ASM

Furnace 250-N

Reference Manual

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Part number: 2120402-01 Revison A.1 (normal paper)

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Preface

Scope

This manual describes the physical and operational characteristics of the ASM Furnace DFS-N 250, and is intended for all users: operators, maintenance personnel and process engineers. It is the only reference manual about the Furnace DFS-N 250.

The illustrations in this manual are there to help you locate a particular component, to show some part, or to explain some control structure. Details have been omitted for clarity - the illustrations in no way replace the engineering drawings contained in the drawing package.

Configurations

The Furnace DFS-N 250 is one part of a larger ASM wafer processing system. Other parts of the system may include a loading frame with boat loaders, a source cabinet containing valves, MFCs, filters, etc., a multi-purpose cabinet containing pumping and ancillary equipment, a bubbler cabinet, and a control cabinet containing the tube controller computers and peripherals. For details of these other parts and special components, refer to the appropriate reference manual or to the drawing package.

This reference manual makes no attempt to describe a specific process configuration, except in the interests of example.To find out how the Furnace DFS-N 250 is configured for your particular processing applications, refer to the drawing package.

The Furnace DFS-N 250 Documentation Set

You are now reading the Furnace DFS-N 250 Reference Manual. Other documentation in the Furnace DFS-N 250 documentation set includes:

Drawings Manual

This manual in A3 format contains all the system engineering drawings.

OEM Documents

The Furnace DFS-N 250 contains many items of equipment that have not been manufactured by ASM but that form a part of the Furnace DFS-N 250. The Original Equipment Manufacturer’s documentation is included as part of the Furnace DFS-N 250 documentation set.

Notes:

Section 1 Introduction

1.1 The Furnace DFS-N 2 50

The following diagram illustrates a System DF S-N250 (right-hand layout). The Furnace DFS-N 2 50 is the reactor section, with up to four horizontal process tubes stacked one above the other:

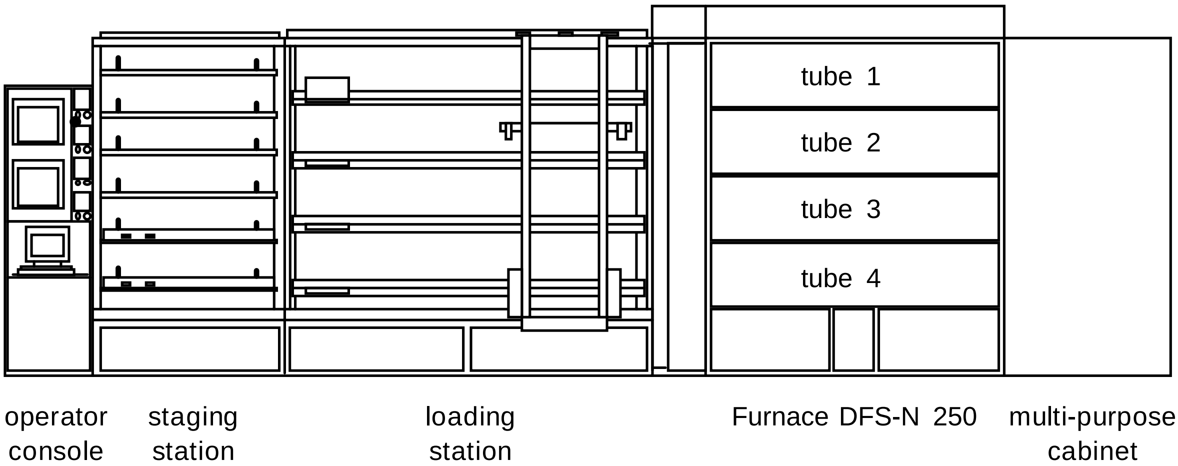


Figure 1-1 Typical ASM System DFS-N25 0 (RH)

In a left-hand system, the configuration is a mirror-image of the one illustrated above.

Configuration

The multi-purpose cabinet gives access to the rear ends of the process tubes, and If LPCVD processes are included, it may also contain vacuum equipment to bring the LPCVD process tube(s) to very low pressure. A gas and bubbler cabinet is located at the rear of the multi-purpose cabinet.

A different process can be installed at each tube level and some processes can even be combined in one tube (combi-process).

The total number of different processes depends on:

- The number of tubes installed (maximum 4).
- The space available for gas source and/or vacuum equipment.
- The fact that some processes are not compatible.

The following diffusion (atmospheric) or LPCVD (Low Pressure Chemical Vapor Deposition) processes are available as standard to the System DFS -N250 user:

Diffusion	LPCVD
Anneal/1	Poly (flat) undoped / doped
Anneal/2	Nitride
Sinter/Alloying	Poly (flat) / thin Nitride
Drive	TEOS
Dry Oxide	Nitride / TEOS
Dry Oxide TCA	
Dry Oxide OTS	
Dry Oxide OTS-TCA	

Different types of the following components may be installed at each tube level in the Furnace DFS-N 2 50; the type depends on the chosen process and the temperature at which it takes place:

- Process tube - see section 4.4.1, on page 25.
- Heating element - see section 4.4.2, on page 32.
- Thermocouples - see sections 4.4.3 and 5.3.
- Process tube door / flanges (if any) - see note below and section 4.4.1.1.
- Power unit - see section 4.3.1.

All other Furnace DFS-N 250 components remain the same whatever the configuration.

Note: To keep the process under vacuum, LPCVD tubes have leak-tight, stainless steel tube flanges and tube doors. Some or all of the flanges may be water-cooled, depending on the process (temperature) and the tube diameter. The type of door also depends on the loader that is used.

Flat-zone

The Furnace DFS-N 250 produces accurate and even temperature profiles in the central region of the heating elements, where the process gases come into contact with wafers. During processing, the temperature in this central region - the "flat-zone" - is within the tolerance of ±0.5ºC over the temperature range of 250-1300ºC.

Ramped temperature profile

In a "ramped" process, temperature in the flat-zone varies linearly with distance along the tube axis. The tolerance specified in the appendix then applies only at the center point of each zone.

Temperature history

In wafer processing, it is important that all wafers in a batch have the same temperature history. This reduces variations in wafer quality within a batch. The flat-zone must therefore:

- Be produced as quickly as possible after heat-up starts
- Be kept flat (or ramped) during process runs
- Continue for as long as possible into the cool-down.

Five-zone temperature control

The Furnace DFS-N 250 produces very accurate and stable flat-zones. This is because:

- The heating elements around the process tubes are divided into five axial zones
- Temperature is monitored and controlled independently in each zone
- A cascade controller is installed that provides advanced temperature control and uses both main and calibration thermocouples for control.

A microprocessor-based controller in closed-loop is dedicated to each tube. It handles five zones at the same time by multiplexing the temperature measurement signals from, and power control signals to, the zones. In the System DFS - N250, the controllers can be ASM SATC (**S**tand **A**lone **T**ube **C**ontroller) 2, 2.5 or 3.

1.2 Operating Specifications

This section gives information about:

- Process temperature accuracy and ranges.
- Power consumption.
- Ventilation and cooling.

Note: Unless specified otherwise, all data in these sections applies to a Furnace D FS-N250 with four process tubes at 1 atmosphere. Load: 150 wafers of 150mm diameter (maximum). Purge flow: N_2, 15 slm.

1.2.1 Process Temperature

Process temperature accuracy and over the range 250 - 1300°C (mains line voltage fluctuations ≤ 10%):

- Process temperature tolerance ± 0.5°C.
- Temperature stability ± 0.5°C.
- Temperature repeatability ± 0.3°C.
- Setpoint resolution 0.1°C.

1.2.2 Power Consumption

At 700°C, the heating element uses 5kW, at 1000°C, 9kW. The maximum load (peak) per element is 25kW.

1.2.3 Ventilation and Cooling

Air drawn through the furnace cabinet by five fan units cools the insulated heating elements in their stainless steel mantles. An air/water heat exchanger then cools the heated air before it leaves the Furnace DFS-N 250. The maximum temperatures in the first table apply to a Furnace DFS-N 2 50 with three tubes at 1200°C:

Max. Temperatures - Furnace Cabinet	
Outer surface of cabinet	50°C
Steel mantle of heating element	250°C
Air immediately after heat exchanger	45°C

Ventilation and Cooling	
Airflow furnace cabinet	2800 m^3/hr
Airflow scavenger (4 boxes)	≥ 200 m^3/hr
Air inlet temperature	< 22°C
Waterflow heat exchanger	10-20l/min.
Water inlet temperature	< 18 °C
Water temperature rise (ΔT)	< 28°C

Section 2 Description

2.1 Introduction

Process and service engineers who are familiar with the Furnace D FS-N250 need not read this section and instead can go to section 4 - Detailed Description. This section gives a short description of the Furnace DFS-N250 for the general reader, for example, an operator who does not need to read the manual further than section 3 - Operation.

The following figure illustrates the right-hand version of the Furna ce DFS-N250:

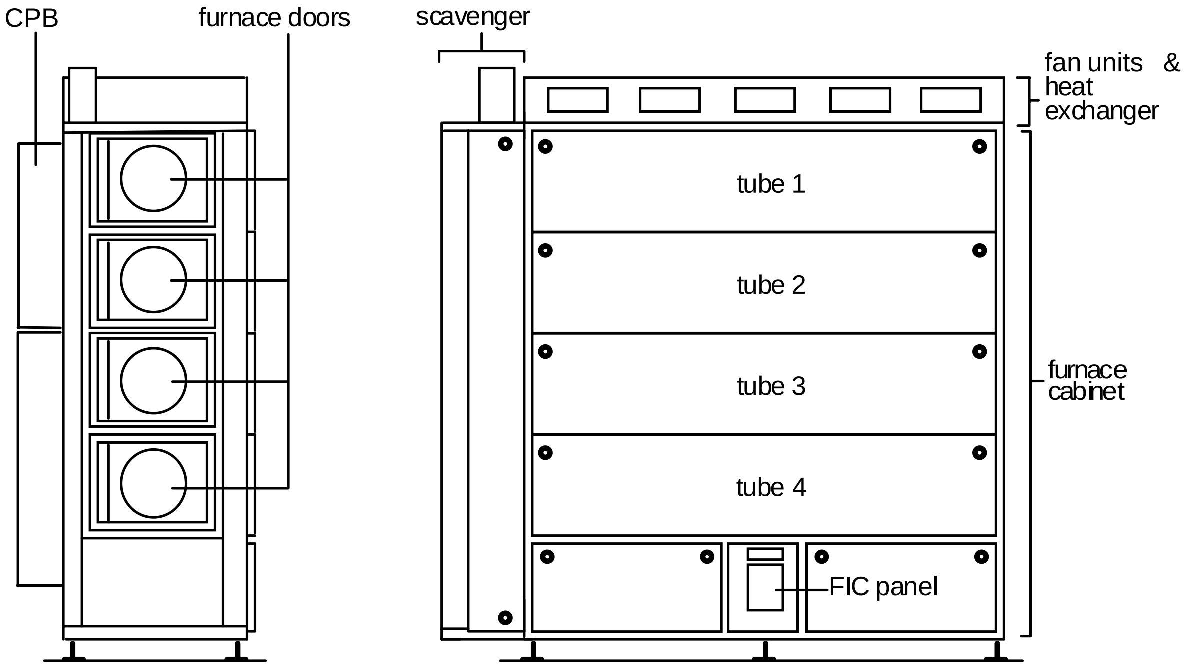


Figure 2-1 Furnace DFS - N250 (RH)

The following units of the furnace are described in this section:

- Furnace cabinet.
- Fan units and heat exchanger.
- Scavenger and furnace doors.
- Furnace Interface Control (FIC) panel.

2.2 Furnace Cabinet

The furnace cabinet can be divided into two sections, bottom section and tube section.

The bottom section of the furnace cabinet contains:

- Power units for up to four tubes, including:
  - Power transformers
  - Thyristors
  - Thyristor control board (microprocessor-controlled).
- Cold Junction Boxes (temperature reference for thermocouples).
- Furnace Interface Control (FIC) panel.

The tube section (with up to four tubes) contains:

- Diffusion and/or LPCVD process tubes
- Standard temperature heating element and thermal insulation
- Main and back-up thermocouples for temperature control
- Overheat protection thermocouples to detect tube overheating
- Calibration thermocouples for tube-profiling and cascade control
- Overheat protection sensor.

Mounted on the rear of the furnace cabinet is the Central Power Box (CPB) with:

- Mains power terminals
- Fuses and circuit breakers
- Power unit relays for tubes 1 to 4
- EMO circuit.

2.3 Fan Units and Heat Exchanger

The fans draw air up through the cabinet to carry away waste heat from around the heating elements. The heat exchanger uses water-cooled tubes to take this waste heat from the air. After leaving the exhausts at the top of the furnace, the cooled air should enter a facility ventilation system. The cooling system can be optionally equipped with:

- Airflow switches to detect fan unit failure or obstructed airflow
- Waterflow switch to detect sufficient water flow.

2.4 Scavenger and Furnace Doors

The scavenger is an exhaust unit located at the loading end of the process tube. Its purpose is to draw off any gas in the door area. For oxidation processes, it draws off process gasses; for other processes it serves to draw off stray gas when the door is open.

The scavenger must be connected to a special facility airduct, into which air contaminated with process gases can be exhausted. Before being exhausted to the atmosphere, the air must be "scrubbed" to remove all the dangerous gases. The scavenger may be equipped with an airflow switch to detect flow in the scavenger exhaust duct. Too little flow can be dangerous because it allows contaminants to leak into the cleanroom.

The scavenger sub-frame provides a mounting for the process tube doors (if fitted) and their automatic drive mechanisms. Behind the hinged steel-plate door at the front of the scavenger there is room for:

- Electric door, drive mechanisms
- Water ducts for the tube flange cooling water
- Baratron pressure sensors.

Note: The last two items are present only when LPCVD processes are installed.

2.5 Furnace Interface Control (FIC) Panel

The FIC panel allows you to switch mains power on and off to the whole Sys tem DFS-N250 or just to individual heating elements at tube levels 1 to 4. There are also visual and audible alarms for tube and chamber overheat, waterflow and airflow detection, with respective reset switches. Operation and appearance of the FIC panel are described in section 3.3.2.

Notes:

Section 3 Operation

3.1 Introduction

The following figure illustrates a typical installation layout for the right-hand version of the System DFS-N 2 50.

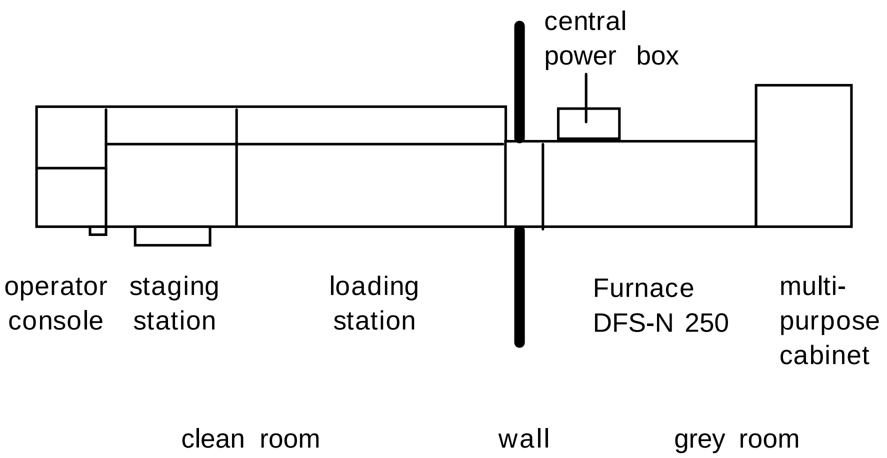


Figure 3-1 Typical System DFS-N 2 50 (RH) Floor Layout

The Furnace DFS-N 250 is in the grey room and the loading station, staging station and operator console are in the cleanroom.

The following aspects of operation are described in this section:

- Furnace operation in the cleanroom.
- Furnace operation in the grey room.
- System safety.

Personnel of the System DFS- N250 will be interested in the following parts of this section:

- Operator section 3.2.
- Production engineer sections 3.2 and 3.3.
- R & D engineer section 3.2 and, if necessary, sections 3.3 and 3.4.
- Service engineer sections 3.3 and 3.4.

The operator is involved on a daily basis; the others only become involved when the operating procedure must be changed or when there is a problem.

3.2 Operation in the Cleanroom

This section gives a short summary of SATC operation of the Furnace DFS-N250 from the cleanroom. For other aspects of Furnace DF S-N250 operation see section 3.3.

Each Furnace DFS-N 250 process tube is controlled from the cleanroom by its own SATC. Two SATC mechanisms are important to Furnace DF S-N250 operation:

- **Exception state** mechanism - monitors safety digital inputs (the SATC can be programmed to go into an exception state if one or more of these inputs becomes active)
- **Temperature control** mechanism - controls temperature in heating element z on es1to5.

The exception state mechanism monitors the following digital inputs from the Furnace DFS-N 2 50:

NAME	value		description
	inactive	active	
TUBEtemp	NORMAL	tooHOT	Tube temperature signal from control panel: active if an overheat protection thermocouple triggers.
WATER (optional)	FLOW	NOFLOW	Signal from heat exchanger cooling waterflow switch: active if insufficient flow is detected.
C.J.BOX	NORMAL	OFF	Signal from Cold Junction Box (CJB) 50°C reference for temperature control: main(spike)/ back-up/calibration thermocouples. Active if CJB is not working.
PW-UNIT (only with Roto power packs)	NORMAL	tooHOT	Signal from thermo-switch on the thyristor cooling block indicating that the temperature of the block is too high.
FURNACE	NORMAL	ALARM	Signal from thermo-switch, inside cabinet at top, that becomes active if the cooling air is too hot (>125°C).
AIRflow (optional)	FLOW	NOFLOW	Signal from airflow switches above fan unit exhausts: active if not enough flow is detected.
WATER-DR (optional)	ON	OFF	Signal indicating waterflow to the door flange.

The digital inputs to the SATC are shown on the operator console screens:

```
DIGITAL INPUTS STATUS DISPLAY
TEMPERATURES          Zone 1    Zone 2     Zone 3     Zone 4     Zone 5
                     ------    ------    ------    ------    ------
Spike       :          898.8      898.7      898.7      898.8      898.9
Backup      :          898.5      898.5      898.5      898.5      898.6
Calibration :          898.9      898.8      898.8      898.9      899.0

DIGITAL INPUTS                                                    Page 1

Name     Value    St       Name     Value    St       Name     Value    St
--------------------      --------------------      ---------------------
TUBEtemp NORMAL            FURNACE  NORMAL            SRClev.  NORMAL
WATER    FLOW              AIRflow  FLOW              Bubl-OT  NORMAL
C.J.BOX  ON                FLAME    ON                SRCtemp. NORMAL
PW-UNIT  NORMAL            WATER-DR ON

Press ^E to Exit, ^K to show keys
```

Figure 3-2 Example of SATC Digital Inputs Status Display

The bottom part of the screen shows the name and value of each digital input (the screen shows digital inputs from the Furnace DFS - N250 as well as other System DFS- N250 sections). If the value goes active, the column headed "St" (State) shows what the **recipe** will do unless the user has chosen to IGNORE the digital input. The recipe exception states are:

- AL (Alarm) - warning sounds, process continues.
- HD (Hold) - warning sounds, process stops until [CONTINUE] button on the Operator Panel is pressed (see f igure below).
- SP (Suspend) - warning sounds, process stops until the digital input goes inactive.
- AB (Abort) - warning sounds, process enters a recipe-defined ABORT sequence.

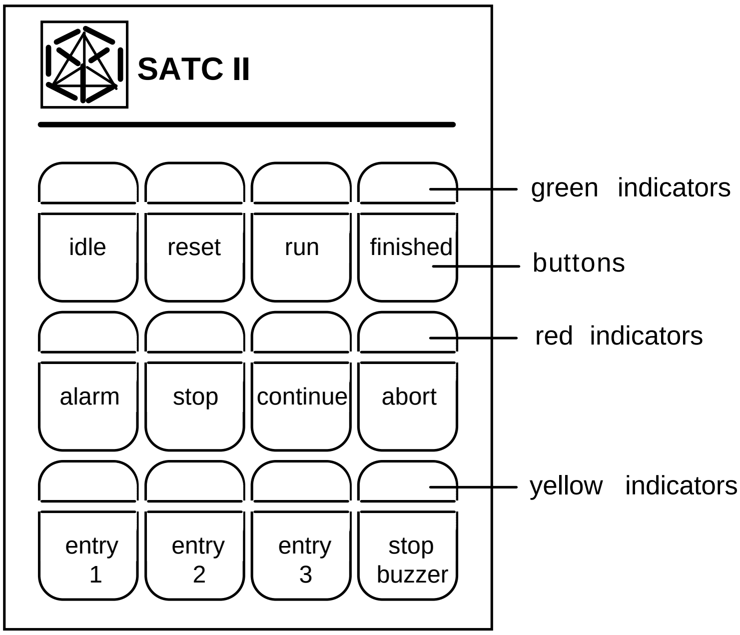


Figure 3-3 SATC Operator Panel

If a combination of digital inputs from the System DFS - N250 triggers a safety mask (not user-defined), SF (Safety) appears in the state column on the screen, a warning sounds and the recipe stops. Safety masks define an unsafe situation and give a combination of digital outputs which force the System DFS-N 250 into a safe state. For information on recipes and safety masks, refer to the system manual for your tube controller.

IMPORTANT: The required action to be taken in the case of an exception state depends on the type of exception, and on whether a recipe was running, and in which step the recipe was in when the exception occurred. refer to your local fab operating procedures.

Cleanroom EMO button

The cleanroom EMergency Off (EMO) button is a large red button mounted at head height on, or near, the SATC operator panel on the front of the operator console. If this is not the case with the System DFS-N 2 50 you are working on, check the service layout supplied with the System DFS-N 2 50.

IMPORTANT: Before working on the system locate the nearest EMO button. Activating the EMO button turns off all power to the whole system. Use it only in an extreme emergency such as FIRE, EXPLOSION, FLOODING, LEAKAGE OF TOXIC GASES or SERIOUS ELECTRICAL SPARKING, as it may cause the loss of a wafer load.

Hitting the EMO button switches OFF the power to the whole System DFS-N 250. After all possible action has been taken to bring the emergency under control, the service engineer must be informed as soon as possible. Only when the whole System DF S-N250 has been declared ready for operation again by the service engineer must the EMO button be pulled out and the system power turned back on.

3.2.1 Temperature Control Mechanism

The top part of the Digital Inputs Status Display (see Figure 3-4) shows zone temperatures. Use the Change Temperature Setpoints screen to alter their values:

```
CHANGE TEMPERATURE SETPOINTS
ZONE                Zone 1    Zone 2    Zone 3    Zone 4    Zone 5
                    ------    ------    ------    ------    ------
Setpoint               800       800       800       800       800
New setpoint          800       820       800       800       800


Change temperature setpoints (Y/N):
```

Figure 3-4 Example of SATC Change Temperature Setpoints screen

Note: For more information on this screen, refer to the system manual for your tube controller.

3.3 Operation in the Grey Room

3.3.1 EMO Button

The Furnace DFS-N 250 usually has two large red EMO (**EM**ergency **O**FF) buttons in the grey room, one at the front of the furnace on the scavenger door and one at the back of the furnace on the Central Power Box. If this is not the case with the system you are working on, check the service layout supplied with the Furnace DF S-N250.

IMPORTANT: Before working on the system locate the nearest EMO button. Activating the EMO button turns off all power to the whole system. Use it only in an extreme emergency such as FIRE, EXPLOSION, FLOODING, LEAKAGE OF TOXIC GASES or SERIOUS ELECTRICAL SPARKING, as it may cause the loss of a wafer load.

3.3.2 Furnace Interface Control (FIC) Panel

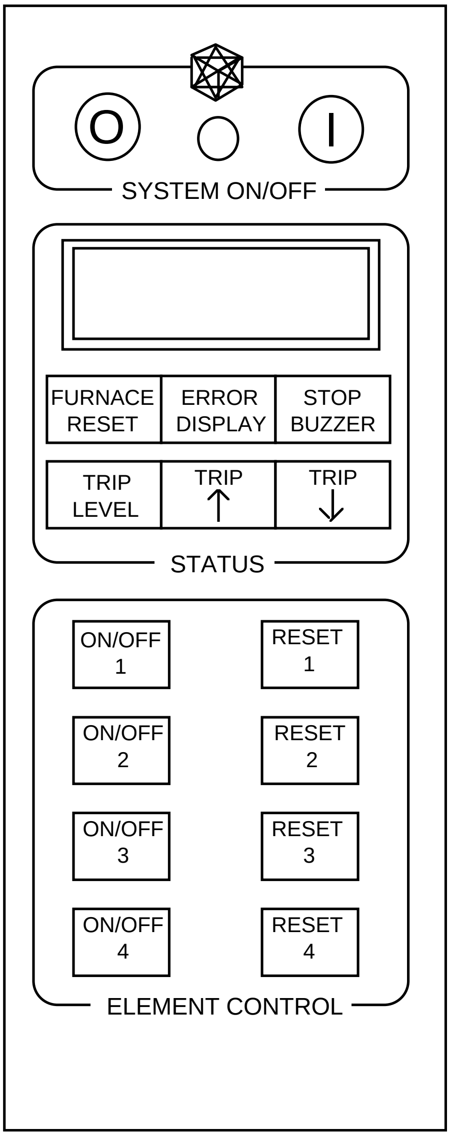


Figure 3.5 FIC Panel

Apart from the EMO buttons and an optional VT220 maintenance terminal, the only controls outside the cleanroom environment which are linked to the Furnac e DFS-N250 are in the Furnace Interface Control (FIC) panel. In addition to enabling the operator to switch power to the elements, the role of the FIC panel is to monitor the temperature of the furnace (and vital cooling functions) and to switch power off if there is any danger of overheating.

System ON/OFF

The large red OFF (0) and green ON (I) buttons at the top of the FIC panel switch power to the whole System DFS-N 2 50; the indicator light between the two buttons illuminates when power is ON.

WARNING When the system is switched off, dangerous voltages are still present in the central power box.

Status

The status part of the FIC panel consists of six pushbuttons and a red LED status display window. During normal operation a moving “0” is displayed to show that the FIC panel is operational. The status part of the FIC panel provides three functions:

- Setting the temperature (trip level) at which power to the tube power unit will be cut (overheat protection).
- Displaying the status of one or more of the monitored inputs if an error situation occurs (error display).
- Functions to reset the furnace and to stop the buzzer.

SETTING THE TRIP LEVEL (OVERHEAT)

The trip level is a temperature setting at which the temperature of the process tube is considered to be too high, and must be set for each process tube. When the temperature exceeds this level (as measured by the overheat thermocouples), power is cut to the affected tube power pack. The trip level must be higher than the process temperature and must allow for possible overshoots during heating up, but must be below any temperature that is critical for the equipment or process.

To set the trip level, press the [TRIP LEVEL] button. The trip level for the first element is displayed. Adjust the temperature using the [↑] and [↓] buttons. Press [TRIP LEVEL] to move to the temperature for the next process tube.

ALARMS AND ABORTS

The FIC panel monitors a number of sensors that are vital to system safety and process integrity. Although these sensor signals are passed on to the SATC, which may be programmed to take action, the FIC panel can take immediate action by sounding an alarm (ALARM status) or even cutting power to the furnace power unit (ABORT status). The FIC panel is a first line of defense and will always work, even if the SATC is not on.

If an alarm occurs you can silence the buzzer by pressing the [STOP BUZZER] button. This does not

ERROR CONDITION	ALARM DELAY	ABORT DELAY
Tube Overheat Temperature from the overheat thermocouples exceeds the trip level setting.	no alarm	0 secs.
Furnace Overheat Temperature inside the cabinet exceeds the value of the temperature switch.	0 secs.	2 secs.
Waterflow Heat Exchanger Flow of cooling water has dropped below the level of the flow switch.	2 secs.	5 mins. (if set)
Water Door Error Flow of cooling water to the door has dropped below the level of the flow switch.	2 secs.	5 min. (if set)
Air Flow Sensors Flow of air has dropped below the level of the flow switch.	2 secs.	2 secs. abort only if more than 50% capacity is lost
Thyristor Unit Overheat (if Roto power packs are used) Thyristor cooling block too hot.	no alarm	2 secs.
Cold Junction Box CJB is no longer working.	2 secs.	5 mins. (if set)

clear the problem however, and an abort may occur if the problem is not solved within the abort delay time. To view the source of one or more errors, press the [ERROR DISPLAY] button.

FURNACE RESET

Three of the error conditions in the above table, furnace overheat, waterflow heat exchanger and air flow sensors will cause power to all elements to be switched off. When the cause of the problem has been fixed, check that the heating is switched on, then press the [FURNACE RESET] button to return power to the whole furnace. The other error conditions affect tube elements individually.

IMPORTANT The interlock hardware can only be reset when the cause of the problem has been removed.

Element Control

The four [ON/OFF] buttons in the element control part of the FIC panel enable you to switch power to the elements individually. The four [RESET] buttons allow you to reset the elements individually if an error condition has cut off power to an element. Press the [RESET] button to return power to the affected element. Beware that by resetting the elements you can trip the automatic fuse in the Central Power Box.

3.4 System Safety

The Furnace DFS-N 2 50 has the following safety systems:

- Overheat protection TCs for tube areas: left (zone 1 + 2), center (zone 3) and right (zones 4 + 5). If temperature rises above a preset level, power to that tube is turned off.
- Cabinet overheat protection to prevent the ambient in the furnace getting too hot. Power to all tubes is turned off.
- Waterflow switch: low cooling waterflow in heat exchanger (optional) - power to all tubes is turned off.
- CJB status: CJB NORMAL or OFF - alarm.
- Airflow switches: low cooling airflow through the furnace cabinet (optional). Power to all tubes is turned off.
- Scavenger airflow switch (optional): low airflow through the scavenger.
- Low water flow to door flanges (optional) - alarm.

The FIC panel is microprocessor-based and performs self checks on power up, including EPROM integrity. A watchdog timer monitors the processor and forces it to a safe state if the processor malfunctions; a power fail detection circuit monitors the 5V supply.

Section 4 Detailed Description

4.1 Introduction

The following figure illustrates the Furnace DF S-N250 (right-hand version):

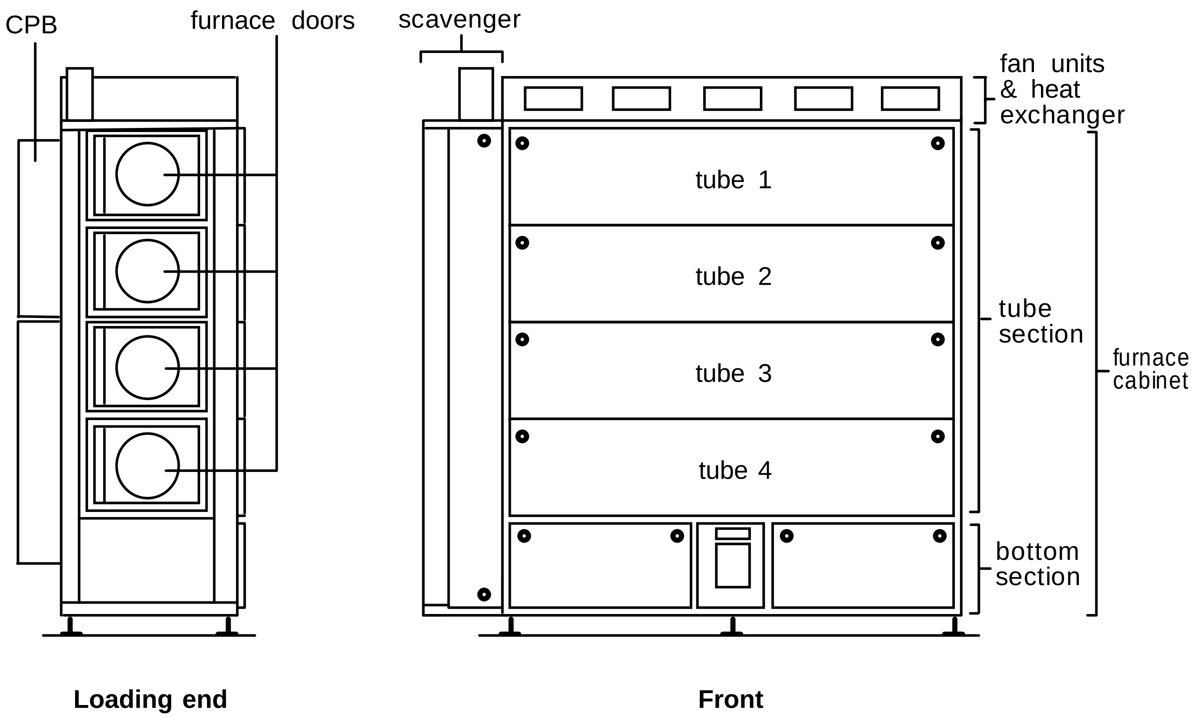
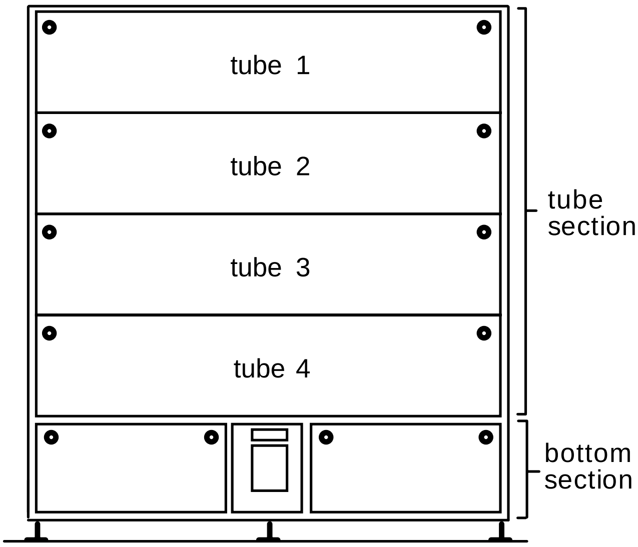


Figure 4-1 Two views of the Furnace DF S-N250 (RH)

The following parts of the furnace are described in more detail in this section:

- Furnace cabinet.
- Bottom section.
- Tube section.
- Fan units and heat exchanger.
- Scavenger.
- Furnace doors.
- Central Power Box.

4.2 Furnace Cabinet



Front View

Figure 4-2 Furnace Cabinet

The furnace cabinet encloses the Furnace D FS-N250. The cabinet is symmetrical and can be used for both right-hand and left-hand Furnac e DFS-N250 installations (the scavenger frame being mounted on the left or the right respectively). The cabinet consists of a frame with painted steel panels (tube section) and doors (bottom section) which provide access to, and mountings for, the components inside. It also has:

- Two supports for each heating element.
- Rails in which the power units rest.
- A calibration thermocouple storage tube at each process tube level.
- Cable ducts for the power and signal cabling.

4.2.1 Frame

The frame is a painted, welded construction of square-section steel tubes. Its overall dimensions are:

Width	2100 mm (including scavenger)
Depth	800 mm
Height	2275 mm (plus ground clearance)

The heat exchanger on top of the cabinet adds 161 mm to the height.

The furnace has six adjustable legs which can be screwed in or out to level the furnace. The minimum ground clearance for the furnace is 60 mm.

4.2.2 Access Panels and Doors

The following figure shows the access panels and doors on the furnace cabinet:

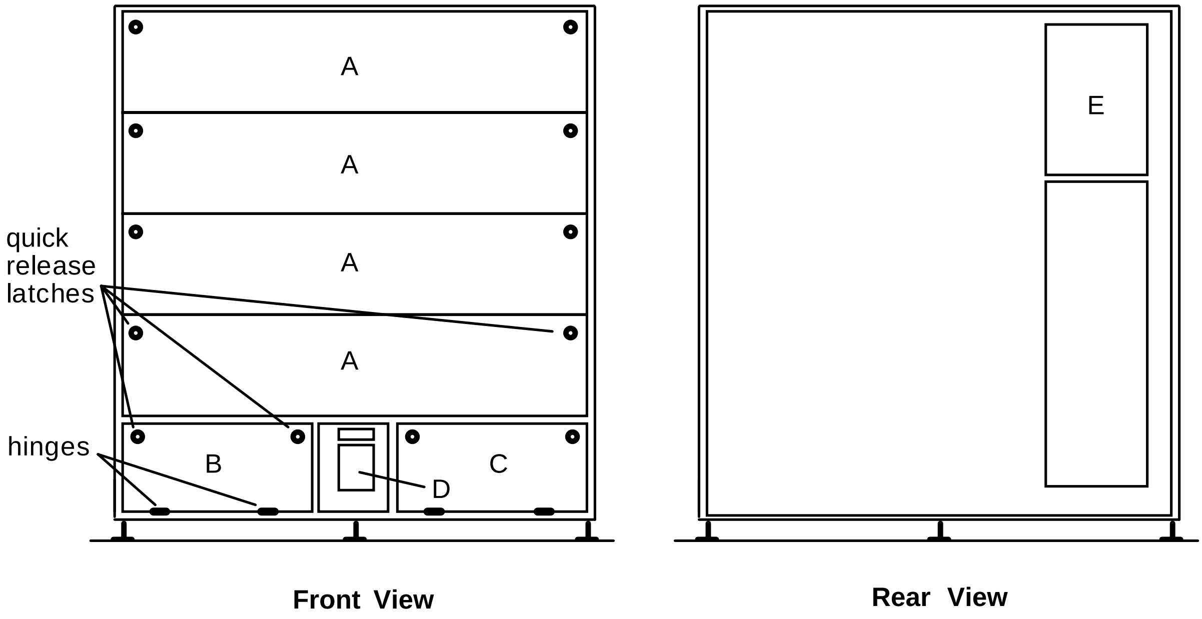


Figure 4-3 Furnace Cabinet (RH) Access Panels and Doors

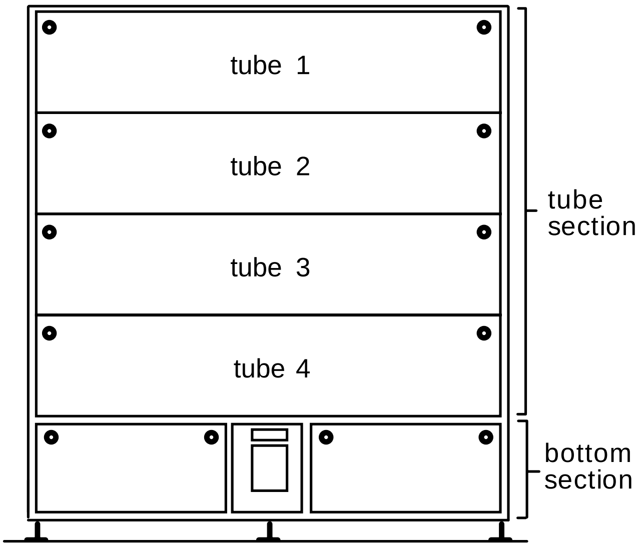
The letters in the figure label the following panels and doors:

A	Panels for access to the heating element supports and connections, thermo-couples and chamber overheat thermo-switch.
B	Door to the power units and the Cold Junction Box for tubes 1 and 2.
C	Door to the power units and the Cold Junction Box for tubes 3 and 4.
D	FIC panel mounting plate.
E	Door to Central Power Box

Note: For convenience, the Central Power Box may be mounted in a different location

4.3 Bottom Section

The following figure shows the location of the bottom section of the furnace cabinet:



Front View

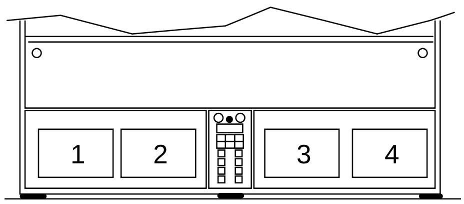
Figure 4-4 Furnace DF S-N250 with Bottom Section Indicated

The bottom section of the furnace cabinet contains the following components:

- Power units 1 to 4.
- Cold Junction Boxes 1 and 2.
- FIC panel.

4.3.1 Power Units

Each process tube has a dedicated power unit. The four power units are located behind the doors at the bottom front of the furnace. The following figure indicates their location:



Front View RH Furnace

Figure 4-5 Location of the Power Units

WARNING When the system is switched on, dangerous voltages are present in the power units. removal of the protective covers and subsequent activities should only be performed by authorized trained personnel.

The dimensions of each unit are:

Width	357 mm
Depth	600 mm
Height	390 mm

Each power unit consists of:

- Transformer.
- Power-switching thyristors.
- Control circuit board.

The power unit supplies each zone of the heating element with low-voltage, high current pulses at full power. The pulse duration and distribution across the zones is regulated by a microprocessor in such a way that optimum heating performance is obtained without high power surges. Short pulsing also avoids the creation of possible harmonics in other electrical circuits. The method used is known as distributed proportional control.

The thyristors switch power to the zones at the AC cross-over point thus creating a minimum of radio frequency interference.

Components

Each power unit consists of three main parts: the transformer, the thyristors and the thyristor control boards.

The **transformer**, mounted at the rear, converts the single-phase AC inlet supply to a lower voltage single-phase AC supply that is suitable for electrical characteristics of the heating element.

The **thyristors** are mounted on large aluminum **heat sinks**, located in front of the transformer. The thryistors switch power to the heating element zones when commanded by the thyristor control boards.

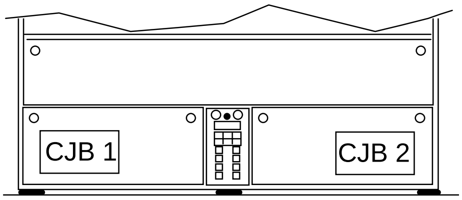
The **thyristor control boards** are mounted on the front of each heat sink. They provide the logic for power control - receive a signal from the tube controller which is proportional to the required temperature and subsequently provide the power to the heating elements as smoothly and efficiently as possible without unwanted side effects, such as overloads, overshoots or interference. A LED on the board indicates that power is being supplied via the appropriate thyristors to a particular zone.

Note: A flashing LED indicates that the thyristor is controlling power supply; a continuously lit LED indicates that control is flat out.

Heat sink over-temperature sensor: a temperature sensor is mounted on the heat sink. If the heat sink becomes too hot (caused, for example, by a defective cooling fan) it will trigger a digital input to the FIC panel.

4.3.2 Cold Junction Boxes

The Cold Junction Boxes (CJB) are mounted on the back of the access doors at the bottom front of the furnace:



Front View RH Furnace

Figure 4.6 Location of the CJBs

The CJB is an accurate 50°C reference for main, back-up and calibration TCs. The overheat protection TCs are not connected to the CJB.

The dimensions of each CJB are:

Width	330 mm
Depth	120 mm
Height	160 mm (without connectors)

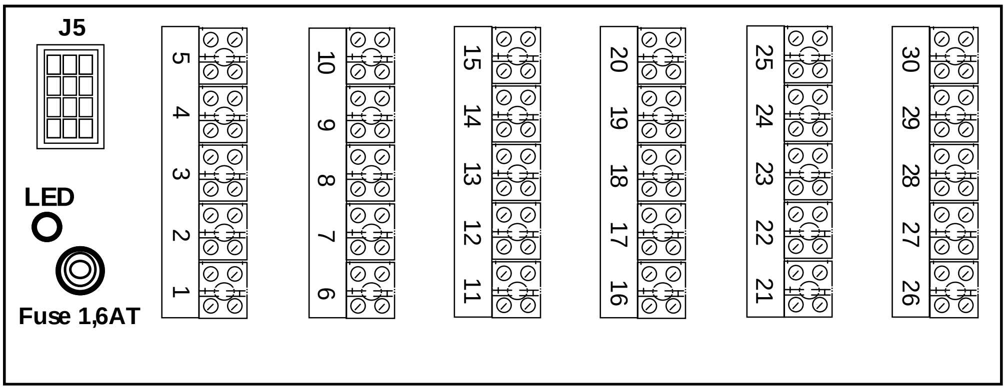
The CJB has the following external components:

- Screw-connector blocks 1 to 30.
- Braided flat-cable connectors J1 and J2.
- 12-pole connector J5.
- Low current fuse.
- Green LED indicator.

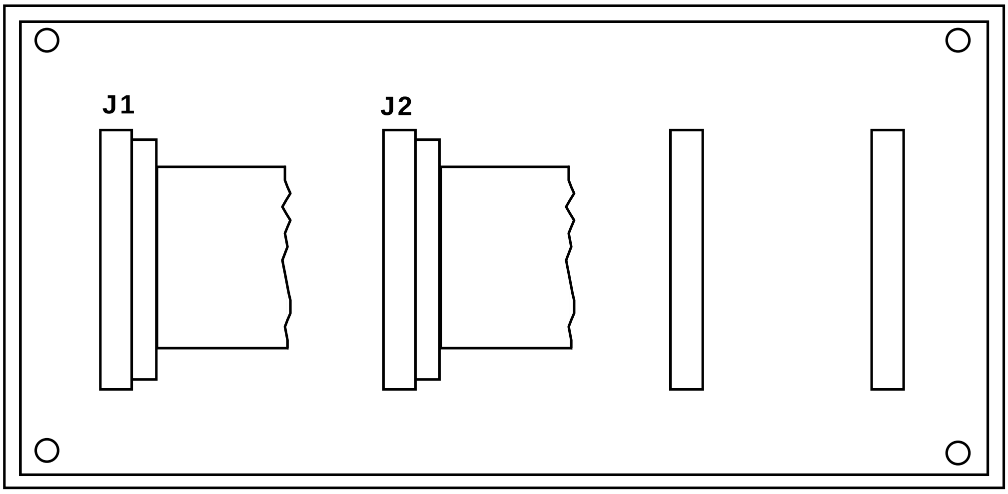
The CJB contains:

- Insulated temperature reference block.
- Heater controller PWBA.

The LED on top of the CJB lights when the heater is ON. During normal operation, the LE flashes approximately every six seconds.



Top View



Front View

Figure 4-6 Cold Junction Box

For further details of the CJB, see section 5.4.

4.3.3 Furnace Interface Control Panel

The FIC panel is located in the centre of the Bottom Section of the Furnace Cabinet:

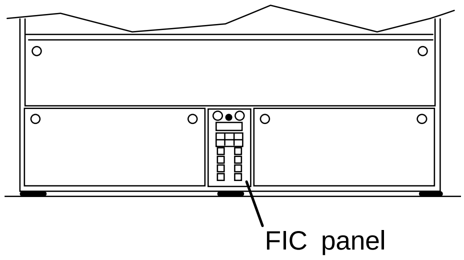


Figure 4-7 Front View of Bottom Section showing FIC Panel

The dimensions of the FIC panel (Figure 3.5 FIC Panel) are:

Width	120 mm
Height	475 mm

The FIC panel is mounted on a frame measuring:

Width	180 mm
Depth	150 mm
Height	430 mm (without connectors)

The following PWBAs are mounted on the back of the frame:

- Overheat protection amplifier boards (one per process tube).
- Overheat protection mother board.

The functions of the FIC panel are:

- Main furnace power on/off (and to other System DFS - N250 sections - source/vacuum, loading/staging sections and system hardware).
- Manual switching of power supplies to power units 1 to 4.
- Overheat protection of heating elements for tubes 1 to 4, overheat alarm indication and buzzer stop/ reset switch.
- Waterflow and air flow alarm indication with buzzer stop/reset switch.
- Cabinet overheat alarm indication with buzzer stop/reset switch.

For operation from the FIC panel, see section 3.3.2; for safety systems, see section 3.4.

4.4 Tube Section

The location of the Tube Section of the Furna ce DFS-N250 is shown in the following figure:

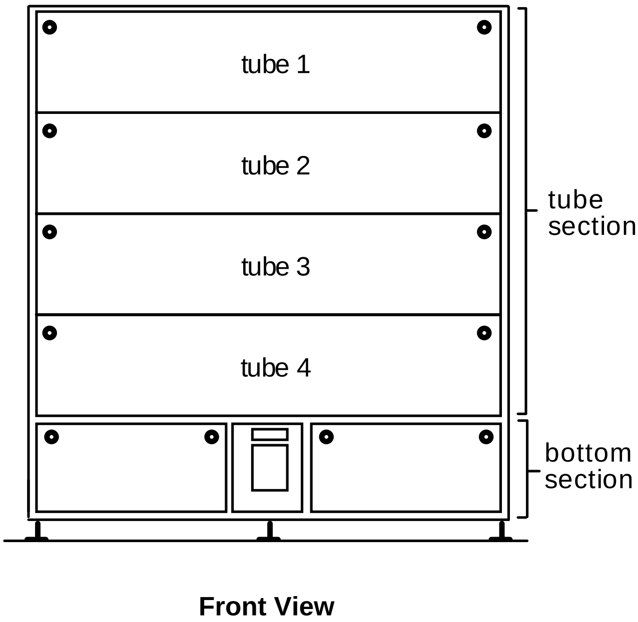


Figure 4-8 Tube Section of Furnace D FS-N250

The tube section contains the following components:

- Process tubes and tube adapters.
- Heating elements and power connections.
- Overheat protection thermocouples, mountings and connectors.
- Main and back-up thermocouples, mountings and connectors.
- Calibration thermocouples, storage tubes and connectors.

4.4.1 Process Tubes

The Furnace DFS-N 250 can accept two types of process tube - diffusion and LPCVD. Their materials, dimensions and shapes are described below. For information on process tube removal, cleaning, installation and start-up procedures, see section 8.2.

Materials

Process tubes for standard temperatures (250 to 1150°C) are made of high-purity clear-fused quartz (SiO_2).

Shapes

The loading end of a diffusion process tube is plain cylindrical; but at the rear end it is almost fully closed, being hemispherical in the quartz version and conical in the silicon carbide version. At the rear end there is a central ball-joint opening with a nominal internal diameter of 30 mm for injection of process gases. There is also a similar but smaller peripheral ball-joint opening with a nominal internal diameter of 15 mm for the insertion of a calibration thermocouple.

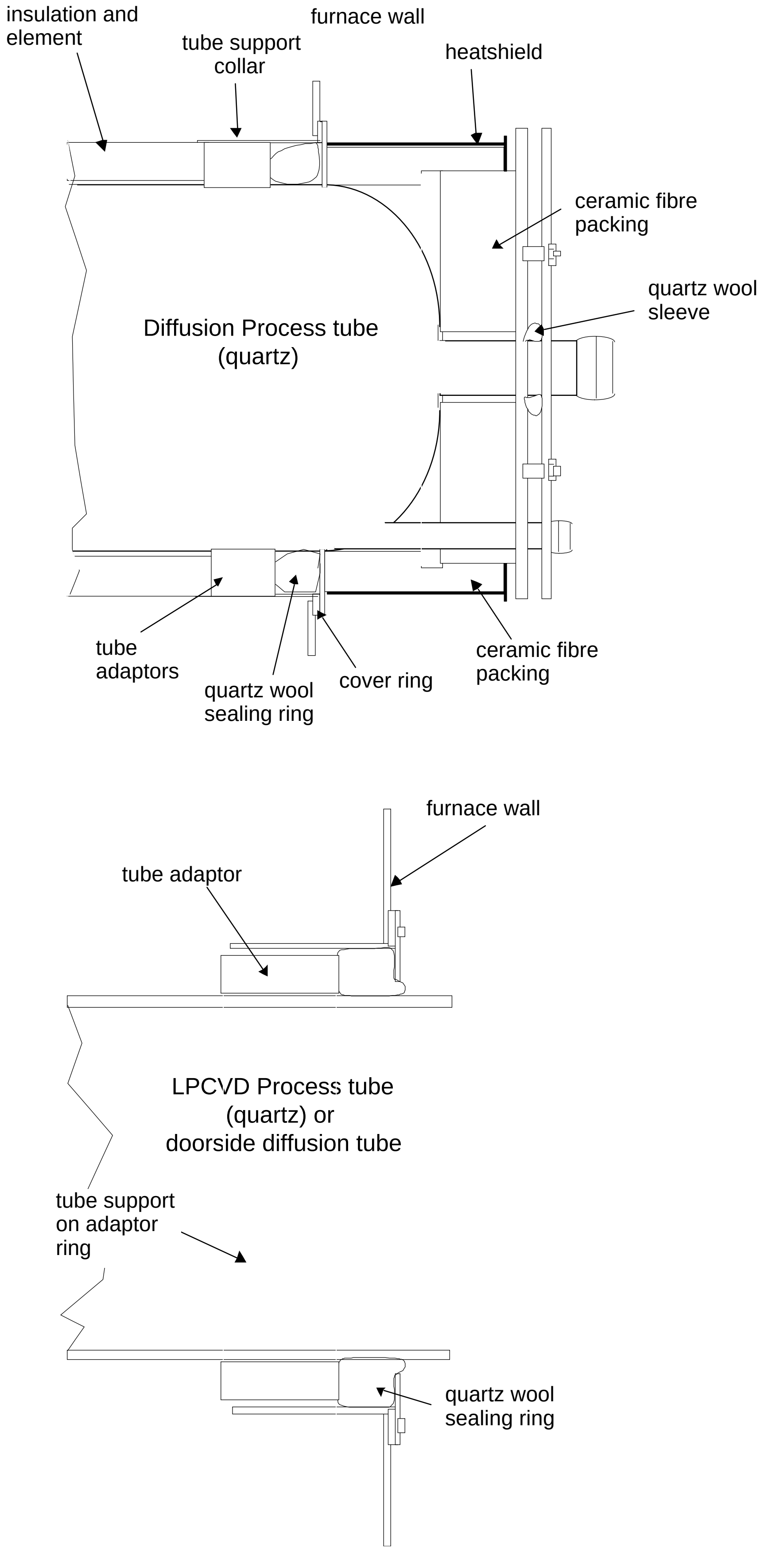


Figure 4-9 Process Tubes

4.4.1.1 Tube Doors

The way the process tubes are closed off at the loading end during processing depends on the type of loading system used. The tubes may be closed off with doors or in some other way. The following loading systems can be used in the Furnace DFS-N250:

- SCL (**S**oft **C**ontact **L**oader).
- SLS (**S**uspended **L**oading **S**ystem): Cantilever loader.
- Manual Loading.

Both the loading and unloading stages of the processing cycle are critical to high quality wafer processing. The choice of loading system can have a detectable effect on wafer processing quality. The relationship between loader and door type is as follows:

LOADER	DIFFUSION PROCESS TUBE	LPCVD PROCESS TUBE
SCL	Note 1	**S**tainless **st**eel (S. St.) automatic door (standard)
SLS Cantilever	Quartz BG Ldoor/CRYSTAR [a] paddle Quartz HERAEUS* door/quartz-sheathed suspension rods Notes 1 & 2	S. St. BGL door/quartz-sheathed suspension rods •Cryco paddle S. St. HERAEUS* door/quartz-sheathed suspension rods Notes 2 & 3
Manual	Baffle	Manual door

a. "Crystar" is a registered trademark of the Norton Company.

NOTES:

1. In certain cases, for example, when the process gases are particularly dangerous, or when the presence of hydrogen gas gives an explosion risk, a stainless steel, gas-tight LPCVD door is fitted.
2. BGL/IAS, *W.C. Heraeus GmbH, •Cryco. These makes are most often installed in the System DFS-N 250. Other companies also make equipment to similar specifications.
3. All stainless steel doors are equipped with Viton O-rings which give a leak-tight seal between the door and the adjacent stainless steel front tube flange. The door and the tube flange are clamped together by a spring loaded mechanism which ensures that no gas leakage can occur during a process run. At low pressures (LPCVD), the door is “pulled” tight by the vacuum.

4.4.1.1.1 Soft Contact Loader Doors

This section describes the process tube doors used with the soft contact loader, and therefore, gives only a short description of the loader. For more details of the soft contact loader, see the Tube Loader System Manual, document no. 2010240.

Functional

The Soft Contact Loader can load up to six cassettes of wafers at the same time. The cassettes, arranged on a quartz or silicon carbide carrier, are loaded onto a silicon carbide "paddle", which is then driven slowly into the process tube. (As with process tubes, the choice of carrier and cassette materials depends mainly on process temperature.)

When the carrier reaches its processing position in the middle of the flat-zone, the SCL gently lowers it onto the bottom of the tube - soft contact - and the paddle then withdraws in lowered position, allowing the automatic door to close and the clamp to shut.

After the process is complete, the door is unclamped and re-opens, allowing the paddle to be driven back into the tube in lowered position and under the waiting carrier. The carrier is gently lifted clear of the tube wall and slowly withdrawn from the process tube.

The diffusion and LPCVD versions of the standard automatic door used with this loading/ unloading system are shown in figure 4-10 and figure 4-11.

Physical

The standard automatic diffusion door is a flat-ground quartz door plate which seals off the process tube when pressed against its flat-ground loading end. The door plate is a hollow quartz disk filled with thermal insulation (ceramic fibre board). It is held in an octagonal stainless steel frame by two gimbals, or swivels, which allow tilting about the horizontal axis. A small, adjustable plate at the bottom left of the door plate stops it tilting too far. This whole assembly is in turn held in a U-shaped stainless steel yoke by two gimbals that allow rotation about the vertical axis. A screw, close to the gimbal in the upper arm of the yoke, stops the door plate rotating too far. The yoke pivots on two vertical hinge-pins on the right-hand upright of the door mounting frame. The whole door assembly can be easily removed by lifting it off these pins. The mounting frame is rigidly attached to the inside of the scavenger box on the furnace frame. The door is opened, closed and clamped by an electric motor driven mechanism - see section 7.2 for details.

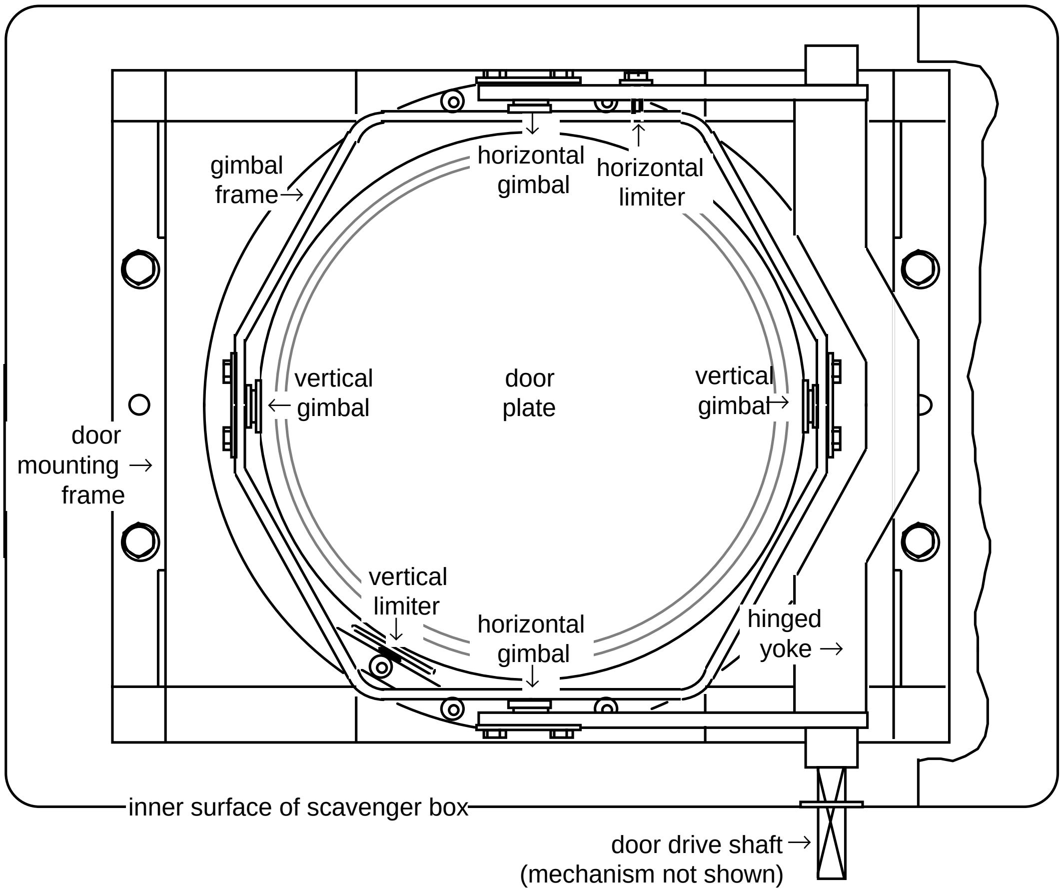
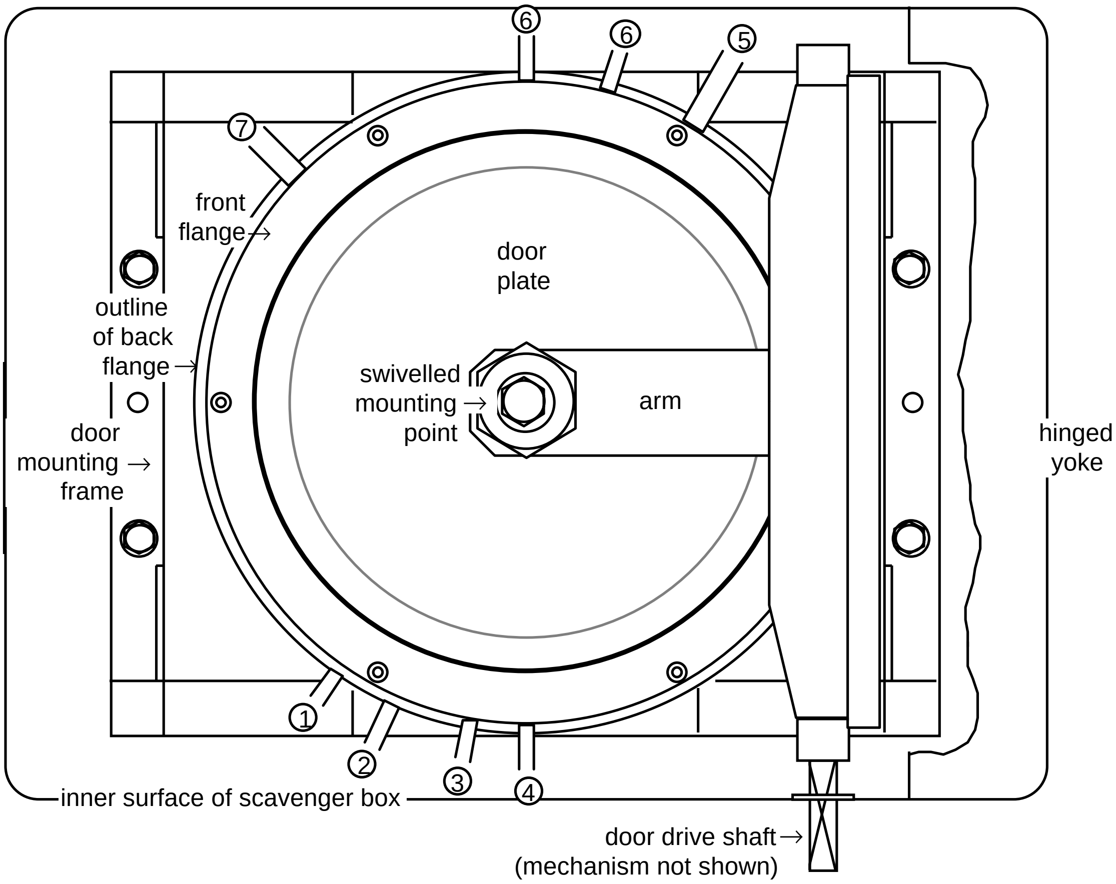


Figure 4-10 Front View of Standard Automatic Diffusion Door

The standard automatic LPCVD door (also used with atmospheric processes involving dangerous gases) is mounted in the scavenger box in the same way as the standard automatic diffusion door. The construction and sealing of the door is, however, completely different. The hinged yoke is T-shaped, and the end of its single arm is attached to the door plate by a swiveled mounting point in the center of the door. This allows limited tilting in all directions. The one-piece stainless steel door plate has a Viton O-ring in a dovetail-shaped, annular groove in its front face. The O-ring closes off the process tube when pressed against the adjacent stainless steel tube flange. The tube flanges may be water-cooled. The front tube flange has openings for source gases and the connection of a pressure gauge. The automatic door mechanism is described in section 7.2.



① back flange - cool water in
② back flange - warm water out
③ front flange - cool water in
④ front flange - warm water out
⑤ TEOS in (option)
⑥ source gas in
⑦ Baratron connection

Figure 4-11 Front View of Standard Automatic LPCVD Door

WARNING The automatic lpcvd door mechanism operates with substantial force. Take care not to obstruct the door in its movement.

4.4.1.1.2 Cantilever Loader Door

This section describes the suspended loading system with its integral door plate, and therefore gives only a short description of the loader. For more details of the suspended loading system, see the Tube Loader System Manual, document no. 2010240.

Functional

The cantilever loader is a non-contact loading/unloading system. The load, consisting of wafers in up to six quartz cassettes (with optional intermediate carrier for BTM) is placed upon two rods or a paddle cantilevered from a carriage unit. A linear drive mechanism then slowly drives the load into the process tube. The cantilever is not supported by the process tube and neither the cantilever nor the boat contacts the process tube wall. Unwanted particles are not generated and the loading/unloading operations are very simple to automate. When the load is in position, the SLS quartz door plate (stainless steel for LPCVD) is firmly pressed against the tube-end by the loader mechanism. This minimizes the escape of process gas and the influx of air and particles. The cantilever in front of the door plate stays inside the tube during processing. After the wafers have been processed, the cantilever loader then withdraws the load from the process tube.

The main differences between the SCL and the SLS are:

- The SLS door plate closes off the tube earlier in the loading stage of the processing cycle.
- The tube, once closed by the SLS door plate, is not as leak-tight.
- Film builds up on the cantilever rods or paddle which must, therefore, be cleaned more often.

Physical

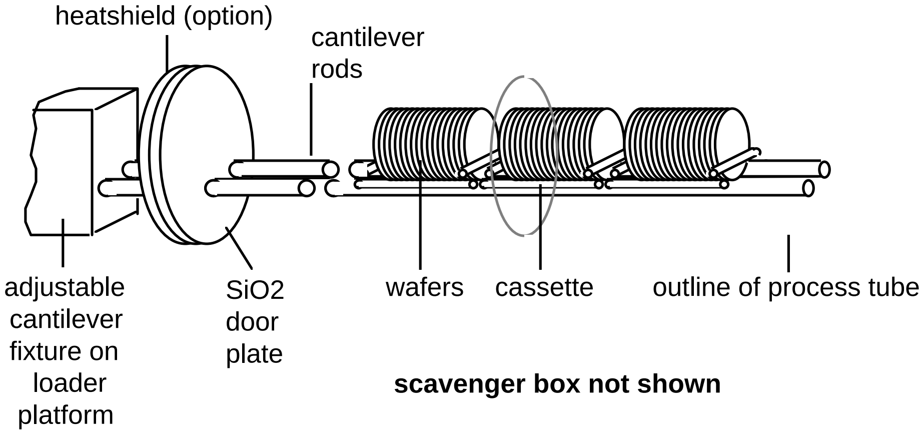


Figure 4-12 Suspended Loading System with Quartz-sheathed Rods

4.4.2 Heating Elements

For replacement procedures see section 8.3.

The heating elements for tubes 1 to 4 are accessed via the panels on the front side of the furnace. Process tubes are fitted with a variety of heating elements for 250 up to 1300°C.

Both ends of each element are mounted in adjustable supports:

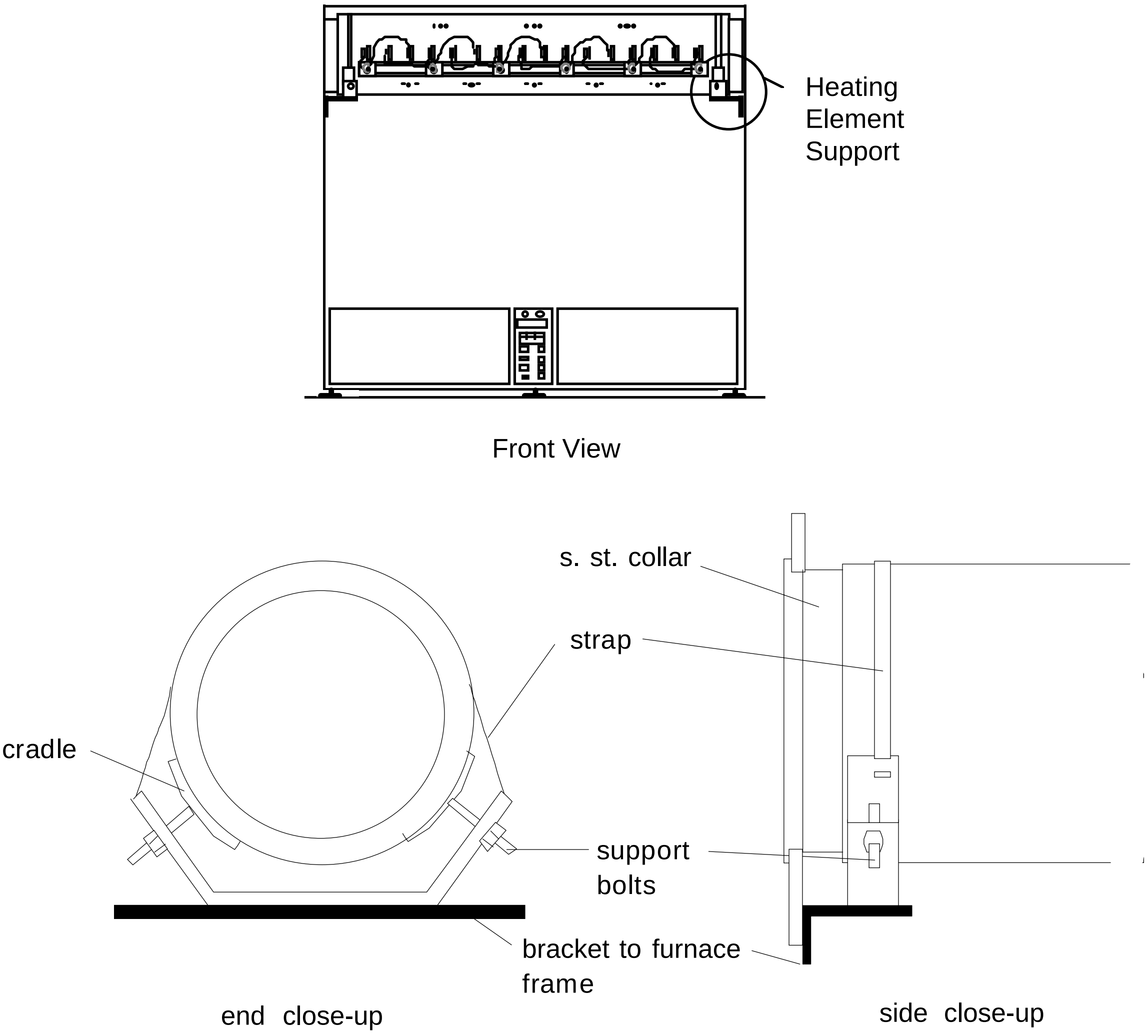


Figure 4-13 Heating Element Supports

A heating element consists of:

- Heating wire coil or shells.
- Power connectors for the heating zones with safety shields.
- Thermal insulation.
- Stainless steel mantle.
- TC holes with ceramic tubes.

Both the insulation and the mantle have holes for power connection and for insertion of spike thermocouples. Fibrothal[1] insulation material was chosen to give good thermal equilibrium and minimum heating power requirements.

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1. "Fibrothal" is a registered trademark of Kanthal GmbH.

WARNING high voltages exist in the heating element area.

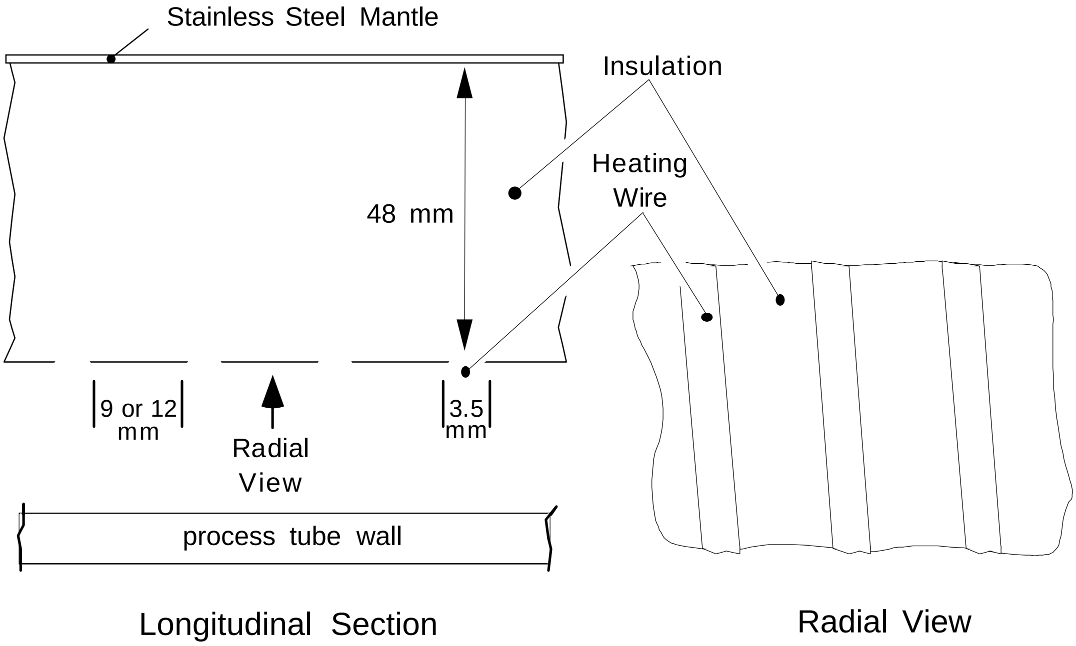


Figure 4-14 Low Temperature Heating Element

4.4.3 Thermocouples

4.4.3.1 Spike Thermocouples

The Furnace DFS-N 250 is fitted with three types of thermocouples (TCs):

- Spike (main) TCs
- Back-up TCs
- Overheat protection TCs

Spike TCs are so called because their ceramic sheath is thin and the hot junction is on top.

TCs are an integral part of the Furnace DFS - N250 and are only replaced when faulty. The zones, 1, 3 and 5 have a combined main and back-up TC in the same ceramic sheath (dual TC). Zones 2 & 4 have only a main TC. A row of three overheat protection TCs are near the top of the heating element (see Figure 4-10 on page 4-29). If the overheat protection TCs sense an overheat condition, power to the element is switched off.

The thermocouple mountings allow adjustment of the position of the sensing end of the TC in relation to the process tube wall; the normal distance is 2 - 4 mm. For replacement and adjustment procedures see section 8.4.

Functional

- Spike (main) TCs measure temperature in all 5 zones.
- Back-up TCs measure temperature in 3 zones: 1, 3 and 5.
- If the difference between main and back-up readings exceeds 10°C, the SATC gives an alarm and switches to the TC with the lowest reading.
- Three overheat protection TCs are used in the overheat protection system. Regions: loader end - zones 1 + 2, center - zone 3, far end - zones 4 + 5.

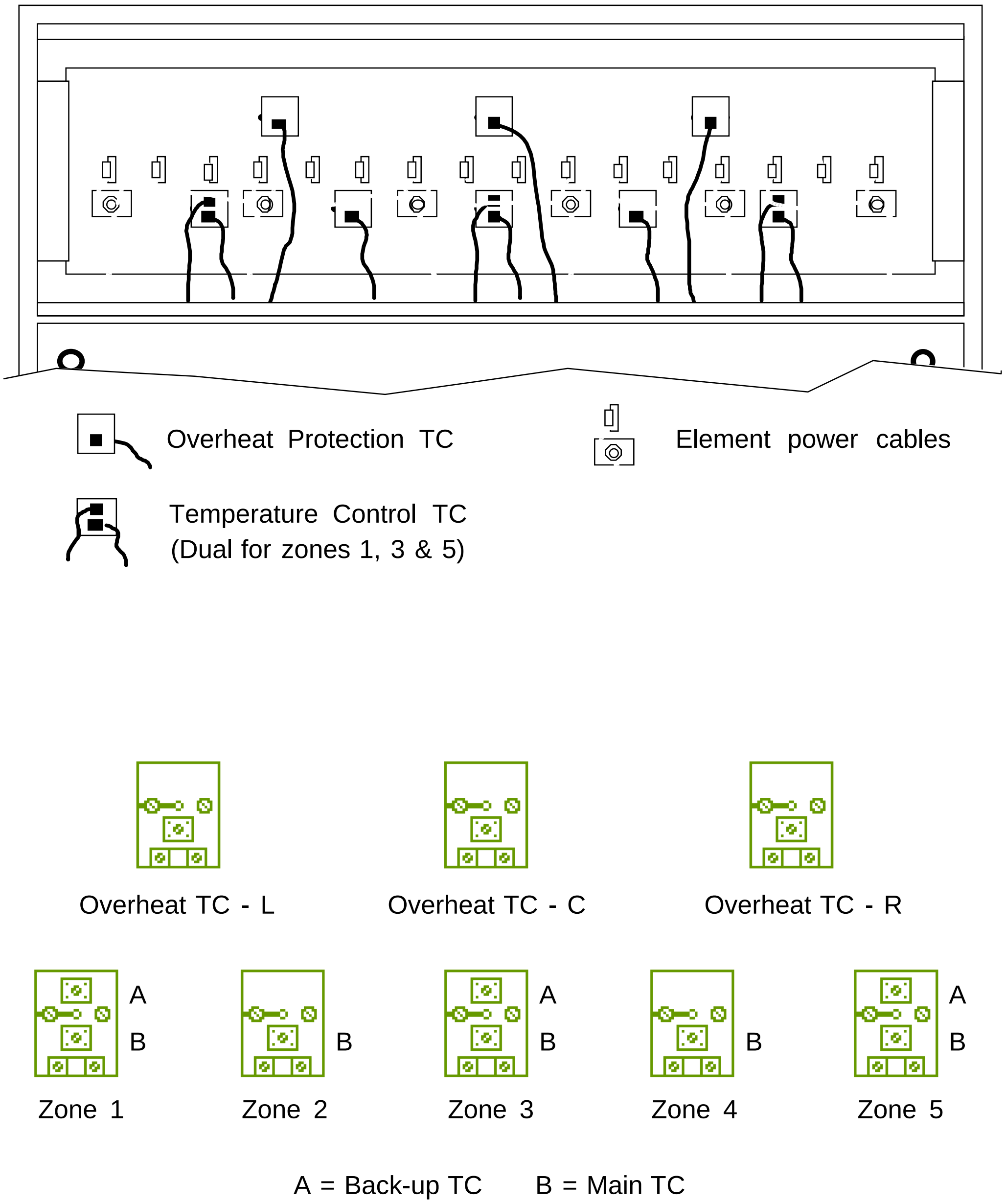
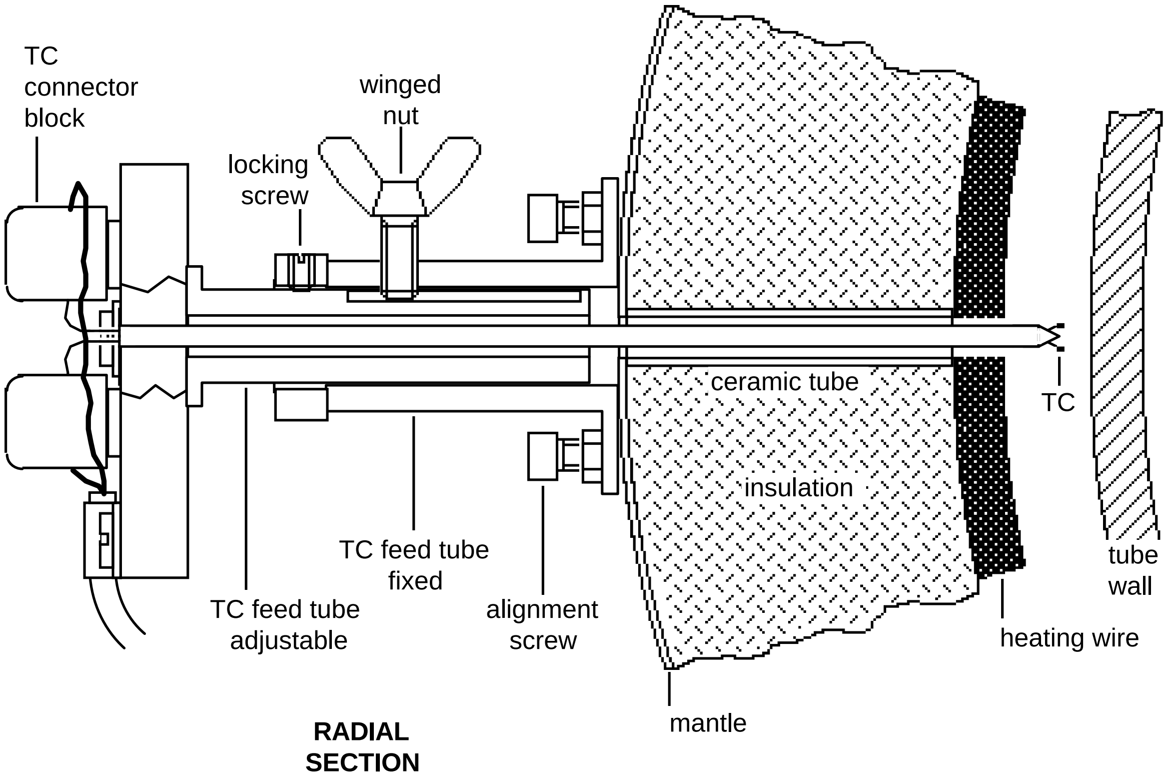


Figure 4-15 Spike Thermocouple Layout (RH System)



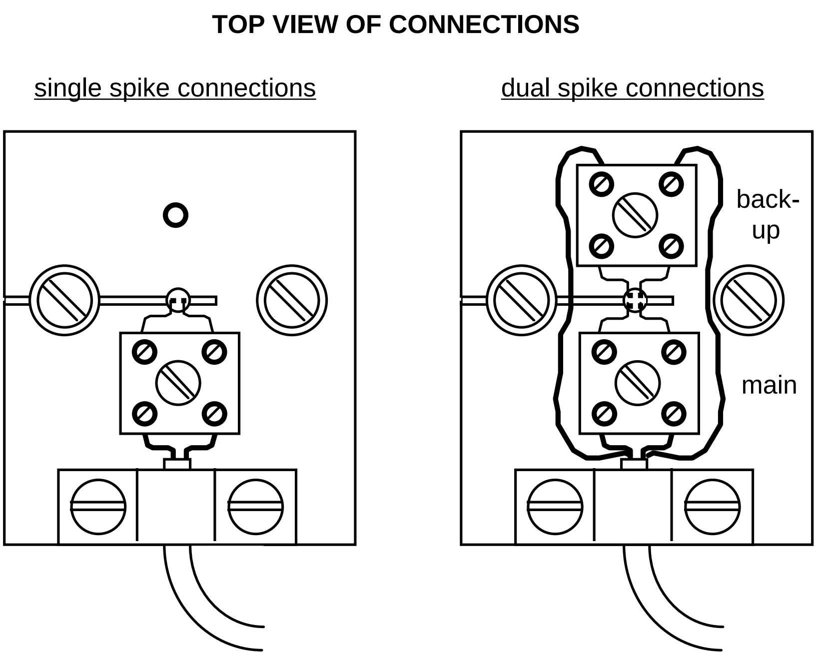


Figure 4-16 Thermocouple Mounting

4.4.3.2 *Calibration Thermocouples*

Calibration thermocouples (TCs) are so named for two reasons. Firstly, these TCs have been tested by the manufacturer at different temperatures, and the readings from the calibration TCs have been compared with the standard for thermocouple output - the IPTS 1968 table. The deviations from the table have been collected and are supplied with the TC in the form of a calibration certificate.

Secondly, calibration TCs are used in the furnace in conjunction with spike TCs to provide accurate temperature control. The calibration TCs, five junctions for a DFS-N 250, are enclosed in a thin quartz tube which is inserted into the furnace at the rear end and lies on the bottom of the process tube. Although the reading obtained is not the actual temperature on the wafer surface, the calibration TCs are closer to the wafers than the spike TCs, and sense changes in in-tube temperature faster than the spike TCs, which are situated just outside the tube, close to the heating element.

There are two temperature regulation methods for the Furnace DF S-N250 - cascade control and spike control. With cascade control, the calibration TCs are used in conjunction with the spike TCs for temperature regulation, so the calibration TCs must always be present in the process tube. For spike control, the calibration TCs are used only for initial profiling of the spike TCs (profiling is a process in which the differences in temperature between the spike TCs and calibration TCs is recorded and saved for a number of different temperatures).

In most Furnace DFS-N 250 configurations, the calibration TC rod is inserted into the process tube from the rear end. If the tube is of the diffusion (ball-joint) type, the calibration TC rod is inserted through the peripheral ball-joint opening provided for this purpose. In LPCVD type tubes, insertion is through a gas-tight Ultratorr connector in the rear-end flange. Calibration TCs are sheathed in a thin quartz tube. The measuring end (with five TCs) is rounded to aid insertion and the handle end is slightly thickened to fit closely in the ball-joint opening or Ultratorr connector. The calibration TC rod has an anodized aluminum alloy handle and a length of flexible cable with a 10-pin plug.

Calibration TCs are used to obtain direct readings of process temperature inside the tube. When in use, the calibration TCs are connected to the CJB by means of 10-hole sockets. These sockets are mounted close to the TC storage tubes (in which the calibration TC is placed when not in use).

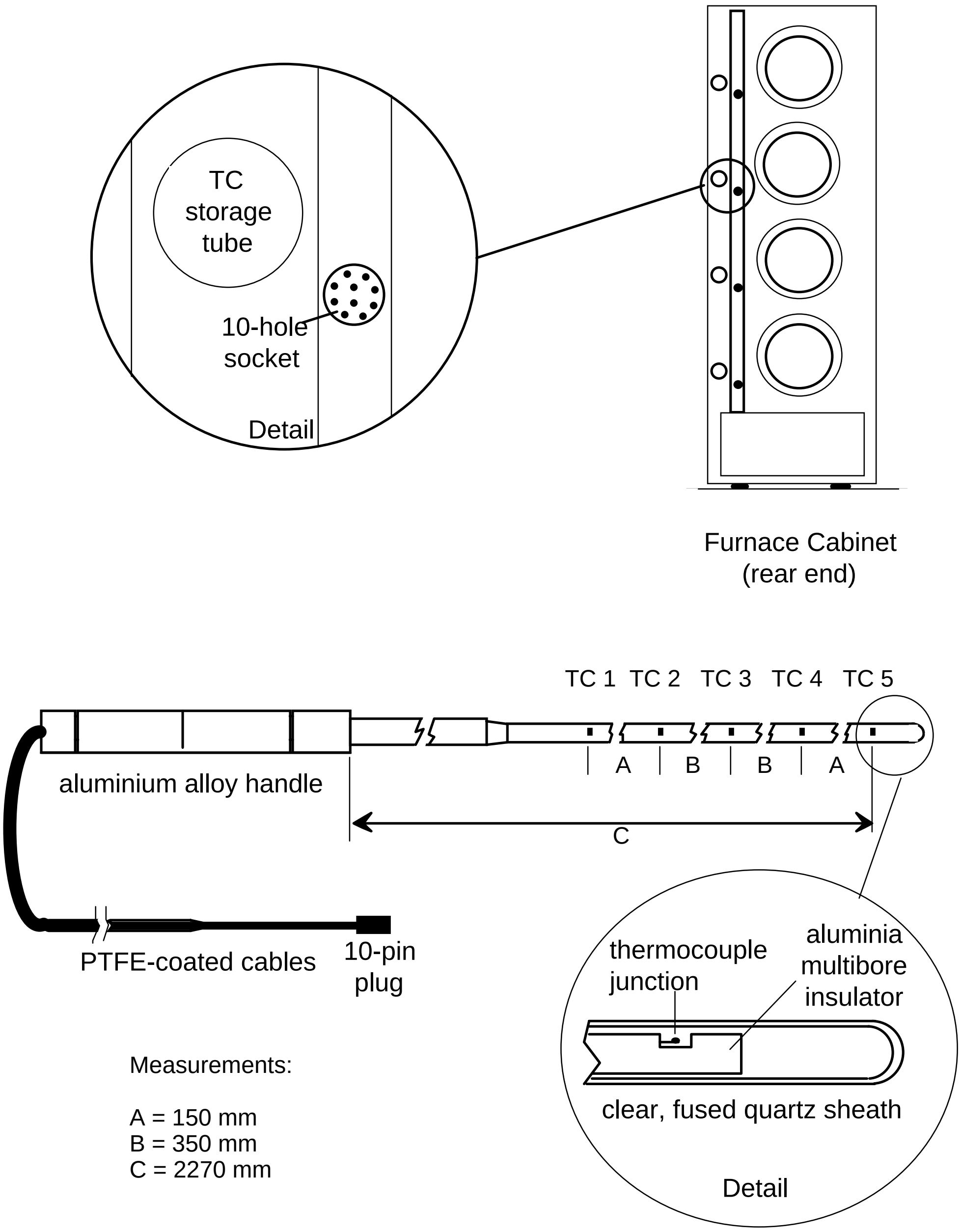
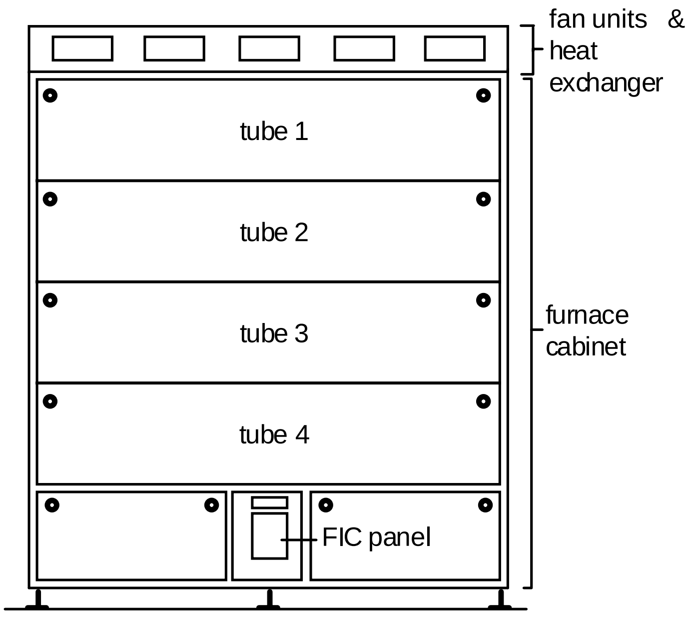


Figure 4-17 Calibration Thermocouples and Connectors

4.5 Fan Units and Heat Exchanger

The Fan Units and Heat Exchanger are in a separate unit mounted on top of the furnace cabinet:



Front

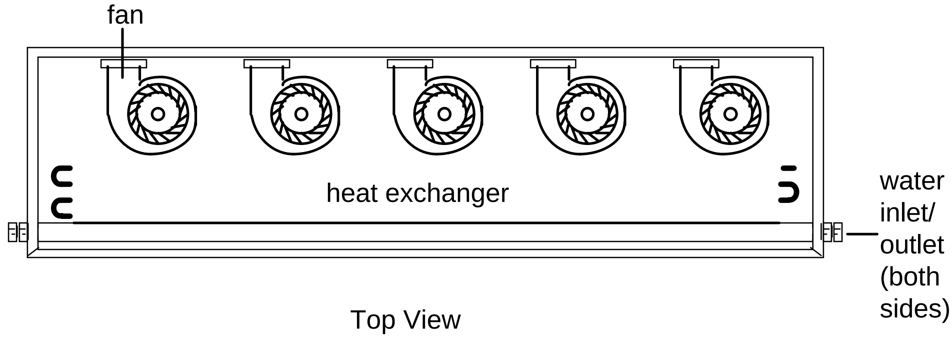
Figure 4-18 Fan Units and Heat Exchanger Location

The unit contains the following components:

- Fans.
- Optional airflow switches (airflow sensors and relays).
- Heat exchanger with mains water connections, drain plugs and air bleed valve.

The unit dimensions, excluding water connections and airflow switches, are:

Width	2100 mm
Depth	800 mm
Height	230 mm



Top View

Figure 4-19 Fan Units and Heat Exchanger

4.5.1 Fan Units

Above the furnace cabinet are five heavy-duty centrifugal fans. The customer may connect an airduct to the exhausts to prevent warm air entering the grey room airspace. Each fan has a plate at the front of the housing with a starting capacitor and motor connections.

The fans draw air up through the furnace cabinet and then into the heat exchanger inlet. A large airflow is needed to keep the mantles cool and to transport waste heat to the heat exchanger.

4.5.2 Heat Exchanger

Physical

The heat exchanger is situated in front of the fan units. It consists of a square array of tubes which are interconnected by U-bends to form one continuous length of tubing running back and forth through a large number of thin, square, metal cooling fins. Mains water running through the tubes extracts heat from the hot air flowing between the cooling fins as it leaves the furnace cabinet.

The heat exchanger is fed with cool mains water from an inlet connection on either the left or right side of the upper section, depending on the configuration of th e System DFS-N250. The left and right water inlet connections are joined by an inlet manifold: an insulated pipe which runs the full length of the upper section, inside the front of the outer casing. The first tube of the heat exchanger is connected to the inlet manifold by an upwardly sloping pipe. A regulator valve, the waterflow switch (optional) and an air bleed valve are mounted, in that order, in this inlet pipe.

Warm water leaves the last tube of the heat exchanger, flows along a second upwardly sloping pipe and into the outlet manifold, which is situated beneath the inlet manifold and joins the left and right water outlet connections. The warm water outlet is normally chosen to be on the same side as the cool water inlet.

A drip pan is situated under the heat exchanger. In the unlikely event of a leak in the tubes in the upper section, this drip pan catches any water and stops it falling into the furnace cabinet. It also catches drops of water which condense on the cooling fins during normal operation. To stop the pan overflowing, the two drain plugs must be connected to appropriate drain tubes by the customer.

Functional

The heat exchanger removes waste heat from the hot air leaving the furnace cabinet. The air is therefore much cooler when it reaches the fan units, and can safely be exhausted into the grey room or, preferably, into a facility airduct.

Note: In a Furnace DFS-N 2 50 with water-cooled tube flanges, the flange-cooling circuit is connected in parallel with the heat exchanger to the same water inlet/outlet connections through the optional waterflow switch.

4.5.3 Flow Switches (optional)

Airflow sensors

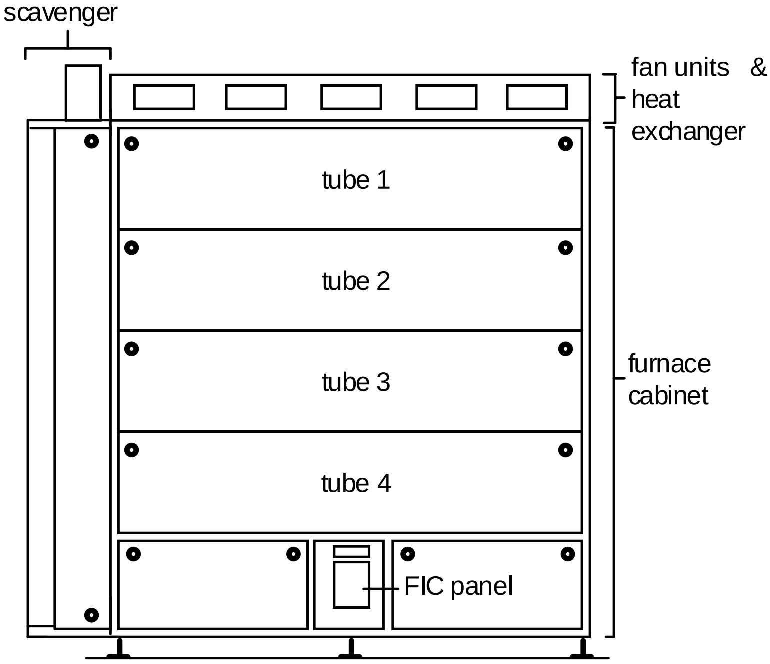
The airflow sensors are arranged in one electrical group. Each sensor is mounted at the left of one of the metal exhaust grills on top of the fan units' housing, so that it can detect air exhaust flow from the fan units. Each sensor signals low airflow to the FIC panel by actuating a small electromagnetic relay. These are mounted on a plate between the motor connections for the first two fan units on the left or right, depending on the Syst em DFS-N250 configuration.

Waterflow switch

The waterflow switch is generally mounted in the outlet pipe on the customer supply side of the furnace (it may optionally be mounted in the outlet pipe connecting the heat exchanger to the inlet manifold). It detects the flow of water around the cooling circuit and signals the FIC panel if the volume flow rate falls below a pre-set level.

4.6 Scavenger

The Scavenger Unit encloses the loading end of the process tube stack:



Front

Figure 4-20 Furnace DF S-N250 (RH) with Scavenger Location

The dimensions of the scavenger unit, viewed from the front of the furnace, are:

Width	350 mm
Depth	800 mm
Height	2336 mm (plus 60 mm ground clearance)

The scavenger consists of a painted steel sub-frame of welded, tubular construction which contains a stainless steel scavenger box around the entrance to each tube. The boxes are connected to a single or divided exhaust duct by two circular apertures. A painted, hinged door at the front of the scavenger gives access to the following components at each tube level:

- Tube flange cooling water tubing and valves (LPCVD processes only).
- Source gas tubing (some LPCVD processes).
- Door mechanisms and associated electrical wiring (LPCVD and some diffusion processes).
- Baratron pressure sensors and associated electrical wiring (LPCVD processes only).
- Overpressure vent tubing, pressure switches and valves located in the bottom of the subframe.

When the furnace is being loaded or unloaded (LPCVD), and at any stage of a process in diffusion tubes (other types of doors), small volumes of gas may escape into the scavenger. A customer-installed fan sucks air and escaped process gases from the scavenger boxes through the exhaust duct. Flow is adjusted by moving the discs in the upper apertures (lighter-than-air gases) and the lower apertures (heavier-than-air gases). A thermal flow sensor is fitted in the exhaust tube (for LPCVD, optional). It is positioned at least one meter from the top of the furnace, otherwise, it will switch when a loader pulls hot wafers out of the furnace. Its digital input signal is relayed directly to the SATC.

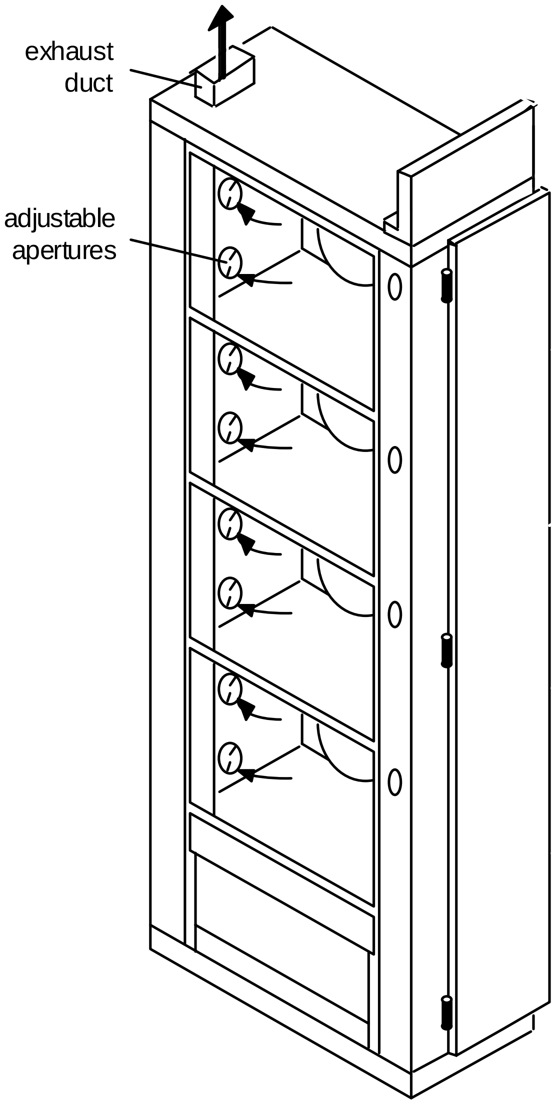


Figure 4-21 Scavenger airflow

4.7 Central Power Box

The Central Power Box is enclosed in a steel cabinet and is mounted at the rear of the furnace on the furnace frame:

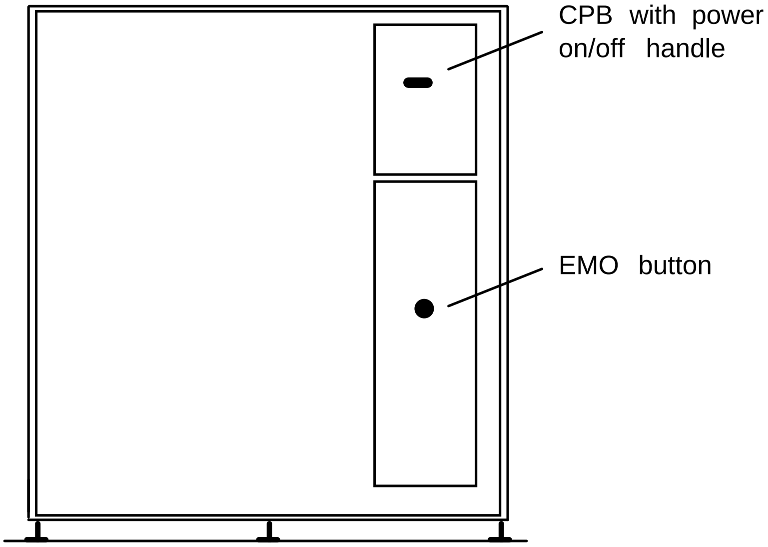


Figure 4-22 Location of Central Power Box (RH System)

Note: For convenience, the Central Power Box may be mounted at a different location.

WARNING The central power box is a top-heavy unit of considerable weight that requires to be securely attached to the furnace frame or to a wall.

The Central Power Box contains the following components :

- Mains inlet terminals
- Mains outlet terminals
- Power unit relays
- Circuit breakers
- High current fuses
- Low current fuses
- 24V control circuit.

The Central Power Box has the following functions:

- Supply of power to power units 1 to 4, to the source, loading and staging sections as well as the system hardware in the operator console.
- Switching and protection of mains power supplies.
- Supply of low voltage power to other electrical components in the Furnace D FS-N250.
- Protection of low voltage power supplies.

Section 5 Temperature Control

5.1 Introduction

This section explains how temperature is controlled in the Syst em DFS-N250. The section is divided as follows:

- Temperature control loop
- Thermocouples
- Cold Junction Box
- SATC temperature control mechanism.

5.2 Temperature Control Loop

The following figure is a diagram of the temperature control loop for one heating zone. It illustrates the link between the separate components of the loop:

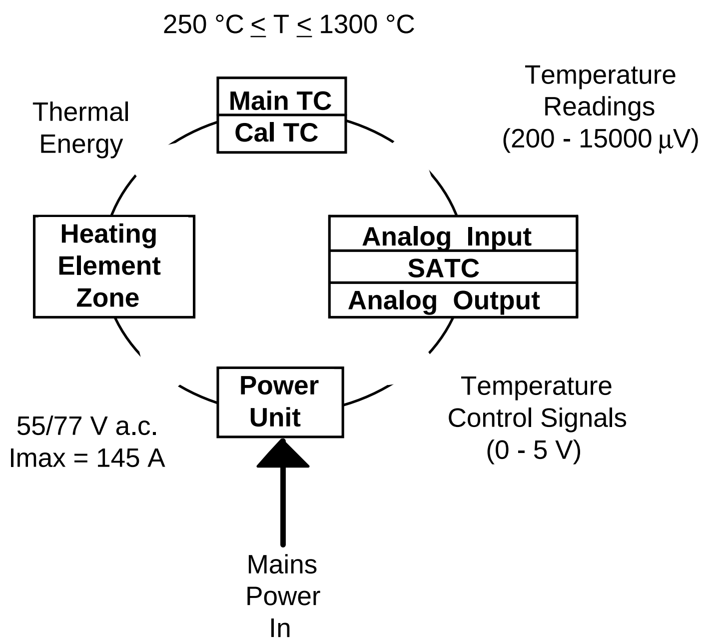


Figure 5-1 Temperature Control Loop (simplified)

- The main thermocouple senses the temperature close to the heating element wire and produces an analog signal in the range 200 to 15 000 mV d.c., which is directly proportional to the temperature.
- The calibration thermocouple senses the temperature inside the tube, beneath the wafer load and produces an analog signal in the range 200 to 15000 mV d.c., which is directly proportional to the temperature.
- The SATC translates these signals into temperatures and calculates the power required either to maintain this temperature or raise or lower it to the required temperature. The calculation performed by the cascade controller is digital and is based on an algorithm that uses empirical system parameters.
- The result of this calculation is an analog signal in the range 0 to 5 V d.c., which is fed to the thyristor control unit. This unit provides the power to the element zones.
- The heating element zone radiates a quantity of thermal energy, and so the loop is closed.

The following diagram shows the temperature control loop for all five heating zones for one tube. The functions of the component systems of this loop are described in the remainder of this section.

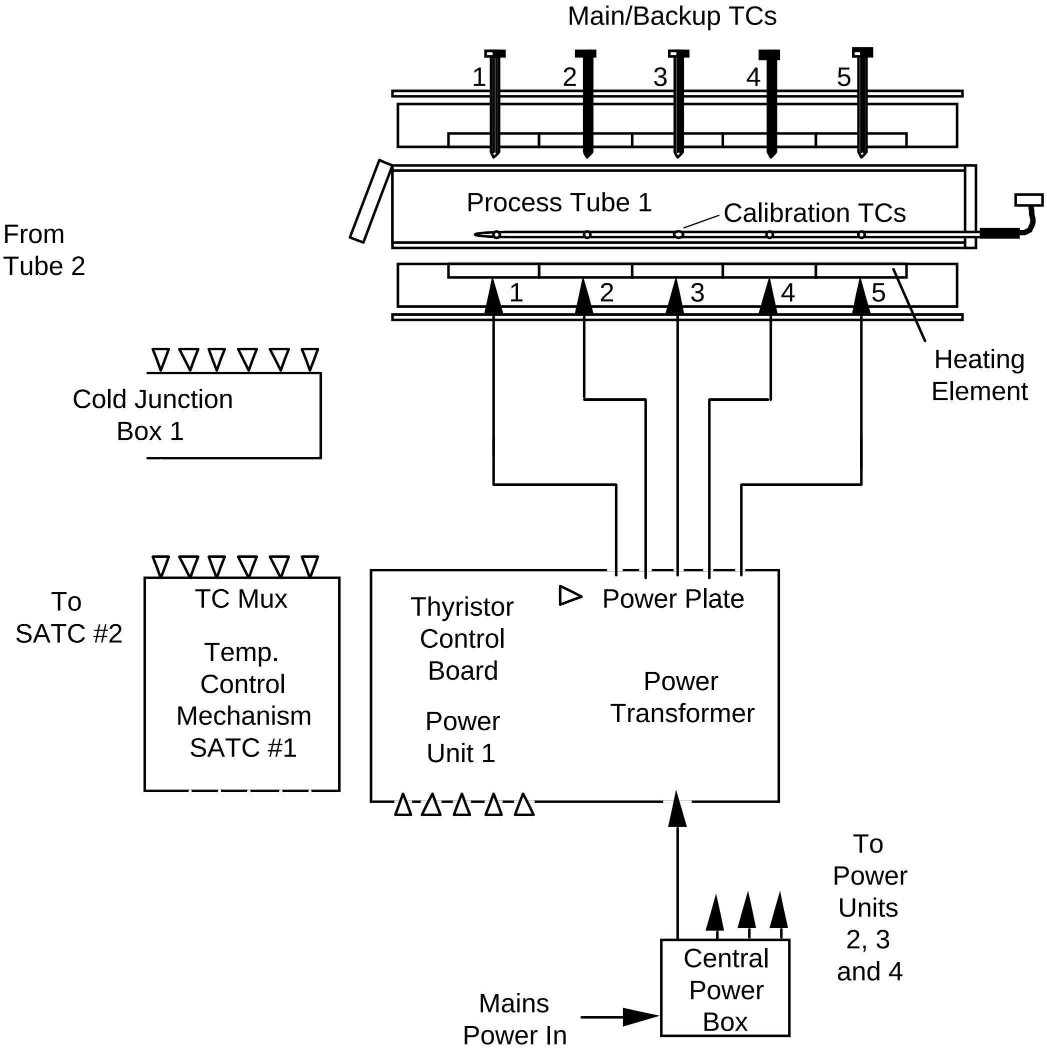


Figure 5-2 Temperature Control Loop

5.3 Spike Thermocouples

5.3.1 Introduction

The following figure shows how the spike TC wires are enclosed in a ceramic casing and are joined at one end to form a temperature sensor. In this case the TC is the dual type, and, therefore, has two junctions, with two positive wires and two negative wires:

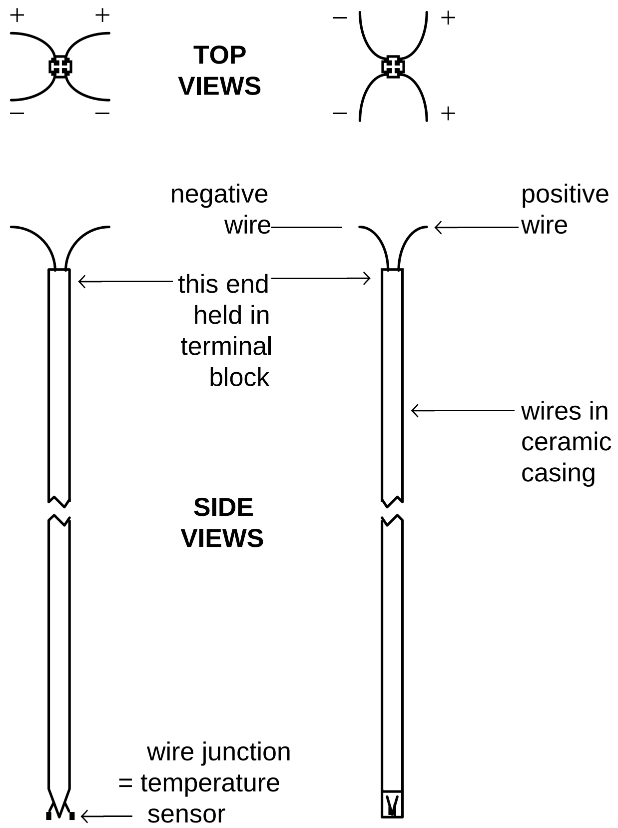


Figure 5-3 Dual Spike T

A thermocouple (see figure 5-4) consists of two conductors, C1 and C2, of material with different thermo-electrical characteristics. An S-type TC (the type most commonly used in the Furnace DFS-N 2 50), for example, has a positive wire of platinum/10% rhodium alloy (C1) and a negative wire of pure platinum (C2). C1 and C2 are joined at one end to form a sensing junction, at temperature T1. In the Furnace DFS - N250, the sensing junctions of the spike TCs are about 4 mm from the process tube wall.

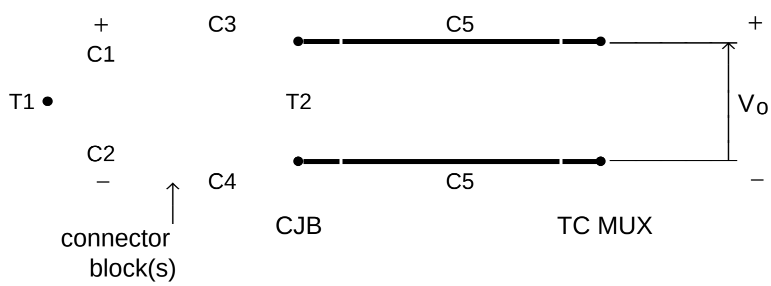


Figure 5-4 Thermocouple

The free ends of the spike TC wires, C1 and C2, are joined with connector block(s) to the extension (or compensation) wires, C3 and C4. The extension wires connect the TC to the reference block of the cold junction box (CJB), which is kept at a constant temperature, T2, of

50°C. The comparatively long distance from the TC connector block(s) to the CJB makes it too expensive to use platinum/ 10%rhodium and pure platinum. Instead, the positive extension wire (C3) is copper and the negative extension wire (C4) is copper/nickel alloy. These materials are less expensive, but have almost the same thermo-electric properties as the TC wires. (Copper and copper/nickel alloy cannot be used for C1 and C2 because they are not suitable for use at temperatures above 150°C).

If there is a temperature difference between the sensing junction and the cold junction, T1 - T2, a thermo-electric voltage, V_o, is produced across the open ends of C3 and C4. This voltage can be translated into the temperature difference between the two junctions by using the standard temperature-voltage characteristics of the type of TC used, the **IPTS-68 table**, which is stored in the SATC. From the CJB, the TC is connected to the analog inputs of the SATC's TC MUX (**T**hermo**C**ouple **MU**ltiple**X**er) board with two ordinary copper wires (C5), because the thermo-electric characteristic of these lengths of wire are not important.

The analog temperature signals from the TCs in the five heating element zones are in the range 200-15000 mV. In the SATC they are multiplexed and then converted to 14-bit digital signals. The temperature control mechanism translates these digital signal into temperatures in °C by referring to the IPTS-68 table.

5.3.2 Types

Normally only one type of thermocouple is used in the furnace DFS - N250:

- S-type:positive 90% platinum/10 % rhodium negative 100% platinum

This type of thermocouple is suitable for temperature ranges from 250°C to 1300°C (approximate). It is important that at each tube level, all main, back-up and calibration TCs must be of the same type, because the main and back-up TCs use the same spike TC correction table and all TCs use the same IPTS-68 table.

5.3.3 Main Thermocouples

The main TCs are used for temperature measurement in all 5 heating element zones at each tube level. Their signals are sent via the CJBs to the SATC's TC MUX board at each tube level.

5.3.4 Back-up Thermocouples

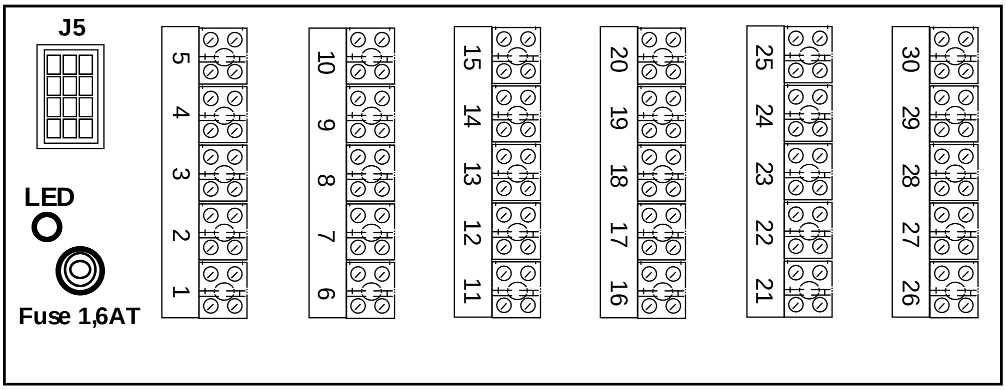
The back-up TCs are only used for temperature control if a fault occurs in the main TC for that zone. Their signals are also sent via the CJBs to the SATC's TC MUX board. The positions of the back-up TCs are shown in figure 4-15 “Spike Thermocouple Layout (RH Sy s tem)” on page34.

The SATC temperature control mechanism constantly monitors the readings of both the main and back-up TCs in each zone. The readings are compared and if the difference is greater than 10°C a visual and audible alarm is given at the operator console and control is immediately and automatically maintained by switching over to the TC giving the lower reading.

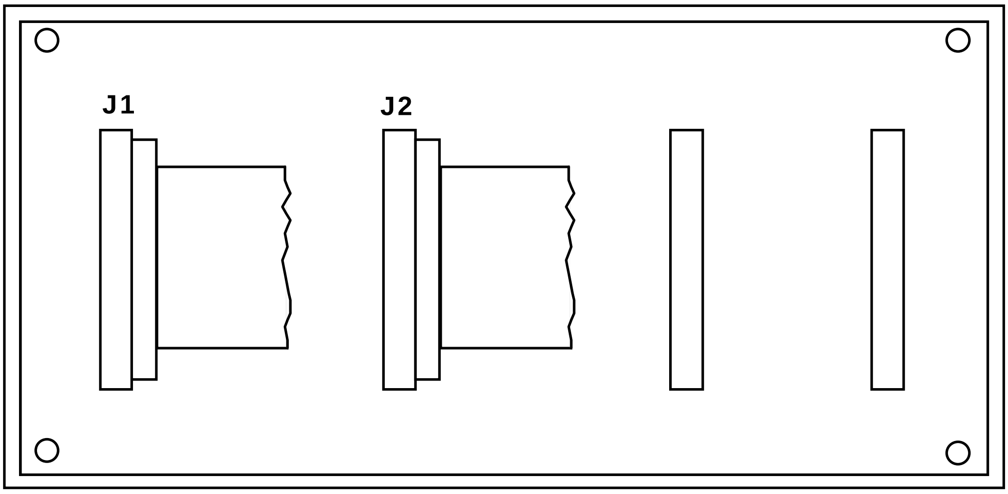
IMPORTANT: Faulty TCs must be replaced as soon as possible.

5.4 Cold Junction Boxes

5.4.1 Connectors



Top View



Front View

Figure 5-5 CJB Connectors

The CJBs provide accurate 50°C references for all TCs except the overheat protection TCs (do not require such a high degree of accuracy). CJB 1 serves tubes 1 and 2, CJB 2 serves tubes 3 and 4 (see section 4.3.2). The signals from the main, back-up and calibration TCs enter the CJBs via the screw-connector blocks 1 to 30 on the top of each CJB. The output signals leave the CJBs for the TC MUX board of the appropriate SATC via connectors J1 and J2.

Connector J5 is the output for CJB status signals to the appropriate SATC. It is also the input for the power supply, which is protected by the 1.6AT cartridge fuse. The LED on the top of a CJB lights up when the heater inside the CJB switches on to supply heat to maintain a constant reference temperature, and goes out when the heater switches off. During normal operation the LED blinks once every six seconds.

5.4.2 Heater Controller

The reference junctions of all the TCs connected to the CJB are buried in a brass temperature reference block, which is supported in the space in the middle of the CJB and is surrounded by polystyrene beads to give good thermal insulation.

IMPORTANT: CJBs must never be opened in the gray room, as the polystyrene beads will spill out and cause serious contamination. Always remove the CJBs in one piece and open them in an unclassified work area.

The temperature in the reference block is kept at 50°C ±0.2°C by a 24V AC heating element. If the temperature falls below 49.8°C, the block is heated; if the temperature rises above 50.2°C, the heater switches off. The LED on top of the box lights when the heater is ON. If the temperature rises to above 55°C, a bi-metalic switch opens and cuts power to the heater.

The temperature in the CJB is kept constant by the heater controller: shown in CJB Heater Controller.

CJB temperature is detected by a solid-state transducer. Its output is compared with an accurate temperature-stable reference voltage source (a heated Zener diode in an insulated enclosure), from which the temperature setpoint is calibrated with a potentiometer. The error signal is input to the proportional and to the integral control amplifier. The output from these amplifiers is compared with a saw-tooth wave whose magnitude gives the proportional band. If the output of the control amplifiers is always higher than the saw-tooth, the reference is too hot and no power flows to the heating element. If the output is always lower than the saw-tooth, the reference is too cold and the heater is switched on. In between, the temperature is in the proportional band. In each cycle, power is turned on when the positive-slope portion of the saw-tooth crosses the amplifier output and is turned off when the negative sloping portion crosses again.

The comparator works as a switch, and its output fires a triac with two opto-couplers. The window comparator compares the magnitude of the error with a fixed setpoint and switches the relay for CJB status signals to the SATC.

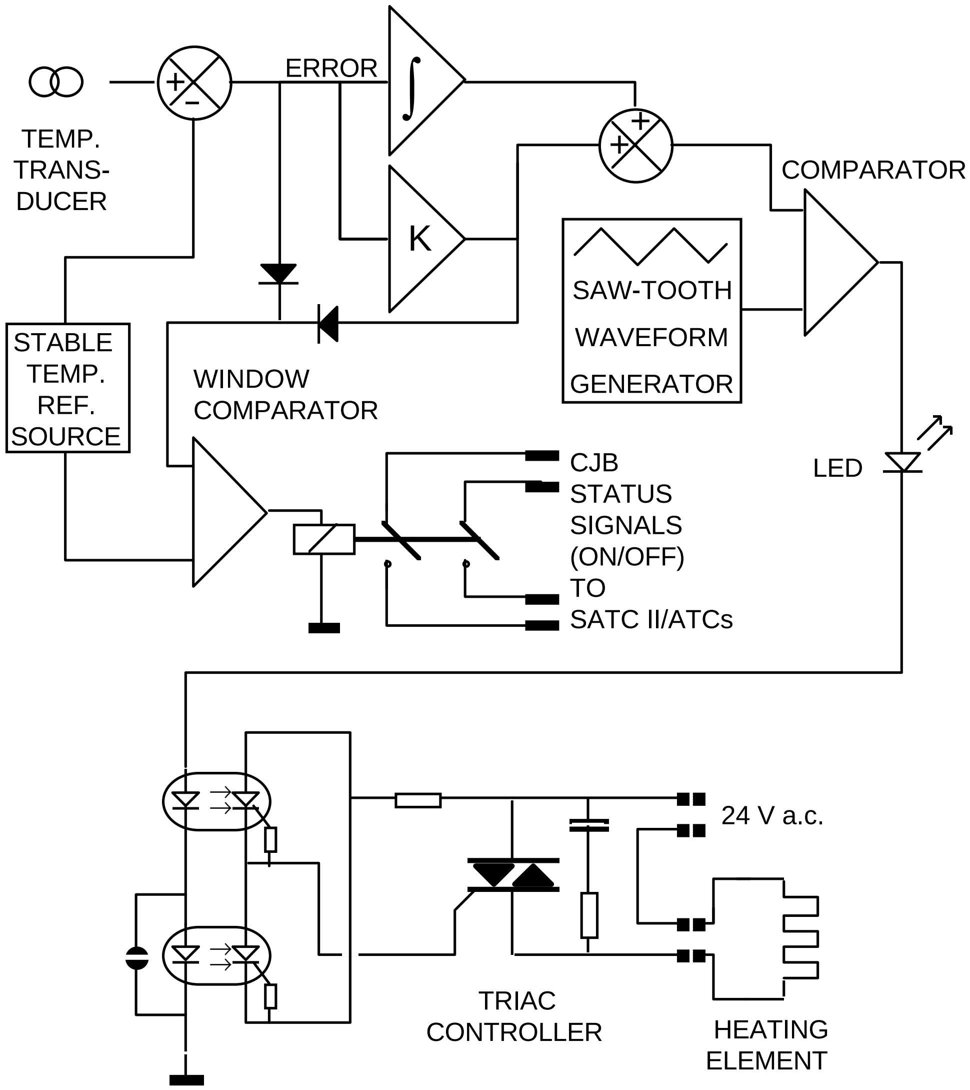


Figure 5-6 CJB Heater Controller

5.5 SATC Temperature Control Mechanism

In the Furnace DFS-N 2 50, temperature control is carried out by the tube controller: the SATC. The SATC is commanded to maintain the temperature specified in the recipe step. This will involve either heating up the process tube by applying full or partial power to reach or maintain the temperature (there is always heat loss), or letting the process tube cool by not heating up (the cooling air cools it down).

The SATC calculates the power (as a percentage) that is required for each zone by reading the current temperature (from the thermocouples), finding the error between the actual and desired temperature and applying a power supply algorithm which is PID-based. PID stands for Proportional, Integral, Differential, and represents three correction factors to provide good thermal performance.

The proportional action or correction is one which gives an output that is proportional to the error. The higher the error, the more response needed to correct it. The integral action is one that reacts to the duration of the error, and is useful for dealing with steady-state errors, like heat loss. The differential action or correction deals with the rate of change of the error and generally improves the speed of the response to temporary disturbances.

When the SATC has applied the algorithm to find the required power percentage (0 - 5V), it passes it on to the power unit. The power unit switches the power directly to the heating element zones.

The power calculation is carried out by the SATC continuously for all main thermocouples and all zones. Also, each thermocouple is sampled six times, and an average from the middle four values taken for each power calculation.

Two types of temperature control are available for the Furnace DFS-N250: spike control and cascade control.

5.5.1 Spike Control

The spike controller uses a PID-based control algorithm that uses the input from the main (spike) TCs to regulate the output to the power units. Because the main TCs are closer to the element than the wafers, they do not provide an accurate reflection of the actual tube temperature. The measured temperatures have to be converted to process temperatures by the entries in the ‘Spike TC corrections table’. The spike corrections table must be generated during a profiling run - a run in which at certain temperatures, the difference between the reading from a calibration TC (present in the tube) and the reading from the main TC is recorded.

The spike controller requires a number of tables:

IPTS-68 Table - gives, for a series of temperatures in °C, the output (mV) of the TC type used at that tube level. The values are taken from the TCs' theoretical temperature-voltage characteristic. During normal operation and profiling, this table is used to convert the digitized outputs (mV) of the main and back-up TCs and the calibration TCs (if connected) into uncorrected temperatures in °C.

PID Constants Table - contains constants which are applied to the PID algorithm. These constants describe the thermal behaviour of a particular process tube and, therefore, supply the customizing factors to the calculation.

Calibration TC Deviations Table - unique to each calibration TC, it contains manufacturer's data on the difference between the measured TC output and the values in the IPTS-68 table.

Spike TC Corrections Table - unique to each process configuration, contains the correction values the spike controller must apply to the main TC readings to obtain the in-tube temperature.

5.5.2 Cascade Control

One major difference between spike and cascade temperature control is that cascade uses both the main TC inputs and the calibration TC inputs for temperature measurement. But why both, why not just the calibration TC? Both types of TC inputs have their advantages and disadvantages: the main TC, being close to the heating element can sense changes in heating element temperature very quickly, but is slower to detect changes in the in-tube temperature. The calibration TC on the other hand gives an accurate record of what is happening in the process tube, but is slow to detect heat transfer changes. If just the calibration TC were used in temperature control, there would be large temperature overshoots. The ideal situation is to use both TC types, which is the case with cascade control.

The cascade controller incorporates:

- A flat zone controller that ensures that the zones maintain the same temperature during ramp-up and ramp-down.
- A setpoint generator that creates artificially high setpoints to trigger the controller into responding very quickly. This generator works dynamically - its output changes as the tube temperature nears the setpoint temperature.

Like the spike controller, the cascade controller uses a PID algorithm but applies it differently. In normal operation, the cascade controller runs in cascade control mode - using both the main and calibration TCs. In the event of a calibration thermocouple failure, however, the controller can switch to spike mode for the affected zone - a mode in which the PID algorithm is used in the same way as with the spike controller.

The cascade controller uses the following tables:

IPTS-68 Table - gives, for a series of temperatures in °C, the output (mV) of the TC type used at that tube level. The values are taken from the TCs' theoretical temperature-voltage characteristic. During normal operation and profiling, this table is used to convert the digitized outputs (mV) of the main and back-up TCs and the calibration TCs (if connected) into uncorrected temperatures in °C.

Profile Table - this table incorporates the spike control profiling table and the spike TC corrections table. When used to determine how profiling is to be carried out, it is called the profile table. After the results of the run have been recorded in the table, it is known as the profiling results table.

Calibration TC Deviations Table - unique to each calibration TC, it contains manufacturer's data on the difference between the measured TC output and the values in the IPTS-68 table.

The cascade controller does not need a PID Constants Table, because part of the thermal characteristics of the furnace are built into the controller and part of the characteristics are determined dynamically, as the furnace is working.

5.5.2.1 Cascade Control Safety Mechanisms

If a TC fails, the cascade controller must continue to function accurately for the remainder of the process time. Two different failures are possible:

1. Cascade control, spike TC failure.

If a main TC fails, the system switches to the back-up TC.

2. Cascade control, calibration TC failure.

The cascade controller switches to the spike PID control mode for the affected zone(s), and the flat-zone controller - if active - is switched off.

A summary of the possibilities is shown in figure 5-7.

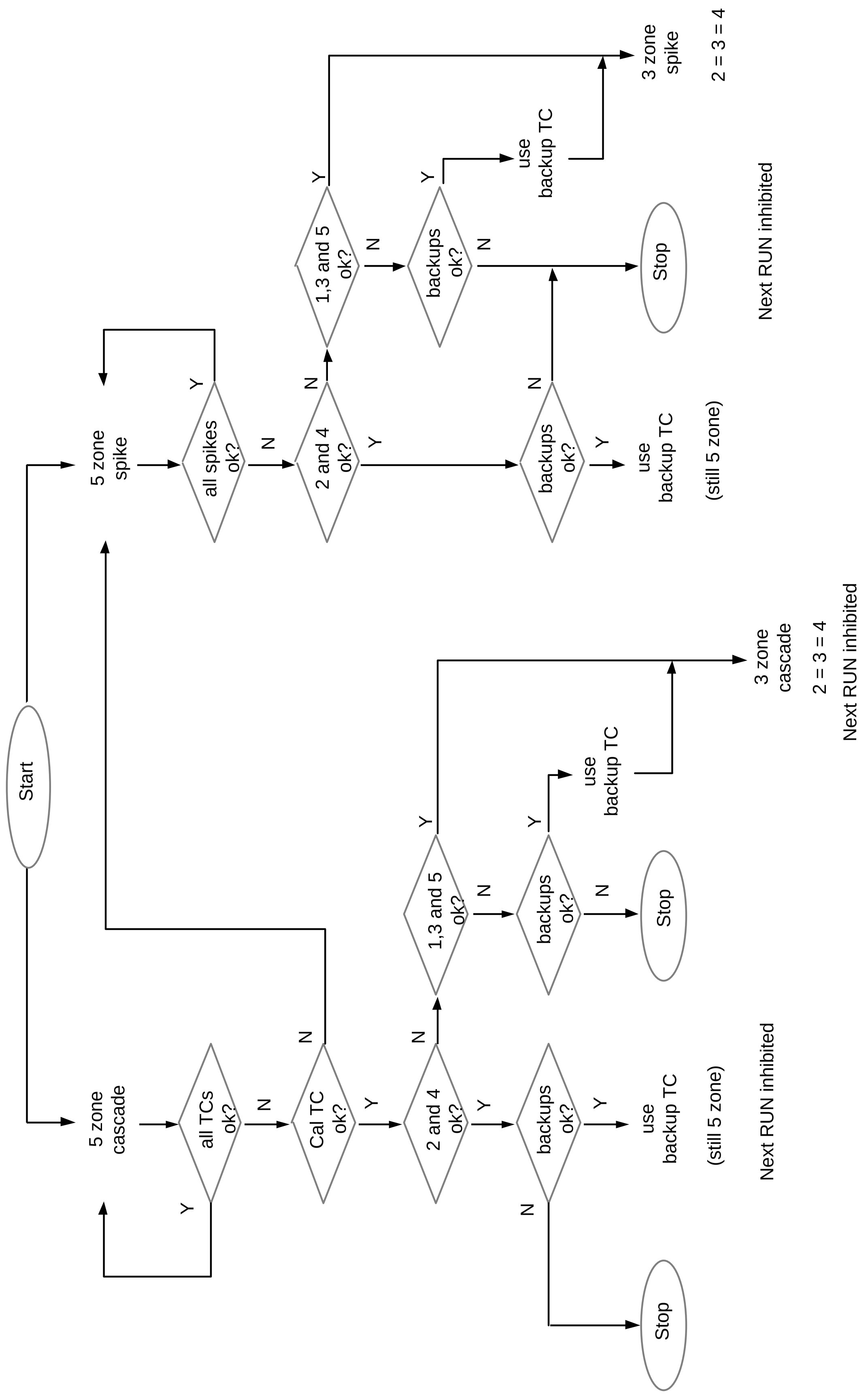


Figure 5-7 Cascade Control Fallback

Section 6 Profiling: Cascade Control

6.1 Introduction

Profiling is required to ensure that the temperatures you specify in a recipe are accurately maintained under all process conditions. During profiling, the system establishes the parameters needed for excellent flat zone control and optimum thermal performance and records them in a table.

The profiling procedure consists of running a recipe with a number of profile steps. In these steps, the tube controller will establish the conditions you specify (temperature, pressure and gas flow) and then stay in the step until the cascade controller adjusts its parameters to maintain temperature to within your required accuracy. At the end of the run, you will be presented with the results of the run in the form of a profiling results table.

Unlike other temperature control systems which require profiling at regular intervals, the cascade controller can keep its parameters up-to-date by profiling in the background during a normal production run. This means that profile results are very accurate because the profiling is done under actual process conditions, with a wafer load and process gases. It also means that the furnace does not have to be out of service (downtime) for profiling.

6.2 When Should You Profile?

Although the cascade controller will profile during each production run, there are circumstances when a profiling run is advisable. These are when:

- The tube controller displays a message that advises re-profiling for one or more zones.
- A tube is replaced.
- A TC is replaced.
- There is a change in process conditions (change in temperature, gas flow, wafer load size, boat, etc.).
- There is a change in furnace conditions (cooling, covers, etc.).
- TCs become inaccurate due to aging.
- A tube liner is replaced.
- Six months of normal operation have passed (more frequently at higher temperatures).

6.3 Profiling Procedure

The profiling sequence for the cascade controller is as follows:

1. Edit and load a Calibration TC Deviations Table.
2. Install a calibration TC rod (if required).
3. Edit and load a profiling recipe.
4. Edit and load a profile table.
5. Run the recipe.
6. Store the profiling results.

6.3.1 Edit and Load a Calibration TC Deviations Table

The Calibration TC Deviations Table must contain the difference (deviation) between the output of the TC for a given temperature and the ideal output as specified in the IPTS-68 table. The output must be specified in °C, and not in uV.

If you already have a table that is filled in correctly, you do not need to edit it for each calibration run.

The Temperatures You Should Specify

You should enter the deviations (offsets) for the temperatures at which you want to profile. There are only 10 possible entries, so choose the process-critical temperatures including at least the temperature of the process step. Because the SATC interpolates between temperatures during profiling, it is a good idea to have a spread of temperatures with a concentration around the process temperature. For example, if the process temperature is the range 850 to 1000°C, it might be best to select profiling values at 350°C, 650°C and then every 25°C from 825°C to 1000°C.

Interpreting the Calibration Certificate to Determine the Deviation in °C

Each calibration TC rod is supplied with a manufacturer's list (calibration certificate) of its measured deviations from the ideal voltage-temperature curve (represented numerically in the IPTS-68 table).

Most TC manufacturers (with the exception of the USA) supply correction values in mV for a series of temperatures.

The easiest way to obtain the °C deviation is to:

- Take the absolute output of a TC at a given temperature, for example, at 700°C the zone 1 calibration TC gives an output of 6281.9mV.
- Look up the value of 6281.9mV in the IPTS-68 table to find the corresponding temperature - in our example, 701°C.
- The deviation for 700°C is therefore -1°C.

Before calibrating, check that the values in the deviation table are appropriate and relevant to the calibration TC rod installed, or the SATC will record profiling results with built-in inaccuracies. If the calibration TC rod is changed, the old deviations (if any) must first be replaced with the new ones.

6.3.2 Install a Calibration TC Rod

In most cases, the calibration TC rod will always be present in the process tube because it is needed for cascade control. If, however, you need to install a calibration TC rod, follow the procedure below.

The calibration TC rod is inserted into the process tube from the rear end. In diffusion tubes, the calibration TC rod is inserted through the peripheral ball-joint opening provided for this purpose (see section 4.4.1 - Process tubes). In LPCVD tubes, the calibration TC rod is inserted through a gas-tight Ultratorr connector (the middle one - the two outside connectors are for injectors) in the rear-end front flange.

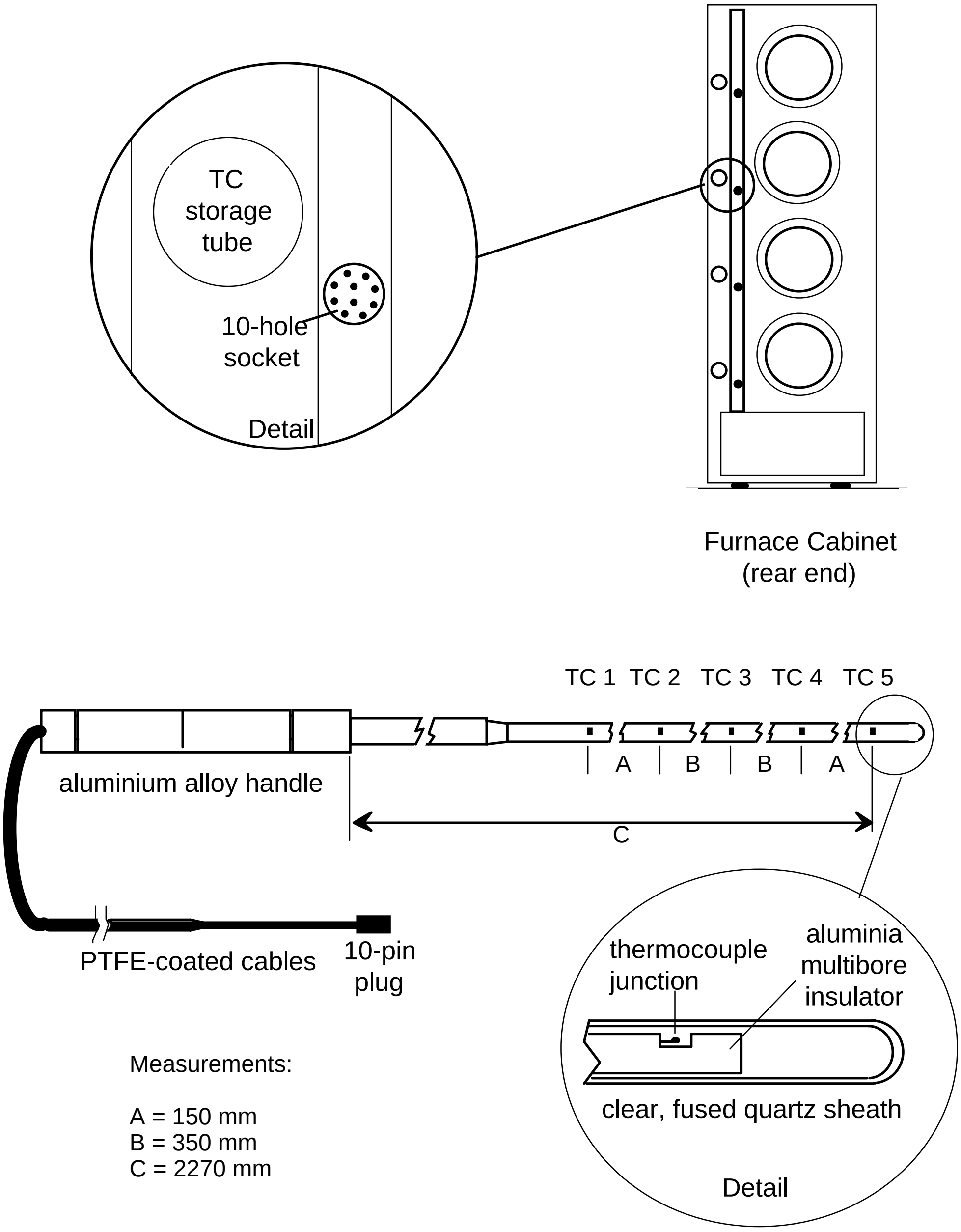


Figure 6-1 Calibration Thermocouples and Connectors

1. Remove the calibration TC from its storage tube, next to the rear-end of the process tube to be profiled.

Note: **IMPORTANT**: To avoid cross-tube contamination, use each calibration tc rod only in its dedicated process tube.

Note: For LPCVD tubes, always leave an Ultratorr connector and O-ring on the handle end of the calibration TC rod. Do not slide it down the (hot) calibration TC rod.

2. Insert the calibration TC rod the correct distance into the tube. The method for doing this is explained below. Figure 6-2 shows the distances.

   a. Measure the distance X from the center zone spike TC to the outside of the flange.

   b. Measure the distance Y from the TC in the center zone of the calibration TC rod to the beginning of the handle.

   c. Calculate the distance Z (Y minus X) and insert the calibration TC rod distance Z.

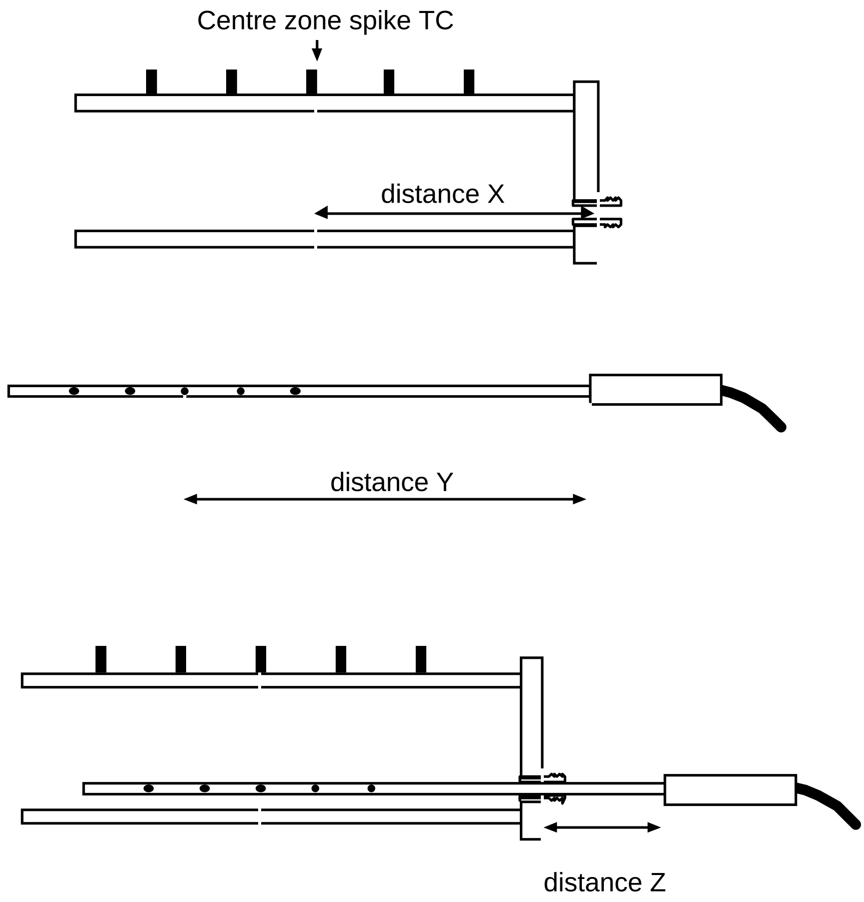


Figure 6-2 Aligning the Calibration TC Rod

IMPORTANT:The calibration TC rod must be aligned accurately, within 1 - 2 mm, to provide proper and accurate temperature control.

3. Connect the 10-pin plug on the end of the calibration TC rod into the matching socket close to the calibration TC storage tube.

6.3.3 Edit and Load a Profiling Recipe

6.3.3.1 Introduction

A profiling recipe is the name given to a recipe that is specially created for profiling purposes. You may profile with a standard production recipe, but you may not want to use process gases and the run-time may be unnecessarily long.

In the profiling recipe, you should create the steps that will be critical for temperature during a production recipe run and where an accurate flat zone is required. In these steps, the cascade controller will optimize temperature performance and will create an entry in the ‘profiling table’ so that it will be able to repeat the control accurac each subsequent run.

The profiling recipe should consist of a number of steps. One step is required for each temperature. So, for example, if you want to profile at 600°C, 625°C, 700°C and 575°C you will need at least six steps (including reset and end). You will also need some ramp steps in between the profiling steps and a few heat stabilization steps. To speed up load and unload temperature recovery times, you should also profile at load and unload temperatures. It is important to profile in those steps where temperature reproducibility and fast temperature recovery is essential.

To achieve very accurate control, you should establish “process conditions” during a profiling step - it is advisable to run N_2 at the same flow as the process gasses, to have the boat in the tube and loaded with wafers, to pump down to process pressure, and for oxidation systems, to have the torch burning. In fact, any parameter that will affect temperature performance.

During profiling, the cascade controller reads the temperatures from the spike and calibration TCs and optimizes its control parameters for the selected temperature and conditions. When profiling for one step is successful (that is, within the required accuracy for a given ‘stable’ time), the cascade controller will calculate an entry for the profiled temperature in the ‘profile’ table. This entry is used in subsequent runs.

What if, during a production run, the cascade controller is at a temperature for which no entry exists in the profile table, such as during a temperature ramp? The cascade controller interpolates, or takes an average, between the temperature it must achieve and the next lowest and highest profiled temperature. If there is no lower temperature, it interpolates to 0°C, where the correction factor is 0; if there is no higher temperature, it interpolates to 2000°C where the correction factor is also 0. It is therefore necessary, in addition to profiling at the required temperature, to profile at temperatures slightly below and slightly above the required temperatures.

6.3.3.2 Profiling Recipes and the Recipe Editor

You use the same editor to create profiling recipes and production recipes. The difference is that you select ‘profile timing’ in a profiling recipe header, and enable profiling in each profiling step.

Timing Modes - Recipe or Profiling

Two timing modes are available in the recipe editor: Recipe timing or Profile timing.

If Profile timing is selected and profiling is enabled in a particular step, the step time will be extended for up to two hours until the cascade controller has profiled to within the limits specified in the profile table.

If Recipe timing is selected and profiling is enabled in a particular step, the cascade controller will try to profile within the step time, but the recipe will continue by going to the next step even if profiling is not complete. For production runs, Recipe timing must be specified so that the processing time is not extended.

The following figure shows how you select Recipe timing or Profile timing:

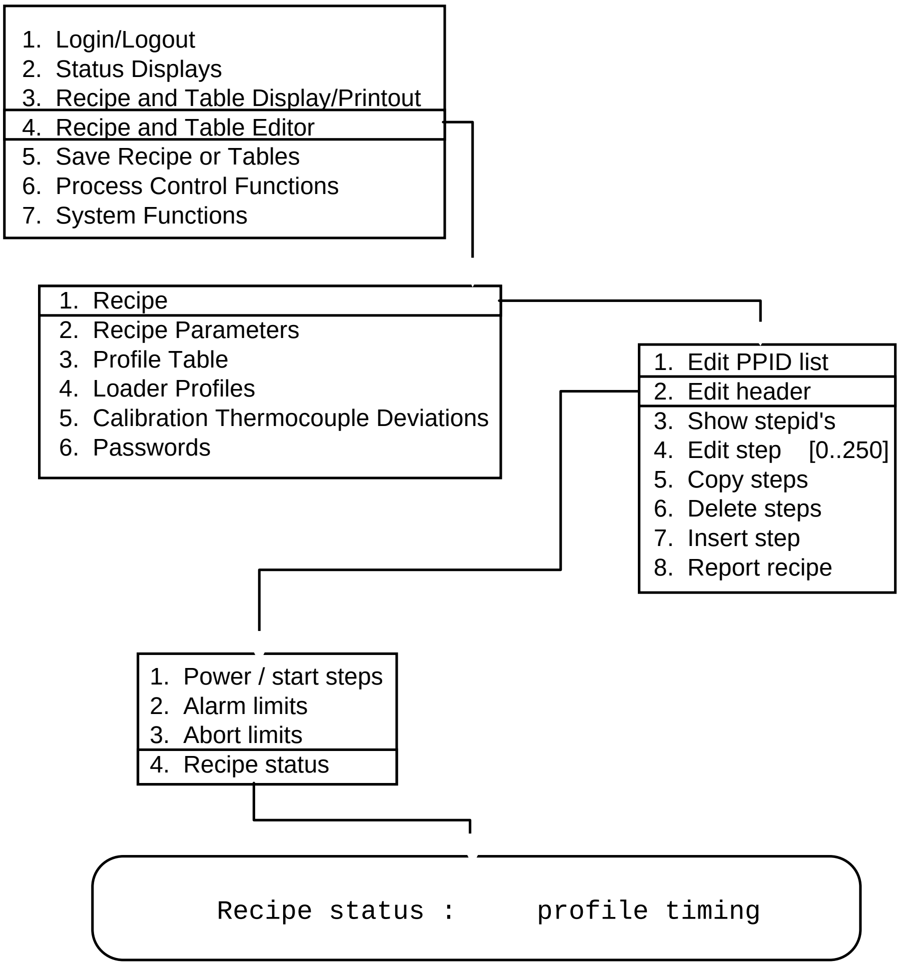


Figure 6-3 Selecting Recipe or Profile Timing

By pressing the [CONTROL] and [T] keys at the same time, you can toggle between Recipe timing and Profile timing.

Enabling Profiling in a Step

You can enable profiling in a step by toggling the profiling field in the temperature screen to ‘enable’:

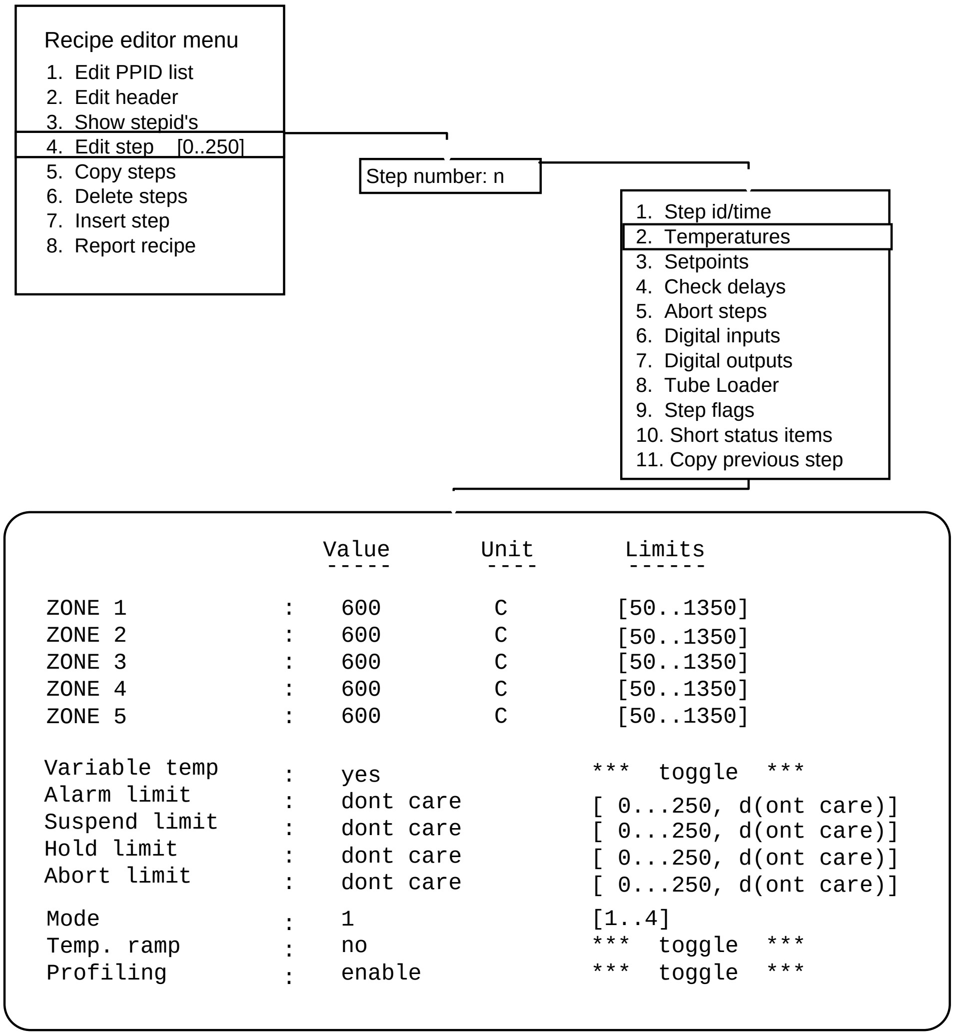


Figure 6-4 Enabling Profiling in a Recipe Step

Note: NOTE:Profiling can only be enabled if:

- The step time is at least 10 seconds.
- Temperature ramp is not selected
- The step is not an end step.

If one or more of these criteria is not met, the profiling field will contain the words: “disabled/not allowed” and you will not be able to toggle the field.

6.3.4 Edit and Load a Profile Table

The profile table serves two purposes:

- It specifies the temperatures and accuracy required during profiling.
- After profiling, it is updated to contain the results of the profiling run and is used by the cascade controller during every run.

Once updated, the profile table is known as the profiling results table.

The profile table must be created and loaded into the tube controller before you run the profiling recipe and must remain in the tube controller at all times.

To edit a profile table, choose the Profile Table option in the Recipe and Table Editors menu. Choose one of the Edit Table options in the Profile Table menu:

```
Cascade Profile Table Editor V<n>EditMain
---------------------------------------------------------------------------


1 : Edit header
2 : Edit table (sort on zone)
3 : Edit table (sort on mode)
4 : Edit table (sort on temperature)
5 : Print table (sort on zone)
6 : Print table (sort on mode)
7 : Print table (sort on temperature)



Enter your choice:
```

Figure 6-5 Cascade Profile Table Editor Main Menu

A profile table similar to the following is displayed:

```
Cascade Profile Table Editor   Edit table
---------------------------------------------------------------------------


No zone mode quality stable time temperature spike temp spike setp

1   1    1     0.5       600         600         600         600
2   2    1     0.5       600         600         600         600
3   3    1     0.5       600         600         600         600
4   4    1     0.5       600         600         600         600
5   5    1     0.5       600         600         600         600


.
50
```

Figure 6-6 Cascade profiling table

The profile table can contain up to 50 lines of data. The fields are:

- **zone**: enter the heating element zone number (1 to 5).
- **mode**: enter the mode number (1 to 4) - this provision allows you to profile for different conditions at the same temperature: for example, mode 1 could be for 600°C without a wafer load, mode 2 for 600°C with a waferload. Beware - for each mode, you must profile at temperatures above and below the required setpoint to avoid interpolation errors. In practice it is usual to use mode 1 all the time.
- **quality**: the flat zone accuracy you require for profiling to end successfully. Enter a value in the range 0.5 to 10°C, with an accuracy of one decimal place. A quality of 0.5°C means that the profiling procedure will terminate successfully if the temperature in all zones is within a ±0.5°C band around the setpoint for at least the time shown in the stable time field.
- **stable time**: user-selectable time indicating the time period during which the temperature should be within the band around the setpoint, specified by the quality value, for profiling to terminate successfully. Default value 600 seconds, minimum value 10 seconds, maximum value 3600 seconds.
- **temperature**: enter the temperature at which profiling is to be done. For profiling to take place, both the mode and the temperature for the entry must correspond to the mode and the temperature setpoint in the recipe step in which profiling is enabled.
- **spike temp** and **spike setp**(oint): these fields will contain the profiling results if profiling is successful. In cascade control mode, the value in spike setp is used as spike setpoint. In spike control mode, the value in spike temp is used for this purpose. Default value for a new table is 600°C.

You must enter data for all temperatures (in all 5 zones) at which profiling is required.

6.3.5 Run the Recipe

Before running the recipe, check the following points:

1. Is the recipe correct and loaded?
   - Is profile timing specified in the header?
   - Is profiling enabled in the steps you want to profile?
   - Are there entries in the profiling table for the temperatures you want to profile at?
   - Have you used the mode consistently throughout the recipe?
2. Is the profiling table loaded?
3. Is the control mode at the tube controller (select ‘system functions’, then ‘change control mode’) <u>cascade</u> for all zones?
4. Is the calibration thermocouple rod correctly installed?
5. Is the calibration TC deviations table the correct one for the calibration TC rod (check serial number with serial number in table), is it filled in correctly and is it loaded?
6. If required, is the boat (with wafers) ready?

When you are sure that everything is in order, start the recipe.

6.3.6 Checking the Progress

When the recipe enters a profiling step it will start profiling. If profiling is not complete (i.e. it could not achieve the quality for the stable time) 10 seconds before the end of the step, the tube controller will go into a SUSPEND state - the step timer stops and the recipe will remain in the step until profiling is complete, <u>or</u> until 120 minutes has passed. The cascade controller will be active with profiling until it can maintain the temperature within the quality limits for the stable time. If it does not succeed within 120 minutes, it will record the quality it could achieve (see status MAYBE below), and the tube controller will start the next step. The profiling run will end when the end step of the recipe is finished and the buzzer sounds. You may then examine the results and store them.

IMPORTANT: When the recipe has finished do not press the reset button until you have examined the results of the run.

6.3.7 Storing Profiling Results

Storing the profiling results is a two-fold process. First, you store the results of the run in memory by pressing the [RESET] button (this replaces the old profile table). Next you should store the table on a diskette for safe-keeping.

6.3.7.1 Storing the Results in Memory

To see the results of the profiling run, choose the System Functions option in the Main Menu and then choose the Profiling Results option. In the Profiling Results menu you may display the results sorted on zone, mode or temperature:

```
PROFILING RESULTS



      1.     Sorted on zone
      2.     Sorted on mode
      3.     Sorted on temperature



      Your choice:  1
```

Figure 6-7 Profiling Results Menu

A table similar to the following is displayed:

```
     Page 1 of 1

Zone   Mode    Stable timeQualityTemp  Spike tempSpike setpStatus   Time
1      1     6000.5600  577.3581.2STORED2262
2      1     6000.5600  568.5569.1STORED2262
3      1     6000.5600  548.2547.5STORED2262
4      1     6000.5600  568.5569.1STORED2262
5      1     6000.5600  548.2547.5STORED2262
1      1     3000.5650  629.0633.4STORED2262
2      1     3000.5650  620.1618.5MAYBE2262
3      1     3000.5650  629.0633.4DONE 2262
4      1     6000.5650  629.0633.4STORED2262
5      1     6000.5650  629.0633.4STORED2262

             Lowest and highest paddle temperature     649.3     650.4
```

Figure 6-8 Profiling Results Table

The first seven fields in the profiling results table are the same as fields two to eight in the profiling table. The status field can display one of three profiling states:

- STORED: Indicates that the results are the same as those in the current profile table in memory.

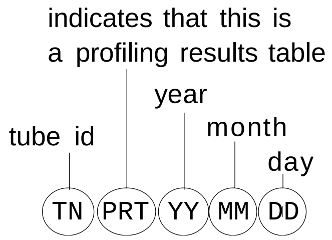
- DONE:Indicates that profiling was successful.
- MAYBE: Indicates that the required quality was not achieved, the results have not yet been stored and you must decide what to do with the data. If 'MAYBE' is highlighted, the lowest and highest paddle temperatures that occurred in that zone during the last period of stable time are displayed at the bottom of the screen. This can help you to decide whether to toggle the 'MAYBE' to:
- DONE: In order to keep the data, or
- REMOVE: In order to discard the data.

IMPORTANT: If 'DONE' is required this must be toggled while the recipe is in FINISHED mode, before going to RESET mode, otherwise the data will be lost.

Once the profiling results are stored, the cascade controller can use them for subsequent runs.

6.3.7.2 Storing the Results on Disk

It is good policy to save a copy of the profiling results table to the floppy diskette or to the supervisory computer. Save each copy with a different name each time, otherwise the tube controller will not be able to overwrite the old table. A good example of a unique name is:



Do not put spaces between the characters. An example is:

A1PRT960811

You can see that this is a profiling results table, for process tube A1. The table was saved on August 11, 1996.

Notes:

Section 7 Adjustments

7.1 Introduction

This section details the adjustment of the automatic doors. It is not within the scope of this manual to detail all preventive and corrective maintenance procedures. Your ASM customer service engineer will be glad to provide advice. Also, the ASM Training department provides a series of maintenance courses to help you keep your Furnace D FS-N250 in good working order.

7.2 Automatic Door Adjustment

The automatic doors and their drive mechanisms do not belong to the Furna ce DFS-N250 from a control point of view. They are controlled by the tube loader controller via a special unit in the loading section called the door relay unit. For further information see the *Tube Loader System Manual*, document no. 2010240.

It should be sufficient to mention here that - if the current recipe step in the SATC contains a command to open or close the door - the SATC first checks with its interlocks to see whether the process conditions are suitable for such an action to take place. If this is the case, door control is claimed by the tube loader controller and acknowledged by the SATC, which then "suspends" in that recipe step. When the opening or closing of the door and the associated loading or unloading actions are complete, control is handed back to the SATC, which then continues with the next recipe step.

Both the diffusion and LPCVD versions of the standard automatic door are opened and closed by the same mechanism, which is designed to apply a constant force to the closed door throughout the process run. This means that when the door reaches the fully-closed position, it is not mechanically clamped; instead, the mechanism continues to apply the same, constant closing force to press the door against the front flange or process tube-end, effectively sealing the process tube.

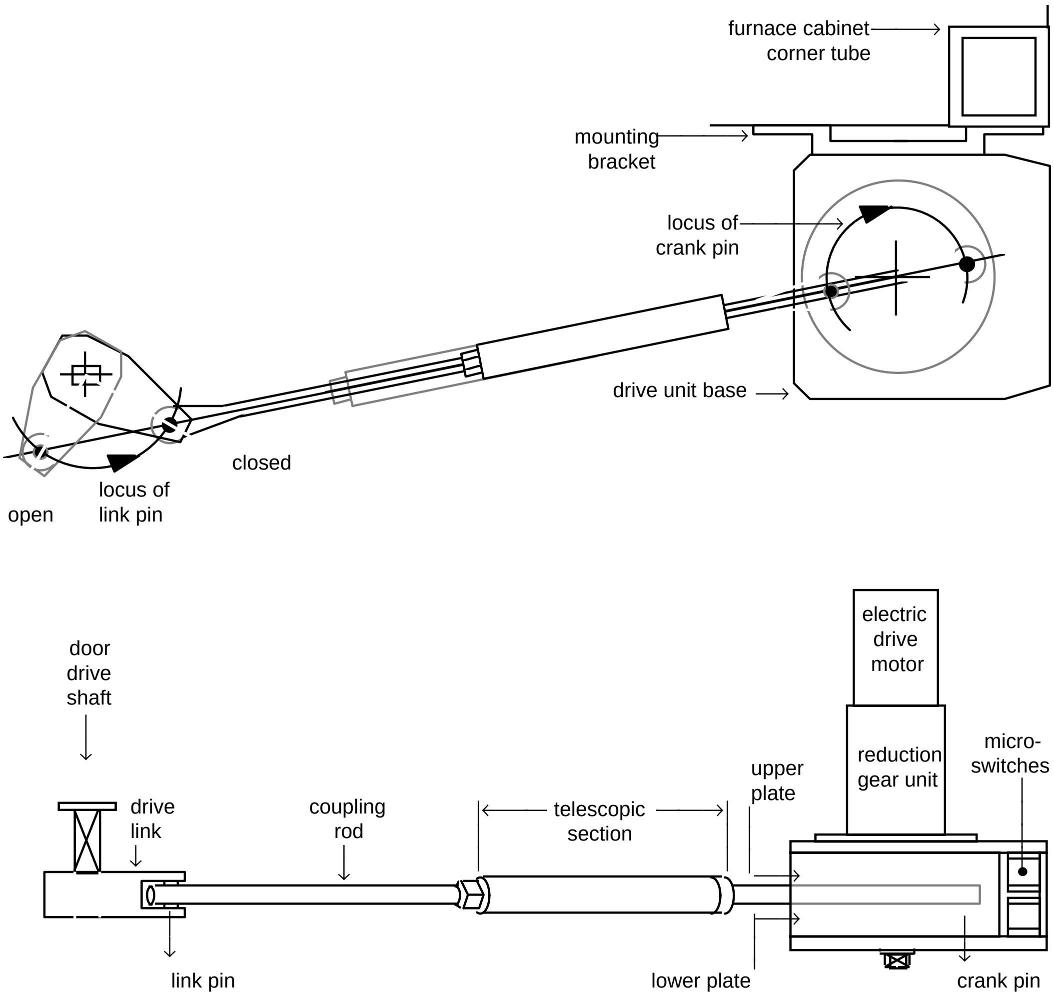


Figure 7-1 Automatic Door Drive Mechanism

The standard automatic door mechanism consists of a drive unit, an eccentric crank mechanism with 4 cam-actuated microswitches for limit switching and signaling, a telescopic coupling and a drive link.

WARNING The automatic lpcvd door mechanism operates with substantial force. Take care not to obstruct the door in its movement.

- The drive unit consists of an electric motor and a reduction gear unit in cylindrical housings, mounted vertically on a hollow base. This base is attached to a bracket, one end of which is fixed to the side of the vertical beam at the front corner of the furnace cabinet.
- Inside the drive unit base is a crank mechanism consisting of two circular plates keyed to the output shaft of the reduction gear unit. A crank pin is fixed eccentrically in these plates and passes through a bearing in the end of the telescopic coupling that lies between the two plates.
- Two segment cams are fastened to the plates of the crank mechanism, one on top of the upper plate and one underneath the lower plate. The raised sections of the cams protrude beyond the circumference of the plates and, as the plates rotate, trip the microswitches, which are mounted in the drive unit base.
- Both the door open and the door close motions are limited by the microswitches tripping. Each motion is stopped by a software stop and, only if this fails, by a back-up hardware stop. The software stop microswitches signal door fully-open or door fully- closed to the tube loader controller. In the first case, the tube loader controller then cuts power to the motor, preventing

further movement. In the second case, the motor continues to apply a constant force to the door. If the crank mechanism continues to turn because the tube loader controller fails to respond to the signals, the second microswitches will trip and force a hardware stop, in which power to the motor is cut directly and independently of the tube loader controller.

- The telescopic coupling is a straight rod in two parts. The solid end of one part fits in the tubular end of the other part, and the hollow space between the end faces contains a spring package, which allows the coupling to extend or be compressed slightly and whose length is so determined that a constant force of 70 N is applied to the closed door to keep it closed.
- The drive link fits over the rectangular end of the door drive shaft, and the pin that passes through the bearing in the corresponding end of the telescopic coupling is eccentric to the door drive shaft. The door drive mechanism is, therefore, a four-bar mechanism.

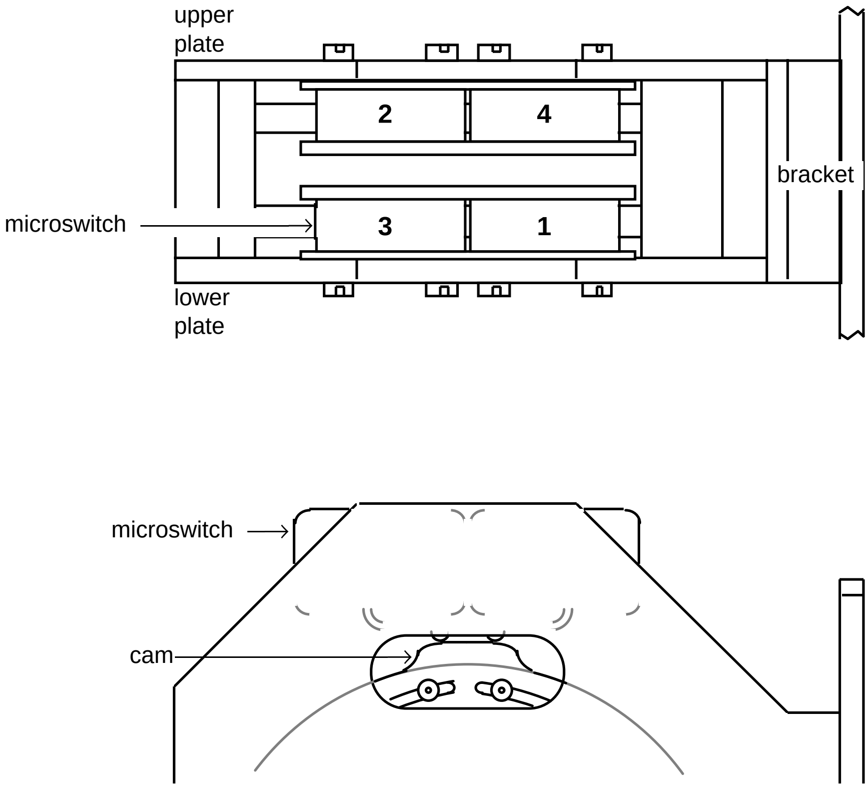


Figure 7-2 Microswitches and Cam

Each cam is held in place by two round head hexagon socket screws which can be reached through slots provided in the upper and lower plates of the drive unit base.

For further details, refer to the *Electric Doors System Manual*, document no. 2044439.

Section 8 Replacements

8.1 Introduction

This section contains details about tube, heating element, and spike TC replacement. It is not within the scope of this manual to detail all replacement procedures. Your ASM customer service engineer will be glad to provide advice. Also, the ASM training department provides a series of courses to help you keep your Furnace DFS - N250 in good working order.

8.2 Tube Replacement

8.2.1 Introduction

This section describes the procedure for replacing LPCVD process tubes. During LPCVD processing, chemical vapor deposits on everything in the process tube and condenses on cold surfaces. The deposits on the tube will eventually grow to such a thickness that they become a source of unwanted particles and contaminate the process. Periodically, therefore, the tube must be replaced with either a new one or a cleaned one. For example, a nitride process tube needs to be changed after about 4 microns of wafer deposition. Of course, tubes must also be changed if they become damaged. This section explains the procedure for removing dirty or damaged tubes and installing new or cleaned tubes via the rear (pump end) of the Furn ace DFS-N250. Diffusion process tubes do not suffer the same degree of contamination and usually only require replacement if they are damaged.

The following figure shows how the process tube is mounted in the Furnace DFS-N250:

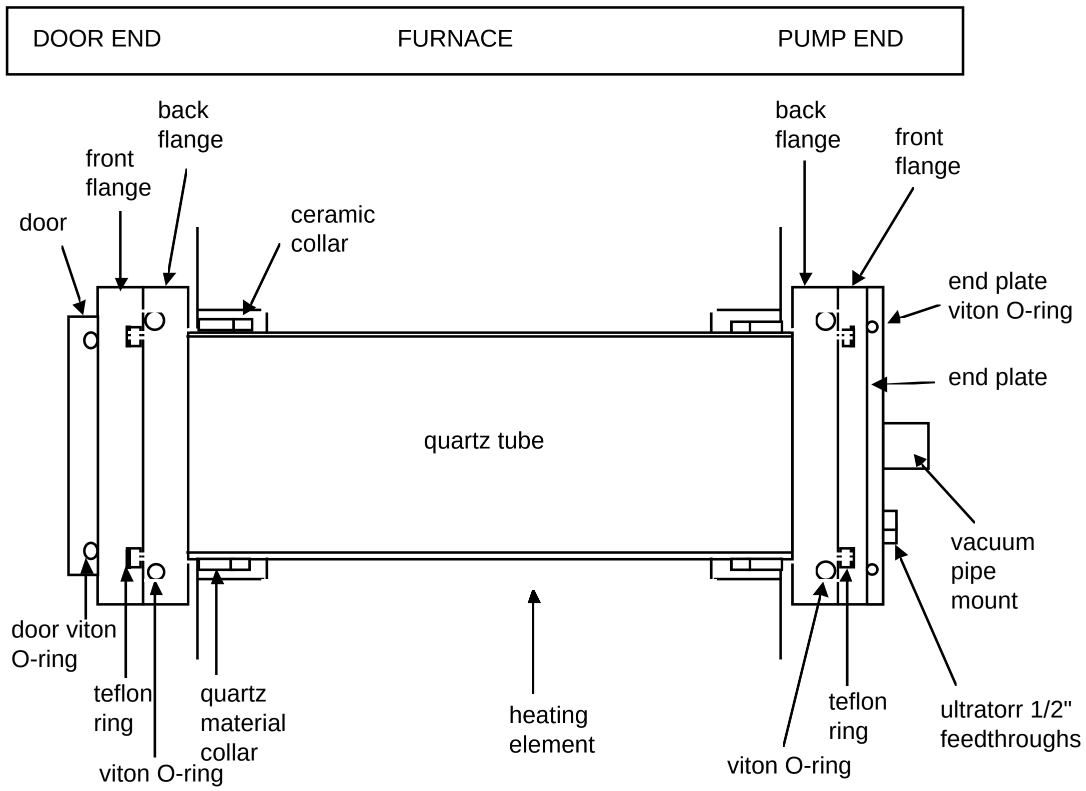


Figure 8-1 Tube Location

8.2.2 Preparation

1. A few hours before tube change, use the control panel to switch OFF power to the heating element of the tube you want to replace, so that the tube has time to cool to a temperature at which it can be handled.
2. Make sure that the tube carrying device is positioned near the multi-purpose cabinet ready to

receive the tube. Position all tools and the following replacement parts near the tube:

- New or clean process tube
- 2 back flange Viton O-rings
- 2 front flange Teflon rings
- 1 door Viton O-ring
- 1 end-plate Viton O-ring (if replacement is necessary)
- 3 Ultratorr feed-through Viton O-rings (if required)

3. Make sure that there are clean plastic gloves available for handling the quartz.
4. If the paddle is being stored in the tube in a nitrogen flow, put the paddle in the home position.
5. Close all manual valves except N_2 valves on the gas panel.
6. Close the valves for the cooling water to the front flanges at both ends of the tube, and if possible, open drain and vent valves to drain all water out of all flanges.
7. Make sure that the isolation (fast pump) valve is closed and that the vent valve is open (in case particles become dislodged when dismantling the pump tubing).

8.2.3 Replacement Procedure

1. Read the spike TC replacement procedure in section 8.4.3.
2. Loosen the wing nut slightly and pull back the both the temperature control (main and back-up) and overheat protection spike TCs to the first notch.

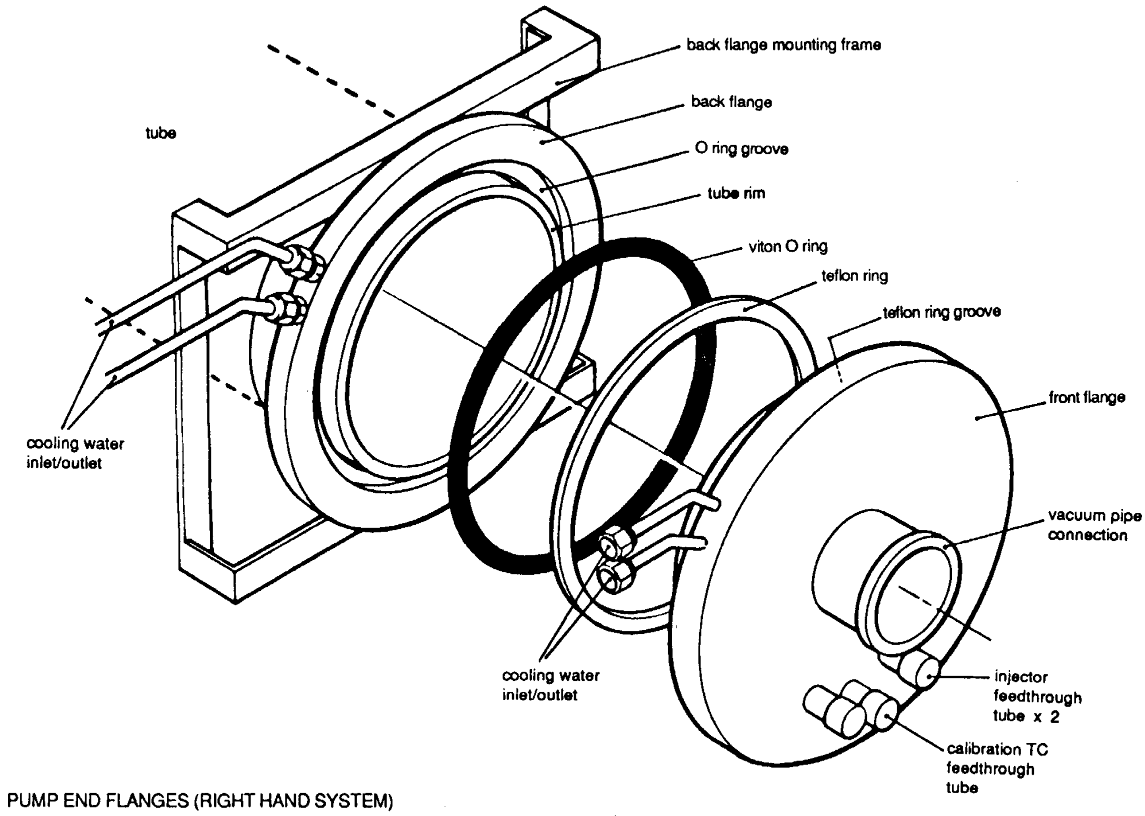


Figure 8-2 Pump-end Flanges

3. The tube is removed through the multi-purpose cabinet. The pump end of the furnace is dismantled to clear the way for the tube as follows:

a. Remove any injectors and/or calibration TCs from the tube. Cap the inlets.

b. Remove the clamps and gasket holding the flexible bellows to the pump side of the vacuum pipe.

c. Remove the vacuum pipe elbow, with bellows attached, from the front flange by undoing the clamps and gasket; cap the ends of the removed section to protect them.

d. Disconnect the cooling water pipes for the front flange at the end of the flexible pipes furthest from the flange - have a container ready to catch any water that escapes (if you were not able to drain the flanges).

e. Remove the end plate - held in place by 4 hexagon socket head screws. remove the two alignment pins and remove the heatshield.

f. Remove the front flange - held in place by 8 hexagon socket head screws.

g. Using a small, clean screwdriver, remove the Viton O-ring from the groove in the back flange and remove the Teflon ring from the front flange. Take care not to scratch the metal surfaces as scratches will produce a gas leak.

4. The door end of the furnace requires the following preparation before the tube can be removed (refer to figure - Door and Door-end Flanges).

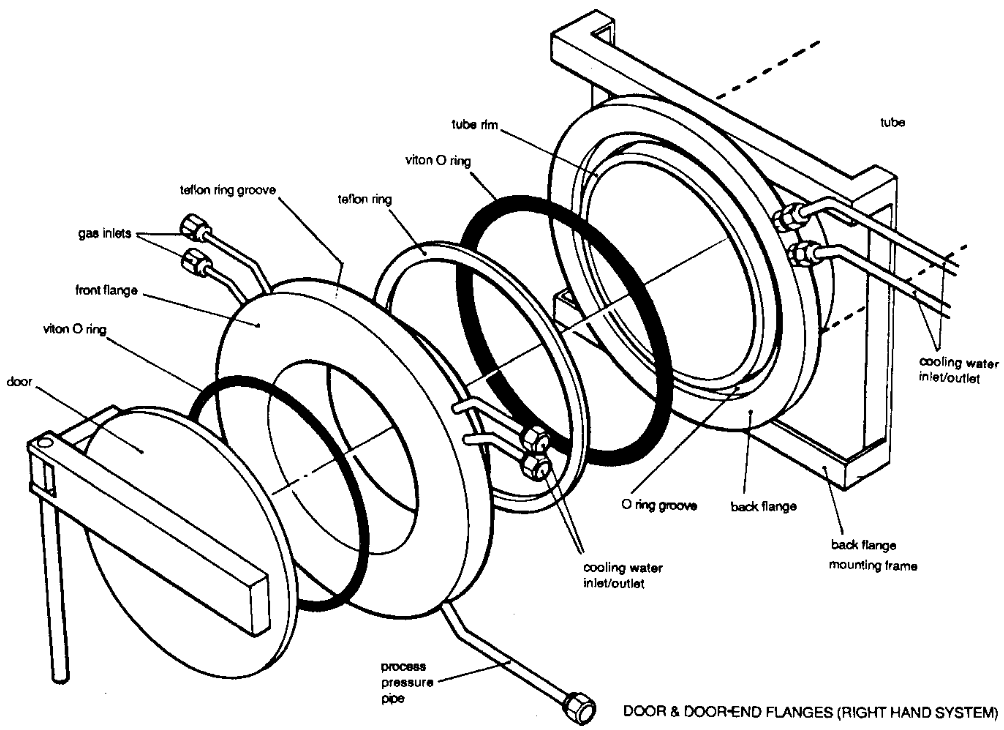


Figure 8-3 Door and Door-end Flanges

a. Open the tube door.

b. Disconnect and cap the gas inlet pipes on the front flange.

c. Disconnect the cooling water pipes in the same way as the pump-end front flange.

d. Disconnect and cap the pipe on the front flange that leads to the Baratron and the tube vent.

e. Remove the front flange - held in place by 8 hexagon socket head screws and alignment screws. If the front flange has a collar, the door must be removed to enable the front flange to be removed (see section 7.2).

f. Using a small, clean screwdriver, remove the Viton O-rings from the grooves in the back flange and the door and removethe Teflon ring from the front flange. Take care not to scratch the metal surfaces as scratches will produce a gas leak.

5. Remove the cover ring of the tube adapter at both tube ends. Twist the tube to loosen the quartz wool collars.

6. Pull out the tube from the pump end of the Furn ace DFS-N250. Have an assistant to support the tube at the door end. The assistant must put his/her arm into the tube so that the gloved palm of his hand supports the tube. As you pull it out, it will slide over the assistant's hand. When it is out of his reach there will be enough tube at your end to withdraw the remaining length of tube safely. Do not scratch the ends of the tube: a gas-tight seal is needed with the back flange Viton O-rings. Also take care not to damage the ceramic spacers between the element windings. Put the tube on the carrying device for transport to the cleaning area.

7. Clean the flanges, if needed, with a brush, scotchbrite and chemical etching. Wipe them clean with a lint-free cloth soaked in alcohol.

8. Insert the new or clean tube from the pump end. Place a tube cap on the front end of the tube to stop dirt getting inside. Do not damage the tips of the ceramic spacers between the element windings and do not scratch the ends of the tube, where a gas-tight seal is needed with the back flange Viton O-rings. Install the new tube with the help of an assistant, who must put his arm into the space for the tube from the door end to support the tube in the same way as when it was removed. Move the tube to its correct position (the tube should extend about 112 mm out of the ring) and tighten the quartz wool collar.

9. The components at the door end of the Furna ce DFS-N250 must be refitted first:

   a. Clean the O-ring grooves in the door and the back flange and the Teflon ring groove in the front flange. Use a vacuum cleaner and then a lint-free cloth soaked in alcohol.

   b. Insert new Viton O-rings in the door and the back flangeand a new Teflon ring in the front flange.

   c. Position the front flange and tighten the screws just enough to hold the flange in place.

   d. Push the tube from the pump end until it touches the Teflon ring in the front flange.

   e. Tighten the front flange screws a little at a time. Each time, tighten different pairs of screws opposite each other so that the Viton O-ring is evenly compressed.

   f. By tightening the front flange screws, the tube is pushed backwards in its supports to its process position (the Viton O-ring forms the gas-tight sealand the Teflon ring acts as a cushion between the rim of the tube and the front flange).

   g. Re-connect the inlet/outlet pipes to the front flange. If the door has been removed, refit the door (see section 7.2).

10. Refit the components at the pump end of the furnace:

   a. Clean the O-ring groove in the back flange and the Teflon ring groove in the front flange as in step 8.1.

   b. Insert a new Viton O-ring in the back flange and end plate, and a new Teflon ring in the front flange.

   c. Refit the front flange. Tighten the screws a little at a time. Each time, tighten different pairs of screws opposite each other so that the Viton O-ring is evenly compressed.

   d. Re-connect the cooling water pipes.

   e. Replace the heatshield (in its original position) and refit the vacuum pipe to the front flange and the flexible bellows to the vacuum pipe that leads to the pumps. (If the original vacuum pipe gaskets and flexible bellows are dirty, clean or replace them).

   f. Replace the Viton O-rings in the 3 Ultratorr feed-throughs in the end plate (if used for injectors or TC).

   g. Re-insert any injectors and/or calibration TCs that are needed in the tube.

11. Re-position the spike TCs (see section 8.4.3).
12. Clean the outer surfaces of the flanges, the door and the vacuum pipe elbow and bellows with a lint-free cloth soaked in alcohol.

That completes the description of the tube replacement procedure. The new tube must now be made operational.

8.2.4 Tube Start-up

- Open the cooling water valves to the front flanges at both ends of the tube.
- Check for leaks.
- Open the manual valves on the gas panel.
- Switch the heating element on at the FIC panel.
- Profile the tube.
- Try a tube loader load/unload cycle to see if a new teach-in is required.

8.3 Heating Element Replacement

8.3.1 Element Removal

Heating elements are not replaced often because very little can go wrong with them. If a replacement does become necessary, follow the procedure below:

IMPORTANT Before doing anything, **turn off power to the heating element** by pressing the FIC panel element control on/off button for that element. as an extra precaution, **turn off power to the whole System** by pressing the red system off (0) button on the FIC panel. the indicator light will go off when power is off.

WARNING Wear a face mask to avoid inhaling element insulation material particles.

1. **Make sure that the heating element has cooled to below 50°C**.
2. Loosen the wing nut slightly on each thermocouple (main, back-up and overheat protection) mounting, and pull back the thermocouple until it reaches the stop in the feed tube.
3. Remove the process tube using the procedure described in section 8.2.3. If the process tube you are removing is not of the LPCVD type, follow the same procedure and ignore the instructions that are not appropriate.

Note: Always use clean quartz-handling gloves when handling process tubes.

4. Disconnect the power cables from the heating element zone connectors.
5. Loosen and remove the stainless steel straps that hold the element in its supports at both ends. Remove the bolts which hold the heating element supports in place at both ends of the frame.
6. Have two assistants lift up the heating element at one end and quickly slide the support out of the way. Repeat at the other end.

Note: You must use at least two assistants to remove the heating element safely. It is long and heavy and must be carefully supported by at least one person at each end at all stages of its removal.

7. Slide the heating element out of position until it is completely outside the furnace cabinet and lower it gently to the floor.

8.3.2 Element Installation

1. Install the new element by reversing the removal procedure steps.
2. Check the torque on the power connections after tightening; it must be 20 Nm.

IMPORTANT When connecting the power cables to the element power connectors, you should be careful not to twist, bend or put tension in any other way on the furnace power connectors. when the cables are tight they should not exert any force on the element power connector (tension-free).

3. Install the process tube using the procedure described in section 8.2.3 - Replacement procedure, steps 8 to 12. If the process tube you are installing is not the LPCVD type (if you are not sure, see section 4.4.1 - Process Tubes), follow the same procedure and ignore the instructions that are not appropriate.
4. Start up the heating element by following the procedure described in the next section.
5. Start up the process tube by following the procedure described in section 8.2.4.
6. The Furnace DFS-N 2 50 is now ready for normal operation.

8.3.3 Element Start-up

Note: After being heated for some time, a heating element can be damaged by mechanical shock. It is therefore advisable not to move a previously-heated element unnecessarily. As a guide, standard elements may be transported and used again but only if they have not been used for more that 5 to 6 hours at a temperature of 1000°C. For lower temperatures, the time is longer.

The procedure for starting up the Kanthal heating elements used in the Furnace DFS-N250 is as follows:

1. Check that all power connectors to the heating element zones are tightened (20 Nm).
2. Raise the element temperature from room temperature to 900°C as quickly as possible.
3. Maintain a temperature of 900°C for a minimum of three hours.
4. Allow the heating element to cool off to room temperature.

The heating element is now ready for normal use.

This procedure must always be followed, even if the heating element is to be used later only at much lower temperatures. The purpose of the procedure is to cause rapid oxidation of the metallic aluminum in the heating wire. The layer of aluminum oxide thus formed protects the heating wire against further corrosion for the lifetime of the heating element. The temperature during start-up may be allowed to exceed 900°C as this will only speed up the process of oxidation. **Never exceed the maximum temperature quoted for the type of element used** as this will weaken the Kanthal wire, after which deformation can occur and eventually destroy the elements.

8.4 Spike TC Replacement

8.4.1 Introduction

Figure 8.4 shows the location of the spike TCs in the Furnace DF S-N250. If a spike TC is faulty, then it must be replaced as soon as possible with a new one. The replacement procedure is described in this section. Note that all TCs on the same tube level must be of the same type (see section 5.3.2).

This section describes the following procedures for the spike TC:

- Removal
- Installation
- Adjustment

Note: At each tube level, every time a TC is replaced with a new one and every time the position of a TC can have changed since the last profiling was done, the tube must be re-profiled.

IMPORTANT Before doing anything, **turn off power to the heating element in which the TCs are situated** by pressing the FIC panel element control on/off button for that element. as an extra precaution, **turn off power to the whole System** by pressing the red system off button (0) on the FIC panel. the indicator light will go off when power is off.

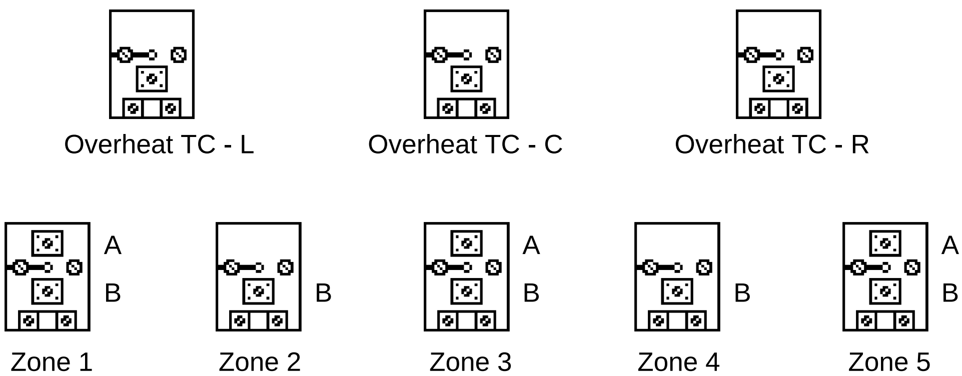
WARNING When the system is switched off, dangerous voltages are still present in the central power box.

8.4.2 Spike TC Location

Note: To access the spike TCs, the furnace cabinet access panel for the appropriate tube must be removed. If profiling is being done on another tube level at the same time, removing the panel will disturb the temperature profile.

- The center and outer zones (1, 3 and 5) each have a dual spike TC - a main and back-up temperature control spike TC in the same ceramic casing.
- There are three overheat protection spike TCs (left, center and right) in a row, just above the temperature control TCs.

The following figure shows the relative location of the spike



TCs: A = Back-up TC B = Main TC

Figure 8-4 Spike TC Location RH System

8.4.3 Replacement Procedure

8.4.3.1 Spike TC Mounting

The fixed feed tube - and therefore the whole assembly - can be aligned to a radial axis of the process tube with the two hexagon socket screws and locknuts on its base (this is only necessary on initial installation or if the mounting has been removed to allow heating element replacement). The collar with locking screw can be set on the adjustable feed tube to give the correct distance between the sensing end of the spike TC and the process tube (2 - 4 mm). Once this has been done, the wing nut is tightened to prevent movement. If the wing nut is loosened, the TC can be retracted for process tube removal and re-installation. The TC is then re-inserted until the collar touches the fixed feed tube, and the wing nut is tightened.

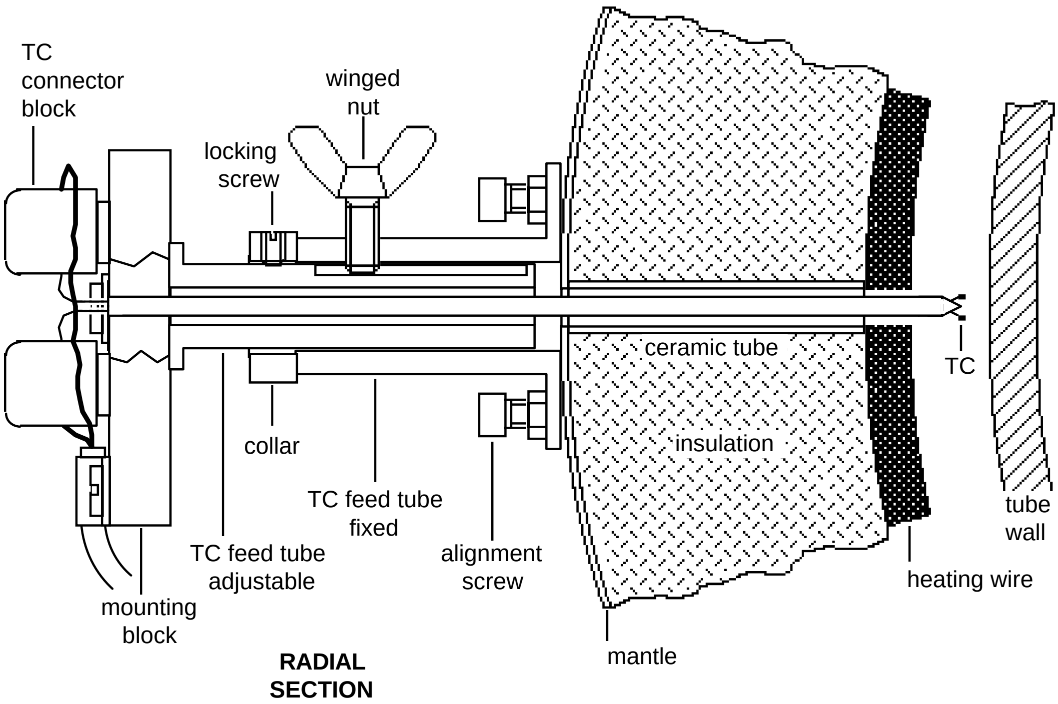


Figure 8-5 Spike TC Mounting

8.4.3.2 Spike TC Connections

Figure 8-6 will help you to follow the description of the spike TC removal and installation procedures. It shows the spike TC and extension wire connections to the connector block(s) of the new model TC mounting (shown with dual spike TC - main and back-up). The main TC is wired to the lower connector block and the back-up TC, if present (dual TC), is wired to the upper connector block in the same way.

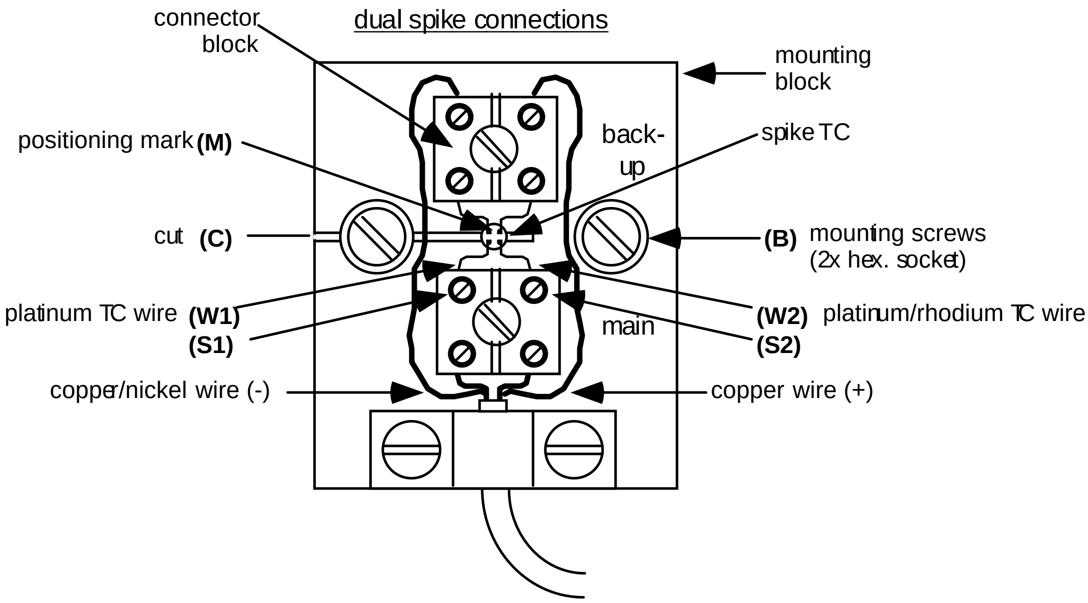


Figure 8-6 Spike TC Connections

8.4.3.3 Spike TC Removal

Letters in brackets - for example (B) - refer to the items in Figure 8-6 “Spike TC Connections” on pa ge76.

1. Loosen the wing nut only a quarter turn (90°). The adjustable feed tube is now free to slide in the fixed feed tube.
2. Holding the mounting block in one hand, pull the adjustable feed tube out until it will move no further.
3. Re-tighten the wing nut and leave the adjustable feed tube in this position while you follo the next steps:

   If the TC has been retracted so that the process tube can be changed, continue as follows:
4. When the tube change is finished, loosen the wing nut only a quarter turn (90°) and - holding the mounting block in one hand - push the TC in until it will move no further (when the collar contacts the end of the fixed feed tube).
5. Re-tighten the wing nut.
6. If the TC that has been removed is faulty and must be replaced, continue as follows:
7. Unscrew the two hexagon socket screws (**B**) that attach the mounting block to the adjustable feed tube and - holding the mounting block in one hand - pull the TC straight out of the adjustable feed tube to avoid bending or breaking it.
8. Loosen the connection screws (**S1** & **S2**) in the connector block(s) and pull out the TC wires (**W1** & **W2**)
9. Put a screwdriver into the cut (**C**) and gently force it open to release the TC from its hole.
10. Install the replacement TC as described in the next section.

8.4.3.4 Spike TC Installation

Letters in brackets - for example (**B**) - refer to the items in figure 8.6.

The two hexagon socket screws (**B**) have been unscrewed to detach the mounting block from the adjustable feed tube, which is in the retracted position, and no TC is present.

Mount the TC to be installed (it must be the same type as the other spikes used for that tube), in the mounting block as follows:

1. Put a screwdriver into the cut (**C**) and gently force it open to allow insertion of the TC into its hole. There is a positioning mark (**M**) on the ceramic casing of the TC which identifies the + wire so that you can correctly position the TC in the mounting block. Take care not to cut into or bend either of the TC wires, as this can cause local work-hardening and electrical property changes in the wire.
2. Loosen the connection screws (**S1** & **S2**), if necessary, and insert the TC wires (**W1** & **W2**) into the holes in the connector block(s).
3. Re-tighten the connection screws (**S1** & **S2**).

Note: The TC wires in the ceramic tube should not be jammed in but should feel free.

Insert the TC as follows:

4. Holding the mounting block in one hand, put the TC straight down the middle of the adjustable feed tube.
5. Attach the mounting block to the adjustable feed tube with the two socket screws (**B**).
6. Loosen the wing nut only a quarter turn (90°). The adjustable feed tube is now free to slide in the fixed feed tube. Holding the mounting block in one hand - push the TC in until it will move no further (when the collar contacts the end of the fixed feed tube).
7. Re-tighten the wing nut.

Note: After installing a replacement TC you must re-adjust the position of its sensing end, as described in the next section.

8.4.3.5 Spike TC Adjustment

Spike TC adjustment is necessary each time a new spike TC is installed in the mounting. If a heating element is replaced, all spike TCs must be adjusted after their mountings have been re-installed. Spike TC adjustment is not necessary after tube replacement. The position of the sensing end of the spike TC can only be adjusted when a process tube is in place.

1. Holding the mounting block in one hand, loosen the wing nut and the locking screw in the collar only a quarter turn (90°). The adjustable feed tube is now free to slide.
2. Very gently push the TC into the fixed feed tube until the sensing end of the TC just touches the process tube wall. <u>Do not exert any pressure</u>, or you will damage the TC junctions.
3. Slide the collar on the adjustable feed tube until it touches the end of the fixed feed tube. Lightly tighten the locking screw.
4. Retract the TC until the distance between the collar and the end of the fixed feed tube is 4 mm (± 0.5 mm). Tighten the wing nut.
5. Loosen the locking screw and slide the collar until it touches the end of the fixed feed tube. Securely tighten the locking screw.

Section 9 Power Distribution

9.1 Introduction

Main power to the DFS-N 2 50 is 277/480V AC 3-phase. It enters the Central Power Box in the furnace section, and from there is distributed to the individual components. The 277/480V AC 3-phase is converted to lower voltages by selective tapping of the phases and/or via transformers where required at specific locations.

A general explanation of the components is given in the following sections. For exact details, refer to the appropriate engineering drawings in the drawings package.

Some components, for example the flow hood can be switched directly as soon as the 24V control circuit supply is available. Many other circuits are conditional - they are wired via relays in such a way that will ensure that a component does not receive power unless certain conditions exist. For example, the roots pump cannot be switched on at pressures ab ove 40Torr - even though all you may have switched the pump on physically, the relay in the system will not actuate until the pressure condition exists.

9.1.1 Central Power Box

The Central Power Box, located on the back of the furnace frame, is the central distribution point for power to the whole system.

The Central Power Box contains:

- Mains Control circuit - 24V AC that is used to switch the relays. Includes connections for power on/off, the EMOs, etc.
- Power Unit relays and fuses
- Mains supply 3-phase connection and power bars
- Flow hood switches and fuses.

9.1.2 Power Unit

The power unit, consisting of the power transformer, thyristors and thyristor control board, derives its power from the Central Power Box. Power for the thyristor control board microprocessor and logic is derived from transformers on the thyristor control board.

9.1.3 Cold Junction Box

The Cold Junction Boxrequires 24V AC for operation. This is supplied from a transformer which is directly connected to the Central Power Box.

9.1.4 Heat Exchanger Fans

The heat exchanger fans receive 220V from the Central Power Box or they can be fed from an independent source.

Notes:

Appendix A Ramp-up, Ramp-down and Recovery Times

The maximum ramp-up (full power ON) and ramp-down (all power OFF) rates are given in the following table. After ramp-up, stability needs a few minutes to recover:

Ramp-up and Ramp-down rates:

	Temp. range	Rate
Ramp-up	700 - 1000°C	15.0°C/min
Ramp-down	1000 - 700°C	3.5°C/min

The following table gives the approximate recovery times for three different temperatures in an LPCVD system, based on a loading speed of 250 mm/min. with 3 cassettes containing a total of 150 6” wafers.

LPCVD recovery times:

Loading speed	Temp.	Rate
250 mm/min	570°C	20 min
250 mm/min	680°C	20 min
250 mm/min	750°C	15 min

The following table gives the approximate recovery times for a diffusion system. The last two rows do not include a load cycle, but do have a temperature ramp.

Diffusion recovery times:

Loading speed	Temp.	Ramp	Recovery time
250 mm/min	700°C	-----	20 min
-----	700 - 1000°C	15.0°C/min	5 min
-----	1000 - 700°C	3.5°C/min	8 min

These figures were obtained using 6 cassettes containing a total of 125 5” wafers.

Notes:

Section 10

Comments Form

DFS-N 250 Reference Manual

Revision A.1   Part number: 2120402

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