



# Installation, Operating & Maintenance Instructions

Coal Ash Fusion Test Furnace  
CAF DIGITAL IMAGING



This manual is for the guidance of operators of the CAF Digital furnace and should be read before the furnace is connected to the electricity and gas supplies. It contains information required for safe and trouble-free furnace operation. If, however, any questions remain unanswered please contact our service division at the address at the end of this manual.

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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 on installation and observe section 3.6 about supply voltage.

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: Carbon Monoxide Warning.

During a test only the yellow Test In Progress light should be illuminated. If any of the other three lights are illuminated (see fig 11) 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 11) 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: Carbon Monoxide Warning.

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: Pressure testing of the Work Tube Assembly.

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 Digital furnace involves the use of carbon monoxide.

When testing in accordance with ASTM: D1857-87 (1994) Carbon monoxide is introduced as a 'reducing' atmosphere gas and carbon monoxide is produced as a by-product when testing in accordance with BS1016: Part 113: 1995 ISO 540: 1995 and ASTM: D1857-87 (1994).

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.



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:

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

Parts per million	Effect.
50	Recommended Exposure Limit (8 hours time weighted average concentration).
200	Headache after about 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*
- *EH40/97 Occupational Exposure Limits 1997. ISBN 0 7176 1315 1*

### 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 Monoxide Warning.

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 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.



### 1.4 **Refractory Fibrous Insulation Warning.**

This furnace contains refractory fibres in its thermal insulation. These materials may be in the form of fibre blanket or felt, vacuum formed board or shapes, mineral wool slab or loose fill fibre.

Normal use of the furnace 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, we strongly recommend that safety precautions are taken whenever the materials are handled:

***Exposure to dust from fibre that has been used at high temperatures may cause respiratory disease.***

***When handling fibre always use an approved mask, eye protection, gloves and long sleeved clothing.***

***Avoid breaking up waste material. Dispose of waste fibre 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 we recommend reference to the European Ceramic Fibre Industry Association Bulletin No. 11 and the UK Health and Safety Executive Guidance Note EH46. We can provide further information on request, alternatively our service division can quote for any repairs to be carried out at your premises or ours.

### 1.5 Viton 'O' ring Seals - Warning.

The 'O' ring seals used in the CAF Digital furnace work tube assembly are manufactured from Viton. Viton is combustible 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 recommend. Burning is not recommended except by an approved or licensed incineration agent.

### 2.0 MODELS COVERED BY THIS MANUAL.

Two basic furnace options are available, which differ only in the gases used to create the 'oxidising' and 'reducing' atmosphere and the control of those gases.

Option 1. CO/CO<sub>2</sub> 'reducing' gas and Air 'oxidising' gas with N<sub>2</sub> 'Purge' gas.

Compatible with - ASTM D 1857-87 Standard Test Method for Fusibility of Coal and Coke Ash.

Option 2. 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.

Compatible with - BS 1016 : Part 113 : 1995 ISO 540 : 1995 Methods for Analysis and Testing of Coal and Coke. Part 113. Determination of Ash Fusibility.

### 3.0 INSTALLATION INSTRUCTIONS.

The furnace contains 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

### 3.1 Unpacking & Handling.

This furnace is heavy, take appropriate precautions when lifting or moving it and use a sufficient number of people.

When unpacking or moving the furnace always lift it by its base. Never lift it by any attachments or protruding parts. 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 Standard lens and camera assembly, see fig 5b.
- 1 off Zoom lens assembly and lens clamp, see fig 5g. *if supplied*
- 1 off Zoom lens mounting bracket. *if supplied*
- 6 off Panel hole blanking plugs.
- 5 off Cable ties.
- 1 off Sample Carrier.
- 100 off Sample tiles.
- 1 off Sample loading tool.
- 1 off 'Window retaining ring' spanner.
- 1 off Cone mould.
- 1 off 150mm length of Gold wire (1063°C fuse wire).
- 1 off 150mm length of Palladium wire (1554°C fuse wire).
- 1 off Carbon Monoxide monitor.
- 1 off RS 232 Interface cable.
- 1 off Camera video extension cable.
- 1 off Computer.
- 1 off Monitor.
- 1 off Keyboard.
- 1 off Mouse.
- 1 off Carbolite software protection dongle.
- 2 off Computer power cables.
- 1 off Set - Trouble shooting discs.
- 1 off Set - Computer operating instructions.
- 1 off Installation, Operating & 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 6.

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, the negative legs of the thermocouple are marked blue, compensating cable colour coding is: Negative = white. Positive = orange.

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 7.

Fit the tube 'O' ring over the front of the work tube and position it uniformly 7.0mm 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.

Attached to the door arm assembly is a conduit carrying the video and power cables for the camera. Pass the wires through the conduit plate aperture in the left-hand side of the furnace case and connect the camera power cable connector situated just inside the conduit plate aperture. Route the camera video cable as shown in fig. 21 and tie into the existing wiring at suitable points using the cable ties provided.

**Note:** take care to route the cable away from sharp edges and hot surfaces.

Fit the camera video cable phono socket into the hole adjacent to the comms socket in the bottom flange at the rear of the furnace case. Secure using the fixings provided.

Fit the furnace case back panel.

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 slackening 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 11. 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 a bung or 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, and check that the work tube assembly does not leak.

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.

### 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: Carbon Monoxide Warning.) and must be ducted out of the building. See also section 3.6: Exhaust Vent Connections.

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 user 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 100mm around the furnace and do not obstruct any of the vents in the case as these are required to keep internal components cool.

### 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 11. Check that the 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 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 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 table 2. The supply must incorporate an earth (ground).

Table 2. Electrical connections:

Supply	Terminal label	Cable colour	Supply type	
			Live-Neutral	Reversible or Live-Live
<b>1-phase</b>	L or L1	Brown or Black	to live	to either power conductor
	N or L2	Blue or Black	to neutral	to the other power conductor
	PE	Green/Yellow	to earth (ground)	to earth (ground)
<b>2-phase</b>	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 & Power Limit Settings.



Check the furnace rating label voltage. If the actual supply is not the same as the voltage on the label, then the controller power limit should be adjusted as follows.

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

Press Page  $\square$  until  $\square P$  (output list) is displayed. Press Scroll  $\curvearrowright$  until  $\square P.H_i$  (Output High) is displayed. Press Down  $\blacktriangledown$  or Up  $\blacktriangle$  once to display the value of  $\square P.H_i$  (it is good practice to write down the original value). To alter the parameter use Down  $\blacktriangledown$  or Up  $\blacktriangle$ .

Correct values for the  $\square P.H_i$  parameter, with new elements, are:

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

See also the section on element ageing – section 5.2.

### 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: Carbon Monoxide Warning.) 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: Positioning The Furnace.



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 12mm x 3/8" BSP adapter suitable for connecting 12mm diameter copper tube. See fig 6.

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

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

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

### 3.8. Gas Connection.

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

*See next page 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 11. 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: Carbon Monoxide Warning.

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

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

*If a mixer box is supplied, then 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 flowmeters 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 11. 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: Hydrogen and Carbon Dioxide Warning.

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

### **3.9. Camera Mounting And Connections – Standard Lens.**

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.

Mount the standard 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 lens firmly in position, push the camera towards the lens and rotate it in the desired direction.

The camera power cable is secured to the rear of the camera by a security bracket. Do not remove this bracket. Connect the camera power cable to the 12V DC camera supply socket on the front of the door arm. See fig 11.

Connect the camera video cable from the front of the door arm to the 'video out' socket on the back of the camera.

#### **3.9.1. Camera and lens settings.**

The camera and lens are pre-adjusted to give the best quality picture. The following settings have been made.

- The shutter switch on the rear of the camera must be set to OFF when using the standard auto-iris lens.
- The standard auto-iris lens has two adjustment screws on the lens body. The screw marked ALC is set to A (fully clockwise). The screw marked LEVEL is set to L (fully anticlockwise).

### **3.10. Camera Mounting & Connections – Zoom Lens.**

The zoom lens is supplied as an option. It shares the camera and lens heat shield assembly used with the standard lens. See fig 5g showing the zoom lens assembly and lens clamp.

#### **3.10.1. Assembly of the zoom lens.**

Disconnect the auto-iris plug from the camera and unscrew the camera from the standard lens. It is not necessary to remove the 5mm spacer ring from the rear of the standard lens (see fig 5b).

Screw the camera onto the rear of the zoom lens assembly (see fig 5h).

Unscrew the lens heat shield assembly from the front of the standard lens. It is not necessary to remove the 43-49mm step up ring from the front of the standard lens (see fig 5b).

Screw the lens heat shield assembly onto the front of the zoom lens assembly (see fig 5j).

#### **3.10.2. Zoom lens mounting.**

**Note:** The zoom lens and camera assembly must be removed from the door arm before opening the door. The door slide mechanism is not designed to carry the extra weight of the zoom lens assembly when the door arm is fully extended. The swing bolts which secure the door cannot be swung clear of the door when the zoom lens mounting bracket is in position; only mount the zoom lens bracket when the door is closed and the swing bolts are secured.

The zoom lens and camera assembly can be conveniently stored between tests by standing it on its end as shown in fig 5p.

Secure the zoom lens and camera assembly to the zoom lens mounting bracket using the screw fixing in the top of the ball joint. Remove the standard camera mounting bracket from the door arm; see fig 5c and 5d. Mount the zoom lens and bracket onto the door assembly by sliding the bracket onto the three fixing screws on the front of the door assembly; see fig 5k. The socket head screws are fixed in position and do not require tightening.

The camera power cable is secured to the back of the camera by a security bracket which should not be removed. Connect the camera power cable to the 12v-dc camera supply socket on the front of the door arm. See fig 11. Connect the camera video cable from the front of the door arm to the Video Out socket on the back of the camera.

### 3.10.3. Camera and Lens Settings.

To give the best quality picture the following settings are required.

The shutter switch on the back of the camera must be set to ON when using the zoom lens.

Set the zoom lens aperture to f22. This gives an image at 815°C sufficient to adjust the lens position before a test. If necessary, a higher aperture setting can be used at lower temperatures to give a brighter image during test set up.

Do not set the lens aperture higher than f22 during a test: the image will burn out at high temperatures.

### 3.10.4. Adjusting the Lens.

The test software must be running in “test grabber” mode to perform this operation. See section 4.5.4.

With the lens at its maximum usable zoom magnification, a 3mm wide and 3mm high object will be displayed in the viewing window of the monitor as an image approximately 110mm wide and 110mm high. Reducing the zoom magnification reduces the size of the displayed image. It is not possible to focus the image over the full zoom range of the lens.

Load the test samples into the work tube (see section 4.4) and securely close the door using the swing bolts. Mount the zoom lens and camera assembly to the door arm as described in section 3.10.2.

When the furnace has reached 815°C there should be sufficient light in the work tube to allow an image to be captured. With the test software in “test grabber” mode release the ball swivel locking screw and move the lens and camera assembly to display an image of the test sample in the viewing window of the monitor. See fig 5m. Once an image is displayed correctly, lock the lens in position using the ball swivel locking screw.

If the image is difficult to see, adjusting the lens aperture may improve it. Remember to set the aperture back to f22 after setting the lens position, or the image will burn out.

Focus the image and adjust its size using the lens operating ring. It may be necessary to rotate the lens and camera assembly to level the image on the monitor; to do this, release the lens clamp screw as shown in fig 5n.

As the furnace heats up the work tube will increase slightly in length and some movement of the test sample may occur. It may be necessary to refocus the camera during the initial CAF test run.

### 3.11. Computer Connections.

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

Insert the Carbolite hardware lock (dongle) into the printer port on the back of the computer.

Connect the camera video extension cable from the phono socket on the back of the furnace case to the Video Card phono 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.

## 4.0 OPERATING INSTRUCTIONS.

### 4.1 Furnace Start-up.

This furnace is available in two options:

- Option 1. CO/CO<sub>2</sub> 'reducing' gas and Air 'oxidising' gas with N<sub>2</sub> 'Purge' gas.  
Compatible with - ASTM D 1857-87.
- Option 2. 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.  
Compatible with - BS 1016 : Part 113 : 1995 ISO 540.

The principle of operation is the same for both options. The furnace is normally supplied programmed to operate between a pre-determined set point (start temperature) and 1500°C (2732°F) at a ramp rate of 7°C/min. (12.6°F/min.). The target temperature is set to 1500°C (2732°F) to avoid operating the furnace at high temperatures unnecessarily. See section 4.5.1. The following text describes how to use the furnace with this program.

- 4.1.1. 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 5.4. for instructions on how to remove and clean the viewing window.
- 4.1.2. 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 11. 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.
- 4.1.3. Switch on the furnace electrical supply, the instrument switch will illuminate and 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. The start temperature is adjustable using the Up and Down buttons (▼▲) on the controller depending on your requirements:

For furnaces constructed to use CO/CO<sub>2</sub> and Air test gases with N<sub>2</sub> 'Purge' gas (compatible with ASTM D 1857-87. The start temperature is adjustable from 400°C (752 °F).

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 1016 : Part 113 : 1995 ISO 540. The start temperature is adjustable from 815°C (1499°F).

To switch the furnace off, set the instrument switch to off. 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, isolate it from the electrical supply.

**Note:** It is not recommended to operate the furnace continuously at temperatures above 1000°C (1832°F). 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 and communicate with the CAF Test Software. The following sections describe how to adjust the controller as necessary to achieve correct operation of your furnace.

### 4.3 Computer Start-up.

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

Microsoft Windows 2000 (earlier models: Windows 98).

Carbolite Coal Ash Fusibility Test software: protected by a hardware lock (dongle).

Although the software is already installed, installation CDs are supplied for system support.

**Note:** Carbolite accept no responsibility for any damage to software loaded onto the computer by the user 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.

Switch on the computer and monitor, and double click on the Carbolite icon displayed on the start up screen. The 'Carbolite Coal Ash Fusibility Test' software initiation screen will be displayed followed by the main test screen. The Carbolite logo will be displayed in the centre of the blank image screen.

**Note:** This software is Windows 2000 compatible; all normal Windows 2000 functions apply (earlier models: Windows 98).

If the software fails to load, the following messages may appear:

#### 4.3.1 "Communication failure" - "Please check serial line and select retry"

Selecting the "cancel" button will only allow the Carbolite software to be used in analysis mode. Check that the Comms lead is correctly connected at both the back of the furnace and the back of the computer. See section 3.11.

Check that the furnace power supply and instrument is switch are turned on. When correct communication is established the 'process value' temperature (the top temperature of the two temperatures displayed on the furnace controller) will be displayed on the left hand side of the computer screen below the time and date.

#### 4.4.2. "Dongle not found" - "Continuing in analysis mode"

Selecting the "OK" button will allow the Carbolite software to load, but the record function is disabled and the software can only be used for analysing stored images. To record images the dongle (hardware lock) must be installed and the 'CAF Test' software re started.

### 4.4 Loading Samples Into The Work Tube.

Use the sample carrier and sample tiles provided. Arrange the samples as shown in fig 13a.

#### 4.4.1 When the furnace has reached its start temperature open the furnace door and swing it clear of the work tube to allow access. Load the samples into the mouth of the work tube to warm up, using the Sample Loading Tool provided. See fig 13b.

**Note:** Do not operate the furnace at temperatures above 815°C (1499°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.

**Note:** if using the zoom lens and camera kit, remove it before opening the door.

After about one minute slowly slide the samples into the tube at a rate of about 25mm per minute to make contact with the control thermocouple sheath. See fig 13c.

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

#### 4.4.2 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 20. This will result in high levels of carbon monoxide leaking from the work tube. See section 1.2: Carbon Monoxide Warning.

## 4.5 Running A Coal Ash Fusion (CAF) Test.

### 4.5.1 Setting the Target Temperature.

**Note:** Avoid operating the furnace at unnecessarily high temperatures 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 from your furnace. The maximum target temperature is 1600°C. Adjust the furnace controller ramp target temperature as follows:

Use the Page Button (⏪) on the controller to select the 'ProG LiSt'. Repeatedly press the Scroll Button (↻) to select 'tGt' in SEG.n 2, then use the Up and Down buttons (▼▲) to select the desired ramp target temperature. The controller will return to its home page automatically after a few seconds.

### 4.5.2 Setting a Controller Ramp Rate.

**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 controller is factory set to give a ramp of 7°C/min. (12.6°F/min.). Adjust the furnace controller ramp rate as follows:

Use the Page Button (⏪) on the controller to select the 'ProG LiSt'. Repeatedly press the Scroll Button (↻) to select 'rAtE' in SEG.n 2, then use the Up and Down buttons (▼▲) to select the desired ramp rate. The controller will return to its home page automatically after a few seconds.

### 4.5.3 Introduction to the CAF Test Software.

The CAF Test Software is designed to capture images from the video camera mounted on the front of the furnace and store them in sequential order. Each image displays the date, time, and temperature at which the image was recorded and an optional sample identification. Images are stored under a file name of your choice, which is entered at the start of the test, and are played back for analysis of the test samples.

Analysis of the results is aided by the use of a 'Results' chart, which enables the critical deformation temperatures to be entered along with individual sample identification. The results chart can then be saved and printed out in report form. The software automatically starts and stops the furnace controller, the start temperature and interval between images are adjustable to suit your requirements.

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:

- Buttons and the main menu bar at the top left of the screen are activated using the 'Alt' key together with the letter underlined in the caption. For drop down menus press the underlined character 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 together with the shift key will scroll the images.
- When the 'Results' window is open the 'arrow' keys move the cursor around the chart in the appropriate direction. Pressing the 'space' bar with the cursor in a valid result box will cause the temperature corresponding to the currently displayed image to be entered into the box. If an incorrect value is entered into one box simply re-enter the value when the correct image is displayed.

### 4.5.4 Operation of the CAF Test Software.

Switch on the furnace and the computer, and load the test samples as described in sections 4.1. to 4.4. Proceed as follows to run a CAF test:

- 4.5.4.1 Select 'Setup' and 'Hardware' at the top left corner of the screen, and the 'Set-up options' window will appear. A selection of camera formats is available, the camera supplied is a CCIR, 768 x 576, 8 bits, 14.8 MHz. Select this option if it is not already displayed. See fig 14.

Enter the required 'Temperature interval'. This is the interval at which the software will record and store an image from the video camera. For example, if 10°C is entered an image will be recorded every 10°C temperature rise above the start temperature.

**Note:** Only whole numbers can be used, the smallest number that can be entered is '1', the largest is 100. The maximum number of images that can be recorded for each separate test is 1500, each stored image requiring 437KB of disc space so it is advisable to use large temperature intervals whenever possible.

Set the 'Start recording' temperature to start recording and storing images at the desired temperature. Try to start recording as close to the expected critical temperatures as possible to minimise the number of stored images; remember that each stored image requires 437KB of disc space.

Select 'Test grabber', this enables you to display a real time image of the samples in the work tube before starting a test sequence.

**Note:** An image will not appear in the image window until around 800°C (1472°F); at temperatures below this there is insufficient light within the tube.

When using the standard lens adjust the camera focus to obtain the best view of the samples. 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 Coal 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. During the test the image displayed in the image window is a real time image, so the camera focus can easily be re-adjusted.

Refer to section 3.10.4 for setting up the zoom lens.

Once you have set the relevant parameters select OK to save your settings. The 'Set-up options' window will disappear, if 'Test grabber' has been selected a frozen image will remain in the image window.

- 4.5.4.2 Select 'Setup' and 'Sample Codes' at the top left corner of the screen and the 'Sample codes' window will appear. Up to 15 sample codes can be entered, though Carbolite do not recommend analysing more than 12 samples per test. Select the number of samples required and enter the identification code (less than 8 characters) for each sample and click OK. This automatically sets the size of the results window and enters the sample identification codes into the results column.

- 4.5.4.3 Enter the desired file name in the 'File Name' box, see fig 15a, this name forms the root of the file names under which the images are stored. If no file name is entered the default name 'temp' will be used.

The 'Sample Identification' is optional, if no identification is entered the identifier is set to 'None entered'. This 'Sample Identification' is displayed on each recorded image.

Invalid file name characters are filtered out automatically, both the 'File Name' and 'Sample identification' boxes are disabled once recording has started.

- 4.5.4.4 When you are satisfied that the information you have entered is correct, select 'Record' to run a CAF test. The 'Record' and 'Play' buttons will fade to grey and a green 'Recording' box will appear.

Selecting 'Record' 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 section 1.1.

The furnace will dwell at its current set point (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 sections 4.5.1 and 4.5.2.

When the furnace reaches the pre-selected 'Start recording' temperature, images will be saved at the pre-selected 'Temperature 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.

When the furnace has reached the selected target temperature it will dwell for 1 minute then the controller will switch off allowing the furnace to cool naturally to its set point (start temperature). The software will stop recording images when the furnace temperature stops rising, select the 'Stop' button to exit record mode. Alternatively the controller, and image recording, can be stopped at any time during the test by selecting the 'Stop' button.

**Note:** Periodically a red box containing the words 'Communication failure' may appear above the 'Sample Identification' box, this occurs when the computer is busy with another task during communication with the furnace controller and should only appear momentarily.

4.5.4.5 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 down the Run/Hold button (●) on the front of the controller until both the words RUN and HOLD at the side of the button are not illuminated.

#### 4.5.5 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.

When the controller program is initiated 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 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 11. 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 4.1.2

**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 1.1.

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

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 open to purge the work tube for a duration of 5 minutes.

**Note:** In the event of a power failure 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.

### 4.5.6 Analysing The Results.

During the CAF test images are stored in the form of ‘Your file name’.tif files in the ‘Images’ directory. These images are viewed by opening the ‘your file name’.log file (see section 4.5.7.). The file directory is constructed as shown in fig 16.

When the CAF test is complete the stored images can be replayed for analysis of the test samples.

### 4.5.7 Analysis of CAF Test results stored images.

Stored images are played back as follows: Select ‘File’ then ‘Open’ at the top left of the screen and open the ‘your file name’ file followed by the ‘your file name.log’ file you wish to play back. The file name will appear in the ‘File Name’ box.

Select the ‘Play’ button, a scroll bar will appear below the ‘Record’ ‘Stop’ and ‘Play’ buttons. Use the scroll bar to scroll through the stored images, alternatively the left and right arrow keys on the keyboard can be used.

#### 4.5.7.1 Record the characteristic deformation temperatures during analysis of the results using the ‘Results’ window during play back:

Select ‘Results’ at the top left of the screen to open the ‘Results’ window. The window can be moved, resized or minimised to reveal the image beneath.

In the results window ‘Identifier’ refers to your own identification code of the samples on the sample carrier. These are entered using the ‘sample codes’ window; see section 4.5.4.2

DT, ST, HT and FT refer to the temperatures at which the characteristic changes of shape occur:

DT = Deformation temperature.

ST = Sphere/softening temperature.

HT = Hemisphere temperature.

FT = Flow/fluid temperature.

Using the scroll bar or ‘Shift + >’ or ‘Shift + <’ keys scroll through the stored images until the relevant deformation temperature for a sample is reached. Each image has a black text box across the top showing the date, time and temperature at which the image was captured and a test identification. When the relevant image is displayed (eg. a sample showing the deformation) simply click in the relevant box beneath that sample identification in the ‘Results’ window using the mouse pointer. The relevant temperature will be entered automatically. Alternatively use the ‘arrow’ keys on the keyboard to move the cursor around the results chart, the space bar enters the image temperature when the cursor is in the relevant box. 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 highlight and delete the text. Note that the shift + < and shift + > keys are only functional when the results window is active.

#### 4.5.7.2 A grid feature is available to assist in analysis of test samples. Selecting ‘grid’ at the top left corner of the screen opens up a transparent grid overlay and control panel. The grid size can be altered and rows and columns added and deleted to suit your requirements. Position the grid over the relevant sample image by dragging it using the mouse pointer. Fine adjustments can be made using the control panel.

*If the grid is not visible after selecting GRID from the menu, left-click the mouse anywhere in the image window and the grid will appear at the selected point.*

Once set up, the grid can be turned on and off using the ‘On/Off’ button on the control panel. The control panel can be left running if required.

When the analysis is complete select ‘OK’ to accept the results. Select ‘File’ and ‘Save’ to save the results to your file directory under ‘Carbolite\Images\DSHF’ as ‘.tif’ files and ‘Data’ as ‘.dat’ files.

A computer print out can be obtained by selecting 'File' and 'Print, the results are presented as a report sheet as shown in fig 18.

The '.tif' image files can be imported into Microsoft Word or Excel for inclusion in test reports etc. The '.dat' files containing the critical temperature data are in tab delimited format and can also be inserted into a Microsoft Word document as a table or opened as a spread sheet in Microsoft Excel.

#### **4.5.8 Overtemperature Alarm.**

Should a fault develop in the control system which causes the furnace exceed its 1600°C (2912°F) limit an overtemperature controller automatically shuts down the furnace and the overtemperature warning light illuminates on the furnace control panel. See fig 11. The overtemperature 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 overtemperature control.

**Note:** The overtemperature control is a safety device to protect the furnace in the event of a fault. If the overtemperature 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 end of this manual.

### 5.0 MAINTENANCE & CALIBRATION.

#### 5.1 General Maintenance.

The outer surfaces may be cleaned with a damp cloth. Do not allow water to enter the interior of the case, work tube or control box. Do not clean with organic solvents.

#### 5.2 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 4.5.1.
- b) Do not select unnecessarily fast ramp rates. See section 4.5.2

There is a feature in the furnace controller which allows the power to the elements to be turned down, this 'power limit' is pre-set at Carbolite. 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 available power figure proceed as follows:

Press Page  $\square$  until  $\square P$  (output list) is displayed. Press Scroll  $\curvearrowright$  until  $\square P H_i$  (Output High) is displayed. Press Down  $\blacktriangledown$  or Up  $\blacktriangle$  once to display the value of  $\square P H_i$  (it is good practice to write down the original value). Use the Up and Down buttons ( $\blacktriangledown$  $\blacktriangle$ ) increase the preset figure as necessary to improve the furnace performance. The controller will return to its home page automatically after a few seconds.

$\square P H_i$  should not be set too high as this will result in poor control and short heating element or furnace life. For standard values of the parameter (as factory set with new elements), see section 3.6.

#### 5.3 Checking And Replacing The Door 'O' Ring Seal.

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: Carbon Monoxide Warning.

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.

#### 5.4 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.

- 5.4.1 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.

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.

5.3.2. Clean the window glass using a suitable cleaning agent. Alternatively an optician equipped with re-polishing machines can restore the clarity of the windows.

5.3.3. When replacing the window glass:

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: Carbon Monoxide Warning.

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. See section 1.2: Carbon Monoxide Warning.

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, hold the window glass in position through the viewing hole in 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.

## 5.5 **Furnace Calibration.**

This procedure describes the process required to achieve correct calibration and performance from your CAF Digital furnace. The furnace is calibrated prior to leaving the factory, but both ASTM and BS standards call for regular checks on calibration. Carbolite recommend that calibration checks are conducted in accordance with these instructions, if the furnace is found to be out of calibration then the control instrument must be adjusted (see section 5.4.5).

### 5.4.1. **Sample Carrier And Tiles.**

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

### 5.4.2. **Sample Preparation.**

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

Gold wire.	Melting point 1063°C (1945°F)
Palladium wire.	Melting point 1554°C (2829°F)

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

Cut a piece of wire 30mm 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 12mm 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.

**5.4.3. Test Procedure.**

The calibration test is based on BS 1016:Part 113:1995 ISO 540:1995, Methods for Analysis and testing of Coal and Coke. Conduct the test as follows:

5.4.3.1 Turn the furnace on, adjust the control instrument set point to 815°C (1499°F) and allow the furnace to stabilise.

As the furnace warms up prepare the sample carrier and samples (see section 5.4.2.) and load into the work tube (see section 4.4.). Close the door and clamp securely to seal the work tube.

5.4.3.2 When the furnace has stabilised at 815°C (1499°F) run a CAF test on a ramp rate of 7°C/min (12.6°F/min) to reach a maximum temperature of 1600°C (2912°F). During the test maintain an ‘oxidising’ atmosphere in the work tube (see section 4.5.).

5.4.3.3 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 (2°F) temperature intervals, starting at 20°C (35°F) below the expected Gold melt point and finishing at 1600°C (2912°F) (see section 4.5.).

**5.4.4. Interpretation Of Results.**

5.4.4.1. 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.

5.4.4.2. Documentation of results.

Record the individual melt temperature of each wire sample using the CAF Test Software (see section 4.5.) 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.

5.4.4.3. 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

## 5.4.4.4. Deviations from limits.

If some or all of the recorded individual melt temperatures 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 using the instrument set-up; see section 5.4.5.

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

## 5.4.5. Control 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:

## 5.4.5.1. 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 5.4.4.

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*)  
 lower calibration temperature correction factor (1063°C – 1060°C) = 3.

## 5.4.5.2. 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 5.4.4.

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 (*calculated from test*)  
 upper calibration temperature correction factor (1554°C – 1559°C) = -5.

## 5.4.5.3. Adjust the lower and upper calibration temperatures.

Lower calibration temperature adjustment:

Use the Up and Down buttons (▼▲) to adjust the instrument set point to the value of the Gold mid melt temperature, and allow the furnace to heat to that temperature.

When the furnace has stabilised select 'iP-LiSt' using the Page button (⏏).

Press the Scroll button (↻) until the 'CALs nonE' is displayed; select 'CAL.S iP1.L' using the Up and Down buttons (▼▲).

Press Scroll (↻) to display the 'Adj' value; this is the lower calibration value.

**Add the lower** calibration temperature correction factor to the 'Adj' value, and enter the new value using the Up and Down buttons (▼▲).

For example, if the lower calibration temperature correction factor is calculated as '3' and the 'Adj' value is '1065', adjust the displayed value to read 1068 (1065+3=1068).

Note: Following alteration the 'Adj' value will lock after approximately 2 seconds. If you pause when entering the new value the 'Adj' feature may lock, indicated by the 'Adj' value changing to ---- whenever the Up or Down buttons are pressed. If this happens exit to the 'iP LiSt' by pressing the Page button (⏏) and re-access 'Adj' as described above.

Press Page (⏏) and Scroll (↻) together to return to the set point temperature.

### Upper calibration temperature adjustment:

Use the Up and Down buttons (▼▲) to adjust the instrument set point to the value of the Palladium mid melt temperature, and allow the furnace to heat to that temperature.

When the furnace has stabilised select 'iP-LiSt' using the Page button (⏏).

Press the Scroll button (↻) until the 'CALs nonE' is displayed; select 'CAL.S iP1.H' using the Up and Down buttons (▼▲).

Press Scroll (↻) to display the 'Adj' value; this is the upper calibration value.

**Subtract the lower** calibration temperature correction factor from the 'Adj' value, then **add the upper** calibration temperature correction factor; enter the new value using the Up and Down buttons (▼▲).

For example, if the lower calibration temperature correction factor is calculated as '3', the upper calibration temperature correction factor is -5 and the 'Adj' value is '1560', adjust the displayed value to read 1552 ( $1560 - 3 + (-5) = 1552$ ).

Note: Following alteration the 'Adj' value will lock after approximately 2 seconds. If you pause when entering the new value the 'Adj' feature may lock, indicated by the 'Adj' value changing to ---- whenever the Up or Down buttons are pressed. If this happens exit to the 'iP LiSt' by pressing the Page button (⏏) and re-access 'Adj' as described above.

Press Page (⏏) and Scroll (↻) together to return to the set point temperature.

5.4.5.4. Following adjustment of the instrument the furnace must be re-tested starting from section 5.5 to prove the results.

**6.0 CIRCUIT DIAGRAMS.**

Please see the separate enclosure or request a diagram from Carbolite if one is not supplied.

**7.0 FAULT ANALYSIS.**

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

**A. Furnace Does Not Heat Up**

- 1. The **HEAT** light is **ON** → An ohm meter applied to the element circuit shows an open circuit → A heating element has failed
- 2. The **HEAT** light is **OFF**
  - The controller shows a **very high temperature** or a code such as S.br → The thermocouple has broken or has a wiring fault
  - There are no lights glowing on the controller
    - The **SUPPLY** light is **ON** → The controller may be faulty or not receiving a supply due to a faulty switch or a wiring fault
    - The **SUPPLY** light is **OFF** → Check the supply fuses and any fuses in the furnace control compartment

**B. Furnace Overheats**

- 1. The **HEAT** light goes **OFF** with the instrument switch
  - 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 may be faulty

## **8.0 AFTER SALES SERVICE.**

Carbolite's service division (Thermal Engineering Services) has a team of Service Engineers capable of repair, calibration and preventive maintenance of furnace and oven products at our customers' premises throughout the world. We also sell spares by mail order. A telephone call or fax often enables a fault to be diagnosed and the necessary spare part despatched.

Each furnace has its own record card at Carbolite. In all correspondence please quote the serial number, model type and voltage given on the rating label of the furnace. The serial number and model type are also given on the front of this booklet when supplied with a furnace.

To contact Thermal Engineering Services or Carbolite see the back page of this manual.

## **8.1 Recommended Spares & Consumables.**

Carbolite can supply individual spares, 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 spares 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. 12.7mm or 19.0mm high.)

All spares will be supplied with service information where applicable.

When ordering spares 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.

### 9.0 SPECIFICATIONS.

Carbolite reserves the right to change specifications without notice.

Maximum external cabinet dimensions:

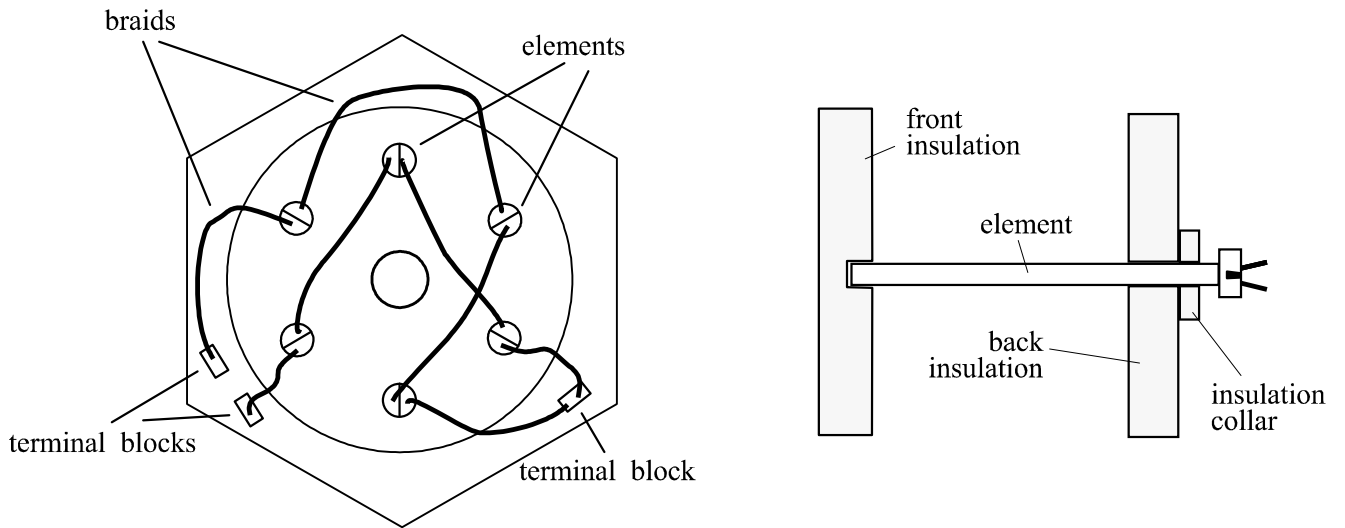
Height	700mm
Width	505mm
Case depth	625mm
Overall depth	1070mm

Work tube dimensions:

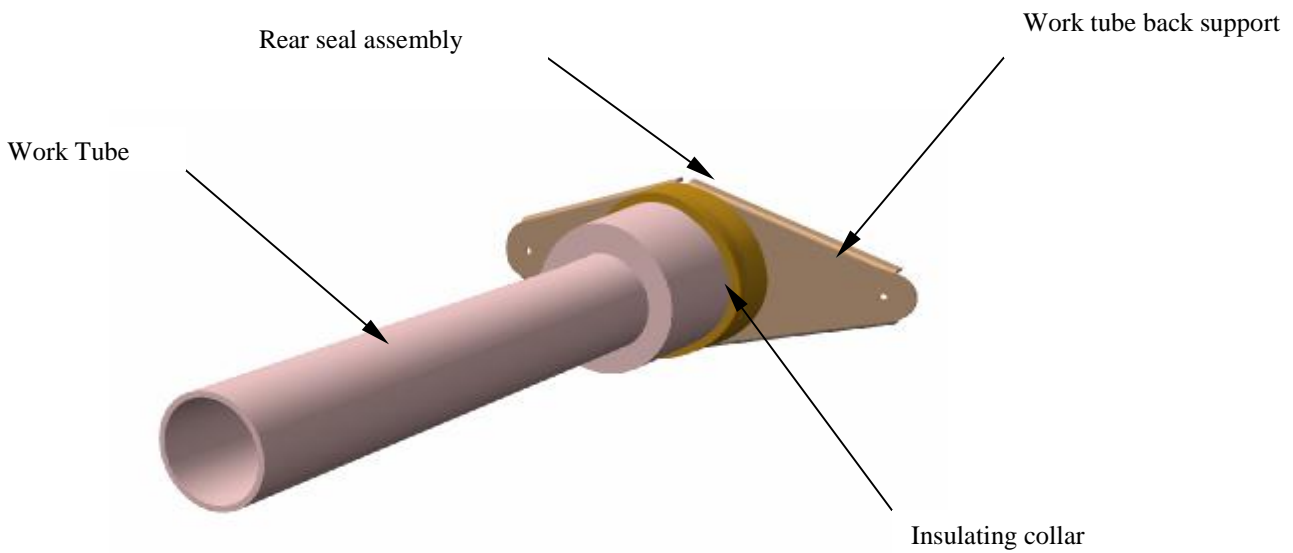
Internal diameter	79mm
Length	650mm
Material	Mullite

**10.0 APPENDIX.**

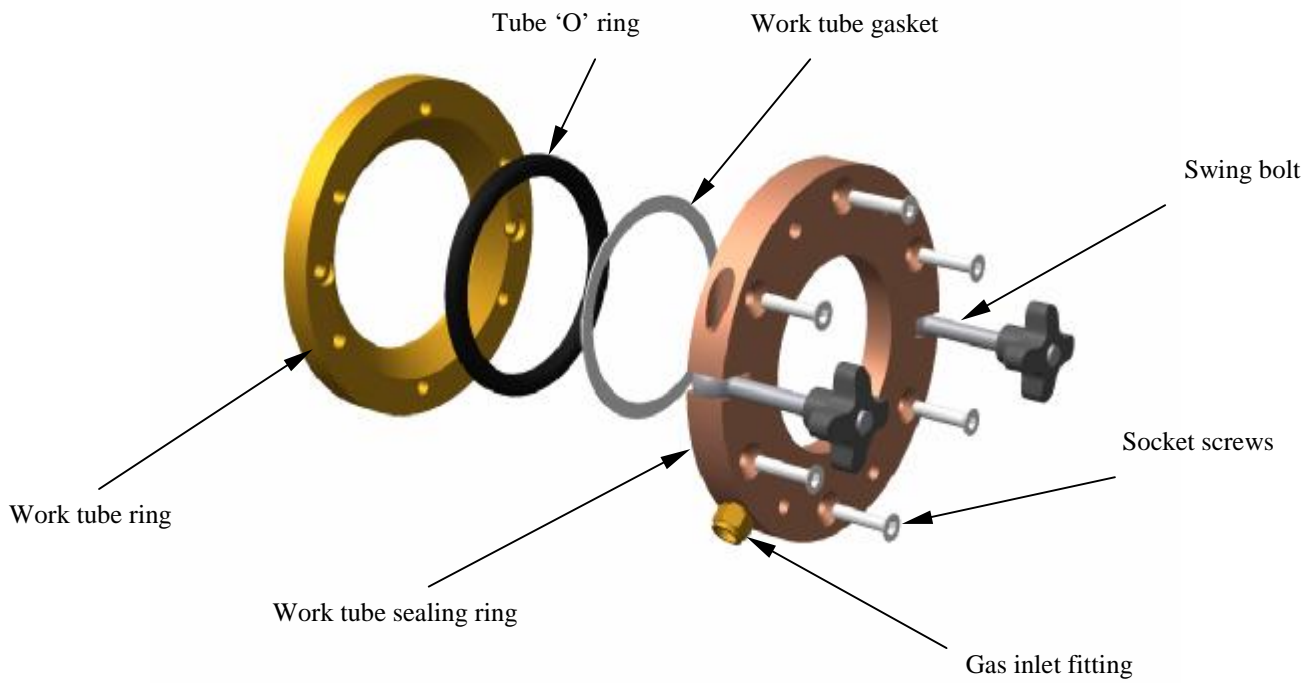
The figures referred to in the previous text are listed below.



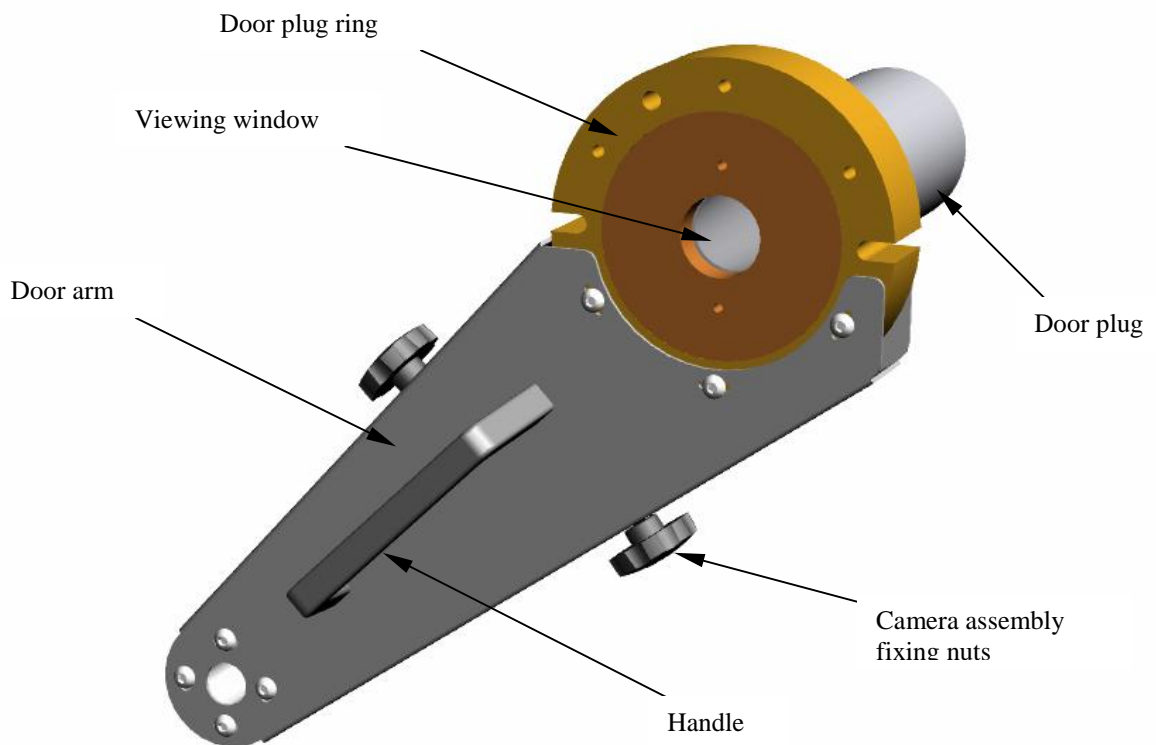
**Fig 1. Element wiring and positions.**



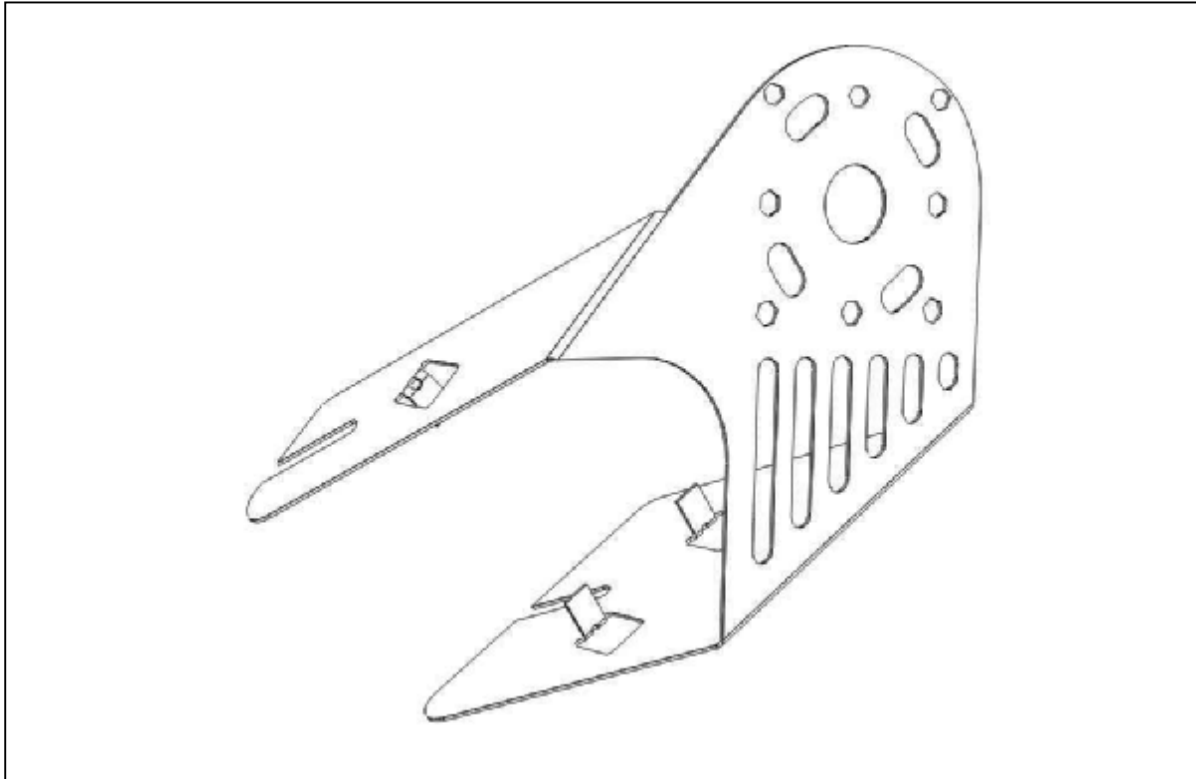
**Fig 2. Work tube and back plug assembly.**



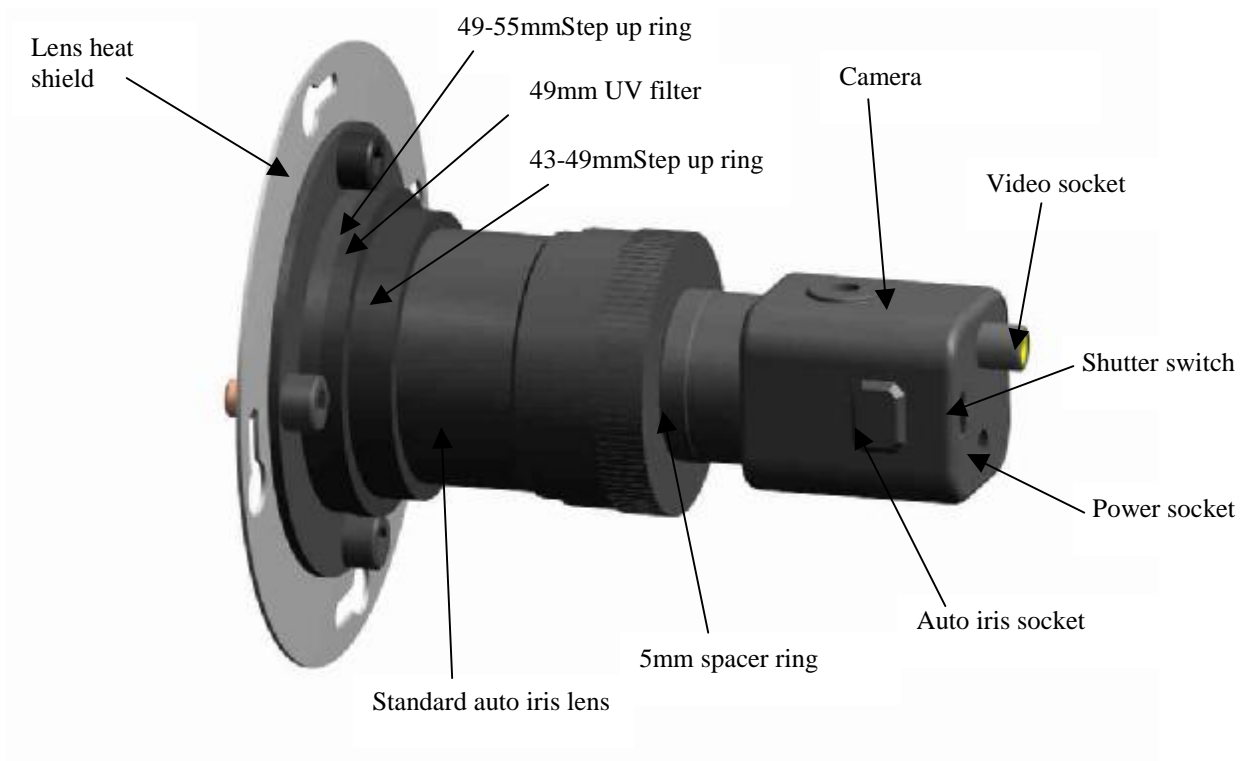
**Fig 3. Front tube seal assembly.**



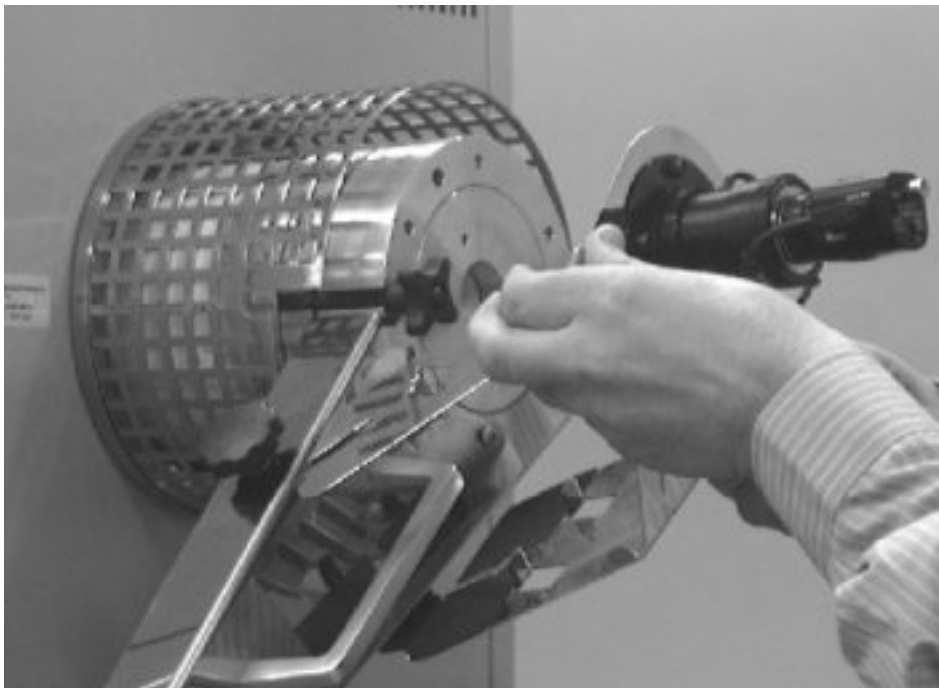
**Fig 4. Door arm assembly.**



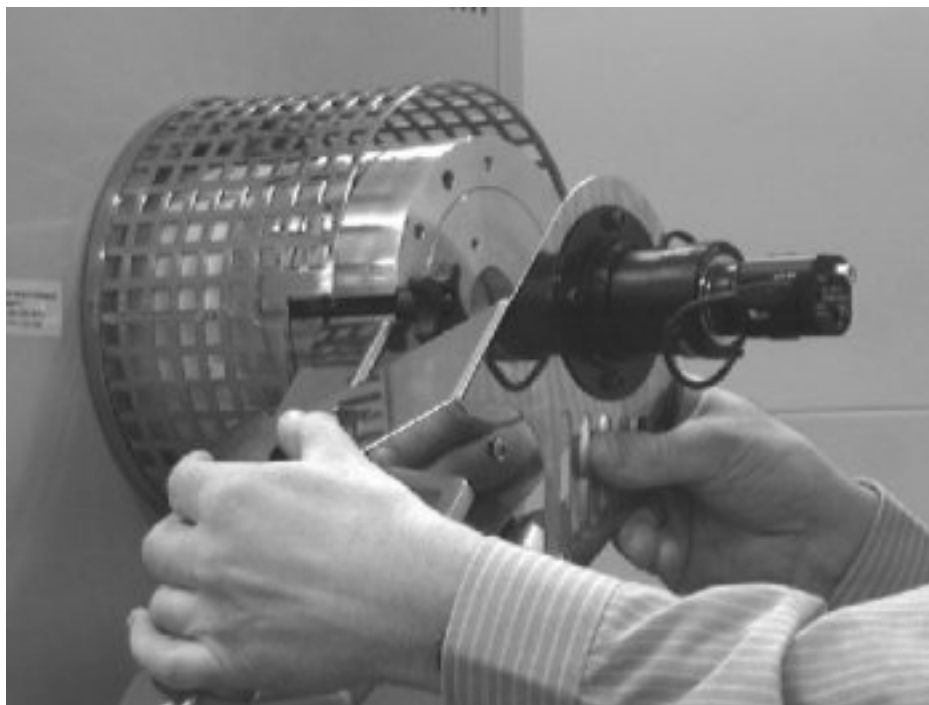
**Fig 5a. Camera mounting bracket.**



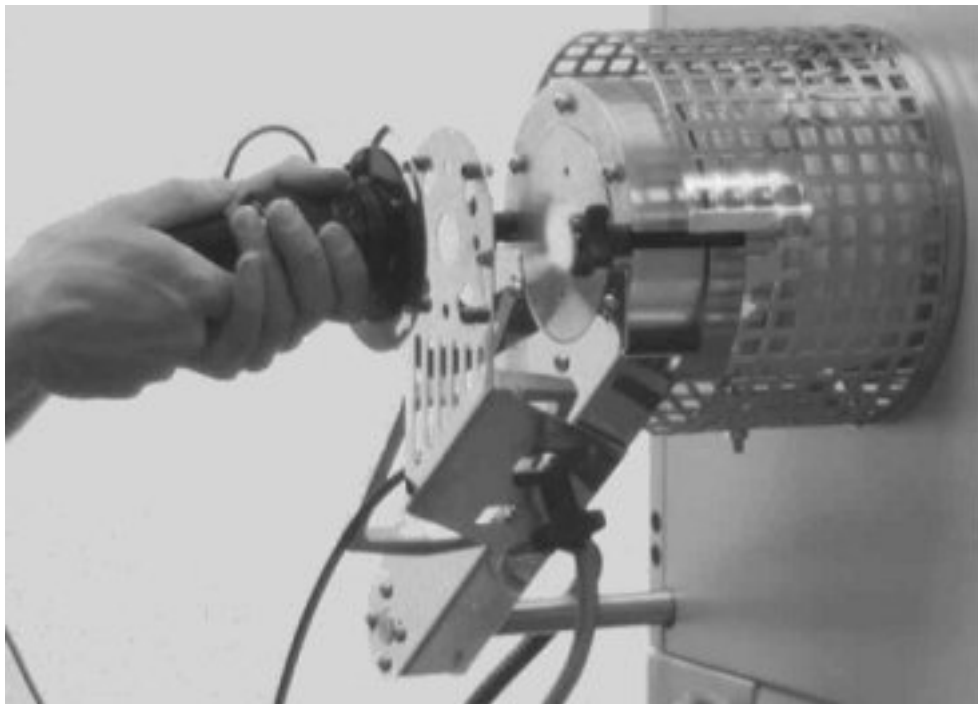
**Fig 5b. Standard lens & camera assembly.**



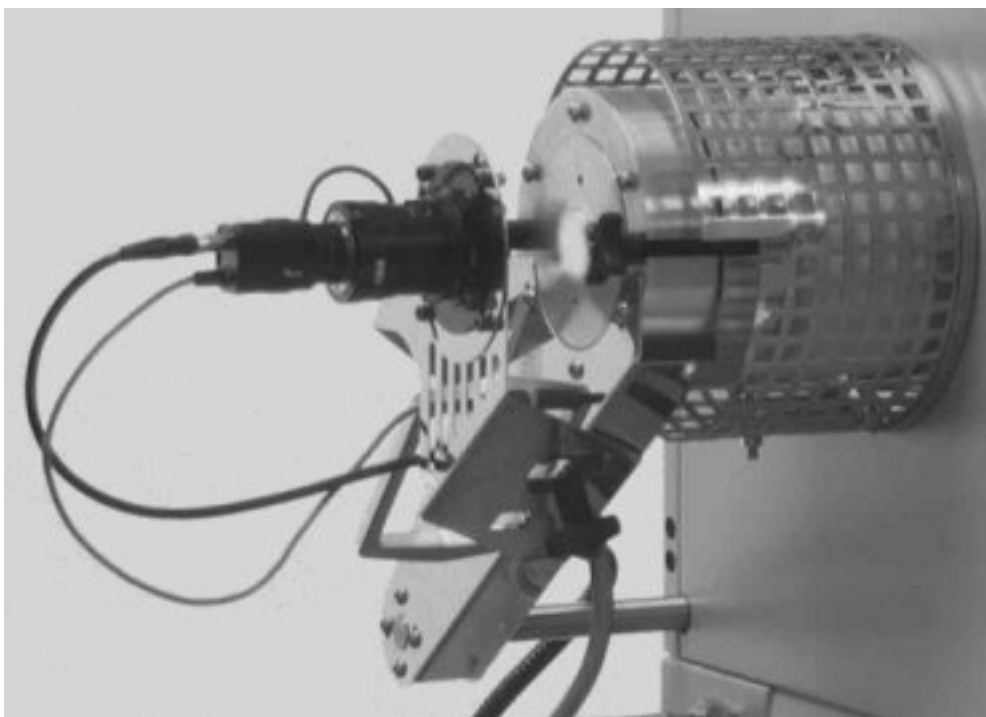
**Fig 5c.** Sliding the camera mounting bracket assembly onto the door arm.  
(note: the camera is not fitted during this operation.)



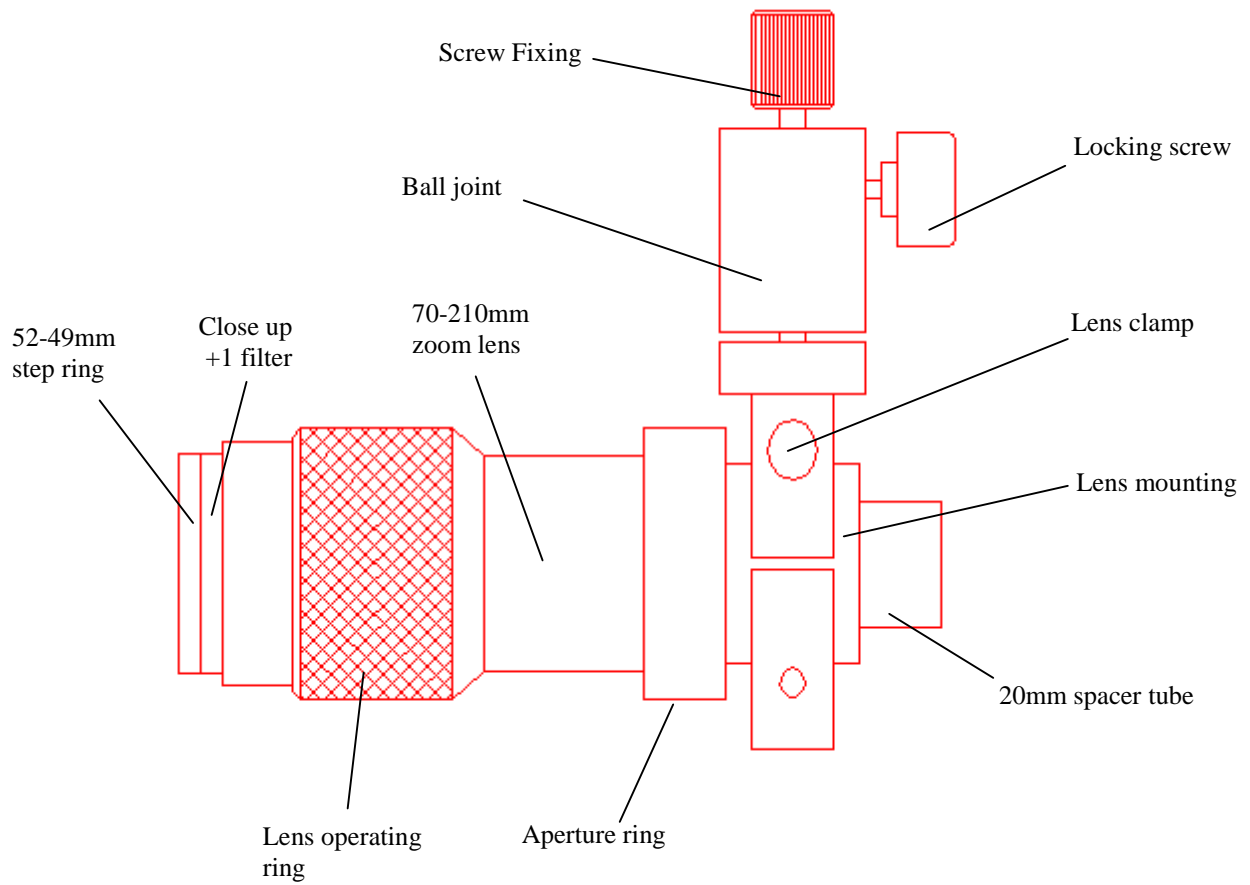
**Fig 5d.** Securing the camera mounting bracket assembly to the door arm.  
(note: the camera is not fitted during this operation.)



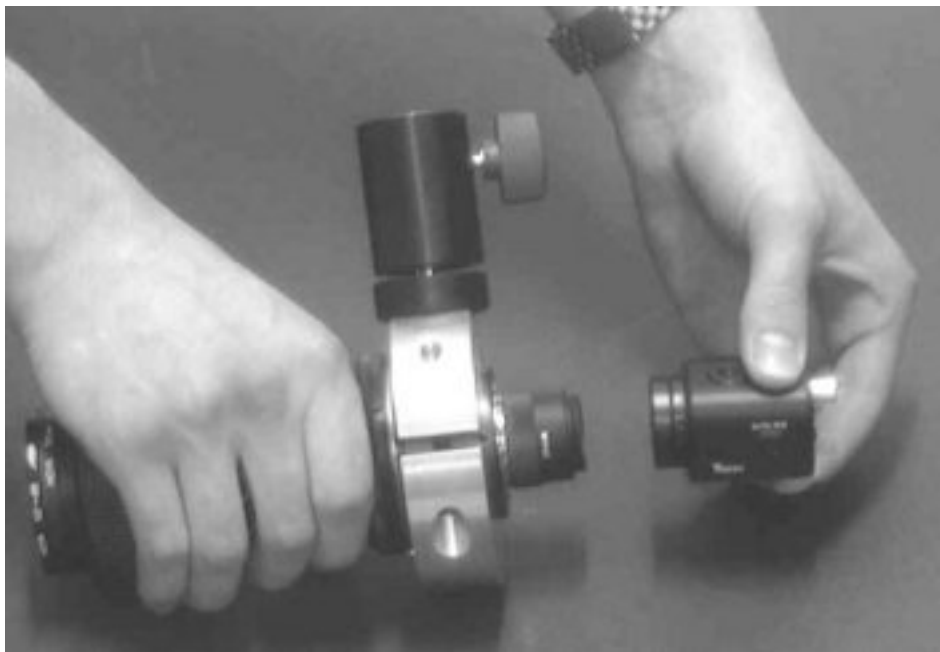
**Fig 5e.** Mounting the standard lens & camera assembly.



**Fig 5f.** Standard lens & camera assembly in position.



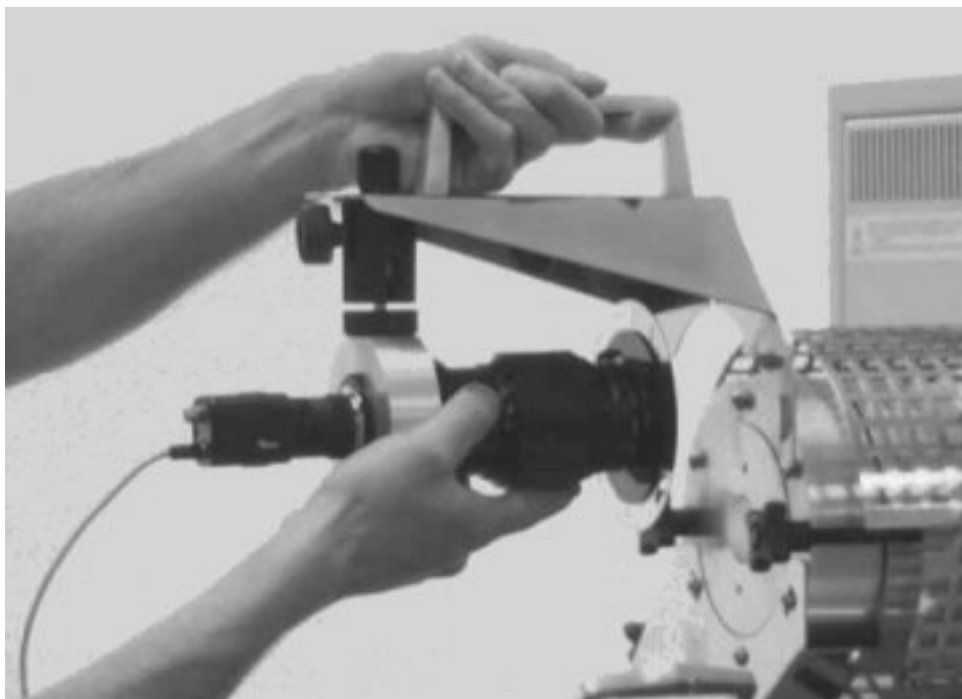
**Fig 5g. Zoom lens assembly & lens clamp.**



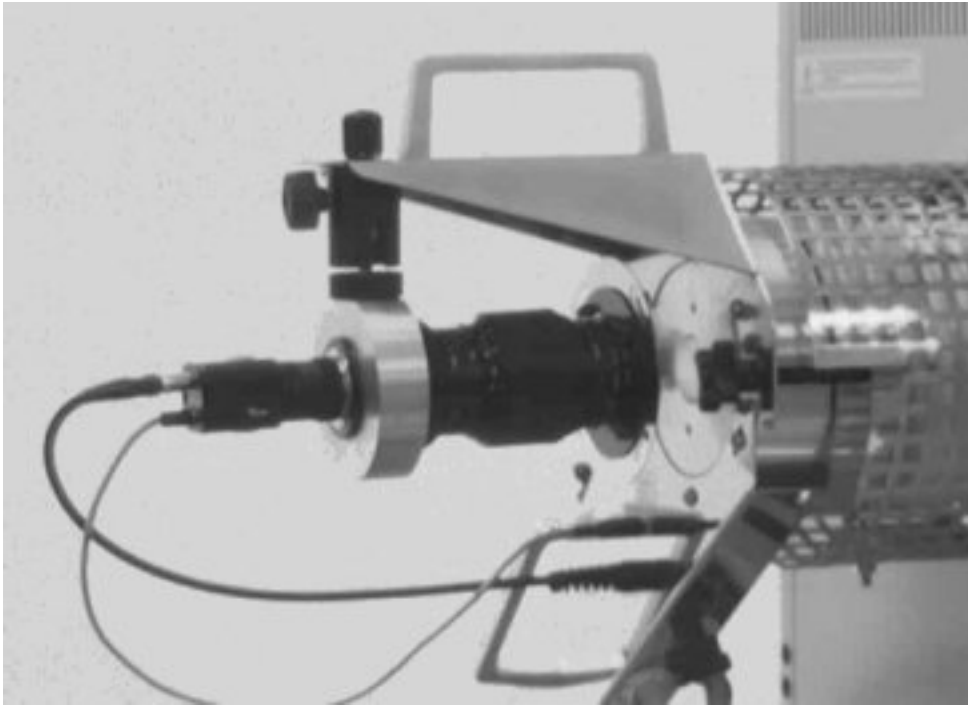
**Fig 5h. Fitting the camera to the zoom lens.**



**Fig 5j. Mounting the lens heat shield.**



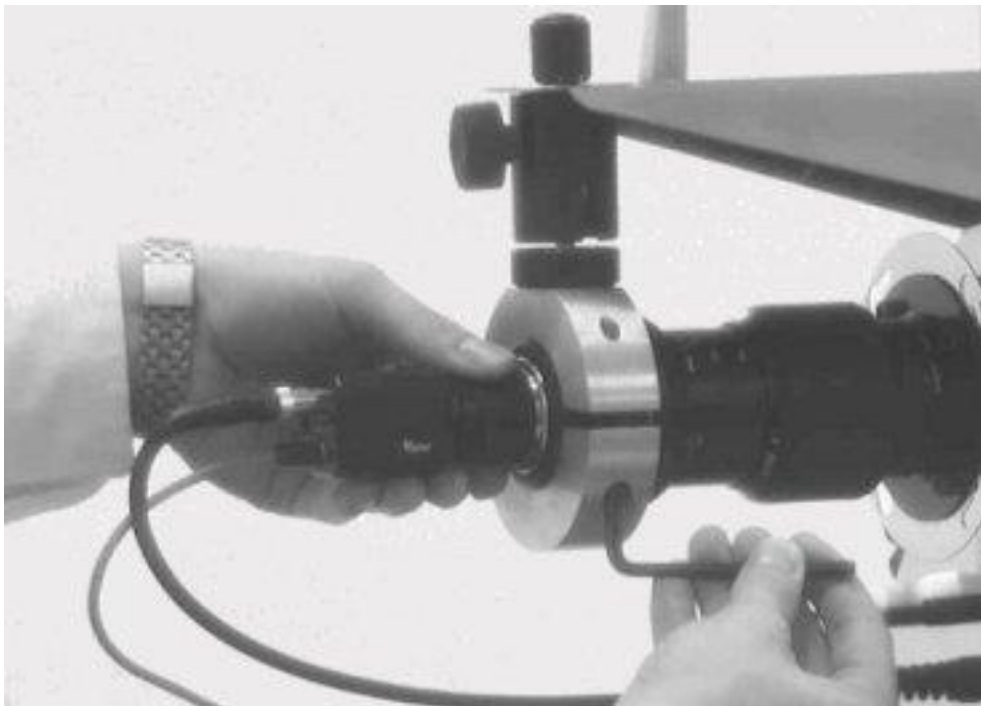
**Fig 5k. Mounting the zoom lens & bracket assembly.**



**Fig 5l. Zoom lens in position.**



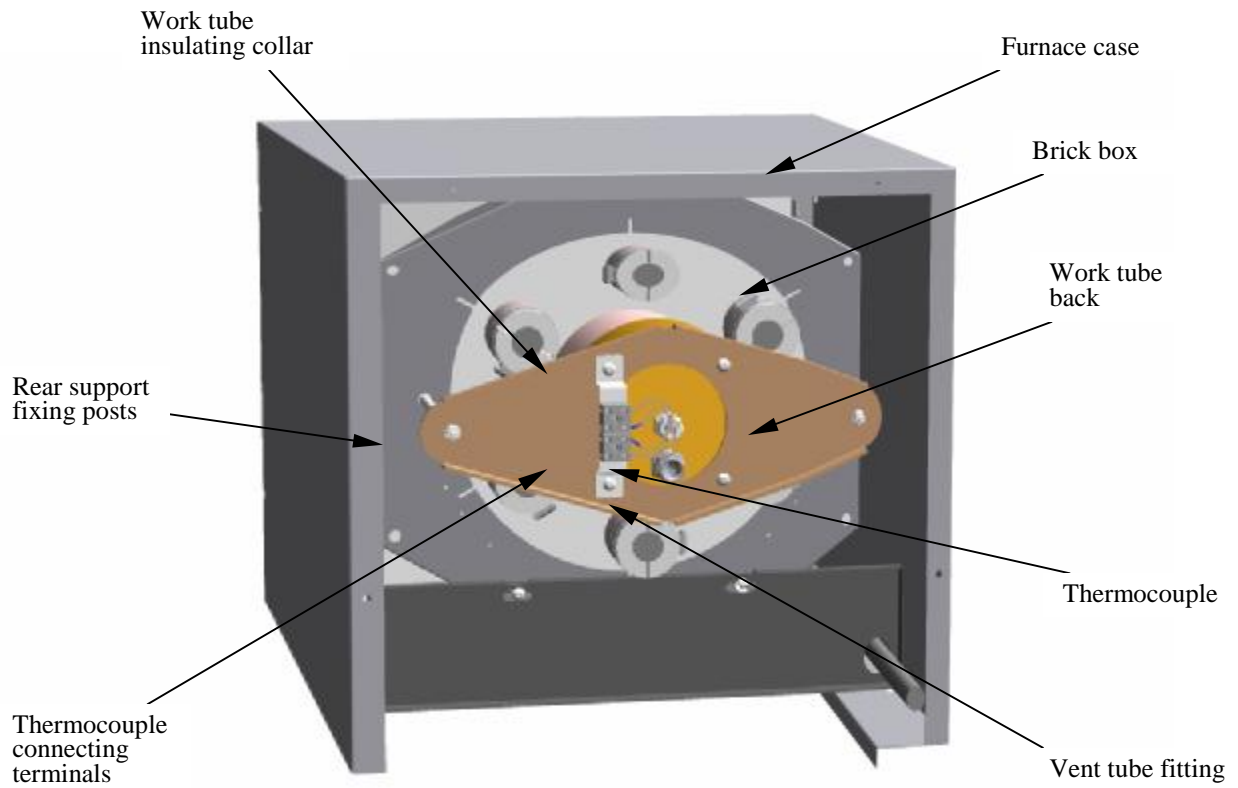
**Fig 5m. Adjusting the position of the zoom lens & camera assembly.**



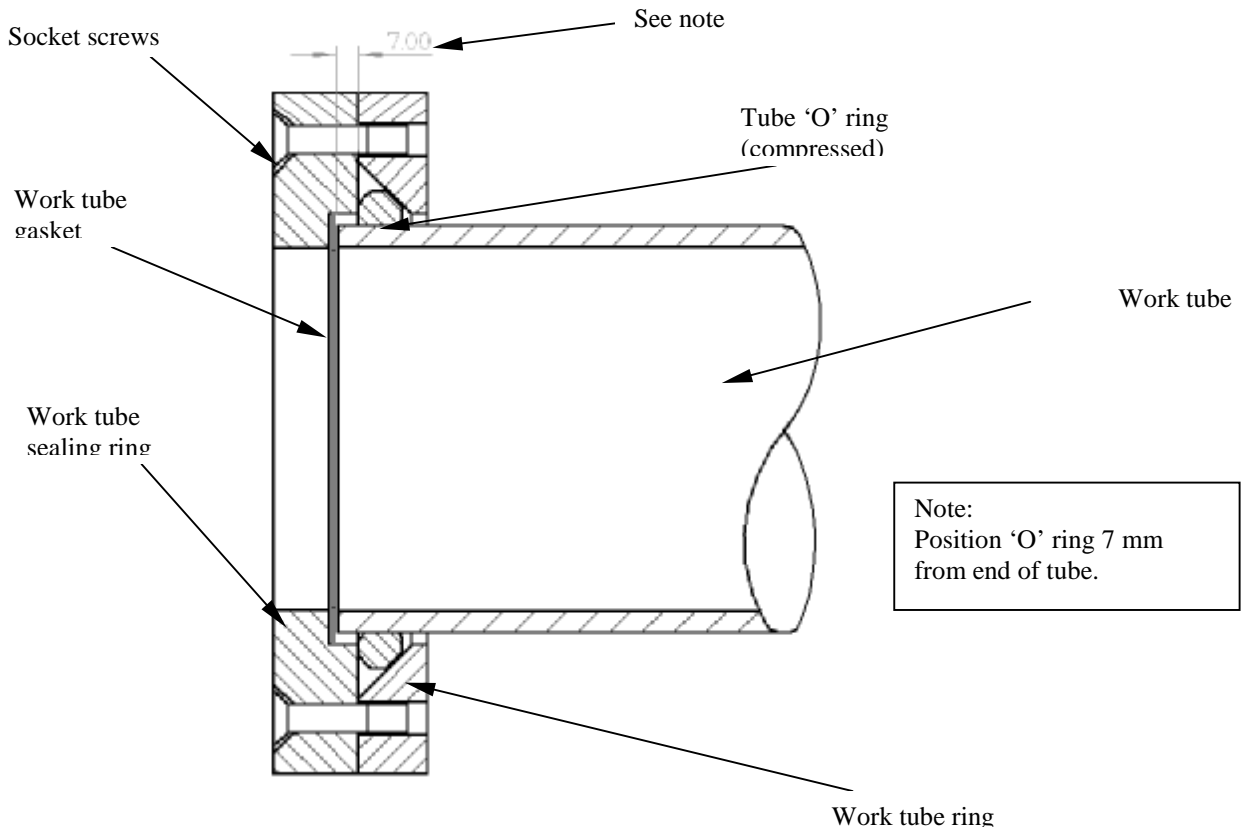
**Fig 5n.** Releasing lens clamp screw to rotate camera & lens assembly.



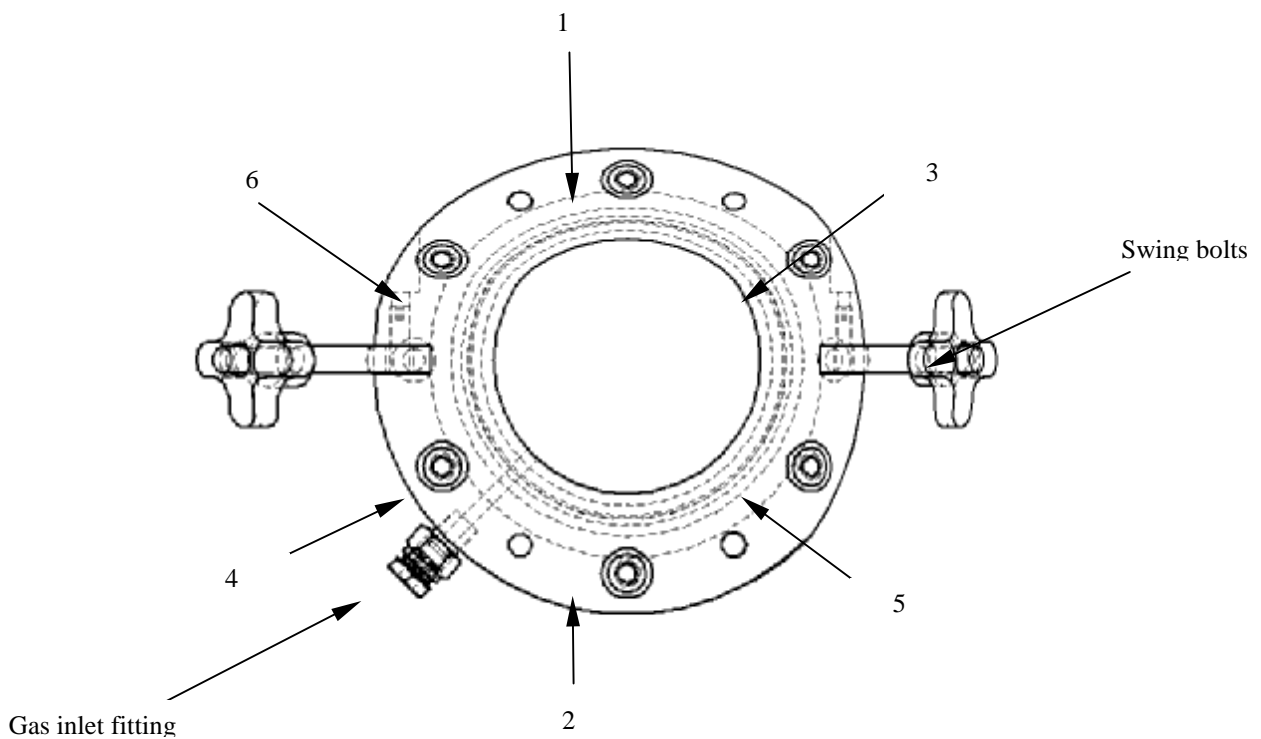
**Fig 5p.** Storing the zoom lens & carrier.



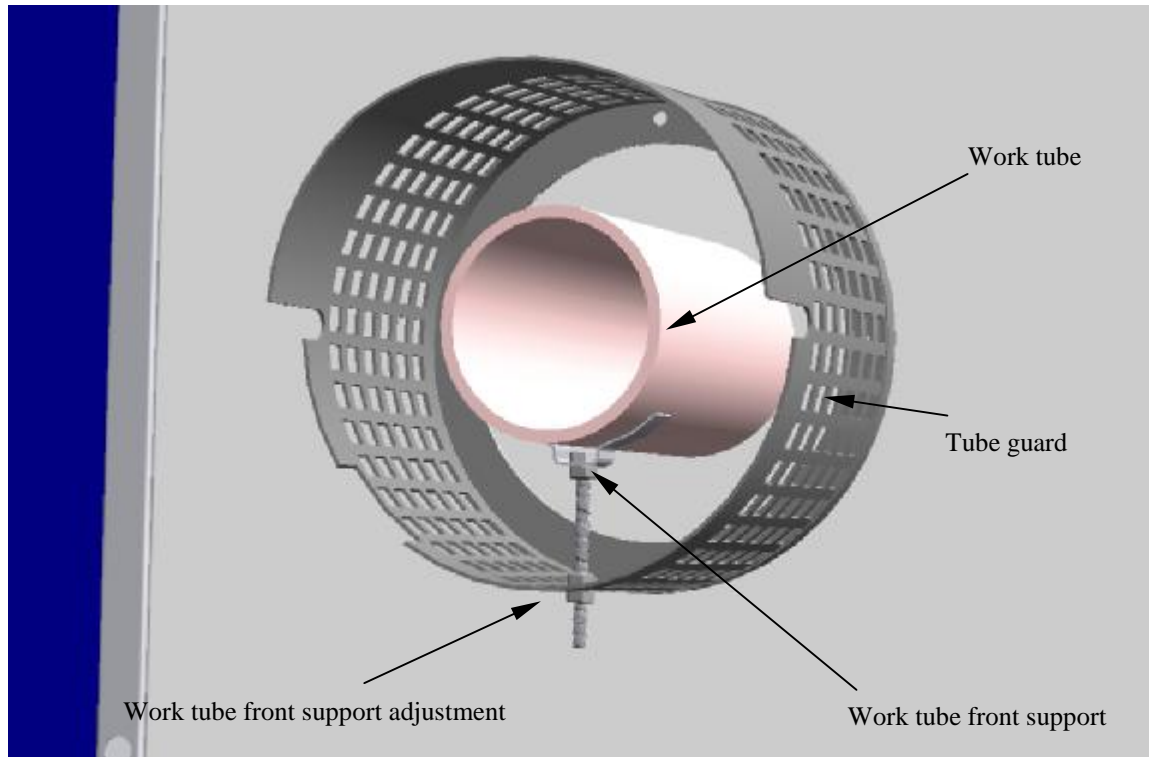
**Fig 6. Rear view of furnace showing brick box assembly.**



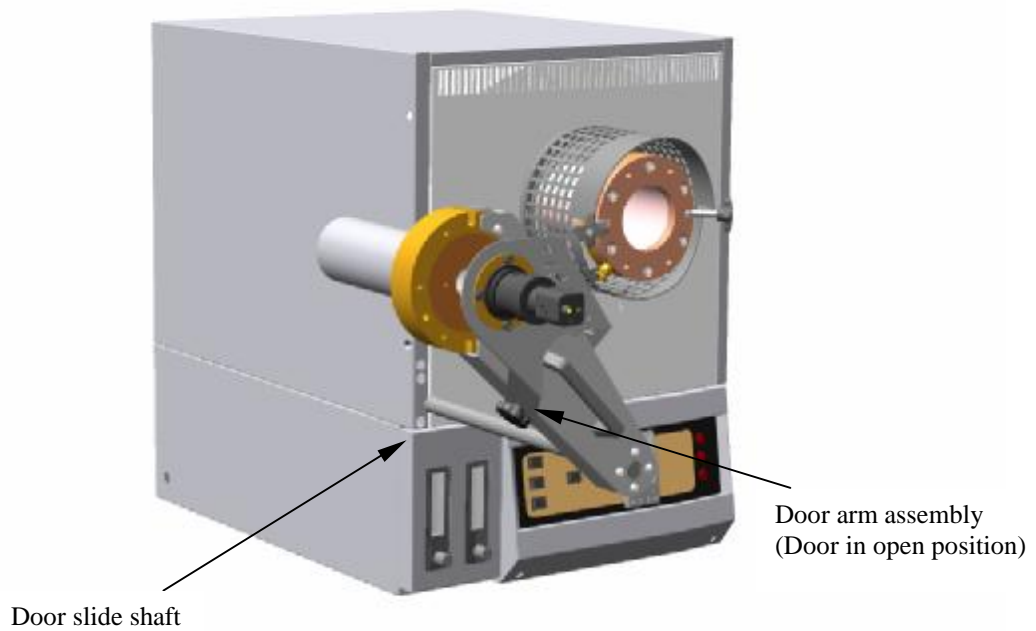
**Fig 7. Front tube seal position.**



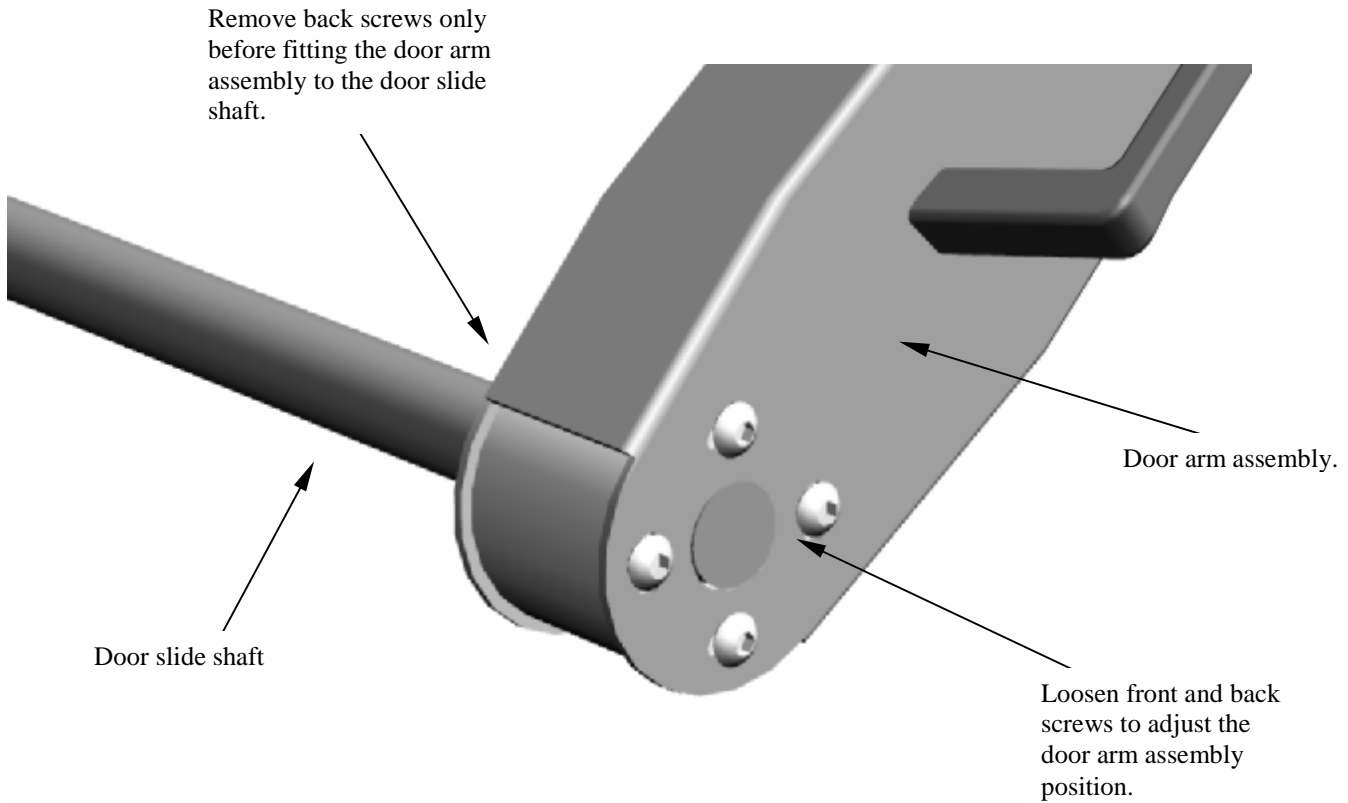
**Fig 8. Tube end seal assembly tightening sequence.**



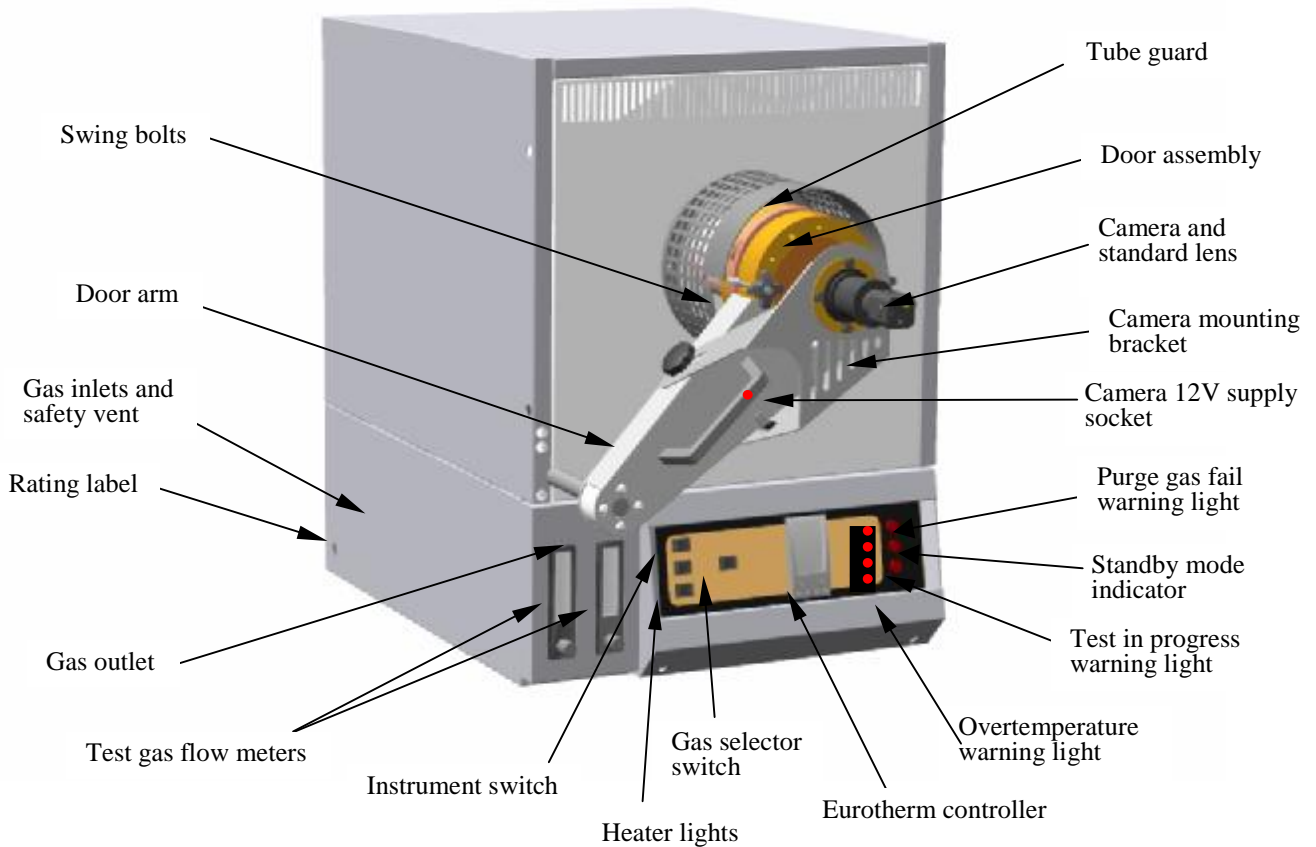
**Fig 9. Work tube front support.**



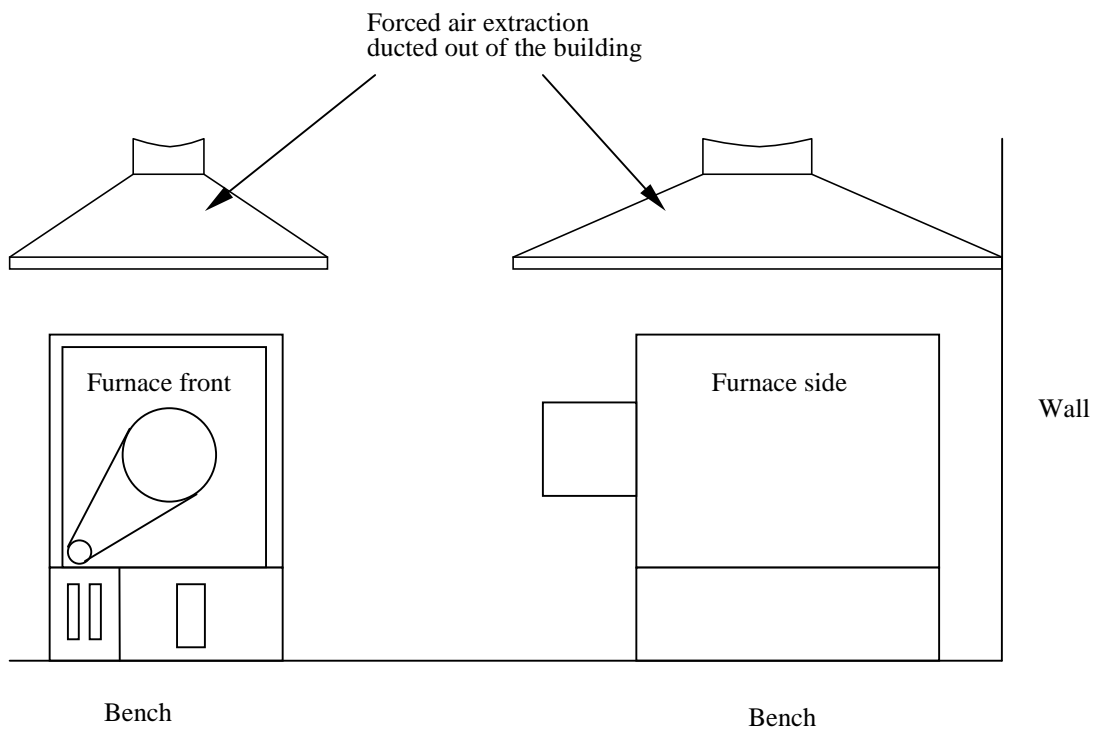
**Fig 10. Fitting the door arm assembly.**



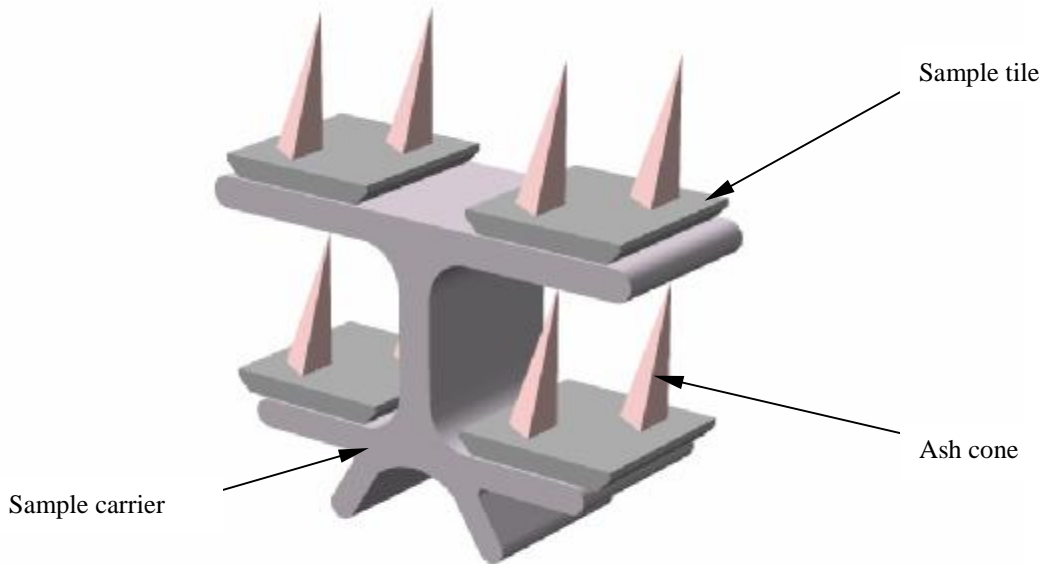
**Fig 10a** Adjusting the door arm assembly.



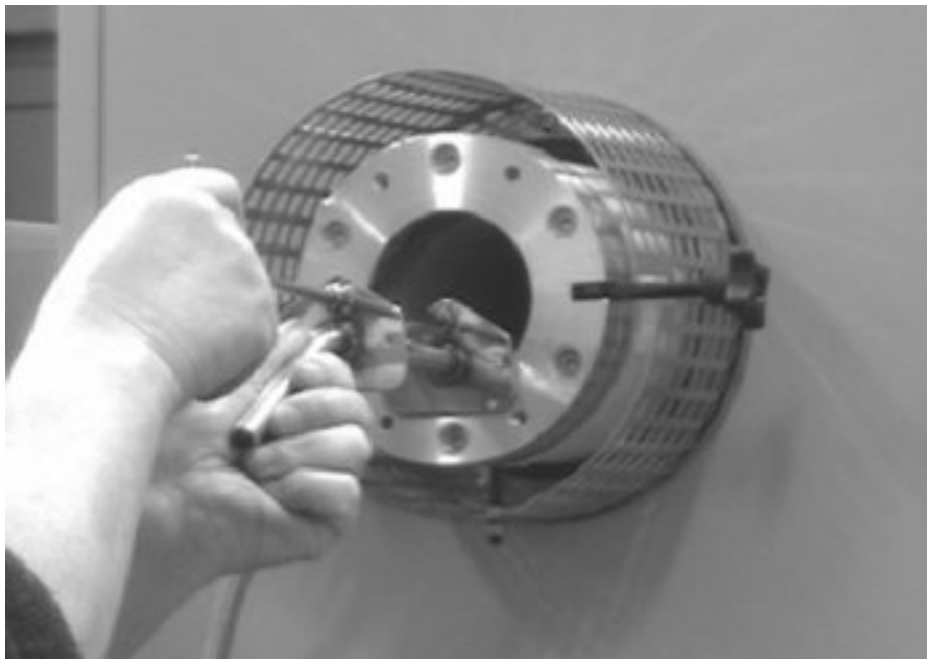
**Fig 11.** Furnace case and controls.



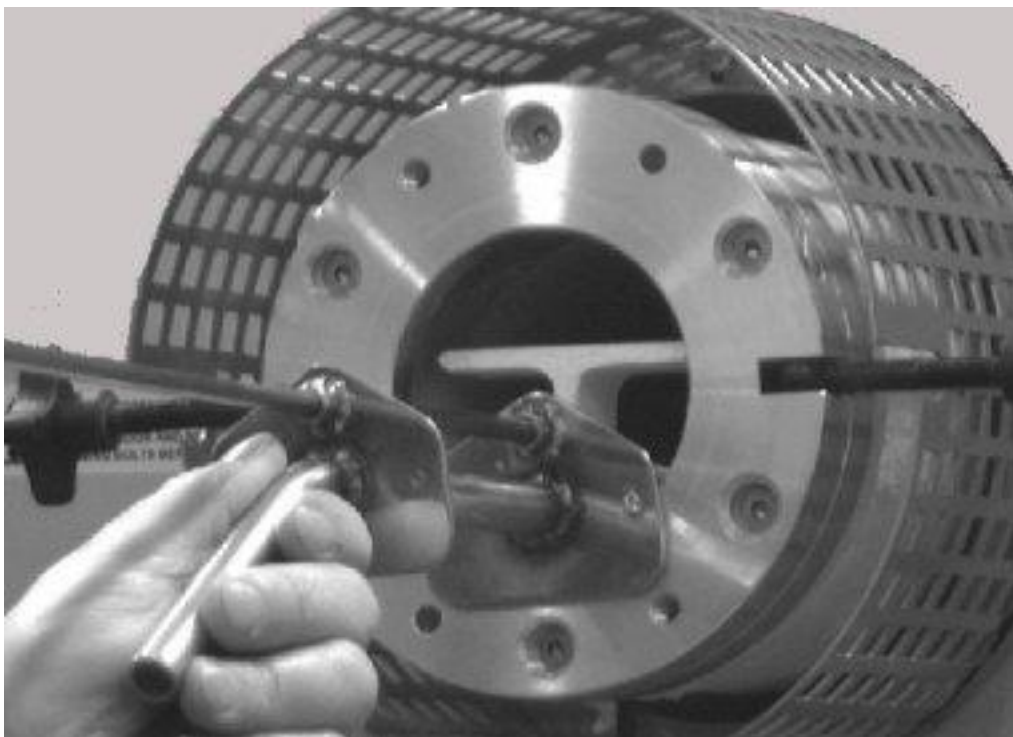
**Fig 12. Positioning the furnace.**



**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.**

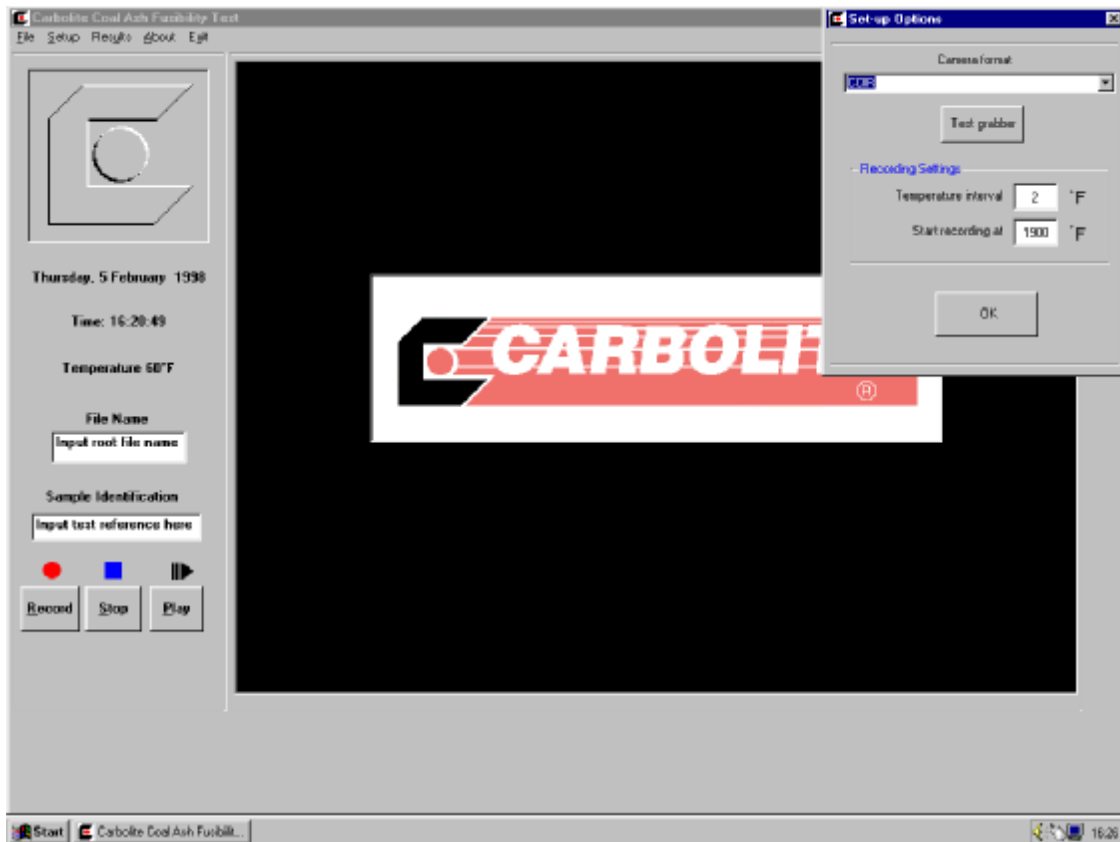


Fig 14. Set-up options.

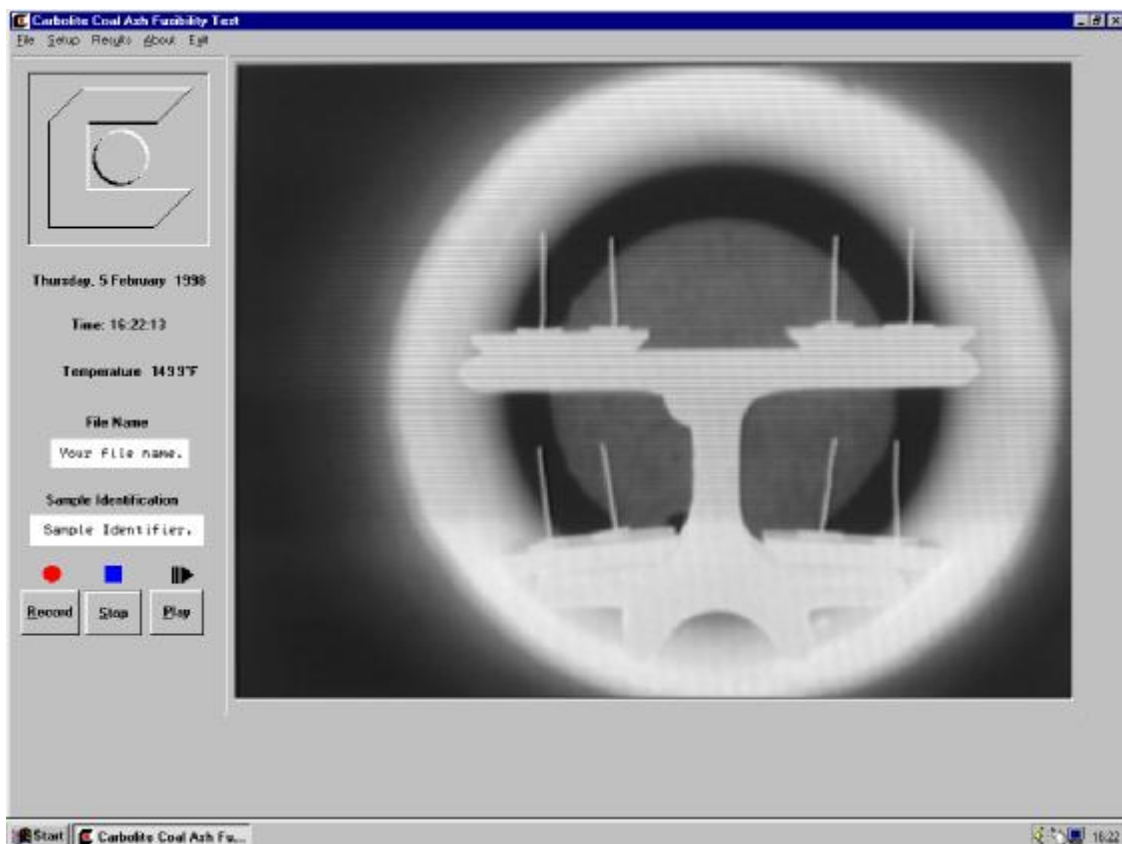
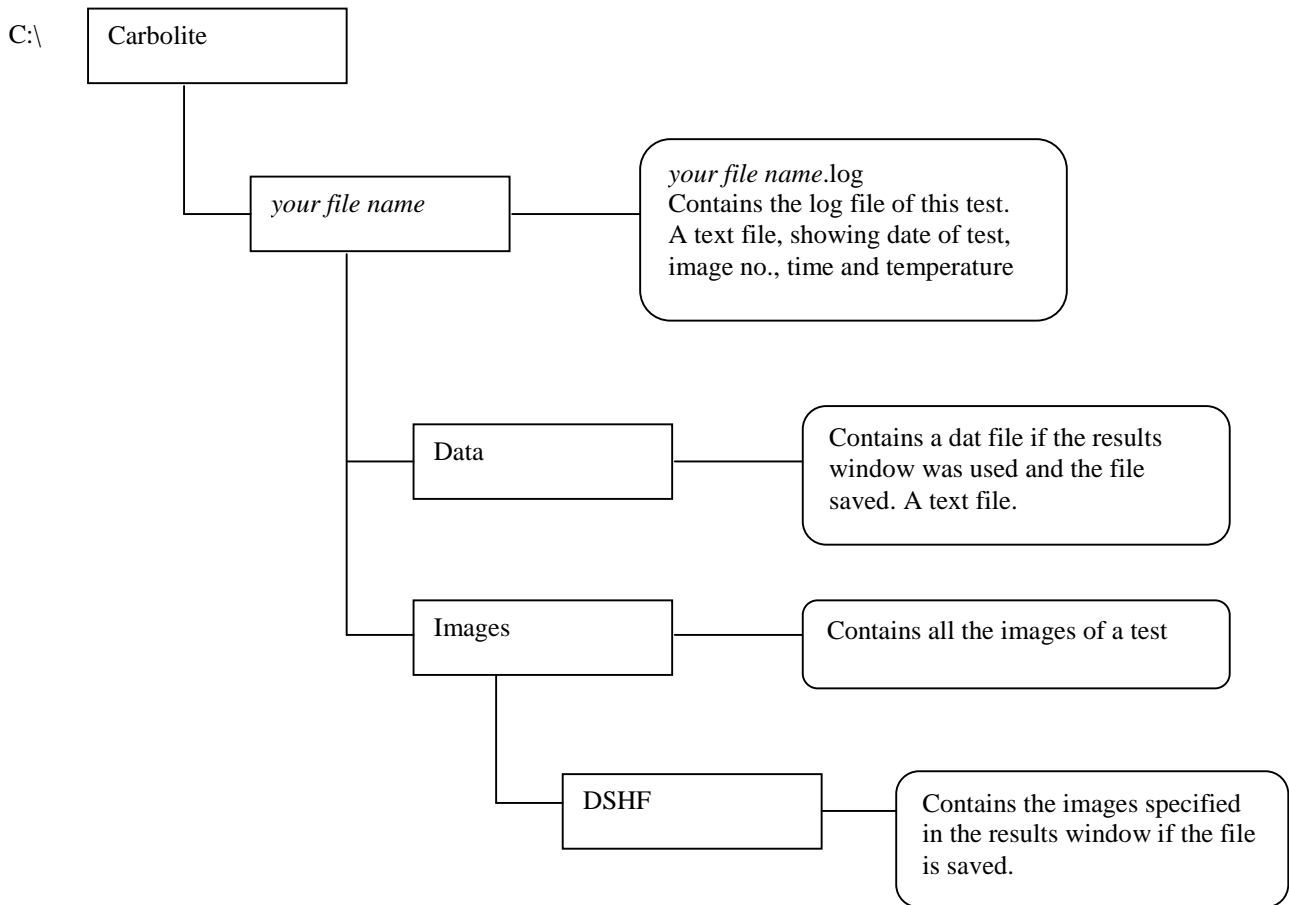
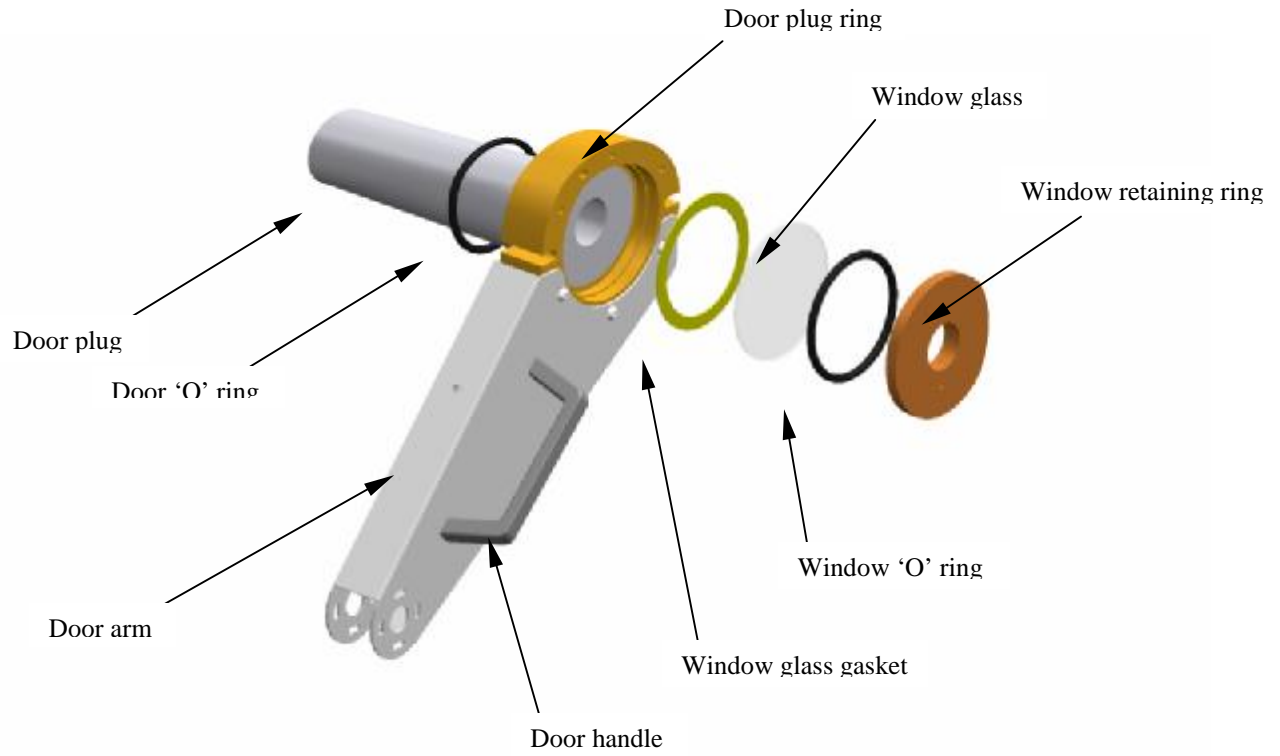


Fig 15a. Enter file name and sample identifier.



**Fig 16. File directory.**



**Fig 17. Door arm assembly exploded view.**

Coal Ash Fusibility Test Results

**Date of test:** Thursday, January 22, 1998  
**Record start time:** 17:15  
**Date of analysis:** Thursday, February 05, 1998  
**Time of print:** 16:30  
**Test reference:** USA TYPE F

Sample Position	1	2	3	4	5	6	7	8	9
Identifier	Au	Au-Pd					Au-Pd	Au	
DT									
ST									
HT									
FT	1946	2632					2632	1940	

Sample Position	10	11	12				13	14	15
Identifier	Au	Au-Pd					Au-Pd	Au	
DT									
ST									
HT									
FT	1942	2638					2634	1942	

Temperature scale = Fahrenheit

DT = Initial deformation temperature

ST = Sphere/softening temperature

HT = Hemisphere temperature

FT = Flow/fluid temperature

**Fig 18. Report sheet.**

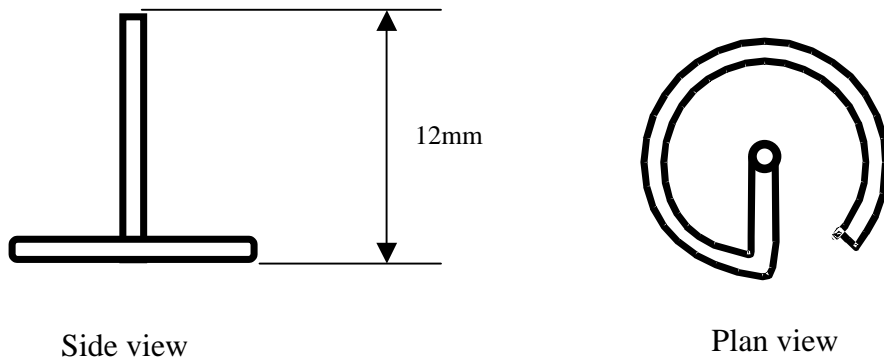


Fig 19. Formed wire sample.

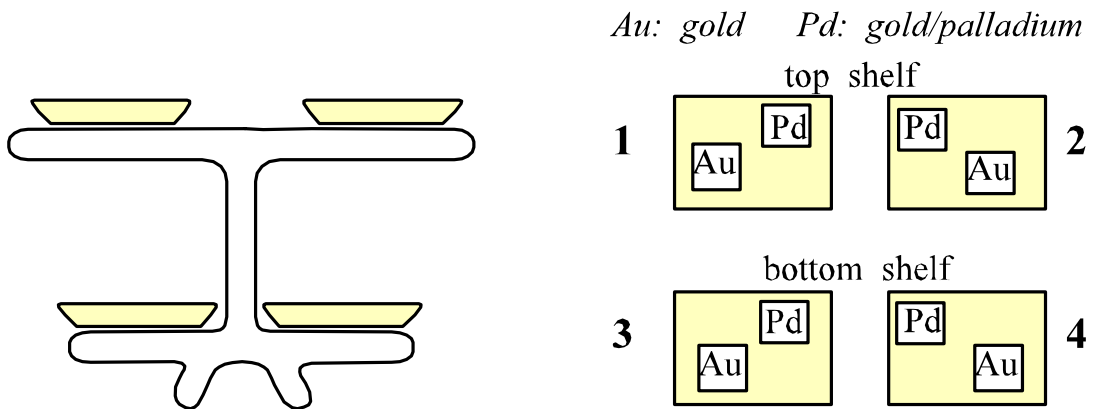
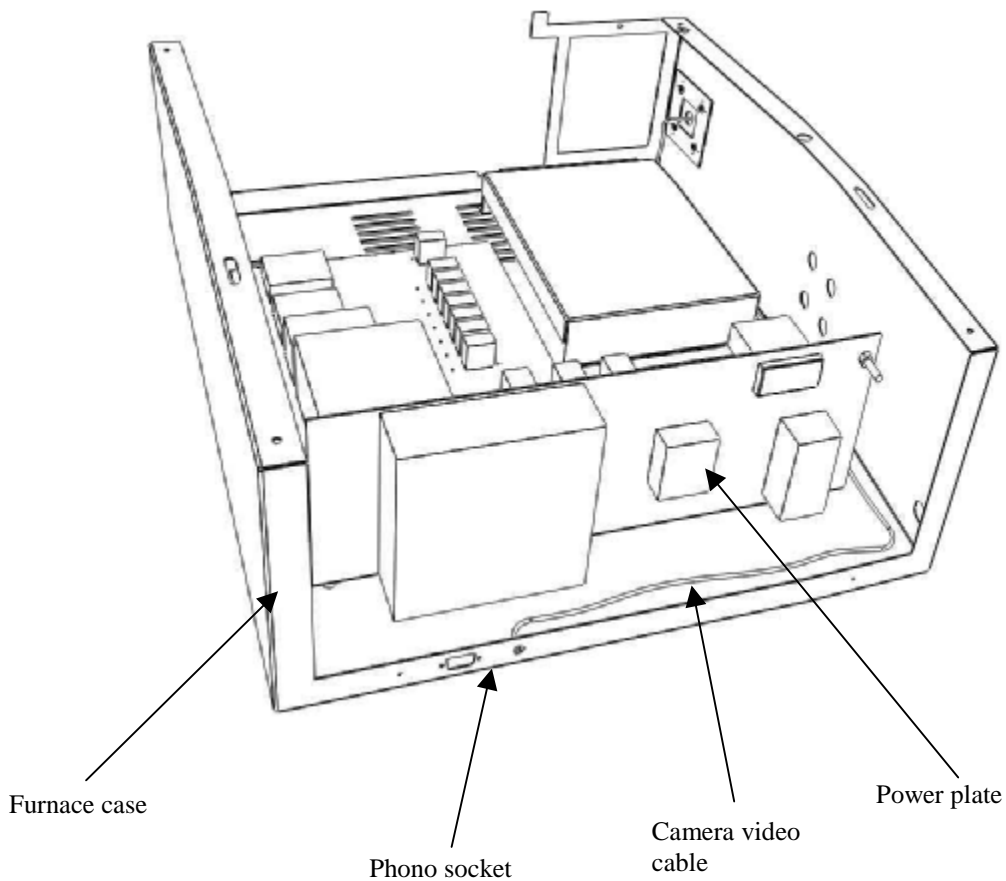


Fig 20. Sample carrier, sample tiles and sample positions.



**Fig 21. Route of camera video cable.**