnace door and swing it clear of the work tube to allow access. See fig 10.

**Note:** Do not operate the furnace at temperatures above 815 °C with the door open. The furnace door must not be left open longer than is necessary to load and unload samples from the work tube.

2. Once the samples are in position on the sample carrier, and the furnace door is open, take the sample loading tool and with the loading arm fully extracted place the forks of the loading tool under the lower branch of the sample carrier, and gently lift into the opening of the work tube.

**Note:** The forks of the loading tool should be in the lower position. See fig 21.

After about one minute slowly slide the samples into the tube at a rate of about 25 mm per minute to make contact with the control thermocouple sheath. See fig 13c. Once the sample is in position allow a couple of minutes for the cones to burn off before closing the door, this will allow any vapours given off by the cones to dissipate out of the tube and reduce contamination of the rear end plug and the viewing window. See section 5.5.

**Note:** It is possible to crack the work tube by inserting samples too quickly. Work tube failures are not covered by Carbolite Gero's guarantee.

**Warning:** Do not use the furnace if the work tube is cracked as there is a risk of exposure to carbon monoxide gas. see section 1.2.

3. Close the furnace door and secure using the two swing bolts. It is important that the swing bolts are tightened evenly to create a gas tight seal between the door flanges.

**Caution:** To allow the door side shaft to slide in and out, some clearance is required in the door mechanism; consequently there is a small radial movement in the door slide arm when the door arm is pushed in towards the work tube. Because of this radial movement it is possible for the door plug to contact the work tube from seal assembly if the door handle is lifted as the door arm is pushed inwards: take care to avoid this happening.

**Warning:** Do not operate the furnace with the door or window 'O' ring seals removed. See fig 17. This will result in high levels of carbon monoxide leaking from the work tube. see section 1.2.

4. Over-Temperature Alarm

Should a fault develop in the control system which causes the furnace to exceed its 1600 °C limit an over-temperature controller automatically shuts down the furnace and the over-temperature warning light illuminates on the furnace control panel. See fig 11a. The over-temperature controller is mounted inside the furnace case and is not accessible to the operator. Turning the instrument switch off and then on again once the furnace has cooled down will reset the over-temperature control.

**Note:** The over-temperature control is a safety device to protect the furnace in the event of a fault. If the over-temperature control has operated it is an indication that there is a fault present in the furnace, it is recommended that the furnace is not used until the fault has been rectified. Contact our local distributor or our service division at the address shown at the back of this manual.

## 4.6 Introduction to the CAF Test Software

The CAF G5 test software is designed to capture images from the digital camera mounted on the front of the furnace and store them in sequential order. Whether automatic analysis, manual analysis or mixture of both is preferred the method of image capture is always the same. Each image captured displays the date, time and the temperature at which the image was recorded and an optional sample identification. Test images are stored in a folder file name of your choice, which is entered at the start of the test and each individual image is recorded with the date, time, temperature and sequence number and can be played back for analysis of the test samples.

Once the images have been captured the analysis of the results can be carried out by either an automatic or manual method:

- Automatic Analysis. Each of the samples is identified by placing a numbered grid over each individual sample. The operator then has the option to activate the automatic analysis mode. When activated the system will identify the sample profile and its position within its own grid boundary. The program will then systematically analyse the deformation of each of the sequential images and identify each of the deformation points. When the program has finished analysing the images the critical deformation temperatures are automatically displayed in the results form along with the individual sample identification. Graphical data of the melting profiles are also recorded. The results table can then be saved and printed out in report form.  
**Note:** Only 8 samples can be automatically analysed at any one time.
- Manual Analysis. To aid analysis each of the samples is identified by placing a numbered grid over it. Analyses is aided by the use of a results form, which enables the critical deformation temperatures to be entered manually along with individual sample identification. The results form can then be saved and printed out in report form.

In both cases the software automatically starts and stops the furnace controller, the start temperature and interval between images is adjustable to suit your requirements. See section 4.7.2.2.

The software is designed primarily to be used with a mouse, however most operations are selectable from the keyboard if necessary and are as follows:

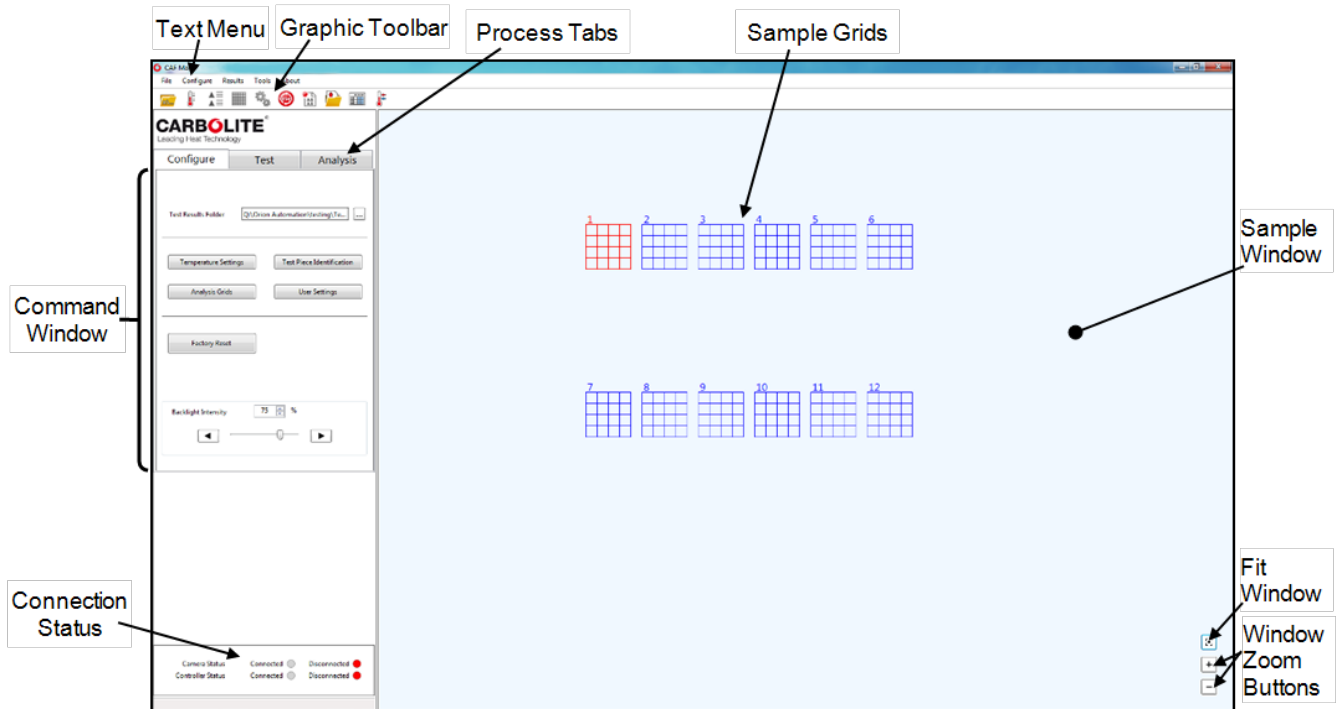
- Commands on the text menu bar at the top left of the screen are activated using the 'Alt' key together with the first letter of the respective command. For drop down menus select the first letter of the respective command without using the 'Alt' key.
- When using the 'play back' facility the images can be scrolled back and forth by dragging the scroll bar, or using the left and right 'arrow' keys. When the results window is active the < and > keys will scroll the images.

### Language Options

Initial language settings can be set by choosing from a list of 11 languages, by selecting 'Tools', 'Languages'.

Chinese	English	Japanese
Czech	French	Russian
Danish	German	Spanish
Dutch	Hungarian	

### 4.6.1 CAF Interface



## 4.7 Operation of CAF Software

Switch on the furnace and the computer, and load the test samples as described in sections 4.1 to 4.5. Proceed as follows to run a CAF test:

### Sample Window

Once the samples have been loaded into the furnace and the camera is positioned correctly a live image of the samples will be displayed in the sample window if sufficient light is available in the tube. For temperatures below 700 °C the rear lighting option (if fitted) should be used to provide illumination see section 4.7.2.7.

### Window Zoom

The image can be manipulated in the sample window by the controls in the lower right hand side of the sample window. The image can be zoomed in and out with the + and - buttons. **Note:** the image can also be zoomed by double clicking a position in the sample window (this must be outside the sample grid area). To return to the original image size select the 'Fit Window' Button.

### Command Selection

The software can be navigated using the 'Text Menu' or the 'Graphic Toolbar' or primarily the 'Process Tabs'.

### Graphic Toolbar

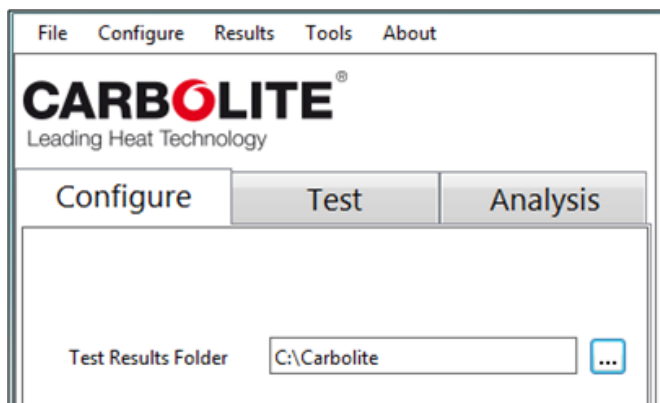
The 'Graphic Toolbar' is shown by default but can be hidden if not required by selecting from the text menu, Tools - Tool Bars - Show/ Hide.

### Connection Status

The bottom left of the software screen is the connection status indicators for the camera and the controller. Green indicates connected, red indicates disconnected.

#### 4.7.1 Process Tabs

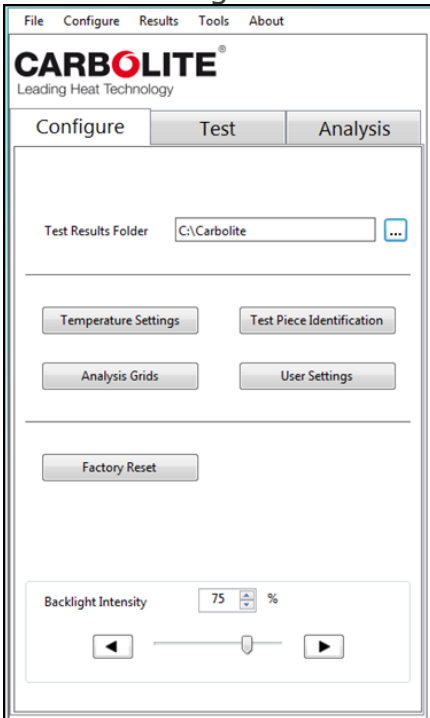
The CAF test software has been designed to maximise operator work flow by the use of process tabs along the top of the command window on the left hand side of the screen.



The Tabs will guide you through three areas of operation:

- |                  |  |
|------------------|--|
| <b>Configure</b> | Setting up the test operating parameters                               |
| <b>Test</b>      | Defining the test name, starting the test and selecting analysis type. |
| <b>Analysis</b>  | Reviewing the test data analysing and storing the results              |

## 4.7.2 Configure



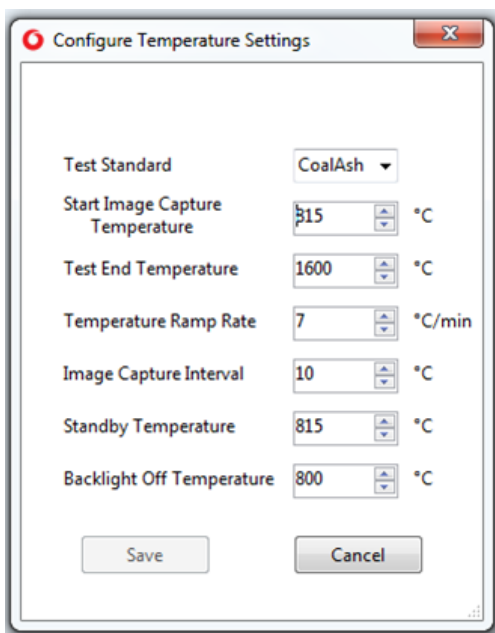
Select the 'Configuration' tab to set up the test parameters.

### 4.7.2.1 Test Results Folder

Selecting the text box or the ellipsis (square box with three dots) at the end of the test results folder box, will open the file browser where the folder location can be specified and new folders can be created.

The folder location entered will be automatically updated on the Test and Analysis tabs.

### 4.7.2.2 Temperature Settings



Click the 'Temperature Settings' button to open this window.

The test temperature parameters can be entered and saved using this window.

**Test Standard** - CoalAsh or Biomass can be selected. This will set a range of default temperatures for the selected test standard. **Note:** this is only a generic set of

temperatures as outlined in the relative standard. Users can set their own test parameter as described below.

**Start Image Capture Temperature** - Select the temperature at which the software starts to record images. It is advisable to start recording at a temperature that is as close as possible the first sample melt point as this will reduce the number of stored images. Each stored image requires 2 Mb of disc space.

**Test End Temperatures** - Set the maximum temperature the furnace will reach during the test. Range 20 °C - 1600 °C. **Note:** Avoid operating the furnace at unnecessarily high temperature as this will reduce the life of the elements, furnace insulation and tube end seals. Set the target temperature as low as possible (depending on your application) to gain the most economical use of your furnace.

**Temperature Ramp Rate** - This is the rate of rise in temperature during the test. Range 3 ° - 10 °C. **Note:** Avoid operating the furnace at unnecessarily fast ramp rates as they may cause premature failure of the work tube. Set the controller ramp rate as slow as possible (depending on your application) to gain the most economical use from your furnace. The default setting is 7 °C/ minute.

**Image Capture Interval** - Set temperature rate at which the software will record and store an images i.e. If set at 5 °C an image will be captured every 5 °C throughout the test. The maximum capture interval for automatic analysis should be no more than 5 °C/ minute. If a higher number than this is selected the software will prompt that automatic analysis is not possible above this capture interval.

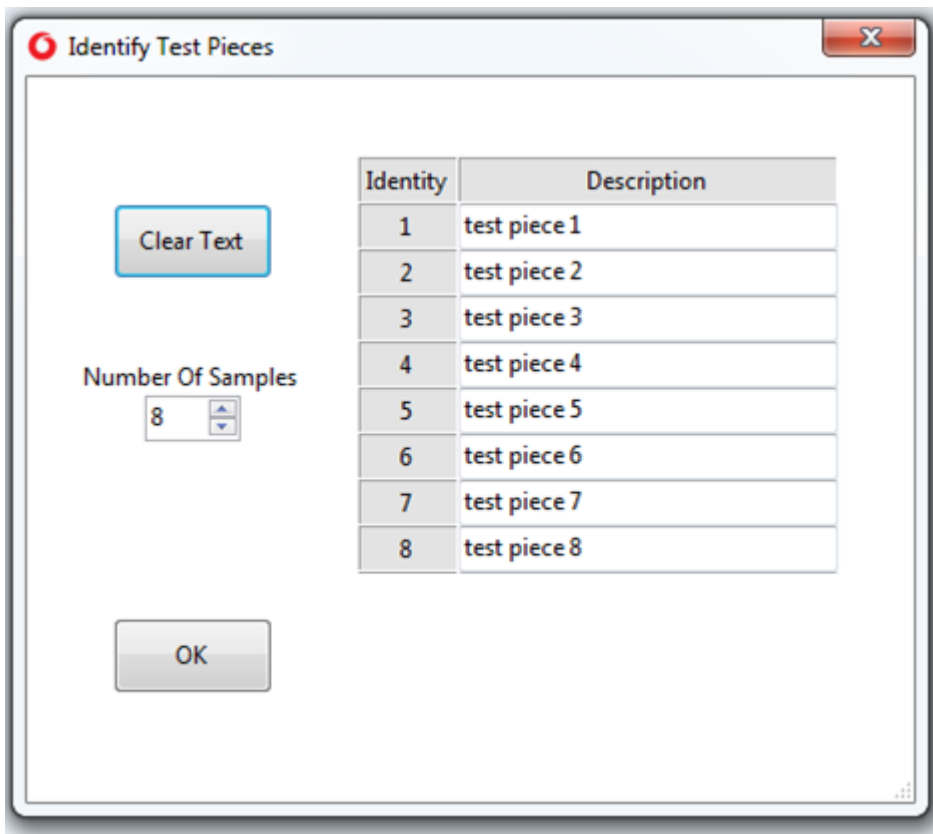
Range - 1 °C - 10 °C. Only whole numbers can be used, the smallest number that can be entered is 1, the largest is 20. Each stored image requiring 2 Mb of disc space so it is advisable to use large temperature intervals whenever possible.

**Standby Temperature** - Set the temperature the furnace will maintain before and after a test. Range 20 °C - 1600 °C.

**Backlight Off Temperature** - Set the temperature at which the back lighting will be switched off. After approximately 700 °C the radiant light from the elements will be sufficient to light the chamber. Range 0 °C - 1000 °C

**Save** - Once the settings have been adjusted to suit the test application, clicking the save button will save the selected temperatures. **Note:** The Eurotherm temperature controller is updated by the software and always holds the latest values.

### 4.7.2.3 Test Piece Identification



Click the 'Test Piece Identification' button to open this window. Adjust the quantity and description of test pieces. Maximum number of 8 samples to be used for automatic analysis.

**Clear Test** - This can be used to reset the test piece descriptions to the default values e.g. test piece 1 etc.

**Number of Samples** - Select the number of test pieces required for the test, up to 20 sample codes can be entered.

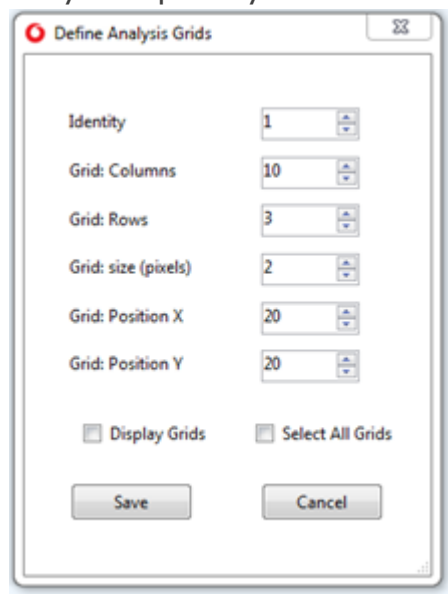
**Note:** No more than 8 samples can be used for automatic analysis and Carbolite Gero do not recommend more than 8 samples per test for manual analysis.

This automatically sets the number of test piece shown in the results window, see section 4.7.4 and enters the test piece description into the results description column. The number of samples selected also controls the number of grids, see section 4.7.2.4 below.

**Test Piece Description** - Enter a unique description for each test piece. This can be reset if required using the "Clear Test" button above.

#### 4.7.2.4 Analysis Grids

The analysis grids are an integral part of the automatic analysis program and must be set up before the test is started if the 'Auto Analysis' option is selected, see section 4.7.3.4 where automatic analysis is to be carried out after the furnace has finished its test cycle. The grids must be adjusted so that they are central to the test piece and that they completely cover the sample and its proposed deformation area.



Click the 'Analysis Grids' button to open this window.

Each test piece can be assigned a grid which is to be overlaid over the test piece. The size and position of the grid can be set here.

**Note:** Right mouse clicking anywhere in the display window will activate this box. Adjustment of the grids can be made at any time prior to the analysis of the test pieces.

**Identity** - this is the identity of the grid on the screen. The grid identified will be highlighted in red and the grid identity number is shown on the top left corner of the grid. When highlighted an individual grid can be adjusted.

**Note:** The number of grids is controlled in the 'Test Piece Identification' screen, see section 4.7.2.3.

**Grid: Rows and Columns** - This changes the number of columns and rows of the selected grid.

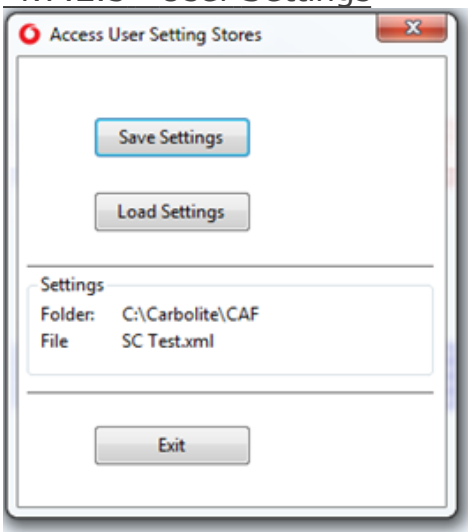
**Grid: Size (Pixels)** - This changes the global pixel size of the individual grids. This has no dimensional relationship.

**Grid: Position X and Y.** The grid position on the screen can be specified. Grids can also be positioned by using click and drag.

**Grid Display** - Selecting the check box will display or hide the grids on the screen.

**Select all Grids** - With this box selected all the grids shown on the screen can be adjusted at the same time, except for the grid position.

#### 4.7.2.5 User Settings



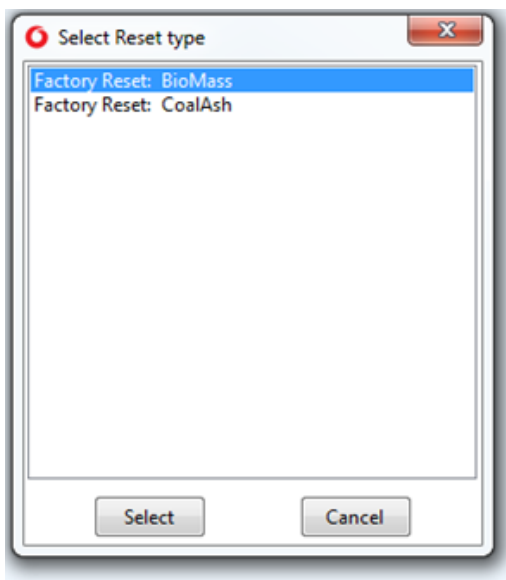
Clicking the 'User Settings' button will open this window. The Temperature Settings, Test Identifications Settings and the Analysis Grid Settings can be stored in one unique file.

**Save Settings** - Once the Temperature Settings, Test Identification Settings and the Analysis Grid Settings have been adjusted the value can be saved to a custom file name in a folder location of the users choice. **Note:** There is no limit to the number of configuration files that can be saved.

**Load Settings** - Select the file name of any previously saved user settings.

**Settings** - The settings panel shows the current user settings loaded and its file location.

#### 4.7.2.6 Factory Reset



Clicking the 'Factory Reset' button opens this window.

The temperature Settings Test Identification Settings and the Analysis Grid settings can all be reset back to the factory default settings.

**Note:** this does not delete any of the saved user settings files.

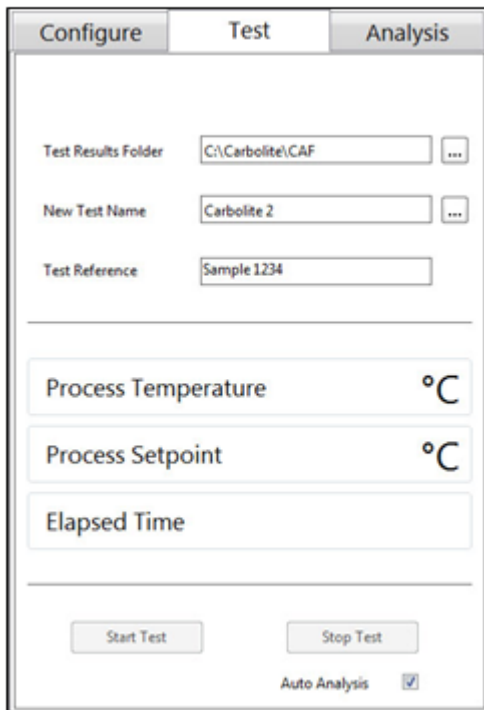
Highlight the appropriate test type and press the select key to reset factory defaults.

#### 4.7.2.7 Backlight Intensity (If Available)

The back-light intensity is located in the lower part of the command window and can be adjusted with either the slider bar or by directly inputting a percentage light intensity value in the numerical box above the slider. This cannot be adjusted once the test is started.

### 4.7.3 Test

Select the 'Test' tab to set up the test identification parameters and start a test.



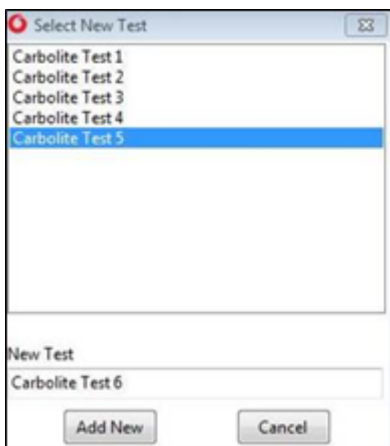
Select the 'Test' tab to set up the test references and run the test.

#### 4.7.3.1 Test Results Folder

The 'Test Results Folder' box may already be populated with the correct folder if set up previously in the Configure tab, see section 4.7.2. If there is no folder specified in this box or the folder shown is incorrect, the value can be changed by following the same procedure as outlined under section 4.7.2.1.

The folder location entered will be automatically updated on the Configure and Analysis tabs.

#### 4.7.3.2 New Test Name



By selecting the 'new test name' text box or the ellipsis at the end of the text box will open the 'Select New Test' window. The upper part of the window shows a list of previous test names which are located in the selected 'Test Results Folder'.

**Note:** If there are no previous tests listed, no previous test may have been carried out (if being used for the first time) or the test files are located in another folder.

A new file name can be added directly in the 'New Test' text box or a previous test name can be selected from the above list and then incremented.

**Note:** For security of data a previous test name cannot be overwritten.

#### 4.7.3.3 Test Reference

A test reference can be entered into the 'Test Reference' text box. This may be a specific sample number, batch number or a LIMS related reference if required.

#### 4.7.3.4 Auto Analysis Selection

When this is selected the auto analysis will be carried out straight after the heat up cycle is completed and all the deformation images have been captured, hence the whole test from heat up through to analysis is one continuous process.

#### 4.7.3.5 Start Test

When you are satisfied that the information you have entered is correct, select 'Start' to run a CAF test.

Selecting 'Start' will automatically set the furnace controller to 'Run' and start the furnace program. The yellow 'test in progress' light will illuminate on the control panel. The green Standby Mode indicator will go out.

**Note:** Do not open the furnace door when the 'test in progress' light is illuminated. See 1.1

The furnace will dwell at its current setpoint (start temperature) for 5 minutes then ramp to the selected target temperature at the pre-selected ramp rate.

**Note:** Avoid operating the furnace at unnecessarily high temperatures and ramp rates. See section 4.7.2.2.

When the furnace reaches the preselected 'Start Image Capture Temperature' images will be saved at the pre-selected 'Image Capture Interval' up to the ramp target temperature. As the images are stored the black text box will flash across the top of the image window.

Both the 'Configure' and 'Analysis' tabs are disabled once recording has started.

#### 4.7.3.6 Start/ Stop the Program

The furnace controller program can also be started and stopped independently of the CAF test software:

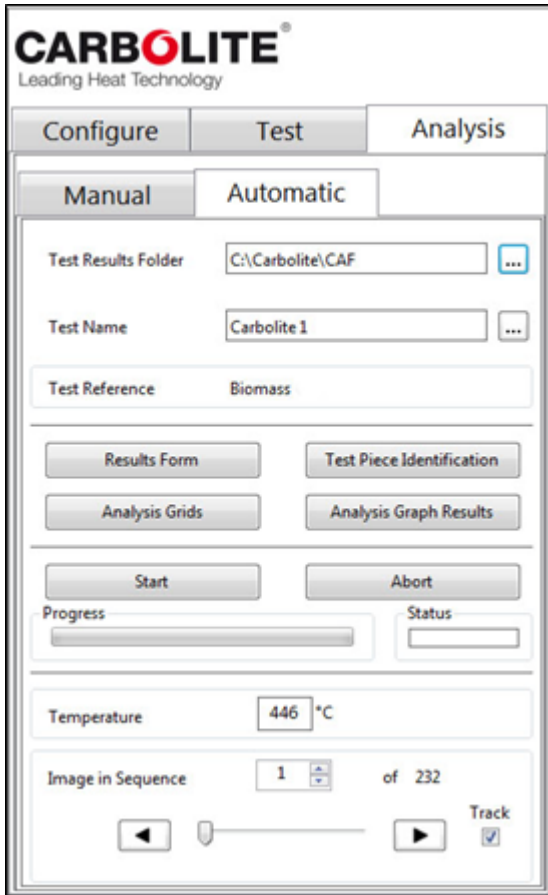
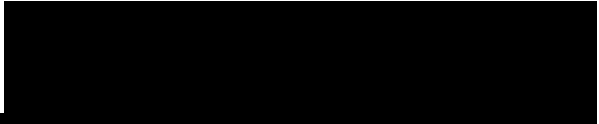
To start the program: press the Run/ Hold button (•) on the front of the controller, the word RUN will illuminate at the side of the button to signify that the program is running.

To stop the program: hold the Run/ Hold button (•) on the front of the controller until both the words RUN and HOLD at the side of the button are no longer illuminated.

#### 4.7.4 Analysis: Automatic and Manual

The analysis tab is used to open previous test images, carry out automatic or manual analysis of the test pieces and record the characteristic deformation temperatures. During the CAF test, images are stored in the form of 'Date-Time-Temperature-Sequence.tif' files in the folder headed with the 'Test Name'. These images can be viewed and analysed either automatically or manually by opening the folder with your test name (see section 4.7.3.2). The file folder is constructed as shown in fig 16.

The stored images can also be replayed immediately after a heat up cycle is complete. The images can then be analysed automatically or manually if required.

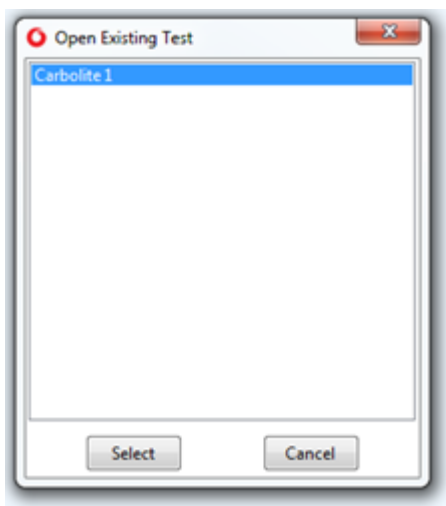


Select the 'Analysis' tab to open previous test images and store the identified deformation points by using automatic or manual analysis methods.

#### 4.7.4.1 Test Results Folder

The "Test Results Folder" box may already be populated with the correct folder if set up previously in the Configure tab, see section 4.7.2. If there is no folder specified in this box or the folder shown is incorrect, the value can be changed by following the same procedure as outlined in 'Test Results Folder' under "Configure". The folder Location entered will be automatically updated on the Configure and Test tabs.

#### 4.7.4.2 Test Name



Selecting the 'test name' text box or the ellipsis at the end of the text box will open the 'Open Existing Test' window. The window shows a list of previous test names which are located in the selected 'Test Results Folder'.

**Note:** If there are no previous tests listed, no previous test may have been carried out (if being used for the first time) or the test files are located in another folder.

Once the test name is selected the 'Test Reference', 'Temperature' and 'Image Sequence' boxes, will be populated with data from the selected test. The first test image of the sequence will also be shown in the image test window.

#### 4.7.4.3 Automatic Analysis

If the Automatic Analysis option was chosen before the test was started see section 4.7.3.4.

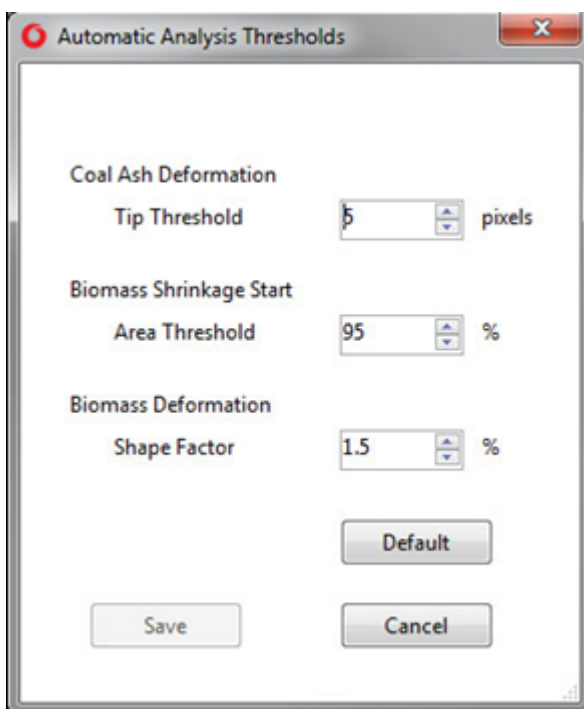
If the 'Auto Analysis' option was not selected before the start of the test, the automatic analysis can be started at any time as long as the test sequence has been completed, or a previous test reference can be selected for the analysis.

The following parameter must be set up before starting an Automatic Analysis:

- Identify number of test pieces and add description as required, see section 4.7.2.3.
- Locate a grids over each individual sample, see section 4.7.2.4 .
- If image tracking is required, ensure the "Track" option check box is selected. (Located at the side of the image sequence scroll bar).
- Adjust the Automatic Analysis Threshold, see section 4.7.4.4

#### 4.7.4.4 Automatic Analysis Thresholds

Adjustments can be made to the initial deformation points of either the Coal Ash or Biomass samples using the Automatic Analysis Thresholds.



**Coal Ash Deformation Tip Threshold** - The radius of the tip is measured in camera pixels. The software then looks for an increase in radius by the amount entered. The operator can change this value between 1 and 20 pixels.

**Biomass Shrinkage Start Area Threshold** - The Biomass standard refers to SST as being the temperature where the area of the test piece falls below 95% of the original test piece area at 550 °C. The operator has the option to change this ratio between 90% and 100%.

**Biomass Deformation Shape Factor** - The Biomass standard refers to DT as being the temperature where there is a change of 1.5% in the shape factor (this maybe

shown as 15% in some standards). The operator has the option to change this ratio between 0.5% and 20.0%.

#### 4.7.4.5 Running with Automatic Analysis

Once the above parameters have been selected the automatic process can be started.

Start - Selecting 'Start' will activate the automatic analysis process.

Abort - Selecting 'Abort' will cancel the test that is being analysed.

Progress - The progress bar indicates how much of the test is completed.

Status - The status displays 3 colours when an analysis run is finished.

- Green indicates image and melt point analysis completed.
- Orange indicates analysis aborted by the operator, i.e. The Abort button has been pressed. The analysis process has finished before all images have been analysed.
- Red indicates analysis failed, in particular the image analysis.

This may be due to:

- Grids not positioned correctly.
- Lack of contrast between the sample and the background
- Sample did not follow definition criteria

Once the automatic analysis is completed the 'Progress' and 'Status' bars will both be shown in green if the analysis has been successful.

**Note:** The test can be re-run again at any time if the test results are found to be undesirable although previous test results will be lost.

#### 4.7.4.6 Results Form

The screenshot shows a window titled 'Results Form' with the following fields and table:

Test Name: Carbolite 1  
Test Reference: Biomass Only  
Acquisition Date/Time: 20 November 2014 15:07

Identity	Description	SST	DT	HT	FT
1	test piece 1				
2	test piece 2				
3	test piece 3				
4	test piece 4				
5	test piece 5				
6	test piece 6				
7	test piece 7				
8	test piece 8				

Buttons: Print, Save and Exit, Cancel

Clicking the 'results form' button will open this window.

Automatic and manual deformation points are recorded and saved here.

The characteristic deformation temperatures are recorded on the 'Results Form' when the analysis tab is active.

The results form is headed with the 'Test Name', 'Test Reference' and Acquisition date and time of the selected test.

The results form show the Identity number and description of the test pieces to be analysed. These are initially set up using 'Test Piece Identification' command. See section 4.7.2.3.

Analysis of CAF test results stored images.

The four columns headed DT, ST, HT, FT for coal ash or SST, DT, HT, FT for Biomass refer to the temperatures at which the characteristic changes of shape occur:

Coal Ash:

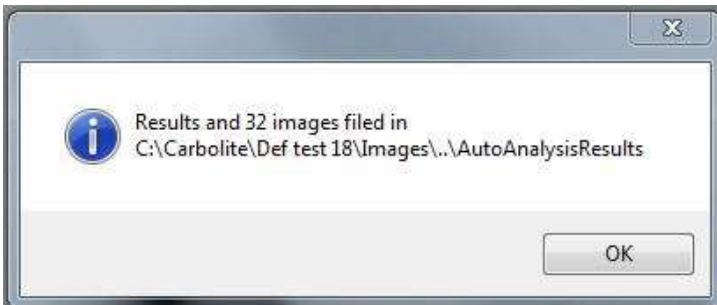
- DT = Deformation Temperature
- ST = Sphere/ Softening Temperature
- HT = Hemisphere Temperature
- FT = Flow/ Fluid Temperature

Biomass:

- SST = Shrinkage Start Temperature
- DT = Deformation Temperature
- HT = Hemisphere Temperature
- FT = Flow/ Fluid Temperature

#### 4.7.4.7 Automatic Entry of Test Results

Once the Automatic Analysis routine is complete, an information window will open indicating how many images have been saved into the 'AutoAnalysisResults' folder under your chosen folder together with the Results.csv and Results.xml files containing the result information, see section 4.7.4.10. This step can be repeated at any time from the results forms 'Export and Exit' function (see Automatic Analysis Results Form).



Select "OK" to save the images to the indicated folder.



#### Automatic Analysis Results Form

The results form on the "Automatic" tab will be populated by the test results once the automatic analysis routine is complete.

The results table should be used in conjunction with the sample grids therefore the grids should be activated prior to opening the Results Form, see section 4.7.2.4.

No test results can be added or removed from the automatically generated results form.

If manual analysis is to be carried out the manual analysis results table should be used, see section 4.7.4.9.

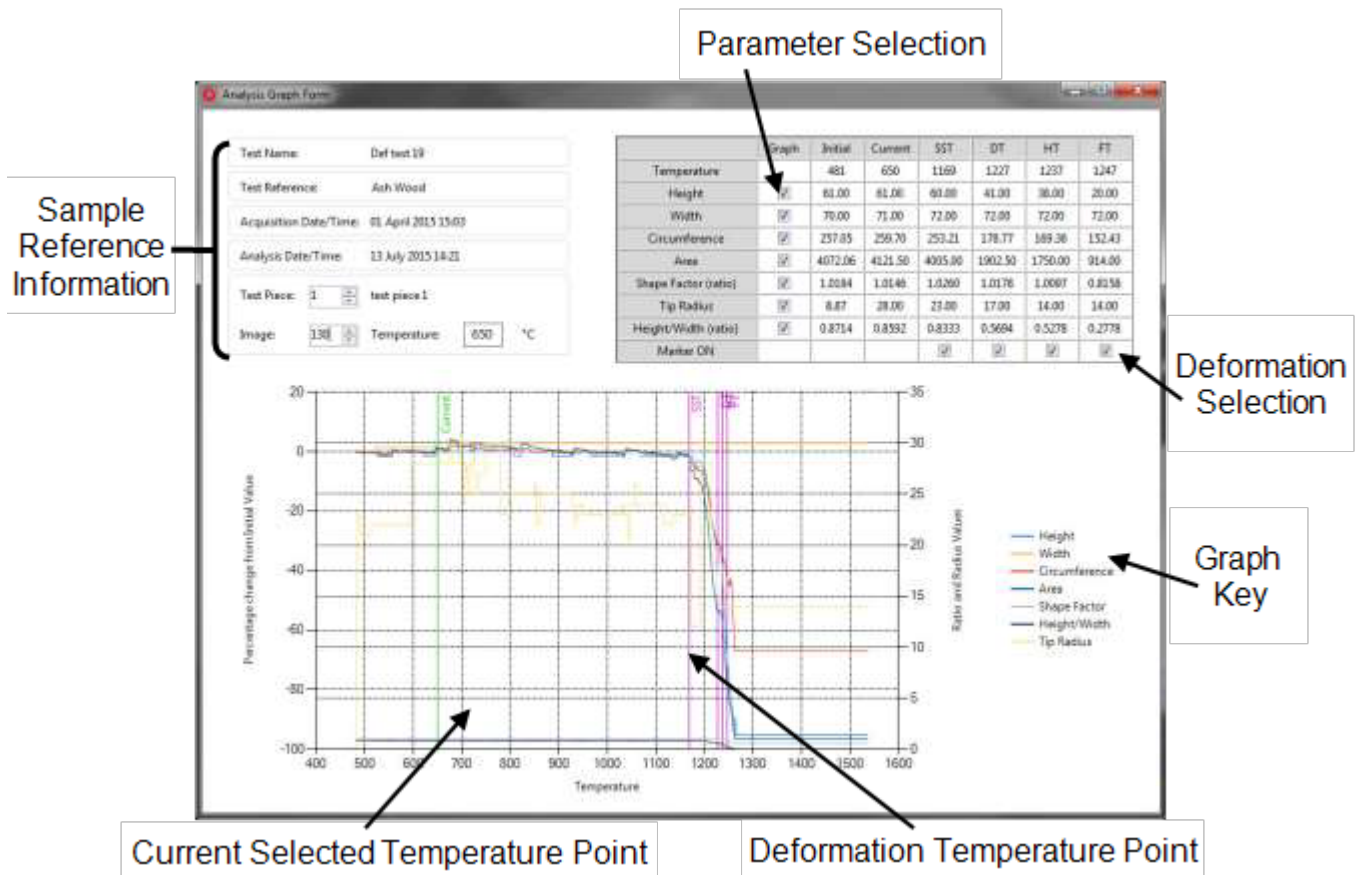
A test piece number row can be activated by selecting the corresponding grid number. When the grid is selected it will highlight in red and the corresponding item number row on the results table will be highlighted in blue.

If the deformation results are acceptable select 'Export and Exit' to save the selected deformation images into the 'AutoAnalysisResults' folder under your chosen folder together with the Results.csv and Results.xml files containing the result information see section 4.7.4.10.

A computer printout can be obtained by selecting 'Print', the results are presented as a printdata.pdf report sheet as shown in fig 18.

#### 4.7.4.8 Analysis Graph Form

Additional deformation information can be viewed by selecting 'Analysis Graph Results' button. Parameters such as Height, Width, Circumference, Area, Shape factor ratio, Tip radius and height width/ ratio can be viewed together or individually on the graph. The identified deformation temperature points for each individual test piece can also be highlighted on the graph together with the current selected temperature points.



The analysis graph form is split into three areas:

**Sample Reference Information** - The upper part of this area shows the test details such as 'Test Name', 'Test Reference', 'Acquisition date/time' and 'Analyse Date/ Time'.

The lower section controls the test piece identity number and the image number and/ or temperature of the 'Current Selected Temperature Point' (this is shown by a green line headed 'Current').

To show the parameters of a test piece enter the number of the test piece into the 'Test Piece' box. This will highlight the corresponding sample grid in the sample window and show the parameter data and the graphical data for the selected sample.

The current selected temperature point can be advanced by entering the image number into the 'Image' box or by selecting a defined temperature point. This will also advance the sample image in the Sample Window.

**Parameter Selection** - The parameters for each individual test piece can be shown on the graph by selecting the tick box in the graph column. Individual or all parameters can be selected at any time. The graph key information will be shown at the right hand side of the graph when a parameter is selected.

**Deformation Selection** - The deformation temperature points can be shown on the graph by selecting the tick box in the 'Marker ON' row under each of the deformation point columns. Each deformation point when selected is highlighted with a magenta coloured line which is headed with its deformation identification i.e. SST, DT, HT, FT.

**Analysis Graph** - The graph shows any parameters or deformation points that have been selected from the Parameter selection or the Deformation selections.

**Note:** No graph will be shown if none of the parameters are selected.

#### 4.7.4.9 Manual Entry of Analysis Results

To enter results manually, the manual analysis tab should be first selected.

**Note:** Automatic and manual results are saved independently of each other in two separate folders, see section 4.7.4.10.

The results table should be used in conjunction with the sample grids therefore the grids should be activated prior to opening the Results Form, see section 4.7.2.4.

To enter the selected deformation temperature for a test piece into the form, the sample number must first be selected. The active test piece is then identified by a highlighted blue row on the form.

The test piece number row can be activated in one of two ways:

- Selecting a corresponding grid in the test window, i.e. if grid 2 is selected (this will be highlighted red), row 2 on the form will be highlighted in blue.
- Selecting the 'Active Grid' number by scrolling up and down using the up/ down arrows or by entering a number directly into the 'Active Grid' box.

Once the test piece row has been selected the identified deformation temperatures can be entered into the relevant columns, by simply selecting the cell which the temperature is to be entered.

To find the relevant deformation image, the test images can be scrolled through in a number of ways:

- Dragging the scroll bar situated in the lower part of the Analysis tab window.
- Selecting the arrows on the end of the scroll bar
- Entering a sequence number into the 'Image in Sequence' box.
- Entering a temperature into the 'Temperature' box.
- Scrolling through images with a wheel mouse.
- Using the left and right arrows on the keyboard.

**Note:** These commands are only functional when the Analysis tab window is active. (standard Windows functionality)

As the images are scrolled a text box is shown in the lower left corner of each image showing the Temperature, Date, Time and test ID. When the relevant image is displayed (e.g. a test piece showing the deformation) simply click in the relevant box beneath that sample identification in the 'Results Form' window using the mouse pointer. The relevant temperature will be entered automatically.

If the wrong temperature is entered into the wrong box locate the correct image and re-click in the relevant box to over write the text or right mouse click to delete the entered text.

When the deformations have been identified select 'Save and Exit', if temperatures have been entered into the selected cells an information window will open indicating how many images have been saved into the '*analysisfolder*' under your chosen folder together with the Results.csv and Results.xls files containing the result information, see section 4.7.4.10.

A computer printout can be obtained by selecting 'Print', the results are presented as a printdata.pdf report sheet as shown in fig 18.

#### 4.7.4.10 File Folders

**{User test name}** folder. This is the header folder which contains all the data and results, for both the manual and automatic analysis for the name test. See section 4.7.4.11 below for more information.

**AnalysisResults** folder. This folder is created when the first deformation test results are saved. This folder holds all the saved deformation point images for the name test in the former:

*'Test piece description\_D.tif'*

*'Test piece description\_S.tif'*

*'Test piece description\_H.tif'*

*'Test piece description\_F.tif'*

The Results.xlsx and Results.csv files are also saved in this folder, see section 4.7.4.11.

**AutoAnalysis** folder. This folder holds all the results from the automatic image analysis program in the format 'Date-Time-Temperature-SequenceNumber.xml'. The data contained within this file is for software functionality only and is not relevant to the user.

**AutoAnalysisResults** folder. This folder is created when the first automatic deformation test results are stored. This folder holds all the saved deformation point images for the named test in the same format as the 'AnalysisResults' folder, together with the Results.xlsx and Results.csv files, see section 4.7.4.11.

**Images** folder. This folder is created when a test is run and images are captured. This folder contains all the captured test images in the format 'Date-Time-Temperature-SequenceNumber.tif'.

#### 4.7.4.11 File Formats

There are several files created when running the CAF software:

**.tiff** Image Files. These files are stored in two different formats in the 'AutoAnalysisResults', 'AnalysisResults' and 'Images' folders.

'Date-Time-Temperature-SequenceNumber.tif'. These files are saved in the Images folder and each file is approximately 1.8Mb.

'Test piece description plus the melt letters.tif'. These files are saved in the 'AutoAnalysisResults' and 'AnalysisResults' folder and each file is approximately 1.8Mb.

The '.tiff' image files can be imported into any Image editing program or Microsoft Word or Excel for inclusion in test reports etc. The Results.csv and the Results.xml files containing the temperature data can also be inserted into a Microsoft documents as a table or opened as spread sheets.

**CaptureSettings.xml**. This file is created in the 'User Test Name' folder. It is a record of the settings used when the test was first run. Time stamp will indicate when the test was started.

**AutoSettings.xml**. (Automatic Analysis) This file is created in the 'User Test Name' folder. It is created every time the automatic analysis 'Start' button is selected. The data contained within this file is for software functionality only and is not relevant to the user.

**Settings.xml**. This file is created in the 'User Test Name' folder. It is written during the analysis phase. When any settings are changed while in Analysis mode this file will be updated. This could include changing test piece names, grid parameters, etc. time stamp will indicate the last change.

**AutoResults.xml**. (Automatic Analysis) This file is created in the 'User Test Name' folder when the automatic analysis is complete. This holds the data from the automatic analysis results.

**Note:** AutoResults.xml and Results.xml look very similar in their layout but they are not interchangeable.

**Results.xml** (Manual Analysis) This file is created in the 'User Test Name' folder when test piece results are saved. This holds the data from the manual results form, i.e. Temperature, filename for the original image at that temperature, modified filename (test piece description plus the melt letters) for the image at that temperature, plus grid position information. If you move the grid, for example for test piece one between saving each temperature, this information will be saved here.

**Results.xlsx**. This file is created in the 'AnalysisResults' or the 'AutoAnalysisResults' folder when the results table is saved and is in the same format as the first page of the analysis report printout.

**Results.csv**. This file is also created in the 'AnalysisResults' or the 'AutoAnalysisResults' folder and holds the same information as the Results.xlsx file but as comma separated value format.

## 4.8 Post-Operation Cooling

After the completion of testing, the furnace must be allowed to cool gradually.

Ceramic work tubes are subject to thermal expansion when heated to high temperatures, increasing in both length and diameter. Rapid changes in temperature can cause stress upon the work tube material which may cause it to break; a process known as thermal shock.

To mitigate the risk of thermal shock to the work tube, a cool down rate **no greater than 5°C per minute** is recommended.

**Note:** The customer is responsible for any damage to the furnace caused by exceeding the recommended cool down rate.



**Note:** Because the exact details of the customer's process are unknown, it is not possible to account for process-specific wear to the work tube material. The working life of the work tube is variable and depends entirely on the operating temperatures, program ramp rates, and properties of the materials being heated. Subsequently the work tube is classed as a consumable item and is not covered by the standard Carbolite Gero warranty terms.

## 5.0 Maintenance

### 5.1 General Maintenance

Preventive rather than reactive maintenance is recommended. The type and frequency depends on the product use; the following are recommended.



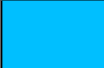












### 5.2 Maintenance Schedule

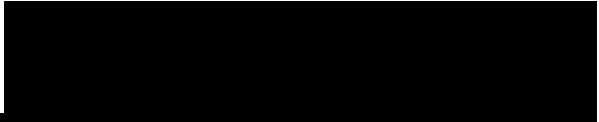
 CUSTOMER


 QUALIFIED PERSONNEL



**DANGER! ELECTRIC SHOCK.** Risk of fatal injury. Only electrically qualified personnel should attempt these maintenance procedures.

Maintenance Procedure	Method	Frequency				
		Daily	Weekly	Monthly	Bi-Annually	Annually
<b>Safety</b>						
Over-Temperature Safety Circuit	Electrical measurement 					
Door Plug	Visual inspection, checking the seal and whether it is free of any damage					
Door Plug	Replacement where necessary					
Extraction Pipe	Check that the connection is tight, and clean out the pipe if necessary					
Electrical Safety (external)	Visual check of external cables and plugs					
Electrical Safety (internal)	Physically check all connections and cleaning of the power plate area					
Gas Safety (external)	Visually check that all pipework is in place and free of damage. Physically check that all connections are tight					
Gas Safety (internal)	Leak test the gas system					
Cooling Fans	Check whether the cooling fans are working					
<b>Function</b>						
Temperature Calibration	Tested using certified equipment, frequency dependent on the standard required					
Operational Check	Check that all functions are working normally					
Operational Check	Thorough inspection and report incorporating a test of all functions					



Performance						
Element Circuit	Electrical measurement 					6
Power Consumption	Measure the current drawn on each phase / circuit					6
Tube Insulation Collars	Visual check for fit and damage, and correct positioning					

### 5.2.1 Cleaning

Soot deposits may form inside the furnace, depending on the process. At appropriate intervals remove these by heating as indicated in the General Operation Notes.



The product's outer surface may be cleaned with a damp cloth. Do not allow water to enter the interior of the case or chamber. Do not clean with organic solvents.

## 5.3 Element Ageing

Silicon Carbide heating elements gradually increase in resistance with use and the power of the furnace gradually declines until the furnace can no longer keep up with its program. To maximise the element life it is advisable to follow the recommendations below:

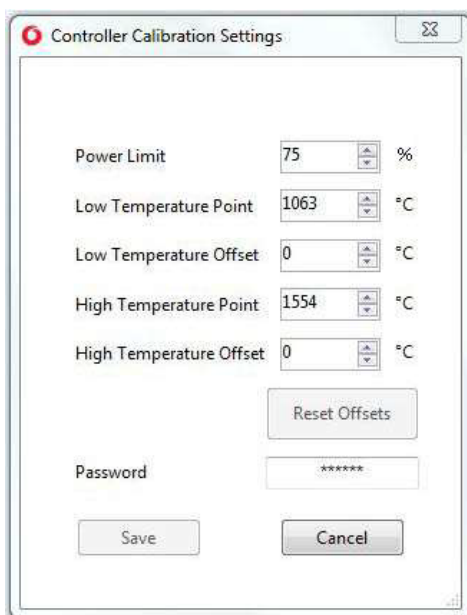
- a. Do not run the furnace at higher temperatures than you need. See section 4.7.2.2.
- b. Do not select unnecessarily fast ramp rates. See section 4.7.2.2.

There is a feature in the Software which allows the power from the elements to be adjusted. This 'power limit' is pre-set at Carbolite Gero. As the element performance declines the available power can be increased to compensate. The maximum power figure available is 100 (%), if the furnace performance is still poor when the power is set to 100 (%) the elements must be replaced.

To adjust the power settings proceed as follows:

With the software open, select 'tools' 'Calibration' from the text menu bar.

The 'Controller Calibration Settings' window will appear.



At this stage it is a good idea to write down the original power limit value.

In the 'Power Limit' number box either enter a value directly or use the up and down arrows to adjust the % power limit.

## Save Settings

To save the calibration settings, the save button must first be activated by entering a password of 525 in the password box. The word 'Activated' will be displayed if the correct password is entered and the save button will be highlighted. Select the save button to save the settings.

The Eurotherm temperature controller always holds the latest values.

## 5.4 Checking and Replacing the Door 'O' Ring Seal

Warning: Wear neoprene gloves before handling the 'O' ring seals - see section 1.5.

Regularly check the condition of the door 'O' ring seal, see fig 17. The 'O' ring seal is a push fit into the groove in the door plug ring, carefully remove it by hand, do not use sharp tools as this could damage the seal and the door plug ring.

Inspect the condition of the door 'O' ring seal, it must be uniform in shape and section, and free from cuts, cracks, dust and grit. If the seal is damaged replace it, a faulty seal can cause leakage of carbon monoxide during testing. See section 1.2.

Clean the seal faces of the door plug ring and work tube front seal assembly, these must be free from dust, grit, chips and scratches. Any damage to these faces can cause leakage of carbon monoxide during testing and must be rectified.

To re-fit the door 'O' ring seal simply push it into the groove in the door plug ring. A small amount of high temperature grease smeared over the back face (groove side) of the 'O' ring will help to retain it.

## 5.5 Cleaning the Viewing Window

Clouding of the silica (fused quartz) viewing window may occur. It is not certain whether this is caused by impurities in gases supplied into the furnace or by volatiles given off from the cones. The effects of any volatiles in the cones can be minimised by allowing a couple of minutes for the cones to burn off before closing the door after loading the furnace. A cloudy glass absorbs more heat than a clear one and heat accelerates the corrosion of the surface, regular cleaning of the glass before a test can avoid cumulative effects.

### 5.5.1 To remove the viewing window for cleaning or replacement:

Ensure that the furnace is cool and the electricity and gas supply is isolated.

Remove the camera and mounting bracket assembly, see fig 5b and 5c.

Warning: Wear neoprene gloves before handling the 'O' ring seals - see section 1.5.

Withdraw the door assembly fully from the work tube to avoid damaging the door plug. Hold the door arm securely and using the tool provided unscrew the viewing window retaining ring anti clockwise. Remove the retaining ring carefully, noting the positions of the window 'O' ring seal, window glass and window glass gasket. See fig 17. Hold the window by the edges and avoid touching the glass surface, traces of perspiration can etch the surface of the glass when it is heated.

### 5.5.2 Cleaning the Window

When cleaning the window, use a suitable cleaning agent. Alternatively an optician equipped with re-polishing machines can restore the clarity of the windows.

### 5.5.3 When Replacing the Window

Ensure that the glass is clean and free from dust, grit, chips, scratches and cracks. If the glass is damaged replace it, a faulty window glass can cause leakage of carbon monoxide during testing. See section 1.2.

Inspect the condition of the window 'O' ring seal, it must be uniform in shape and section, and free from cuts, cracks, dust and grit. If the seal is damaged replace it, a faulty seal can cause leakage of carbon monoxide during testing.

Clean the inside of the viewing window retaining ring and door plug ring. Pay particular attention to the 'O' ring seal faces, these must also be free from dust, grit, chips and scratches. A vacuum cleaner is the best method of removing the dust and grit. Take care not to damage the back face of the door plug during cleaning.

Fit a new window glass gasket, if this gasket is not fitted the window glass will break when the window retaining ring is tightened.

Fit the window 'O' ring seal onto the window retaining ring. Place the window glass in position in the door plug ring and re-fit the window retaining ring and tighten the window retaining ring to finger tight.

Using the tool provided tighten the window retaining ring to seal the viewing window. Whilst tightening the window retaining ring hold the door plug in position to prevent it from rotating, the gas inlet hole in the door plug must line up with the gas inlet in the work tube front seal assembly. See fig 17.

Prior to using the furnace conduct a pressure test of the work tube assembly to ensure integrity of the work tube and 'O' ring seals, see section 3.3.5.

## 5.6 Furnace Calibration

This procedure describes the process required to achieve correct calibration and performance from your CAF G5 furnace. The furnace is calibrated prior to leaving the factory, but all test standards call for regular checks on calibration. Carbolite Gero recommend that calibration checks are conducted in accordance with these standards, if the furnace is found to be out of calibration then the control instrument must be adjusted (see section 5.7).

### 5.6.1 Sample Carrier Tiles

To obtain an accurate calibration result the correct sample carrier and tiles supplied with the furnace must be used.

### 5.6.2 Sample Preparation

Two types of wire are used to check the furnace calibration:

Gold Wire                      Melting Point 1063 °C

Palladium Wire                Melting Point 1554 °C

Four pieces of each wire type are required, the samples are prepared as follows:

Cut a piece of wire 30 mm in length.

Using a pair of pin nose pliers, form one end of the wire into a coil so that when standing on a flat surface it supports a 12 mm vertical column of wire. See fig 19.

The samples are positioned on the sample tiles, which are placed on the sample carrier as shown in fig 20.

### 5.6.3 Test Procedure

The calibration test is based on BS ISO 540: 2008, Methods for Analysis and testing of Coal and Coke. Conduct the test as follows:

- Turn the furnace on, adjust the standby temperature to 815 °C and allow the furnace to stabilise. As the furnace warms up prepare the sample carrier and samples (section 5.6.2) and load into the work tube. Close the door and clamp securely to seal the work tube (see section 4.5).
- When the furnace has stabilised at 815 °C run a CAF test on a ramp rate of 7 °C/minute to reach a maximum temperature of 1580 °C. During the test maintain an 'oxidising' atmosphere in the work tube (see section 4.6)
- A digital image sequence of the samples is required as they pass through their melt temperatures to enable the melting sequence to be assessed after completion of the test. Set the digital image software to record at 1 °C temperature intervals, starting at 20 °C below the expected Gold melt point and finishing at 1580 °C (see section 4.6).

### 5.6.4 Interpretation of Results

#### 5.6.4.1 Definitions:

The "individual melt temperature" of a wire sample is the temperature at which the wire sample, having fallen over onto the sample tile, melts and forms one or more stable "balls" of molten material.

The "mid melt temperature" of a set of four wires is the average of the lowest and highest of the four individual measured melt temperatures.

The "spread" of melt temperature is the difference between the highest and lowest of the four individual melt temperatures.

The "actual" melt temperature is a fixed value for each wire sample type.

#### 5.6.4.2 Documentation of Results

Record the individual melt temperature of each wire sample using the CAF Test Software (see section 4.6 ) and print out the results using the report sheet. See fig 18.

For each wire type work out the mid melt temperature and the spread.

#### 5.6.4.3 Temperature Limits

The following limits apply with respect to the melt (ball) temperatures of the wire samples.

	Furnace in °C	Furnace in °F
Actual Gold Melt (ball) temp	1063 °C	1945 °F
Min. permissible Gold Melt (ball) temp	1057.5 °C	1935 °F
Max. permissible Gold Melt (ball) temp	1068.5 °C	1955 °F
Actual Palladium Melt (ball) temp	1554 °C	2829 °F
Min. permissible Palladium Melt (ball) temp	1548.5 °C	2819 °F
Max. permissible Palladium Melt (ball) temp	1559.5 °C	2839 °F
Max. permissible spread (both wire types)	11 °C	20 °F

#### 5.6.4.4 Deviations from Limits

If some or all of the recorded individual melt temperature fall outside the maximum or minimum permissible temperatures for the relevant material, but the spread is within the maximum permissible spread, then it is possible to correct the temperature displayed by the control instrument set-up; see section 5.7.

If the spread lies outside the permissible limit, then the furnace will require rectification of its temperature uniformity; contact Carbolite Gero for further advice.

Any servicing or modifications to the furnace or controls may affect the calibration of the furnace and will require a re-test.

## 5.7 Instrument Calibration Adjustment

A two point calibration function within the furnace controller allows adjustment of the displayed value at both the Gold and Palladium melt temperatures. Proceed as follows:

- Calculate the lower calibration temperature (displayed Gold melt temperature) correction factor:
- Calculate the lower calibration temperature (displayed Gold melt temperature) correction factor:

Calculate the Gold mid melt temperature from the results obtained, as given in section 5.6.4.

Calculate the lower calibration temperature correction factor as the difference between the Gold actual melt temperature and the Gold mid melt temperature:

*Gold:*

actual melt temperature - mid melt temperature = lower calibration temperature correction factor

For example: actual melt temperature = 1063 °C (from table)

mid melt temperature = 1060 °C (calculated from test)

$(1063\text{ °C} - 1060\text{ °C}) = 3.$

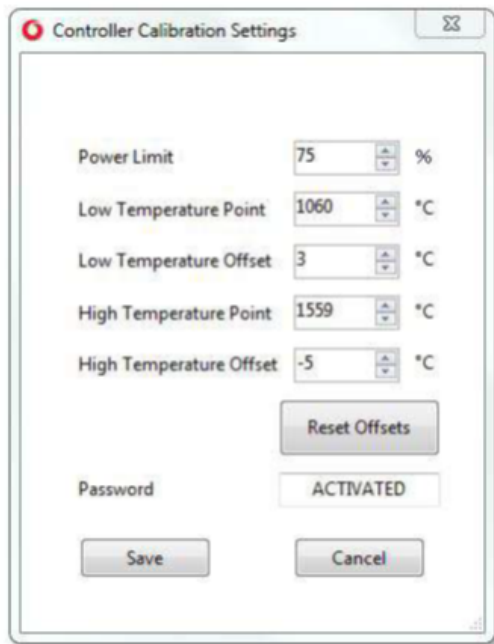
- Calculate the upper calibration temperature (displayed Palladium melt temperature) correction factor:  
Calculate the Palladium mid melt temperature from the results obtained, as given in section 5.6.4.  
Calculate the upper calibration temperature correction factor as the difference between the Palladium actual melt temperature and the Palladium mid melt temperature:  
*Palladium:*  
actual melt temperature - mid melt temperature = upper calibration temperature correction factor

For example: actual melt temperature = 1554 °C (from table)

mid melt temperature = 1559 °C (calculate from test)

upper calibration temperature correction factor  
(1554 °C - 1559 °C) = -5

- Adjust the lower and upper calibration temperatures.  
To adjust the lower and upper calibration temperatures proceed as follows:  
With the software open, select 'tools' 'calibration' from the text menu bar.  
The 'Controller Calibration Settings' window will appear. The values for temperature and offset can be entered directly into the number box or by using the up and down arrows at the side of the corresponding box.



**Lower Calibration Temperature Adjustment:**

From your previous calculations enter the lower mid melt temperature calculated into the 'Low Temperature Value' box e.g. 1060 °C.

Enter the lower calibration temperature correction factor into the 'Low Temperature Offset Box' e.g. 3.

Once saved the correction value will now be  $1060 + 3 = 1063$

**Upper Calibration Temperature Adjustment:**

From your previous calculations enter the upper mid melt temperature calculated into the 'Low Temperature Value' box e.g. 1559 °C.

Enter the lower calibration temperature correction factor into the 'Low Temperature Offset Box' e.g. -5

Once saved the correction value will now be  $1559-5 = 1554$

**Save Settings**

To save the calibration settings the save button must first be activated by entering a password of 525 in the password box. The word 'Activated' will be displayed if the correct password is entered and the save button will be highlighted. Select the save button to save the settings.

The offsets can be reset to zero by selecting the 'Reset Offset' button.

**Note:** This will only be activated if an offset value is present.

- Following adjustment of the instrument the furnace must be re-tested starting from section 5.6 to prove the results.

## 5.8 After-Sales Service

Carbolite Gero Service has a team of Service Engineers who can offer repair, calibration and preventive maintenance of furnace and oven products both at the Carbolite Gero factory and at customers' premises throughout the world. A telephone call or email often enables a fault to be diagnosed and the necessary parts to be despatched.

In all correspondence please quote the serial number and model type given on the rating label of the product. The serial number and model type are also given on the back of this manual when supplied with the product.

Carbolite Gero Service and Carbolite Gero contact information can be found on the back page of this manual.

## 5.9 Recommended Spare parts and Consumables

Carbolite Gero can supply individual spare parts, or a kit of the items most likely to be required. Ordering a kit in advance can save time in the event of a breakdown. Each kit comprises one thermocouple, one solid state relay, a set of elements and braids, one of each type of internal fuse, window glass gasket, work tube gasket and door/ window 'O' ring seal. Other spare parts available are:

- Work tube
- Work tube 'O' ring seal
- Viewing window glass
- Door plug
- Rear plug
- Sample carrier
- Sample tile
- Cone mould (specify which cone mould is required, i.e. 12.7 mm or 19.0 mm high).

All spare parts will be supplied with service information where applicable.

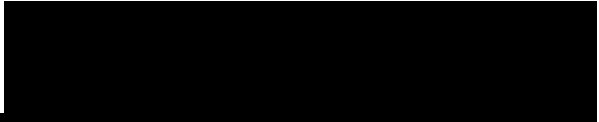
When ordering spare parts please quote the serial number, model type and voltage given on the rating label of the furnace.

For further information contact our service division at the address given at the end of this manual.

## 6.0 Fault Analysis

A general fault analysis chart can be seen below; see section 4.0; for a more detailed fault analysis of the control system.

A. Furnace Does Not Heat Up					
1.	The HEAT lamp/ s is/ are ON	▶	A heating element has failed	▶	Check that the SSRs are working correctly
		▶	An ohm meter applied to the element circuit shows an open circuit	▶	A heating element has failed
2.	The HEAT lamp/ s is/ are OFF	▶	The controller shows a very high temperature or a code such as S.br	▶	The thermocouple has broken or has a wiring fault
				▶	A relay maybe faulty
				▶	The SSR could be failing to switch on due to internal failure, faulty logic from the controller or faulty controller
		▶	The controller is not illuminated	▶	Check the supply fuses and any fuses in the furnace control compartment
				▶	The controller may be faulty or not receiving a supply due to a faulty switch or a wiring fault.



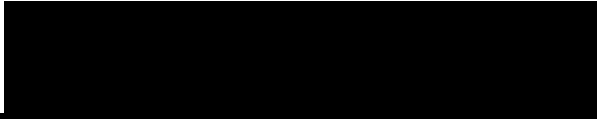
B. Furnace Overheats					
1.	The HEAT light goes OFF when the instrument switch is switched OFF. When switched back ON.	▶	The controller shows a very high temperature	▶	The controller is faulty
		▶	The controller shows a low temperature	▶	The thermocouple may have been shorted out or may have been moved out of the heating chamber
				▶	The thermocouple may be mounted the wrong way round.
				▶	The controller maybe faulty
				▶	Over-Temperature controller may require resetting. Located on the back of the power plate press the page and scroll buttons at the same time.
2.	The HEAT light does not go OFF when the instrument switch is switched off	▶	The SSR has failed "ON"	▶	Check for an accidental wiring fault which could have overloaded the SSR
3.	Cooling fans not running	▶	Fan fuse (F1) has failed	▶	Switch off the furnace immediately, investigate or contact Carbolite Gero
		▶	Fan has failed	▶	Switch off the furnace immediately, investigate or contact Carbolite Gero

**C. Rear Internal Lighting**

1.	Rear lighting does not illuminate when instrument switch is on and the computer connected and the software is running.	▶	The 'Back light is off temperature' is lower than the standby temperature	▶	Increase the 'Back light off temperature' to a value greater than the standby temperature
		▶	The process temperature is greater than the 'Back light off temperature'	▶	Allow the furnace to cool below the 'Back light off temperature'
				▶	Increase the 'Back light off temperature' to a value greater than the process temperature
2.	Rear lighting does not illuminate when instrument switch is on and the computer is not connected.	▶	No signal to switch lights on from the controller	▶	The controller is faulty
		▶	LED's faulty	▶	Investigate or contact Carbolite Gero
		▶	Faulty Wiring	▶	Investigate or contact Carbolite Gero

**D. Computer Software**

1.	No image in software sample window from the camera	▶	Camera status indicator is showing red as disconnected	▶	Check the furnace instrument switch is turned on
				▶	Check all the Ethernet cable connections
				▶	Close the CAF software and restart
		▶	Camera Faulty	▶	Contact Carbolite Gero
2.	No temperature readings shown in the command window	▶	Controller status indicator is showing red as disconnected	▶	Check the furnace instrument switch is turned on
				▶	Check all the serial cable connections
				▶	Close the CAF software and restart



E. Gas System					
1.	Purge gas not flowing	▶	Control system will activate an alarm buzzer and illuminate a warning light on the control panel	▶	This alarm will continue until the furnace is turned off and the 'purge' gas supply is restored. While the alarm is activated the control system will not allow introduction of 'reducing' gas.
		▶	Faulty solenoid valve or solenoid coil connection	▶	Investigate or contact Carbolite Gero
		▶	Faulty Relay (R2, R4)	▶	Investigate or contact Carbolite Gero
		▶	Pressure switch not set at the correct pressure	▶	Investigate or contact Carbolite Gero (do not tamper with pressure settings as this may void warranty claims).
2.	Process gas not flowing. No indication of gas flow though the flow meters.	▶	Flow meter requires adjustment	▶	Adjust the flow rate to comply with working standards
		▶	Faulty solenoid valve or solenoid coil connection	▶	Investigate or contact Carbolite Gero
		▶	Gas oxidising/reducing selector switch faulty	▶	Investigate or contact Carbolite Gero
		▶	Faulty Relay (R2)	▶	Investigate or contact Carbolite Gero
		▶	Controller Logic Faulty	▶	Faulty controller, contact Carbolite Gero
		▶	Pressure switch not set at the correct pressure	▶	Investigate or contact Carbolite Gero (do not tamper with pressure settings)

**F. Internal Carbon Monoxide Sensor**

1.	CO alarm buzzer and CO warning light is on	▶	Fumes from the insulation binders during first heating cycle may cause alarm to be initiated.	▶	Press the CO alarm reset switch during the first heating cycle. The CO warning light will remain on during this period. When the furnace has completed its initial heating cycle turn the instrument switch off then back on to cancel the alarm.
		▶	Carbon Monoxide is leaking from the worktube during the test cycle	▶	The process gases will stop flowing and the purge gas will flow continually. It is recommended that the furnace is allowed to purge for at least 5 minutes before turning off the instrument switch. The audible CO alarm can be switched off during this period by pressing the CO alarm reset switch. The CO warning light will remain on during this period. Identify the source of the leak before switching the furnace back on (see section 3.3)
		▶	The CO Sensor has overheated	▶	Check that the centre fan on the back of the furnace is blowing inwards onto the sensor. If the fan is not working, allow the furnace to cool immediately. Once the furnace has cooled and with the furnace disconnected from the power supply, check the wire connections to the fan. If the sensor or fan are still not working contact Carbolite Gero.

## 7.0 Wiring Diagrams

For wiring diagrams, please contact Carbolite Gero Service. Please quote the serial number and model.

## 8.0 Specifications

*Carbolite Gero reserves the right to change the specification without notice.*

Maximum external cabinet dimensions:	
Height	804 mm
Width	505 mm
Case Depth	625 mm
Overall Depth	1070 mm
Work tube dimensions:	
Internal Diameter	79 mm
Length	650 mm
Material	RCA

### 8.1 Environment

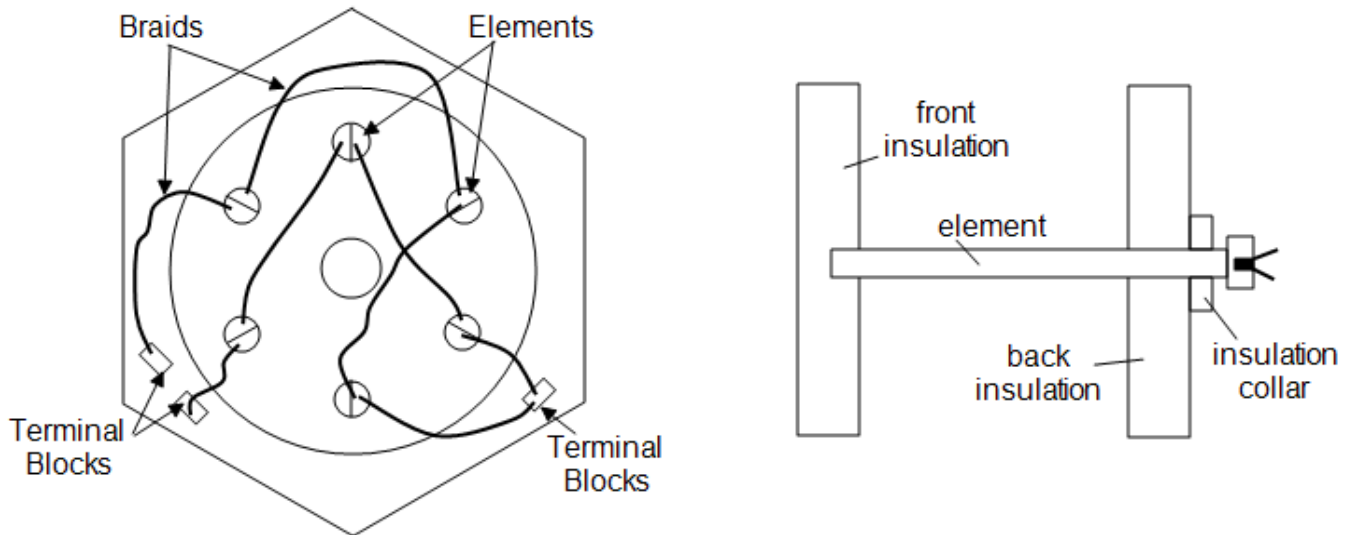
The models listed in this manual contain electrical parts and should be stored and used in indoor conditions as follows:

Temperature: 5 °C - 40 °C

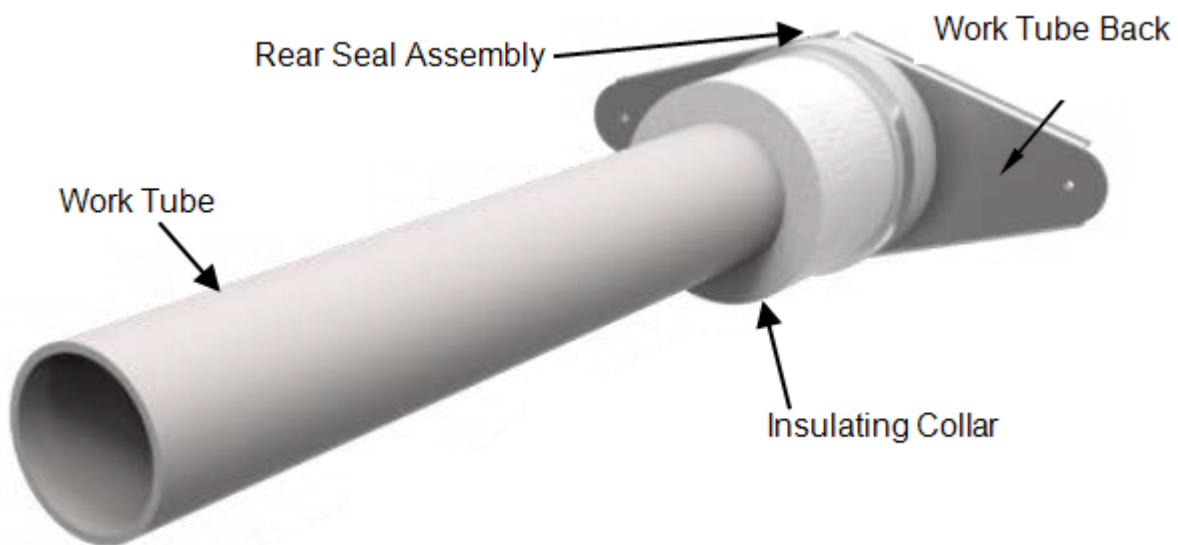
Relative humidity: Maximum 80 % up to 31 °C decreasing linearly to 50 % at 40 °C

## 9.0 Appendix

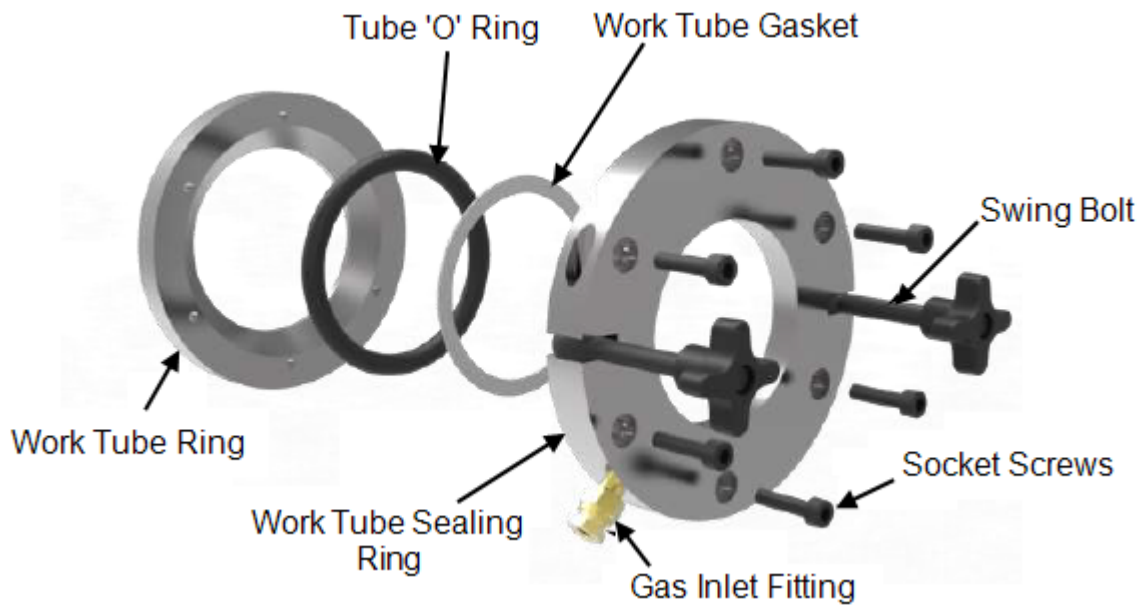
The figures referred to in the previous text are listed below.



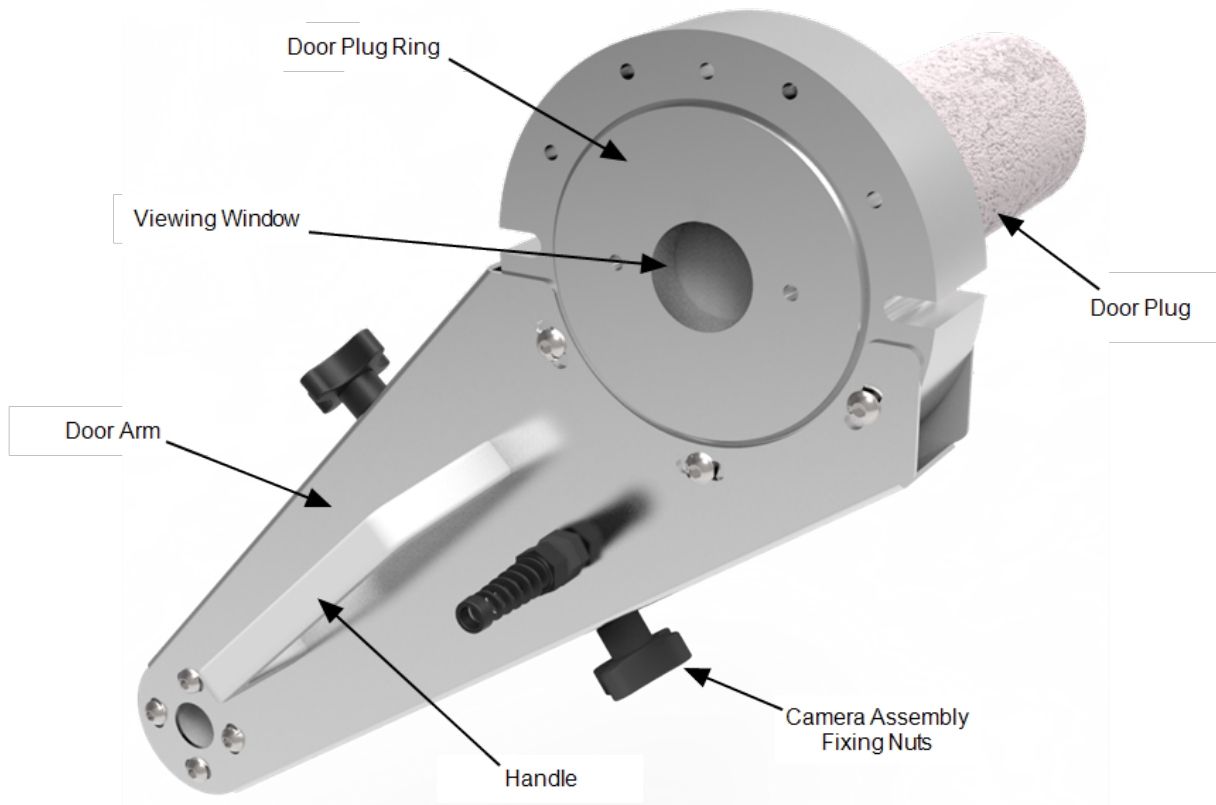
**Fig 1. Element Wiring and Positions**



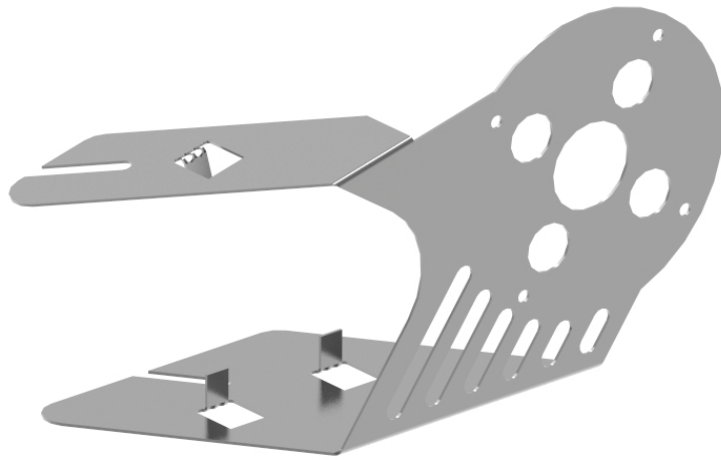
**Fig 2. Work Tube and Back Plug Assembly**



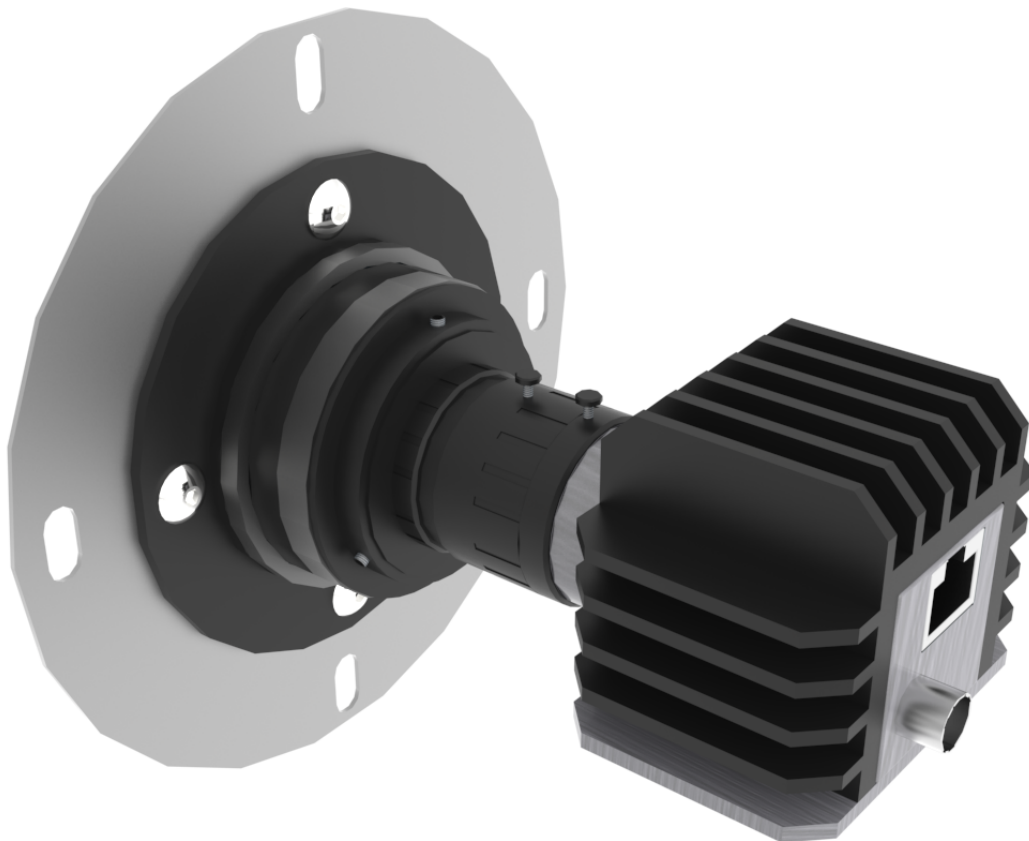
**Fig 3. Front Tube Seal Assembly**



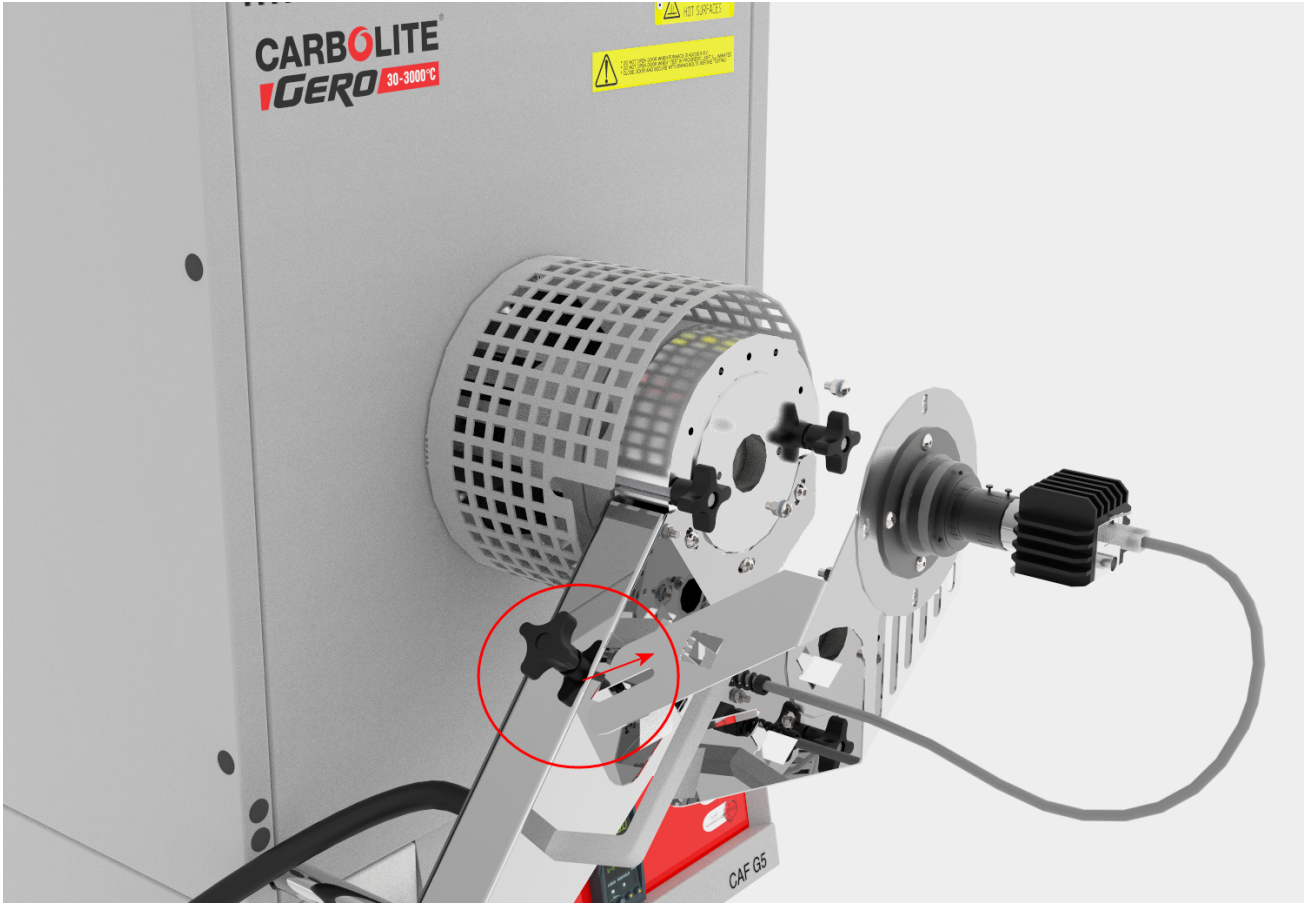
**Fig 4. Door Arm Assembly**



**Fig 5a. Camera Mounting Bracket**



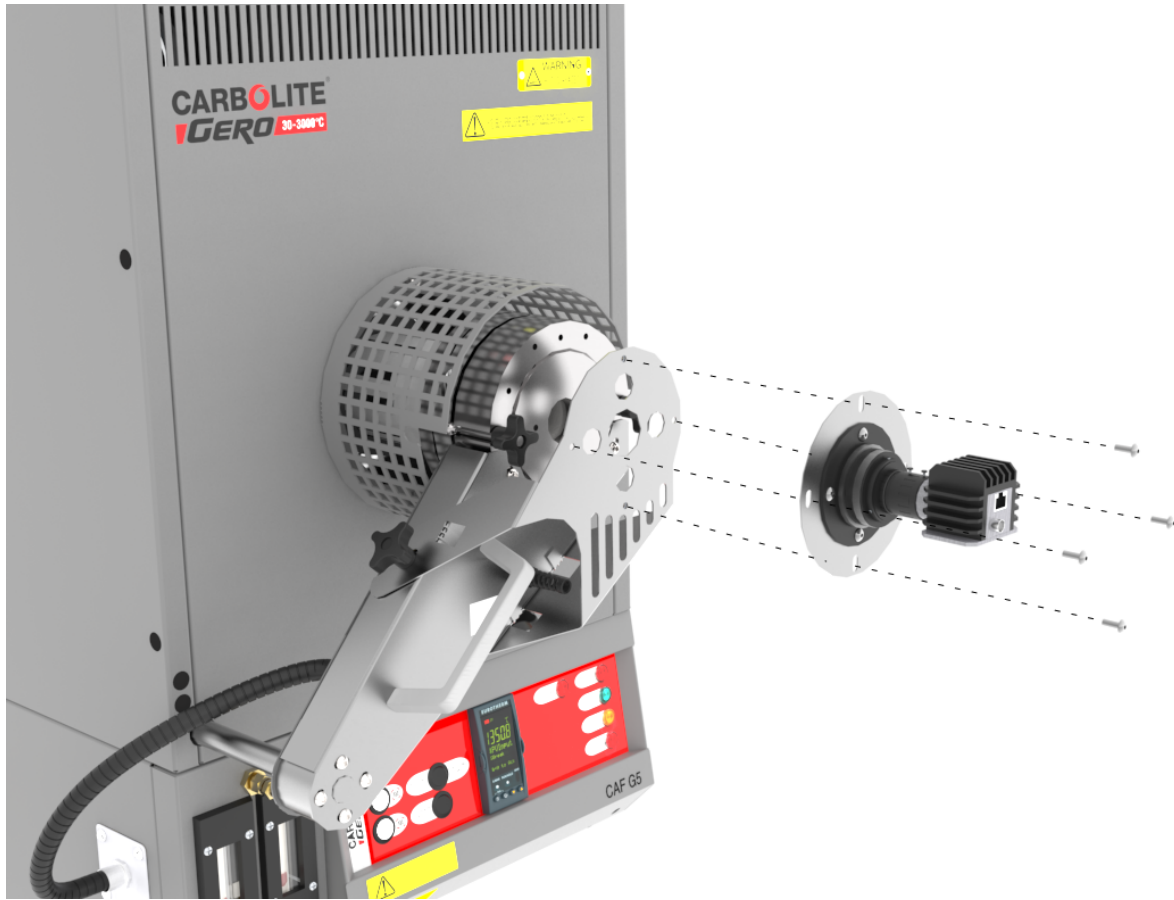
**Fig 5b. Lens and Camera Assembly**



**Fig 5c. Sliding the Camera Mounting Bracket Assembly onto the Door Arm**



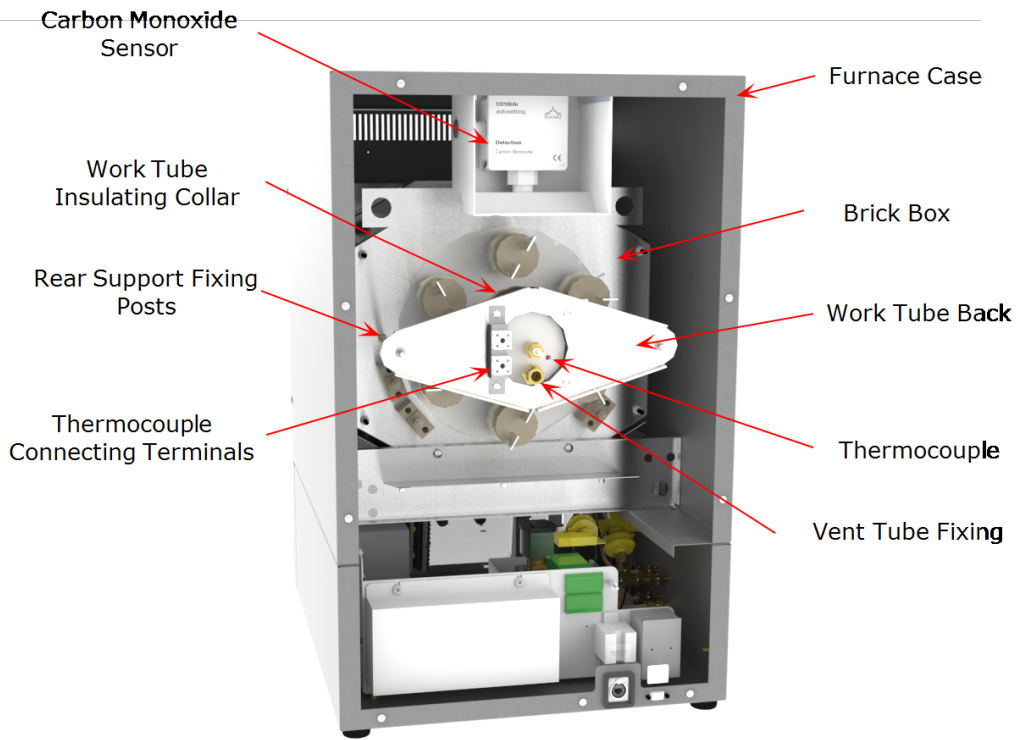
**Fig 5d. Securing the Camera Mounting Bracket Assembly to the Door Arm**



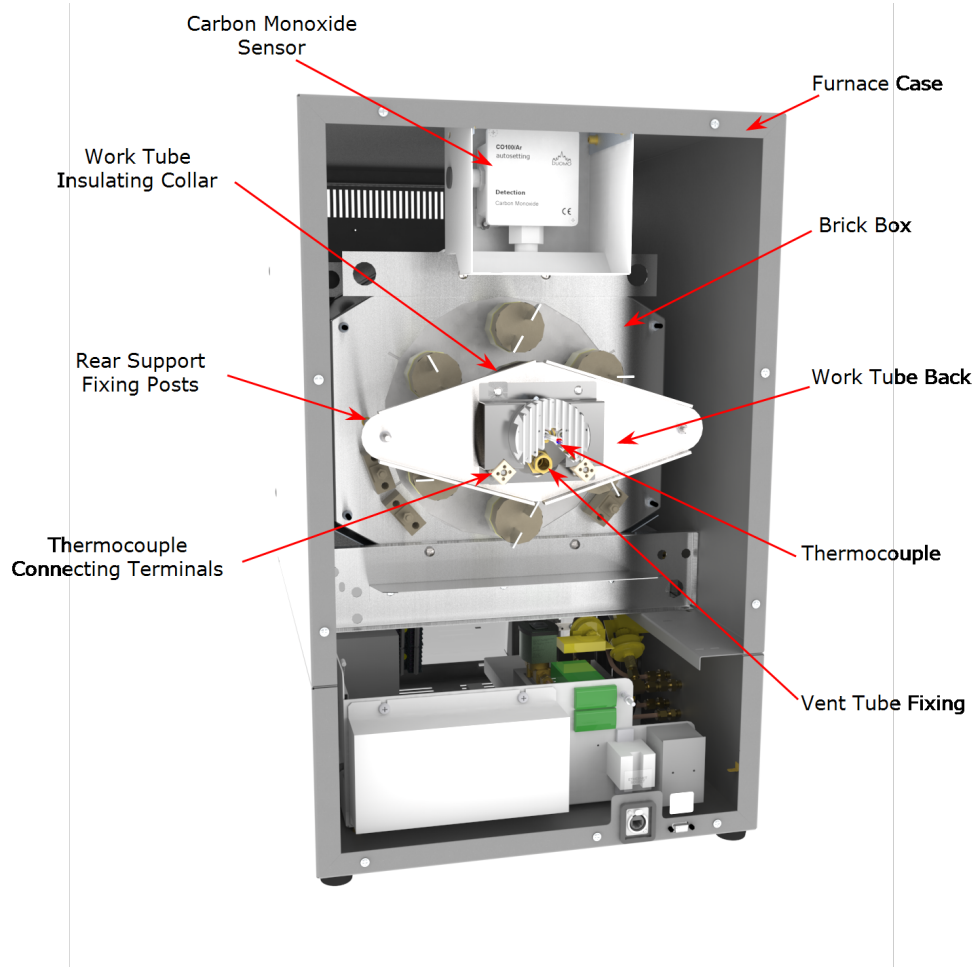
**Fig 5e. Mounting the Lens and Camera Assembly**



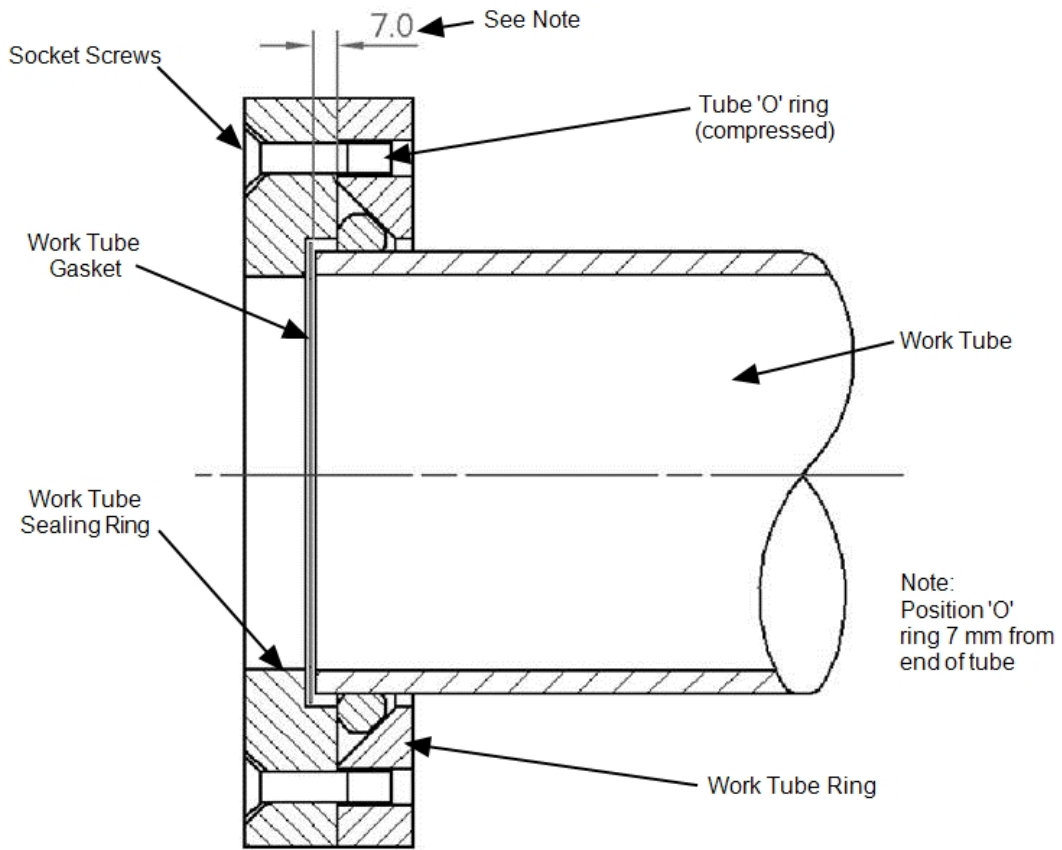
**Fig 5f. Lens and Camera Assembly in Position**



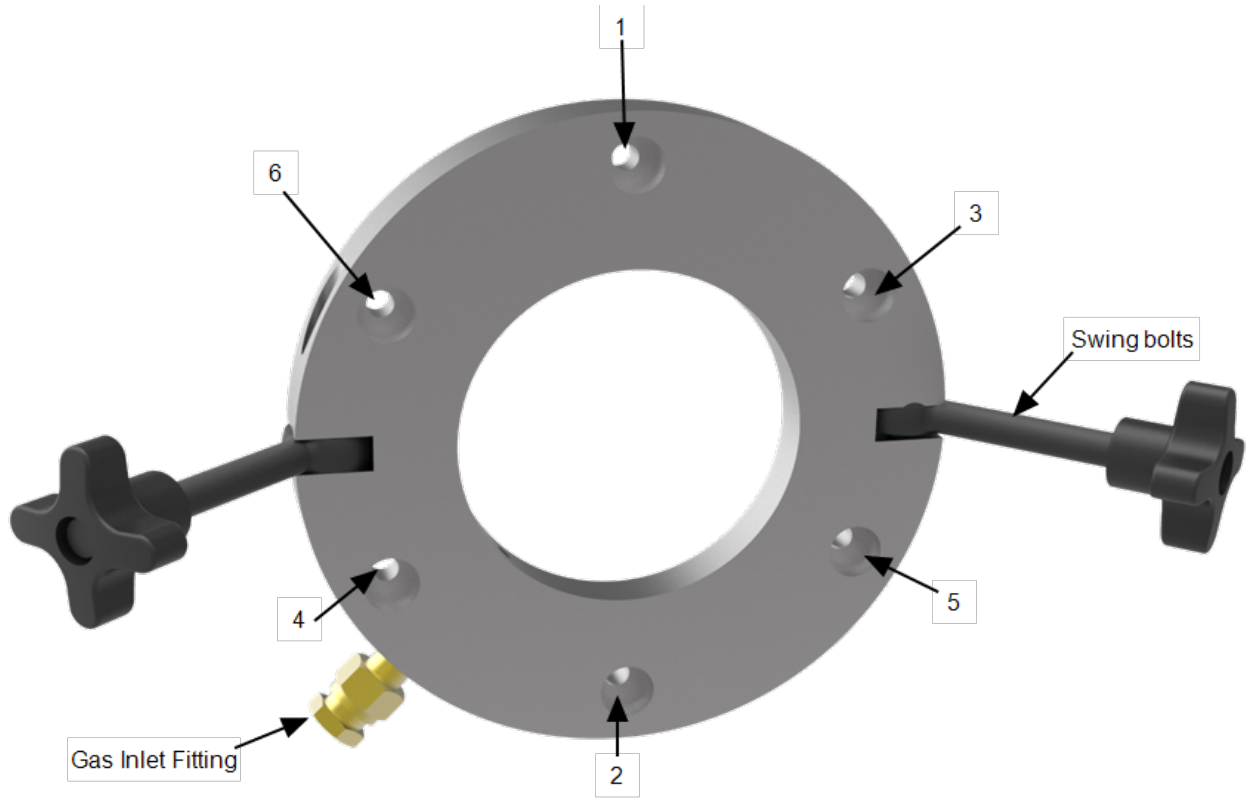
**Fig 6a. Rear View of the Standard CAF G5 Furnace Showing Brick Box Assembly**



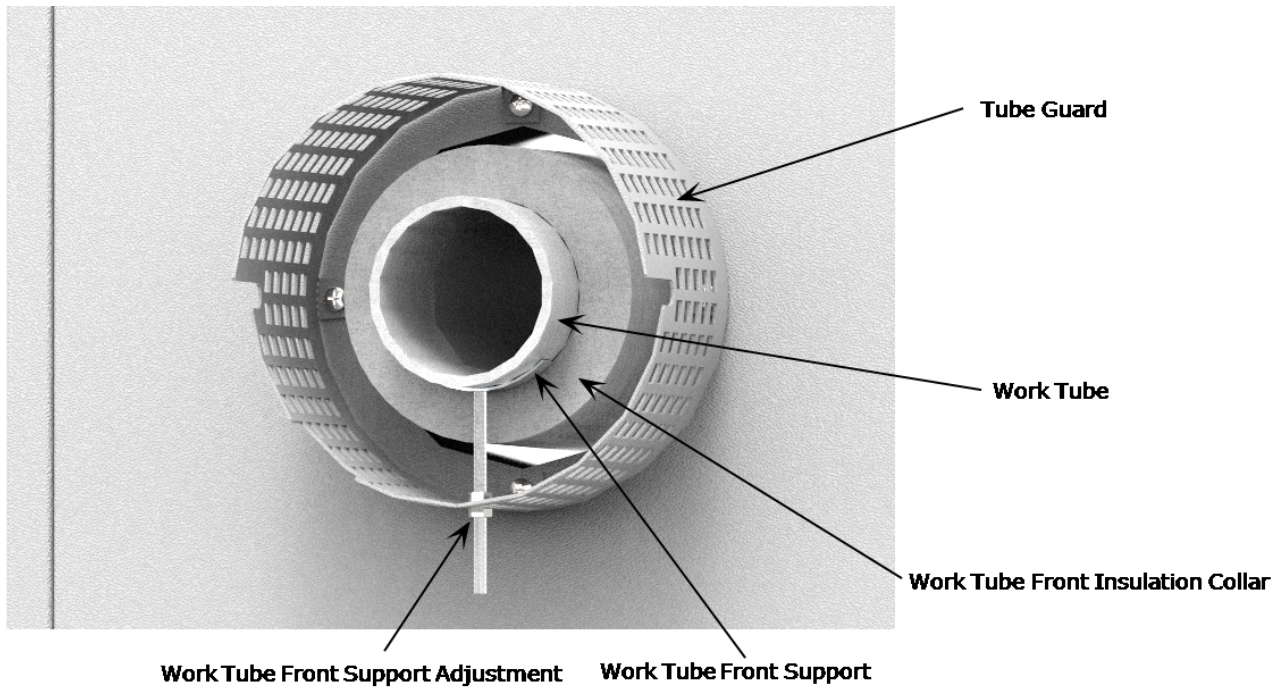
**Fig 6b. Rear View of the CAF G5 Biomass Furnace with Rear Illumination Showing Brick Box Assembly**



**Fig 7. Front Tube Seal Position**



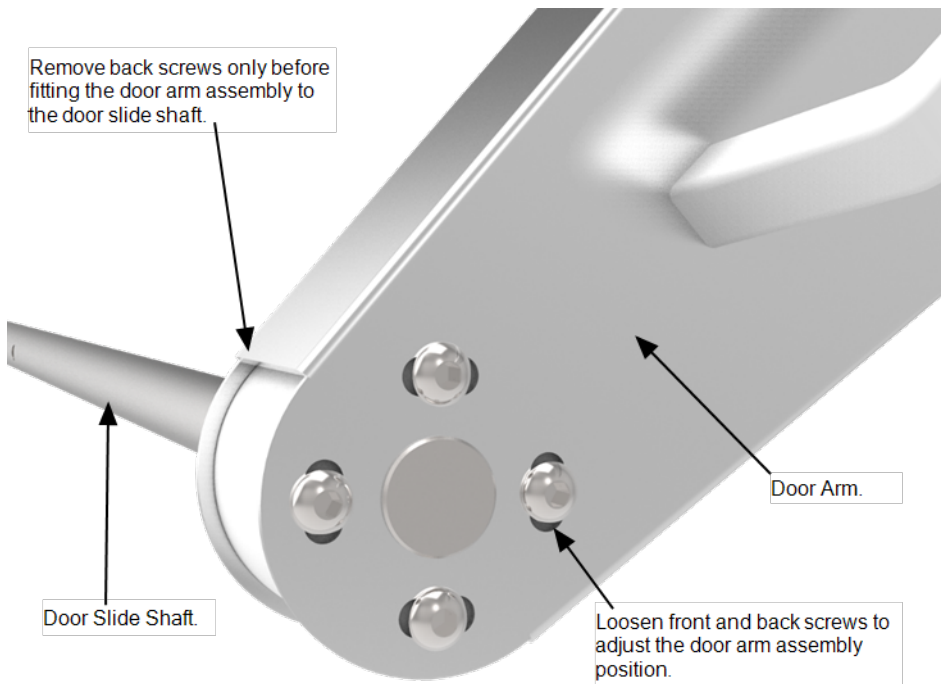
**Fig 8. Tube End Seal Assembly Tightening Sequence**



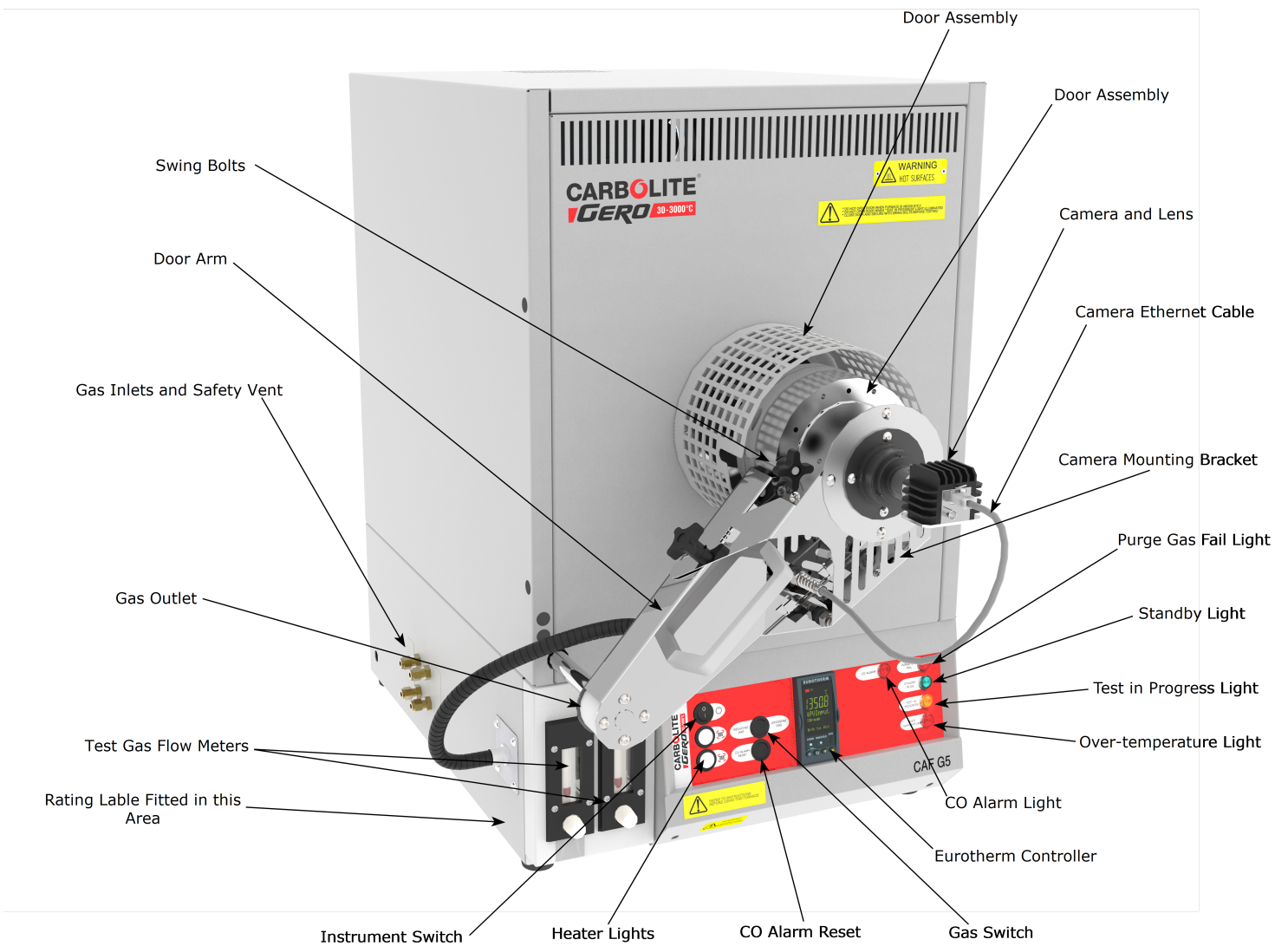
**Fig 9. Work Tube Front Support**



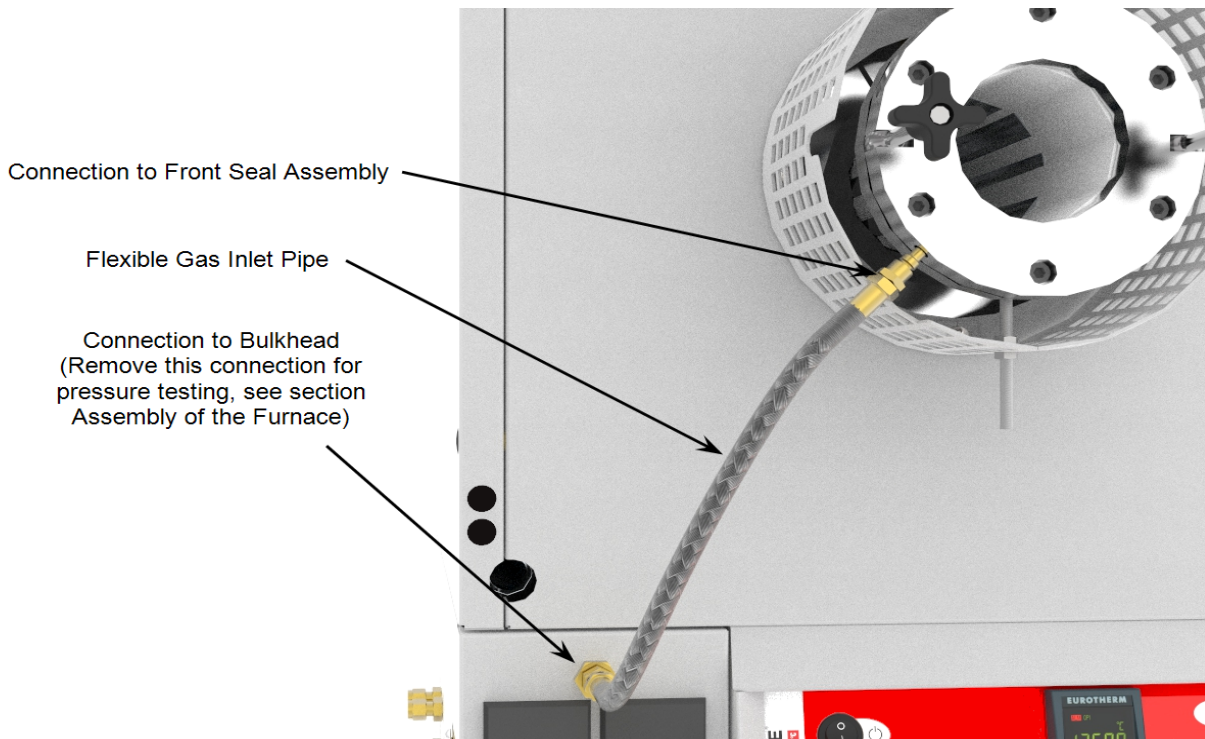
**Fig 10. Fitting the Door Arm Assembly**



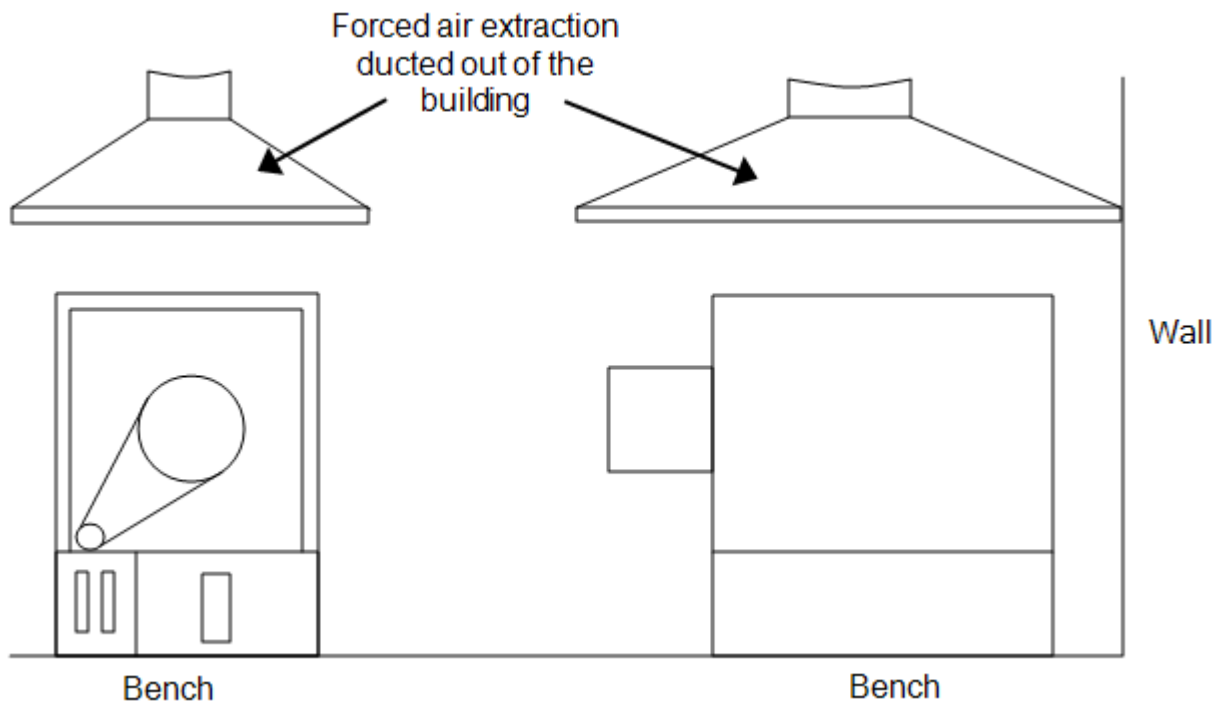
**Fig 10a. Adjusting the Door Arm Assembly**



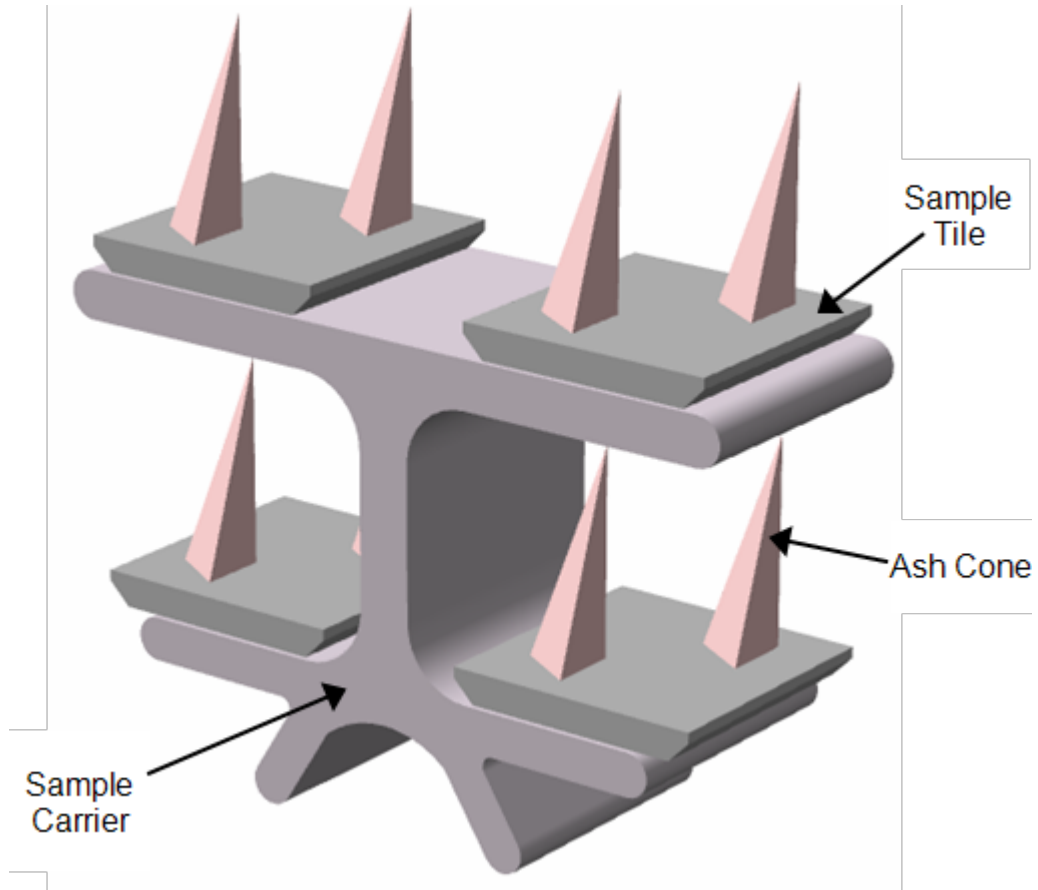
**Fig 11a. Furnace Case and Controls**



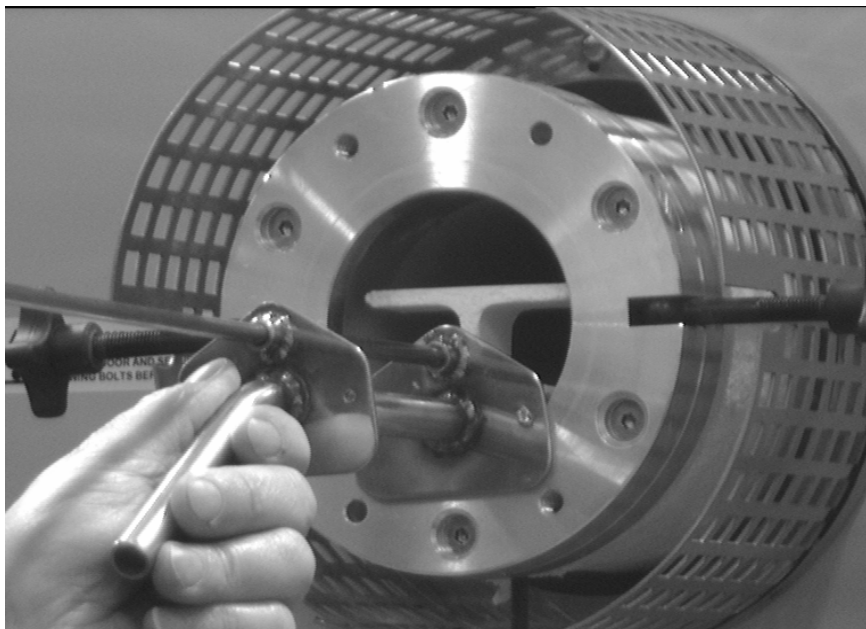
**Fig 11b. Gas Inlet Pipe**



**Fig 12. Positioning the Furnace**



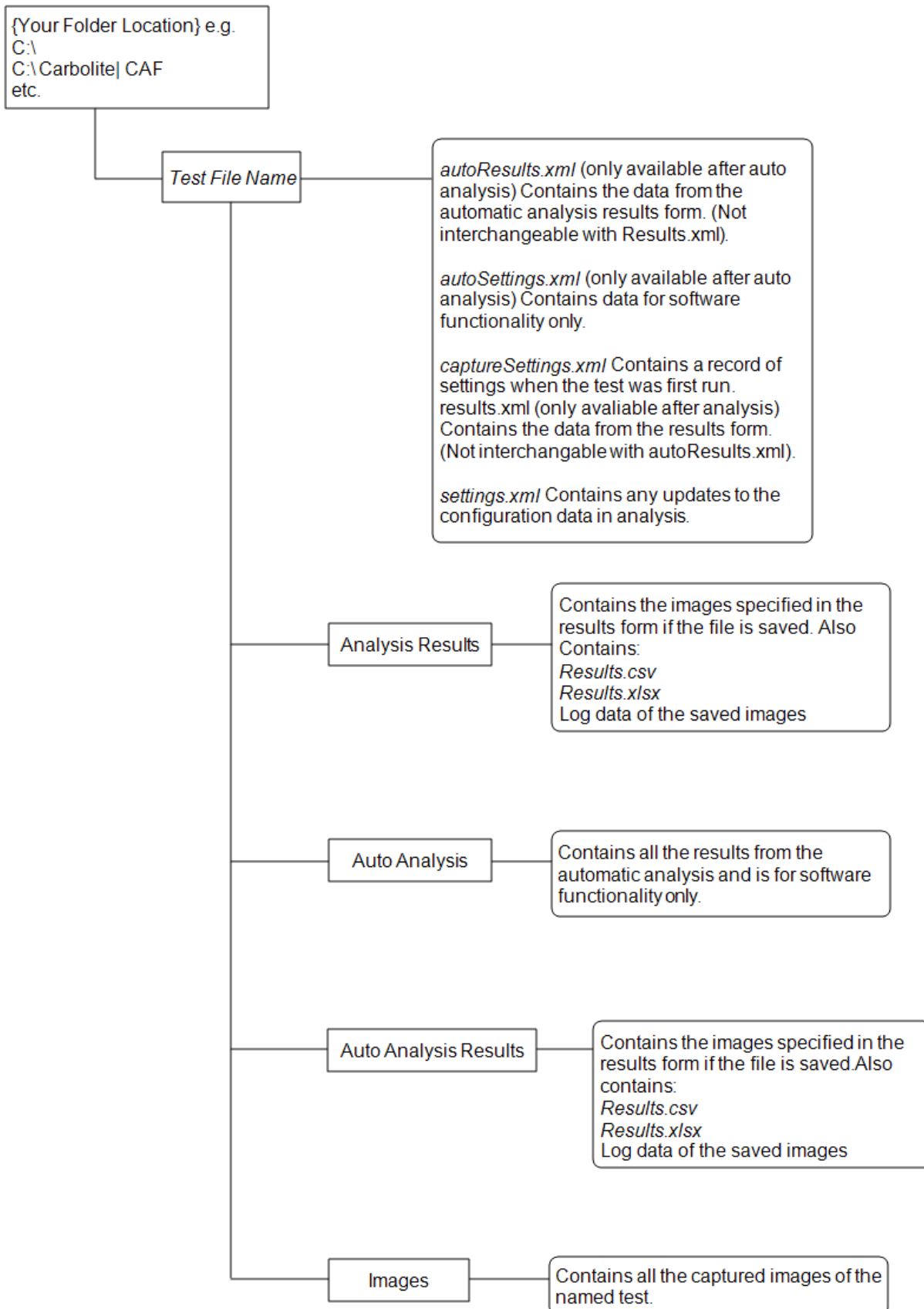
**Fig 13a. Positioning Samples on the Sample Carrier**



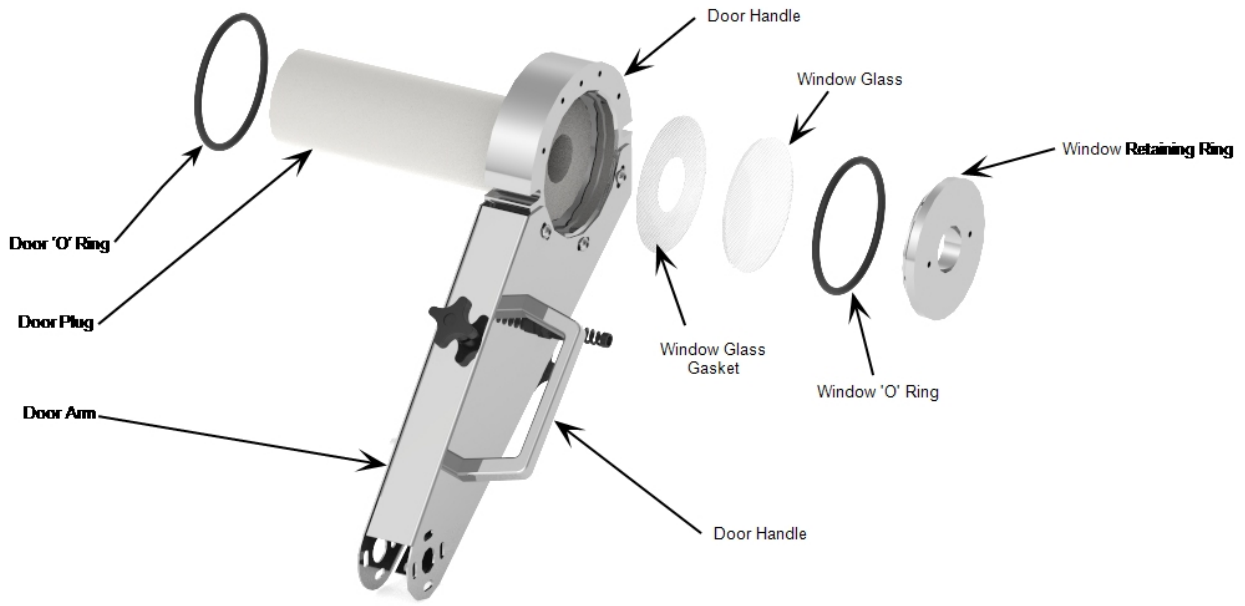
**Fig 13b. Loading Samples into the Mouth of the Work Tube**



**Fig 13c. Loading Samples into the Work Tube**



**Fig 16. File Folder**



**Fig 17. Door Arm Assembly Exploded View**

**CARBOLITE**  
**IGERO** 30-3000°C

**Ash Fusibility Results**

Date of Test: 01 April 2015  
 Test Start Time: 15:03  
 Date of Analysis: 23rd April 2015  
 Time of Analysis: 16:01  
 Test Name: Carbolite Gero Biomass  
 Test Reference: ESG Ash Wood

Identity	Description	SST	DT	HT	FT
1	test piece 1	1209	1230	1242	1251
2	test piece 2				
3	test piece 3				
4	test piece 4				
5	test piece 5				
6	test piece 6				
7	test piece 7				
8	test piece 8				

Temperature Scale = Celsius  
 SST = Shrinkage Starting Temperature  
 DT = Deformation Temperature  
 HT = Hemisphere Temperature  
 FT = Flow/ fluid Temperature

**Fig 18. Report Sheet Page 1**

**CARBOLITE**  
**IGERO** 30-3000°C

Date of Test: 01 April 2015  
Test Start Time: 15:03  
Date of Analysis: 23 April 2015  
Time of Analysis: 16:01  
Test Name: Carbolite Gero Biomass  
Test Reference: Ash Wood

Identity	Description	SST	DT	HT	FT
1	test piece 1	1209	1230	1242	1251

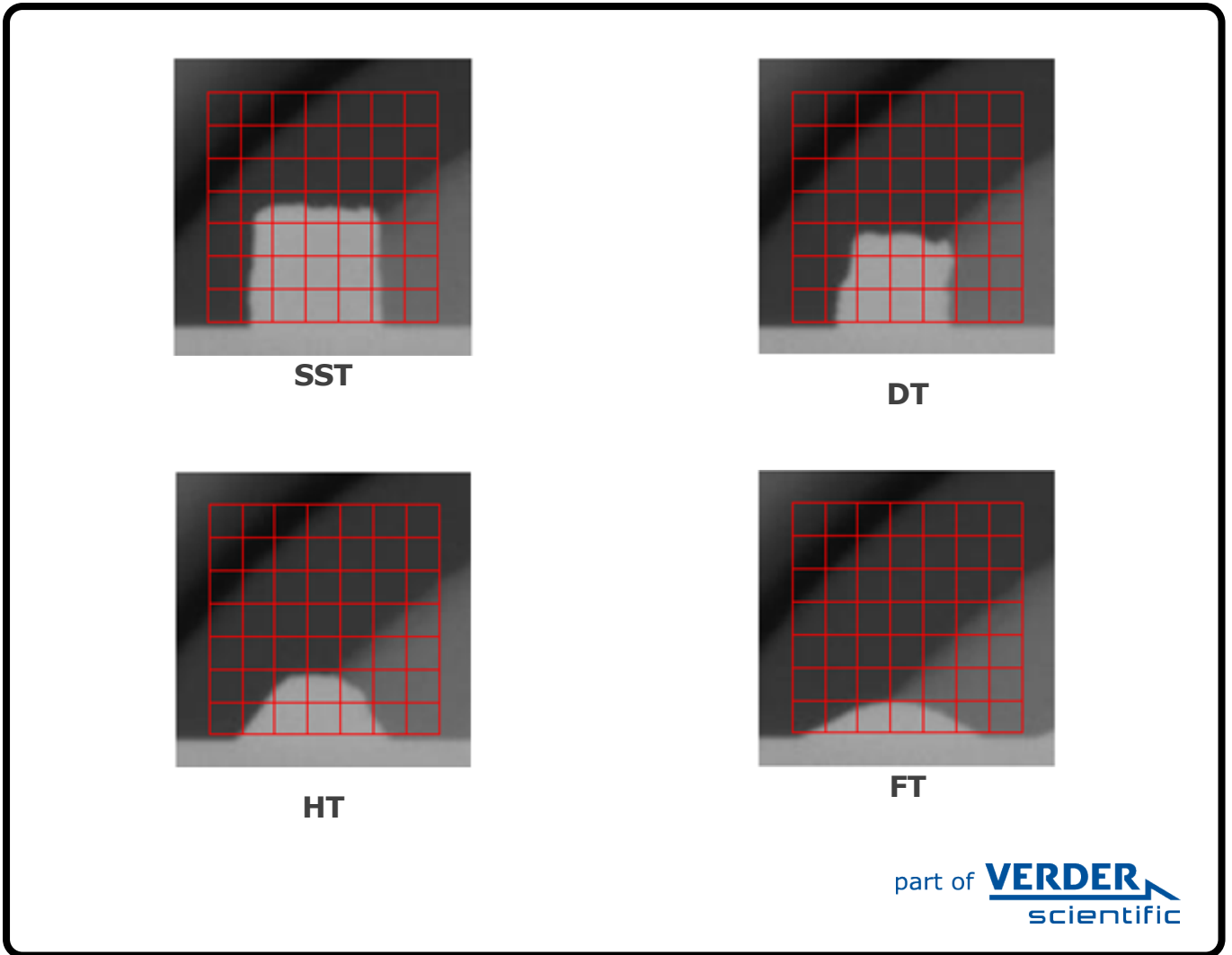


Fig 18. Report Sheet Page 2

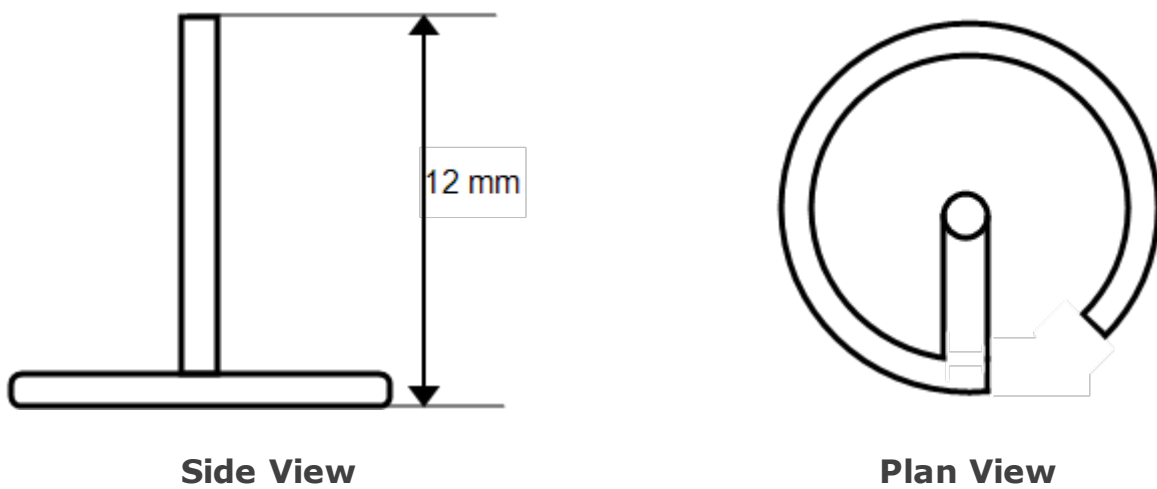
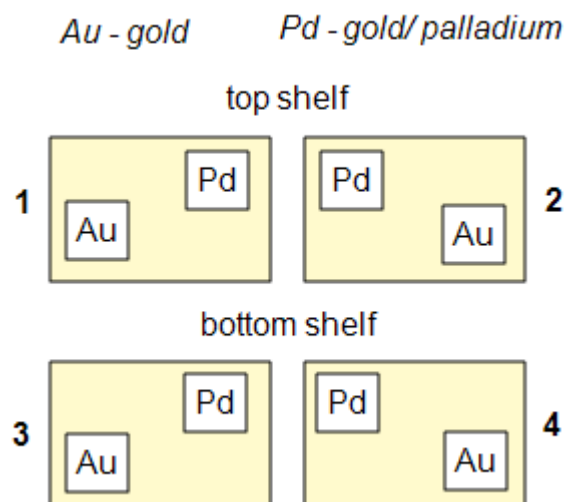
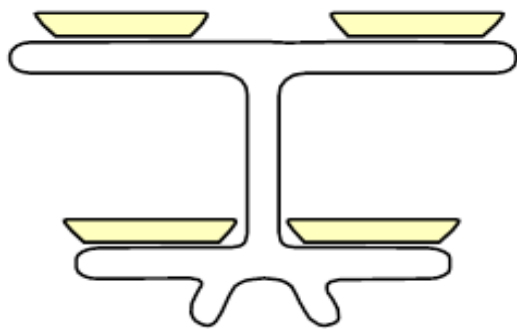
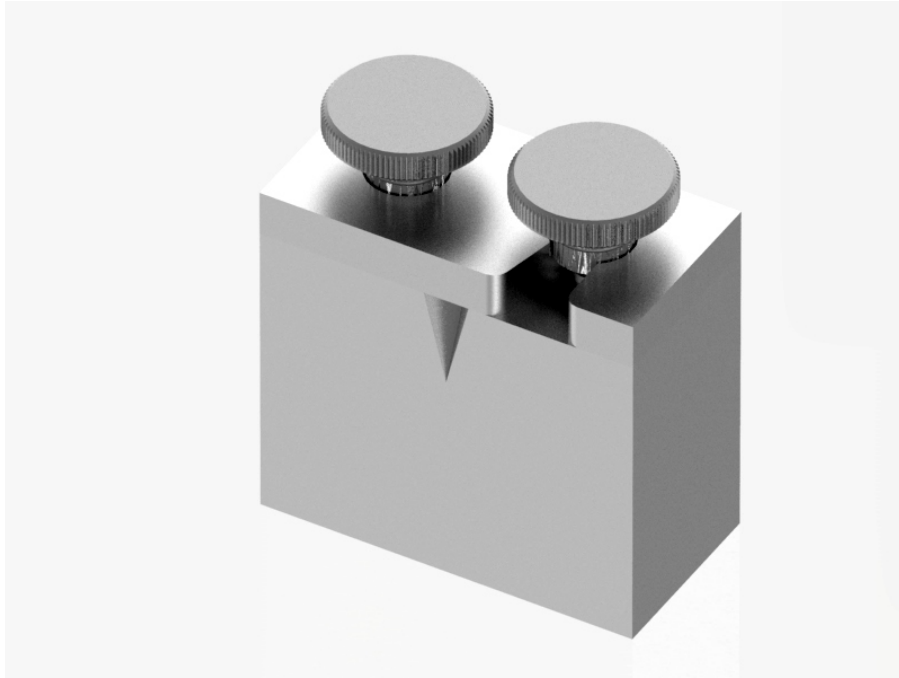


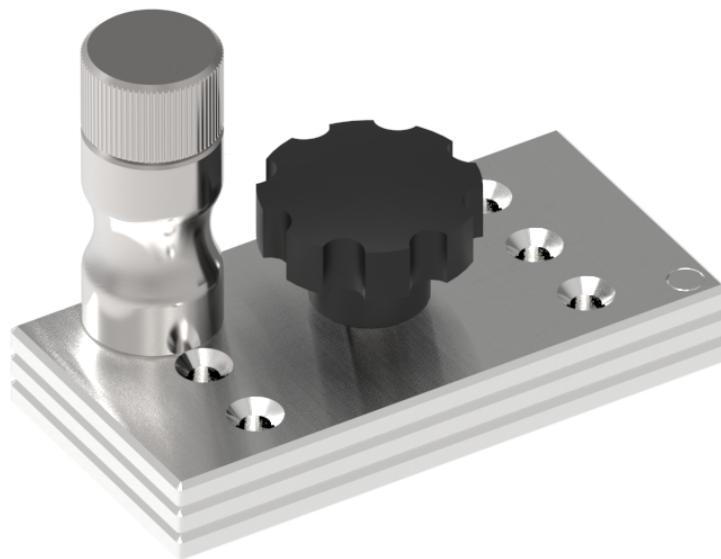
Fig 19. Formed Wire Sample



**Fig 20. Sample Carrier, Sample Tiles and Sample Positions**



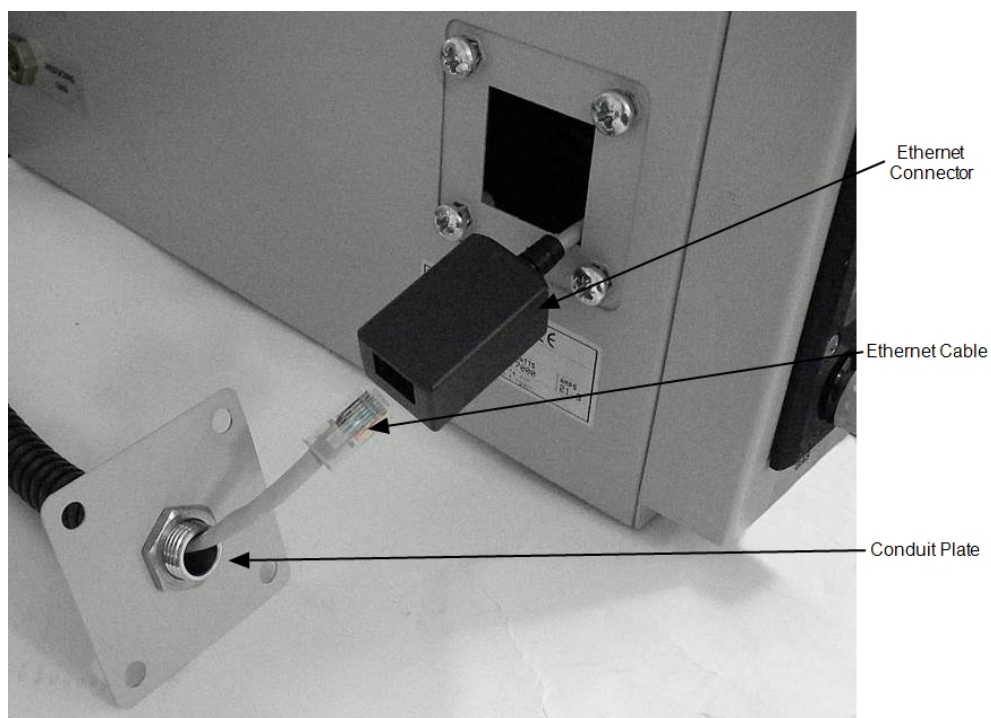
**Fig 21a. Coal and Coke Test Piece Mould**



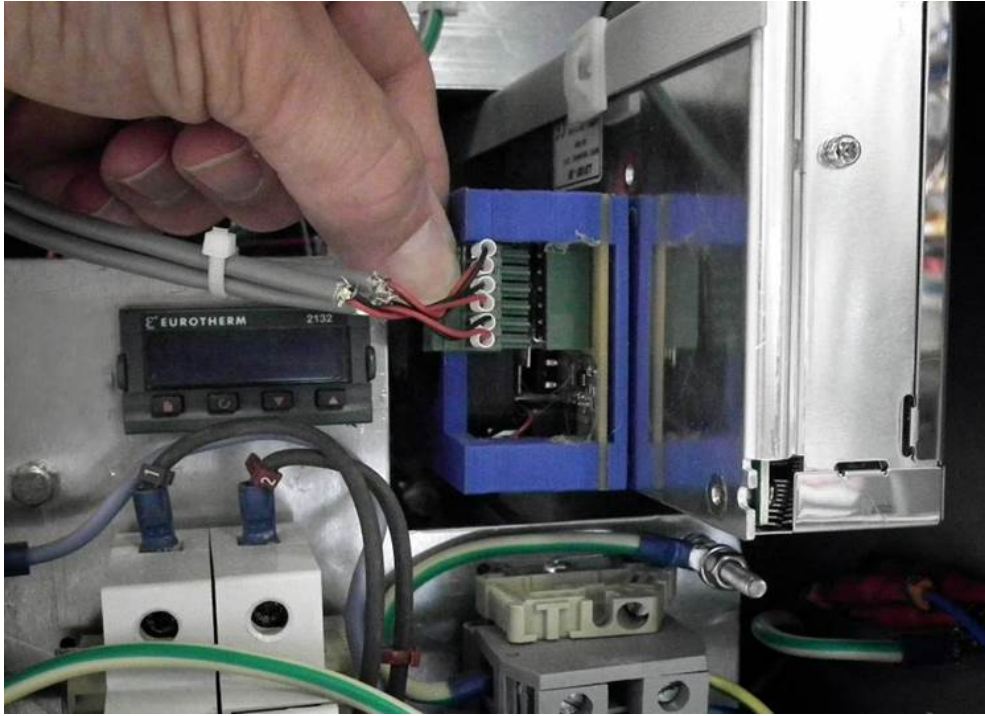
**Fig 21b. Biomass Test Piece Mould and Hand Press**



**Fig 22. Sample Loading Tool**



**Fig 23. Camera Ethernet Connection**



**Fig 24. LED Driver Connection**



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