AS-One 100

Rapid Thermal Processor

User's manual

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Rapid Thermal Processor AS-One 100– User's Manual	2.04	May 12, 2014	6476_ASOne100_User_Manual_EN_V2-04.docx

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1. CONSTRUCTOR'S FOREWORD

This manual contains original instructions for the manufacturer of the machine.

⚠ WARNING

SAFETY INSTRUCTIONS

The user must carefully read the following instructions.

The user is responsible for installing the system in safe conditions and in an environment that complies with the local regulation.

The Annealsys system can be used for various applications. Many different types of gases can be used in the system; consequently, the user must take all the necessary precautions to prevent hazardous mixtures occurring inside the process chamber.

The customer must be aware of the effects of process gases and vapors used during the process and their consequences on the machine, accessories and vacuum pump. All manuals must be carefully read in order to check the conditions of operations.

The constructor declines all responsibility for any incidents caused by insufficient precautions or handling errors, and their consequences.

The constructor specifies that the Annealsys system has no protection against any possible toxic emanations.

The responsibility for installing the machine in an environment which complies with the relating legislation is left entirely to the initiative and charge of the user, who is considered to be aware of the effects of the gases that he uses, as well as those of the decomposition products and gases generated by the processes in operation.

The user shall be responsible for connecting the exhaust line and the pump exhaust of the system to a gas scrubbing installation which is compatible with the process gases and gas flows and that complies with local regulation.

The user is responsible for ensuring that supply pipes and cables as well as exhaust are routed in such a way to eliminate trip hazard. Also, floor surface is to be suitable and must reduce as far as possible any slip hazard for the operator or others in the vicinity of the machine. Adequate lighting and any fire suppression system is also the responsibility of the user

The constructor also specifies that the quartz, ceramic and graphite parts and all parts exposed to vacuum or process gases must only be handled with gloves to avoid any pollution.

All maintenance and servicing work should be carried out by skilled personnel and, where specified, in relation with Annealsys Customer Service Department.

2. SAFETY INSTRUCTIONS

The signal words for the safety instructions and labels are DANGER, WARNING and CAUTION.

⚠ DANGER

DANGER is the signal word used to indicate an imminently hazardous situation that, if not avoided, will result in death or severe injury.

⚠ WARNING

WARNING is the signal word used to indicate a potentially hazardous situation which, if not avoided, could result in death or severe injury.

⚠ CAUTION

CAUTION is the signal word used to indicate a potentially hazardous situation which, if not avoided, could result in moderate or minor injury. It may also be an alert against unsafe practices.

2.1 Pictogram definitions

	**Hot surface** **Burn hazard while touching hot parts.** **This label warns the user from eventual burning hazards.**
	**Electricity, Electrical hazard** **Contact may cause electric shock or burn** **This label prevents the user of eventual electrical hazards**
	**Toxic material, poison** **This label warns the user from the danger and lethal risks involved when using toxic or corrosive chemicals**
	**Pinch hazard** **Possible pinch hazard with mechanical moving parts.** **This label warns the user of eventual mechanical hazards**
	**General warning** **This label warns the user from eventual hazards with possible injury or damage to the system.**

2.2 Personnel qualifications

All installation or maintenance operations should only be carried out by persons who have suitable technical training and the necessary experience.

2.3 Safety information

2.3.1 Process gases

	**⚠ WARNING** **Toxic gases** **Some gases are toxic and inhaling them should be avoided.** **Take steps to ascertain whether or not the gases being used are known toxic substances. Refer to the Material Safety Data Sheets covering the gases in question**

2.3.2 Burn hazard

	**⚠ WARNING** **Burn hazard** **Substrate and quartz window may be at high temperature.** **After manual heating of after a process both substrate and quartz window may still be at high temperature.** **Wait for sufficient cool down of the substrate for unloading.**

2.3.3 Electrical shock hazard

	**⚠ WARNING** **Electrical shock hazard** **The power supply line and the furnace circuit breakers must be switched off and locked before starting maintenance operations.** **These operations must be carried out by trained and authorized technicians only.**

2.3.4 Eyes damage

	**⚠WARNING** **Possible eye damage** **The lamp furnace emits strong visible and infrared light during operations. Some light can be seen from the rear exhaust duct.** **Never look furnace light from the rear of the system during operation. This may lead to eye damage. A warning label affixed on the backside lid warns the user of potential hazard**

3. UNPACKING

3.1 Initial verification: visible defects

The condition, compliance, absence of visible defect and number of goods must be checked on delivery, in the presence of the carrier; the Client is responsible for the costs and risks relative to the verification. Any visible defect or non-compliance of goods must be stated on the carrier documents with sufficient reserves (non visible defects) at the reception of the goods.

Any complaint, reservation or dispute should be stated on the documents provided and confirmed to Annealsys in writing (fax, e-mail or registered letter with a reply slip) **WITHIN 8 DAYS of delivery** of the goods, and to the carrier within the period set out in the transport contract. Annealsys is not responsible under any circumstances for damage or loss caused by the transport of the goods.

The Client must provide proof of the reality of the defects observed (pictures). Annealsys reserves the right to carry out, directly or through an authorized representative, observations, verification and possible repairs on the spot.

Any failure to observe these conditions will mean that goods have been received without reserve.

Any return of goods as a result of a visible defect must be agreed expressly and in advance by Annealsys. After agreement goods will either be replaced by identical goods or repaired by Annealsys.

3.2 Unpacking

Unpack the system very carefully and check with the part list that you unpack all the parts from the crate.

All parts from the following list must only be handled with gloves to avoid any pollution:

- Halogen lamps
- Quartz parts (windows, pins, etc.)
- Graphite and silicon coated graphite parts
- Vacuum fittings
- Gas fittings and components

4. INSTALLATION

4.1 Environmental conditions for the furnace

· Temperature:	15°C to 35°C
· Humidity:	< 60%

4.2 Dimensions and weight of the system

Dimensions without computer (mm):	510 (W) x 800 (D) x 1425 (H)
Weight:	194 kg

4.3 Facilities to be provided by the customer

4.3.1 Electrical supply

The AS-One 100 RTP system can be delivered for different power voltage supply. Refer to your system specifications (see the electrical plate on the rear panel) to check the power supply voltage

4.3.1.1 3x220V (± 10%) + Ground

· Voltage:	3 x 220V (± 10%) + Ground, 50/60 Hz
· Maximum power:	30 kW
· Maximum current for 3x220V:	79 A
· Maximum current for 3x200V:	87 A
· Recommended power line circuit breaker:	100A, D curve, 3 poles
· Power cable:	4 x 25 mm²

4.3.1.2 3x400V (± 5%) + Neutral + Ground

· Voltage:	3 x 400V (± 5%) + N+ Ground, 50/60 Hz
· Maximum power:	30 kW
· Maximum current:	44 A
· Recommended power line circuit breaker:	63A, D curve, 4 poles
· Power cable:	5 x 10 mm²

4.3.2 Cooling water

· Flow*:	10 l/min
· Minimum inlet pressure:	2 bars
· Maximum inlet pressure:	4 bars
· Maximum outlet pressure:	1 bar
· Minimum inlet temperature:	2°C over the dew point
· Maximum inlet temperature:	25°C
· Maximum outlet temperature:	70°C
· Filtration:	≤ 25 µm
· Calcium hardness:	< 50 ppm
· pH:	6.5 < pH < 8

**** The cooling water flow may be reduced depending on the process conditions. The system is equipped with a flow controller that is set to 4 l/min. If water flow is lower the system cannot operate. If the water flow is between 4 l/min and 10 l/min the system may operate but is subject to overheating alarm if long or high temperature processes have to be performed.***

4.3.3 Compressed air

· Pressure:	6 bars
· Flow:	0.1 m^3/h
· Quality:	Dry and oil free

4.3.4 Purge gas

· Pressure:	1 bar

4.3.5 Process gases

· Pressure for purge gas line :	1 bar
· Pressure for process gas lines with mass flow controllers:	1 to 2 bars

4.4 Installation

Refer to the installation manual for detailed installation instructions.

4.4.1 External failure

The external failure allows the user to connect an external interlock to the AS-One system like gas detection system, exhaust control, etc.

In case of external interlock the AS-One will automatically stop the process and close all the vacuum and gas valves. The process chamber will be pumped down.

The external failure connector on the rear panel of the AS-One is supplied with 24VDC. This is a safety loop interlock that will stop the system when it is open.

⚠ CAUTION

The external safety loop is supplied with 24 VDC.
Only potential free contact must be connected to the external failure connector.
Connecting to a non-free potential may lead to serious damage of the equipment

Connector wiring information:

Terminal	Function
1	24V
2	Signal to PLC
3	Not used

5. SYSTEM OVERVIEW

5.1 General overview

The AS-One system has been specially developed to meet the requirements of Universities, Research Laboratories, Quality Control and small-scale Production. The high reliability assures low cost of ownership.

The AS-One rapid thermal processor main features are:

- Stainless steel cold wall chamber
- Single air cooled quartz window
- Infrared halogen lamp furnace
- Thermocouple temperature control
- Optical pyrometer temperature control
- High speed digital temperature controller
- One purge gas line
- Up to 5 process gas lines with mass flow controllers
- Vacuum valve and vacuum gauge
- Full PC control

The system is divided in two main parts:

The reactor and the associated circuits located in the upper part:

- Process chamber
- Furnace
- Cooling circuit
- Gas panel
- Vacuum equipment

The control rack is in the lower part and includes:

- Programmable logic controller (SAIA PCD3)
- Temperature controller (SRX)
- Temperature sensor interface board
- Interface board for mass flow controllers
- Contactors
- Circuit breakers
- Transformer
- Power blocks

The PC is installed close to the system. It allows full process monitoring, data acquisition and pyrometer calibration for a large range of substrate.

5.2 Control panel

- ON/OFF push buttons
- Emergency switch
- Alarm light

5.3 Reactor

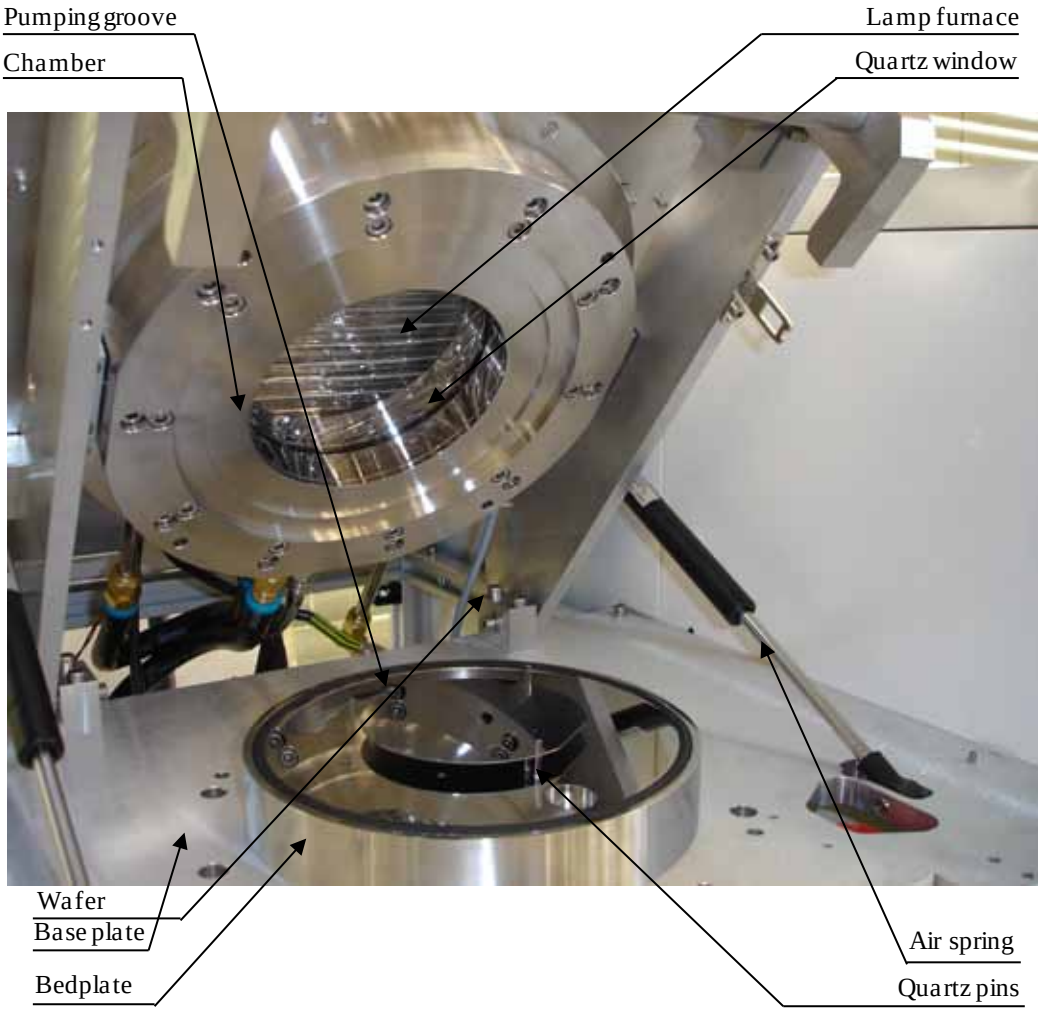
The process chamber is made of water-cooled polished stainless steel.

The reactor is made of two parts. One part is the bedplate that holds the substrate and is fixed on the aluminum base plate. The other part is installed in a rotating lead that allows the loading and unloading of the substrates.

The chamber is installed in the rotating lid and it is closed on the top side by a quartz window. The lamp furnace is installed on the top of the quartz window. Two air springs hold the chamber in the open position and the rotating handle tightly close the chamber.

The gas inlets are located below the quartz window on the front side. This gas injection distribution avoids any cold point due to gas circulation on the substrate during the process. The gases are evacuated through the pumping groove on the backside of the bedplate.

The bedplate is equipped with two thermocouple feedthroughs and two holes for pyrometers. One hole is equipped with a pyrometer viewport. The pyrometer viewport can be installed on the central hole or on the edge viewport (for temperature control of susceptors).



The chamber has vacuum capability and allows performing process from vacuum to atmospheric pressure.

Three quartz pins hold the substrates. The quartz pins are especially designed to reduce the thermal transfer with the substrate. The quartz pins can be changed within a minute to switch to a different size of samples. Quartz pins for other sample sizes are available upon request.

5.4 Furnace

The halogen tubular lamp furnace is installed on the topside and heats the substrate through the quartz window. The tubular halogen infrared lamps are installed in a stainless steel water-cooled and polished reflector.

The lamps are supplied in 3 zones by 3 special power converters specially developed for rapid thermal processes. The power converters controls the power applied to the lamps.

The lamps are air cooled by tangential fans. One fan on each side of the furnace cools down the lamps connections. A fan on the front of the furnace cools downs the quartz tubes and the quartz window.

The hot air is evacuated on the backside of the furnace. The external surface of the furnace cover is kept cooled by cooled air circulation.

Furnace specifications:

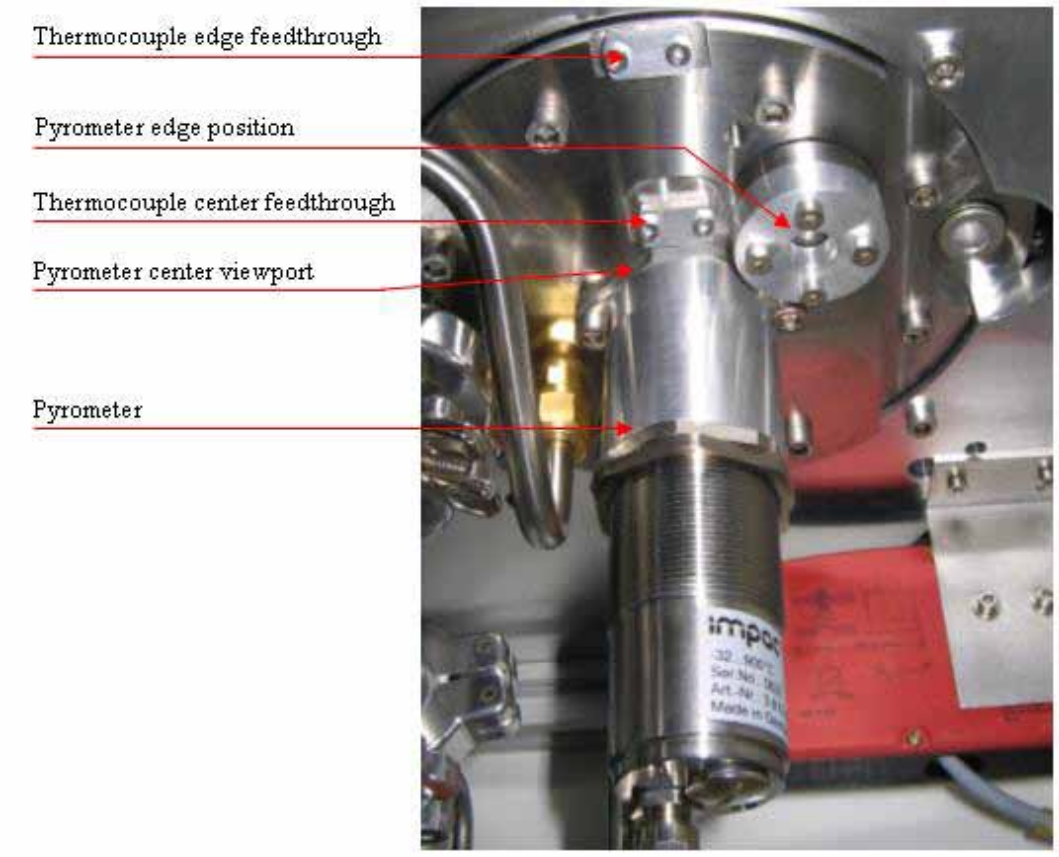
· Reflector:	Polished stainless steel
· Reflector cooling:	Water
· Number of lamps:	12
· Lamp cooling:	Fans
· Number of heating zones:	2
· Maximum power:	30 kW

5.5 Temperature measurement

The system is equipped with 2 thermocouples feedthroughs and two locations for pyrometer installation.

The system is equipped one pyrometer viewport. A second pyrometer viewport is available as an optional feature.

Location of the temperature sensors inside the system



5.5.1 Optical pyrometers

The system is provided with one optical pyrometer for high or low temperature control range (refer to the system specifications for the pyrometer type which is provided with this system).

The pyrometer measures the temperature from the backside of the substrate. Thanks to the special design of the reactor, the pyrometer only receives signal from the wafer and not from the lamps. This is the guaranty for an accurate temperature measurement.

There are two holes in the bedplate for the pyrometer installation. As a standard feature one hole is equipped with a viewport and the other one with a cap. The user can move the viewport and the pyrometer depending on the application.

The system cans receive two different types of pyrometer:

- High temperature pyrometer range: 400°C to 1300°C
- Low temperature pyrometer range: 150°C to 1000°C

The high temperature pyrometer is usually installed in the center of the bedplate and is used for direct temperature measurement on the wafers.

The low temperature pyrometer is usually installed on the edge and is used for the temperature measurement with graphite susceptors.

As an optional feature the AS-One can be equipped with 2 pyrometers.

The pyrometer requires a calibration made according to the K thermocouple. The calibration tables are saved on the computer hard disk. It is possible to save different tables for different substrate materials and to associate them to process recipes.

5.5.2 Thermocouples

5.5.2.1 Thermocouple utilization conditions

	**⚠ CAUTION** **Carefully read the thermocouple utilization conditions.** **Thermocouple utilization is restricted to some particular process conditions.** **Thermocouple may be rapidly broken if the utilization conditions are not fulfilled. The thermocouples are not covered by the warranty.**

Unsheathed K type thermocouples are sensitive to process gases and must be pre-treated to protect them. At first use, a process in air at 800°C for 5 minutes with a silicon wafer must be carried out to create an oxide sheath that protects the thermocouple wires. Failure to follow this procedure will result in a quick break when using the thermocouples in neutral atmosphere even below 1000°C.

Standard lead free thermocouples can be used from ambient temperature up to 1000°C and only with non-active gases and not reducing atmosphere. When they are used under other conditions, their lifetime is much shorter. For special process atmosphere Annealsys can provide sheathed thermocouples.

Sheathed thermocouples are usually provided with Inconel sheath. This material is compatible with most of process atmospheres. Anyway for utilization for sulfuration or selenization AISI 310 sheathed thermocouples must be used. Contact Annealsys if you need any further information.

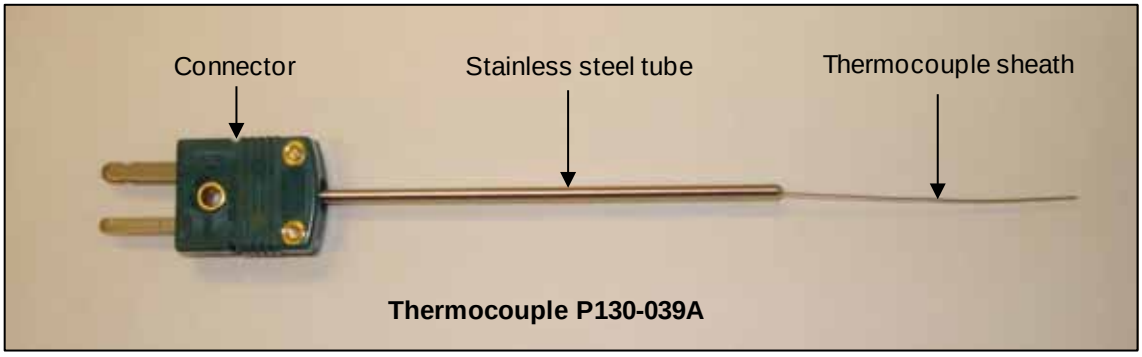
The thermocouples are used for pyrometer calibration and for some low temperature processes. Sheathed thermocouples can be used for susceptor temperature control.

- Thermocouple type: K
- Number of thermocouple: 2
- Thermocouple temperature range: Room temperature to 1000°C

One of the thermocouple can be use for the temperature control (connected to CONT cable). The other one (connected to READ cable) can be used only for temperature measurement.

The central thermocouple feedthrough is mainly used for pyrometer calibration. The edge feedthrough is mainly used for temperature control on susceptor using a sheathed thermocouple.

	**⚠ CAUTION** **Sheathed thermocouples** **The bending radius of the thermocouple sheath must not be less than 2 mm in order to avoid thermocouple breakage**

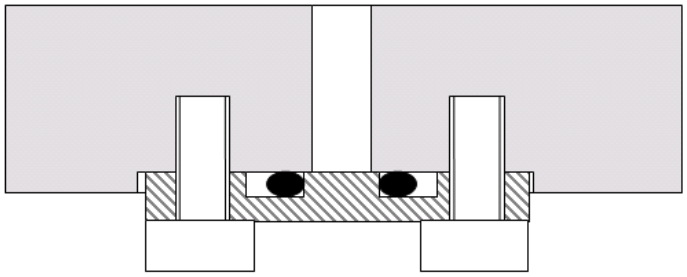


Thermocouple P130-039A

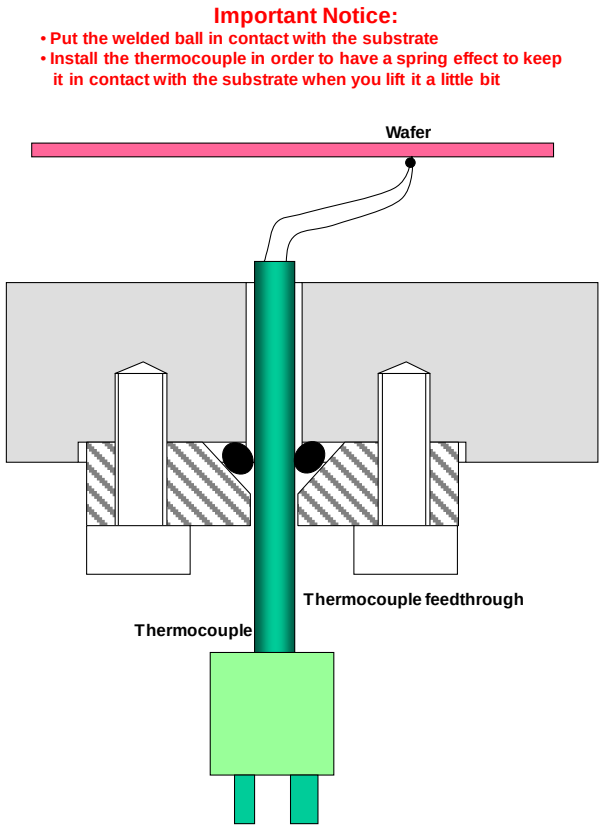
5.5.2.2 Thermocouple installation

The system is delivered with blank flanges on the thermocouple feedthroughs. They insure a perfect tightness of the chamber when the thermocouples are not installed. Each blank flange is installed with 2 screws and one O-ring.

Thermocouple blank flange



The blank flange must be dismantled in order to install the thermocouple. The thermocouple is installed using the special flange provided with the system. Install the thermocouple through the flange add one or 2 O-rings and install the thermocouple as shown on the following drawing.



Adjust the thermocouple height to have a good contact with the wafer.

Remove the thermocouple and reinstall the blank flange when the thermocouple is no more used.

5.5.2.3 Thermocouple installation with susceptor

A sheathed thermocouple must be used with the susceptor. The thermocouple is installed through the edge feedthrough of the bedplate as indicated above.

The end of the thermocouple is installed inside the small hole on the edge of the susceptor as shown on the following pictures. Push the end of the thermocouple until it comes in contact with the bottom of the hole (about 5 mm).

The thermocouple must be connected to cable TC1 for temperature control of the susceptor.

5.6 Temperature control

The system is provided with a state of the art fast digital PID temperature controller. The closed loop system with thermocouple or optical pyrometer provides repeatable and accurate temperature control. The system can also be used in power mode (open loop) for pre-heating steps of special applications.

- Temperature control accuracy: ± 1°C

5.7 Gas panel

The gas panel is located in the lower side of the system. It includes one purge gas line and up to 5 process gas lines with mass flow controllers.

The gas lines are made of stainless steel components with Swagelok 1/4 fittings (VCR upon request).

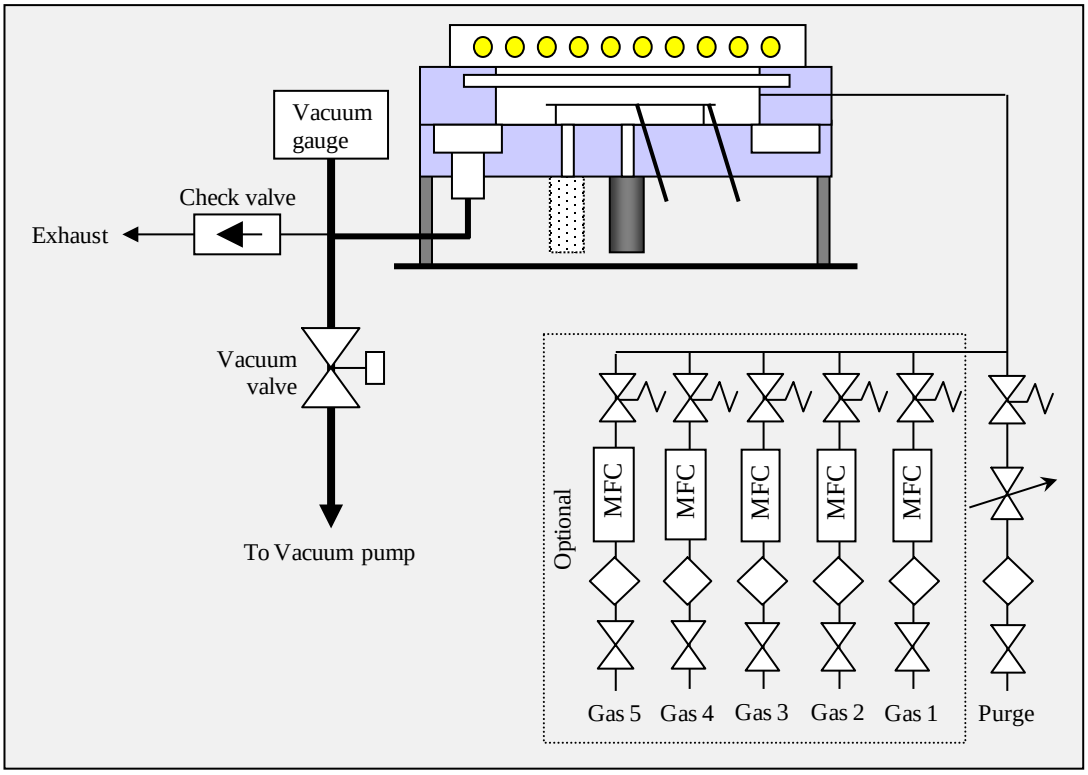
The system is provided with a purge gas line for the venting of the process chamber. The purge gas line can be used during the process. The purge gas flow is controlled by a needle valve.

The process gas lines are provided with mass flow controllers.

Purge gas line features:	Manual shut-off valve Filter 0.50 µm Metering valve Solenoid valve
Exhaust line features:	Check valve (one way valve)
Process gas lines features:	Manual shut-off valve Filter 0.50 µm Digital mass flow controller Solenoid valve

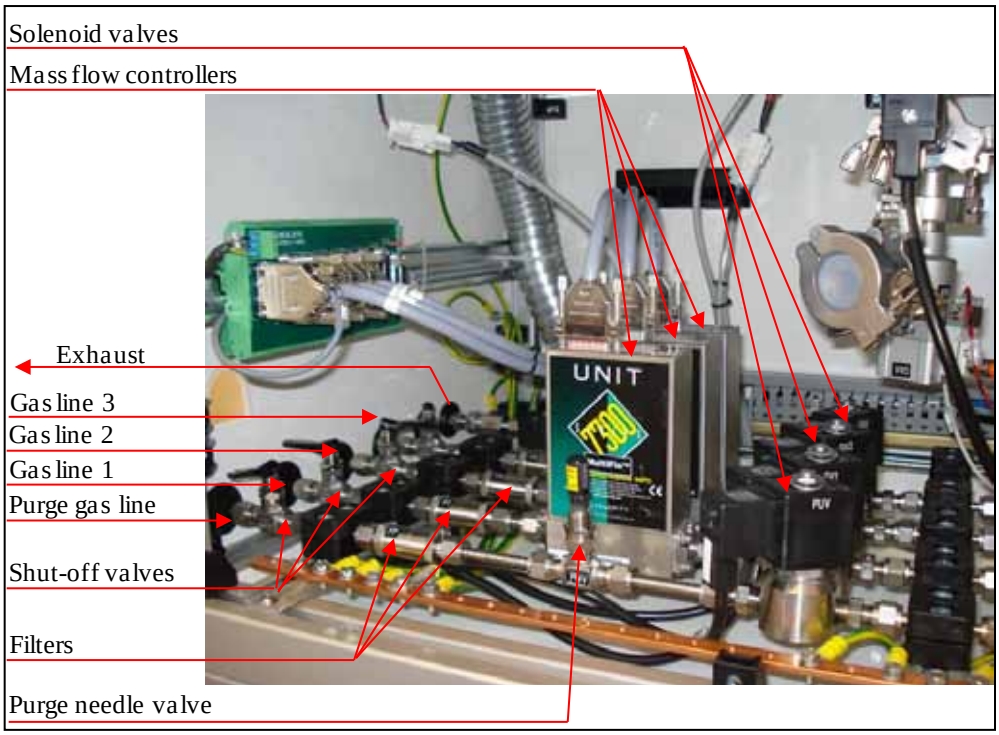
The system has full gas mixing capability. The valves and mass flow controller are fully controlled by the system. Gas flow can be changed at each step of a recipe.

Schematic diagram of the gas panel



Refer to the vacuum and gas technical manual for the exact number of gas lines of your systems, of the gas line natures and the mass flow controller ranges.

Location of the gas components inside the system



5.8 Vacuum equipment

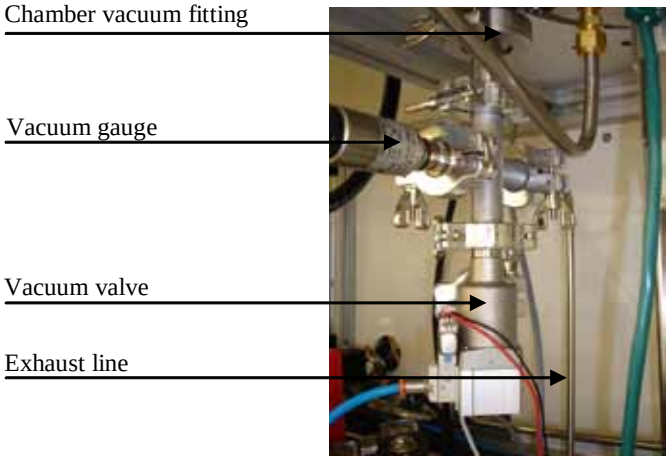
The system has high vacuum capability and can perform processes from vacuum to atmospheric pressure. Each step of a process can be performed under atmosphere or under vacuum if system is provided with necessary pumping equipment.

Standard vacuum features:

- DN16 solenoid bellows valve
- Constraint gauge 1000 mbar full range

The vacuum valve is controlled by the system and can be opened or closed at each step of a recipe.

The system can receive an optional turbomolecular-pumping unit upon request.



5.8.1 Vacuum pump option

The vacuum pump is an optional feature.

Annealsys proposes different vacuum pump as optional features. The vacuum pump should be selected according to the application.

Standard rotary vane pump can be used for evacuating the chamber. It can pump down neutral gases and air. This pump should not be used to pump down hydrogen or gas mixture with more than 20% of oxygen.

The Fomblin rotary pump can be uses with any type of gas and can pump down pure oxygen. It should be use with a gas ballast to pump down gas with more than 4% hydrogen concentration.

Scroll pump is oil free and provides the cleanest process conditions. This pump can be used for Air, neutral gases, pure oxygen and forming gas with up to 4% hydrogen concentration.

Other pumping equipment is available upon request.

Refer to the technical manual (Vacuum and gas) to check the actual pump that has been provided with the system.

When the vacuum pump is provided with the furnace, it is electrically controlled by the system. The pump is switched on and off when the furnace is switched on or off.

5.8.2 Capacitance manometer option

In addition to the existing vacuum gauge the system can receive a capacitance manometer. The capacitance manometer is used for the pressure control or with the turbo pump to get cleaner conditions.

The vacuum range of the capacitance manometer can be selected from 0.1 to 1000 Torr (Refer to technical manual to check the actual gauge range of your system).

The capacitance manometer is heated in order to insure a better reproducibility and a better reliability annealing process after annealing process.

The capacitance manometer is usually installed on the front side of the system and under the bedplate as shown on the following picture.

5.8.3 Utilization of hydrogen

⚠ WARNING

Hydrogen
The system is compatible with the utilization of pure or diluted hydrogen. However to hydrogen must be diluted to a maximum concentration of 4% at system exhaust and vacuum line to avoid any hazardous conditions and explosion.

In order to operate under safe conditions the hydrogen must be diluted in the exhaust and the vacuum line to a maximum concentration of 4%.

The system can be provided with a ballast line upon request. Supply the ballast line with nitrogen. The ballast line is equipped with a nitrogen ballast flow sensor and interlock.

If the RTP furnace is not equipped with a ballast line the user is responsible for the installation of the ballast according to the local regulation.

The process chamber must be pumped down before opening when hydrogen has been used during the process or in manual mode.

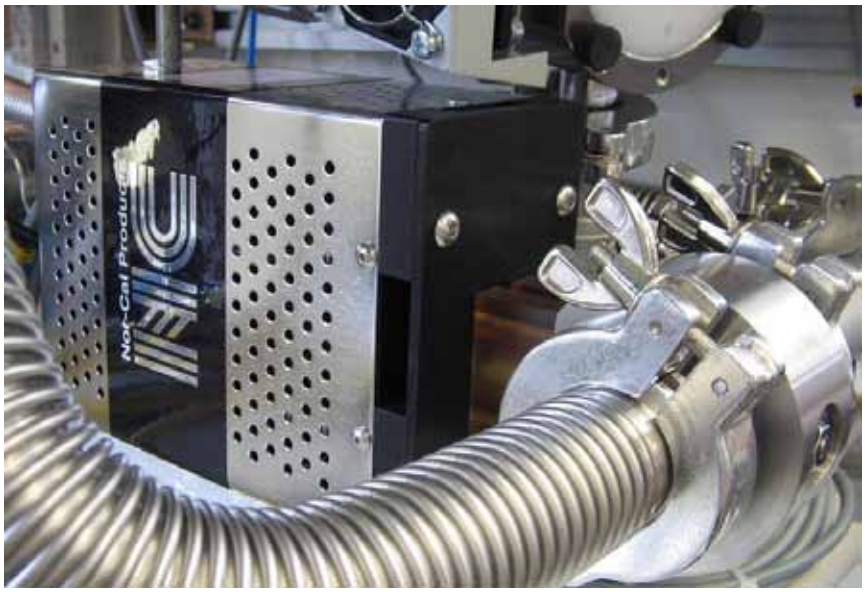
5.8.4 Pressure control option

The AS-One can receive a pressure controller with a throttle valve as an optional feature. The throttle valve is installed downstream the process chamber and the vacuum valve on the backside of the system. The pressure control system uses the signal of the capacitance manometer.

The pressure control option is installed with the capacitance manometer option.

The pressure controller is directly integrated on the top of the throttle valve. The valve is installed inside the furnace frame and under the bedplate.

Pressure control throttle valve with integrated controller



5.8.5 Turbo pump option

The system can receive an optional turbo-pumping unit for cleaning of the process chamber.

The turbo pump is installed in addition with a rotary pump or scroll pump that must be installed to pump down the chamber at high pressure. This pump is used as a forepump for the turbo pump.

The turbo pump is supplied and fully controlled by the system. It is equipped with an isolation valve. The turbo pump is air-cooled.

The turbo pump kit is entirely housed inside the frame of the AS-One.

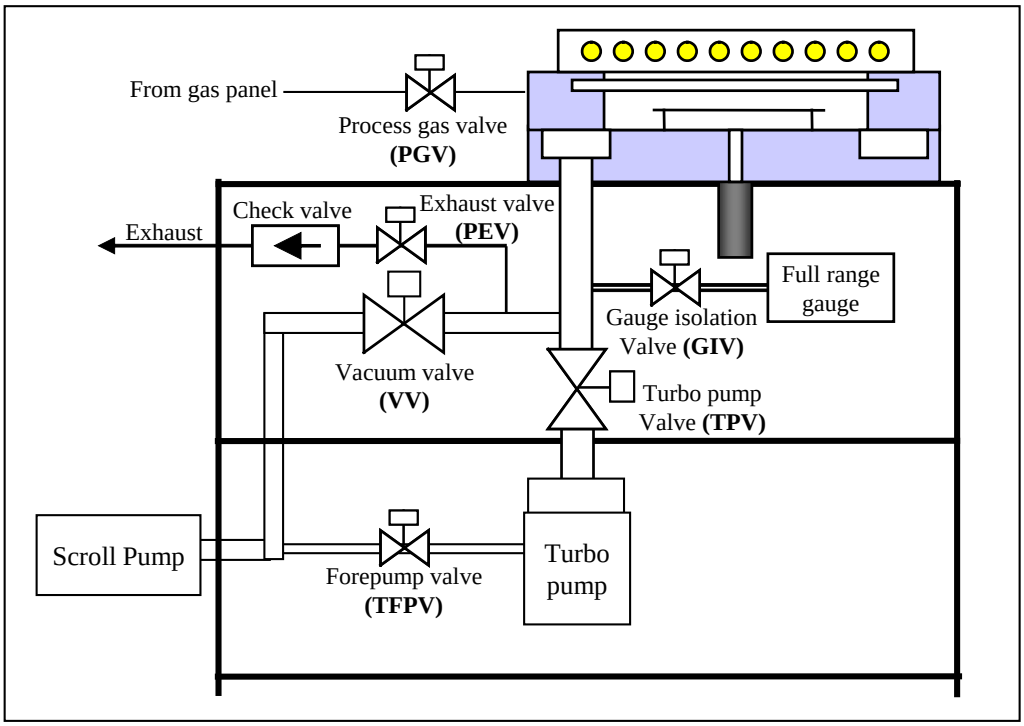
The improved tightness option is required with the turbo pump kit. It consists of isolation valve on reactor gas inlet (PGV) and outlet (PEV).

Turbo pump specifications:

- Pump manufacturer: Pfeiffer Vacuum
- Pump type: TMH 071 P
- Pumping speed for N2: 60 l/s
- Pumping speed for H2: 45 l/s
- Inlet flange: DN 63 ISO-KF
- Ultimate pressure of the pump: $< 10^{-8}$ mbar
- Forepump: Uses primary pump installed on the equipment
- Vacuum gauge: Full range gauge with isolation valve

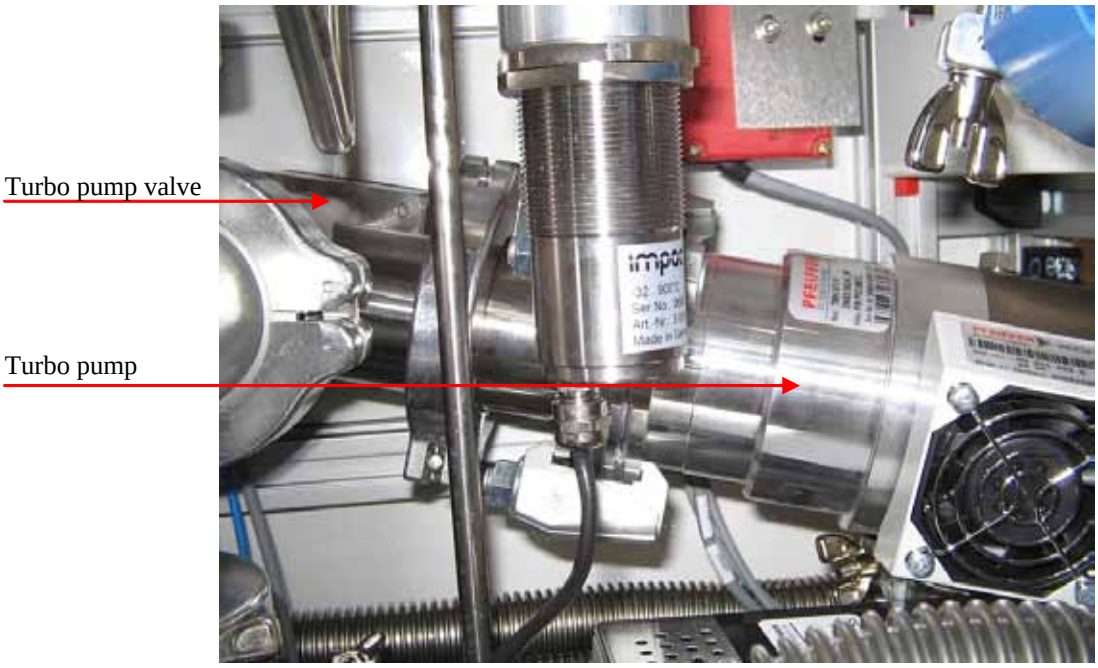
Note: The turbo pump will not start or stop automatically.
The user must start and stop the turbo pump using the manual mode.

Turbo pump installation diagram



The turbo pump kit includes:

- Turbo pump with controller, air cooling and isolation valve
- Full range gauge and isolation valve
- Pneumatic valve for forepump line
- Vacuum fittings, installation
- Full PC control



6. SYSTEM SPECIFICATIONS

6.1 Applications

- Implant annealing
- Contact Alloying
- Rapid Thermal Oxidation (RTO)
- Rapid Thermal Nitridation (RTN)
- Densification and Crystallization
- Glass reflow
- Silicidation
- Etc.

6.2 System characteristics

	AS-One 100
Maximum substrate diameter	100 mm
Chamber diameter	130 mm
Chamber height	25 mm
Number of lamps	12
Number of heating zones	2
Multi zone control	No
Temperature range	Up to 1250°C (1500°C for high temperature version)
Pyrometer port in center	Yes
Pyrometer port on the edge	Yes
K thermocouples	2
Gas injection	Under the quartz window
Purge gas line with needle valve	1
Process gas lines with mass flow controller	Up to 5
Vacuum valve and gauge	Yes

6.3 Performances characteristics

- Temperature range (standard version): Ambient to 1250°C
- Temperature range (high temperature version): Ambient to 1500°C
- High temperature pyrometer control range (Silicon): 400 °C to 1500 °C
- Low temperature pyrometer control range (Silicon): 150 °C to 1000 °C
- Thermocouple range control: Ambient to 1000 °C
- Maximum heating rate (silicon wafer 100 mm): 200°C/s
- Temperature accuracy: ± 2 °C
- Temperature reproducibility: ± 1 °C
- Cooling rate control: 0.01°C/s to physical limit
- Lamp time life: Depending on process, usually > 1000 hours

Lamp lifetime decreases with process temperature.

6.4 Maximum step duration versus temperature

The maximum process duration is shorter at high temperature due to the cooling capacity of the machine.

The maximum step duration values versus temperature are given in the following table. Depending on the different heating steps the maximum time for the highest temperature may be reduced.

It is recommended not to make a recipe with longer heating time for each temperature that the duration indicated in the table. Nevertheless the machine is equipped with thermal switches for overheating interlock and the system will automatically stop heating and process in case of too long heating process at high temperature. There is no risk for the machine or for the operator to make a recipe with a longer step that the duration given in the table.

AS-One 100 standard version:

Temperature	Maximum duration
1300°C	**60 s**
1250°C	**180 s**
1200°C	**5 mn**
1150°C	**6 mn**
1100°C	**7 mn**
1050°C	**10 mn**
1000°C	**12 mn**
900°C	**60 mn**
< 800°C	**3 hours**

AS-One 100 high temperature version:

Temperature	Maximum duration
1500°C	**30 s**
1400°C	**150 s**
1200°C	**15 mn**
950°C	**3 hours**

The operator must also select a temperature that is compatible with the temperature sensor that is selected for the temperature control. The sensor temperature ranges are typically:

- Thermocouple: 0 to 1000°C
- Low temperature pyrometer: 150°C to 1100°C
- High temperature pyrometer: 400°C to 1500°C

7. UTILIZATION

7.1 Before start-up

It is strongly recommended to read the whole user's manual before starting up the system.

Check that all the connections have been completed and that the furnace is supplied with:

- Electricity
- Water
- Compressed air
- Process gases

7.2 Start-up

Procedure to start-up the system:

- Switch on the general circuit breaker on the system backside
- Start the computer
- Press the green button to switch-on the AS-One
- Start the software on the computer

7.3 Open and close the process chamber

The chamber is locked by an electromagnetic locker. It is locked if the system is not powered on. If the chamber is locked use the software manual mode to unlock it.

To open the process chamber, pull the stainless steel handle and lift the chamber with the handle. The chamber is installed inside a rotating top lid. Two air springs keep the reactor in the open position.

⚠ WARNING

Mechanical pinch hazard
The system is tightly closed with the front handle. The closing system is manual but the user must keep the hands on the handle to close the chamber.
Always close the reactor with the 2 hands on the handle in order to avoid any pinch hazard.

To close the process chamber, take the stainless steel handle with 2 hands and gently pull it down. When the lid reaches the horizontal position slow down descend with the handle and pull the handle to you. When the chamber is in contact with the bedplate, firmly push the handle with 2 hands to tightly close the chamber.

⚠ WARNING

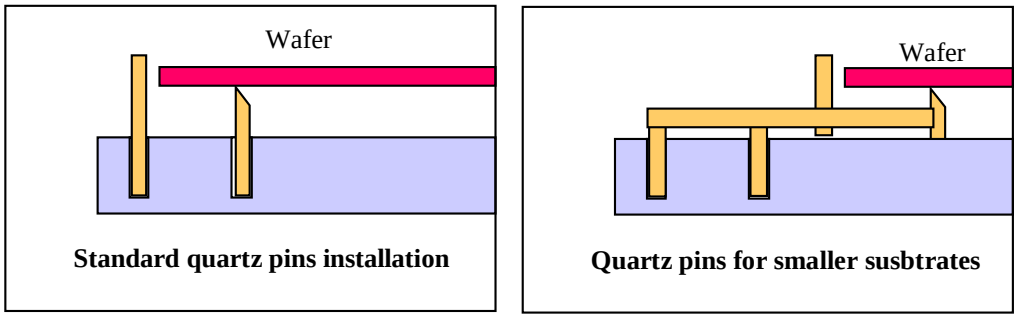
Burn hazard
Substrate and quartz window may be at high temperature.
After manual heating of after a process both substrate and quartz window may still be at high temperature.
Wait for sufficient cool down of the substrate for unloading.

7.4 Quartz pins installation

The substrate is held by 3 beveled quartz pins. Three other higher quartz pins are installed around the substrate in order to facilitate the positioning of the substrate during loading.

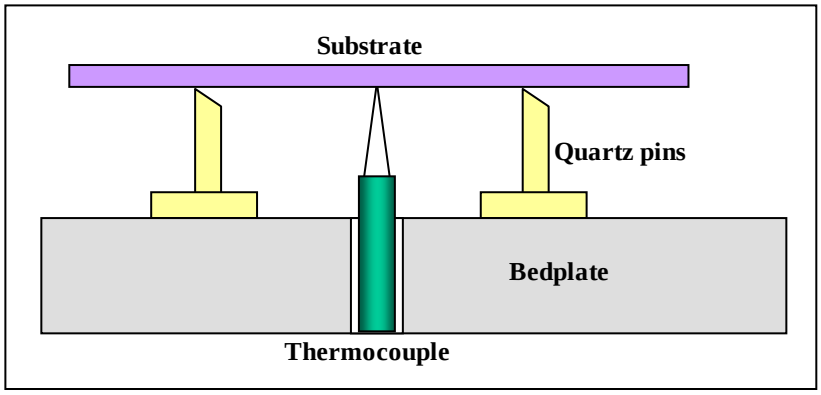
Just insert the quartz pins in the holes to install them.

Upon request Annealsys can provide quartz pins to hold smaller substrates. These quartz pins are installed using the same holes according to the drawing hereafter.



Quartz pins with drawing pin shape are available to hold samples of any size or shape.

These pins can be installed at any location on top of the water-cooled bedplate.



7.5 Wafer loading

Open the chamber and install the wafer (or susceptor) on the 3 beveled quartz pins. Use the 3 outer quartz pins to center the wafer inside the process chamber.

	⚠ WARNING	
	**Burn hazard** **After process both substrate and quartz window may still be at high temperature.** **Wait for sufficient cool down of the substrate for unloading. Wear high temperature gloves to load and unload the substrate inside the process chamber.**	

7.6 Quartz liner

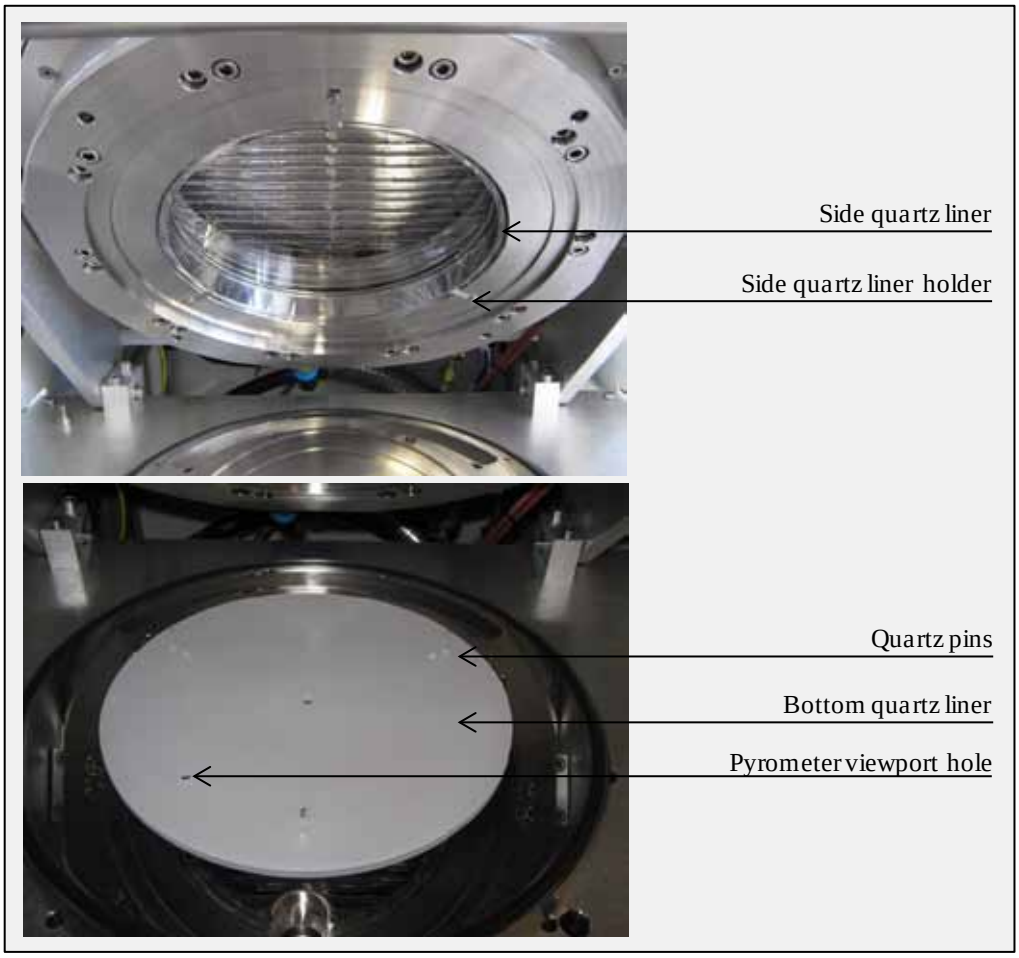
The chamber can receive a quartz liner as an optional feature.

The quartz liner is made in two parts: side quartz liner and bottom quartz liner.

The side quartz liner is a cylindrical part that is inserted inside the process chamber. This part is held by 3 small stainless steel holders bolded on the bottom side of the chamber flange and that come in the corresponding grooves of the quartz part.

The bottom liner just lies on top of the stainless steel bedplate and is positioned by the quartz pins.

The installation of the two parts is fast and easy.



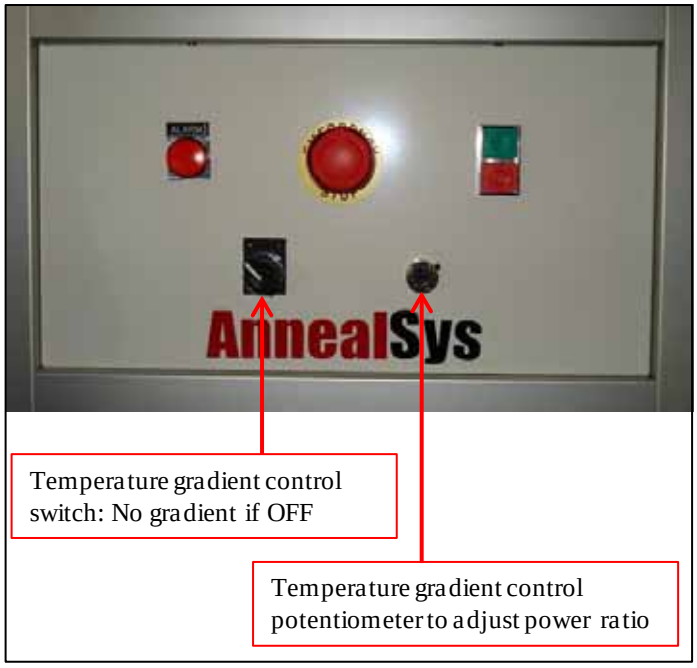
When installing the bottom quartz liner, check that the hole for the side pyrometer viewport is on top of the corresponding hole on the bedplate.

7.7 Temperature gradient option

For some special applications it is possible to generate a temperature gradient between to front part and the back part of the process chamber.

The gradient in controlled by setting a power ratio between the front heating zones (6 lamps) and the rear heating zone (6 lamps).

The temperature gradient is manually controlled by a switch and a potentiometer installed on the control panel.



When the switch is OFF, there is no temperature gradient and both lamp heating zones get the same power setpoint to have good temperature uniformity.

When the switch is ON, the power ratio between front zone and back side zone can be adjusted with the potentiometer.

8. SOFTWARE CONTROL ARCHITECTURE

The control system of the AS-One is made of:

- a PC which is the interface between the user and the equipment
- a PLC that controls process operation and safeties

The operator interface is a PC running under Windows XP Professional.

The PC and the PLC are connected by an Ethernet communication line.

A RS485 communication line between the PLC and the temperature controller allows entering the temperature control parameters to the temperature controller directly from the computer.

This control architecture offers high reliability and easy operations. The AS-One can run the process under safe conditions even if there is a problem with the PC.

9. SOFTWARE UTILIZATION

The software utilization is described in a separated manual according to each software version.

Refer to the software manual for the utilization. The software manual describes most of the utilization of the AS-One furnace.

There is no run-time license rights on the Annealsys software and it can be installed on several computers.

10. PROCESS

⚠ WARNING

PROCESS INFORMATION
The user must carefully read the following instructions.
The user must also read the process recommendations and take necessary steps to operate the system in a way that will not damage the samples, the susceptor or the tool.

10.1 Information on infrared heating furnace

The RTP furnace is using radiation heating. This means that the heat is transferred from the lamps to the substrate by infrared radiations.

The pyrometer receives infrared radiation emitted by the substrate. It does not receive infrared radiation from the lamps thanks of the chamber design and the selected wavelengths.

The thermocouple measures the temperature of the material that is in contact with the hot junction (means the welding point of the 2 different materials that make the thermocouple).

If there is no substrate inside the furnace it cannot work properly because the temperature sensors are not able to measure any actual temperature and will only measure a limited temperature increase for the environment. The pyrometer does not receive infrared radiation from the lamps. The thermocouple receives a limited amount of heat directly from the lamps. If there is no substrate inside the process chamber the temperature control cannot operate correctly as temperature sensors will measure a small temperature increase even if there is a high heating power. The furnace may apply full power to the lamps for a relatively long time. Even if there is a safety interlock that checks discrepancies between the setpoint and the actual temperature and generates an alarm, there is a risk to damage the infrared lamps.

The furnace must not be operated without a substrate inside the process chamber

It is also better not to set the furnace in power mode at 100%. Typically the heating power is below 50% for most of the processes. Utilization of the power mode must be used with great care and after checking values from some process historical. Otherwise it may lead to substrate damages.

10.2 Ramp rate limitations

The RTP tool is working in radiation heating mode and there are some limitations in term of ramp rate depending on the dwell temperature setpoint.

The AS-One 100 has a maximum heating rate of 200°C/s on 100 mm diameter silicon wafers.

The heating rate must be limited to 50 C/s when using a susceptor. For a long lifetime of the susceptor we recommend to run processes with a maximum heating rate of 20°C/s.

The infrared heating law is that the heating power is proportional to the power 4 of the temperature (in Kelvin): Power = k.(Temperature)^4. This means that at low temperature the heating power is extremely low (few percents of the full power). If the user programs a fast ramp then the system applies full power and due to the thermal inertia of the furnace lamps there is a high overshoot if the dwell setpoint is at a low temperature requiring a typical heating power of few percents.

If dwell is at high temperature it is possible to have fast ramp rates without overshoot. If dwell is at low temperature the ramp rate must be reduced. This is due to physical limitations independent from the furnace. It is not possible to run a process with 150C/s ramp and dwell at 300°C. The user must select the heating ramp rate according to the dwell temperature level. The phenomenon is amplified with a susceptor as the thermal inertia of the substrate is higher.

10.3 Recipe download

The process parameters (recipe, calibration tables, PID table and configuration) are saved on the computer's hard disk. During the process the system is controlled by the PLC and the data must be downloaded to the PLC before starting the process.

If one parameter from a recipe or one of the associated tables or of the configuration has been modified, it is necessary to download again the recipe in order for the system to take into account the modification in the new process.

10.4 Substrate loading and unloading

⚠WARNING

Burn hazard
Quartz window may be at high temperature if some process has been performed before loading or when unloading the substrate.
Wear high temperature gloves to load and unload the substrate in the process chamber.

Before starting the process the user must load the sample and close the chamber.

During the process the chamber is locked.

10.5 Substrate installation

If the substrate is processed without a susceptor if must be installed on top of the quartz pins.

The substrate must not be installed directly on the bedplate because it could not heat.

There are typically 3 holding quartz pins that hold the substrate and 3 centering pins that help the operator to install the substrate at the right position inside the process chamber.

There is some clearance between the substrate and the centering pins. The operator must check that the substrate covers the edge pyrometer viewport hole in case the edge pyrometer is going to be used for process temperature control. Otherwise temperature measurement may be altered and the process may lead to sample damage (overheating).

If a susceptor is used for the process the susceptor must be installed on the quartz pins as explained above. The sample is installed inside the susceptor cavity. The operator must check that the cavity is deep enough and that the susceptor cover is not going to touch the sample when it comes on top.

10.6 Thermocouple installation

The thermocouple must be installed if it is going to be used for the temperature control during the process.

If the susceptor is used the sheathed thermocouple end must be installed inside the small hole on the susceptor edge.

If susceptor is not used the operator must carefully check thermocouple installation and that there is a good contact between the thermocouple extremity (measuring point) and the substrate.

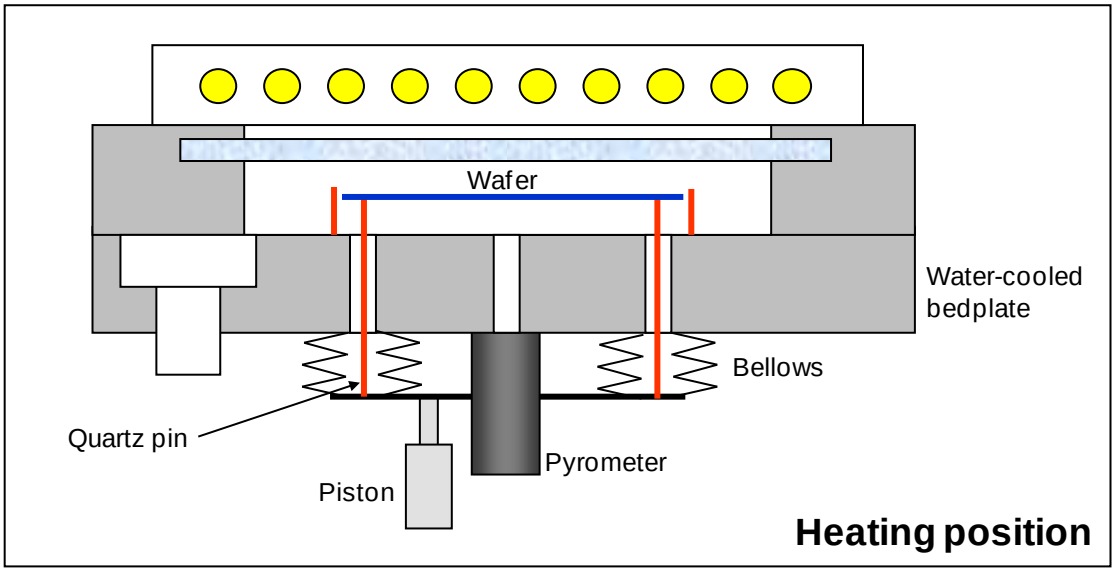
10.7 Fast cooling kit

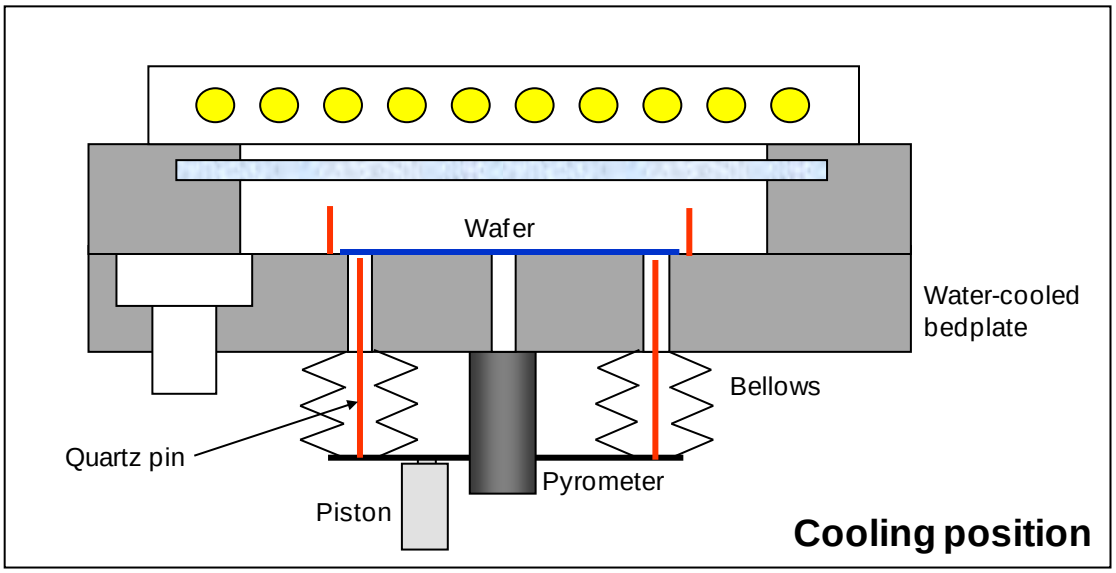
When this option is installed, the system receives a special bedplate which is equipped with a mechanism to move the holder quartz pins up and down during the process.

This feature allows putting the sample in contact with the stainless steel water-cooled bedplate at the end of the heating step and to cool down the sample to the room temperature in few seconds.

The quartz pins are installed inside stainless steel bellows and system can operate under atmospheric pressure or under vacuum.

This system is fully recipe controlled and can be activated at any time during the process.





The fast cooling system is only compatible with 4-inch substrates

	**⚠ CAUTION** **The quartz pins must be in upper position for heating.** **The quartz pins must usually be in upper position for heating. If quartz pins are in lower position most of the substrate will not heat even with full heating power and this may lead to lamp damage.**

11. SYSTEM SHUT DOWN

The system shut-down is performed using the following procedure:

- Shut down software
- Switch-off the system
- Shut down the computer
- Equipment isolation
- Verify isolation

11.1 Shut-down software

If the system is equipped with a turbo pump stop the turbo pump using the manual mode before system shut-down. If the software is temporary shut-down but not the system, then the turbo pump can remain running.

⚠ CAUTION

Turbo pump control

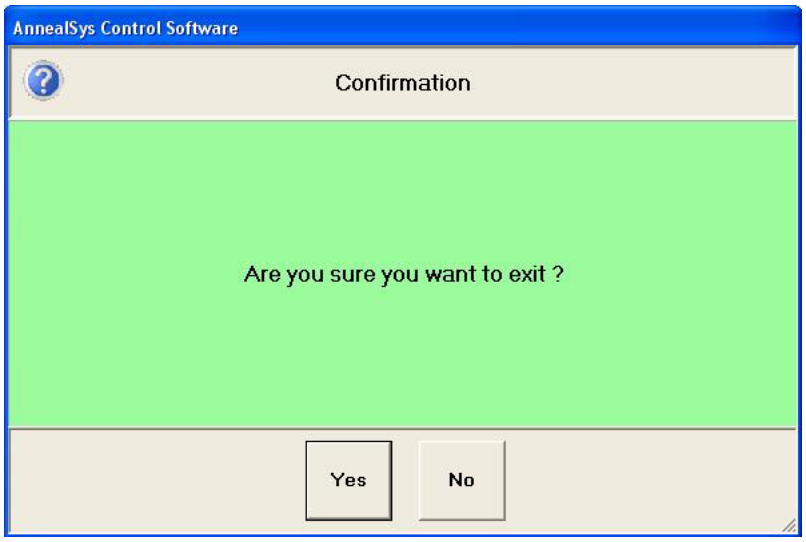
If the furnace is equipped with a turbo pump and if the furnace is going to be stopped, then the turbo pump must be stopped using the manual mode before switching off the furnace.

The PC software can be shut-down without stopping the turbo pump if the furnace is not going to be switched off.

The software can be shut-down using the "Shut-down" button in the main navigation bar or by a right click on the mouse.

The PC software can be stopped even if the machine is running. Nevertheless it is recommended to stop both PC and machine.

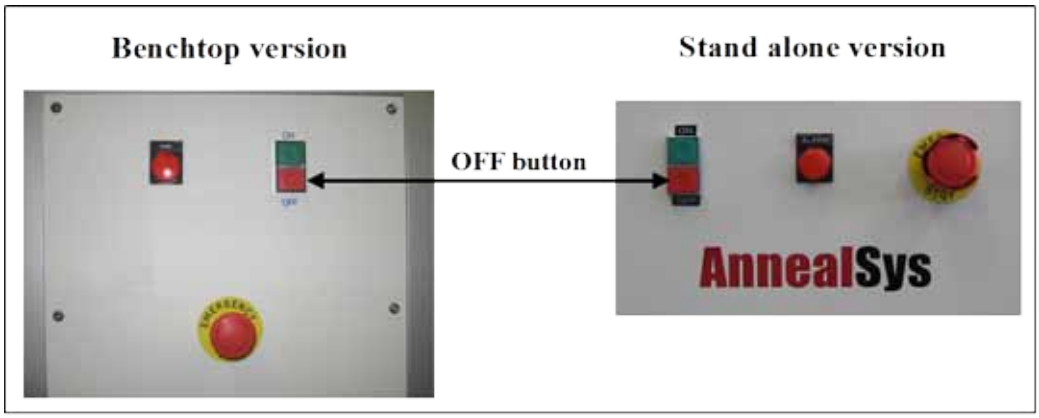
The system will ask for shut-down confirmation:



Confirm by "Yes" to exit.

11.2 Switch-off the system

Switch-off the system by pressing the red OFF button on the front panel.



11.3 Shut down computer

The computer is usually supplied by the sockets installed on the system backside. When the general circuit breaker is switched off these sockets are de-energized.

The computer must be shut down before switching off the general circuit breaker and isolating the system.

11.4 Equipment isolation 3x220V version

The equipment can be isolated using the general circuit breaker on the backside panel.

For the 3x220V version: Turn the handle on the left side (white part on top the circuit breaker is ON).

Circuit breaker ON

Circuit breaker OFF

Lockout of the circuit breaker:

The circuit breaker can be lockout when it is in off position. Pull the small plastic slider to open the hole for the installation of a padlock.

11.5 Equipment isolation 3x400V+N version

The equipment can be isolated using the general circuit breaker on the backside panel.

For the 3x400V+N version: Push the handle down.

	
Circuit breaker ON	**Circuit breaker OFF**

When the circuit breaker is in OFF position the locking device that is provided with the system can be installed with a padlock to lock the general circuit breaker in isolating position.

Insert the 2 metallic end of the locker inside the small groove in the black part on the circuit breaker handle and under the white enclosure as shown on the picture. Then push the orange plastic part and install a padlock between the orange part and the metal ring.

11.6 Stored energies

The power blocks include power capacitors but they are equipped with resistors to dissipate stored energy. It takes less than 2 seconds to relieve the stored energy. The power blocks can be dismantled without risk after the system has been isolated.

11.7 Verify isolation

In addition of the general circuit breaker it is recommended to isolate the equipment supply line and to check that there is no more energy by measuring the voltage on the supply cable terminal.

	**⚠ WARNING** **Electrical shock hazard** **If the power line is not isolated the supply cable terminal and wired to the main circuit breaker will remain energized.** **The service operations must be carried out by trained and authorized technicians only.**

If the power line remains energized the isolation of the system from the general circuit breaker can be checked on control circuit breaker and power contactor inlets.

12. THERMOCOUPLE CALIBRATION

⚠ CAUTION

Thermocouple calibration table.
A wrong thermocouple calibration table can lead to unexpected thermal behavior of the system.
Always take great care to enter the calibration table parameters. The calibration must only be carried out by trained technicians.

For each recipe the operator can associate a thermocouple calibration table. This feature can be used for special applications.

The system is provided with K type thermocouples and temperature sensor interface board as standard features. The K type thermocouple calibration table is set at Annealsys facilities using a thermocouple calibrator in order to correct the thermocouple amplifiers error. It should usually not be modified by the user.

For special applications and requirements about thermocouple calibration table contact Annealsys.

13. PYROMETER CALIBRATION

⚠ CAUTION

Pyrometer calibration
A special care must be taken in creating or modifying the pyrometer calibration tables.
The modification of the configuration parameters and especially of the calibration tables may have a big impact on the system thermal behavior.
These operations must only be carried out by trained technicians.

13.1 Why doing a pyrometer calibration?

Pyrometer calibration is an essential operation. A good temperature measurement will result from the quality of the calibration.

The pyrometer is a sensor that receives infrared radiation from the substrate and converts it into an electric signal. This signal is then converted in a digital value by the PLC. The quantity of radiation received by the pyrometer depends on:

- Substrate nature (Silicon, GaAs, Graphite, etc.)
- Doping of the substrate
- Nature of layers on substrate surface (oxide)
- Temperature of substrate

The calibration table allows the system to know the relationship between the pyrometer signal and the substrate temperature. Many calibration tables can be saved on the computer hard disk. For each recipe it is possible to associate a calibration table depending on the substrate to be used and the process conditions.

Usually the calibration does not change for the same type of substrate. If calibration changes check that:

- The pyrometer window is clean
- The pyrometer emissivity has not been changed
- The type of substrate is the same (with no additional layers on it)
- Process parameters have not been changed

13.2 Materials

Some substrates, especially GaAs, may have their optical properties definitely changed if they reach some temperature levels. The calibration must be always performed with a substrate with the same "thermal past" than the substrates that have to be processed in the system with the same calibration table.

Note that Silicon and GaAs are transparent for infrared at low temperature. For this reason the thermocouple can see the lamps through the wafer at low temperature. This may impact on thermocouple temperature measurement below 600°C when using high power. Calibration at low temperature should be performed using low ramp rates and low heating power.

Graphite is not transparent at infrared radiation even at low temperature. When using susceptor it is possible to run low temperature pyrometer calibration down to room temperature.

14. TEMPERATURE CONTROL

The system is provided with a state of the art fast digital PID temperature controller. The closed loop system with thermocouple or optical pyrometer provides repeatable and accurate temperature control. The system can also be used in power mode (open loop) for pre-heating steps of special applications.

- Optical pyrometer: 1 (2 in option)
- Thermocouple: 2 K type
- Control: Fast digital PID temperature controller

Standard lead free thermocouples can be used from ambient temperature up to 1000°C and only with non-active gases and under none reducing atmosphere. When they are used under other conditions (with H_2 for example), their lifetime is much shorter. For special process atmosphere Annealsys can provide sheathed thermocouples.

The system is provided with one optical pyrometer for high or low temperature control range. The pyrometer measures the temperature from the backside of the substrate. Thanks to the special design of the reactor, the pyrometer only receives signal from the wafer and not from the lamps. This is the guaranty for an accurate temperature measurement. Pyrometer ranges:

- High temperature pyrometer range (silicon wafer): 400°C to 1400°C
- Low temperature pyrometer range (silicon wafer): 150°C to 1100°C

The pyrometer requires a calibration made according to the K thermocouple. The calibration tables are saved on the computer hard disk. It is possible to save different tables for different substrate materials and to associate them to process recipes.

The system can receive a second pyrometer as an optional feature.

14.1 Thermocouples

One thermocouple can be used for temperature control (CONT cable). The thermocouples give a few millivolts signal for a measured temperature. This voltage is amplified by a special interface board.

A second thermocouple can be used for temperature measurement (READ cable).

Threads are mounted in a stainless steel sheath and connected to a compensated plug. Tightness is obtained by an epoxy paste. Two stainless steel feedthroughs with Viton O-ring located in the bedplate allow easy installation of the thermocouples.

Note: The lifetime of lead free thermocouple is dramatically reduced in reducing atmosphere. The welding has some oxide that protects it and that will be removed in reducing atmosphere. The lifetime can be as short as few process cycles. For reducing atmosphere or any atmosphere with thermocouple resistance issue Annealsys can provide sheathed thermocouple. The Inconel sheath offers a good resistance to different type of gas atmospheres.

Sheathed thermocouples must be used for temperature control of susceptors.

14.2 Optical pyrometer

System is provided with one optical pyrometer for high or low temperature control range. The pyrometer looks at the backside of the substrate and only receives signal from the wafer (or susceptor) and not from the lamps.

For accurate and repeatable temperature control, check the pyrometer calibration regularly. If the system is used with a new type of substrate a pyrometer calibration must be performed.

An additional pyrometer can be provided as an optional feature.

14.3 Thermocouple range and pyrometer calibration

It is not possible to use the K type thermocouple up to1400°C because it will shortly break if it is used over 1000°C and melt over 1200°C. The thermocouple should usually not be used over 1000°C to have a good lifetime.

There are big emissivity changes of semiconductor materials below 800°C but the emissivity is relatively stable over 1000°C. One can consider that the calibration curve is linear over 1000°C and up to 1400°C.

15. SAFETY

15.1 Emergency switch-off

The system is equipped with an Emergency switch (EMO) on the front panel.

This switch shut down the machine when it is pushed. It can be activated at anytime in case of emergency. There is no risk for the tool even if it is switched-off during a heating cycle.

Turn the EMO red button in the clockwise direction to release it.

15.2 PLC watchdog

The PLC is equipped with a watch dog interlock that controls an internal contact.

When the operator closes the rear panel general circuit breaker, the PLC runs a diagnostic routine that takes several seconds. When the initialization cycle is completed the alarm indicator turns to red and the system can be switched on using the green push button. The alarm can be reset after powering up the system by clicking on the alarm indicator on the software screen. Otherwise it will be automatically reset when the first process is performed.

Each time the system is switched off (by the red push button); the alarm indicator turns to red to inform the user of a system power off.

If there is any diagnostic problem of the PLC when the system is running then the watch dog interlock is activated and the power is automatically shut-down by hardware interlock.

15.3 Hardware interlocks

There are some hardware interlocks that automatically switch off the power contactor in case of alarm. When power contactor is off there is no more power to the lamps. Other sub-systems (including cooling) are still powered on.

The hardware interlocks that are necessary to operate the power contactor are:

- Thermal switches on the lamp reflector and inside furnace cover (overheating interlock)
- Water flow switch (insufficient water flow interlock)

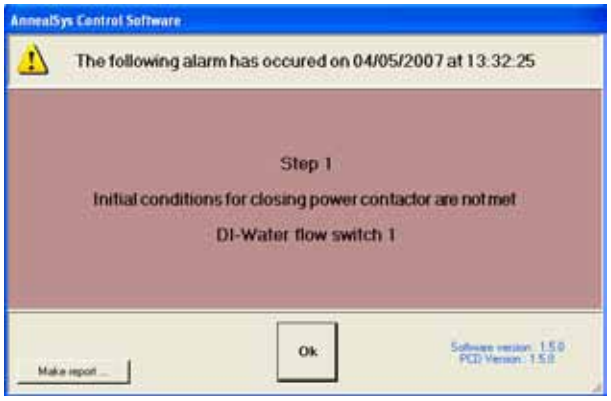
These interlocks are also software interlocks.

15.4 Software interlocks

During process the system checks safety interlocks that are listed in the table hereafter.

If any utilization condition is not fulfilled the system generates an alarm, the process stops and the system runs a cooling and a purge sequence to clean the process chamber.

The screen displays an alarm message:



The user must press OK to acknowledge the alarm when the alarm message is displayed.

The problem must be fixed prior to any new process.

Note that the Alarm light is switched on when an alarm occurs. This Alarm light is switched off as soon as the operator acknowledges the alarm by clicking on OK button.

The user can automatically generate an alarm report that is automatically copied in the clipboard. This report can be saved in another file or copy into an email to Annealsys customer support.

The alarms are saved in an alarm list that can be displayed by the user.

AS-ONE : List of alarms(20)

Date	Time	Description
27/04/2007	11:07:39	Host requested to stop
27/04/2007	11:09:56	TC1 is broken
27/04/2007	11:20:50	TC1 is broken
27/04/2007	11:23:35	Host requested to stop
27/04/2007	11:28:36	Host requested to stop
27/04/2007	11:47:57	Host requested to stop
27/04/2007	17:02:04	Host requested to stop
30/04/2007	10:25:21	Cooling was expected DI-Water flow switch 1
30/04/2007	10:49:24	Host requested to stop
30/04/2007	11:37:48	Gas 1 band alarm
30/04/2007	11:41:29	Gas 1 band alarm
30/04/2007	18:03:30	End of step condition found at step time 0
04/05/2007	13:29:10	Air pressure failure
04/05/2007	13:32:25	Initial conditions for closing power contactor are not met DI-Water flow switch 1
04/05/2007	13:45:13	Vacuum failure Open TFPV
04/05/2007	17:31:44	Air pressure failure
04/05/2007	18:27:34	Initial conditions for closing power contactor are not met DI-Water flow switch 1
04/05/2007	18:31:03	Air pressure failure
04/05/2007	18:55:54	Air-Gas 1 mixture interlock
04/05/2007	19:07:31	No on going alarm

The interlocks of the system are described in the software manual.

16. PROCESS RECOMMENDATIONS

16.1 Temperature uniformity

The temperature uniformity depends on several parameters. In the AS-One the temperature uniformity depends on:

- Reactor design
- Temperature
- Utilization of a susceptor
- Gas flow

The reactor has been designed in order to provide the best temperature uniformity for the standard wafer size.

The position of the substrate on the quartz holder inside the process chamber has been determined in order to give the best temperature uniformity using the reflection on the flanges and the chamber geometry.

The quartz pins that hold the substrate are beveled to reduce the thermal contact with the substrate and to reduce the cold points on the substrate.

The utilization of the susceptor will improve the temperature uniformity but it will reduce the heating and cooling rates because of a high thermal inertia.

The gas flow may impact on the temperature uniformity. Annealsys recommend reducing or stopping the gas flow during the heating steps. The chamber is 85 mm diameter. The cross section of the chamber is 56.7 cm^2 and a gas flow of 100 sccm will give an average gas flow speed of more than 1.75 cm/s at atmospheric pressure.

16.2 Using a susceptor

16.2.1 Silicon carbide coated graphite susceptors

Annealsys provides optional SiC (silicon carbide) coated graphite susceptors for heat treatment of small samples or compound semiconductors.

Susceptors are made out of graphite because of:

- Good mechanical properties at high temperature
- Good thermal conductivity for homogeneous temperature
- Excellent resistance to thermal shock
- Low thermal mass for fast heat-up rate
- Low level of metallic impurities

Graphite however is porous and may release graphite dust. In order to prevent this and to further increase purity, the susceptor is coated with a silicon carbide layer, by a CVD process. Proper selection of the graphite ensures a good adhesion of the coating and resistance to thermal shock.

Silicon carbide (SiC) is a hard and inert ceramic material. The chemical resistance of SiC is extremely good. The SiC is resistant to oxidation in air up to a temperature of 1800 C. During HCl etching (for cleaning), SiC is not thermodynamically stable. The kinetics however are such that even after thousands of etch cycles, no reduction of the SiC coating thickness can be measured. Conditions that enhance etching of the SiC coating are reduced pressure and the presence of metals.

⚠ CAUTION

Maximum temperature for SiC coated graphite parts.
The silicon carbide coated graphite susceptors and lids can be used up to 1250°C.
Utilization a higher temperature may lead to damage of the SiC layer.

16.2.2 Graphite susceptors without silicon carbide coating

Graphite susceptors and lids without SiC coating are available upon request. These parts must not be used under oxidizing atmosphere otherwise they will burn during the process.

There parts are made of purified, very fine grain, high density, graphite, with a very low permeability.

Graphite susceptors and lids are more resistant to thermal stress and less expensive than coated parts.

16.2.3 Susceptors made of bulk silicon carbide

Graphite susceptors and lids made of bulk silicon carbide are available upon request. These parts can be used under the same condition than the SiC coated parts. There is no risk for carbon contamination in case of degradation of the surface.

There parts are anyway sensitive to thermal stress and much more expensive than SiC coated parts.

16.2.4 Temperature control with the susceptor

⚠ CAUTION

The susceptor and susceptor lid are sensitive to temperature gradients.
High ramp rates generate high temperature gradients that may lead to crack into the susceptor or lid coating cracks and breakage of the parts.
Do not use heating rate over 50°C/s and avoid power peaks with susceptors.
User must take steps to avoid thermal stress to the susceptor and lid and must carefully read the user's manual before performing any process.
Only use edge thermocouple or pyrometer for susceptor temperature control.
The susceptors and lids are not covered by the warranty.

The silicon carbide coated susceptors and lids as well as the bulk silicon carbide susceptors and lids are very sensitive to thermal gradient that generate stress into the parts. For this reason it is important to follow the recommendation hereunder for processing with these parts and have an extended lifetime of the susceptor and the lid.

The most current reason for thermal stress is fast ramping and high power peaks of the lamp furnace.

16.2.4.1 Ramp rates

The maximum ramp rate with a susceptor is 50°C/s. It is any way recommended to limit the ramp rate to 20°C/s for an extended lifetime of the susceptor and lid especially if the process temperature is below 700°C.

Higher ramp rates can be used for high temperature processes but will impact on the susceptor and lid lifetime.

16.2.4.2 Avoid power peaks

High power peaks may occur at the beginning of the heating cycle. These peaks lead to high stress into the susceptor and especially the lid.

To avoid power peak in thermocouple control mode:

- Install the sheathed thermocouple into the susceptor hole on the edge
- Connect the thermocouple to TC1 cable (temperature control is TC1 only)
- Select a PID table for susceptor and thermocouple control
- Select thermocouple temperature control in the recipe from step 1
- Make a step 1 of 10 seconds without heating
- Limit the ramp rate to 20°C/s

To avoid power peak in pyrometer control mode:

- Use the edge pyrometer (typically low temperature type) for the temperature control
- Be sure that the susceptor covers the edge pyrometer viewport hole
- Select a PID table for susceptor and pyrometer control
- Start the heating cycle with a power mode step: typically 8% until pyrometer reaches 150°C to 200°C. Power and temperature setpoints must be increase if a high temperature pyrometer is used.
- Make a step at 150°C to 200°C for temperature stabilization. Temperature setpoints must be increase if a high temperature pyrometer is used
- Limit the ramp rate to 20°C/s

16.2.4.3 Autotuning

Do not perform autotuning with susceptor. Only use available PID tables for susceptor or contact Annealsys. During the autotuning the temperature controller applies several power peaks that lead to thermal stress to the susceptor and reduce the susceptor lifetime.

16.2.5 Using the susceptor with the lid

The thermal exchanges and thermal inertia are quite different when using a susceptor than using a single wafer. For this reason some precautions must be taken for the temperature control of the susceptor.

The susceptor is normally used with the lid (cover) and the substrate is installed inside the graphite box made by the susceptor and the lid.

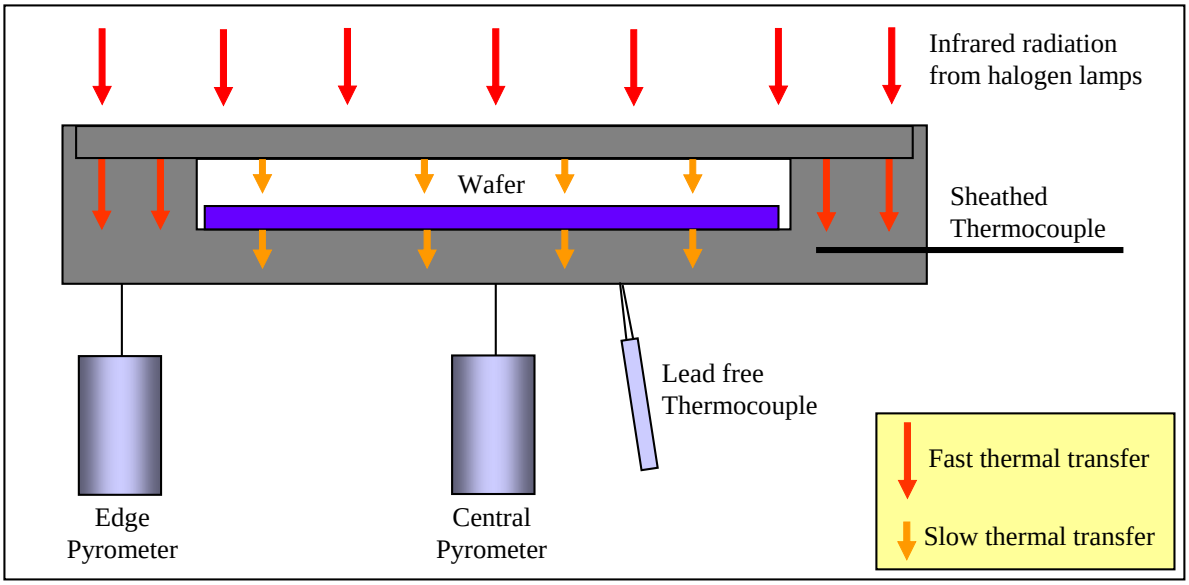
There is a small hole on the edge of the susceptor that allow installing a sheathed thermocouple close to the substrate. The thermocouple is usually used for the pyrometer calibration but can be use for the process as well.

The advantage of using the pyrometer for the temperature control is to avoid any contact of metallic part with the susceptor that may lead to pinhole formation and reduced lifetime of the susceptor. In addition the pyrometer control provides a non contact temperature measurement and does not require checking installation of the temperature sensor at each process like with the thermocouple. The thermocouple also has a limited lifetime when the pyrometer has an unlimited lifetime and much better long term reproducibility.

The graphite box creates a nearly isothermal environment to the substrate and provides excellent temperature uniformity.

The standard location of the pyrometer is on the center backside of the substrate. When single silicon or other semiconductor wafer is used there is a fast transfer of the energy from the lamps through the wafer (topside to backside) and a short response time of the temperature sensor (pyrometer) that give fast feedback to the temperature control loop. With the susceptor the situation is different.

Thermal transfer with susceptor and lid



When the susceptor is used with the lid the temperature transfer in the center is:

- Heating of the top side of the lid by the lamps
- Transfer of the heat through the lid
- Heating of the substrate by radiation from the lid
- Transfer of the heat through the wafer
- Transfer of the heat from the wafer to the susceptor top side by conduction and radiation
- Transfer of the heat through the susceptor

So in the center the heat transfer is relatively long from the lamps to the susceptor backside. This leads to delay in the temperature control loop and may lead to oscillations and temperature overshoots.

On the edge the thermal transfer is much faster:

- Heating of the top side of the lid by the lamps
- Transfer of the heat through the lid
- Transfer of the heat from the lid to the susceptor topside by conduction and radiation
- Transfer of the heat through the susceptor

In order to have a good temperature control of the susceptor the system bedplate allows installation of the pyrometer in order to measure the temperature on the edge of the susceptor.

The edge location of the pyrometer assures good temperature control of the susceptor.

16.2.6 Using the susceptor without the cover

It is also possible to use the susceptor without the lid in order to process small samples.

In this case both sample and susceptor edges are directly heated by the infrared lamps.

In the center the heat transfer from top to bottom is:

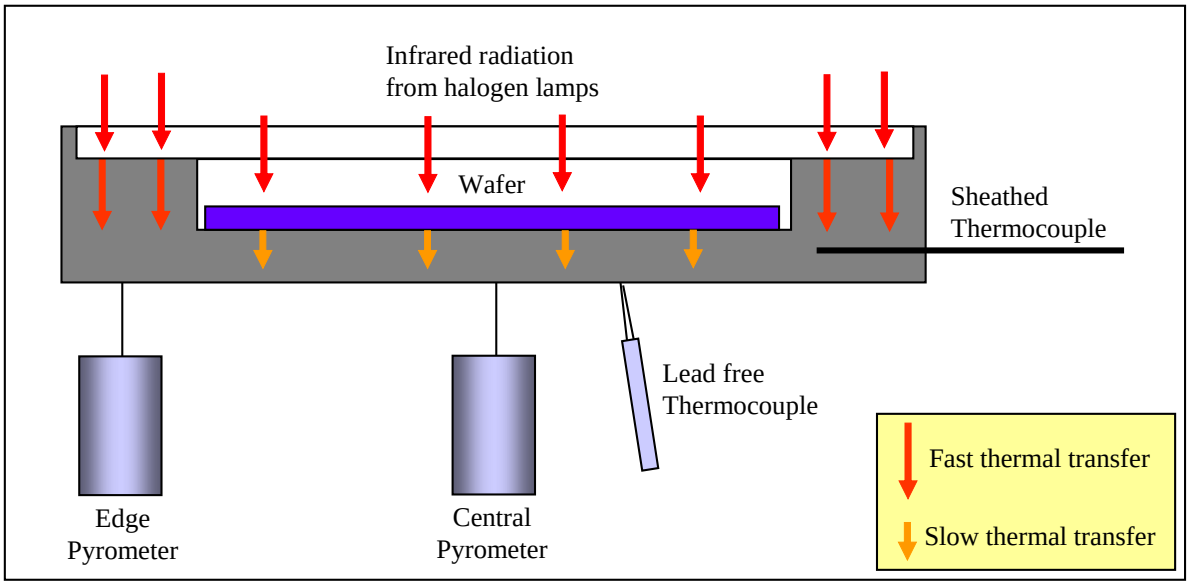
- Heating of the substrate by radiation from the lamps
- Transfer of the heat through the wafer
- Transfer of the heat from the wafer to the susceptor top side by conduction and radiation
- Transfer of the heat through the susceptor

On the edge the heat transfer is:

- Heating of the top side of the susceptor by the lamp
- Transfer of the heat through the susceptor

Again there is a faster heat transfer on the edge than in the center and it is recommended to use the edge pyrometer.

Thermal transfer with susceptor and without lid



Nevertheless the wafer environment is quite different than in the configuration with the lid. Especially the sample is no more inside a nearly isothermal environment like the graphite box formed by the susceptor and the lid.

When the process is performed without the lid, the upper surface of the sample can be at much higher temperature than the susceptor. Both sheathed thermocouple installed in the hole and the pyrometer installed on the susceptor backside will not be able to provide accurate information about the temperature from the sample.

If the process must be performed without the lid for any special reason it is recommended to avoid fast ramp rates. During ramping the upper side of the sample can be at much higher temperature than the temperature measured by the sensors.

It is also recommended to make a kind of calibration of the process performing first processes at a lower temperature than the process requirement and then increasing the temperature setpoint until expected process results can be obtained.

16.2.7 Susceptor lifetime

SiC coated susceptors have a limited lifetime. The susceptors and lids are not covered by the warranty. It is strongly recommended to take necessary precautions to get the longer lifetime of the silicon carbide coated graphite parts.

The most common phenomenon limiting the use of the susceptor is the occurrence of pinholes in the SiC coating. The susceptor cannot be used anymore because of the contamination level or the formation of spots on the backside of the wafer. Recommendations are given hereafter to reduce pinhole formation.

The susceptors are also sensitive to temperature gradients. High temperature gradients can lead to cracks in the susceptor (see above recommendations for temperature control with susceptor).

16.2.7.1 Pinhole formation

In spite of the inertness of SiC, small and large holes can develop in the SiC coating. Pinholes have a size in the order of 0.1 mm.

The pinholes are often visible by a gray or yellow discoloration around a hardly visible hole. In virtually all cases, the presence of metals is responsible for the creation of the pinholes. As an example, the use of stainless steel tweezers for loading and unloading susceptors leads to a rapid formation of holes on the places where the SiC has been touched. Metallic residue or particles will react with HCl and form a product that will react with the SiC.

To reduce the pinhole formation:

- Take the susceptor in the sealed bag into the clean room.
- Carefully open, do not touch the susceptor with knife.
- Handle with plastic or rubber gloves.
- Do not place on a metal table! Use clean room wipes/tissues.
- Make sure not to touch metal parts of the reactor when installing the susceptor.
- Use peek tweezers for sample loading and unloading

16.2.7.2 Over-etching

Corrosion of the SiC only takes place during the HCl cleaning step. In the initial stage of the cleaning step, the whole susceptor is covered with Silicon. The recesses are covered with the silicon layer from the pre-coat step.

The first part of the SiC coating that becomes exposed is the wafer recess. During the rest of the cleaning step, there is no layer of SiC over the recess. This is why pinholes are usually first observed in the recess.

Whenever there is silicon present on the susceptor, the HCl mixture will etch the silicon, forming silicon chlorides. Formation of these chlorides leads to a reaction equilibrium which means that the etch activity of HCl on silicon free parts is reduced. When over etching, pure HCl reacts strongly with the weak spots in the SiC coating. Reducing the over-etch time is essential in improving the lifetime of susceptors.

16.2.7.3 Temperature gradients

The SiC coated graphite susceptors and covers are sensitive to temperature gradients. These parts should preferably be used with temperature ramp rates that do not exceed 20°C/s. The user must be aware that the gas injection can lead to higher temperature gradient and breakage in susceptor and cover. Annealsys strongly recommend using small gas flow for processes with susceptor especially if temperature exceeds 600°C.

16.2.7.4 Conclusion

Pinhole formation is the predominant cause of susceptor failure. The main cause is metal contamination in the graphite or from the outside of the susceptor, as metals cause pinhole formation. The lifetime of susceptors can be extended by preventing any kind of metal contamination of the SiC coating. Careful handling will extend the lifetime of the susceptors.

Use process conditions that will reduce the temperature gradients in the susceptor and cover.

Contact Annealsys for further information.

17. MAINTENANCE

Refer to the technical manual for maintenance operations.

18. TROUBLESHOOTING

The software diagnostic mode is a strong feature to find out the reason for technical issues on the RTP furnace.

18.1 Impossible to unlock the chamber

The chamber must reach the atmospheric pressure to be unlocked. The chamber pressure is usually measured by a constraint vacuum gauge that measures the absolute pressure.

Depending on the altitude of the system the atmospheric pressure can change and if it is not set to the right value the chamber will not be unlocked.

The atmospheric pressure can be set in the configuration mode. Set it to the right value so that the chamber can be unlocked when the pressure of the chamber reaches the atmospheric pressure

18.2 Impossible to open the chamber

After heating in process or manual mode it may be impossible to open the chamber.

During heating the gas inside the chamber is heated by the wafer and it expends. This increase the pressure inside the chamber and some gas will go out the chamber through the exhaust line.

During cooling down the gas will cool down as well and the pressure inside the chamber will decrease. As the exhaust line is provided with a check valve (one way valve) no gas will enter the chamber. This lower pressure inside the chamber will keep it close.

To release the chamber purge it for few seconds using the manual mode.

18.3 Customer support

Annealsys and our representatives will do our best to support you in case of any issue with the system.

For customer support inquiry you can contact our local representative or Annealsys customer support at service@annealsys.com

For any customer support request please provide the following information:

- System type: AS-One 100 or AS-One 150
- Serial number
- Substrate type: wafer size and material, susceptor with or without lid, etc
- Type of temperature control sensor: thermocouple or pyrometer
- Location of temperature control sensor: Center, edge, into susceptor hole, etc
- Send us the process historical files: ″.his″ file (not screen copy)

19. EC DECLARATION OF CONFORMITY

EC Declaration of Conformity

We, Annealsys,
Bâtiment T2, PIT de la Pompignane,
Rue de la Vieille Poste,
34055 Montpellier Cedex 1,
France,

herewith declare that the product described below is in accordance with the relevant safety and health requirement of the EC standards regarding design and version when delivered from our factory.

The agent responsible for compiling the technical documentation is Mr. Franck Laporte, Annealsys, Bat T2 PIT de la Pompignane, rue de la Vieille Poste, 34055 Montpellier Cedex 1.

This declaration becomes invalid whenever the product has been modified without our consent.

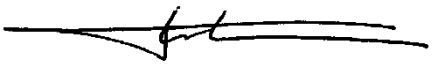
Description of product	**Rapid Thermal Processor**
Type	**AS-One 100**
Serial number	**AS0310R4-6476**

The product is in conformity with the following directives.

- 2006/42/EC: Machinery safety directive
- 2006/95/EC: Low voltage directive
- 2004/108/EC: Electromagnetic compatibility

Montpellier, May 12, 2014,

Franck Laporte
President



Revision history

Revision History			
Document Title	**AS-One 100 User's manual**		
Filename	**ASOne100_User_Manual_EN_V2-04.docx**		
Version Number	**2.04**		
Author	**Franck Laporte**		
Version	**Brief Description of Changes**	**Date of Issue**	**Initials**
1.0	Creation	October 4, 2004	FLA
1.1	18.4.2.1: Autotuning procedure 15.1.1: Function hold 15.1.2 : Function next step	December 16, 2004	FLA
1.2	New software	December 29, 2005	FLA
1.3	Turbo pump control	December 30, 2005	FLA
1.4	Additional recommendations to meet SEMI S2 standard	January 28, 2006	FLA
1.5	Separated software manual	April 20, 2006	FLA
1.6	Pressure for purge gas = 1 bar	June 12, 2006	FLA
1.7.0	Added floor standing version	January 30, 2007	FLA
1.7.1	Added automatic opening version	October 18, 2007	FLA
1.7.2	10.3: Fast cooling kit option	July 30, 2008	FLA
1.7.3	16.1: Maximum step duration versus temperature	November 13, 2008	FLA
1.7.4	Benchtop version is removed as no more manufactured Warning about utilization of Hydrogen Gas ballast for exhaust and vacuum	December 13, 2008	FLA
1.7.5	Temperature sensor interface board replaces converters	December 20, 2008	FLA
1.7.6	10.1 Information on infrared heating 10.4 Substrate installation 10.5 Thermocouple installation	April 29, 2009	FLA
1.7.7	7.6 Quartz liner option 10.2 Ramp rate limitations	May 20, 2009	FLA
1.7.8	16.3: Using a susceptor 16.3.4: Temperature control with the susceptor 18.4 Customer support	June 12, 2009	FLA
1.7.9	7.7: Temperature gradient option	December 14, 2009	FLA
1.8.0	New logo 16.9. temperature versus time for high temperature version	March 16, 2010	FLA
1.8.1	Additional warning in constructor's forewords	February 23, 2011	FLA
1.8.2	Thermocouple utilization information	September 19, 2011	FLA
1.8.3	16.2.4. Susceptor utilization	January 4, 2012	FLA
2.00	Document contains original instructions of the manufacturer The EC declaration of conformity is added	December 27, 2012	FLA
2.01	Thermocouple installation with susceptor	January 10, 2013	FLA
2.02	Set of quartz parts for enhanced temperature uniformity	February 11, 2013	FLA
2.03	Additional warning on susceptor ramp rates Warning on thermocouple bending	December 5, 2013	FLA
2.04	Maximum temperature for SiC coated graphite parts	March 21, 2014	FLA