System Manual

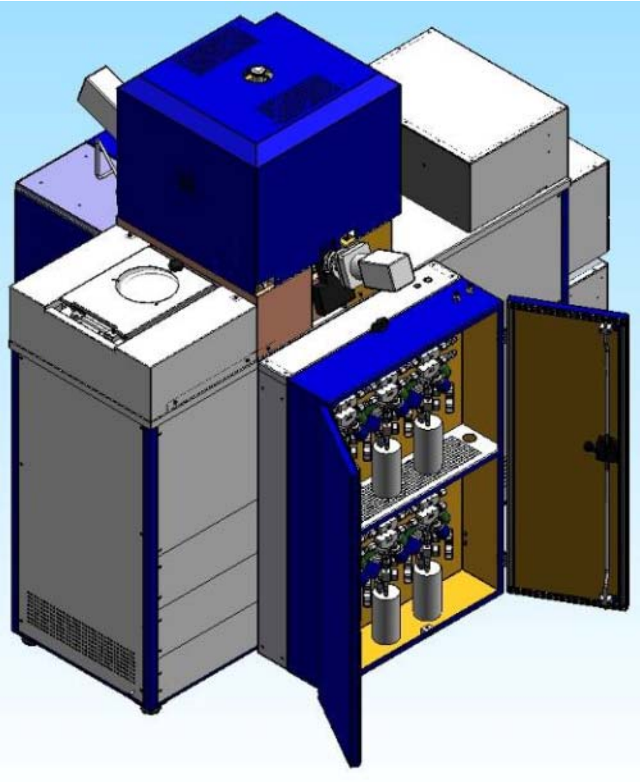
Oxford Instruments Plasma Technology

FlexAL®II

Issue 01 / February 2011 / Original Instructions

Works order number: 94-220027

University of Notre Dame



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The Business of Science®

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PREFACE

Welcome to the System Manual for the Oxford Instruments Plasma Technology ALD **FlexAL**® tool. The ALD (atomic layer deposition) **FlexAL**® is a modular plasma processing system that can be configured to perform remote plasma and thermal ALD processes. The system can be tailored to suit different rates of throughput by using transfer and load lock chambers with manual or automatic loading. Combinations of processes can be achieved by using a transfer chamber robot to serve up to four process chambers.

About the technical manual set

The technical manual set for the ALD **FlexAL**® comprises:

- System Manual (this handbook).
- System Diagrams.
- Other Equipment Manufacturer (OEM) manuals.

This System Manual provides all the information necessary for the safe and proper operation and maintenance of ALD **FlexAL**® . The topics included in this manual are:

Certain components of the system are supplied by other manufacturers and therefore have separate OEM manuals. Refer to the OEM manuals for detailed operation, maintenance and repair information on the respective components.

Navigating the e-published manual

The e-published edition of this manual is delivered as a portable document format (PDF) file. The PDF file contains hyperlinks colored **blue**. The entries in the table of contents and some figure annotations are also hyperlinks.

Click on a link to go directly to the referenced item on another page.

Use the arrow buttons to move from page to page.

Use the PDF search facility to find words or phrases.

Customer support

Oxford Instruments Plasma Technology (OIPT) has global customer support facilities that provide a coordinated response to customer's queries. All queries are recorded on our support database and are dealt with as quickly as possible. If we are not able to answer the query immediately, we will contact you promptly.

Before contacting a customer support facility, please ensure that you have referred to the appropriate section of your system manual, OEM manuals and electrical drawings.

Please direct all queries through your nearest support facility (see below) and have the following details available:

System type	ALD **FlexAL**®
Works order number	**94-220027**
Contact information	Your name, the name of your company, and how we can contact you.
Details of your query	The nature of your problem, part numbers of spares required, etc.

You can contact us at the following telephone numbers and email addresses:

China
Bejing
Tel: +86 10 6518 8160
Email: **china.ptsupport@oxinst.com**
Shanghai
Tel: +86 21 6360 8530/1/2/3
Email: **china.ptsupport@oxinst.com**

Europe
Tel: +49 6122 937 161
Email: **plasma@oxford.de**

Japan
Tel: +81 3 5245 3261
Email: **info.jp-pt@oxinst.com**

Singapore
Tel: +65 6337 6848
Email: **oipt.support@oxford-instruments.com.sg**

UK
Tel: +44 (0) 1934 837000
Email:**ptsupport@oxinst.com**

Americas
Phone: +1 978 369 9933
Email: **info@ma.oxinst.com**

Rest of the World
Tel: +44 (0) 1934 837000
Email:**ptsupport@oxinst.com**

System identification

This system, with the works order number **94-220027** for the **University of Notre Dame**, is identified by this label attached to the rear of the power box:

CE OXFORD INSTRUMENTS

Plasma Technology Ltd.- North End - Yatton - Bristol
England - BS49 4AP
Tel :- (01934) 837000
Fax :- (01934) 837001
e mail :- plasma.technology@oxinst.com

Serial Number :- 94-220027

Model Type :- FlexAl Mk2

Frequency :- 60 Hz

Rated Voltage :- 208 VAC 3 ~

Max Rated Input Current :- 67.2 Amps

Interrupt Current :- 35KA

Diagram No. :- SE91A19752

Year of Manufacture :- 2011

Health & safety information

FlexAL®contains hazardous areas, materials and substances. Before working with **FlexAL**®, all personnel must read and become thoroughly familiar with the information given in **Chapter 1**. In particular, users must read, understand and strictly observe all:

- Warning notices.
- Caution notices.
- Safety labels and markings on the equipment.

For ease of reference and rapid response in an emergency, this handbook must be safely kept in close proximity to **FlexAL**®.

Intended users

Intended users of **FlexAL**® include the body with authority over the equipment, and the following persons who handle and work with the equipment:

- Operators - persons trained in the use of **FlexAL**® for the purposes for which **FlexAL**® is intended.
- Service engineers - persons trained in the installation, commissioning, maintenance, repair, testing and decommissioning of **FlexAL**®, and who operate any part of **FlexAL**® for the purpose of performing checks, tests, adjustments and/or repairs to the equipment.

Users of **FlexAL**® must have received adequate training on its safe and effective use before attempting to work with the equipment. Please contact Oxford Instruments Plasma Technology for information on training requirements and training courses that are available.

Training requirements vary from country to country. Users must ensure that training is given in accordance with all applicable local laws and regulations.

Use of FlexAL®

FlexAL® is designed and intended to be used for remote plasma and thermal ALD processes.

FlexAL® is intended to be installed, used and operated only for the purpose for which **FlexAL**® was designed, and only in accordance with the instructions given in this manual and other accompanying documents. Nothing stated in this manual reduces the responsibilities of users to exercise sound judgement and best practice.

The installation, use and operation of **FlexAL**® are subject to laws in the jurisdictions in which the equipment is installed and in use. Users must install, use and operate the equipment only in such ways that do not conflict with said applicable laws and regulations.

Use of the equipment for purposes other than those intended and expressly stated by Oxford Instruments Plasma Technology, as well as incorrect use or operation of the equipment, may relieve Oxford Instruments Plasma Technology or its agent of the responsibility for any resultant non-compliance, damage or injury.

The equipment has been designed to be used in a clean room environment, under stable conditions. System services must be maintained within the limits defined by the system services specification. The system must be operated and maintained using sound vacuum and semiconductor practice.

Typographical conventions

For clarity and ease of explanation, the following typographical conventions are used:

- Modes of operation are expressed in upper case, italic letters. Thus:

  AUTO, MANUAL, SERVICE.

- On-screen objects in the graphical user interface (GUI) are expressed in bold letters. Thus:

  manual button, **Position** panel, **Forward** field.

- The names of on-screen windows and panels in the GUI are expressed with upper-case initial letters. Thus:

  AMU Service Util panel.

- The names of physical controls are expressed in bold letters. Thus:

  Alt key (on the PC keyboard), **ON** button.

- Keys to be pressed in sequence are expressed thus:

  <Crtl> <S>.

- Keys to be pressed simultaneously are expressed thus:

  <Crtl> + <S>.

- Directory paths are expressed thus:

  C:\name\name\name

Disclaimers

Oxford Instruments Plasma Technology assumes no liability for use of this document if any unauthorised changes to the content or format have been made.

Every care has been taken to ensure that the information in this document is accurate. However, Oxford Instruments Plasma Technology assumes no responsibility or liability for errors, inaccuracies or omissions that may occur herein.

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Acknowledgements

The following tradenames and trademarks that appear in this manual are the property of Oxford Instruments Plasma Technology:

ALD **FlexAL**® ® is a registered trademark of Oxford Instruments plc or its subsidiaries.

All other tradenames and trademarks that appear in this manual are hereby acknowledged.

Acronyms, abbreviations and special terms

A **GLOSSARY** of acronyms, abbreviations and special terms is given at the end of this manual.

Certification

Copies of the formal certification document for this ALD **FlexAL**® and Oxford Instruments Plasma Technology quality control forms (QCF) are given in **Appendix A**.

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1 HEALTH AND SAFETY

This chapter describes all health and safety considerations relating to the Oxford Instruments Plasma Technology **FlexAL**® tool. The chapter comprises the following sections:

- **About this safety information**
- **Warning and caution notices**
- **Lockout and tagout**
- **Hazard overview**
- **Detailed hazard information**
- **System safety features and interlocks**
- **Personal protective equipment**
- **Mandatory safety procedures**
- **Warning and hazard labels**
- **Solid waste**
- **Risk assessments**
- **System modifications**

1.1 About this safety information

The safety information contained in this chapter must be read and understood before approaching, operating or maintaining the ALD **FlexAL**® system.

It is the user's responsibility to ensure the system is operated in a safe manner. Consideration must be made for all aspects of the system's lifecycle, including, handling, installation, normal operation, maintenance, dismantling, decontamination and disposal. It is the user's responsibility to complete suitable risk assessments, to determine the magnitude of hazards, particularly when using hazardous process gases and chemicals. The use of gas, chemical and fire detection equipment must be considered.

It is a requirement that the procedures and practices taught in Oxford Instruments Plasma Technology training courses are followed.

The equipment must not be used in a manner other that specified by Oxford Instruments Plasma Technology. Doing so can impair the hazard protection provided by the equipment.

Read this chapter carefully. Particularly note that certain aspects of the system can present more than one hazard. For example, certain process gases can produce a toxic hazard, a fire hazard and a corrosive hazard.

Some of the safety features fitted to the system provide protection against more than one hazard. For example, certain viewports protect against ultra-violet (UV) light emission, radio frequency (RF) energy emission, and incorporate an implosion guard.

This document encompasses all system options, and may contain warnings that are not appropriate to a particular machine configuration.

1.2 Warning and caution notices

Warning notices appear throughout the manual to draw attention to hazards. Warning notices always state the nature of the hazard and the means by which it can be avoided. Failure to obey the information given in the warning notices could result in exposure to the hazard, causing serious injury or death. A typical warning notice is shown below.

WARNING 1.1	**TOXIC GASES** **Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.**

Caution notices appear throughout the manual to draw attention to circumstances or procedures that could cause damage to the equipment or the process wafers. Caution notices always state the nature of the hazard and the means by which it can be avoided. Failure to obey the information given in the caution notices could result in damage to the equipment or the process wafers. A typical caution notice is shown below.

Caution 1.1	**CAUTION** Inadequate flow of N2 purge gas can cause damage to the pump. Ensure that the flow rate is set to the value recommended by the pump manufacturer.

1.3 Lockout and tagout

Proper lockout and tagout procedures must always be followed when working on the equipment. In general, all system facility (energy) sources such as electrical power, compressed air, gases and cooling water must be isolated and locked off before starting any maintenance work.

It is recommended that the customer fit the means to safely isolate all energy supplies to and from the ALD **FlexAL**® system, including cooling fluids, compressed gases and exhaust gas.

Any stored energy should also be released from the system before starting any maintenance work. Capacitors in the system are provided with bleed resistors to automatically remove stored electrical charge after a few minutes.

Operating the air dump valves on the front panel of the machine isolates the system pneumatic supply and releases trapped air pressure from the system pneumatics (see **Figure 1-2**):

- Operating the **SLIT VALVE LOCKOUT** knob removes the compressed air supply from the whole system, including the loadlock slit valve and the ICP source isolation-valve.
- Operating the **PRECURSOR LOCKOUT** knob removes the compressed air supply from the precursor modules.

The main power box electrical isolator (see Figure 1-1) and the air dump valves are the only recommended lockout points on the system. However, attention must be paid to auxiliary equipment that may have separate power feeds, such as heater/chiller units and vacuum pumps.

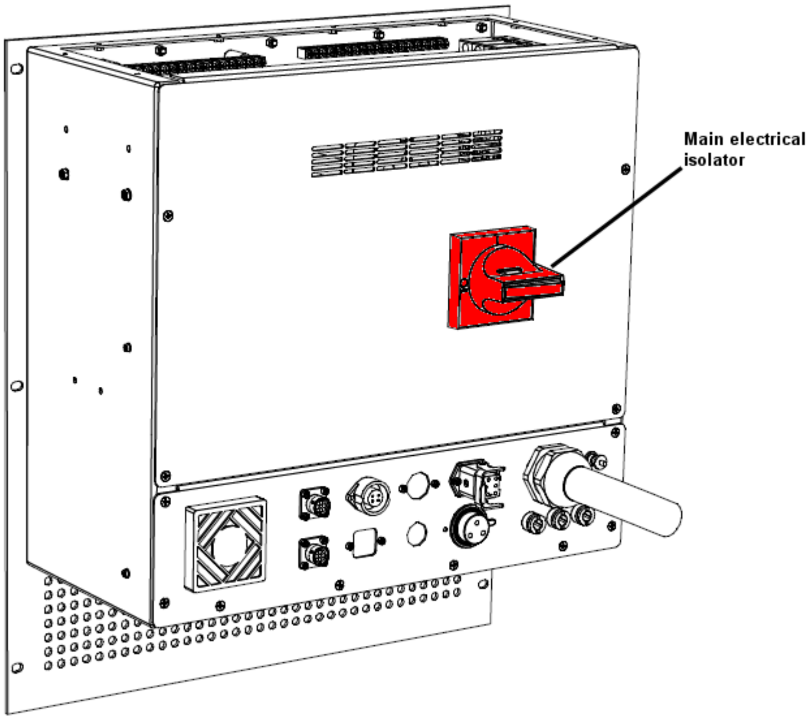


Figure 1-1 Location of the main electrical isolator

Figure 1-2 Location of the air dump valves

Specific lockout and tagout requirements are detailed in the relevant sections of this manual. However it is the customer's responsibility to perform risk assessments, and to design and enforce suitable lockout and tagout protocols for maintenance tasks.

1.4 Hazard overview

This section lists specific hazards that may be present on the system. Refer to the relevant section for a detailed description of each hazard and the precautions that must be taken to avoid injury or damage.

1.4.1 Electrical hazards

The system contains voltages that are high enough to cause death or serious injury. Isolating the electrical power to the system is not always sufficient to provide personal protection as hazardous electrical energy may be stored in capacitors.

Ensure that all lockout and tagout steps, and any other recommendations contained in maintenance procedures are strictly observed.

See **Section 1.5.1** for more information on electrical safety.

1.4.2 Electromagnetic radiation

Parts of the system produce non-ionising electromagnetic radiation with frequencies ranging from audio to 100 MHz. This radiation can cause death or injury if proper shielding is not in place. RF energy can be induced - it is not necessary to make contact with live electrical components to cause injury.

See **Section 1.5.2** for more information on electromagnetic radiation safety.

1.4.3 Gases

Some process gases and cleaning fluid vapours are toxic, corrosive, carcinogenic, flammable or pyrophoric. Gases can also cause asphyxiation by displacing the oxygen in the atmosphere. Pressurised gases store mechanical energy which can cause death or serious injury.

Read and understand the materials safety data sheets of all gases used on the system before performing maintenance on the system.

See **Section 1.5.3** for more information on gas safety.

1.4.4 Mechanical hazards

The system contains moving parts and sprung components that can cause serious injury. Deposited layers under stress and embrittled wire can also cause injury.

See **Section 1.5.4** for more information on mechanical hazard safety.

1.4.5 Weight and lifting

The equipment contains heavy components that could cause injury if not properly secured. Lifting heavy components during maintenance or installation can also cause injury.

See **Section 1.5.5** for more information on weight and lifting safety.

1.4.6 Light

Parts of the system can produce hazardous levels of ultraviolet or laser light. If not properly shielded, these light sources can produce permanent eye damage or blindness.

If an end-point detector is fitted, the system may contain lasers of class 1 or 2.

See **Section 1.5.6** for more information on light safety.

1.4.7 High temperature

Some parts of the equipment operate at temperatures that are high enough to cause severe burns, if allowed to contact the skin.

See **Section 1.5.7** for more information on high temperature safety.

1.4.8 Low temperature

Some parts of the equipment and gases used in the equipment operate at very low temperatures. These items can cause severe injury if allowed to contact the skin.

See **Section 1.5.8** for more information on low temperature safety.

1.4.9 Materials and residues

Some etch and deposition processes leave residues on the vacuum surfaces within the system. These residues may be toxic, carcinogenic, corrosive or flammable.

See **Section 1.5.9** for more information on materials and residues safety.

1.4.10 Vacuum

Components under partial vacuum store mechanical energy, which can cause death or serious injury.

See **Section 1.5.10** for more information on vacuum safety.

1.4.11 Compressed air

Compressed air stores mechanical energy, which can cause death or serious injury. Pneumatically actuated components can move suddenly, even when the system is not operating, causing serious injury.

See **Section 1.5.11** for more information on compressed air safety.

1.4.12 Liquid nitrogen

NOTE: Liquid nitrogen is only used on systems fitted with a cryogenic substrate table.

Liquid nitrogen has a temperature of less than 78 K (-195°C). Touching pipework or other system components that carry liquid nitrogen can cause severe injury.

If liquid nitrogen is trapped in an un-vented volume, the pressure can build up and cause an explosion. All parts of the liquid nitrogen system must be fitted with a pressure relief valve to release excess pressure.

Spillage of liquid nitrogen can produce large volumes of nitrogen gas, which can displace the oxygen from the air and cause death by asphyxiation.

See **Section 1.5.12** for more information on liquid nitrogen safety.

1.4.13 Magnetic fields

Strong magnetic fields can interfere with the operation of cardiac pacemakers, possibly causing death or serious injury. Strong magnetic fields can also cause metallic items such as tools to move suddenly, which can cause serious injury.

See **Section 1.5.13** for more information on magnetic field safety.

1.5 Detailed hazard information

Each of the following sub-sections describes a specific hazard that may be encountered on the system, and gives the precautions that must be taken to avoid harm or injury. All services (energy sources) must be isolated from the system, if possible, before maintenance is carried out.

1.5.1 Electrical safety

WARNING 1.2

HAZARDOUS VOLTAGE

Contact with hazardous voltage can cause death, severe injury or burns. Any work requiring the removal of covers or panels must only be performed by authorised personnel who are aware of the hazards involved. Before removing any covers or panels, power down the system and perform the recommended lock out / tag out procedure.

Parts of the system carry high voltages, which are capable of causing death or serious injury. Take great care when carrying out maintenance tasks. Maintenance tasks must only be performed by personnel who are trained in lockout and tagout procedures and who fully understand the hazards associated with stored electrical energy.

Do not operate the system with any of the doors, panels or covers removed. Parts of the system may still contain hazardous electrical energy even when they are isolated by a switch, blown fuse, or a control function. Note that if the main electrical isolator on the system is turned off there are still hazardous voltages contained within the power box.

Ensure that all system units are connected to a local electrical earth (ground). Refer to **Section 10.2.2.1** for details of the required electrical installation.

Proper lockout and tagout procedures must be followed when performing maintenance on the system. Lockout must only be applied to the recommended lockout point, and must only use an approved lockout device. Refer to **Section 1.3** for the recommended lockout procedure. Lockout requirements are detailed in the maintenance procedures described in this manual.

Occasionally it may be necessary to perform maintenance and calibration procedures with electrical components at hazardous voltages exposed. Live electrical working must be avoided if at all possible. If live electrical working is unavoidable, this work must only be carried out by skilled personnel who are aware of the hazards involved. Precautions must be taken to ensure other personnel are not exposed to any hazard.

Electrical safety interlocks must be tested before the system is used for the first time, and at scheduled intervals thereafter. Refer to the maintenance schedule (**Chapter 7**) for recommended test intervals. These tests must be performed by suitably qualified personnel, and the results must be recorded. Do not operate the equipment if any safety interlocks are faulty. Do not override safety interlocks.

Inspect the system regularly for signs of damage to electrical components. In particular check that all cables and connectors are in good condition and are properly secured, and that switches operate correctly. If any faults are found during this inspection, the equipment must not be used until the damaged components have been replaced and properly tested. Refer to **Chapter 7** for electrical tests that must be performed on a regular basis.

Contact with live electrical parts may cause serious injury. Ensure adequate earth bonding is always maintained. When replacing system panels, refit panel earth wires and ensure the panels are secure and have good contact with the frame. Ensure earth continuity is maintained between the system primary earth stud, in the power box, and the building electrical earth. Maintenance must only be performed by a trained and qualified electrician. Modification to the system wiring must only be performed after first consulting with OIPT. Ensure wires and crimps are tight, and that there are no loose wires that can come free or get snagged. Always use appropriately rated mains cables and plugs.

If any water leaks are detected, immediately isolate the system at the local electrical services isolator, if it is safe to do so.

1.5.2 Electromagnetic radiation safety

WARNING 1.3

HAZARDOUS RF AND MICROWAVE EMISSIONS
Exposure to RF and microwave emissions can cause severe injury or burns. Before turning on the system power, ensure that all RF and microwave shielding is correctly fitted, and that all connectors and flanges are in place. RF energy can be induced; contact is not necessary to cause injury.

Parts of the system produce non-ionising electromagnetic radiation ranging from audio frequencies up to 100 MHz. The field strength level at all frequencies within this range is sufficient to cause injury. Oxford Instruments Plasma Technology specify acceptable limits for the electrical and magnetic field strengths within the environment of the system. These limits are based on the lowest permitted emissions under all relevant standards; in particular:

SEMI S2**Ref:[11]** and the DIRECTIVE 2008/46/EC of The European Parliament And Of The Council of 23 April 2008**Ref:[12]**.

The chamber viewport is considered to be a particular risk area, so OIPT specify lower acceptable limits for emissions from the viewport. The equipment incorporates shielding to ensure that these specified field strengths are not exceeded.

The system must be tested using suitably calibrated equipment to ensure that radiation is within the limits specified by OIPT. These tests must be carried out after any maintenance activity that may disturb RF shielding components, and also every three months as part of the periodic maintenance schedule.

Ensure that all waveguide components, flanges and cables are correctly fitted, are secure, and are undamaged.

Viewports on the system are fitted with a metal grid to provide shielding from RF radiation. Ensure that these viewports are correctly assembled and are undamaged. Only replace viewports with the correct part.

If a viewport is not fitted with a metal grid, and there is any doubt whether one should be fitted, contact Oxford Instruments Plasma Technology for advice before operating the system.

If it is necessary to disassemble or replace a viewport as part of a maintenance activity, the system must be properly tested for RF radiation before returning it to service.

Do not operate the equipment with any panels removed. If a maintenance procedure requires the equipment to be operated with a panel removed, this procedure must only be performed by skilled personnel who have access to a suitable field strength meter. Precautions must be taken to prevent exposure of any other personnel to RF radiation.

Modifying the equipment, or operating it with panels removed, may increase the radio interference generated by the equipment, causing the interference to exceed permitted levels. This may cause neighbouring equipment to malfunction or to operate unexpectedly.

1.5.3 Gas safety

WARNING 1.4

FLAMMABLE GASES

Flammable material can ignite in the presence of heat or arcing, causing severe injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

WARNING 1.5

TOXIC GASES

Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

WARNING 1.6

CORROSIVE GASES

Exposure to corrosive gases can cause severe injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

WARNING 1.7

EXCESS PRESSURE

FlexAL II systems do not provide any excess pressure regulation or protection for process gases. It is the customer's responsibility to ensure that suitable regulation and protection, in accordance with all applicable standards, is installed external to the system. It is the customer's responsibility to ensure that this equipment is properly maintained.

Gases are used for venting and purging (e.g. nitrogen), for assisting heat transfer (e.g. helium), and for establishing the process environment (process gases).

The process gases vary from system to system, depending on the process for which the system is designed.

Gases may produce one or more of the following hazards:

- Toxic hazard
- Carinogenic hazard
- Corrosive hazard
- Flammability hazard
- Pyrophoric hazard
- Asphyxiant hazard

Before operating or maintaining a particular system, ensure that the material safety data sheets (MSDS) of all gases connected to the system have been read and understood. MSDSs can be obtained from the gas supplier. Treat all effluents from plasma systems as toxic.

Ensure that system effluents are extracted into a safe disposal system and are treated before release into the atmosphere. The internal diameter of all extraction pipework must exceed the internal diameter of the outlet of the system backing pump that is connected to it.

Exhaust lines for hazardous gases must be separated from other exhaust lines.

If toxic, flammable or corrosive gases are to be used, the entire exhaust system must comply with best practice for the semiconductor production industry and with local building codes. The following sources can also be used as guidance:

- The regulations contained in the United States document *Uniform Fire Code Article 51* **Ref:[1]**.
- *The Safe Storage, Handling & Use of Special Gases in the Micro-Electronics Industry*. British Compressed Gases Association (BCGA) code of practice 18 **Ref:[2]**. This document is available from BCGA.

If toxic, flammable or corrosive gases are to be used, the entire system must be sited in a purged or extracted environment fitted with suitable gas detection equipment.

It is the customers responsibility to perform a risk assessment for all consumable process materials used on the system, and to decide if gas sensors and gas pod extraction monitoring are required.

It is the customer’s responsibility to fit appropriate gas detection equipment to protect personnel from accidental gas release. The detection equipment must isolate all toxic gas supplies, and provide a suitable warning, if the detected gas concentration exceeds a threshold value.

Even non-toxic gases can cause a hazard by displacing the oxygen in the atmosphere. It is recommended that the customer installs oxygen detection equipment in a suitable location to warn personnel if the available oxygen concentration falls below a threshold value.

The operation of all gas detection equipment must be formally verified every two weeks. Refer to the appropriate manufacturer's manuals for instructions on testing gas detection equipment.

Gas pods supplied by Oxford Instruments Plasma Technology incorporate a 100 mm diameter extraction collar. If toxic, flammable or corrosive gases are used in the gas pod, this collar must be connected to a suitable extraction facility.

Purge gas that is extracted from the gas pod must be monitored by suitable gas detection equipment to provide warning of any leakage of hazardous gas.

The extraction system for the gas pod purge gas must be designed to withstand corrosion or combustion.

Gas lines must be regularly leak-checked to ensure their integrity. Refer to **Section 4.3.13.4** for information on checking leaks in gas lines.

Ensure that the system is completely purged before any maintenance activity is started, and leak tested after maintenance has been completed.

As far as is practical, gas lines should be isolated when not in use.

Vacuum pumps must always be operated in accordance with the manufacturer's manuals and with Oxford Instruments Plasma Technology training courses.

Pumps that are fitted with a nitrogen purging facility must always be purged during any activity that might cause process gas to enter the pump. Pumps must also be purged for a suitable period after such an activity has completed.

The mass flow controllers supplied with the system have all been specified for the particular gas that was configured at the time of purchase. Do not use mass flow controllers with a different gas to that specified without consulting Oxford Instruments Plasma Technology.

Each gas line in the gas pod is interlocked according to the nature of the gas it contains. Do not connect a different gas to a gas line without consulting Oxford Instruments Plasma Technology for advice.

1.5.3.1 Exhaust emissions

The gas emitted by a plasma etch process is mostly made up of the input gases. However this gas contains a small, but significant, component of etch or plasma by-products (up to ~10% in an RIE tool, possibly more for ICP). The exact amounts of these by-products depend on process type and conditions and can be any combination of etch gas material and etched material.

For example:

$Si + CF_4 = SiF_X, CF_X, F$ etc.

$SiO_2 + CHF_3 = SiF_X, CO_X, CF_X, F, HF, CH_X, SiOF_X$ etc.

Resist + $O_2 = CO_X$, O etc.

Where the left hand side of each equation consists of process gases and etched materials, while the right hand side consists of etch by-products.

As many of these by-products are toxic, it is a minimum requirement that these gases are exhausted in an enclosed extraction system to the roof of the building - following health and safety regulations. In addition to this, depending on local regulations, it may be necessary to implement some form of gas scrubbing before releasing these materials to the atmosphere.

Even if there are no gases running through the system, the system exhaust must be extracted correctly to remove small droplets of pump oil which are present in the pump exhaust. These oil droplets are harmful to lung function.

Another important consideration is the gas absorbed in the pump oil. Since the exhaust gases may contain hydrofluoric acid (HF) there can be a build up of HF in the pump oil. Therefore, it is important to use the correct protective equipment when servicing the pump or changing pump oil, i.e. suitable gloves, protective clothing, filtered facemask or breathing apparatus.

Perfluorinated polyether (PFPE) oil, rather than mineral oil, must be used in vacuum pumps when using oxygen processes. There is a risk of fire or an explosive reaction between oxygen and mineral oil.

1.5.4 Mechanical safety

Mechanical hazards can come in many forms. Some examples include moving parts which can crush or cut, sharp edges that can cut, hands becoming trapped in closing valves or pump mechanisms, chamber or loadlock lids pinching when they close, objects falling or toppling under gravity, potential exposure to fluid under high pressure, and implosion of vacuum components. This list of possible mechanical hazards is not exhaustive.

WARNING 1.8

PINCH POINT
This pinch point could cause severe injury. Take care when closing the chamber lid.

Take care when closing the chamber lid. Ensure that personnel are clear from the vicinity of the lid and its operating mechanism to avoid trapping fingers, etc.

Take care when handling sprung components that are under tension or compression. Take suitable precautions, including eye protection, before maintaining such components.

WARNING 1.9

ITEMS CAN MOVE UNDER AUTOMATIC CONTROL
This can cause severe injury or death. Ensure that the system is locked out before working near automatic machinery.

Keep clear of all moveable machinery unless it has been properly locked out. Items such as robotic arms, substrate lifting mechanisms and shutters can move suddenly if their stored energy has not been removed. Ensure that all safety guards are correctly fitted before operating such machinery.

Take care of deposited layers on vacuum surfaces or processed wafers. Such layers may be under stress and can eject particles with considerable force. Wear suitable eye protection before cleaning or disturbing deposited layers.

Take care when handling wire components that may be embrittled, such as filaments. Wire components can break and become embedded in the skin.

1.5.5 Weight and lifting safety


WARNING 1.10

HEAVY OBJECT
Incorrectly lifting heavy objects can cause severe injury. Use the appropriate lifting equipment, operated by fully trained personnel, when handling heavy system components. When handling heavy rack-mounted components, ensure that the weight is safely distributed between sufficient personnel.

Serious injury can be caused by attempting to lift heavy components. Always use assistance or lifting equipment when removing or refitting heavy components. If in doubt whether it is safe to perform a lift, consult the local safety representative before proceeding.

Do not attempt to lift any item unaided if the operation requires excessive reaching, leaning or twisting. Injury can be caused by poor posture as well as by the weight of the object itself.


WARNING 1.11

TOPPLING (TIPOVER) HAZARD
If heavy items are not kept vertical, they can topple causing severe injury. When transporting or manoeuvring heavy items, ensure that they remain vertical at all times.

Take care when moving heavy components to ensure they cannot topple or fall. Use the support frames or stabilizers provided when moving, installing or decommissioning equipment.

1.5.6 Light safety


WARNING 1.12

LASER RADIATION
Exposure to laser radiation can cause severe eye damage or burns. Ensure that all covers are fitted correctly before operating the system. Ensure that the manufacturer's instructions for all laser equipment have been read and fully understood. Do not look directly into the beam produced by any class of laser.

Laser equipment can seriously damage eyesight when handled incorrectly or when operated in a damaged condition. Read the manufacturer's instructions carefully and ensure they are followed. Ensure that all equipment covers provided by Oxford Instruments Plasma Technology are correctly fitted before power is applied to the equipment. Do not look directly into the beam produced by any class of laser.


WARNING 1.13

ULTRA VIOLET RADIATION
Exposure to ultra violet radiation can cause severe eye damage or burns. Ensure that all viewports are assembled correctly, and that any replacement filters are of the correct specification.

Viewports on the system are fitted with clear plastic ultra violet (UV) filters (Perspex® -VE-clear-003). Replace this filter with the correct part only. Ensure that viewports are correctly assembled.

If a filter is not fitted, or if there is any doubt that the correct filter is fitted, contact Oxford Instruments Plasma Technology for advice before operating the equipment.

Viewports made of either glass or quartz are available. Most of the viewports on Oxford Instruments Plasma Technology systems are made of glass, but quartz viewports are used in certain applications. Quartz viewports pass much more UV light than glass ones, and so present a greater hazard. Quartz viewports require careful shielding or filtering. If there is any doubt whether a viewport is made of quartz or glass, contact Oxford Instruments Plasma Technology for advice before operating the system.

UV light can also escape from other parts of the system (e.g. high density plasma sources and downstream plasma discharge tubes). Careful filtering and shielding is required to avoid UV exposure.

UV light can produce ozone from ambient air. Detectable quantities of ozone are produced by high density plasma sources fitted with a quartz tube. Ozone is a harmful gas and local extraction must be used to remove it if the system contains a high density plasma source.

1.5.7 High temperature safety

WARNING 1.14

HOT SURFACES
Contact with hot surfaces can cause serious injury and burns. Allow sufficient time for heated components to cool to room temperature before carrying out maintenance.

Some components can become heated to a hazardous temperature during operation of the system. Allow these components to cool to a safe temperature before handling them.

Components that become hot during operation include electrically heated chambers, chamber liners, the substrate table, specimen holders, and recirculating chillers and associated pipework. Items such as high density plasma sources operate at high temperatures.

1.5.8 Low temperature safety

WARNING 1.15

COLD OBJECTS
Contact with cold objects can cause serious injury to the skin and can cause the skin to adhere to the cold object. Allow sufficient time for cold components to return to room temperature before carrying out maintenance. If cold objects must be handled, ensure that suitable protective clothing is worn.

Components that are cooled in refrigerated or cryogenically cooled systems can damage the skin if allowed to contact it. Allow such components to warm up to a safe temperature before handling.

Components that can reach extremely cold temperatures include cryogenically cooled lower electrodes, all components that use liquid nitrogen, and recirculating chillers and associated pipework.

1.5.9 Materials and residues safety

WARNING 1.16

TOXIC MATERIALS

Some materials used in, and resulting from, deposition and etching processes can be dangerously toxic. Exposure to these substances can cause serious injury. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.

WARNING 1.17

CORROSIVE MATERIALS

Some materials used in, and resulting from, deposition and etching processes can be dangerously corrosive. Contact with these materials can cause serious injury. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.

WARNING 1.18

FLAMMABLE MATERIALS

Some materials used in, and resulting from, deposition and etching processes can be flammable. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Only use appropriate materials when cleaning flammable coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.

Some of the compounds used in, or produced by, deposition and etching processes are toxic, corrosive, carinogenic or flammable. These compounds may be deposited on the vacuum surfaces within the system and also within the extraction systems and pump exhaust lines. Residues may produce hazardous dust. A risk assessment must be completed and appropriate personal protective equipment must be used when working in these areas.

Cleaning fluids may be toxic or flammable. They may also produce toxic or flammable gases when they contact contaminated surfaces. Only use such fluids with adequate ventilation. Avoid direct or indirect ingestion of such substances.

Always use suitable personal protective equipment, including eye and skin protection, when handling vacuum pumps and pump fluids. As well as the hazards described below, pumps and fluids may be contaminated with hazardous chemicals.

Study all relevant materials safety data sheets (MSDS) before carrying out maintenance work.

It is recommended that a dedicated set of tools is used for maintenance on **FlexAL®** systems. This is to avoid accidentally spreading any toxic material that may be picked up on the tools. If dedicated tools are not used, tools must be thoroughly cleaned after use on **FlexAL®** systems.

All materials used in the construction of the system are non-hazardous when they are installed. However overheating of materials that contain fluorine can produce hazardous by-products, which could result in death or serious injury.

The following materials are of particular concern:

- Fluoroelastomer (FKM/FPM e.g. Viton®), which is used in O-rings.
- Perfluoroelastomer (FFKM e.g. Kalrez®), which is used in O-rings for special applications.
- Teflon® or other tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE) materials, which are used as electrical insulation.
- Certain lubricating greases or fluid, such as Fomblin®, Krytox®, or the NCI™ range from Leybold.

Great care must be taken to ensure that fluoroelastomer (FKM/FPM) or perfluoroelastomer (FFKM) O-rings are not exposed to high temperatures. Decomposition occurs at temperatures exceeding 315°C, producing a highly acidic residue containing hydrofluoric acid (HF).

If it appears that a fluoroelastomer (FKM/FPM) or perfluoroelastomer (FFKM) O-ring may have been subjected to temperatures in excess of 300°C, the following actions must be carried out:

a) Consult a competent authority regarding the following items (b) to (e).

b) Wearing suitable personal protective equipment, remove the O-ring and dispose of it in accordance with local health and safety regulations.

c) Wearing suitable personal protective equipment, thoroughly clean the contaminated area, disposing of any residue and contaminated cleaning materials in accordance with local health and safety regulations.

d) Fit a new O-ring.

e) Investigate the cause of the excessive temperature and review operating procedures and control systems to prevent a recurrence of the problem.

Great care must be taken to ensure that Teflon® or other TFE or PTFE materials are not exposed to high temperatures. If these materials are over-heated, they decompose, producing volatile by-products containing fluorine.

If it appears that any Teflon® or other TFE or PTFE material may have been subjected to temperatures in excess of 300°C, the following actions must be carried out:

a) Consult a competent authority regarding the following items (b) to (e).

b) Wearing suitable personal protective equipment, remove the decomposed material and dispose of it in accordance with local health and safety regulations.

c) Wearing suitable personal protective equipment, thoroughly clean the contaminated area, disposing of any residue and contaminated cleaning materials in accordance with local health and safety regulations.

d) Fit a new component.

e) Investigate the cause of the excessive temperature and review operating procedures and control systems to prevent a recurrence of the problem.

Great care must be taken to ensure that PFPE lubricating fluids (e.g. Fomblin®, Krytox®, NCI® etc.) are not exposed to high temperatures. If these materials are over-heated, they decompose, producing volatile by-products containing fluorine.

If it appears that any PFPE lubricating fluids may have been subjected to temperatures in excess of 300°C, the following actions must be carried out:

a) Consult a competent authority regarding the following items (b) to (e).

b) Wearing suitable personal protective equipment, remove the decomposed material and dispose of it in accordance with local health and safety regulations.

c) Wearing suitable personal protective equipment, thoroughly clean the contaminated area, disposing of any residue and contaminated cleaning materials in accordance with local health and safety regulations.

d) Replace the fluid or grease with fresh material.

e) Investigate the cause of the excessive temperature and review operating procedures and control systems to prevent a recurrence of the problem.

NOTE: All PFPE material, including spillages of fresh fluid, must be disposed of with great care. PFPE material must be kept away from fire, cigarettes and other smoking materials.

1.5.10 Vacuum safety

WARNING 1.19

IMPLOSION HAZARD
Vacuum chambers can present an implosion hazard. Before evacuating the system, ensure that all covers and screens are fitted correctly. Do not remove covers or screens while the chamber is under vacuum.

Process chambers and loadlocks which are under vacuum are sources of stored energy. Releasing this energy accidentally can cause mechanical motion or implosion, resulting in serious injury. These spaces must be vented to atmospheric pressure before the system is shut down for maintenance.

Take care when handling vacuum capacitors. If these items are knocked or dropped, they can implode, causing serious injury.

All viewports with a diameter greater than 100 mm must be fitted with an implosion eye guard. The eye guard is a clear plastic shield that fits on the outside of the viewport. The guard must only be replaced by the correct part. Ensure that all viewports are correctly assembled before evacuating the system.

If a plastic implosion eye-guard is not fitted, or if there is any doubt about the type or condition of an eye-guard that is fitted, contact Oxford Instruments Plasma Technology for advice before proceeding.

Take care when opening vacuum vessels that have been vented, in case they are over-pressurised by the vent gas.

1.5.11 Compressed air safety

Compressed air is used to power pneumatic items on the machine. Trapped volumes of compressed air constitute a source of stored energy, which can cause death or serious injury if released accidentally.

Before working on the system, the compressed air supply must be locked out and all compressed air pressure must be released. Refer to **Section 5.2.4** for the detailed shut-down procedure that is required prior to performing maintenance tasks.

WARNING 1.20

PNEUMATIC PRESSURE

Pneumatic valves or components can move unexpectedly, causing severe injury. Lockout the compressed air supply, and release the stored pressure, before working near pneumatic items.

Ensure that the compressed air supply is locked out, and that any stored pressure has been released, before working on pneumatic items. Take particular care with slit valves or gate valves, which could cause serious injury if operated accidentally.

Use the following sequence to release the air pressure from pneumatic items, prior to working in their vicinity:

a) Remove electrical power from the system and lockout the main circuit breaker.

b) Isolate and lockout the pneumatic supply to the system and disconnect the pneumatic supply pipes to the system.

c) Operate the air dump valve on the services panel at the rear of the system. This releases air pressure from both sides of the valve actuators.

1.5.12 Liquid nitrogen safety

WARNING 1.21

EXPLOSION

Explosion hazard caused by the boil-off of liquid nitrogen. Ensure that all liquid nitrogen facilities are designed to avoid pressure build-up.

When it absorbs heat, liquid nitrogen vapourises to produce large volumes of nitrogen gas. If this occurs in a sealed volume, an explosion can result. Uninsulated components containing liquid nitrogen condense moisture from the atmosphere, which then freezes. The resulting ice can block parts of the circuit, if the delivery system is not properly designed.

It is important to ensure that all liquid nitrogen delivery systems are designed to avoid pressure build up. All parts of the liquid nitrogen system must be fitted with a pressure relief valve to release excess pressure. The customer must perform a risk assessment to ensure that the liquid nitrogen system is fit for purpose.

WARNING 1.22

COLD OBJECTS
Contact with cold objects can cause serious injury to the skin and can cause the skin to adhere to the cold object. Allow sufficient time for cold components to return to room temperature before carrying out maintenance. If cold objects must be handled, ensure that suitable protective clothing is worn.

Components carrying liquid nitrogen are at a temperature below 78 K (-195°C). Touching such objects can cause the skin to adhere, causing serious injury. Liquid nitrogen components must be thermally insulated to prevent accidental contact.

Ensure that components that could contain liquid nitrogen have warmed up to a safe temperature before touching them. Wear suitable personal protective equipment (e.g. thermally insulated gloves) if touching cold objects is unavoidable.

WARNING 1.23

ASPHYXIATION
Liquid nitrogen produces nitrogen gas, which can displace the oxygen from air. This can cause death. Ensure that adequate ventilation is provided. Take care to avoid spilling liquid nitrogen.

When its temperature rises above approximately 78 K (-195°C), liquid nitrogen produces large volumes of nitrogen gas. This nitrogen can displace the oxygen from air, producing an asphyxiation hazard. Ensure that all areas which contain liquid nitrogen are adequately ventilated. Take precautions to prevent spillage. It is recommended that the customer installs oxygen detection equipment in a suitable location to warn personnel if the available oxygen concentration falls below a threshold value.

Liquid nitrogen systems must be regularly inspected to ensure the above requirements are met.

1.5.13 Magnetic field safety

WARNING 1.24

MAGNETIC FIELDS
Powerful magnetic fields can interfere with the operation of cardiac pacemakers. Do not approach the equipment if you wear a cardiac pacemaker.

Some parts of the machine may contain powerful electromagnets, depending on the system configuration. These electromagnets can produce a powerful magnetic field, which can interfere with the operation of cardiac pacemakers in the vicinity of the system.

Personnel who wear a cardiac pacemaker must not approach the system at any time, even when it is powered off.

WARNING 1.25

MAGNETIC FIELDS
Powerful magnetic fields can cause metallic items to move unexpectedly. Take care when working in the vicinity of magnetic fields.

Strong magnetic fields can also cause metallic items to move suddenly, possibly causing injury. Take care when using magnetic tools or other magnetic items near areas of the machine that contain magnets

1.5.14 Precursor health and safety

1.5.14.1 General precursor health and safety considerations

WARNING 1.26

TOXIC SUBSTANCES
Exposure to toxic substances can cause death or serious injury. Perform a risk assessment before using a precursor material. Ensure that all relevant personnel are familiar with the recommended handling, interlock and process requirements for all precursor materials installed on the system.

WARNING 1.27

CORROSIVE SUNSTANCES
Contact with corrosive materials can cause serious injury. Perform a risk assessment before using a precursor material. Ensure that all relevant personnel are familiar with the recommended handling, interlock and process requirements for all precursor materials installed on the system.

WARNING 1.28

FLAMMABLE SUBSTANCES
Flammable substances can ignite in the presence of heat or arcing, causing severe injury. Perform a risk assessment before using a precursor material. Ensure that all relevant personnel are familiar with the recommended handling, interlock and process requirements for all precursor materials installed on the system.

Please read this section in conjunction with **Section 1.4.3**. This section contains some generic health and safety recommendations with respect to common precursors used in ALD processing.

For an explanation of the specific terms used throughout this chapter, please read the **GLOSSARY** at the end of this manual before reading this section.

Due to the research nature of ALD and the wide variety of novel precursors used, it is vital to review each MSDS carefully and perform an appropriate risk assessment.

There are many hazards associated with ALD precursors, but broadly they can be categorised into any or all of the following;

- Toxic
- Corrosive
- Flammable or flammable decomposition products
- Pyrophoric
- Not hazardous to health*

It is important to remember that decomposition products may be hazardous or flammable.

* Health and safety information on novel ALD precursors used for research can often be limited, it is recommended in these cases to keep the quantities small (<50 g) and treat the precursor as hazardous to health.

Only liquids or solids with a vapour pressure less than 100 Torr must be placed inside the precursor module. Those precursors with higher vapour pressures will require increased extraction on the precursor module or must be delivered as a standard gas via the main gas pod.

1.5.14.2 Gas detection and emergency procedures

The customer is responsible for any monitoring of the extract lines from the precursor modules and the ambient environment surrounding the system that is deemed necessary by their own risk assessment.

OIPT recommends you consider any/all of the following monitoring:

1. Gas Detection. Should a gas alarm be raised the system emergency stop circuit should be tripped. Follow the instructions in the installation document. As a guideline gas detection can be split into the following categories:
   a) HCl detector for halide precursors, e.g. TiCl4
   b) Flammable metal organic detector* (e.g. one calibrated for pentane has some cross sensitivity to other organics)
   c) Flame, heat or smoke detector

Depending on the risk assessment for a particular precursor and the facilities the following may be also considered:

2. Extract flow rate detection. Should the extraction levels drop below the flow rates specified in the installation document the system emergency stop circuit can be tripped. Follow the instructions in the installation document. In many facilities it is common to have a central extract flow rate monitor that will raise a general alarm. When writing a risk assessment such central extract monitoring must be considered when determining if local extract monitoring is required.

Since many ALD precursors are novel and supplied in small quantities most gas sensor manufacturers will not have a sensor specifically calibrated for a particular ALD precursor or know relative cross sensitivities. The gas detection manufacturers are usually able to calibrate a particular sensor by releasing a known volume of precursor into a cabinet. Such a calibration usually costs several thousand USD. For expensive precursors used as a one off this is clearly not a viable financial option.

In this case the following can be taken into account when writing a risk assessment for a new precursor:

- Carefully review the hazard information available in the MSDS.
- Limit the quantity stored inside of the module.
- A general metal organic detector may have some cross sensitivity.
- Extraction is running at all times.
- The precursor module is constructed of stainless steel.
- A glove box is used during precursor changeover.

Tripping the emergency stop circuit will close the isolation valves inside the precursor module. This will seal the precursor inside of the precursor module. Should the leak be coming from the precursor ampoule connections, shutting these isolation valves will not stop the leak. In this case extraction must continue. In the event of either alarm staff must be evacuated to a safe area.

Staff must only return when the precursor modules are being extracted and gas detection levels have dropped.

1.5.14.3 Extraction Failure

WARNING 1.29

TOXIC SUBSTANCES
Exposure to toxic substances can cause death or serious injury. If the extraction system fails, there is a risk of release of toxic gas. Evacuate all personnel to a safe area.

In order for extraction to be effective, the precursor modules are not sealed.

Single-precursor ovens modules incorporate a fan, which draws air in through the bottom of the module. The air is expelled through the extraction port.

Six-way precursor cabinets incorporate an extraction port. Air is drawn through the grills at the side of the cabinet, and passes across the extraction port.

The precursor modules are not sealed, and they only provide low level containment if the extraction fails. Staff must be evacuated to a safe area if any part of the extraction system fails. Staff must only return when the precursor modules are being extracted and it has be confirmed that all gas concentrations in the atmosphere are within safe limits.

In the unlikely event of a gas alarm and an extraction failure full PPE must be worn when opening the precursor module door even if monitoring in the ambient environment surrounding the system shows no signs of precursor due to the risk of increased levels of precursor inside of the un-extracted module.

The nitrogen purge into the module provides a *suppressed* atmosphere. It only reduces the moisture and oxygen levels inside. The module cannot be considered an inert environment since it is not sealed.

1.5.14.4 Personal protective equipment

Heat resistant gloves must be worn when operating the manual ampoule valves inside of the oven or precursor cabinet. The ampoule valves inside an oven are at the same temperature as the precursor pot. If jacket heating is used, the ampoule valves are at a lower temperature than the precursor pot, but the valves can still be hot enough to cause burns.

All precursor gas pipe operations and chemical handling must be carried out with the precursor ampoule COLD. The level of PPE required depends on the precursor and specific advice must be sought from the MSDS, but generically the following should be made available to user:

- The glove box
- Full face mask with correct filter or self contained breathing apparatus
- Chemically resistant gloves or flame resistant gloves/gauntlets (elbow length)
- Chemical or flame resistant apron or suit

1.5.14.5 Exhaust and exhaust treatment

Please consult OIPT for specific advice; however the following must be considered for exhaust gases, particles and condensates from the reactor:

- Gas reactor column (GRC) with appropriate absorbent granules – pay particular attention for compatibility with pyrophorics.
- Foreline filter traps are available from OIPT.
- All exhaust lines must be metal.

OIPT recommends heating the foreline between the chamber and the foreline trap or pump. Consult the installation datasheet for specifications of heater tape to be used.

Personal protective equipment must always be worn when servicing a foreline or exhaust from any ALD reactor. This PPE must include chemical or flame resistant gloves or gauntlets, a respirator, and overalls. Heating the foreline greatly reduces the build up of deposits, but does not totally eliminate them. Even when heating is used, there will be a small amount of residue (from solids/powders to semi-solid partially reacted precursor deposits) left in the foreline pipework.

When using ultra low vapour pressure liquids or solids that are highly toxic exhaust heating is essential.

1.5.14.6 Dealing with a spillage of ALD precursor

When dealing with ALD precursors an appropriate chemical spill kit (suppliers include Arco & 3M) along with trained personnel wearing appropriate PPE must be readily accessible.

The drip tray beneath each precursor ampoule is designed to catch liquid spillages. In the event of a spillage full PPE must be worn according to the MSDS of the chemical that has spilt. The spillage team must then use appropriate absorbent material to remove the liquid from the drip tray while it is still inside of the precursor module. The spillage kit must then be placed into the appropriate container (e.g. acid resistant, flame resistant, sealed, etc.) and disposed of as hazardous waste according to local regulations.

1.5.14.7 Opening and servicing an ALD reactor

Before opening or servicing an ALD reactor:

- All precursors must be pumped from the lines.
- All lines must be pumped and purged.
- All lines must be leak checked.

Follow the procedures in **Chapter 4**.

Wear appropriate PPE when servicing a reactor. Always assume liquid can be released from gas lines, and never place unprotected hands (or other parts of the body) underneath the pipe in a path where liquid could spill/flow.

1.6 System safety features and interlocks

This section describes the principle safety features incorporated into the system, and how they impact the operation and maintenance of the machine.

1.6.1 EMERGENCY STOP buttons

The system is provided with **EMERGENCY STOP** buttons. Pressing any of the buttons once removes electrical power from all parts of the system except for the main distribution panel. When operated, the buttons latch in the OFF position to ensure that electrical power is removed from the system.

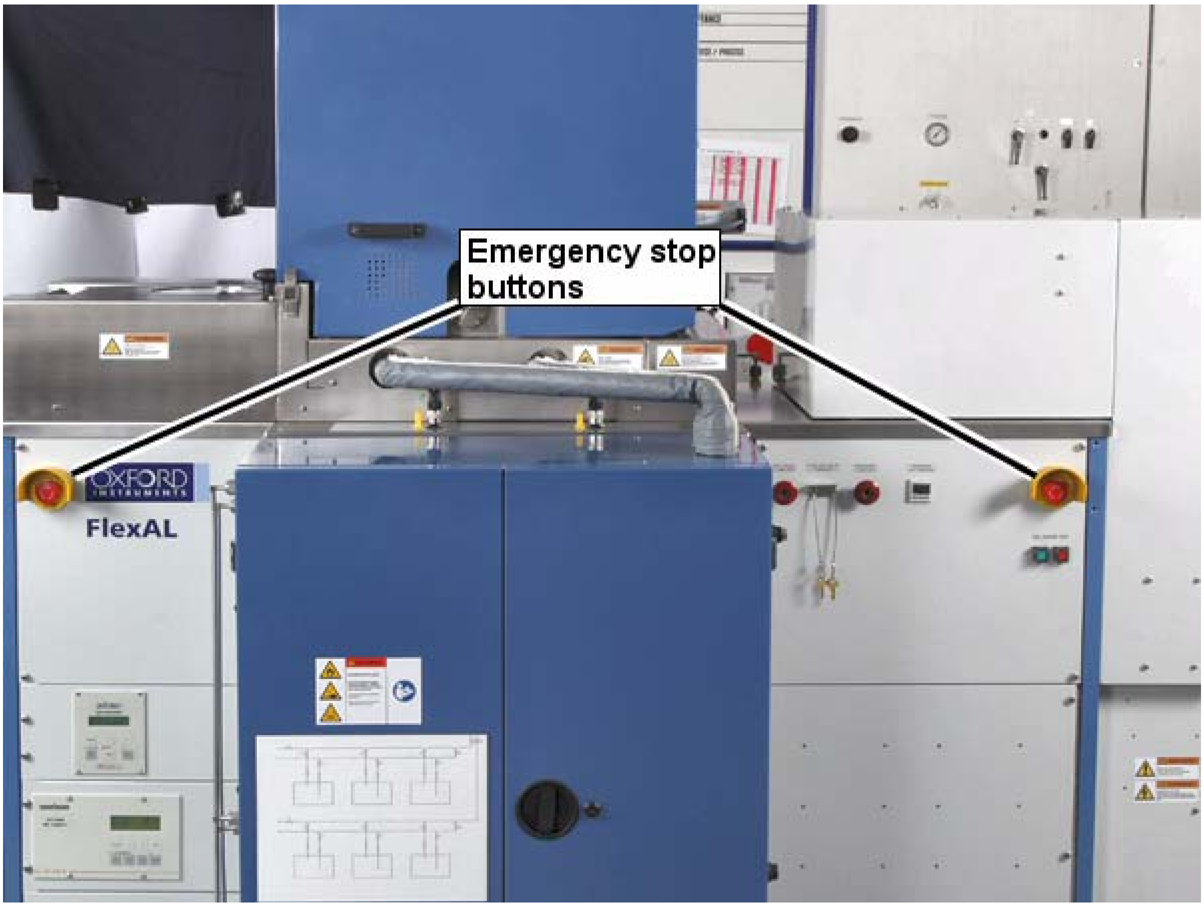


Figure 1-3 Location of the EMERGENCY STOP buttons

NOTE: Customers may fit additional **EMERGENCY STOP** buttons in other locations, for example near a remote gas pod or pump. The operation and function of additional buttons is identical to that of the main emergency stop buttons.

The **EMERGENCY STOP** buttons are intended for use when electrical power must be immediately removed from the system to prevent personal injury or an imminent hazard. They should also be operated if the building is being evacuated because of fire, earthquake or other major event.

1.6.1.1 Hazards present after an emergency stop

It must be noted that pressing an **EMERGENCY STOP** button does not remove all potential hazards from the system. In particular the following hazards may still be present:

a) Hazardous voltages in the mains input cable.

b) Hazardous voltages on the main circuit breaker and contactor in the power box.

c) Hazardous voltages on the 24 VDC power supply in the power box.

d) Hazardous voltages on the power box cooling fan.

e) Stored electrical energy in capacitors.

f) Toxic gases trapped within the gas pod, gas lines, vacuum pumps and process chamber.

g) Pressurised air trapped in pneumatic components.

h) Parts of the system may still be under vacuum.

i) Parts of the system may still be at high or low temperatures.

Caution 1.2

EMERGENCY STOP
Only press an **EMERGENCY STOP** button if an immediate hazard is perceived. Repeated use of the **EMERGENCY STOP** buttons can degrade parts of the system, resulting in premature failure.

The **EMERGENCY STOP** buttons do not shut the machine down in a controlled way, and must not therefore be used for shutting the machine down for maintenance, or as part of the routine operation cycle.

Once an **EMERGENCY STOP** button has been pressed, it can be released by rotating the red button. This must only be done by trained personnel once the emergency has been resolved and all potential hazards have been isolated. The normal machine start-up sequence must then be performed to return the system to service. Care must be taken to evacuate and purge the chamber and loadlock in order to remove toxic gases before opening these items.

1.6.2 Safety interlocks

The system incorporates many interlocks. In general, interlocks occupy one of two classes:

Safety interlock
The primary function of a safety interlock is to protect personnel from exposure to a hazard.

Equipment interlock
The primary function of an equipment interlock is to protect the equipment from damage.

Interlocks which have both a safety and an equipment function are classed as safety interlocks.

The following functions are protected by safety interlocks:

- Enabling RF power.
- Enabling process gases.
- Enabling the end-point laser (if fitted).

The main interlock chain is discussed in more detail in **Section 1.6.2.1**. Additional safety interlocks are discussed in **Section 1.6.3**.

1.6.2.1 Main interlock chain

The main interlock chain consists of a set of electrical contacts wired in series and fed from a 24 VDC supply. The interlocks form a continuous chain, which must be complete before the process gases and RF power supplies are enabled. An output to disable external devices unless the lid is closed is also provided; this is typically used to disable a lid-mounted endpoint detector laser.

The interlock chain is monitored by the software, but acts independently. It is also supplemented by machine protection sensors, which operate only via the software.

To enable RF power, the following conditions must all be true:

- The vacuum interlock switch (Vacstat) must be closed (pressure <600 mbar).
- The process chamber lid must be shut.
- The primary process pump must be running.
- The primary process pressure gauge (normally a capacitance manometer) must be less than full-scale.
- The load lock inter-chamber valve (where fitted) must be closed.
- Customer-supplied external alarm devices must be in their safe state.
- The inert gas purge to the primary process pump must be flowing.

To enable process gases, the following conditions must all be true:

- RF power must be enabled (i.e. all of the above interlocks must be good).
- The gas box lid must be shut.

Refer to **Section 2.10.4** for a complete description of the interlock chain.

Specific gases can be set in the gas box hardware so that they cannot be turned on together (see **Section 1.6.3**).

1.6.2.2 Customer external interlock input

An electrical interlock input is provided to allow the customer to connect any external safety alarm devices into the main interlock chain. Examples of devices that might be connected include exhaust scrubber alarms, gas detectors, smoke detectors, fire alarms, water spillage detectors etc.

The input requires a simple electrical contact to complete the interlock chain. Any customer devices must provide relay contact outputs that fail safe (i.e. the contact breaks if a fault condition is detected or if the customer device fails for any reason).

If no external devices are connected, the customer alarm input must be linked out.

1.6.3 Gas panel interlocks

1.6.3.1 Main gas pod interlock

To enable process gases, the RF interlock chain must be complete. The gas box interlock is shown in **Figure 1-4**.

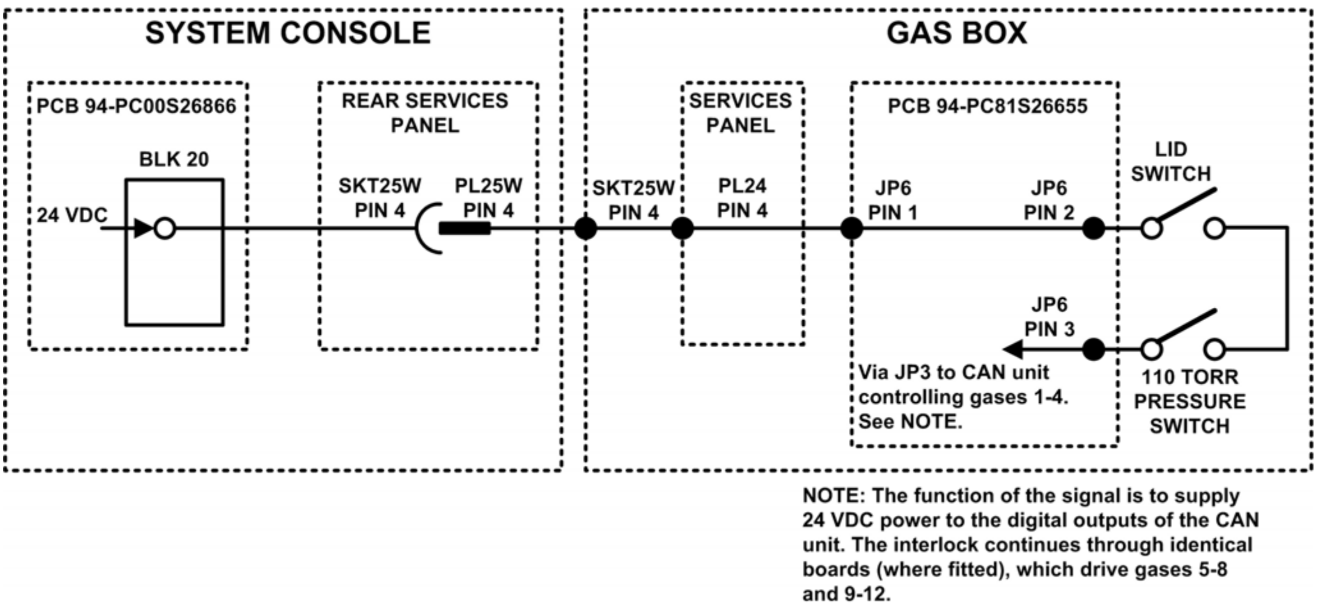


Figure 1-4 Gas pod interlock chain

1.6.3.2 Gas pod manifold pressure interlock

On **FlexAL**® systems, the gas pod manifold incorporates a pressure switch. This switch prevents excessive pressure building up inside the manifold if there is a blockage, or failed valve, between the manifold and the process chamber. The pressure switch disables the gas pod interlock chain when the pressure exceeds 110 Torr.

1.6.3.3 Incompatible gases interlock

The gas panel contains an additional safety interlock circuit to prevent incompatible gases from mixing. This circuit is located on the gas control card, located at the bottom of the gas pod.

Each gas line has an associated circuit link which can be connected in one of three ways:

- Fuel gas.
- Oxidiser gas.
- Neither fuel or oxidiser gas.

These links are configured in the factory to match the gas configuration specified by the customer. The gas control card uses safety relays to prevent any fuel gas mixing with any oxidiser gas.

For example, if silane (a fuel gas) is already flowing into the chamber, the interlock circuit prevents the operator opening the selection valve for oxygen (an oxidiser gas).

Refer to **Section 2.10.4.1** for a complete description of the gas control card interlocks.

1.6.3.4 Gas pod door interlock

The gas pod contains a microswitch that operates when the door is closed. Opening the door causes the microswitch contacts to break, which in turn interrupts the 24 VDC supply to the gas pod. The 24 VDC supply powers the pilot valves that control the pneumatic valves in the gas pod. Interrupting this power supply forces all normally closed valves in the gas pod to close and all normally open valves in the gas pod to open. Refer to **Section 2.10.4.1** for a complete description of the gas pod door microswitch.

1.6.3.5 Precursor module door interlock

The precursor module contains a microswitch that operates when the door is closed. Opening the door causes the microswitch contacts to break, which in turn interrupts the 24 VDC supply to the precursor module. The 24 VDC supply powers the pilot valves that control the pneumatic valves in the precursor module. Interrupting this power supply forces all normally closed valves in the precursor module to close and all normally open valves in the precursor module to open.

1.6.4 Equipment interlocks

The interlocks listed in this section are designed to protect the equipment from failure, and do not have a primary safety function.

Turbo pump interlock

If the system has a turbo pump, the following interlock must be made in order to start the pump:

- Nitrogen pressure on the turbo pump bearing purge line must be sufficient to purge the pump bearings (pressure switch on the purge line).

Backing pump interlock

The following interlocks must be made in order to start the pump:

- Nitrogen flow in the pump purge gas line must be sufficient to purge the pump bearings (flow-switch on the purge line).

1.6.5 Electrical protection devices

Power box circuit breakers and protection devices are given in the drawings in Volume 2.

1.7 Personal protective equipment

It is important to wear the correct personal protective equipment (PPE) when working on the system. This section lists typical items of PPE for guidance only. It is the customer's responsibility to perform risk assessments and to produce their own list of personal protective equipment.

Table 1-1 Examples of personal protective equipment

PPE Item	Use
Latex or nitrile gloves.	Handling any vacuum components. Working near components that may contain toxic or corrosive gas or residues. Using solvents or cleaning materials. Working near process wafers.
Eye protection (e.g. safety goggles or face mask).	Working near components that may contain toxic or corrosive gas or residues. Changing gas bottles. Using solvents or cleaning materials. Performing any tasks that may generate dust or particles. Maintaining any part of the system that may contain pressurised gas. Maintaining any components that may contain springs. Working near cryogenic components.
Self-contained breathing apparatus.	Changing gas bottles that contain toxic or corrosive gas. Maintaining components that may have contained toxic or corrosive gas.
Filtered mask (e.g. 3M® 6899B with an appropriate filter such as ABEK2P3).	Changing gas bottles that contain certain toxic or corrosive gases. Maintaining components that may have contained certain toxic or corrosive gases. General cleaning operations when organic solvents are used.
Dust mask.	Cleaning or maintaining vacuum components that may contain toxic or corrosive deposits. Performing any tasks that may generate dust or particles. NOTE: A dust mask does **not** provide protection against toxic or corrosive gas.
Disposable overall.	Handling any vacuum components. Working near components that may contain toxic or corrosive gas or residues. Using solvents or cleaning materials. Performing any tasks that may generate dust or particles.

Table 1-1 Examples of personal protective equipment

PPE Item	Use
Thermal protective gloves.	Working near cryogenic components. Handling or transporting cryogenic fluids (e.g. liquid nitrogen).
Safety shoes.	Moving or lifting heavy items.

1.8 Mandatory safety procedures

It is the customer's responsibility to perform risk assessments and to develop and enforce suitable safety procedures. However, the following sections stipulate minimum precautions that must be taken when performing various tasks.

1.8.1 Maintenance on the chamber or vacuum system

1.8.1.1 If toxic or corrosive gases are present on the system

WARNING 1.30

TOXIC GASES

Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

If toxic or corrosive gases are present on the system, perform the following mandatory procedure before maintaining the process chamber or vacuum system:

1. Allow the process chamber to pump down to its base pressure after the gas supply has been turned off.
2. Vent and pump the process chamber twice without opening the chamber lid (see **Section 5.6.4**).
3. Vent the process chamber and perform the maintenance. Wear appropriate personal protective equipment.
4. Treat all vacuum components as toxic and corrosive.
5. Dispose of any vacuum components or cleaning materials according to local and national regulations.
6. Perform a vacuum leak check on the system before returning it to service.

1.8.1.2 If flammable gases are present on the system

WARNING 1.31

FLAMMABLE GASES
Contact with flammable gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

If flammable gases are present on the system, perform the following mandatory procedure before maintaining the chamber or vacuum system:

1. Allow the process chamber to pump down to its base pressure after the gas supply has been turned off.
2. Vent and pump the process chamber twice without opening the chamber lid (see **Section 5.6.4**).
3. Vent the process chamber and perform the maintenance, using appropriate PPE.
4. Perform a vacuum leak check on the system before returning it to service.

1.8.2 Maintenance on gas components and the gas pod

WARNING 1.32

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. Trapped volumes of hazardous gas may be present in process gas supply lines, including the gas pod. Ensure that all gas lines and gas components are purged and isolated before disconnecting or removing any part of the gas delivery system. Wear personal protective equipment as necessary.

If toxic, flammable or corrosive gases are present on the system, trapped volumes of hazardous gas may be present in process gas supply lines, including the gas pod. Care must be taken to follow the appropriate pump, purge and bypass procedures before performing any action that may release this trapped gas. If equipment failure prevents the operation of normal evacuation and purge procedures, consult the local safety representative before proceeding. A risk assessment must be performed to decide the safest method for resolving the issue before any action is attempted.

Perform the following mandatory procedure before disconnecting or removing any part of the gas delivery system:

1. Shut all gas delivery valves at source (e.g. the point-of-use valves or gas bottle valves).
2. Evacuate each gas line in turn, including gas lines that are not directly affected by the maintenance. Use the proper procedure for evacuating gas lines, including correct operation of the bypass valves (see **Section 8.3.1**).
3. Purge and evacuate the gas line that is to be worked on. Use the proper procedure for purging the gas line (see **Section 8.3.1**).
4. Perform the maintenance, using appropriate PPE.

5 Treat all components that may have come into contact with toxic or corrosive gas as toxic and corrosive.

6 Purge, evacuate and leak check all gas components that have been disturbed or replaced before turning on the gas supply.

1.8.3 Maintenance on the precursor delivery modules

Perform the procedure described in Chapter 7 before opening any gas or vacuum connections in the precursor module.

1.9 Warning and hazard labels

Warning and hazard labels are placed at appropriate locations on the system to warn personnel about potential hazards. The following categories of label are used:

- DANGER
  Exposure to the hazard **would** result in serious injury or death.
- WARNING
  Exposure to the hazard **could** result in serious injury or death.
- CAUTION
  Exposure to the hazard could result in minor injury or damage to the equipment.

Table 1-1 shows all the labels that may be encountered, and lists their locations.

Table 1-2 Equipment hazard warning labels

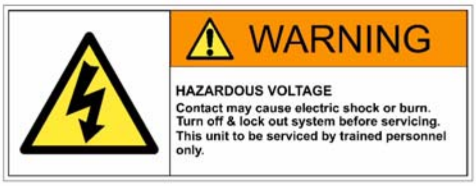
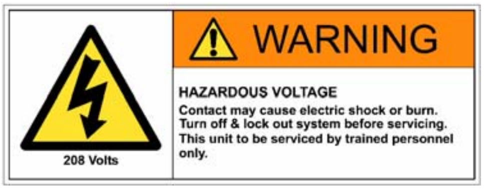
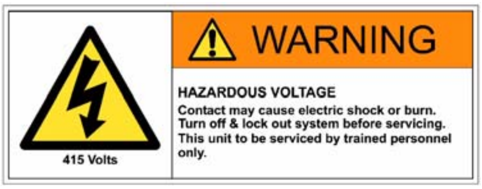
Label	Description	Location
	The assembly that this label is attached to contains hazardous voltages. Ensure that the electrical power to the system is locked out before removing the assembly covers or attempting to service the assembly.	Turbo pump outer cover. Recirculation chiller controller. Three-phase filter outer cover. Vacuum valve outer cover. RF/DC generator outer cover. Power box out cover and inside box.
	The assembly that this label is attached to contains hazardous voltages up to 208 V. Ensure that the electrical power to the system is locked out before removing the assembly covers or attempting to service the assembly.	Turbo pump outer cover. Recirculation chiller controller. Three-phase filter outer cover. Vacuum valve outer cover RF / DC generator outer cover. Power box outer cover and inside box.
	The assembly that this label is attached to contains hazardous voltages up to 415 V. Ensure that the electrical power to the system is locked out before removing the assembly covers or attempting to service the assembly.	Turbo pump outer cover. Recirculation chiller controller. Three-phase filter outer cover. Vacuum valve outer cover RF / DC generator outer cover. Power box outer cover and inside box.

Table 1-2 Equipment hazard warning labels

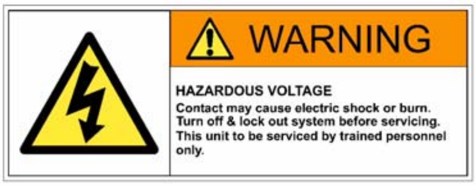
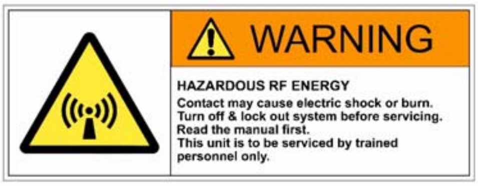
Label	Description	Location
	The assembly that this label is attached to contains hazardous voltages. Ensure that the electrical power to the system is locked out before removing the assembly covers or attempting to service the assembly.	
	Warns of the risks associated with a high leakage current.	Power-box mains cable.
	The assembly that this label is attached to contains hazardous RF energy. Ensure that the electrical power to the system is locked out before removing the assembly covers or attempting to service the assembly.	
	The assembly that this label is attached to contains hazardous RF energy. Ensure that the electrical power to the system is locked out before removing the assembly covers or attempting to service the assembly.	
	There is a hot surface adjacent to this label. Ensure that suitable protective gloves are worn, or that the surface has cooled to a safe temperature, before accessing this area.	Chamber walls. Loadlock walls. Precursor cabinet.
	Danger of physical injury due to a tilt hazard.	Precursor cabinet.
	There is a pinch point adjacent to this area. Ensure that operating personnel are aware of the hazard. Keep fingers and hands clear of the mechanism unless the electrical and pneumatic supplies to the machine are locked out.	Upper process chamber. Upper loadlock.

Table 1-2 Equipment hazard warning labels

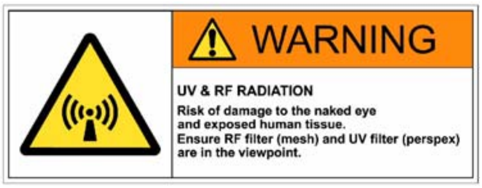
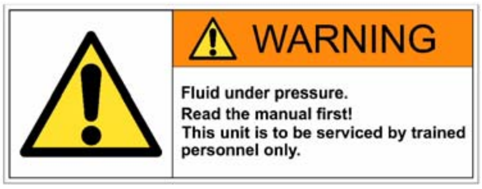
Label	Description	Location
	Warns that there is electrical equipment mounted on the reverse of the panel that the label is affixed to.	System exterior panel.
	The equipment generates UV and RF radiation. Ensure that the viewport has a RF filter and a UV filter fitted. Do not operate the equipment without the filters in place.	RF shielding. RF generator cover. RF coaxial cable.
	Danger of physical injury from RF and UV radiation from the labelled components.	Process chamber viewport.
	The assembly that this label is attached to contains fluid under pressure. Read the manual before servicing this item.	Gas pod. System services panel.
	Read the relevant section of this manual before servicing the assembly that this label is attached to.	Turbo pump controller outer cover. Recirculation chiller controller. Vacuum gauge outer cover. Three phase filter outer cover. MFC outer cover. RF / DC generator outer cover. Foreline pump outer cover. Power box external and internal panels.
	Warns that the pump has been drained of oil and that the pump should not be operated.	Process chamber backing pump.

Table 1-2 Equipment hazard warning labels

<table>
<tr><th>Label</th><th>Description</th><th>Location</th></tr>
<tr><td>
</td><td>The assembly that this label is attached to may contain hazardous fluid. Read the manual before servicing this item. Perform a risk assessment to consider what hazards may be present and enforce the use of suitable procedures and personal protective equipment accordingly.</td><td>Precursor cabinet exterior panel. Gas pod outer door.</td></tr>
<tr><td>
</td><td>Warns of the risks of mixing incompatible pre-cursors.</td><td>Precursor cabinet, inside and outside.</td></tr>
<tr><td>
</td><td>Warns of a possible explosion risk if any container of water is fitted to the cabinet.</td><td>6 way bubbler precursor cabinet or similar.</td></tr>
<tr><td>
</td><td>Warns of potential explosion hazard if instructions are not followed.</td><td>System services panel.</td></tr>
<tr><td>
</td><td>Warns that a filter gasket must be fitted in the indicated location.</td><td>Gas-pod interior panel.</td></tr>
</table>

Table 1-2 Equipment hazard warning labels

Label	Description	Location
	General warning label where a specific warning label won't fit.	Any hazard.
	Identifies recommended location for fork lifting.	System frame.
	Identifies the location of electrical safety ground.	Power box, earth studs around system.

1.10 Solid waste

Oxford Instruments Plasma Technology endeavour to use components and materials that are compliant with the Restriction of Hazardous Substances (RoHS) directive**Ref:[17]** in the construction of the system. However some parts can become contaminated with plasma effluent or vacuum oil during use, and can thus become solid waste.

This section lists items that become solid waste as a result of the operation, maintenance and servicing of the equipment, and that are constructed of, or contain, substances whose disposal might be regulated.

- Vacuum pipework downstream of the turbo pump, in a turbo pump system. This includes flexible pipes, solid elbows and tees that may have become contaminated with plasma effluent.
- Vacuum pipework downstream of the automatic pressure controller / gate valve assembly, in a plasma enhanced chemical vapour deposition (PECVD) system. This includes flexible pipes, solid elbows and tees that may have become contaminated with plasma effluent.
- Turbo pump isolation valve, on turbo pump systems.
- All vacuum O-rings.
- Chamber viewport glass.
- The lithium battery in the programmable logic controller (PLC).

1.11 Risk assessments

It is the customer's responsibility to perform their own set of risk assessments before operating or maintaining the system. Risk assessments must follow the recommendations outlined in BS EN ISO 14121: 2007 (Safety of Machinery - Risk Assessment part 1)Ref:[3]. The following list contains some possible items for evaluation.

NOTE: It is the customer's responsibility to perform risk assessments. This list is for illustrative purposes only and does not absolve the customer of any responsibility.

Gas detection equipment
Evaluate what gas detection equipment is required to protect personnel from harm. This equipment may include detectors for high concentrations of toxic or flammable gas, or for low levels of oxygen. The risk assessment must carefully consider the types of gas that may be present, optimum locations for the sensors, visual or audible warnings if a hazard is detected, and any other action that should be triggered by the alarm.

Personal protective equipment
Evaluate which items of PPE are required for various tasks, including normal operation of the system, changing gas bottles, and typical maintenance activities. The level of PPE required depends on the processes being run on the system, and the hazardous nature of any source gases.

Training
Evaluate the level of skill and training that is required to perform various tasks, including production operation of the system, engineering operation of the system, changing gas bottles, and various maintenance activities.

Keys
The system incorporates several key-operated items. Assess which personnel should have access to the system keys and enforce a suitable protocol for access to keys.

Tools and equipment
Evaluate if any special tools or equipment are required during maintenance of the system. Examples include lifting aids, portable radiation monitors and portable gas detectors.

Emergency equipment
Evaluate if any equipment is required in case of an emergency. Examples include first aid kits, fire extinguishers, eye wash-bottles, HF treatment packs, spill containment equipment and emergency extraction systems.

Procedures
The customer must evaluate and enforce operating and maintenance procedures in accordance with their own safety protocols. For example, some customer sites allow suitably trained personnel to work on live electrical equipment while some sites do not.

1.12 System modifications

In general system modifications are not permitted unless authorised in advance by Oxford Instruments Plasma Technology. Unauthorised modifications will void the system warranty.

RF components, such as RF ion sources, may be purchased from Oxford Instruments Plasma Technology and fitted to the customer's system. Such an installation requires a system designed to prevent leakage of RF emissions, and requires careful testing by the installer before use.

It is not possible to give a full list of necessary safety precautions, and advice must be sought from a competent authority. However, some of the points to be considered are as follows:

a) The system and all of its assemblies must be very well grounded (earthed), using low impedance straps. Ensure that all impedances between power supplies and the chamber are <0.1 Ω at 25 A.

b) Viewports must be shielded with fine conducting mesh to prevent the transmission of RF energy, and must be filtered to prevent the transmission of UV light.

c) Doors and flanges must provide metal-to-metal contact. In case of doubt, and in the case of access doors, the use of copper beryllium finger strips or wire mesh over elastomer core (e.g. Zemrex® products from Laird Technologies) must be considered. Small flanges in the vacuum system must be joined with clamps made of metal, not plastic.

d) Assess all types of electrical feedthrough and vacuum gauge, together with any cables leaving them, to decide if they need shielding.

e) Interlocks must be wired into the system to ensure safe operation. These include interlocks with the system access door, the customer's water supply to the RF product, and the system vacuum. The product purchased from Oxford Instruments Plasma Technology will also have interlock switches. These interlocks must all force the disconnection of power from the RF, microwave and HV power supplies if they are opened.

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2 TECHNICAL DESCRIPTION

This chapter describes the function and layout of the ALD **FlexAL**® system. The topics discussed here include:

- **Overview of ALD FlexAL®**.
- **Base unit**
- **Process chamber**
- **RF generator and AMU**
- **Loadlock**
- **Gas handling system**
- **Vacuum system**
- **Services panel**
- **Precursor delivery modules**
- **System control**

2.1 Overview of ALD FlexAL®

FlexAL® is an ALD processing system that can be configured to deposit a wide range of materials. Various options are available to precisely tailor **FlexAL**® to customer requirements. The system features an automatic vacuum loadlock which allows substrates to be loaded without venting the main process chamber. **FlexAL**® can process a wide range of substrate sizes up to wafers of 200 mm (8”) in diameter. Substrates smaller than 200 mm are manually loaded on to a carrier.

The substrate, or carrier, to be processed is manually loaded into the loadlock. The system automatically transfers the substrate into the process chamber, runs the desired process, then returns the substrate to the loadlock.

The process chamber can be configured to run a plasma process or a thermal ALD process:

> The plasma process uses radio frequency (RF) power to create a plasma inside a plasma source. The reactive ionic species generated within the plasma are guided on to the front surface of the substrate.
>
> The thermal process uses elevated temperatures to promote deposition on the front surface of the substrate.

ALD processes often use hazardous precursor materials. **FlexAL**® incorporates advanced safety features to protect users from these hazards.

Optionally, an Ozone Delivery System (ODS) can be used provides the oxidant for ALD processes. Ozone is delivered via the water vapour process gas line (see **Appendix C**).

Figure 2-1 shows an outline of a typical **FlexAL**® plasma system.

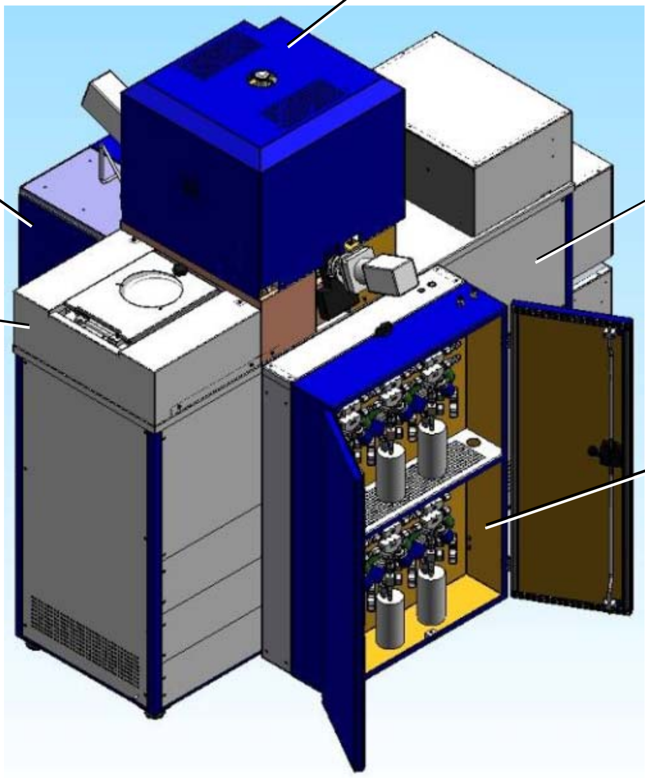

Figure 2-1 General view of a FlexAL® plasma system

The primary components of **FlexAL®** are:

- **Base unit** - which provides the system frame and houses equipment for electrical power distribution, compressed air and nitrogen services, cooling water distribution, and part of the control system.
- **Process chamber** - a vacuum chamber located on the base unit: it provides the environment in which plasma deposition or thermal ALD take place.
- **RF generator and AMU** (not shown) - mounted above the process chamber or in the base unit of plasma systems only. The RF generator provide the power for the plasma ion source. The auto match unit (AMU) matches the impedance of the process chamber and the ion source to that of the RF generator.
- **Pumping module** (not shown) - which provides vacuum pumping for the system. Various configurations are available to suit the customer's process. Most of the pumping module is attached to the base unit and contained within the frame, although the backing pump may be located remotely.
- **Loadlock** - attached to the process chamber to provide the air interface between the chamber and the outside environment. Unprocessed wafers are manually loaded into the loadlock: processed wafers are returned to the loadlock and manually unloaded.
- **Gas handling system** (not shown) - manages the flows of the various process gases required by **FlexAL®**. The gas pod is located apart from the main assembly.

- **Precursor delivery modules** - which provide the precursor necessary to achieve the desired deposition of compound on the substrate. FlexAL is supplied with a precursor delivery module (PDM) that has a six-way precursor system. Two additional PDMs, each with a single precursor oven, are also available.
- **Services panel** (not shown) - a convenient central point for the connection of gases.
- **System control** (not shown) - which runs the PC2000 software and ALD recipes that control **FlexAL**® and the deposition process.

2.1.1 Principle of operation

The basic principle of operation of **FlexAL**® is illustrated in **Figure 2-2**.

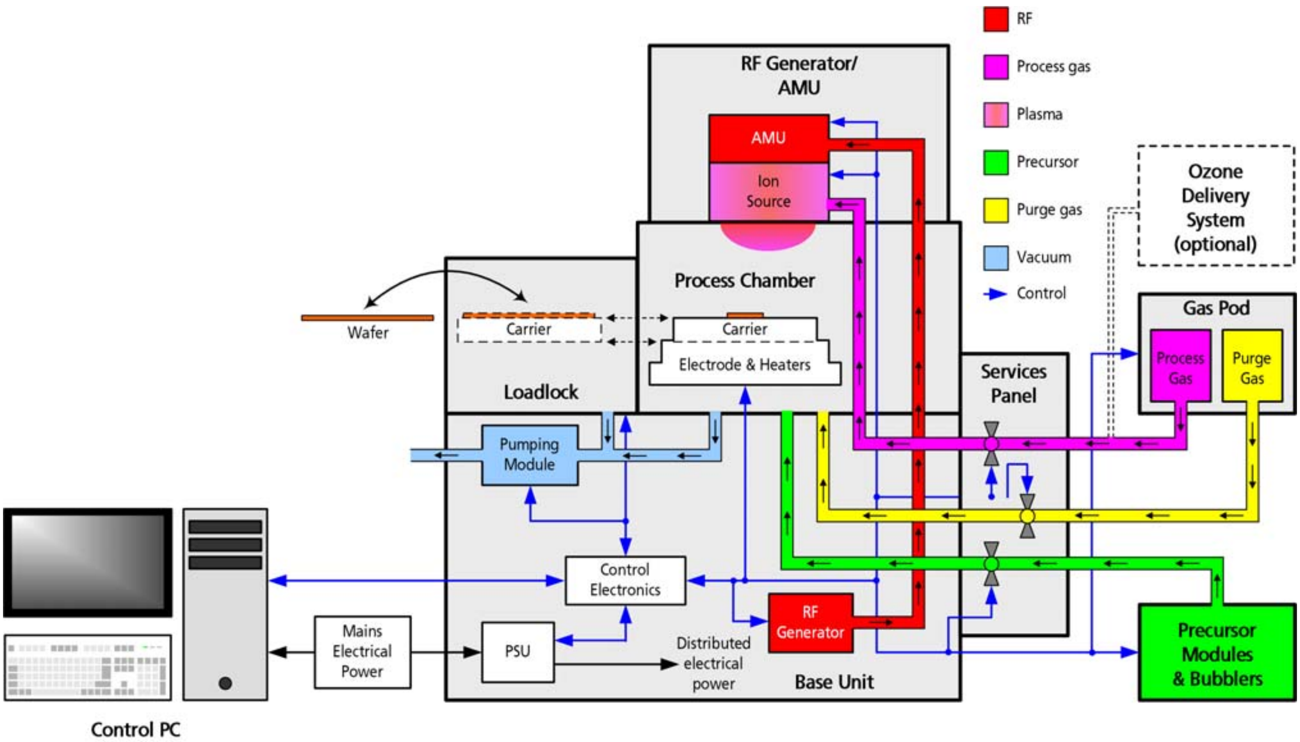

Figure 2-2 Principle of operation of FlexAL®

In summary, the principle of operation is:

1. The required recipe is selected at the PC.
2. The substrate wafers to be processed are manually placed on the carrier, or directly onto the loading arm.
3. The wafers are automatically transferred into the process chamber, where they are placed on the lower electrode (also known as the *table*).
4. The chamber is evacuated, and the lower electrode is heated to increase the efficiency of the deposition process.
5. Thermal ALD (see **2.1.1.1**) or remote plasma ALD (see **2.1.1.2**) take place.
6. When the process chamber has been purged on completion of the recipe, the processed wafers are transferred to the loadlock.
7. The processed wafers are manually removed from the carrier in the loadlock.

2.1.1.1 Thermal ALD

Deposition is performed by repeatedly exposing the substrate to two precursors in sequence. The process is arranged so that the two precursors never directly mix. The substrate is heated to provide the correct conditions for the reaction to occur.

Figure 2-3 represents a vertical section through the process chamber. Precursors and purge gas flow into the chamber via the two inlets shown.

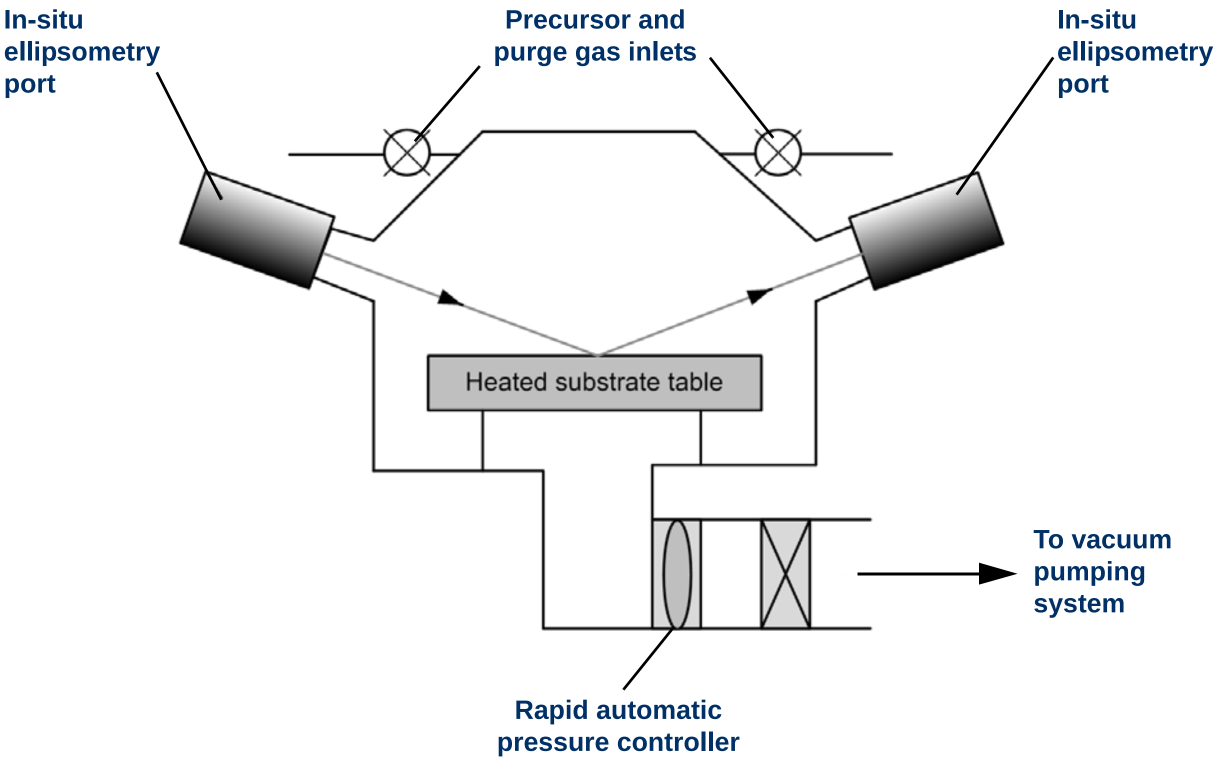

Figure 2-3 Process chamber configured for thermal ALD

A thermal ALD process cycle consists of four basic steps:

1) Flow the first precursor into the chamber. This deposits a monolayer of intermediate material on the substrate.
2) Purge the chamber to remove any unreacted precursor.
3) Flow the second precursor into the chamber. This reacts with the monolayer deposited in step 1) to form the required compound.
4) Purge the chamber to remove any unreacted precursor.

Each cycle deposits an atomic monolayer of the required material. Repeating the cycle increases the thickness of the deposited material, one atomic layer at a time.

An ellipsometer system can be fitted to measure the thickness and refractive index of the deposited layer as it forms.

2.1.1.2 Remote plasma ALD

Deposition is performed by repeatedly exposing the substrate to two precursors in sequence. The process is arranged so that the two precursors never directly mix. One or both of the precursors is a reactive species formed by dissociating a vapour or gas in a plasma chamber. The substrate can be heated, if required.

Figure 2-4 represents a vertical section through the process chamber. Precursors and purge gas flow into the chamber via the two indicated inlets. Gas can also be injected into the top of the ICP source to provide the precursor species for plasma ALD.

A process cycle consists of the following four steps:

1) Flow the first precursor into the chamber. This deposits a monolayer of intermediate material on the substrate.
2) Purge the chamber to remove any unreacted precursor.
3) Flow the second precursor source material into the plasma source, to produce a precursor species. This species reacts with the monolayer deposited in step 1) to form the required compound.
4) Purge the chamber to remove any unreacted precursor.

Each cycle deposits an atomic monolayer of the required material. Repeating the cycle increases the thickness of the deposited material, one atomic layer at a time.

An ellipsometer system can be fitted to measure the thickness and refractive index of the deposited layer as it forms.

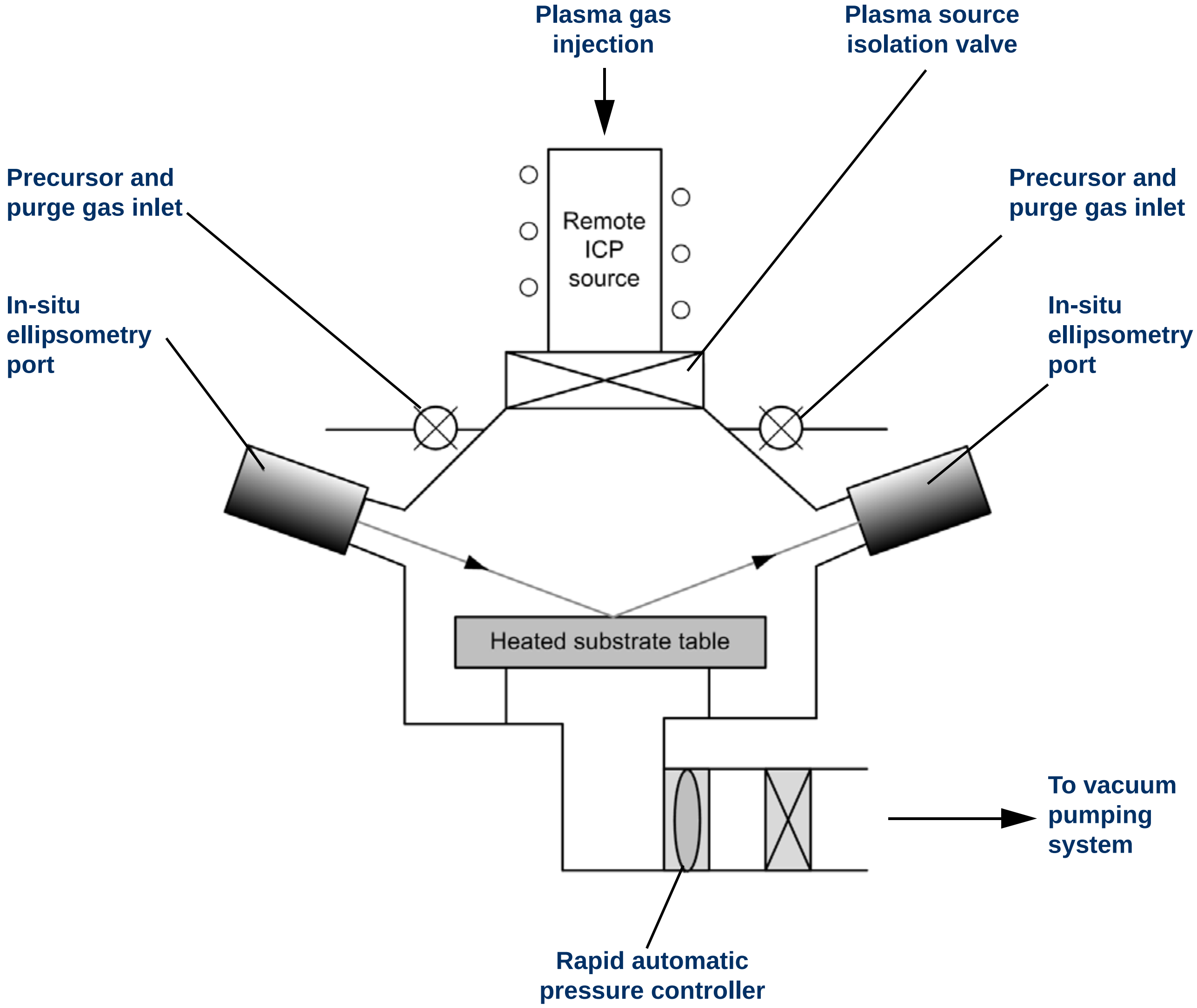

Figure 2-4 Process chamber configured for plasma ALD

2.2 Base unit

The base unit of **FlexAL**® is located in the main body of the system. It houses the process chamber, electronic sub-systems, control units, services and power supplies. The module is mechanically compatible with the requirements of the Modular Equipment Standards Committee (MESC) and is constructed using proven OIPT hardware designs.

FlexAL® is fully interlocked to protect the system hardware from service failure, and to protect personnel from hazards. A lock out valve and a padlock mounted on the frame can be used to inhibit the action of all pneumatically-operated devices during servicing.

2.2.1 Frame

The frame is constructed from steel with removable access panels. Casters and adjustable feet fitted to the bottom of the frame enable the frame to be easily manoeuvred, levelled, and locked in position.

2.2.2 Electrical power box

The electrical power box assembly is mounted on the outside of the frame. The power box distributes mains electrical power, via circuit breakers and contactors, to frame-mounted electrical units, remote auxiliary units (such as vacuum pumps), and the +24 V (±15 V) power supply unit (PSU). For details of power distribution, refer to the relevant drawings in Volume 2 of this manual.

A 24 V DC emergency stop circuit connects all the internal and external emergency stop buttons on the machine. If an **EMERGENCY STOP** button is pressed, main contactor K1 de-latches and the distribution of mains electrical power within the system is shut off.

NOTE: Note mains power remains present at the input side of main contactor K1.

Free-standing auxiliary units such as water recirculators, residual gas analysers, and the system control PC may not be powered from the base unit power box. These accessories require dedicated electrical service points and may remain live when the system **EMERGENCY STOP** button is pressed.

If it is necessary to power off all accessories when the **EMERGENCY STOP** button is pressed, the user must supply a power distribution unit with outlets for the accessories, and contact the factory for electrical access to the machine emergency stop circuit.

2.2.3 Heater distribution box

The heater distribution box is mounted on the outside of the frame. This distributes mains electrical power to the heater circuits. The heaters are controlled by a controller mounted in the top box.

2.3 Process chamber

Figure 2-5 and Figure 2-6 show the main components associated with the process chamber.

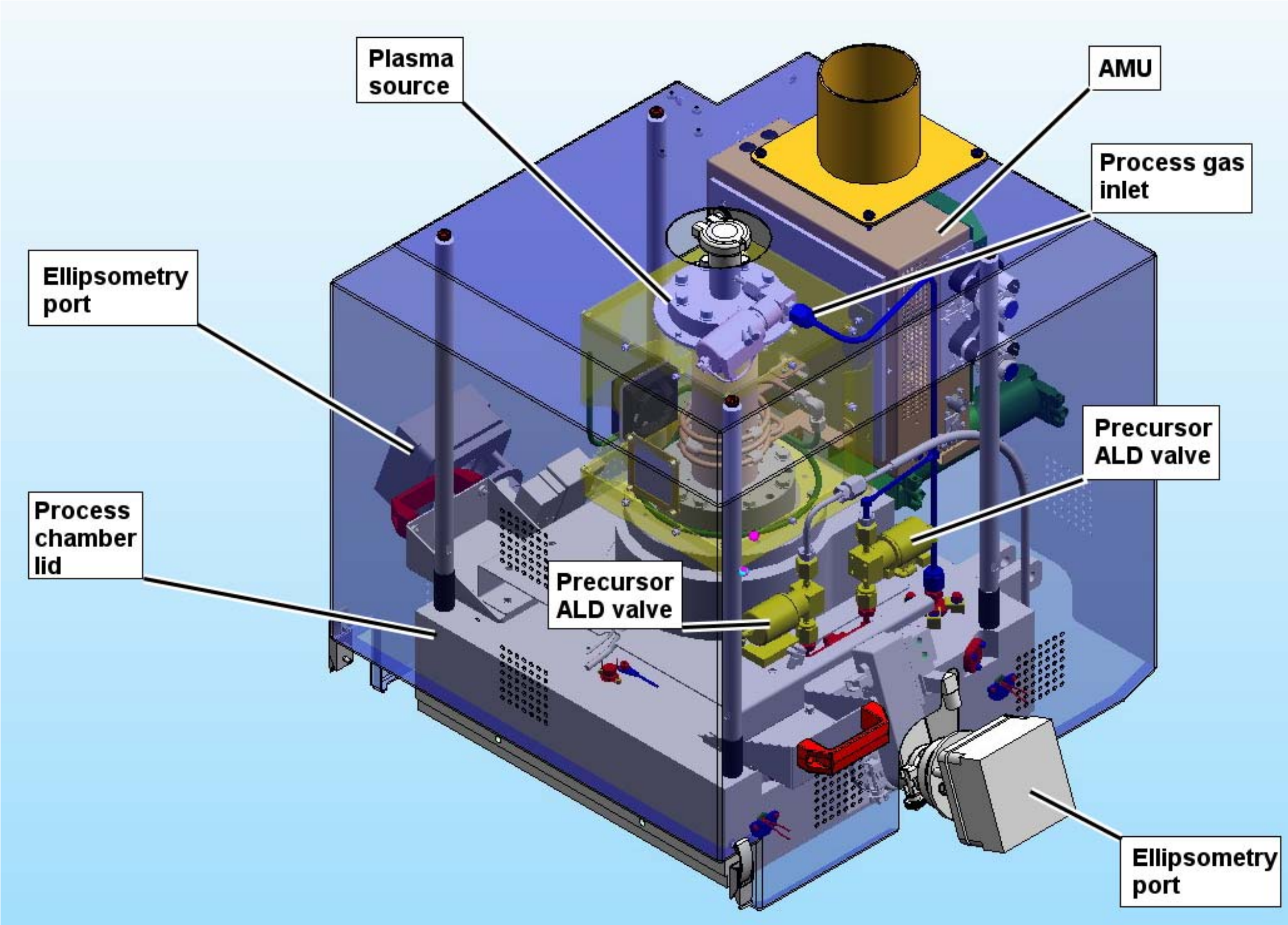

Figure 2-5 ALD process chamber and associated components

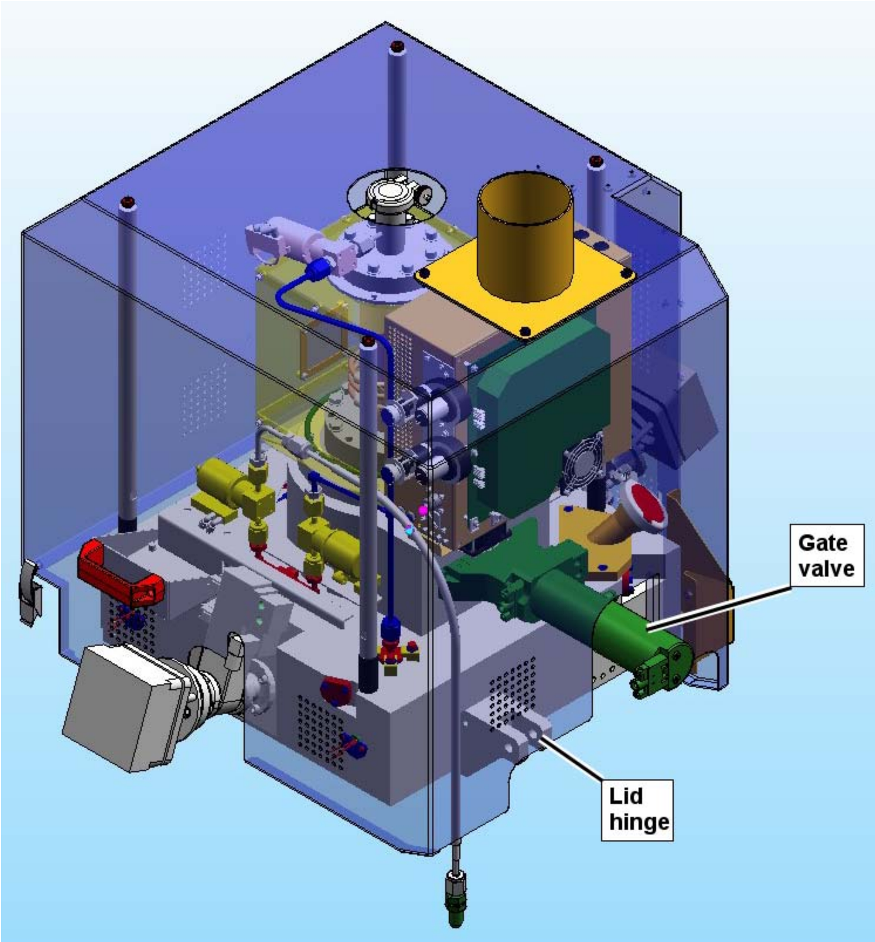

Figure 2-6 ALD process chamber (alternative view)

Plasma source - creates the plasma from the RF power and the process gas.

AMU - maintains process efficiency by matching the impedance of the process chamber and the ion source to that of the RF generator.

Gate valve - obstructs the flow of precursor during a plasma or process step to prevent coating of the ICP tube with precursor.

Process chamber upper part - containing a conical cut-out that accommodates the conical shield that continues the distribution of the species.

Process chamber lower part - containing the lower electrode.

Ellipsometry port - one of two ports at 70 degrees to the norm, for mounting ellipsometry or characterisation devices.

Precursor ports - for the delivery of the precursor liquid.

Pumping port - a pumpdown pipe of 100 mm diameter for extracting gases from the process chamber.

Wafer transfer port - to which a pneumatically-operated slit valve is attached.

Process gas inlet port - for the application of process gases to the ion source.

Vacuum measurement ports - for the connection of vacuum measurement instruments.

2.3.1 Operation of the process chamber

The aluminium upper chamber is attached to the lower chamber by hinges and supported by gas struts. When closed, the upper chamber is secured by two latches. An interlock sensor detects the open/closed status of the upper chamber. An O-ring seals the upper chamber to the lower chamber. If the chamber becomes pressurised, for example during chamber venting, the hinges of the lid lift to prevent the potentially dangerous development of gas over pressure.

The process gas and precursor flow into the base and sides of the lower chamber, and through internal passages to the upper chamber. This connection is made when the upper and lower chambers are in contact. The precursors then enter the upper chamber in the conical section. The plasma and thermal gases flow upwards through the top of the upper chamber and are distributed by two pipes to the side of the plasma source isolation valve or the top of the ICP source.

The wafer lift is pneumatically operated. It raises the wafer off the table so that the wafer can be placed on the transfer arm of the loadlock or transfer chamber.

The gate valve for connecting to the selected wafer insertion device is pneumatically operated. The valve is attached to the chamber by six claw bolts and is positioned by two locating pins (dowels). Sealing is provided by a rectangular O-ring.

2.3.2 Lower electrode

The lower electrode shown in **Figure 2-7**, is a disc of 240 mm in diameter. To increase the efficiency of the deposition process, the electrode is electrically heated to a temperature of 400°C, or optionally 500°C. The temperature of the electrode is controlled directly from the programmable logic controller (PLC) and the electrode is electrically grounded.

The wafer is lifted 15 mm clear of the table for transfer into a load lock or transfer chamber by the wafer lift assembly. Compressed air flowing into the air cylinder forces its piston and plunger upwards. The plunger contacts the base of the bellows, which is connected to a push rod. In turn, the push rod contacts the electrode wafer lift mechanism, which rises, lifting the wafer clear of the table. The push rod and the electrode wafer lift mechanism are lowered by the force exerted by their respective return springs.

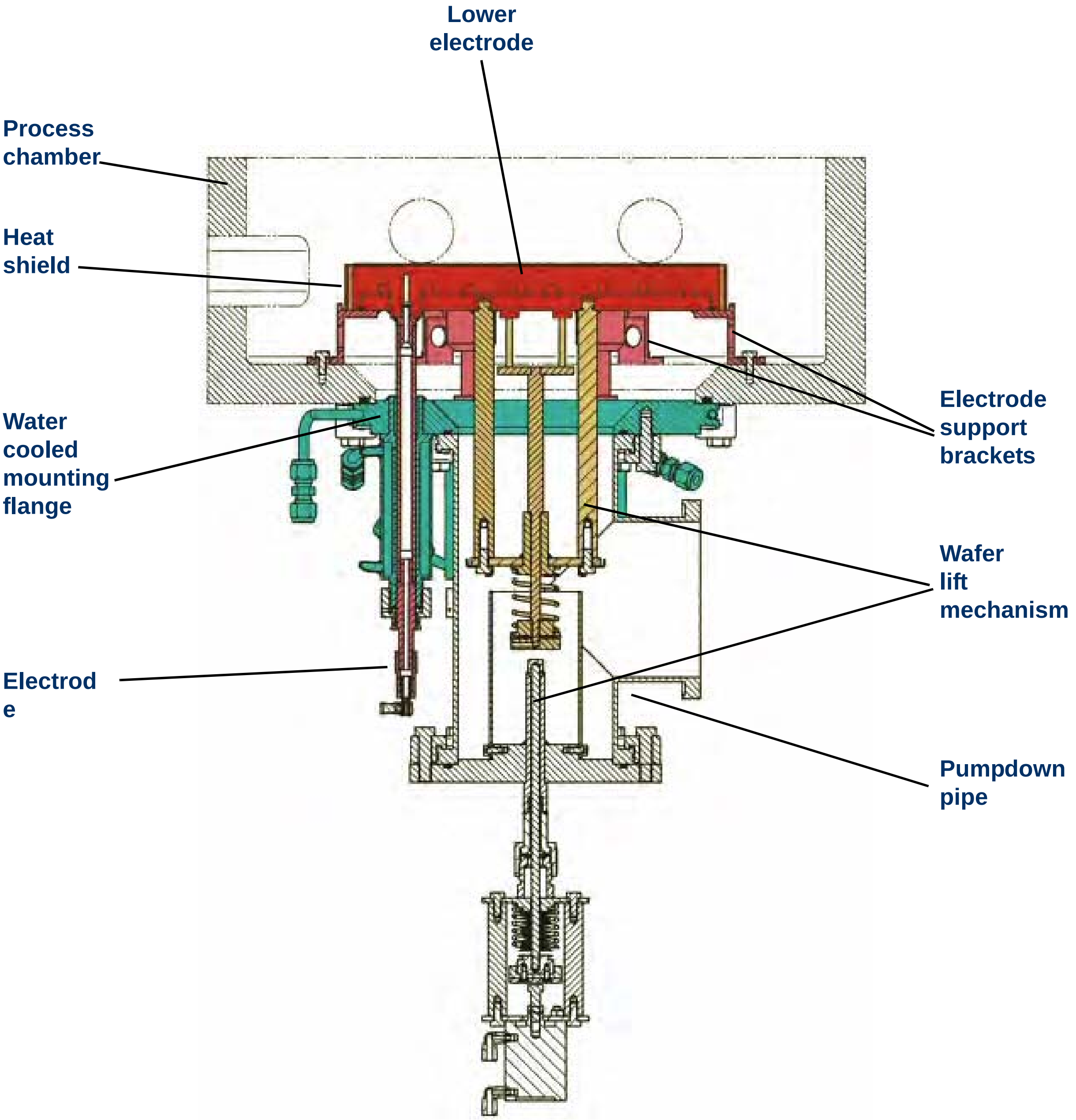

Figure 2-7 Lower electrode

2.4 RF generator and AMU

2.4.1 Auto match unit

The purpose of the AMU is to match the impedance of a process chamber or RF ion source to the RF generator. The output impedance of all RF generators used in OIPT systems is 50 ohms at an operating frequency of 13.56 MHz.

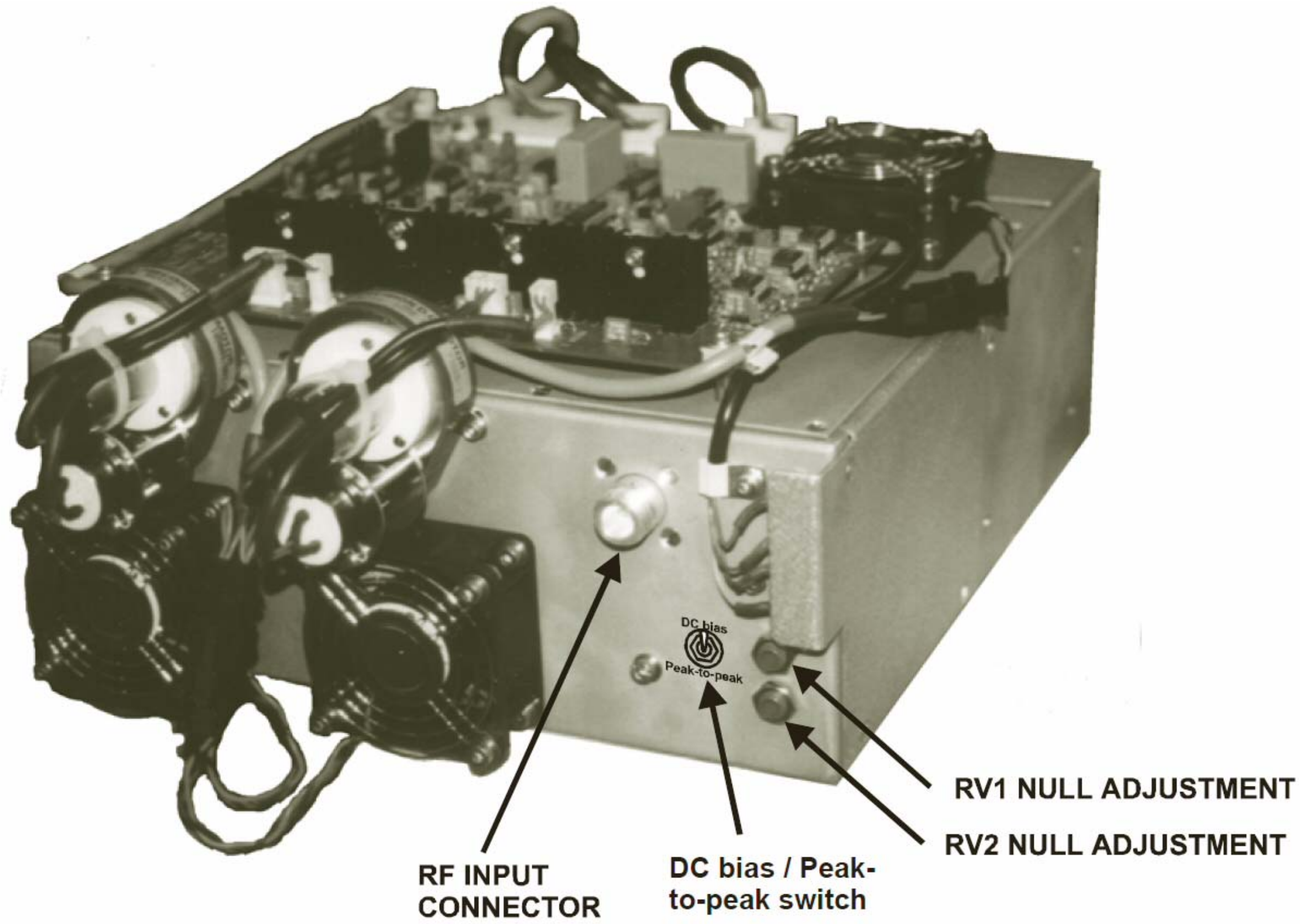

Figure 2-8 Example of AMU

Different versions of internal components exist, but all AMU in this series share common electronic controls and setup instructions. The main versions are:

Low power AMU - the two impedance-matching capacitors are of the air-cooled, vane type. This version is used for single-wafer electrodes matching up to 500 W. The air vane AMU is rated for 300 W operation in all OIPT tools, and for use up to 500 W in specific builds.

High power AMU - the two matching capacitors are water-cooled vacuum types. This version is used in most other applications, including batch electrode matching, 3 kW ICP source, and 3 cm and 15 cm RF ion sources.

NOTE: OIPT also manufactures a 5 kW AMU for use with an ICP 380 source and the 35 cm RF ion source.

2.4.2 Main components of the AMU

The AMU comprises:

an input section - with a type N coaxial connector, and a coupler that provides out of match error signals when the reflected power exceeds 1% of the forward power.

an RF section - containing two motor-driven variable capacitors, together with a coil where necessary.

an electronic control board - which uses the error signals to drive the variable capacitors towards match.

a DC bias/peak to peak - set by local switch and control signal. (Only fitted to AMUs used for matching to a powered wafer table.)

The AMU is controlled by the PC2000 software (see **Section 4.3.7.9**).

2.4.3 Layout of the impedance matching components

The layout of the impedance matching components depends on the device to be matched to the RF generator to ensure maximum power transfer. Typical layouts of the components are shown in **Figure 2-9**.

In the typical layout, padding capacitors can be added in parallel with C1 and C2 to modify their capacitance ranges.

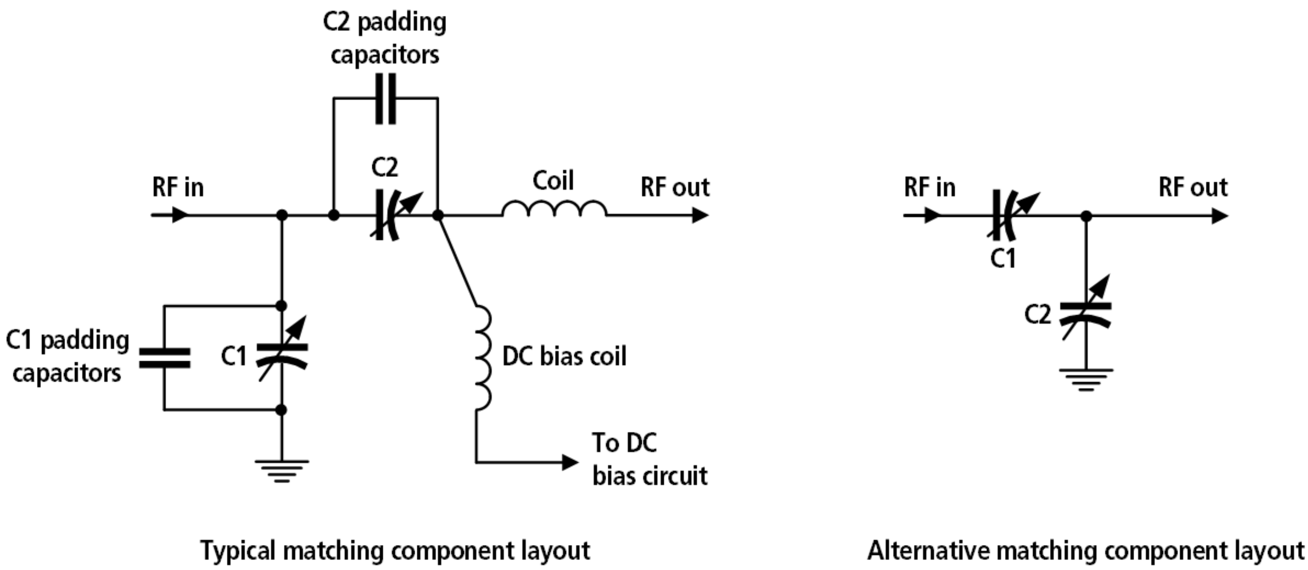

Figure 2-9 Layouts of the matching components

2.4.4 Layout of the sense and control PCB

Refer to drawing 94-SE00A17801 for a circuit diagram of the AMU. The layout of the sense and control PCB is shown in **Figure 2-10**.

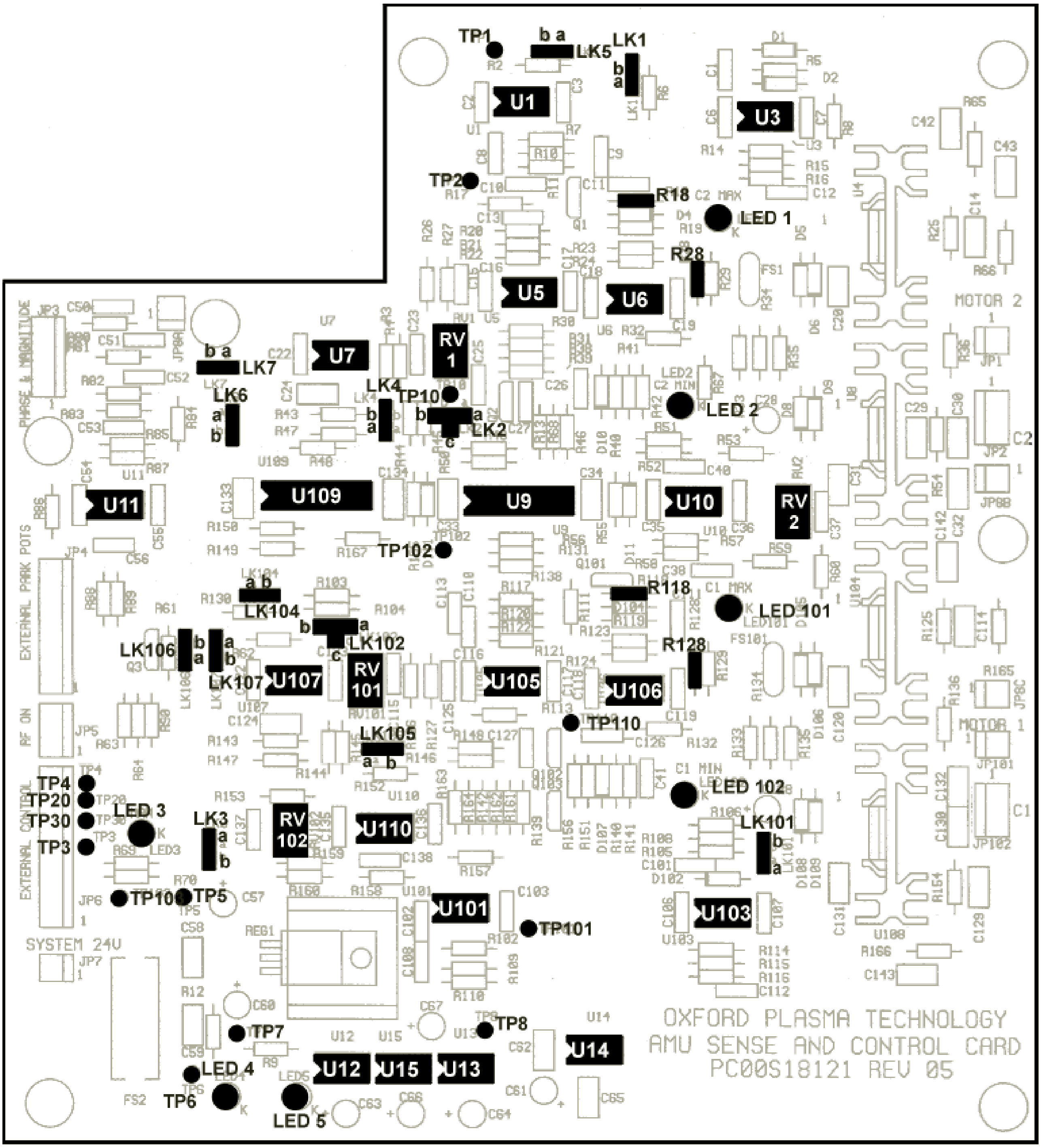

Figure 2-10 Layout of the sense and control PCB

2.4.5 RF generator

The RF generator produces a 13.56 MHz output that is fed, via the automatch unit, to the driven electrode. This creates the plasma. The automatch unit adjusts the impedance of its output to match the impedance of the lower electrode, thus ensuring maximum power transfer.

The AMU can be manually adjusted if necessary (see **Section 5.11.3**).

2.4.6 Plasma source

The inductively-coupled plasma source (ICP 65) is shown in **Figure 2-11**.

Power from the RF generator is fed via the AMU to the RF coil of the plasma source. This creates a plasma within the insulating tube of the source, which is under vacuum. Process gas is supplied to the top of the insulating tube, and to the gas ring in the process chamber.

The screening box cover incorporates a NW40 pumping port to enable ozone removal. This must be connected to an extraction system with a flow rate of at least 5 m^3/hour before powering up the system. The cover is interlocked to prevent the application of electrical and RF power if the cover is not in place.

The source is mounted on the lid of process chamber lid via a conical shield, see **Figure 2-11**.

WARNING 2.1

TOXIC GAS
Prolonged exposure to ozone can cause injury. Ensure that a suitable extraction system is connected to the NW40 port on the ICP65 screening box before powering up the system.

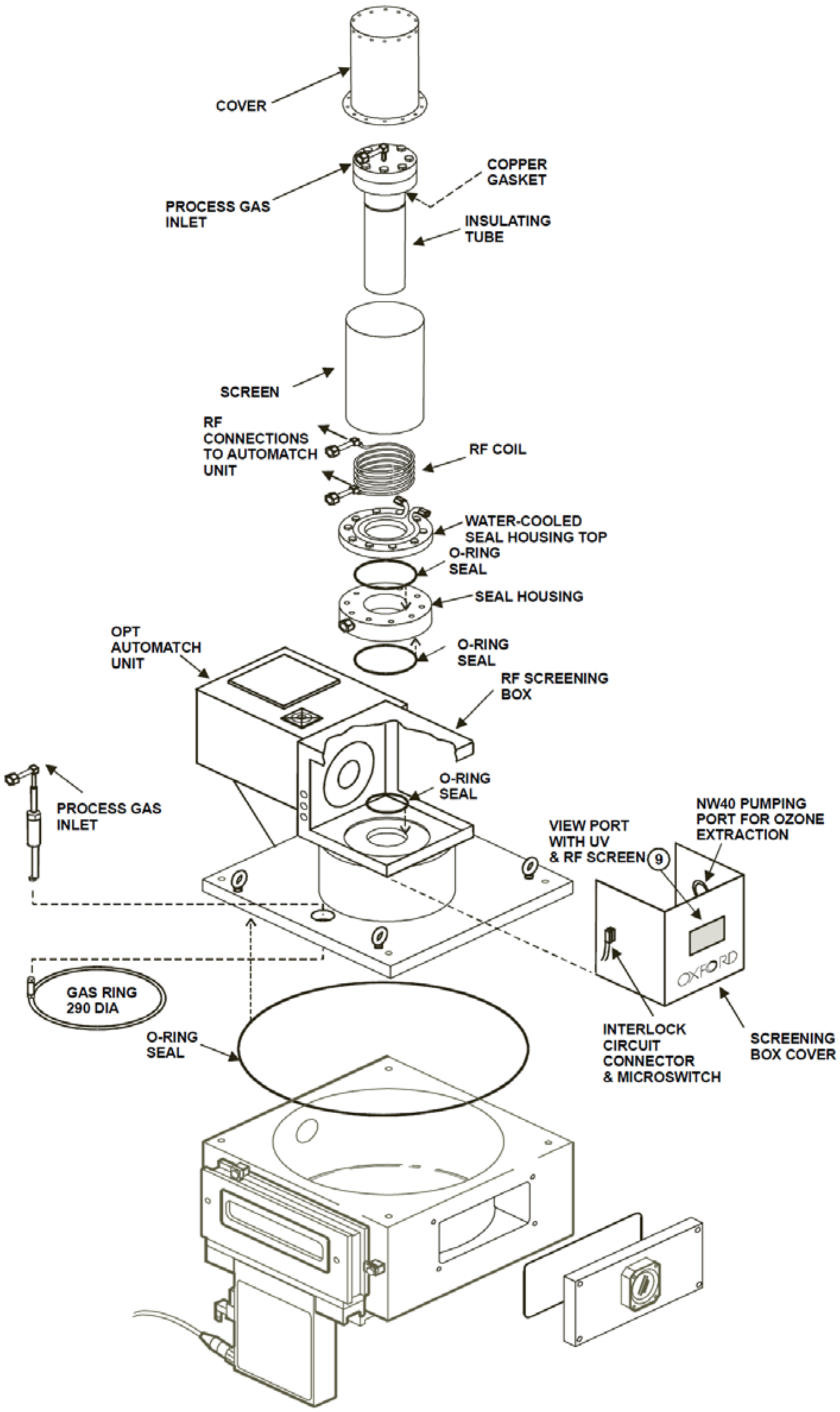

Figure 2-11 Typical ICP 65 plasma source

For more details of the RF generator and the AMU, refer to the respective manufacturer’s literature in Volume 3 of this manual.

2.5 Loadlock

The single wafer automatic loadlock is illustrated in **Figure 2-12**.

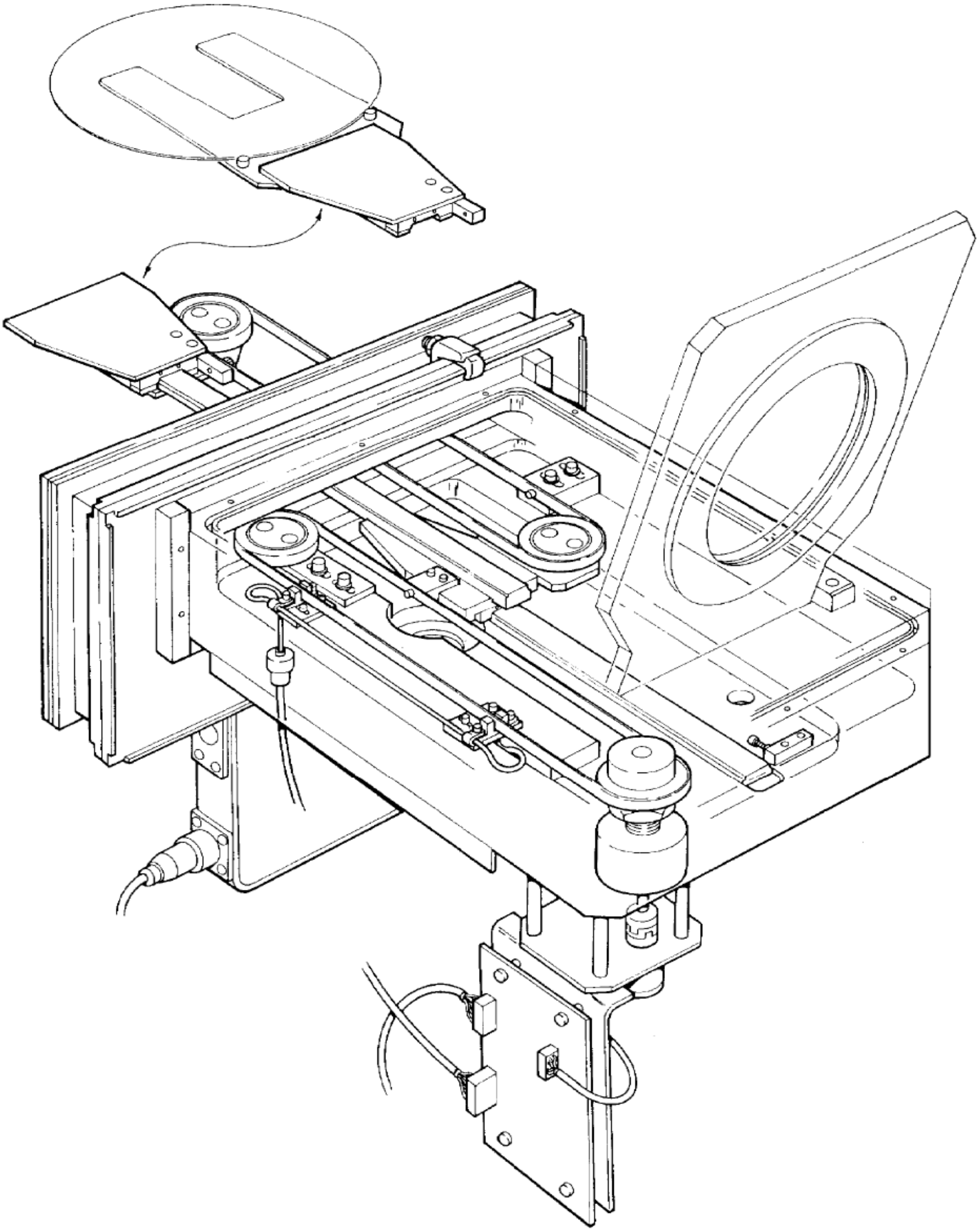

Figure 2-12 Single wafer automatic loadlock

The automatic load lock enables wafer loading and unloading to be automatically achieved under vacuum. These operations are controlled by the PC2000, requiring minimum operator involvement.

The Oxford Instruments Plasma Technology design results in a very compact load lock (395 mm in length, with 400 mm of wafer support travel). The load lock is capable of handling MESC1 standard wafers up to 200 mm diameter.

2.5.1 Wafer transfer operating principle

The operating principle of the automatic load lock wafer transfer mechanism is shown in Figure 2-13. This simplified illustration shows the three main components of the mechanism: the fixed track, the carriage and the wafer support.

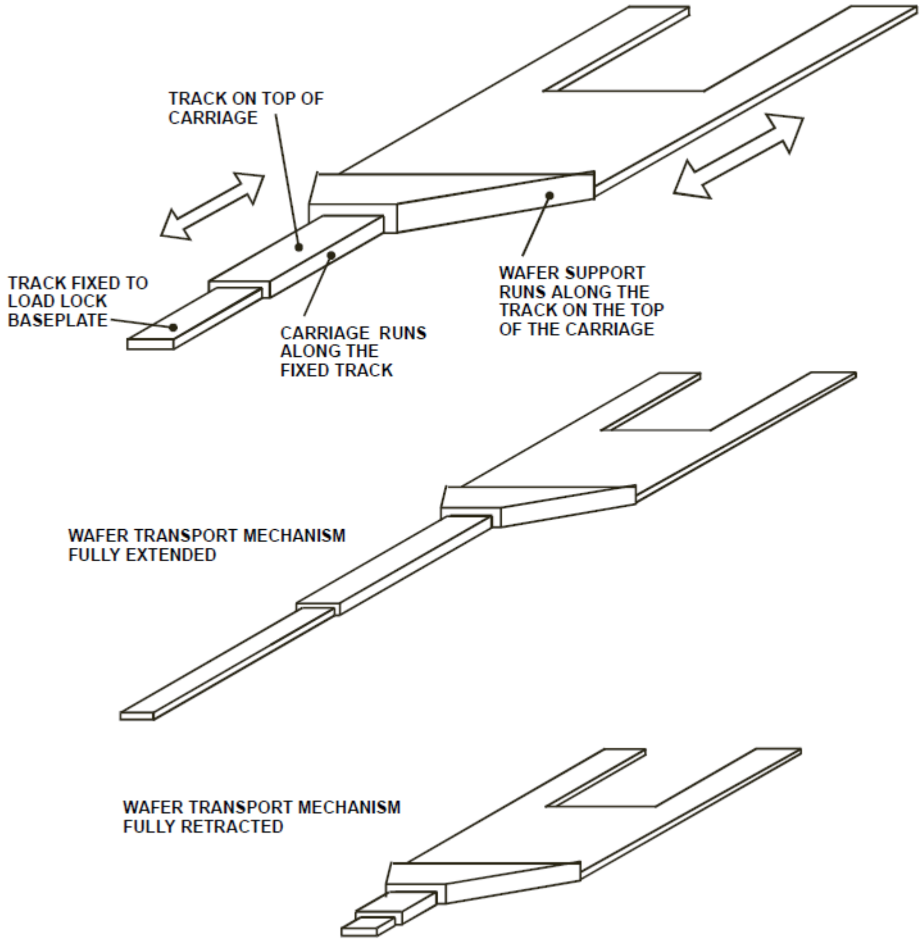

Figure 2-13 Simplified wafer transport mechanism operation

The fixed track is mounted on the load lock's baseplate and provides the bearing surface on which the carriage runs. The carriage also has a top bearing surface on which the wafer support runs.

When the mechanism is driven, the carriage runs along the fixed track and the wafer support runs along the carriage's track simultaneously. This enables the wafer support to travel from its fully retracted position (entirely contained in the load lock) to its fully extended position (wafer load/unload position in the processing chamber).

2.5.2 Functional description of the single wafer automatic loadlock

The load lock, shown in **Figure 2-12**, is fabricated from aluminium and incorporates a hinged lid containing a viewport. The chamber is pumped by a rotary pump or a turbomolecular pump with the pressure being detected by an appropriate vacuum gauge mounted on the chamber base plate. A pneumatically operated gate valve enables the load lock chamber to be isolated from the processing chamber.

The wafer is transported from the load lock into the processing chamber on a wafer support, which runs on a carriage, which in turn runs on a track.

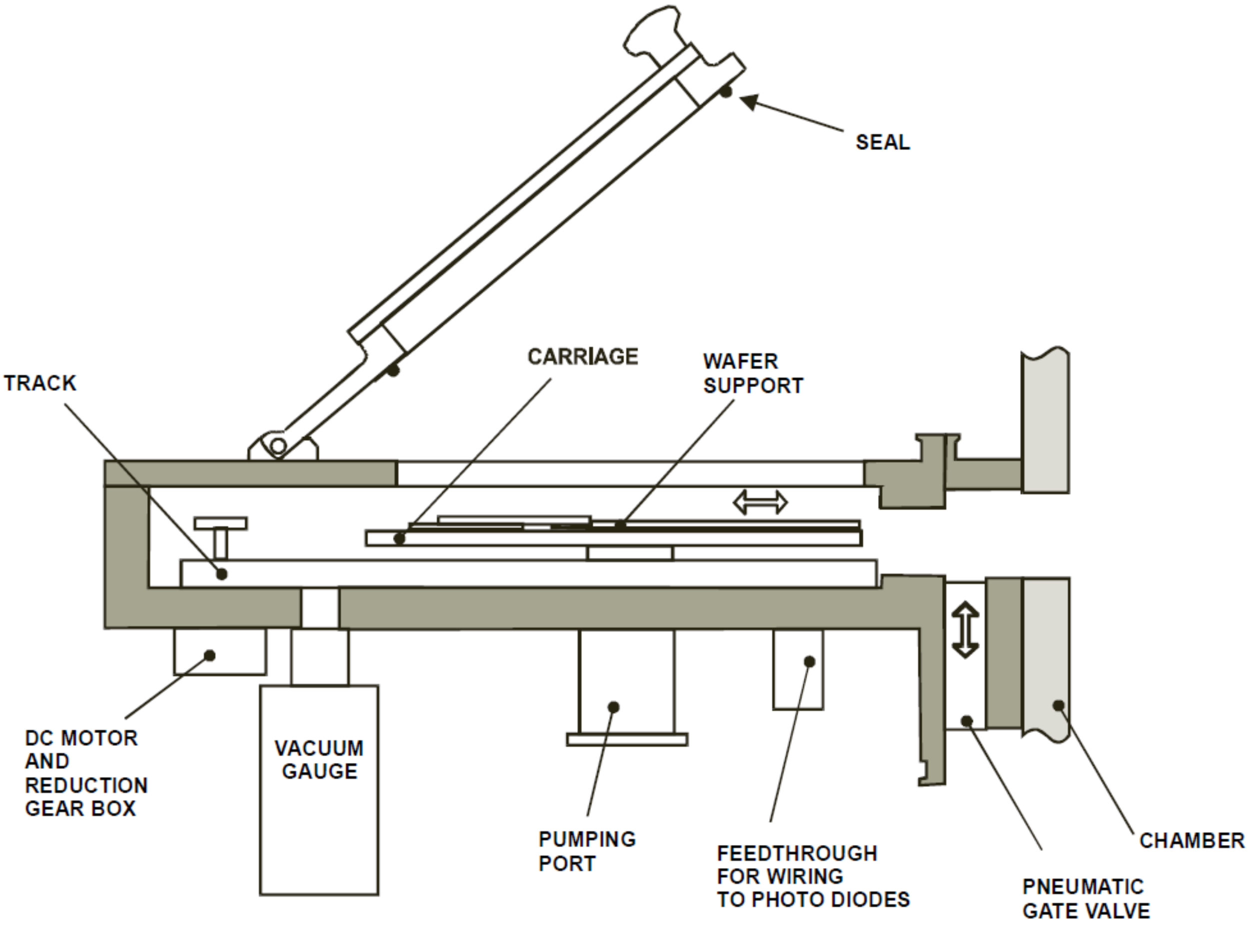

Figure 2-14 Automatic loadlock side view

The wafer transport mechanism, shown in **Figure 2-15**, comprises the following main components:

a) A DC motor and associated reduction gearbox located outside the load lock with the drive shaft entering the load lock through a vacuum seal.

b) Two steel belts each carried by two pulley wheels.

c) A track fixed to the load lock baseplate.

d) A carriage, which runs linearly along the track. The carriage is attached to steel belt 1.

e) A wafer support mounted on the carriage. The wafer support runs linearly along the carriage and is attached to steel belt 2.

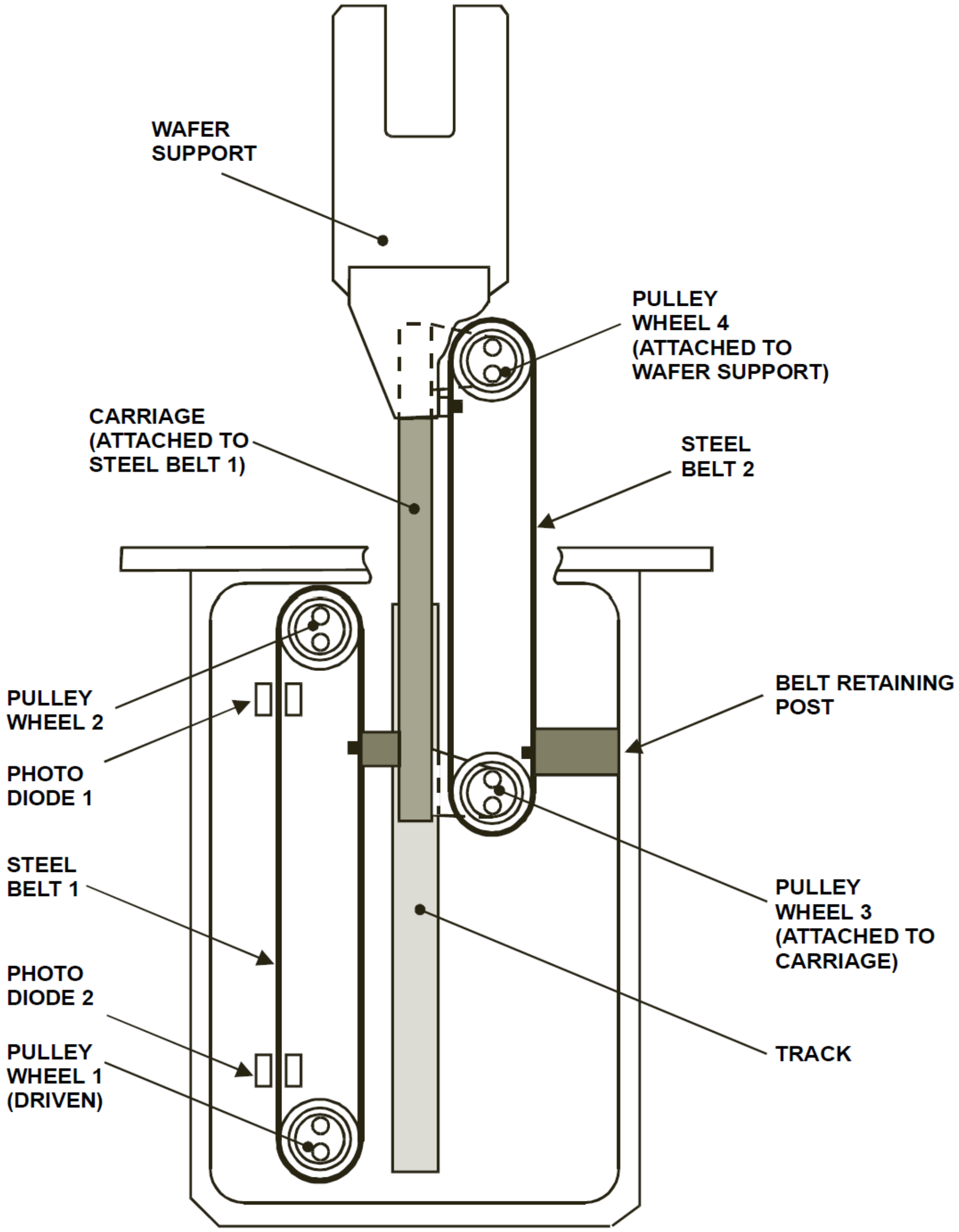

Figure 2-15 Automatic loadlock wafer transport mechanism

Before operation, the wafer support is fully retracted into the load lock. To load a wafer into the process chamber, the following sequence occurs:

1. The operator opens the load lock door, places the wafer on to the wafer support, and then closes the load lock door.
2. The load lock chamber is pumped down to base pressure.
3. The pneumatically operated gate valve is opened.

4 The DC motor drives steel belt 1 via pulley wheel 1. Pulley wheels 1 and 2 are mounted on the load lock baseplate. As steel belt 1 is driven, it moves the carriage, which is attached to it.

5 As the carriage travels, it causes steel belt 2 to travel around pulley wheels 3 and 4.

Pulley wheels 3 and 4 are attached to the carriage, and steel belt 2 is prevented from moving with respect to the load lock chassis by the retaining post. As steel belt 2 travels with respect to the carriage, it causes the wafer support attached to it to travel along the carriage.

6 As the wafer support reaches the end of its travel, a hole in steel belt 1 is detected by photo diode 2 to stop the DC motor.

7 The wafer is lifted from the wafer support by a wafer lift within the processing chamber, the wafer support is withdrawn from the chamber, and the wafer is lowered onto the processing table by the wafer lift.

8 As the wafer support reaches its fully retracted position within the load lock, the hole in steel belt 1 is detected by photo diode 1 to stop the DC motor.

9 The gate valve is closed and the load lock can be vented if required.

The above sequence of events is repeated to remove the wafer from the processing chamber.

2.5.3 Wafer support (end effector)

The automatic load lock end effector (wafer support) can accommodate wafer diameters of 3” to 8”. See **Section 7.7.6** for the end effector wafer size adjustment procedure.

2.6 Gas handling system

WARNING 2.2

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

2.6.1 12-line gas pod

The purpose of the gas pod is to feed a mixture of process gases, at specified flow rates, to the process chamber. Selection of gases and flow rates are determined by the system controller. A clean gas line can be incorporated to feed an etch gas mixture into the process chamber to remove process residues.

The 12-line gas pod, shown in **Figure 2-16** comprises a steel case with a folded removable cover. In the unlikely occurrence of a leak, an extraction collar at the top of the case enables any leaked gas to be safely removed by a laboratory extraction system. The rear panel of the case is fitted with fixing holes for wall or frame mounting.

The case incorporates stations for up to 12 gas lines. The outputs from the gas lines are fed into a common manifold, which is connected to the process chamber gas line. The gas output manifold can be split to provide two outputs; one to the process chamber and the other to another device such as a gas ring.

Pneumatically operated shut-off valves in each gas line are driven by associated SMC valves mounted on the controlled area network (CAN) PCB of the associated gas lines. Each SMC valve is powered by compressed air and controlled by signals from the system controller.

Three CAN PCBs are fitted, each controlling four gas lines:

one CAN PCB controls gas lines 1 to 4;
one CAN PCB controls gas lines 5 to 8;
one CAN PCB controls gas lines 9 to 12.

All gas pod functions are controlled by interlocks, (refer to **Section 2.10.4.1** for details). A gas pod cover interlock microswitch disables all gas pod functions unless the cover is correctly fitted.

Each gas pod CAN PCB receives signals from the system controller, to control the SMC valves and the mass flow controllers (MFC) fitted in the associated gas lines. For a circuit diagram of a gas pod CAN PCB, refer to the electrical drawings in Volume 2 of this manual.

A clean gas line can be fitted in place of gas line 1.

The clean gas line flow rate can be set manually by a variable valve, or by an MFC. The clean gas is usually supplied from a cylinder containing the required gas mixture, but an alternative method is to mix separate gases in optional additional gas lines.

WARNING 2.3

TOXIC GASES

Exposure to toxic gases can cause death or serious injury. A blockage in the connection between the gas pod and the process chamber will prevent pumping and purging of the gas pod and associated pipework. This increases the risk of exposure to toxic gas during maintenance. Do not fit a shut-off valve in this connection without checking with Oxford Instruments Plasma Technology.

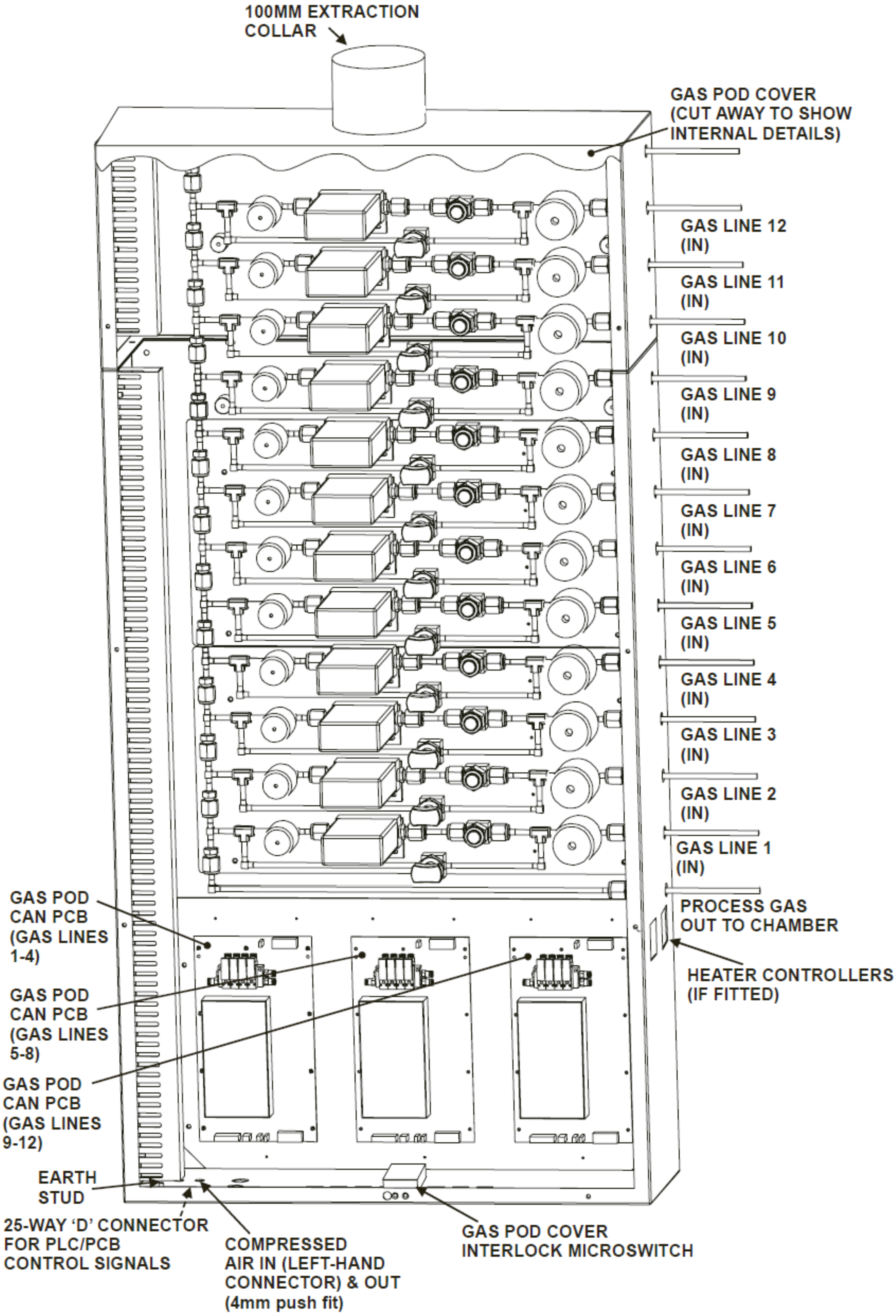

Figure 2-16 Typical 12-line gas pod

2.6.2 Standard non-toxic gas line

The standard non-toxic gas line is shown in **Figure 2-17**. All gas fittings are VCR and all stainless steel pipework connections are welded. The gas in tube passes into the side of the case, protected by a grommet. A ferrite core fitted to the gas in tube reduces the susceptibility of the gas pod electronics to signals from nearby transmitting devices such as mobile phones, modems, etc.

Gas from the customer’s cylinder/regulator/filter flows into the gas in tube to the filter.

The gas flows through the 2 µm filter to the MFC, which controls the flow of gas as commanded by the system controller. The gas then flows through the pneumatically controlled outlet shut-off valve and into the gas out manifold, where it is mixed with the other process gases before flowing into the process chamber.

WARNING 2.4

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. The inlet valve in the non-toxic gas line is rated to 5 bar. It is the customer’s responsibility to perform a risk assessment to consider if equipment failure upstream of the valve could produce pressures in excess of 5 bar. It is the customer’s responsibility to fit additional protection equipment if the risk assessment requires it.

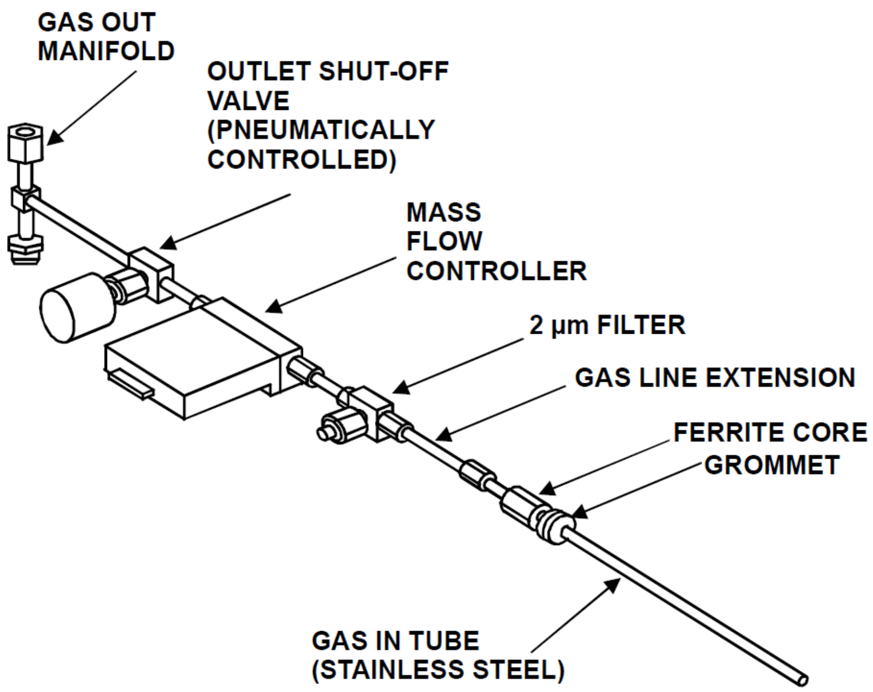

Figure 2-17 Standard non-toxic gas line

2.6.3 Standard toxic gas line

The standard toxic gas line is shown in **Figure 2-18**. All gas fittings are VCR and all stainless steel pipework connections are welded. The gas in tube passes into the side of the gas pod case, protected by a grommet.

Gas from the customer's cylinder/regulator/filter flows into the gas in tube to the filter.

WARNING 2.5

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. The inlet valve in the toxic gas line is rated to 5 bar. It is the customer's responsibility to perform a risk assessment to consider if equipment failure upstream of the valve could produce pressures in excess of 5 bar. It is the customer's responsibility to fit additional protection equipment if the risk assessment requires it.

With the inlet and outlet valves open and the bypass valve closed, the gas flows through the 2 μm filter to the MFC, which controls the flow of gas as commanded by the system controller. The gas then flows through the outlet valve and into the gas out manifold, where it is mixed with the other process gases before flowing into the process chamber.

The bypass valve is manually operated. When open, the gas flows through the bypass line directly to the gas out manifold, to enable the toxic gas line to be evacuated by pumping down the process chamber. This is necessary to prevent air entering the gas line and contaminating it during a gas cylinder changeover, and to service the gas line in the event of an MFC or filter blockage.

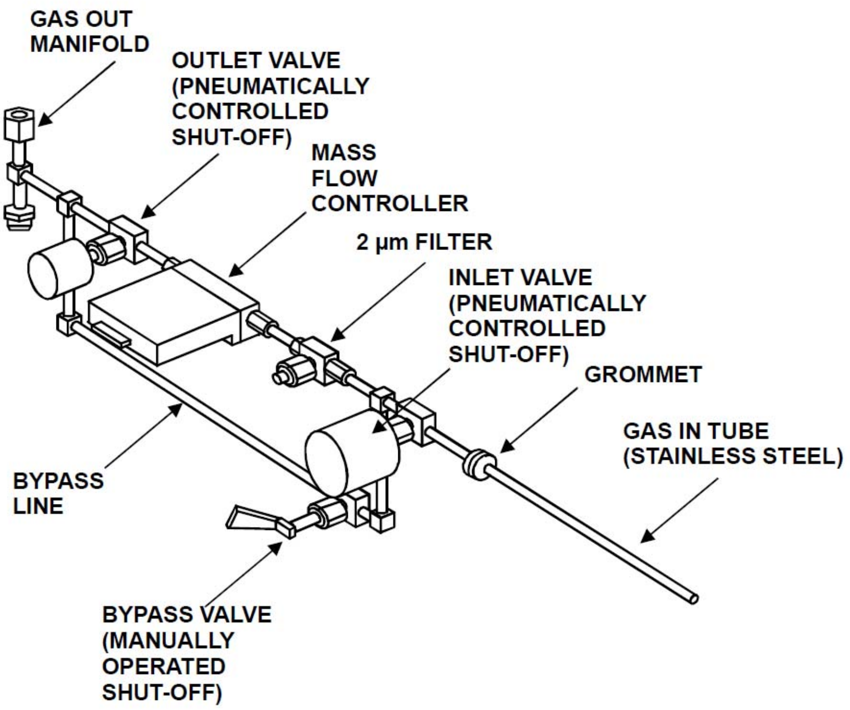

Figure 2-18 Standard toxic gas line

2.7 Vacuum system

A typical vacuum system is shown in Figure 2-19. The process chamber is pumped by a turbomolecular pump backed by a dry pump via a heated APC and heated gate valve. The process pressure in the chamber is measured by a heated, temperature-compensated 250 mTorr capacitance manometer gauge. The output of the gauge does not stabilise until it has been switched on and under vacuum for 15 minutes.

A vacuum switch monitors the chamber pressure. When the pressure falls below 600 mbar, the contacts of the switch close to enable the 24 V process line and allow the process gases and the RF to operate.

The automatic load lock is pumped by a turbo pump backed by a dry pump. Pressure is measured by a Pirani gauge.

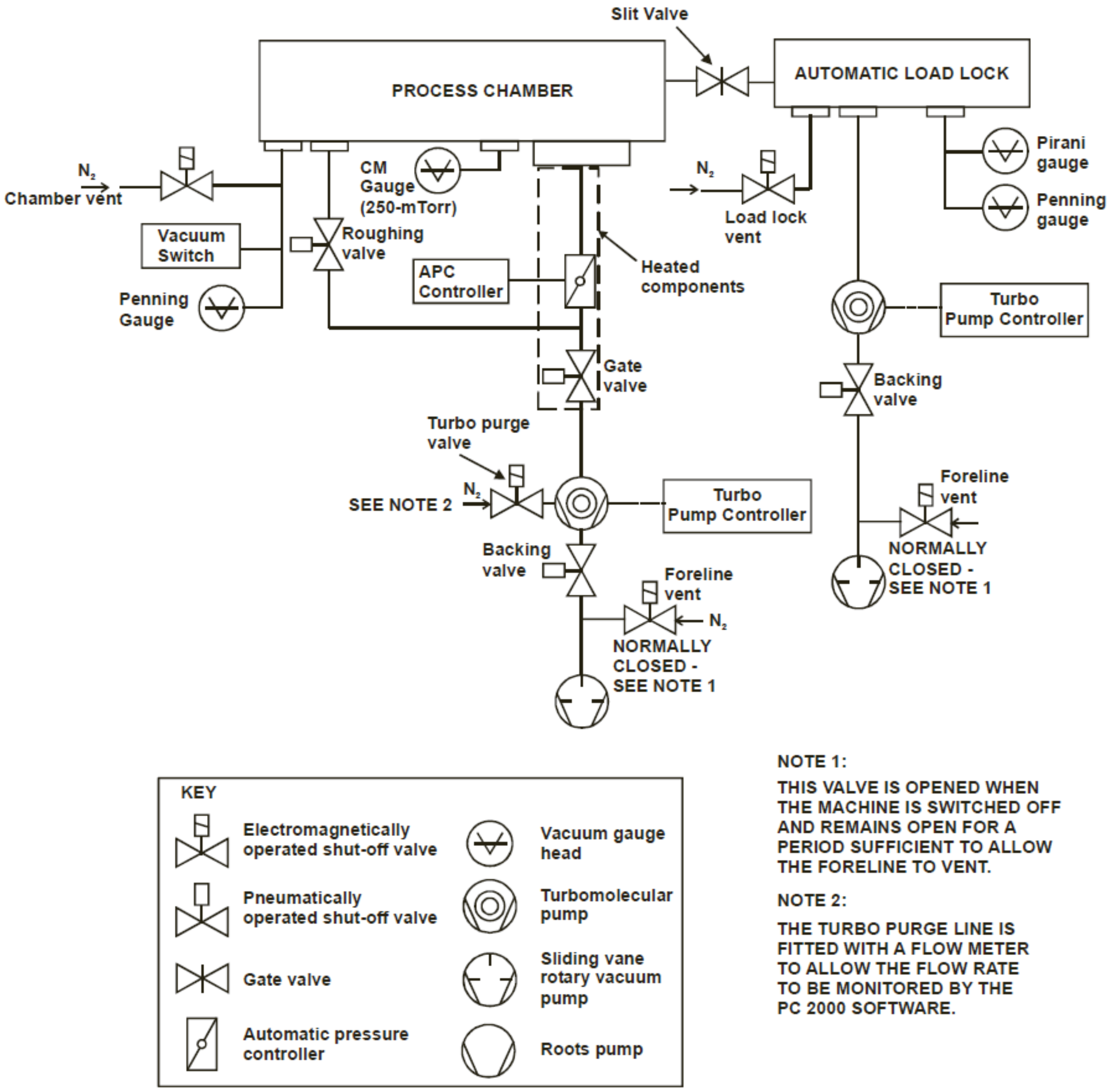

Figure 2-19 Schematic diagram of vacuum system

2.8 Services panel

This section discusses the services panel that provides a convenient central point for the connection of gases.

2.8.1 Nitrogen vent and purge gas

Nitrogen (N_2) is supplied to the system via the services panel to allow the process chamber, foreline and automatic load lock to be filled during system venting and to provide a purge gas supply to the turbo pump (if fitted) and precursor pod(s). The N_2 distribution circuit is shown in the services flow diagram; see the following paragraph.

Nitrogen enters the system at the services panel through a ¼" Swagelok bulkhead connector. It is then fed to a regulator and pressure gauge (located behind a panel to prevent unauthorized adjustment) via a stainless steel pipe. The outlet pressure of the regulator can be manually adjusted. To set up the outlet pressure of the regulator, refer to **Section 5.11.1**.

The outlet from the regulator is connected to:

- A check valve (over-pressure relief valve).
- The turbo pump purge line (if a turbo pump is fitted).
- If a Maglev turbo pump is fitted, directly to the turbo pump (for use by the Alcatel turbo controller during system venting).
- The process chamber vent line.
- The foreline vent line (if fitted).
- The automatic load lock vent line.
- Precursor Pod N_2 purge.

2.8.1.1 Check valve

The check valve is installed to limit the maximum pressure that the regulator can supply. The valve is normally closed and will open at pressures above 5 psi. The outlet of the check valve is fed to the air out connector on the services panel to allow any excess nitrogen to be piped out of the clean room if required.

WARNING 2.6

ASPHYXIATION
The nitrogen check valve can release nitrogen gas, which can displace the oxygen from air. This can cause death if adequate ventilation is not provided. It is the customer's responsibility to perform a risk assessment and to take appropriate precautions to alleviate this risk.

WARNING 2.7

EXCESS PRESSURE
There is a risk of over-pressurising the system if the nitrogen check valve is damaged or blocked. It is the customer's responsibility to ensure that this equipment is properly maintained. Do not remove or blank off the check valve.

2.8.1.2 Turbo pump purge valve (if fitted)

The turbo purge line supplies nitrogen to the turbo pump purge gas inlet via a mass flow meter, restrictor and the turbo purge valve. The mass flow meter's readback is monitored by the PC2000 software. If the nitrogen flow is too low, this state is detected by the PC2000 software to display a blue system alert followed after three minutes by a red system alert and subsequent system shut down to prevent damage to the turbo pump. For details of system alerts, see **Section 5.8**.

The turbo purge valve is pneumatically controlled by the system software.

The process chamber vent line supplies nitrogen to the process chamber during the venting sequence via a restrictor and chamber vent valve. The chamber vent valve is pneumatically controlled by the system software.

2.8.1.3 Foreline vent line (if fitted)

The foreline vent line supplies nitrogen to the foreline during the venting sequence to prevent backstreaming of vapour from the rotary vane pump. Nitrogen is fed from the regulator to the foreline via a restrictor and the foreline vent valve. The foreline vent valve is opened for a period when the primary vacuum pump is turned off.

2.8.1.4 Automatic loadlock vent line

The automatic load lock vent line supplies nitrogen to the automatic load lock during the venting sequence via a restrictor and chamber vent valve. The chamber vent valve is pneumatically controlled by the system software.

2.8.1.5 Rotameters

A typical rotameter is shown in **Figure 2-20**. It is a manually-controlled variable valve/ indicating tube used to manually set the flow rate for various gas supplies. Typically, a rotameter is used to set the purge flow rates for turbomolecular, rotary vane and dry pumps, glove boxes and etch gas supplies for process chamber cleaning.

In most systems, turbomolecular pump purge flows are set automatically and monitored by the system software via a flow meter. These systems do not incorporate a rotameter for the turbo pump purge.

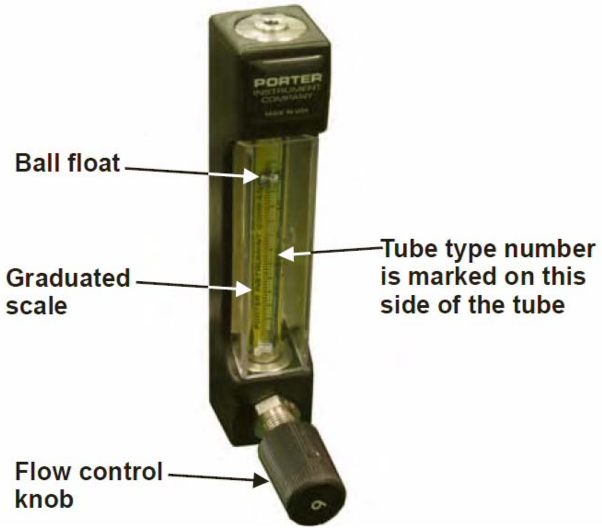

Figure 2-20 Typical rotameter

Rotameter models

The models of rotameter used for setting purge gas flows are fitted with a common scale, reading from 0 to 6 as flow is varied from zero to full scale. The full-scale flow depends on:

the tube type (marked on the tube itself);

the ball material;

the gas type;

temperature;

pressure.

Table 2-1 shows the full-scale flows for different rotameter models at a temperature 20° C and 1 atmosphere pressure of air or nitrogen gas.

NOTE: Flow rates are given in standard cubic centimetres per minute (sccm) or standard litres per minute (slpm).

Table 2-1 Rotameter models and their full-scale flows

Model (OIPT part)	Tube Number	Ball Material	Typical Use	Full-scale Flow	Unit
G/GAS/ROT/050	A125-3	glass	turbo pump purge	53	sccm
G/GAS/ROT/25L	A250-4	carboloy	rotary pump purge, PECVD	27.5	slpm
G/GAS/ROT/40L	A250-6	stainless steel	pump exhaust purge	43.4	slpm
G/GAS/ROT/800	A125-7	stainless steel	CF_4/O_2 clean gas metering	850	sccm
G/GAS/ROT/900	A250-1	stainless steel	rotary pump purge, etch, PECVD	4.4	slpm

The flow-setting knob can be on the upstream or downstream side of the tube.

If the knob is upstream (below the tube), the pressure in the tube is close to the exit pressure, which should be close to 1 bar absolute for pump or exhaust pipe purging.

If the knob is downstream (above the tube), the pressure in the tube is close to the supply pressure of the gas. This method is normally used if the exit pressure is below atmospheric pressure, which is often the case in turbomolecular pump purging.

If in doubt, control downstream is always safe because the ball float will operate normally and the purge flow will be slightly higher than given in Table 2-1.

2.9 Precursor delivery modules

FlexAL® is supplied with a precursor delivery module (PDM) that incorporates a six-way precursor system. This can be supplemented by one or two additional single-precursor ovens.

2.9.1 PDM with six-way precursor cabinet

The **FlexAL**® precursor delivery module houses six precursor ampoules. The ampoules are connected together using two manifolds, with three ampoules connected to each manifold (see **Figure 2-21**).

Figure 2-21 General view of the six-way precursor cabinet

The main features of the precursor delivery module are:

- Extracted stainless steel lockable cabinet
- Six precursor ampoules, individually temperature controlled and heated up to 200ºC
- Two separately-controlled, heated and purged precursor manifolds up to 200ºC.
- Three-way ALD valves, used for dose control.
- Nitrogen purge and an attachable glove panel for safe precursor changeover.
- Hardware interlocks to prevent unsafe operation.

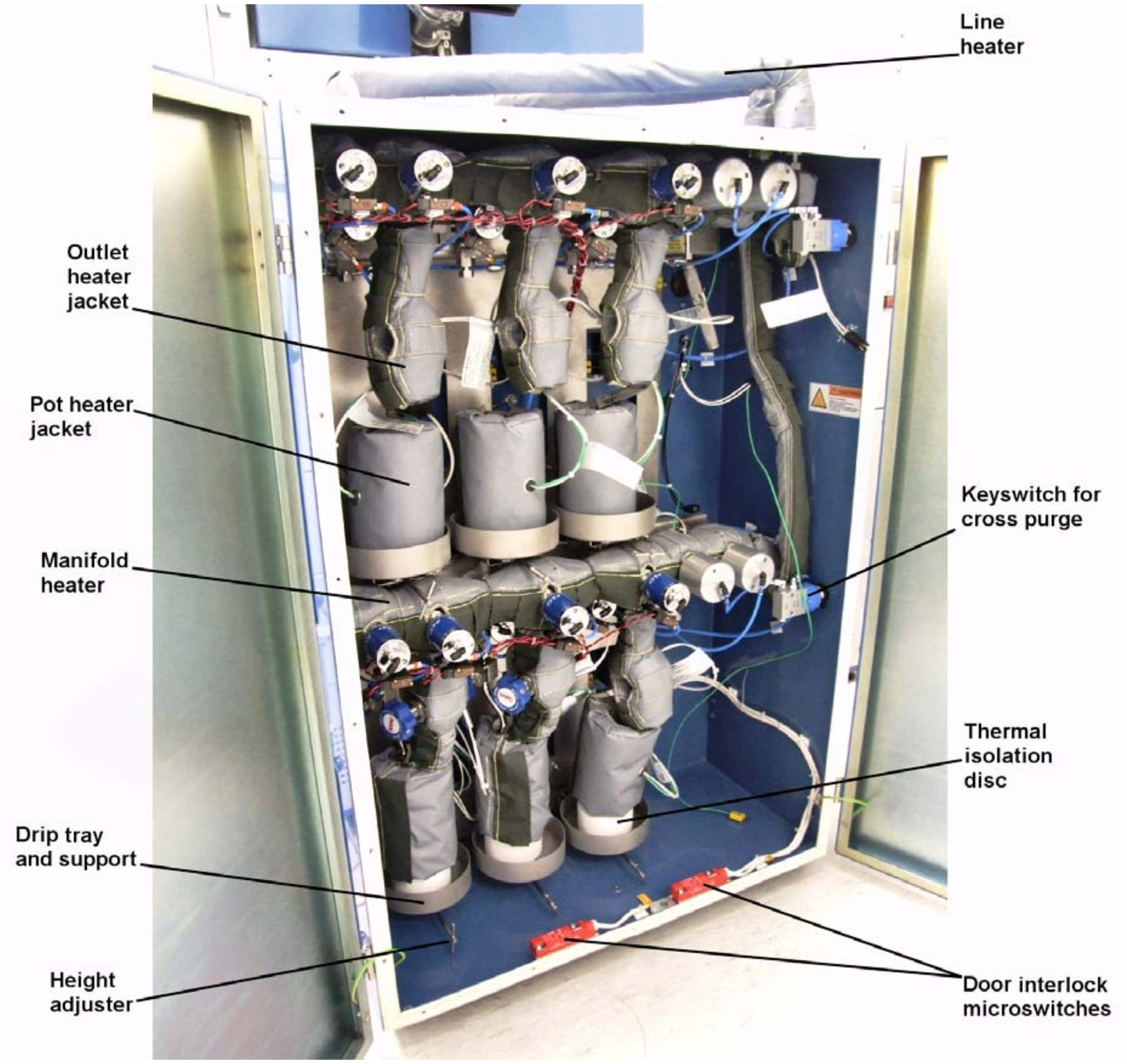

Figure 2-22 Interior of the precursor cabinet

2.9.1.1 Function of the six-way precursor cabinet

Argon is fed to the PDM from two argon MFCs, which are located in the system console. The bubbler MFC supplies argon to the inlet manifold. The purge MFC supplies argon to either outlet manifold, or to the process chamber via the key-switch operated valve. In normal operation, only one of the six precursors is in use at one time (see Figure 2-23).

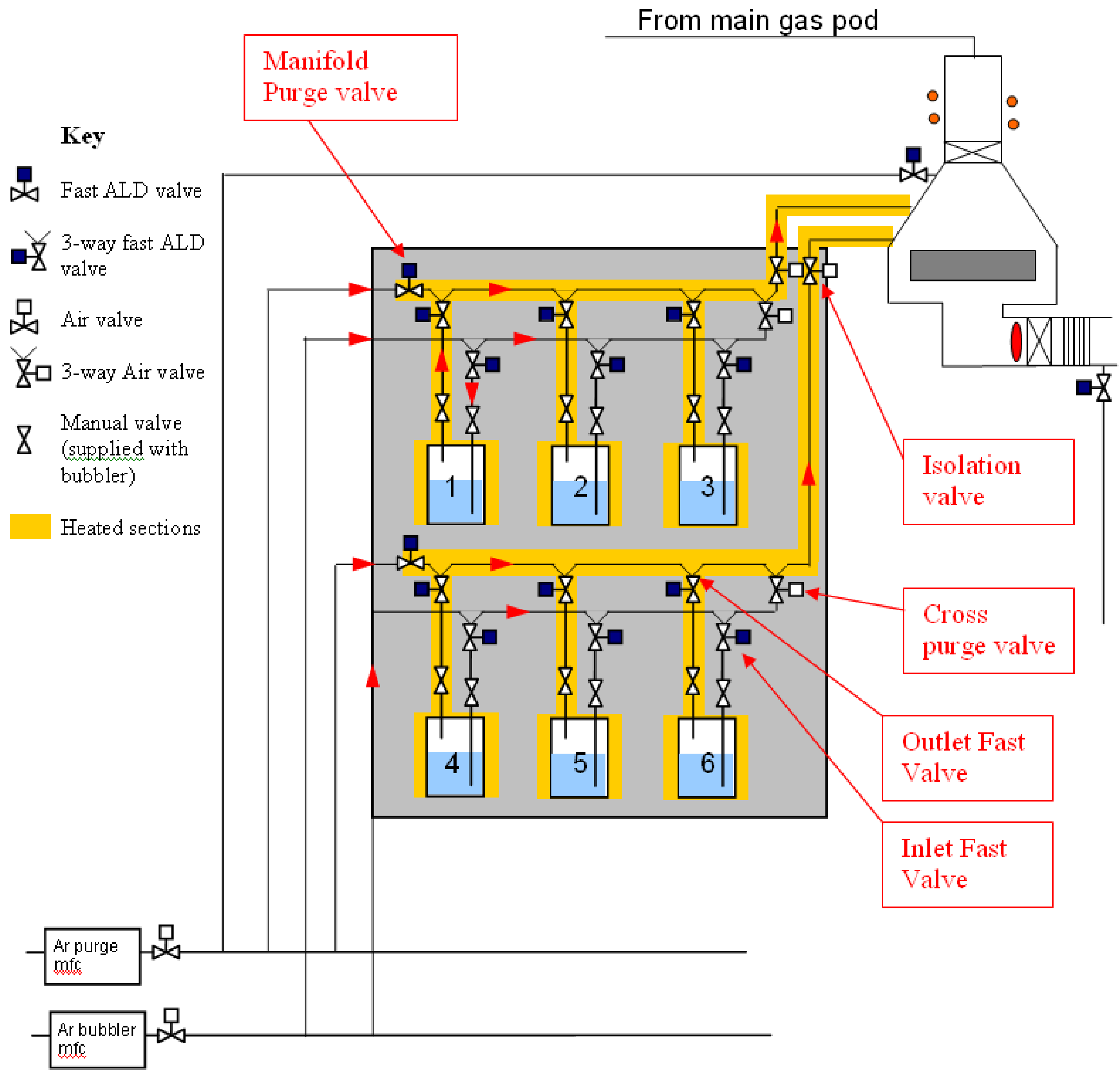

Figure 2-23 Schematic of the six-way precursor cabinet

Each ampoule has a pair of manual valves attached to it to allow the ampoule to be isolated during removal and refitting. If operating a precursor in bubbler mode, both valves must be opened. If operating a precursor in vapour draw mode, the inlet manual valve must be closed.

The precursor module includes a pneumatic valve on the inlet and outlet of each ampoule (marked as outlet fast valve and inlet valve in Figure 2-23).

These two valves operate together, driven by the same electrical signal. There is also a pneumatic isolation valve between each manifold and the process chamber.

The isolation valve is driven directly from the main interlock chain. If all the interlocks are in a good state, the valve opens. If one or more interlocks fail, the valve closes.

Figure 2-24 shows the flow of gas when precursor 5 is operating in bubbler mode.

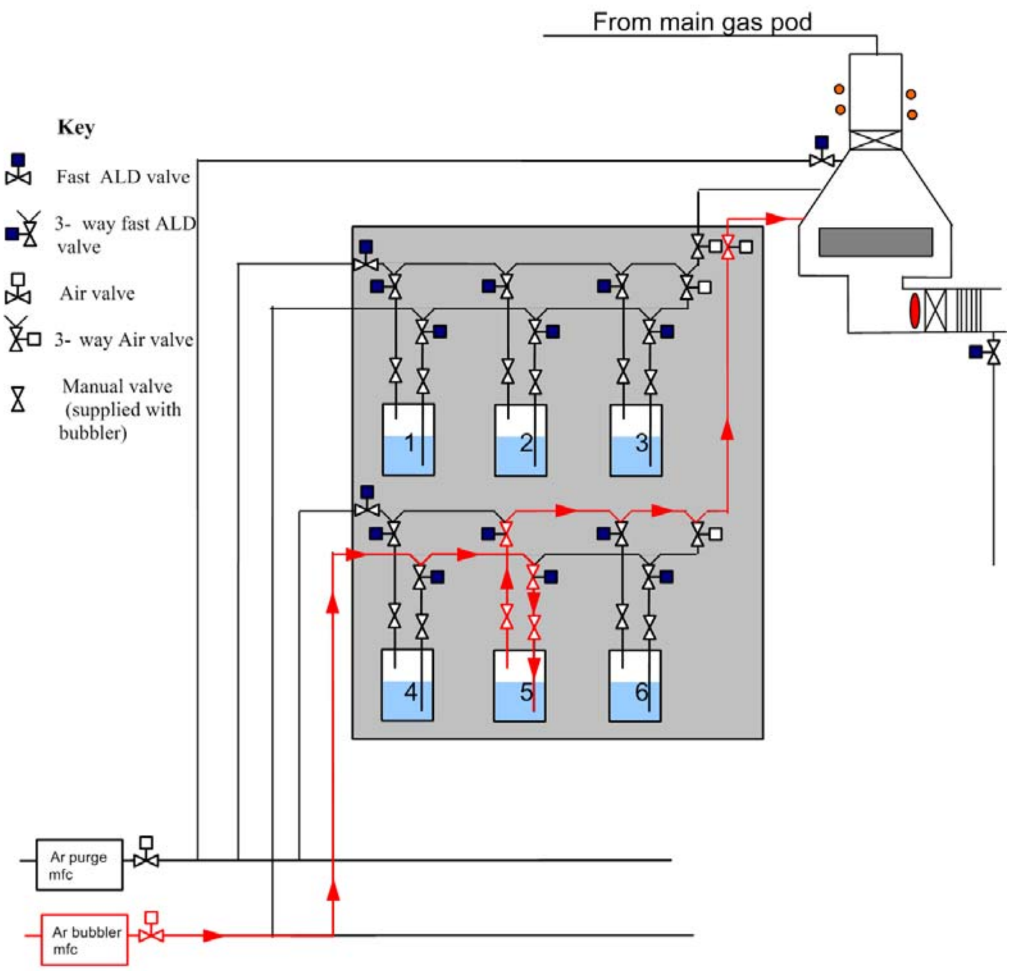

Figure 2-24 Flow of gas in six-way cabinet when precursor 5 is operating

Figure 2-25 shows the flow of vapour when precursor 5 is operating in vapour draw mode. Because the precursor inlet and outlet pneumatic valves are driven from the same electrical signal, both valves are open. However, the ampoule manual inlet valve is closed, isolating the inlet line.

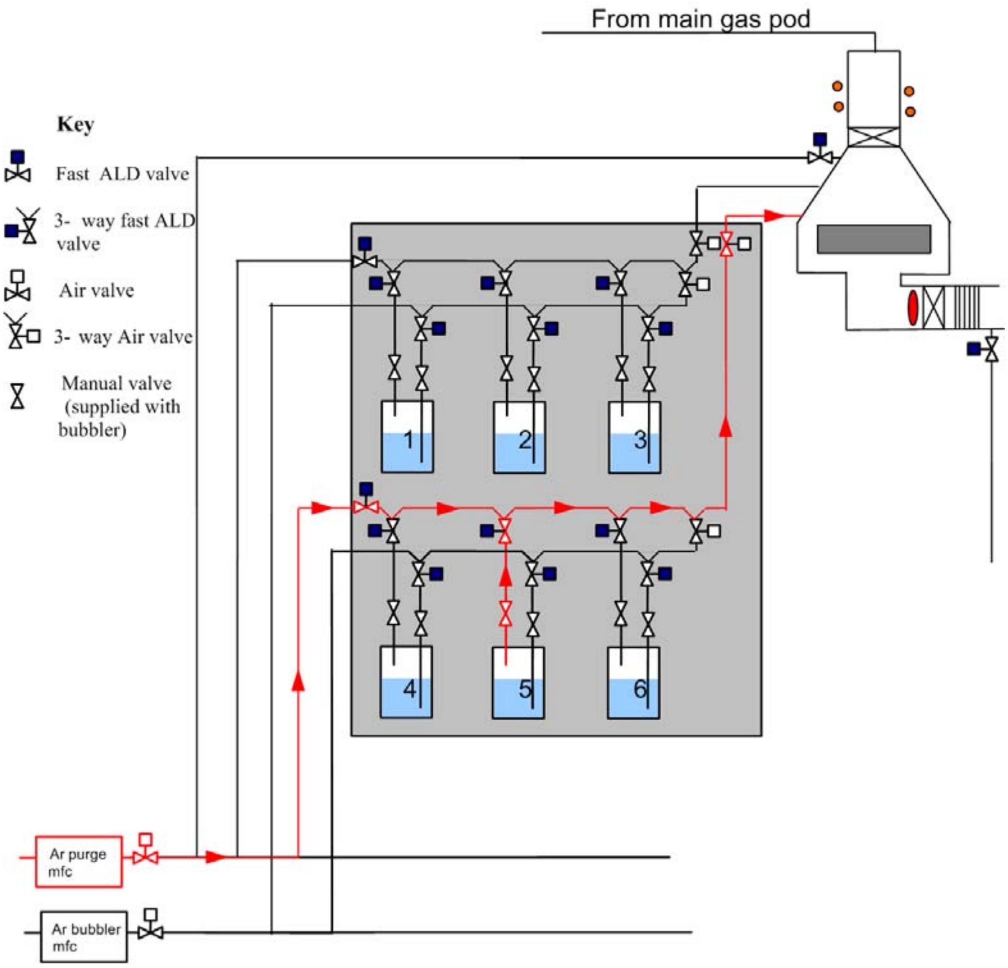

Figure 2-25 Flow of gas when precursor 5 is operating in vapour draw mode

Table 2-2 shows the valve operating sequence for normal operation of a precursor.

Table 2-2 Precursor valve states during normal operation

Operating Mode	Bubbler Manual Inlet Valve	Bubbler Manual Outlet Valve	Bubbler Fast Inlet Valve	Bubbler Fast Outlet Valve	Argon Bubbler MFC	Argon Purge MFC	Manifold Isolation Valve	Cross-Purge Valve	Argon Purge Valve
Bubbling	OPEN	OPEN	OPEN		200 SCCM	0 SCCM	OPEN	CLOSED	CLOSED
Vapour Draw	CLOSED	OPEN	OPEN		0 SCCM	200 SCCM	OPEN	CLOSED	OPEN
Purging a Manifold	CLOSED	CLOSED	CLOSED		200 SCCM	200 SCCM	OPEN	OPEN	OPEN

Each manifold in the PDM also includes a manifold purge valve and a cross purge valve, to allow the inlet and outlet lines to be purged.

2.9.1.2 PDM interlocks

The compressed air supply to all the PDM valves is interlocked with the main interlock chain and with the PDM cabinet door interlock microswitches. All the PDM pneumatic valves are disabled if the PDM cabinet door is opened, or if an interlock in the main chain is broken. Refer to **Section 2.10.4** for details of the main interlock chain.

2.9.1.3 Cabinet extraction and purge

The precursor cabinet incorporates an extraction connection and a nitrogen purge connection. The extraction connection is via a KF40 port, which must be connected to a suitable extraction system. The cabinet incorporates air vents that can be manually closed. During normal operation, ambient air flows into the air vents and exits through the extraction port.

The nitrogen flush can be turned on and off by a switch on the outside of the cabinet. When the flush is turned on, the air vents must be closed by the operator to maximise the effect. Turning the nitrogen flush on causes nitrogen to flow through the cabinet, exiting through the extraction port.

2.9.1.4 Precursor heating

All parts of the PDM that are highlighted in yellow in **Figure 2-23** are heated by moulded heater jackets. The temperature of each ampoule can be individually controlled. The temperature of each manifold can also be individually controlled. As there are six precursors and two manifolds, the PDM uses a total of eight heater zones.

2.9.1.5 Glove box

The glove panel is a sealed perspex panel fitted with corrosion resistant gloves. The box attaches to the front of the PDM cabinet when the doors are open. It allows the operator to work inside the cabinet without exposing the work area to the environment (see Figure 2-26). The box can be fitted to the cabinet in one of two possible positions, allowing access to the upper and lower banks of precursors.

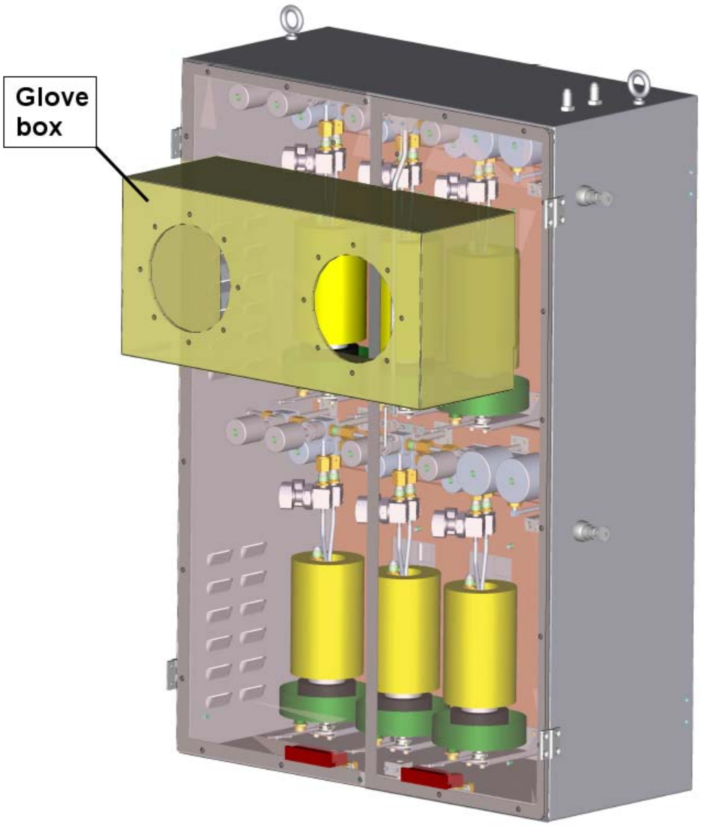

Figure 2-26 Glove box fitted to the upper manifold in the cabinet

2.9.2 Single precursor oven

In addition to the six-way precursor cabinet, ALD **FlexAL®** can be delivered with an additional two PDMs, each of which contains a single ampoule for the delivery of different precursors.

The PDM with a single ampoule comprises two sub modules:

an upper module known as the *oven*;

a lower module known as the *distribution box* (see **Figure 2-27**).

The distribution box houses electrical and control assemblies.

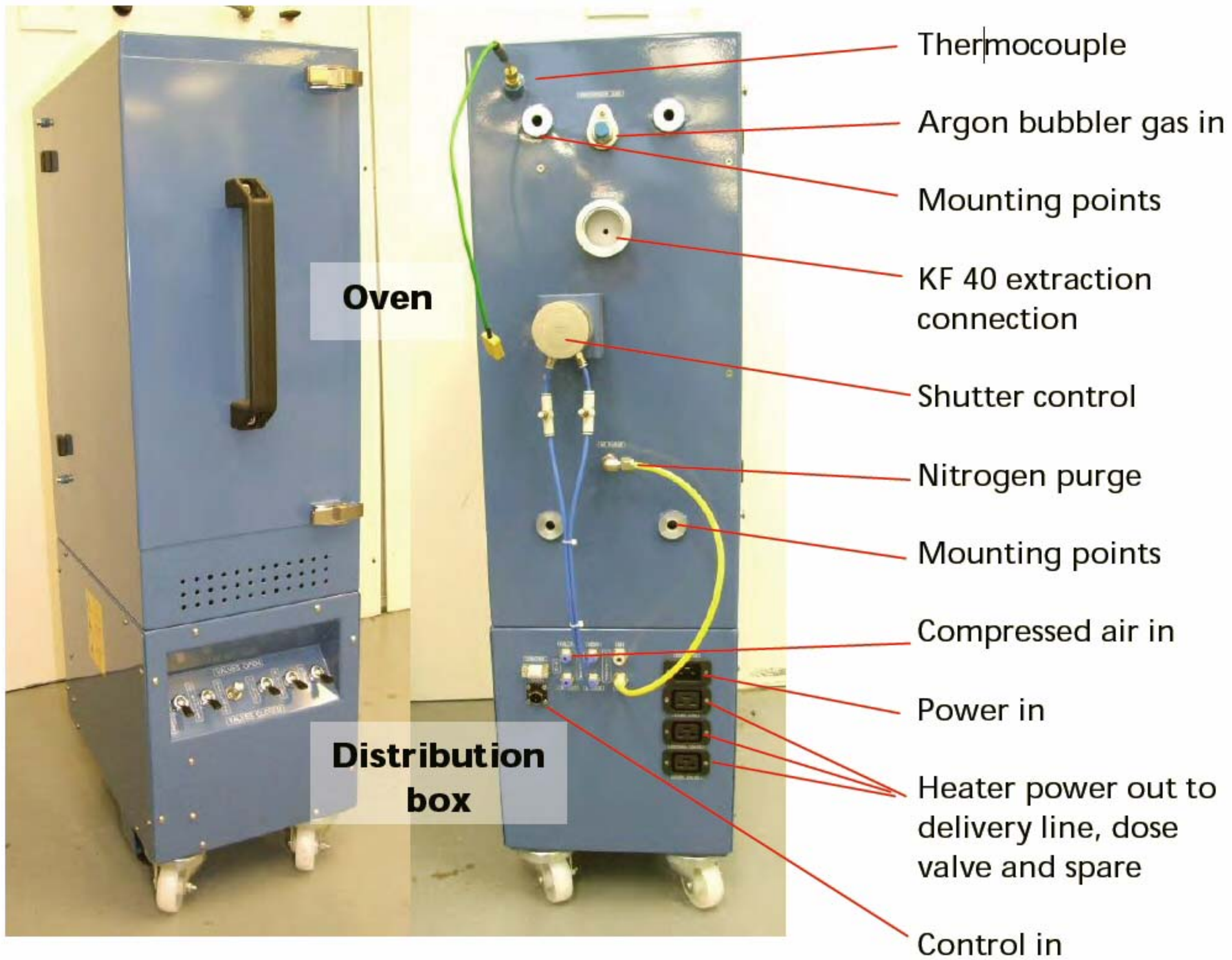

Figure 2-27 View of single-precursor oven

The precursor oven is shown in **Figure 2-28**. The main constituents of the oven are:

- A dedicated argon gas bubbling line which is fed from a remotely mounted argon bubbler mfc.
- A fan-assisted 200°C temperature-controlled cabinet with an extraction port. Consult the information datasheet for extraction rates.

- A manually operated shutter for regulating the temperature of the hot air in the oven. This shutter must be closed when the air temperature inside the oven is required to be above 100°C.
- A type K thermocouple for controlling the air temperature inside the oven. Thermal snap switches are fitted to protect the oven hardware from thermal runaway. Note that the snap switches operate at 220°C. Some precursors decompose after a few hours at this temperature. In the rare event that the oven over-heats (e.g. if a solid state relay fails), consult Oxford Instruments Plasma Technology for advice on recovering the precursor.
- Three high-temperature manually air operated Nupro valves. These valves are controlled using toggle switches which are mounted on the distribution box and labelled as inlet, purge and outlet.
- A heated precursor delivery line connecting to the processing chamber and containing a fast vapour delivery valve.
- Nitrogen purge line to provide a suppressed atmosphere in case of vapour release inside the cabinet.
- A dedicated glove box for the safe connection and removal of precursor pots. Note: The glove box is only to be used at ambient temperature and during precursor pot installation and changeover (please refer to Health and Safety recommendations)

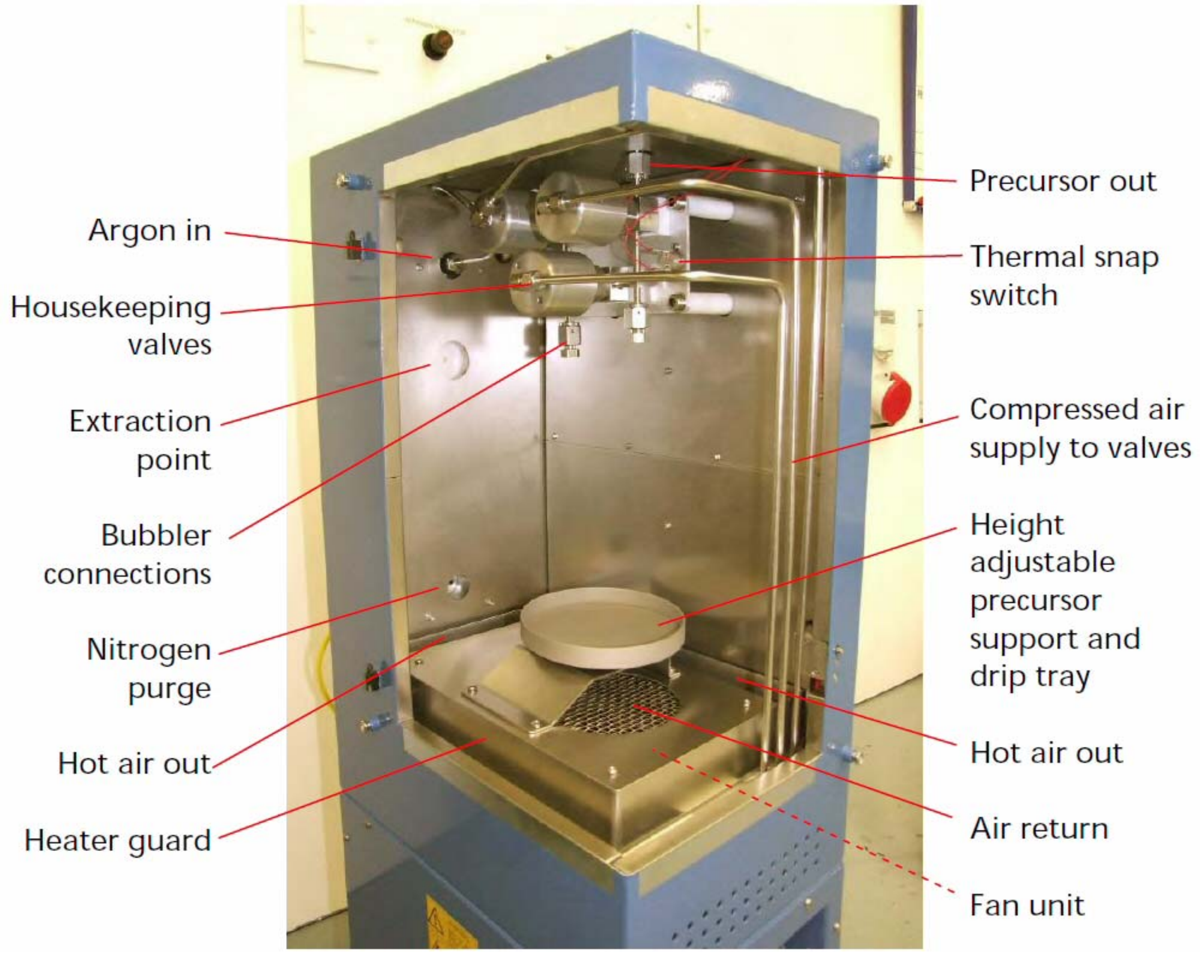

Figure 2-28 Upper part of a single precursor oven

2.9.2.1 Warning label and safety notice on single precursor oven

The warning label shown in Figure 2-29 is displayed on the switch panel for the precursor modules. Figure 2-30 shows the possible hazard with which the warning label is associated.

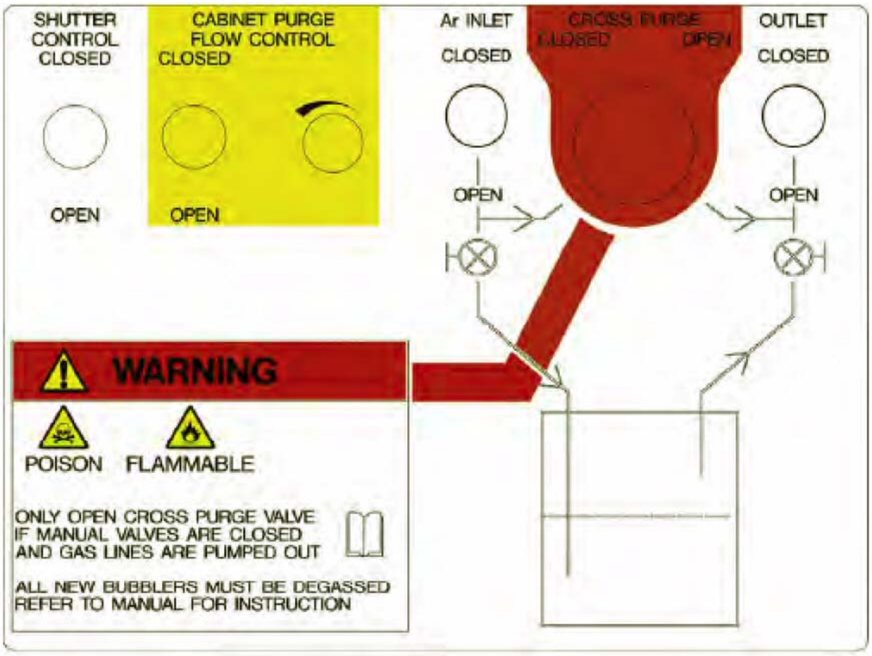

Figure 2-29 Warning label on single precursor oven

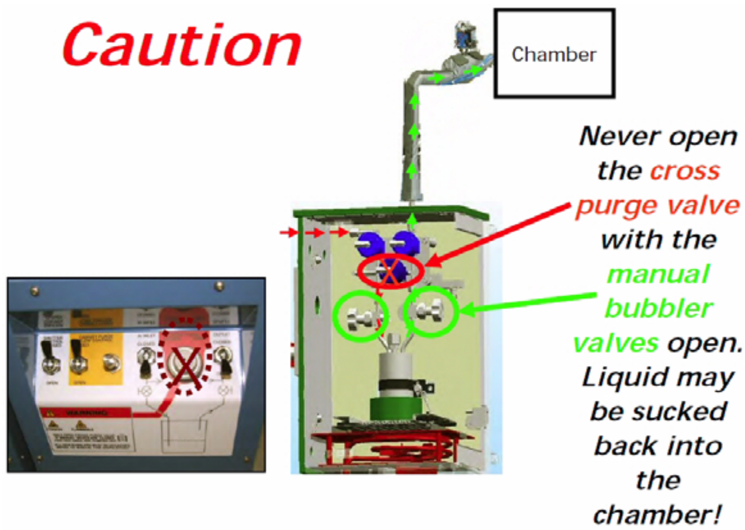

Figure 2-30 Cross purge valve hazard scenario on single precursor oven

2.9.2.2 Gas for single precursor oven

A single argon MFC is switched by means of rapid ALD valves between all ampoules, the chamber and the foreline divert.

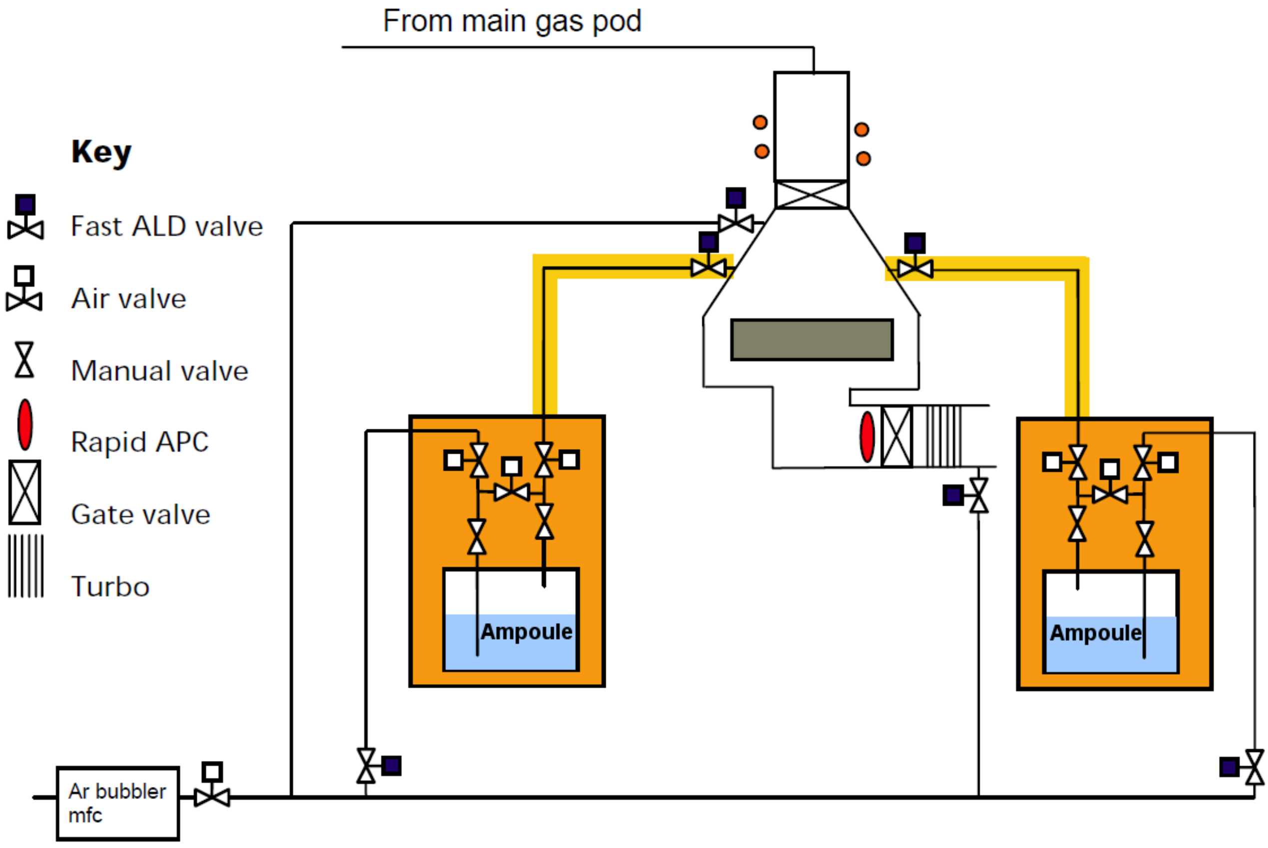

Figure 2-31 Gas schematic for single precursor ovens (two shown)

2.10 System control

2.10.1 PC2000 hardware and software with licence

FlexAL® is controlled and monitored by an IBM-compatible personal computer (PC) running the Microsoft Windows operating system. The computer is fitted with a compact disk drive to allow software updates. An Ethernet interface card, for communicating with the programmable logic controller (PLC), is fitted in one of the expansion slots. If required, a modem can be fitted to use the *PC Anywhere* software.

2.10.2 PC2000 software and single-user licence

The PC2000 control software runs as a Windows-based application allowing multiple levels of system control, all of which are accessed by password entry:

SYSTEMS MANAGER

SYSTEMS ENGINEER

PROCESS DEVELOPER

MAINTENANCE ENGINEER

PROCESS EDITOR

OPERATOR

The system status is displayed on graphic mimic diagrams, with all operational parameters and status displays accessible through pop-up windows selected by using the mouse pointing device. All the major process parameters are accessible from the recipe and process step set-up pages, including definition of gases on each line and calculation of mass flow settings in sccms. The software includes data logging to disk for off-line verification and analysis of process conditions.

Processing recipes can be formulated and stored in the computer and the system can be run in fully automatic mode using the recipes. Alternatively, the system can be run in the manual mode with each phase of the process controlled and initiated separately. All the parameters can be monitored in real time using the PC2000 software.

2.10.3 System controller

The system is controlled from a remote IBM-compatible PC terminal using Oxford Instruments Plasma Technology's PC2000 software via a programmable logic controller (PLC) housed in the base unit (see Figure 2-32).

Communication between the PC and the PLC are via an Ethernet link. Communication between the PLC interface PCB and the CAN modules is via a CAN bus.

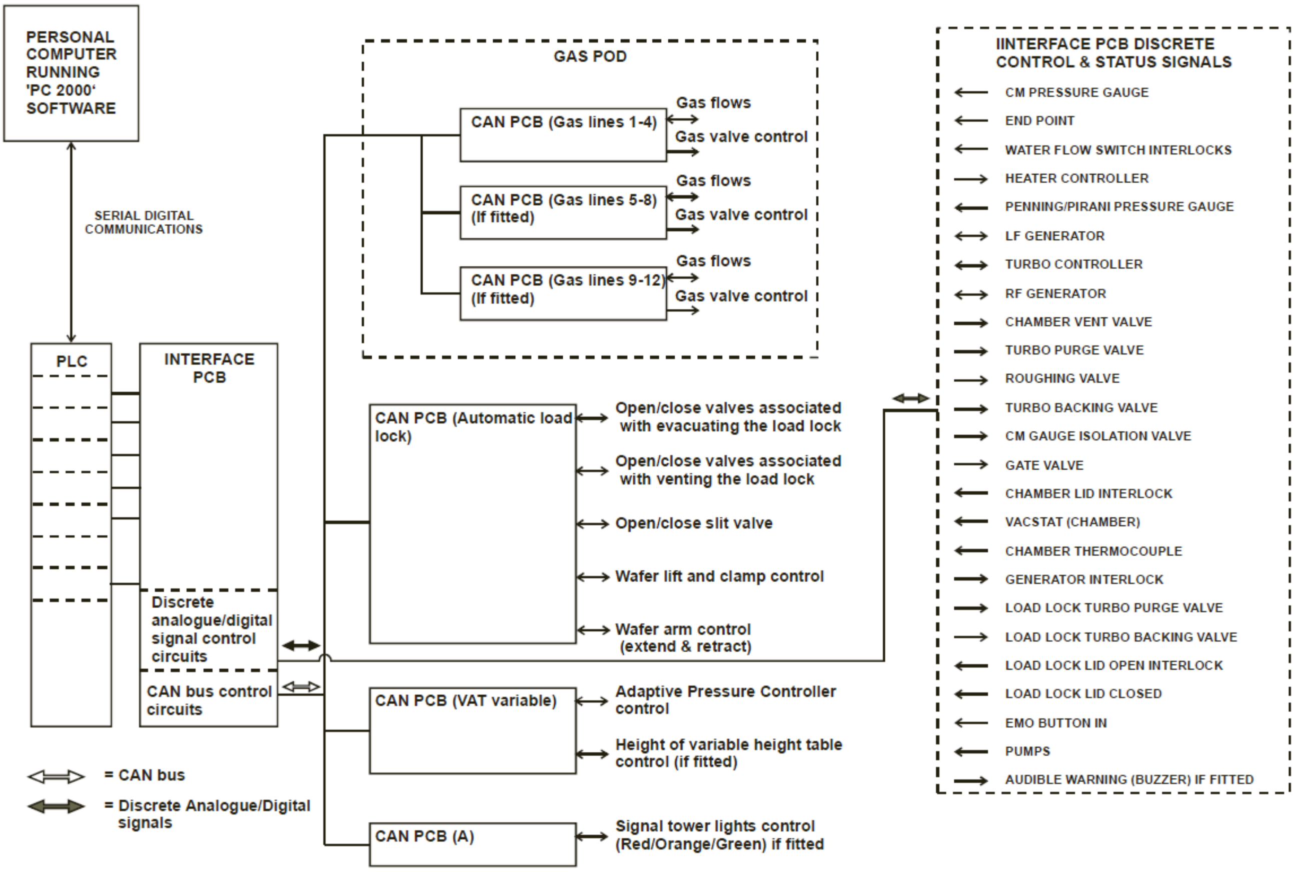

Figure 2-32 Typical control system

The system can be run from the PC terminal in manual mode, that is using direct real-time control over the process, or in automatic mode where the system performs the entire process according to previously entered recipes. The extensive Oxford Instruments Plasma Technology process library supports all **FlexAL**® configurations.

2.10.4 PLC interlock chain

The interlocks form a continuous 24 V DC chain, which must be complete before the process gases and RF power supplies are enabled. An output to disable external devices unless the lid is closed is also provided: this is typically used to disable a lid-mounted endpoint detector laser.

The interlock chain is monitored by the software, but acts independently. It is also supplemented by machine protection sensor, which operate only via the software.

To enable RF power, all of the following conditions must true:

- The 600 mbar vacuum switch (Vacstat) must be at low pressure.
- The process chamber lid must be shut.
- The primary process pump must be running.
- The primary process pressure gauge (normally a capacitance manometer) must be on scale.
- The load-lock inter-chamber valve (where fitted) must be closed.
- Customer-supplied external alarm devices must be in their safe state.
- The inert gas purge to the primary process pump must be flowing.

To enable process gases, the following conditions must be true:

- RF power must be enabled.
- The gas box lid must be shut.
- Specific gases can be set in the gas box hardware to be mutually exclusive, so that they cannot be turned on together.

Machine protections fitted where appropriate:

- A nitrogen pressure switch to detect adequate purge pressure to turbomolecular pump bearings.

OR:

- A nitrogen flow meter to detect purge gas flow to pump bearings.
- Water flow switch(es).

RF enable interlock chain details are given in **Table 2-3**. Also refer to drawing 94-SE00A26865 (PC2003 interface schematic).

Table 2-3 RF enable interlock chain details

Interlock	Device	PCB Input	PCB1 LED	Link Out	Comments
Vacuum switch	Vacuum switch	BLK17	11	None	Pressure below 600 mBar
Hoist/lid	Air cylinder microswitch or	BLK18	12	None	Lid closed or hoist down. This interlock also enables the end-point laser via JP51
	Guardmaster N/O switch	BLK19	13	None	
Generator interlock	Output	Internal	na	None	Output to enable contactor K4.
Primary vacuum pump running	Current monitor in power box	JP44	6	15	Interlock disabled if an independent/dry pump fitted.
Process pressure gauge is on scale	Capacitance manometer gauge (e.g. Baratron™)	JP16	5	None	Analogue input must be below 11.5 VDC. This switches comparator U5.
Spare interlock 1	External voltage-free contact or 24V DC input to PCB	JP52	14	Can be bypassed using LK19.	Customer-supplied device. Voltage-free contact JP52 pins 1 and 4. OR 24V DC input JP52 pin 4.
Spare interlock 2 or	External voltage-free contact	JP53	15	20	Customer-supplied device or
load lock valve	Inter-chamber valve must be shut.				Used on 100 and 133 systems.
Process pump purge	Gas flow switch at primary pump	JP55	16	LK21A	Fit LK21B, if fitted.

If the above conditions are satisfied, then 24 V DC is passed to BLK20, 21 & 22 pin 1. This enables contactor K4 which, in turn, switches electrical power to the RF generator.

2.10.4.1 Gas box interlock chain

Refer to drawing: 94-SE81B26657 (PC2003 gas pod loom).

To enable process gases, the RF interlock chain must be complete. The gas box interlock is shown in Figure 2-33.

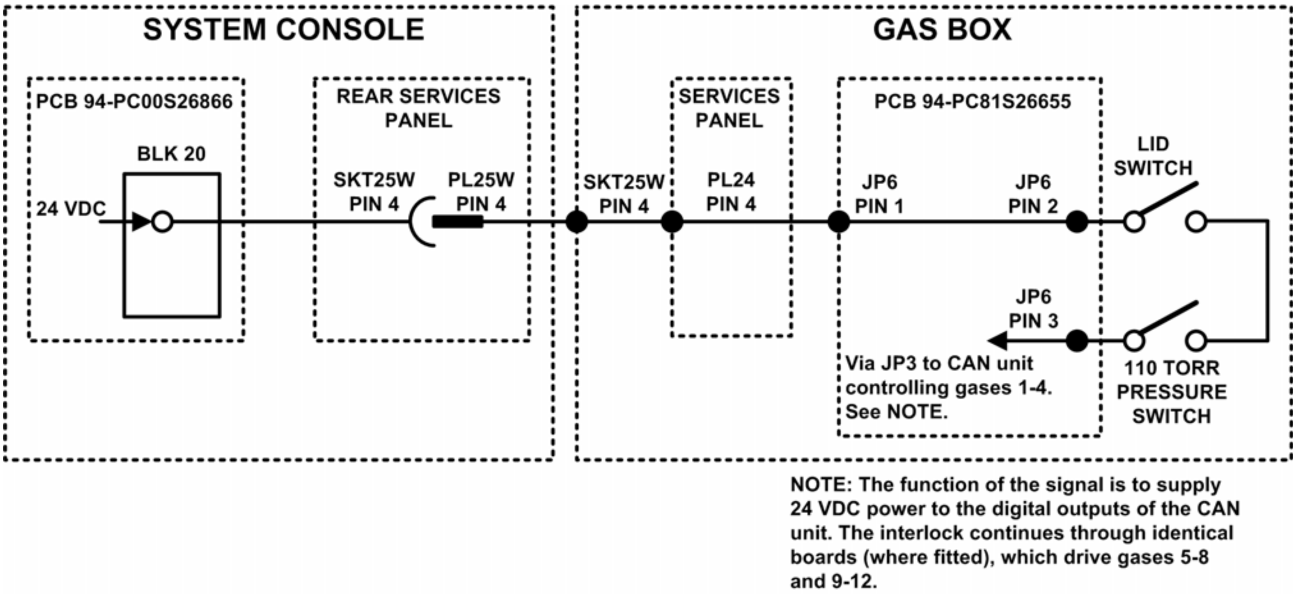

Figure 2-33 Gas box interlock chain

2.10.4.2 Incompatible gases interlock

The gas box has a facility to prevent incompatible gases from being enabled simultaneously. By configuring the solder links on the gas control card, each gas is designated as one of three types:

- Gas type A - oxidising gases (e.g. oxygen, chlorine)
- Gas type B - fuel gases (e.g. hydrogen)
- Gas type X - neither oxidising or fuel gas (e.g nitrogen)

If any type A gas is enabled, the interlock circuit disables all type B gas lines.

Table 2-4 lists the solder links that apply to each gas line.

Table 2-4 Incompatible gas interlock links

	1st PCB Gas	2nd PCB Gas	3rd PCB Gas	Type A	Type B	Type X
1st Gas	Gas line 1	Gas line 5	Gas line 9	LK3A+4	LK3B	LK3A
2nd Gas	Gas line 2	Gas line 6	Gas line 10	LK5A+6	LK5B	LK5A
3rd Gas	Gas line 3	Gas line 7	Gas line 11	LK7A+8	LK7B	LK7A
4th Gas	Gas line 4	Gas line 8	Gas line 12	LK9A+10	LK9B	LK9A

2.10.4.3 System links and LEDs

Table 2-5 lists the system configuration links.

Table 2-5 System configuration links

Link Name	Function	Notes
LK1	Analogue 0V to chassis	
LK2	Digital 0V to analogue 0V	
LK3	Non-controller cryo enable	
LK4	Heater snap switch bypass	
LK5	Fit if no OEM controller is fitted.	
LK6 A	Non PM140 end-point detector	See LK7 A/B
LK6 B	PM410 end-point detector	
LK7 A	Non PM140 end-point detector	See LK6 A/B
LK7 B	PM410 end-point detector	
LK8	+24 VDC to RL2 COM1	
LK9	+24 VDC to RL2 COM2	
LK10	+24 VDC to RL6 COM1	
LK11	+24 VDC to RL6 COM2	
LK12	+24 VDC to RL7 COM1	
LK13	+24 VDC to RL7 COM2	
LK14 A	Non dry pump fitted.	
LK14 B	Dry pump fitted.	
LK15	Pump current bypass	
LK16	+24 VDC to RL8 COM2	
LK17	Non-controller heater alarm	
LK18	Non-controller heater enable	
LK19	Spare interlock 1 bypass. Not fitted on systems 100 or 133.	
LK20	Spare interlock 1 bypass. Not fitted on Ebara dry pumps.	RL23
LK21 A	Purge switch is not fitted.	
LK21 B	Purge switch is fitted.	
LK22	100 system on LED/bulb bypass.	
LK23	Dry pump signal 4	
LK24	700°C temperature range enabled.	
LK25 A	Loadlock wet pump	
LK 25B	Loadlock dry pump	

Table 2-5 System configuration links

Link Name	Function	Notes
LK26 A	Fit these links for dry pumps. Do not fit these links for an Ebara pump.	See LK27 A & C
LK26 B		
LK27B		
LK27 A	Fit these links for Ebara pump. Do not fit these links for dry pumps.	See LK 26 A&B and LK27 B.
LK27 C		
LK28	n/c	
LK29	Air pressure input bypass	
LK30 A	Power box K2 is controlled.	
LK30 B	Power box K2 is enabled.	

Table 2-6 lists the system LEDs.

NOTE: When the interlock chain is complete, all the LEDs listed in Table 2-6 are illuminated.

Table 2-6 System LEDs

LED Name	Colour	Monitoring
LED1	Green	+24 VDC
LED2	Red	+15 VDC
LED3	Yellow	-15 VDC
LED4	Green	+5 VDC
LED5	Red	CM gauge comparator is OK.
LED6	Red	Pump current switch
LED7	Red	Nitrogen pressure switch
LED8	Red	Waterflow switch three
LED9	Red	Waterflow switch two
LED10	Red	Waterflow switch one
LED11	Red	Vacuum interlock switch (VacStat)
LED12	Red	RL10 (hoist control)
LED13	Red	Hoist
LED14	Red	Spare interlock 1
LED15	Red	Spare interlock 2
LED16	Red	Pump purge switch
LED17	Red	RL14 (master slave) active slave
LED18	Red	Spare digital input (waterflow switch 4)

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3 INSTALLATION AND COMMISSIONING

This chapter provides information on how to install and commission **FlexAL**®. The topics discussed here include:

- **Installation information**
- **Commissioning the system**
- **System adjustments**

Refer to **Chapter 10** for the technical specifications of the **FlexAL**® tool.

3.1 Installation information

This section provides general information that is required to install a **FlexAL**® system.

3.1.1 Responsibilities for installation

The installation and cabling of this system are the responsibility of the customer (unless this has been specifically altered in the sales contract). On completion of the system installation, the system is commissioned by OIPT.

3.1.2 Installing the system

The following instructions are a general guide for installing a typical **FlexAL**® system supplied with a remote gas pod and rotary vane pump. Customers must be aware of any special requirements for their system: e.g. rotary pump purging, hazardous processes, endpoint detectors, etc.

WARNING 3.1

POTENTIALLY HAZARDOUS EQUIPMENT
The FlexAL® system can present various hazards if it is not installed correctly. These hazards can cause death or serious injury. Before installing the system, ensure that all relevant personnel have read and understood Chapter 1 of this manual (Health and safety). If you have any concerns or questions, contact Oxford Instruments Plasma Technology before proceeding with the installation.

3.1.2.1 Unpacking the system

Unpack system components and check for damage and missing items against the packing list. If any items are damaged or missing, report immediately to the carrier and OIPT.

3.1.2.2 Positioning the system components

WARNING 3.2

HEAVY OBJECT
Incorrectly lifting heavy objects can cause severe injury. Use the appropriate lifting equipment, operated by fully trained personnel, when handling heavy system components. When handling heavy rack-mounted components, ensure that the weight is safely distributed between sufficient personnel.

WARNING 3.3

TOPPLING (TIPOVER) HAZARD
If heavy items are not kept vertical, they can topple causing severe injury. When transporting or manoeuvring heavy items, ensure that they remain vertical at all times. Use appropriate lifting or handling equipment. Ensure that any support frames that were supplied with the system are correctly fitted whenever the system is transported, manoeuvred, or dismantled for service or maintenance. It is user's responsibility to ensure that all components are supported safely before and during any transporting, manoeuvring or maintenance operations. Support frames provided by Oxford Instruments Plasma Technology are not necessarily adequate for any such operations. Further precautions may be required even if a support frame is not supplied with the system.

1 Transport the system frames to the clean room, then position them in the required location.

NOTE: OIPT recommends that a service access space of at least 600 mm is allowed between any obstacle (e.g. walls, partitions, etc.) and serviceable items, e.g. the power distribution unit.

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2 Adjust the feet to level the system frames, ensuring that the wafer transfer path is aligned from frame to frame.

3 Lock the adjustable feet.

4 Transport the system PC to the clean room and position it at the required location.

5 Transport the gas pod to the grey area and mount it in the required position.

WARNING 3.4

HEAVY OBJECT
Heavy objects can cause severe injury if they fall. Ensure that the gas pod fixings and supports are sturdy enough to bear at least four times the weight of the gas pod. Periodically (e.g. annually), check that the gas pod and its fixings are secure.

6 Transport the rotary vane pump to the grey area and mount it in the required position in accordance with the pump manufacturer's instructions. Refer to the manufacturer's literature in Volume 3 of this manual.

3.1.2.3 Connecting the services

1. Check that all services are switched off and locked out before attempting to connect them. This includes mains electricity, gas, compressed air and water supplies.
2. Ensure that proposed location of cables and other system items will not restrict access to the system emergency off switches and main electrical isolator.
3. Ensure that cables and other services are not located in areas where personnel are likely to walk. OIPT recommends that cables and pipes are located in cable trunking or trenches.
4. Connect the extraction collars on the process chamber(s) (e.g. ICP process chambers) and the gas pod to the appropriate extraction systems.
5. Connect the rotary vane pump exhaust line.
6. Connect the Nitrogen purge lines to the system services panel(s) and the rotary vane pump.
7. Connect the compressed air supply to the system services panel(s) and to the gas pod.
8. Connect the gas supplies to the gas pod, with all gas supply valves closed.
9. Connect the gas outlet line, control cable and earth cable (**Figure 3-1**) from the gas pod to the system console.
10. Connect the cooling circuits to the system console.
11. Connect the system earth point to a local facility earth (see **Section 10.2.2.1**).
12. Connect the emergency stop circuit to any customer devices that are required to shut down the system if a fault is detected, such as gas detectors, smoke detectors etc. (see **Section 10.2.3**).
13. At the system PC, connect the monitor, keyboard and mouse, then connect the control cable(s) from the PC to the system console.
14. Connect the electrical supply from the safety isolation box to the system console. If it is necessary to connect the 3-phase electrical supply cable to the power box, refer to **Section 3.1.2.4** and **Section 10.2.2**.
15. Connect the electrical supply to the PC.
16. Ensure that all covers and panels are fitted and attach notices to the system indicating that the system is not ready for service and must not be powered up until the OIPT installation engineer arrives on site.
17. Complete and sign the System Readiness form QCF 89 (shipped with the system), then fax it to OIPT who will arrange for the system to be commissioned.

Installation is now complete and the system is ready for commissioning by OIPT. Customers who have arranged to commission the system themselves need not read the remainder of this section.

3.1.2.4 Connecting the three-phase supply to the electrical power box

If it is necessary to connect the three-phase supply cable to the electrical power box, proceed as follows:

1. Ensure that the three-phase supply cable is not connected to the safety isolation box.
2. Remove the cover of the electrical power box.
3. Within the electrical power box, remove the clear plastic safety cover. The safety cover is secured to the right side of the electrical power box by four screws.
4. Connect the wires of the three-phase supply cable as shown in **Figure 3-1**.
5. Refit the clear plastic safety cover.
6. Refit the cover of the electrical power box.

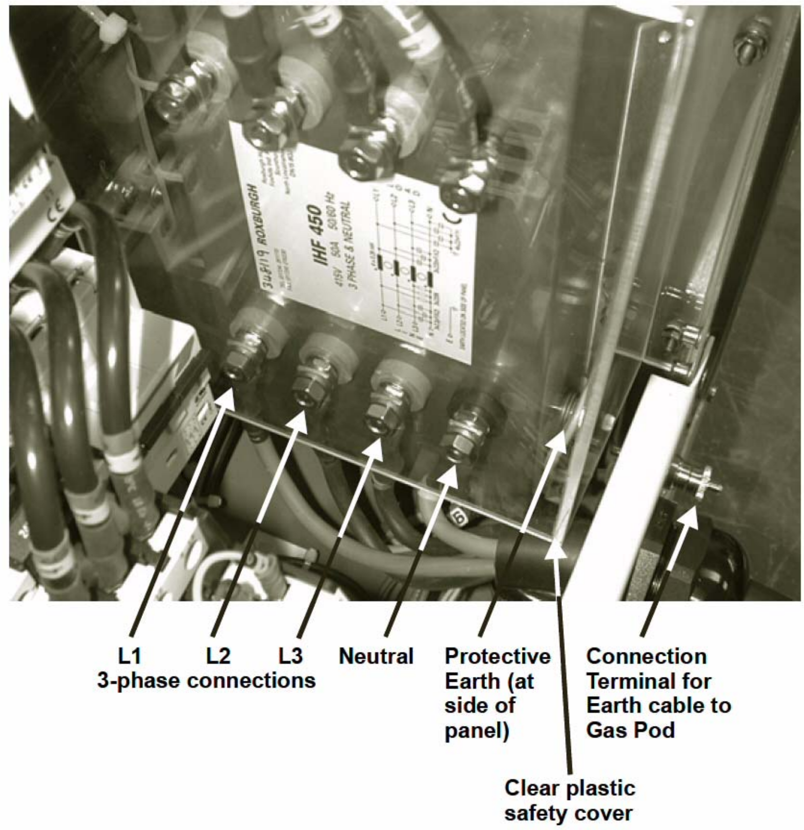


Figure 3-1 Three-phase supply cable connections in the electrical power box

3.1.3 Testing and setting up the AMU

NOTE: Detailed test instructions are contained in Oxford Instruments Plasma Technology Work Instruction No. 39. The following is a summary for the benefit of skilled service engineers. It should not be necessary for operators to perform these setting up operations.

3.1.3.1 Disabling the RF generators

Before removing an RF shielding panel, disable the RF generators by opening the interlock chain. This can be done most easily by partially venting the process chamber using the SERVICE mode vacuum control page to isolate the chamber and open the vent valve for 10 to 30 seconds, until the interlock indicator changes state.

3.1.3.2 Flowchart of the setup procedure

Figure 3-2 shows the steps that must be performed to set up the AMU.

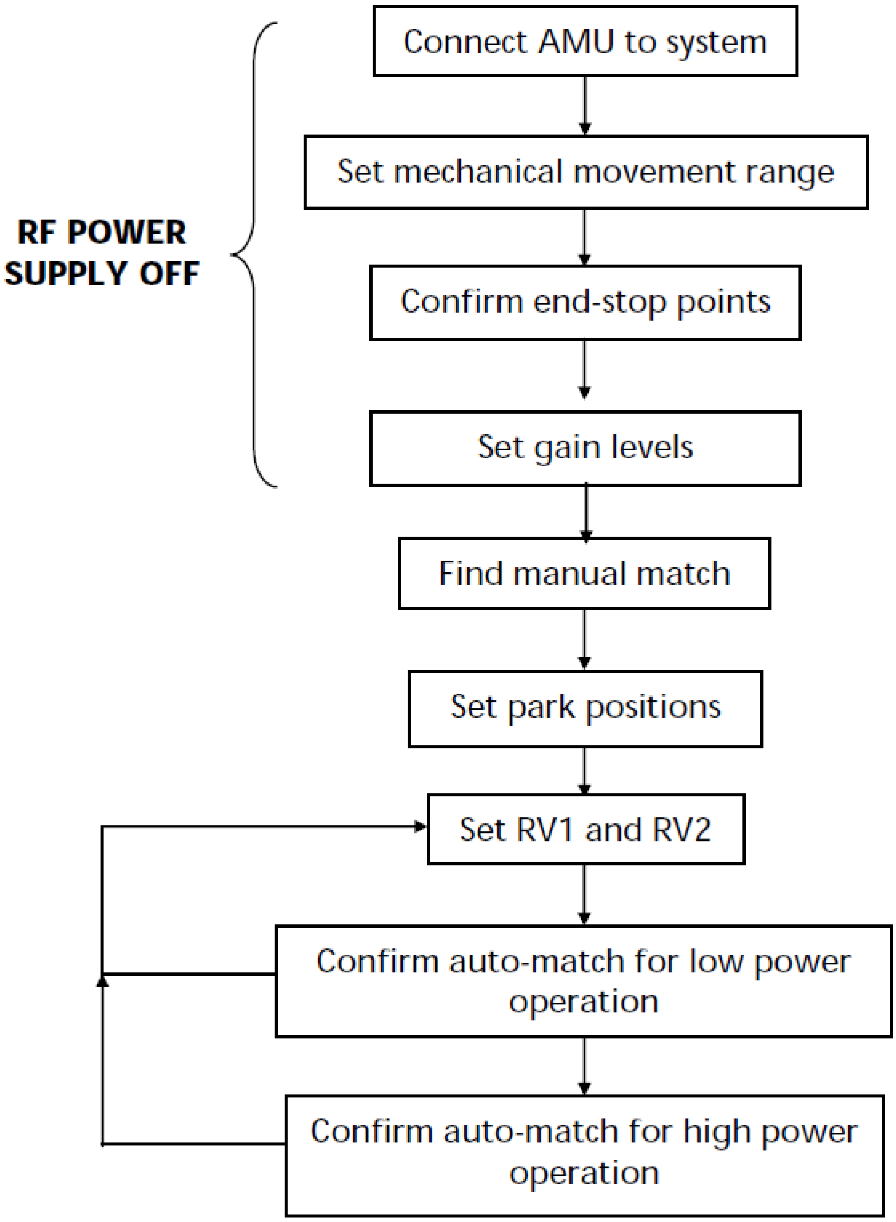


Figure 3-2 Flowchart of the AMU setup procedure

3.1.3.3 AMU setup procedure

WARNING 3.5

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. Any work requiring the removal of covers or panels must only be performed by authorised personnel who are aware of the hazards involved. Before removing any covers or panels, power down the system and perform the recommended lock out / tag out procedure.

1 Connect the AMU to the system. Make a good earth bond between the vacuum chamber and the AMU chassis.

2 Connect the output strap to the plasma electrode with at least a 25 mm wide copper strap, with at least 10 mm clearance between the live strap and any earthed part.

3 Confirm the polarity and voltage of the DC power source before connecting to the Sense and Control PCB:

JP7 pin 1 +24 VDC

JP7 pin 2 0 V

4 Ensure the ventilation fans are all pulling air out of the automatch case and check the system cooling is turned on. For sense board cooling, check one fan is pulling air out and one is pulling air in to the sense board section.

5 Confirm the operation of each motor using the manual button. An increase in capacitor position should make the vanes overlap more. In the case of a vacuum capacitor, an increase in position should turn the capacitor shaft anti-clockwise, when looking at it from the motor end (see **Figure 3-3**). Check with a capacitance meter in case of doubt.

If the motors do not turn in the correct direction check the plug-in connector on the board, refer to OIPT Work Instruction No. 39.

6 Calibrate the motors and their respective positions as follows:

1) For **gear driven** capacitors: loosen screws retaining the motors to the AMU box, but don't remove completely and ensure the gears don't mesh.

For **direct drive** capacitors: unscrew the motor plate attached to the side of the AMU box and pull the coupling apart.

2) Then:
For **air vane capacitor AMU**:
Keeping gears separated, overlap the vanes fully. Then, making sure that the gears don't mesh, drive both motors to maximum (999), using the AMU control panel.

For vacuum capacitor AMU (AMU board REV05 and earlier):
Set the capacitor positions and drive motors to their required position according to the system type as shown in **Table 3-1**.

Table 3-1 Initial capacitor and motor positions for AMU setup

System Type	Set C1 To	Then Move In	Drive C1 Motor To	Set C2 To	Then Move In	Drive C2 Motor To
RIE/DP	Maximum	1 turn	Maximum (999)	Maximum	1 turn	Maximum (999)
ICP180	Maximum	1 turn	Maximum (999)	Maximum	1 turn	Minimum (000)
Ion beam	Minimum	1 turn	Minimum (000)	Minimum	1 turn	Minimum (000)
ICP380	Maximum	1 turn	Maximum (999)	Maximum	7 turns	Maximum (999)

7 To find the minimum position, turn the capacitor shaft in the direction of the arrow, shown in **Figure 3-3**. At the minimum position, the shaft becomes stiff; at the maximum position, the shaft becomes loose. Do not try to turn the shaft past these points. If when turning the capacitor to the maximum position, the shaft becomes loose, turn the shaft back in until it just begins to bite, this is the maximum position.

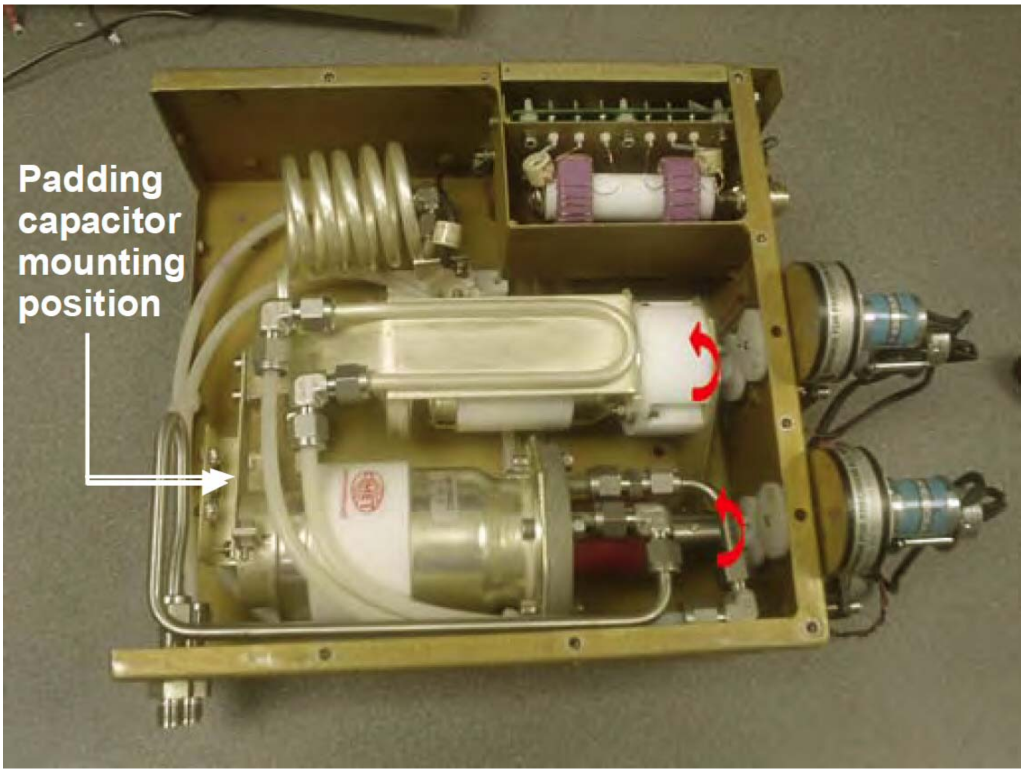


Figure 3-3 Capacitor shafts rotation direction

For vacuum capacitor AMU (AMU board with capacitor range mod.): (applies to all system types) Rotate the vacuum capacitor shaft clockwise as you look at it from the motor end (see **Figure 3-3**) until the shaft just becomes stiff, and then turn in half a turn. Making sure the motors don't mesh, drive both motors to minimum (000).

For gear driven capacitors: Re-mesh the gears and tighten motor retaining screws, ensuring that the motor and capacitor positions don't move.

For direct drive capacitors: Loosen the coupling clamp screw on the capacitor side, turn the coupling on the capacitor side until it lines up wit that on the motor side ensuring neither the capacitor nor the motor change position at any time. Clip the coupling together and tighten the clamp screw. Then re-attach the motor plate.

Confirm the end of range stop functions using the manual drive switches located on the AMU panel:

Drive C1 positive to the stop position; LED 101 lights; stop point in the range 950 to 999.
Drive C1 negative to the stop position; LED 102 lights; stop point in the range 000 to 050.
Drive C2 positive to the stop position; LED 1 lights; stop point in the range 950 to 999.
Drive C2 negative to the stop position; LED 2 lights; stop point in the range 000 to 050.
If these aren't working as stated, refer to OIPT Work Instruction No. 39.

8 Set LK2 and LK102 to position b, and then turn RV1 and RV101 fully clockwise until they begin to click (see **Figure 3-4**).

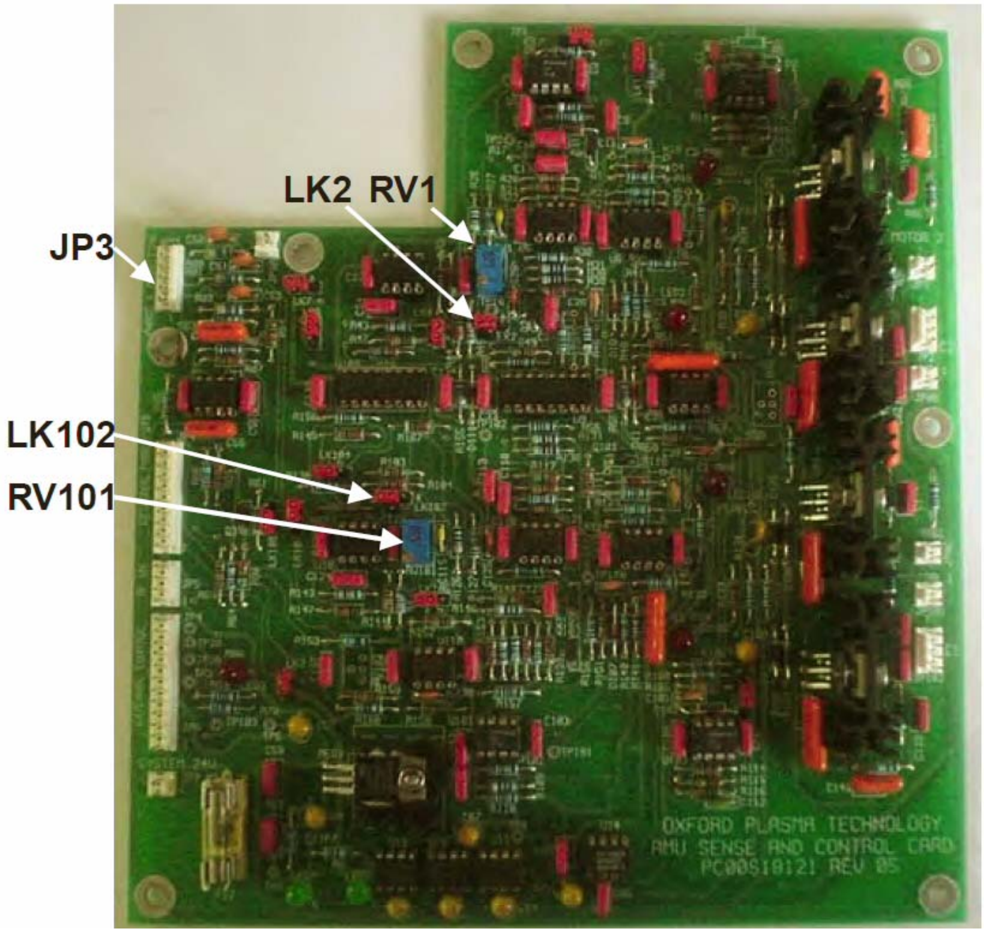


Figure 3-4 AMU setup component locations

9 Fit all covers to the AMU ensuring that they are securely fitted, and then connect the RF generator to the matching unit. Evacuate the process chamber and turn on a low power process.

10 Manually match to the lowest possible reflected power using the RF AUTOMATCH panel (see **Section 4.3.7.9**), and make sure a plasma is running. Adjust the error signal zero potentiometers RV1 and RV2 (located on the same side of the AMU as the RF in connector; see Fig 1), while monitoring the two error signals on JP3 pins 1 and 3 (See **Figure 3-4**). These should be less than 20 mV when a match exists. Amplified error signals are accessible at TP 10 and TP 110; these should be made as low as possible when the RF is well matched.

For vacuum capacitor AMU (AMU board REV05 and earlier):

If it is not possible to find a match position due to the match position being beyond the range of the capacitors, stop the process and remove the AMU cover again. If C1 is attempting to drive above the maximum position, add 180 pF padding capacitor (Part Number 94-ECC1218), or turn 2 turns anti-clockwise towards maximum. If C1 is attempting to drive past the minimum position, remove a padding capacitor if already fitted, otherwise turn 2 turns clockwise towards minimum. If C2 attempts to drive above the maximum position turn 2 turns anti-clockwise, if C2 attempts to drive below the minimum position, turn 2 turns clockwise. Whilst doing this, be careful not to turn the capacitors beyond their physical end stops.

For vacuum capacitor AMU (AMU board with capacitor range mod.):

If C1 attempts to drive above maximum position, add 180 pF padding capacitor. If C1 is attempting to drive past the minimum position, remove a padding capacitor if already fitted. If C2 attempts to drive past maximum or minimum position, check that the correct inductor is fitted and that the capacitors are correctly fitted to the system. If these are correct, the match position is out of the range of C2.

For air vane capacitor AMU:

If C1 or C2 attempts to drive above maximum position, add 180 pF padding capacitor. If C1 or C2 is attempting to drive past the minimum position, remove a padding capacitor if already fitted. It is not necessary to reset the positions of the Air Vane Capacitors.

11 Increase the RF power in a few steps to maximum and check for RF leakage, arcing or local overheating.

12 Rematch manually, when at maximum RF power, manually to less than 1% reflected power if possible; less than 3% is the maximum reflected power acceptable. Refine the zero settings of the error signals.

13 Make a note of the capacitor position values when a good match is achieved. Stop the process and adjust the park positions to a value below that of the match position (within around 050 units on the position display), making sure that C2 is closer to its match position than C1.

14 Re-start the process with the **AUTO** button on the RF AUTOMATCH panel selected (see **Section 4.3.7.9**) to make sure the match is successful. If there is a large reflected power, repeat Step **11**. If there is a small amount of reflected power, which can't be reduced manually, RV1 and RV2 on the side of the AMU can be used to make finer adjustments when in auto mode.

15 If the capacitors oscillate when in auto, reduce the gain of the control circuit by slowly turning RV1 and RV101 anti-clockwise (if C2 oscillates adjust RV1, if C1 oscillates adjust RV101) until oscillations stop. If the potentiometer's RV1 or RV101 begin to click before the oscillations have ceased, turn them fully clockwise until they begin to click again and change LK2 (corresponding to RV1) or LK102 (corresponding to RV101) to position 'a' and begin turning the potentiometers anticlockwise again until the oscillations stop.

16 Confirm the automatching behaviour, increasing the RF power to maximum in small steps, repeating Steps **11** to **14** if necessary.

3.1.4 Connecting a new precursor ampoule

Only perform this section if ampoules have never been fitted to the precursors delivery modules.

Caution 3.1

DO NOT EVACUATE THE OZONE GENERATOR
Do not evacuate the ozone generator (if fitted), as this can cause permanent damage to the unit.

Six-way precursor cabinet

To connect precursor ampoules into a six-way precursor cabinet, perform the following steps:

1. Prepare the module for leak-checking (see **Section 3.1.4.1**).
2. Pump the process chamber (see **Section 3.1.4.2**).
3. Pump and purge the manifolds (see **Section 3.1.4.3**).
4. Prepare to connect an ampoule (see **Section 3.1.4.5**).
5. Prepare the cabinet to fit an ampoule (see **Section 7.7.9**).
6. Fit the ampoule and return the system to service (see **Section 7.7.10**).

Single-precursor oven

To connect precursor ampoules into a single-precursor oven, perform the following steps:

1. Prepare the module for leak-checking (see **Section 3.1.4.1**).
2. Pump the process chamber (see **Section 3.1.4.2**).
3. Pump and purge the manifolds (see **Section 3.1.4.4**).
4. Prepare to connect an ampoule (see **Section 3.1.4.5**).
5. Prepare the cabinet to fit an ampoule (see **Section 7.7.11**).
6. Fit the ampoule and return the system to service (see **Section 7.7.12**).

3.1.4.1 Prepare the module for leak checking (all systems)

A new precursor module from the factory will be shipped with VCR blanks in place of the ampoule. It is important to verify all connections are leak tight before connecting the ampoule, that way any leaks after ampoule connection can be attributed to the two new ampoule connections only.

Figure 3-5 VCR connection points for a new ampoule

1 Ensure that the ampoule connections have blanks fitted to them (see **Figure 3-5**).

3.1.4.2 Pump the process chamber (all systems)

Perform this section for all system configurations. If a six-way precursor cabinet is fitted, this procedure evacuates the delivery lines back to the precursor cabinet.

Caution 3.2

CONDENSATION RISK
If the delivery lines cool, precursor can condense inside them. This condition can be difficult to diagnose. Maintain all delivery lines at their operating temperature throughout this procedure.

1 Start the system pumping.

2 Pump until the CM gauge reads base pressure (usually when the penning gauge is in the 10^{-3} range).

3.1.4.3 Evacuate and purge the manifolds (six-way precursor cabinet)

Only perform this section if a six-way precursor cabinet is fitted. Repeat this section for all precursor manifolds fitted to the system.

1 At the Process Control page, open the pneumatic valves on all the precursors in the selected manifold. This pumps the section of pipe between the ALD dose valve and the VCR blanking fitting. Pump the system for at least 15 minutes (see **Figure 3-6**).

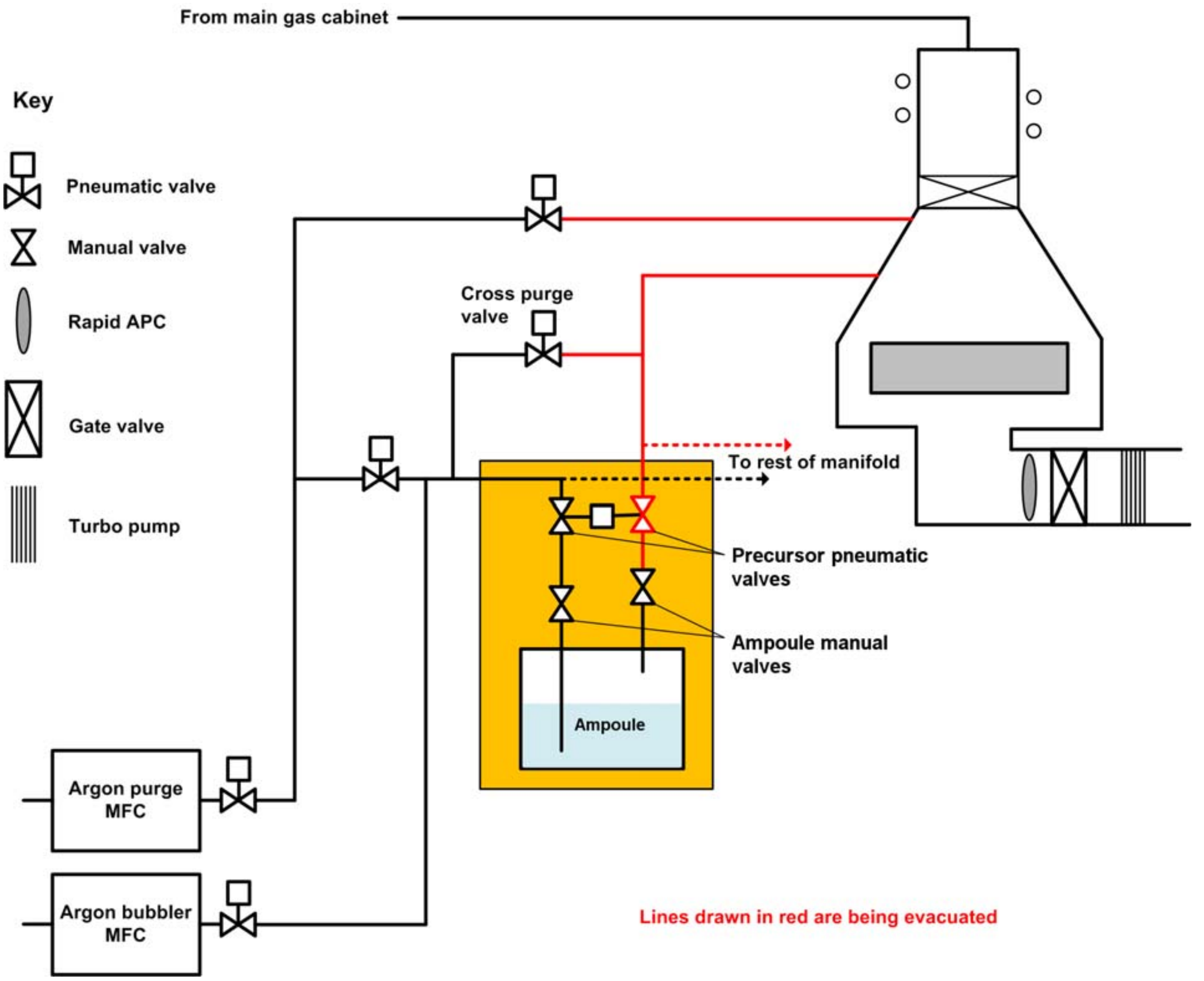


Figure 3-6 Opening all the outlet precursor valves on a manifold

2 Using the keyswitch, open the cross-purge valve on the selected manifold (see Figure 3-7). This enables the inlet or purge manifold to be pumped. Re-start this section if an over-pressure alarm shuts down the process. If more than three over pressure alarms occur consecutively, investigate for a vacuum leak on the ampoule fittings.

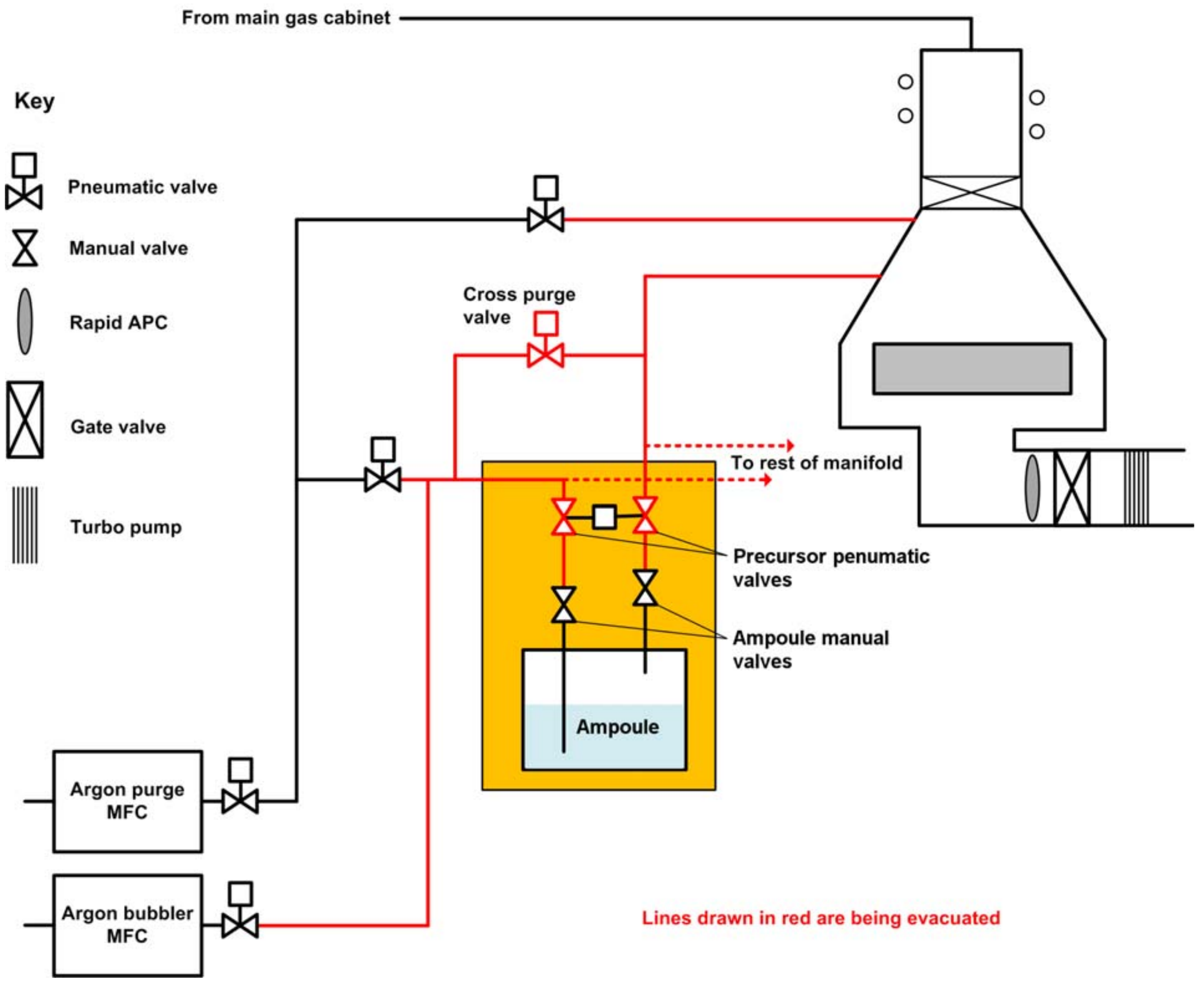


Figure 3-7 Pumping and purging the delivery lines on a manifold

3 Run the following recipe to pump and purge the delivery line:

1) Pump the line for 1 minute with the pneumatic precursor valves open.

2) Purge the line for 30 seconds with 200 sccm Ar (bubbler), precursor pneumatic valves open, Pressure 80 mT.

4 Repeat this sequence at least 45 times.

NOTE: This procedure purges the lines between the precursor pneumatic valves and the ampoule blanks.

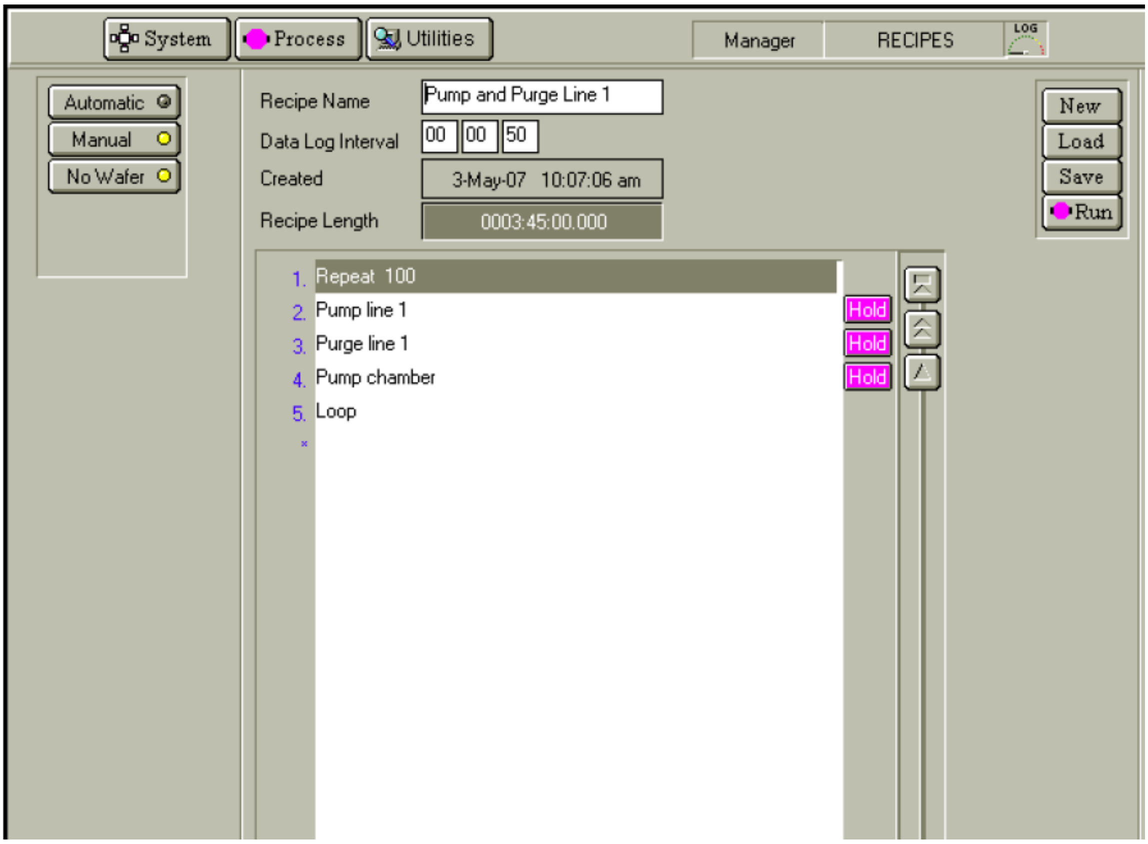


Figure 3-8 Sample recipe for purging the delivery lines

5 Open the Leak Detection page (see **Figure 4-16**).

6 Perform a leak check of the process chamber with all the pneumatic precursor valves closed.

7 Open the pneumatic valves on all the precursors in the manifold that is being checked. Perform a leak check of the chamber and precursor delivery lines. The leak up rate of the delivery system should be <0.2 mT/min higher than the leak rate of the chamber alone. If the leak rate is too high, investigate and fix any faults before proceeding.

8 Close the cross-purge valve, using the keyswitch. Remove the key and store it in a secure place.

9 Close the pair of ALD precursor valves.

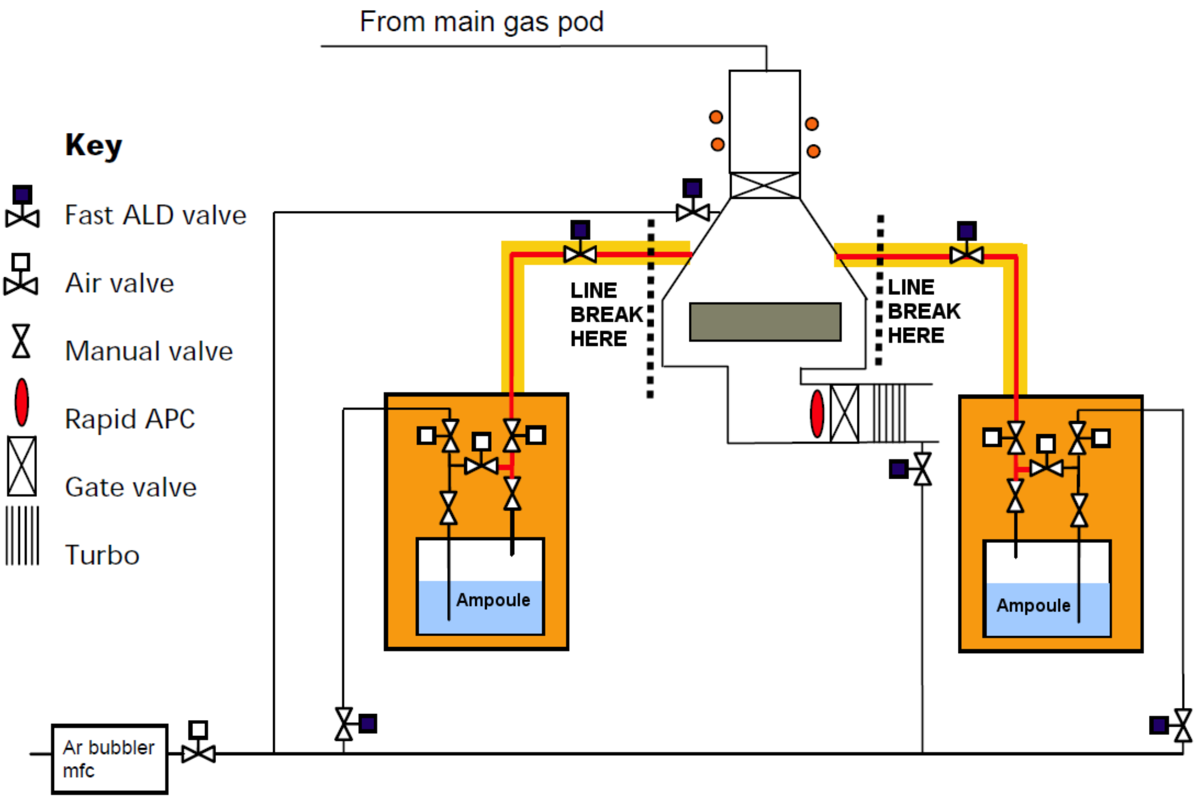
10 Repeat this section for every manifold on the system.

3.1.4.4 Evacuate and purge the delivery lines (single-precursor oven)

Only perform this section if a PDM with a single-precursor oven is fitted.

Open the outlet housekeeping valve and pump

1 Open the outlet housekeeping valve and pump the system for at least 15 minutes.

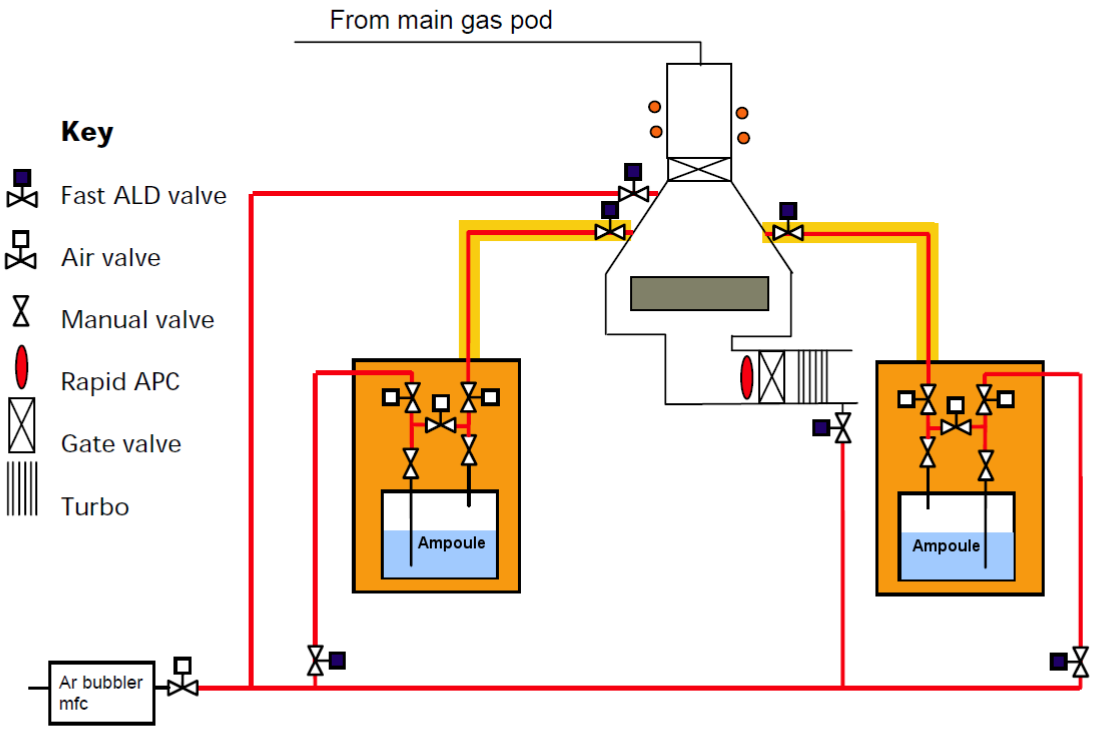


The red lines indicated the sections of line being pumped at this stage in the procedure.

Figure 3-9 Opening the outlet housekeeping valves

Pump and purge the delivery lines

2 Open the inlet and cross-purge housekeeping valves. (see **Figure 3-10**).



The red lines indicated the sections of line being pumped at this stage in the procedure

Figure 3-10 Pumping and purging the delivery lines

3 Run the following recipe to pump and purge the delivery line:

1) Pump Line 1 for 1 minute with Line 1 valve open.

2) Purge Line 1 for 30 seconds with 200 sccm Ar (bubbler), Line 1 valve open, Pressure 80 mT.

4 Repeat this sequence at least 45 times.

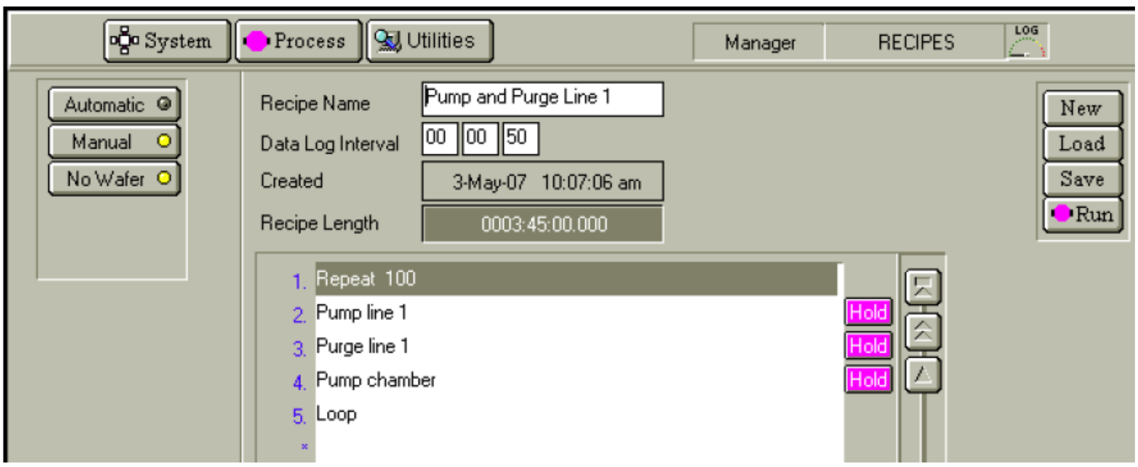


Figure 3-11 Sample recipe for purging the delivery lines

Leak check the delivery lines

5 Ensure that all housekeeping valves are still open.

6 Use the software leak up feature (see **Figure 4-16**).

7 The leak up rate of the delivery system should be <0.2 mT/min higher than the chamber alone.

Close all housekeeping valves

8 Close all the housekeeping valves.

3.1.4.5 Prepare to connect the ampoule

1 Open the precursor cabinet doors.

2 Offer up the ampoule to the pipes and ensure that they line up. Only certain ampoules are compatible with the precursor cabinet. Consult the precursor ordering guide for further details.

3 Remove the VCR blanks on the precursor module and fit new VCR gaskets ready for connection.

3.2 Commissioning the system

The **FlexAL®** will be commissioned by OIPT in accordance with standard procedures and any additional requirements stated in the sales contract. Generally, the commissioning process will include the following:

1 Checking that the system has been satisfactorily installed.

2 Powering up the system.

3 Checking the operation of the system, including the Emergency Off facility and all interlocks.

4 Ensuring that the system can perform the processes specified in the sales contract.

5 Providing training on the system.

3.3 System adjustments

This section gives details of adjustments which may be necessary depending on system configuration. In addition to these adjustments, refer to the operator adjustments detailed in **Chapter 4** of this manual.

3.3.1 Heaters

If your **FlexAL**® system has a remote heater with a Eurotherm Controller, please note the following:

- The Eurotherm controller has a default temperature setpoint. For the system to operate correctly, the setpoint must be set to a temperature suitable for the system and coolant used.
- Check the setpoint before using the system and, if necessary, change the setting in accordance with the instructions given in the Eurotherm Controller's manual.

3.3.2 Process pump purge

An inert gas (usually nitrogen), is added to the primary mechanical pump of the process chamber for several reasons:

a) When pumping condensable vapours, they flow via the gas ballast port. This helps to prevent condensation during compression and reduces the amount of liquids such as water vapour or $SiCl_4$ in the pump fluid.

b) When pumping reactive gases, they are bubbled through the pump fluid to help to drive out acidic compounds.

c) When pumping flammable or explosive gases, they are added to dilute the gas below the threshold for explosion.

d) In dry pumps, the purge gas flow is important for managing heat and limiting particle build-up.

WARNING 3.6

TOXIC GASES

Exposure to toxic gases can cause death or serious injury. The flow of inert purge gas does not make the pump exhaust effluent safe to breathe. The pump exhaust must be contained in an adequate exhaust duct. Pump exhaust gases must be appropriately treated before releasing them to the atmosphere. It is the customer's responsibility to design the pump exhaust system and to ensure it is fit for purpose.

If your **FlexAL**® system is supplied with a dry pump (e.g. Alcatel ADP122P or ADS602P), that includes an integral purge gas monitor with an output suitable for inclusion in a hardware interlock chain, it is permissible to use this instead of the OIPT purge kit.

If your **FlexAL**® system is supplied with an oil filled rotary pump (e.g. Alcatel A2063C2), the purge kit supplied is configured for the process gases specified.

3.3.2.1 Inert pumping

Tools that pump atmospheric gases only, do not require special purge arrangements other than any minimum purge required by the specific pump.

3.3.2.2 Etch tools - halogen gases

Tools that use gases containing halogens (fluorine, chlorine, and bromine – including compounds which contain these elements, e.g. CHF_3), are supplied with purge into the pump, via a rotameter of full scale at least 4 standard litres per minute (slpm).

3.3.2.3 Etch tools - flammable gases

Certain processes use the flammable gases hydrogen (H_2) and methane (CH_4), often in combination with chlorine (Cl_2) to etch compound semiconductors. The primary pump for these is purged with sufficient gas to bring the exhaust to one third of the lower flammability limit.

A rotameter is used to set and read the flow. A flow switch monitors the purge. The process gases are turned off by means of a hardware interlock if the flow switch reports low flow below 7.5 slpm.

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4 USER INTERFACE

This section describes the controls and indicators on the**FlexAL**® tool, and introduces the main pages of the PC2000 control software. The topics discussed here include:

- **Controls & indicators**
- **Privileges and modes of operation**
- **Graphical user interface**

FlexAL® is controlled from three locations:

- The power box at the rear of the base unit, which is used to power the system on and off.
- The system control panel on the base unit, which is used to remove electrical power in an emergency.
- The control PC running the PC2000 application, which is used to control the pumping system, the gas pod, the RF generator, etc. It is also used to edit and run process recipes.

It is strongly recommended that the system remains switched on and pumping continuously (i.e. do not switch off the system or vacuum pumps). This ensures the maximum lifetime for system and pumps and optimum process repeatability.

It is further recommended that every process run is datalogged - the information contained in the log files is invaluable for diagnosing equipment or process faults.

Refer to **Chapter 5** for detailed operating instructions.

4.1 Controls & indicators

4.1.1 System control panel

Figure 4-1 shows the controls and indicators on the system control panel.

Figure 4-1 System control panel

EMERGENCY STOP button
Pressing this button immediately removes electrical power from the system. The switch latches in place to prevent the power from being restored accidentally.

SYSTEM ON button
Press this button to power up the **FlexAL**® system. The green lamp in the button illuminates when the button is pressed. The lamp extinguishes when the system is shut down or if the **EMERGENCY STOP** button is pressed.

SYSTEM OFF button
Press this button to shut down the **FlexAL**® system. The red lamp in the button illuminates when it is pressed. The lamp extinguishes when the system is powered up.

SLIT VALVE LOCKOUT knob
Pull this knob outwards to remove the compressed air supply from the whole system, including the loadlock slit valve and the ICP source isolation-valve. Fit a padlock to the spindle of the knob to lock the control in the off position.

PRECURSOR LOCKOUT knob
Pull this knob outwards to remove the compressed air supply from the precursor modules. Fit a padlock to the spindle of the knob to lock the control in the off position.

LOCKOUT VALVE PADLOCK
A bracket to hold the lockout padlock.

4.2 Privileges and modes of operation

4.2.1 Modes of operation

FlexAL® can operate in two modes:

Production mode is provided to make operation of the system as simple as possible. In this mode a special recipe page is provided, which allows users to load and run a recipe and then vent the automatic load lock.

Service mode allows low level operation of the system and is used during certain maintenance activities. This mode can only be accessed by personnel with MAINTENANCE or MANAGER privileges.

4.2.2 Privileges

Access to the PC2000 control software is restricted to persons who have been assigned privileges. There are seven privilege levels:

MANAGER - grants access to all possible functions. A user with these privileges can create and manage new login accounts and perform the same functions as a user with *MAINTENANCE* privileges.

MAINTENANCE - grants MAINTENANCE mode access to the system. This level of access has its own recipes and recipe steps. However it does not allow access to production recipes and steps, nor to the system log.

SUPERVISOR - grants access to all possible functions.

USER - grants a subset of all possible functions. This subset can be configured by the *MANAGER* for each individual user name.

QUIT - grants the ability to view all pages and recipes but not to activate any controls. This user is not able to exit the PC2000 application.

VIEW_ONLY - grants the ability to view all pages and recipes but not to activate any controls. This user is able to exit the PC2000 application.

PRODUCTION - grants the user PRODUCTION mode access to the system.

Your privilege level is established by the *MANAGER,* and applies when you log on to the PC2000 control software.

4.3 Graphical user interface

This sub-section lists the main pages of the PC2000 application and describes the functions of significant fields and controls. The main pages are:

- **Menu bar, menus and status indicators**
- **PUMP CONTROL page**
- **ROBOT CONTROL page**
- **RECIPES page**
- **Production Mode page**
- **Process Control page**
- **Leak Detection page**
- **Mass Flow Calibration page**
- **SERVICE MODE pages**
- **System Presets page**
- **TOLERANCES page**
- **SYSTEM LOG pages**

4.3.1 Menu bar, menus and status indicators

The PC2000 facilities are accessed from the menu bar at the top of the screen, as shown in **Figure 4-2**.

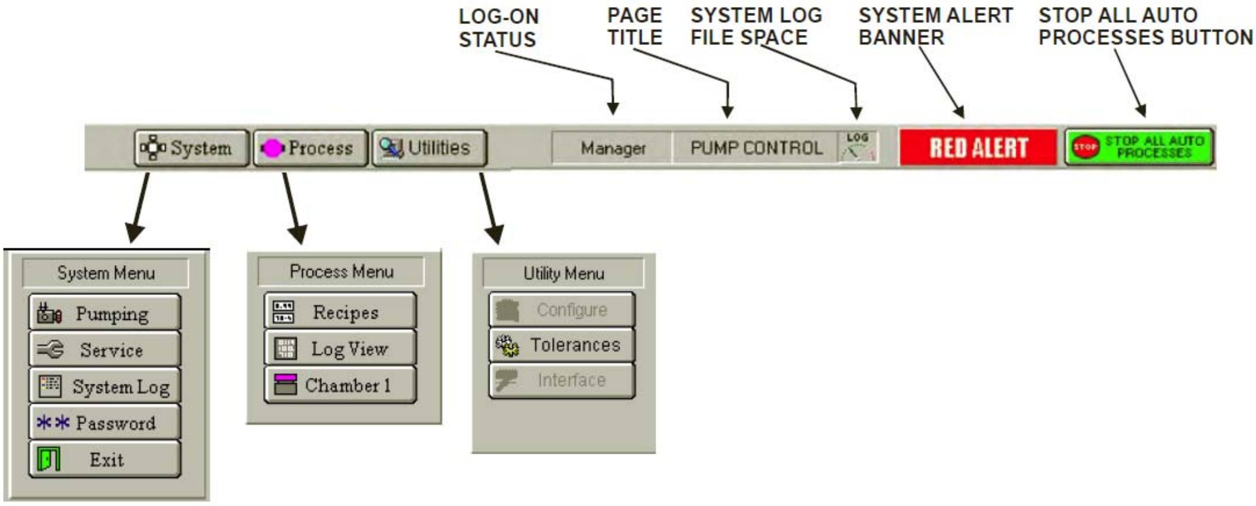


Figure 4-2 Menu bar

System button
Click to open the System Menu and navigate between system pages.

Process button
Click to open the Process Menu and navigate between process pages.

Utilities button
Click to open the Utility Menu and navigate between the utility pages.

NOTE: The **Interface** option in the Utility Menu is for OIPT software configuration and is not available to customers (greyed out).

Logon status field
The login privilege of the current user.

Page title field
The name of the current page.

System log file space indicator
Indicates the amount of file space the system log is using.

System alert banner
Indicates if a system alert is active.

Stop All Auto Processes button
Click to stop the current process.

4.3.2 Status indicators

These indicators are located at the bottom of the PUMP CONTROL page, the Process Control page and the SERVICE MODE pages. They show the current status of the system and the process chamber.

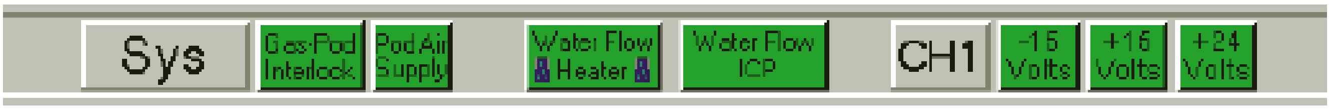


Figure 4-3 PC2000 page status indicators

4.3.2.1 System (SYS) status indicators

Gas Pod Interlock
Green = OK
Red = Fault.

Pod Air Supply
Green = OK
Red = Fault (pressure is 3.5 bar or less).

Water Flow Heater
Green when the heater cooling water flow is in tolerance.
Red when the flowswitch is tripped (i.e. no cooling water flow).

Water Flow ICP
Green when the ICP RF Generator cooling water flow is in tolerance.
Red when the flowswitch is tripped (i.e. no cooling water flow).

4.3.2.2 Process chamber (CH1) status indicators

-15 Volts
Green when the -15 V DC supply is healthy.
Red when the supply is faulty.

+15 Volts
Green when the +15 V DC supply is healthy.
Red when the supply is faulty.

+24 Volts
Green when the +24 V DC supply is healthy.
Red when the supply is faulty.

4.3.3 PUMP CONTROL page

The PUMP CONTROL page permits control and monitoring of the vacuum system. The page is opened by choosing **Pumping** from the System Menu.

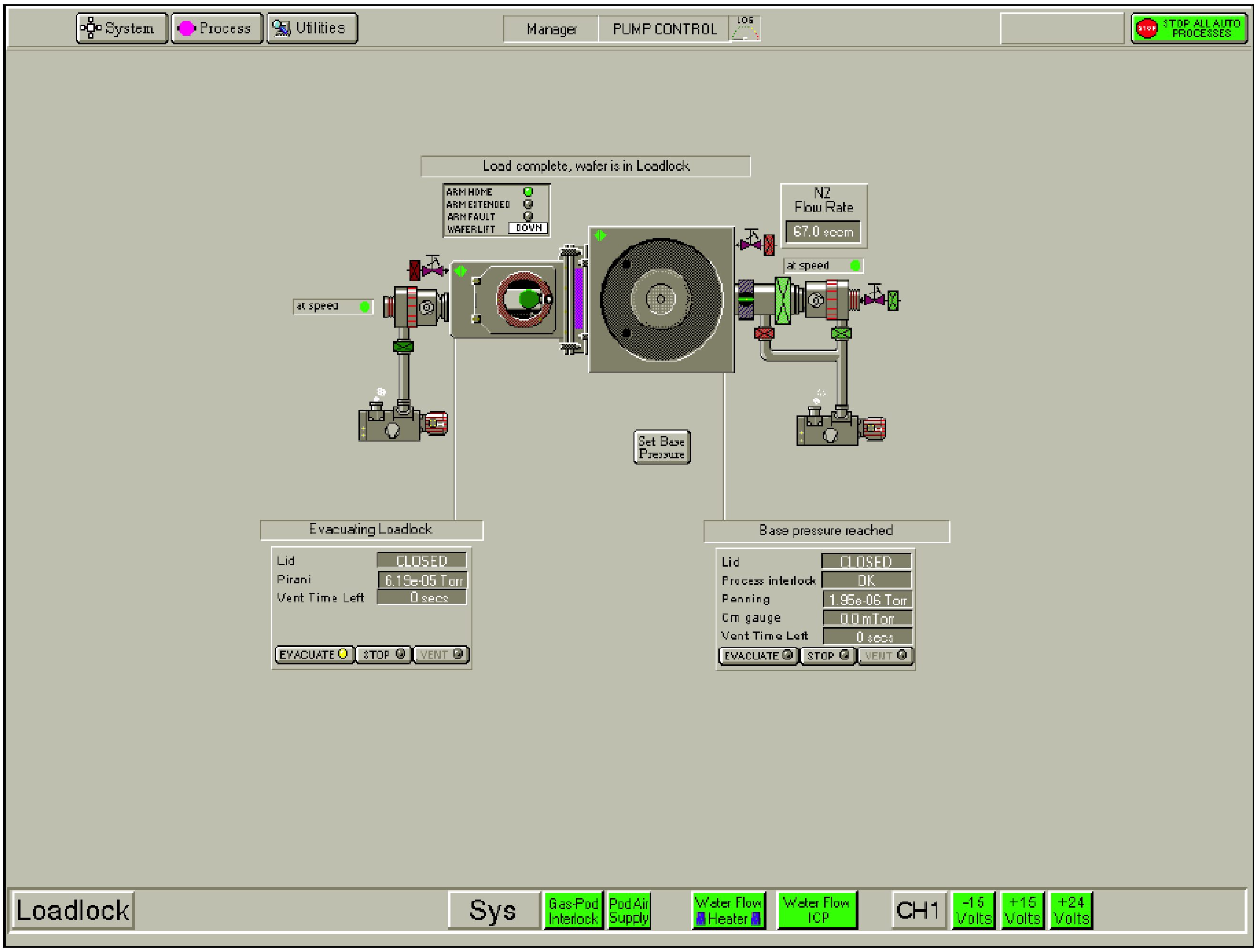


Figure 4-4 PUMP CONTROL page

4.3.3.1 Pump control vacuum system mimic

The vacuum system mimic is shown in Figure 4-5. Each chamber contains a wafer indicator which, when coloured green, indicates that a wafer is present in the chamber. Click on a green wafer indicator to display the ROBOT CONTROL page showing the possible wafer destination.

The automatic pressure controller (APC) mimic displays the current status of the valve: OPEN, CLOSED, MID POSITION or FAULT (indicated by a red dot).

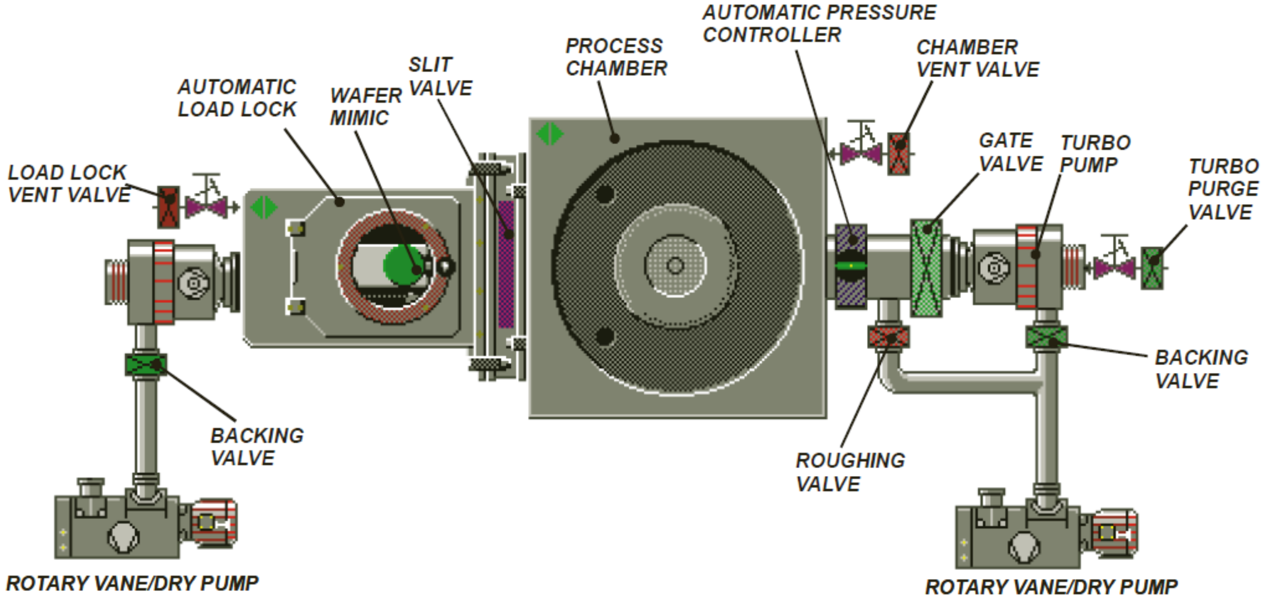


Figure 4-5 PUMP CONTROL page vacuum system mimic

4.3.3.2 PUMP CONTROL page functions

The buttons, controls, indicators and message panels on the PUMP CONTROL page allow you to control the vacuum system and wafer transfers, as shown in **Figure 4-6**, where the operator interface facilities are labelled.

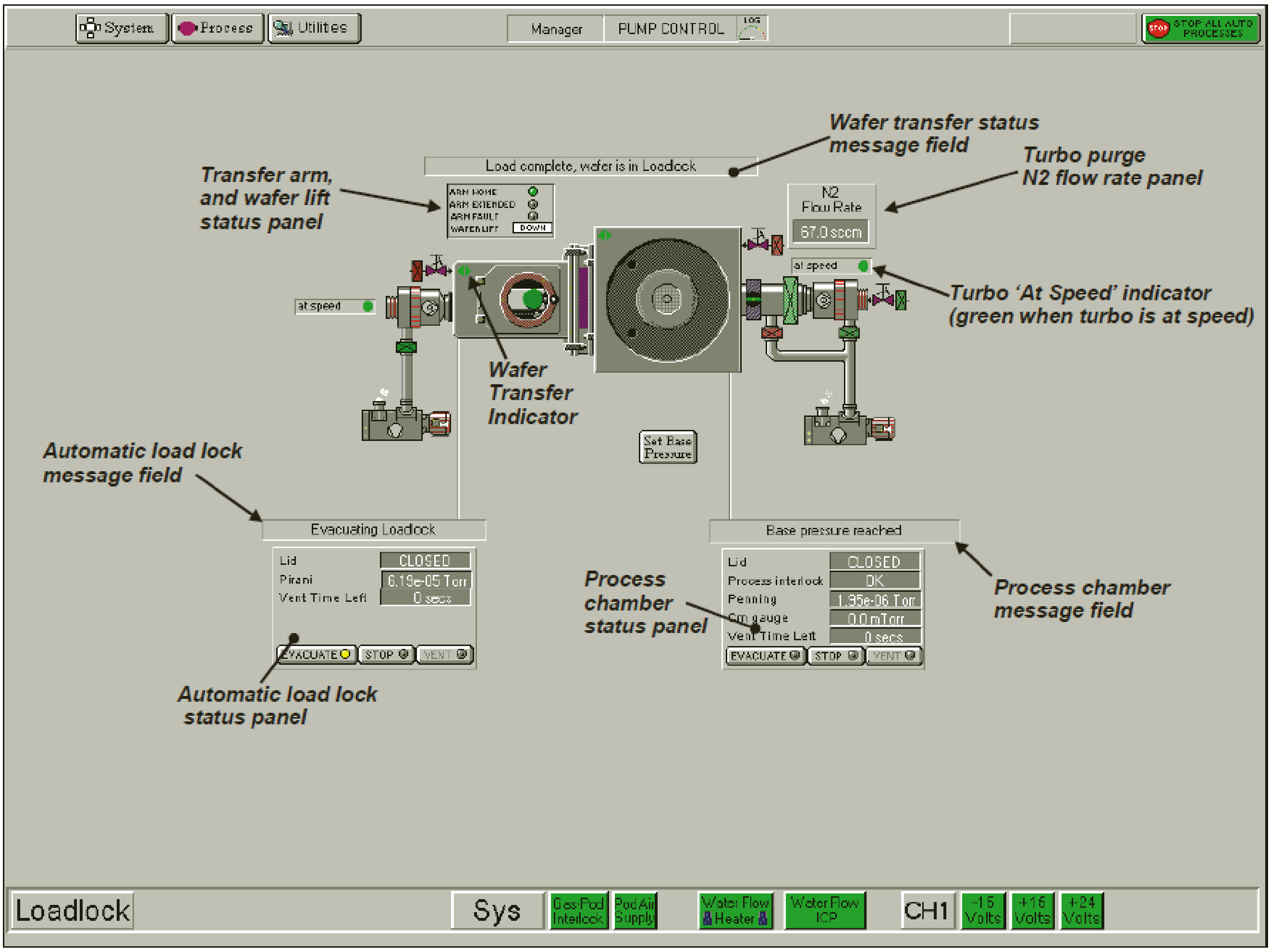


Figure 4-6 PUMP CONTROL page operator interface

Loadlock control and status panel
Controls the loadlock chamber and displays its status.

EVACUATE button - select to pump-down the loadlock.

STOP button - select to stop pump-down or venting of the loadlock.

VENT button - select to vent the loadlock.

Lid field - shows the OPEN or CLOSED status of the loadlock lid.

Pirani - shows the pressure of the loadlock Pirani gauge.

Vent Time Left - shows the time remaining for the loadlock to vent.

Process chamber control and status panel
Controls the process chamber and displays its status.

EVACUATE button - select to pump-down the process chamber.

STOP button - select to stop pump-down or venting of the process chamber.

VENT button - select to vent the process chamber.

Lid field - shows the OPEN or CLOSED status of the process chamber lid.

Process interlock - shows the interlock status of the process chamber.

Penning - shows the pressure of the process chamber Penning gauge.

Cm - shows the pressure of the CM gauge in the process chamber.

Vent Time Left - shows the time remaining for the process chamber to vent.

NOTE: In the control and status panels, the STOP button must be selected before venting to ensure the correct sequencing of the valves.

Valve mimics
Mimics of all valves show the OPEN/CLOSED status of the respective valve. The mimic is coloured green when open and red when closed.

Transfer arm and wafer lift status panel
Displays the status of the wafer lift mechanism.

ARM HOME indicator - illuminated when the wafer lift arm is at the home position.

ARM EXTENDED indicator - illuminated when the wafer lift arm is extended.

ARM FAULT indicator - illuminated if a fault occurs in the wafer lift arm.

WAFER LIFT status field - as described in **Table 4-1**.

Table 4-1 Transfer arm and wafer lift status panel messages

Message	Meaning
UP	The UP microswitch is detected as active.
DOWN	The DOWN microswitch is detected as active.
MOVING	Both microswitches are detected as inactive.
FAULT	Both microswitches are detected as active.

SET BASE PRESSURE button - select to set the base pressure of the process chamber.

Message panels
Context-related message panels for the process chamber, the automatic load lock, and wafer transfer progress. The messages give the current status of the respective item.

Ready for transfer' indicators
Displayed when the associated process chamber or loadlock is evacuated and ready for wafer transfers.

N2 Flow Rate panel
Displays the flow rate of the N2 turbo purge.

Turbo at speed indicators
Show whether the respective turbo pump has reached operating speed.

4.3.4 ROBOT CONTROL page

When **FlexAL**® is operating in automatic mode (i.e. running a recipe), wafers are transferred automatically. The ROBOT CONTROL page is used to manually transfer a wafer between the loadlock and process chambers

The ROBOT CONTROL page is opened by clicking on the green wafer symbol in the mimic on the PUMP CONTROL page.

Figure 4-7 ROBOT CONTROL page

Chamber mimic
A mimic shows the loadlock and the process chamber, as shown in **Figure 4-8**.

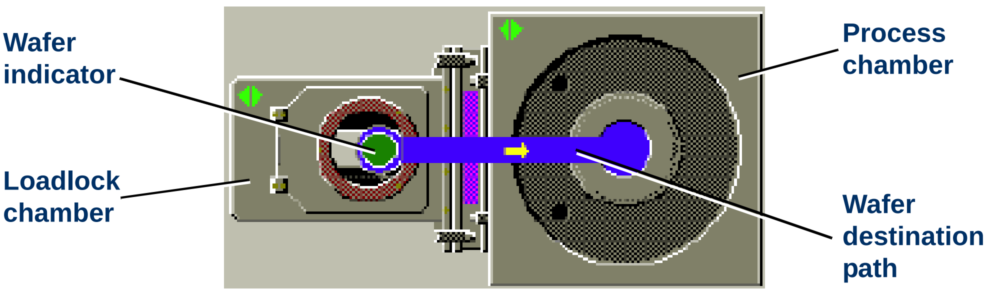


Figure 4-8 Loadlock/process chamber mimic on ROBOT CONTROL page

The location of the wafer is indicated by a green wafer indicator.

The blue, arrowed path shows the destination of the currently available wafer.

Show Pumps button
Opens the PUMP CONTROL page.

Transfer arm and wafer lift status panel
Displays the status of the wafer lift mechanism.

ARM HOME indicator - illuminated when the wafer lift arm is at the home position.

ARM EXTENDED indicator - illuminated when the wafer lift arm is extended.

ARM FAULT indicator - illuminated if a fault occurs in the wafer lift arm.

WAFER LIFT status field - as described in **Table 4-1**.

WAFER CLAMP status field - shows the UP or DOWN status of the wafer clamp.

Transfer status message field
Displays context-related message about the progress of the wafer transfer.

4.3.5 RECIPES page

The RECIPES page is used to create, edit and run recipes. See **Section 5.4** and **Section 5.7** for instructions. The page is opened by choosing **Recipes** from the Process Menu.

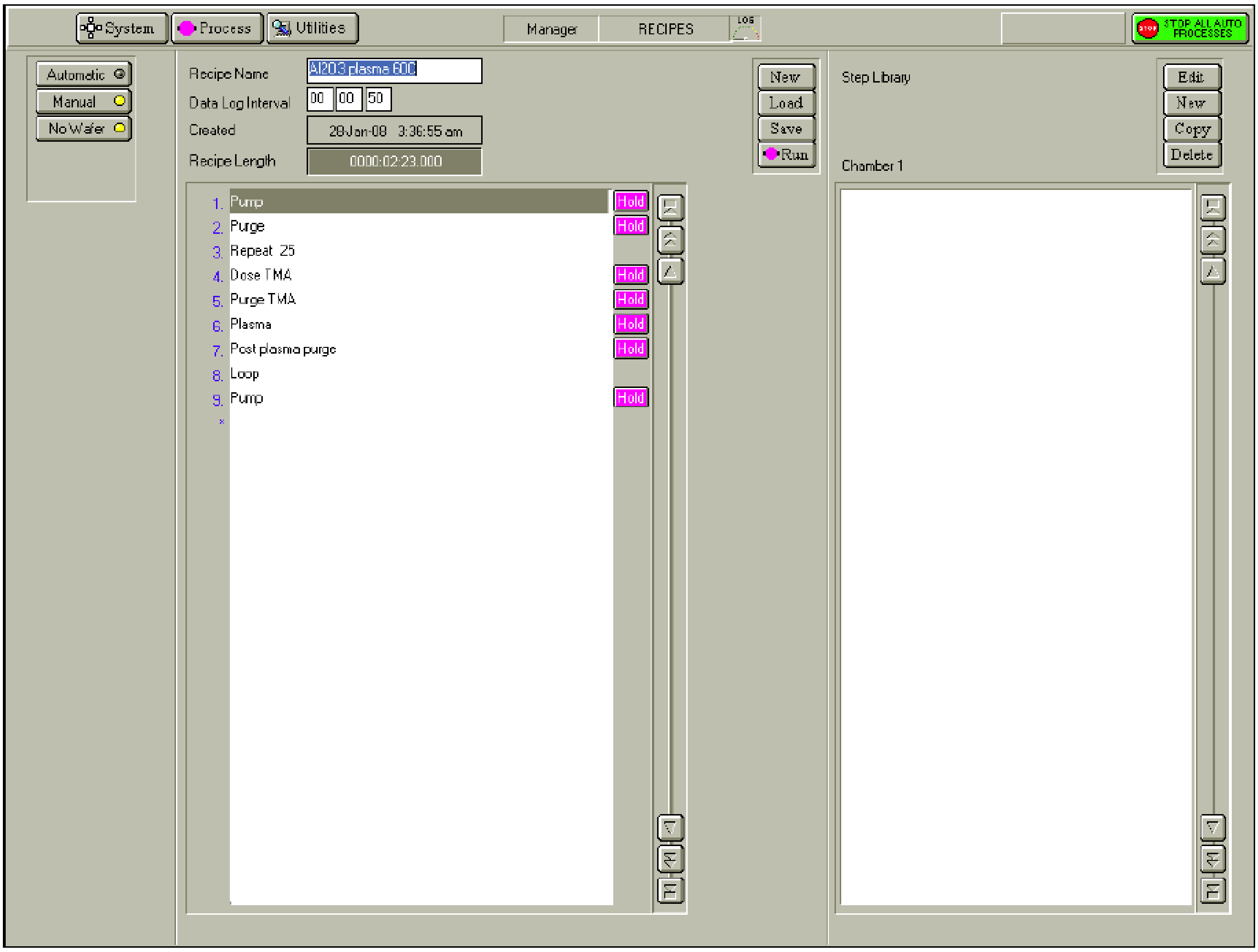


Figure 4-9 RECIPES page

Automatic button
Select to carry out an automatic process run using a recipe. The indicator on the button is coloured yellow when the button is selected.

The recipe is performed on a substrate. The substrate starts at the normal wafer entry point and is automatically transferred to each chamber, as the recipe requires. At the end of processing, the wafer is returned to its start point.

Manual button
Select to carry out a manual process run. The indicator on the button is coloured yellow when the button is selected.

Wafer/**No Wafer** button
The recipe is associated with a chamber. If the **Manual** button is selected, the options **wafer** and **no wafer** are given. No automatic wafer transfers are performed, therefore a wafer must be loaded using the ROBOT CONTROL page if required.

Recipe Name field
The name of the currently loaded recipe.

Data Log Interval field
Displays the data log interval, i.e. the time interval between the logging of system parameters.

Created field
The date and time of recipe creation.

Recipe Length field
The time taken to run the recipe. This is the sum of all the process times, excluding wafer transfer time, process stabilisation and pumping times.

Recipe step list
A scrollable, sequential list of the steps contained in the recipe.

New button
Select to create a new recipe.

Load button
Select to load an existing recipe.

Save button
Select to save the current recipe.

Run button
Select to run the current recipe.

MOVING PARTS
Selecting the **Run** button causes the robotic arm, the slit valve and other components to operate.

Caution 4.1

4.3.5.1 Step Library panel

Edit button
Select to edit the selected (highlighted) recipe step.

New button
Select to create a new recipe step.

Copy button
Select to copy the selected recipe. You are prompted for a new step name.

Delete button
Select to delete the selected (highlighted) recipe.

Step Library list
Displays the recipe steps available in a scrollable list.

4.3.6 Production Mode page

The Production Mode page is automatically displayed when a user logs on in *PRODUCTION* mode. For instructions on using the production mode facility, refer to **Section 5.3**.

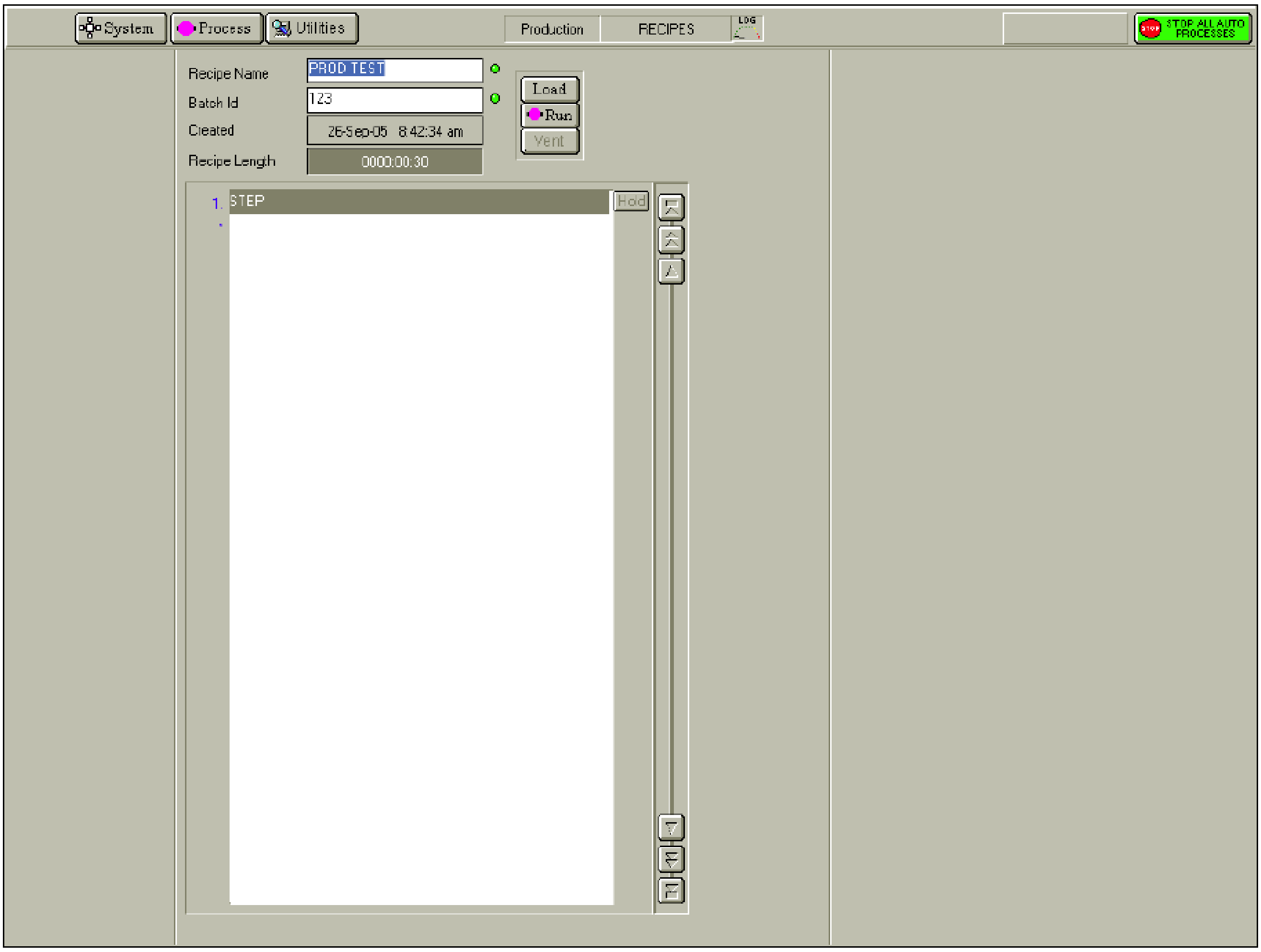


Figure 4-10 Typical Production Mode page

Recipe Name field
The name of the currently loaded recipe. The indicator to the right of this field is coloured red until a recipe is loaded. The colour of the indicator then changes to green.

Batch Id field
Enter the batch identity of the currently loaded wafer. The indicator to the right of this field is coloured red until a batch identity is entered. The colour of the indicator then changes to green.

Created field
The date and time of recipe creation.

Recipe Length field
The time taken to run the recipe.

Load button
Select to load an existing recipe.

Run button
Click to run the current recipe. This button becomes active only when a recipe has been loaded and a batch identity has been entered.

Caution 4.2

MOVING PARTS
Selecting the **Run** button causes the robotic arm, the slit valve and other components to operate.

Vent button
Click to vent the loadlock. This button becomes active only when a run process is complete.

Recipe step list
A scrollable sequential list of steps contained in the recipe.

4.3.7 Process Control page

This page is used to set the process parameters for a manual run, or for a process step to be used in an automatic run recipe. The page is opened by choosing **Chamber** from the Process Menu.

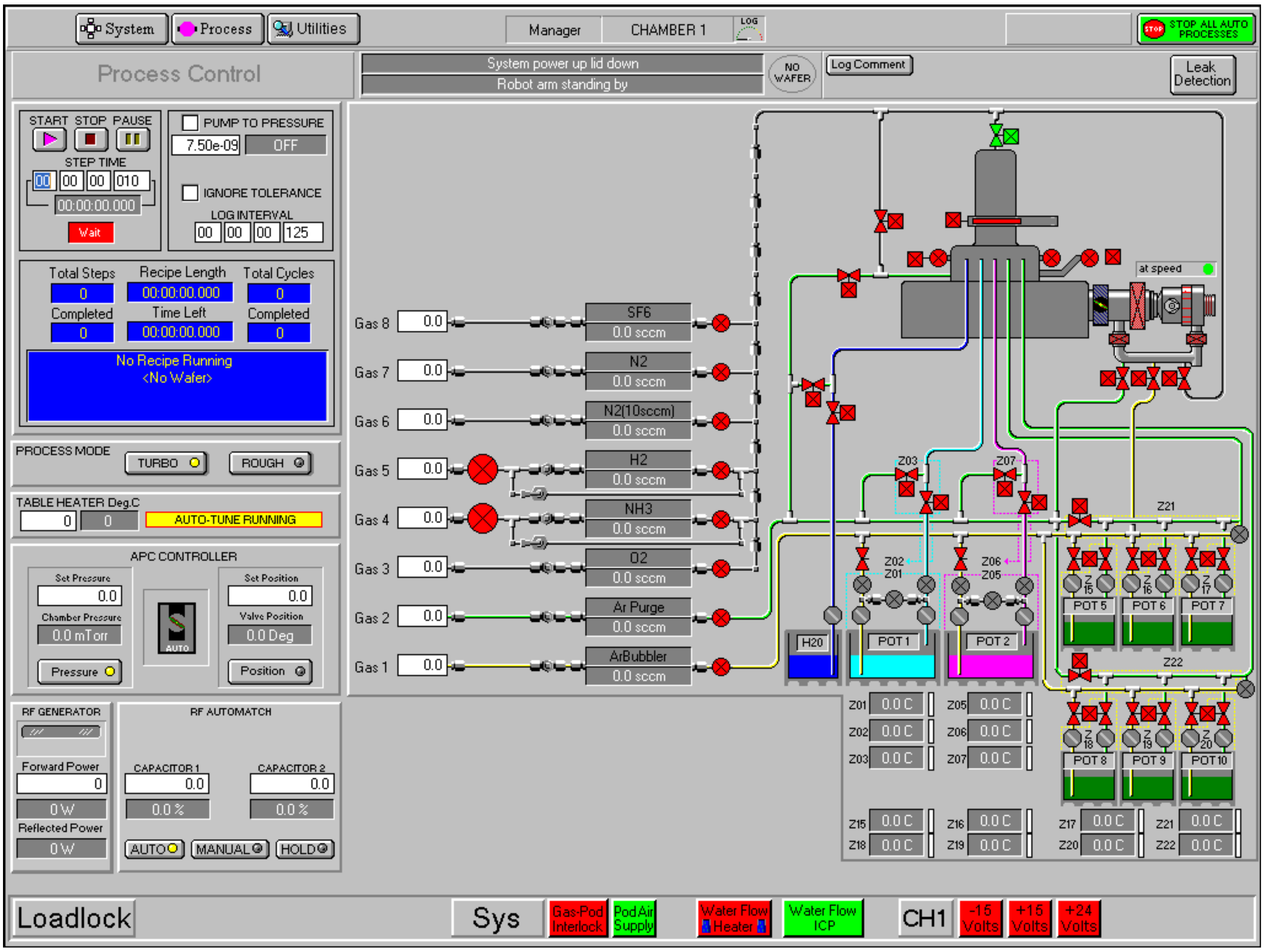


Figure 4-11 Process Control page

4.3.7.1 Process Control page - general message fields

System and process chamber message fields
Display context related messages about the status of the system and the process chamber.

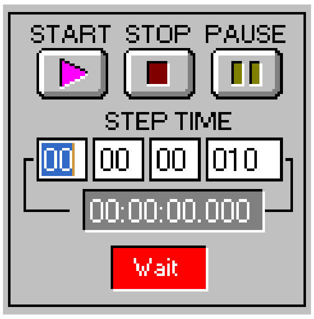
Transfer status/Log Comment message field
Displays context related messages about wafer transfer status. This field is also used to enter comments about the current process run, which can be viewed on the log viewer page.

Wafer status field
Displays context related messages about the wafer currently in the automatic loadlock or process chamber.

Log Comment button
Allows you to enter comments about the current process in the **Transfer status/Log Comment** message field. While entering a comment, the title of the button changes to **OK** to allow the comment to be accepted.

Leak Detection button
Opens the Leak Detection page. See **Section 4.3.8**.

4.3.7.2 Process Control page - start/stop panel



START button
Click to start a manual process run using the parameters set on this page.

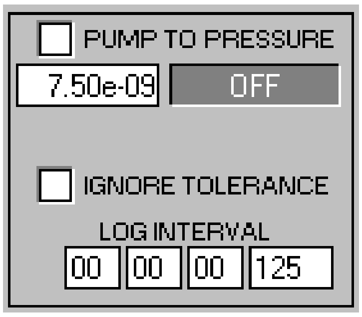
STOP button
Click to stop the current process step.

PAUSE button
Click to pause the current process.

Jump button
Click to jump to the next process step. This button appears only when a recipe is loaded.

Step Time fields
The left, second-left and third-left field are used to enter the required step time in hours:minutes:seconds. While a process is running, the right field displays the time remaining to the end of the step.

4.3.7.3 Process Control page - pump to pressure/ignore tolerance panel



PUMP TO PRESSURE checkbox
Select to create a pumping step. A tick indicates that the box is selected. The system will pump down until the demanded pressure is reached. The step will remain active until this condition is met. Both RF generators are automatically switched off during the step. Except for base pressure, all setpoints are automatically set to zero.

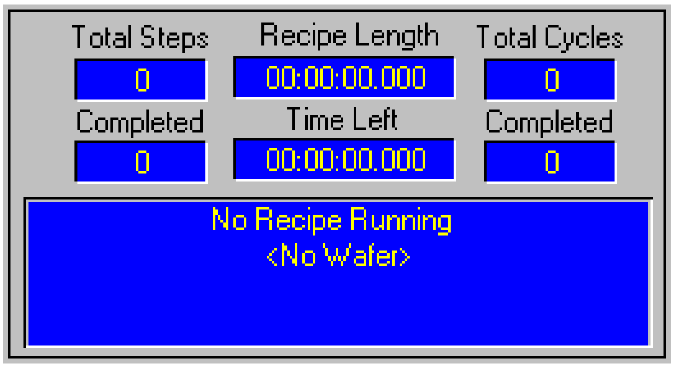
Pressure fields
The left field is used to enter the required process chamber pressure for the step. The measured pressure is displayed in the right field.

IGNORE TOLERANCE checkbox
Select to disable tolerance checking during the current step. A tick indicates that the checkbox is selected.

NOTE: RF switches on immediately, without waiting for flows and pressure to be established.

LOG INTERVAL fields
The left, second-left and third-left field are used to enter the interval required between data logging events in hours:minutes:seconds.

4.3.7.4 Process Control page - recipe status panel



This panel indicates the status of the recipe parameters shown in the panel.

Recipe message field
Displays information about the current recipe, such as the step, the identity of the loaded wafer, etc.

HOLD button
Used in multi-step recipes to keep the plasma on between steps. The button is displayed on the Process Control page only when a recipe is loaded. The hold facility can be selected when creating or editing a recipe by using the RECIPES page.

Running a recipe without the HOLD button selected
When running the recipe, at the end of the process time for a process step without the **HOLD** button selected, all process setpoints (chamber pressure, helium backing pressure, table temperature, RF power, ICP power, gas flow, etc) are set to zero (OFF) before starting the next process step. This means that the plasma would be extinguished between two plasma process steps if the **HOLD** button was not selected.

Running a recipe without the HOLD button selected
When running the recipe, at the end of the process time for a process step with the

HOLD button selected, all process setpoints (chamber pressure, helium backing pressure, table temperature, RF power, ICP power, gas flow, etc) are set to the values of the next process step to run. This means that the plasma remains ON between two plasma process steps if the **HOLD** button is selected.

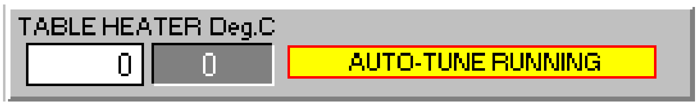
4.3.7.5 Process Control page - PROCESS MODE panel

The buttons on this panel allow you to change between processing via the turbo pump, or processing using the backing pump.

TURBO button
Select this button to use the turbo pump. The indicator in the button illuminates yellow when the button is selected. Turbo selection is most likely for PEALD processes due to the relatively low pressures used.

ROUGH button
Select this button to use the backing pump. The indicator in the button illuminates yellow when the button is selected. Rough selection is most likely for thermal ALD processes.

4.3.7.6 Process Control page - TABLE HEATER panel

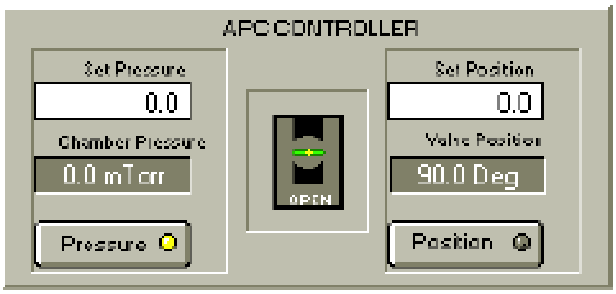


Enter the required table temperature in the left field.

The current table temperature is displayed in the right field.

The message AUTO TUNE RUNNING indicates that the table heater is under control of the table heater PID controller. Other messages can be displayed during system operation.

4.3.7.7 Process Control page - APC CONTROLLER panel



Select the pressure or position option, then enter the required chamber pressure or APC valve position.

Set Pressure field
Enter the required chamber pressure.

Chamber Pressure field
Displays the current chamber pressure.

Pressure button
Select to set the chamber pressure. The indicator in the button illuminates yellow when the button is selected.

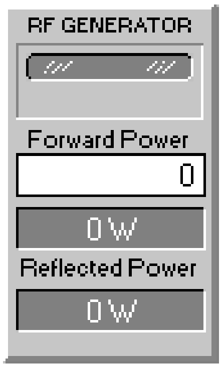
Set Position field
Enter the required APC valve position.

Valve Position field
Displays the current position of the APC valve.

Position button
Select to set the APC valve position. The indicator in the button illuminates yellow when the button is selected.

The valve status icon in the centre of the panel shows the current valve status: OPEN or CLOSED.

4.3.7.8 Process Control page - RF GENERATOR panel



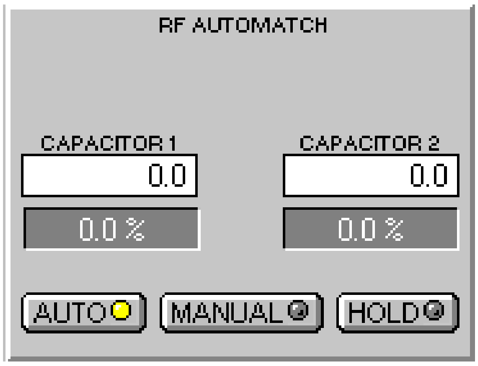
RF POWER indicator
The upper field displays the ON/OFF status of the RF generator. The indicator field is coloured purple when RF power is ON and grey when RF power is OFF.

Forward Power entry field
Enter the required forward power value in Watts.

Forward Power display field
Shows the present forward power value.

Reflected Power field
Displays the present reflected power value.

4.3.7.9 Process Control page - RF AUTOMATCH panel



CAPACITOR 1 fields
The upper field is used to enter the required position for variable AMU capacitor 1. The position can be set between 0% (minimum capacitance), and 100% (maximum capacitance).

The lower field displays the read back of the capacitor position.

CAPACITOR 2 fields
The upper field is used to enter the required position for variable AMU capacitor 2. The position can be set between 0% (minimum capacitance), and 100% (maximum capacitance).

The lower field displays the read back of the capacitor position.

AUTO button
Select to enable the AMU to tune automatically when the RF generator is switched ON. When the RF generator is switched OFF, the capacitors return to the park position.

MANUAL button
Select to enable the AMU to move the capacitors to the values defined in the CAPACITOR 1 and CAPACITOR 2 fields. The capacitors will remain in these positions.

HOLD button
Select to enable the AMU to tune automatically when the RF generator is switched ON. When the RF generator is switched OFF, the capacitors remain at their last position.

4.3.7.10 Process gas mimic

This panel displays a mimic of the gas lines installed in the gas pod as shown in **Figure 4-12**.

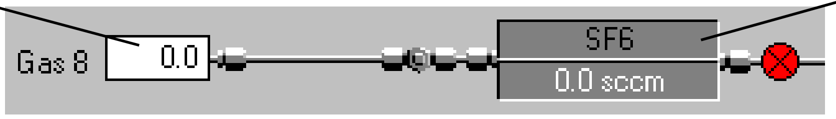


Figure 4-12 Example of gas line in gas mimic

For each gas line, the required gas flow (in sccm), is entered in the respective setting field.

Click on the gas name to edit the associated gas factors. The Gas Factor Editor dialogue opens.

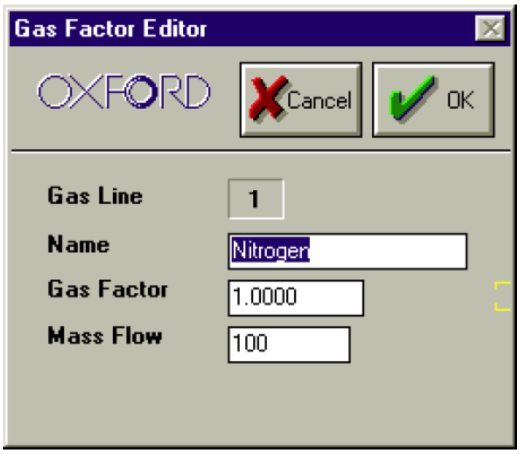


Figure 4-13 Process Control page, Gas Factor Editor dialogue

It is recommended that the **Gas Factor** is kept at the value 1, and the full scale of the MFC for the gas used is entered in the **Mass Flow** field.

For example, if Argon is used with a 100 sccm N_2 MFC. Put gas factor 1 and Mass Flow 141 sccm.

H2O panel
Enter the value 1 to open the H_2O valve.

Gas line 1
Enter the value 1 in the relevant field to open the **Purge**, **P1**, **P2**, **P3**, **P4** or **Exhaust** valves. This is the Argon bubbler line, which allows Argon to be bubbled through liquid precursors so that precursors with low vapour pressure can be transported into the process chamber in sufficient quantities for the process to run efficiently.

4.3.7.11 Vacuum system mimic

Figure 4-14 shows the vacuum section of the Process Control page with a code annotated on the valves. Refer to Table 4-2 for a key to these annotations.

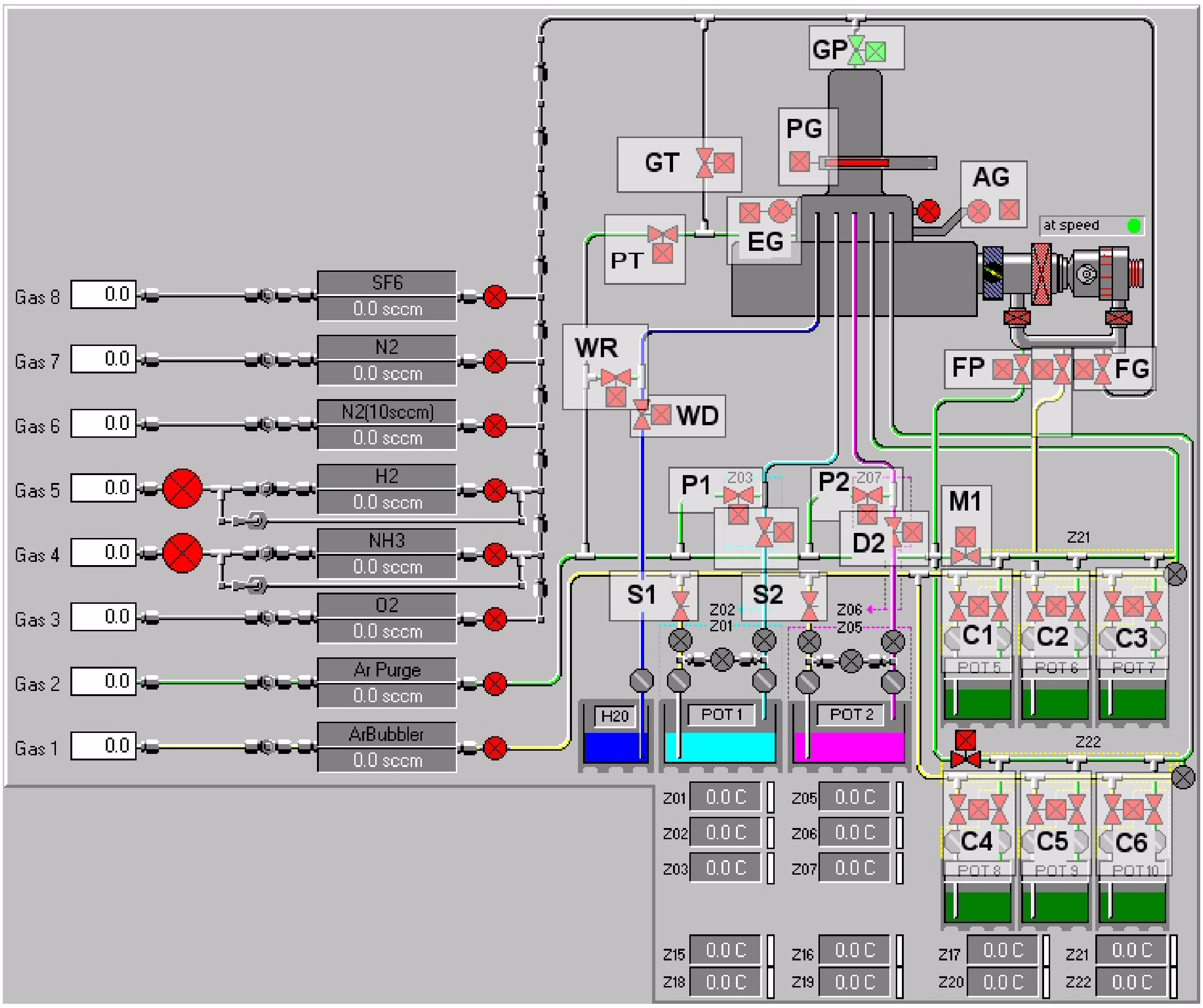


Figure 4-14 Part of the Process Control page with valve annotations

Table 4-2 Key to valve annotations on the Process Control page

Code	Description	Notes
GP	main **G**as to **P**lasma source	Normally open valve.
GT	main **G**as as **T**hermal Precursor	Normally open valve on thermal-only systems, or when not on the same flow circuit as valve GP.
PG	**P**lasma source isolation **G**ate valve	
EG	**E**llipsometry **G**ate valve	Only present if an ellipsometer is fitted.
AG	**A**nalytical port **G**ate valve	
WP	**W**ater line **P**urge	
WD	**W**ater **D**ose	
PT	**P**urge **T**hermal	
P1	**P**urge precursor line **1**	
P2	**P**urge precursor line **2**	
P3	**P**urge precursor line **3**	
P4	**P**urge precursor line **4**	
D1	**D**ose precursor **1**	
D2	**D**ose precursor **2**	
D3	**D**ose precursor **3**	
D4	**D**ose precursor **4**	
S1	**S**witch bubbling gas to line **1** - controlled by D1.	
S2	**S**witch bubbling gas to line **2** - controlled by D1.	
S3	**S**witch bubbling gas to line **3** - controlled by D1.	
S4	**S**witch bubbling gas to line **4** - controlled by D1.	
FP	divert into **F**oreline for **P**urge argon	
FB	divert into **F**oreline for **B**ubbler argon	
FG	divert into **F**oreline for main **G**as	
M1	**M**anifold purge valve **1**	
M2	**M**anifold purge valve **2**	
C1-C6	**C**abinet dose and switch valve pairs **1** to **6**	

If you are uncertain of a valve´s identity, place the cursor on the valve on the Process Control page, and a tool tip is displayed (see **Figure 4-15**).

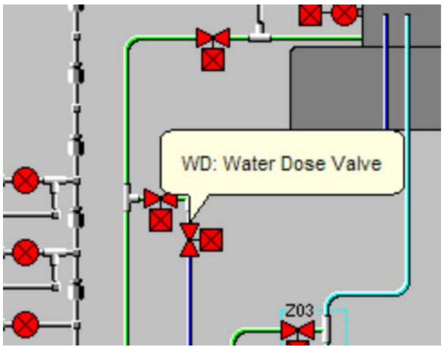


Figure 4-15 A valve showing the tool tip

4.3.8 Leak Detection page

The Leak Detection page is opened by clicking the **Leak Detection** button on the Process Control page. It allows automatic or manual leak detection runs.

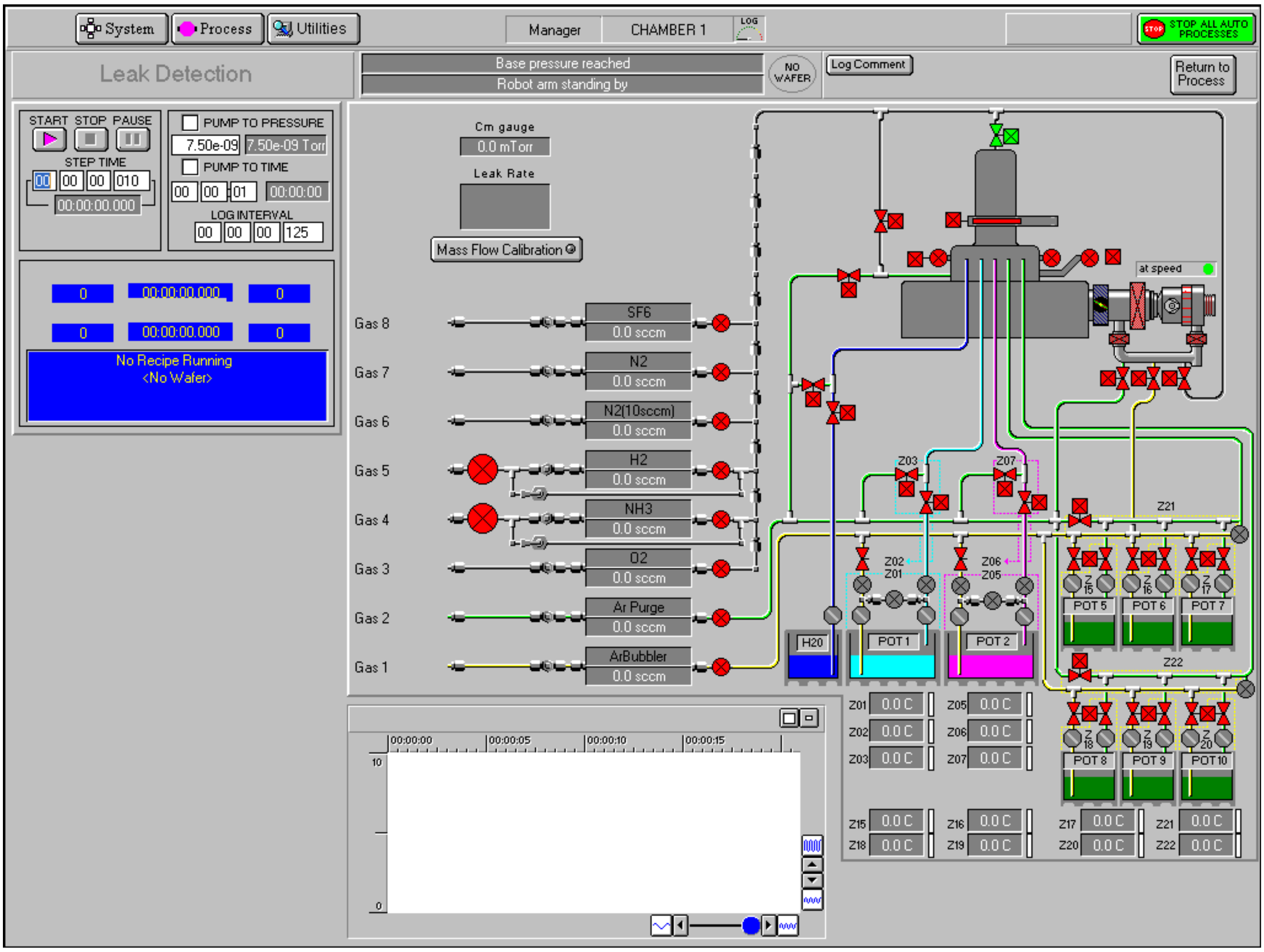


Figure 4-16 Leak Detection page

The Leak Detection page for a process chamber can be used to check the rate-of-pressure rise in a sealed chamber. The chamber is first pumped (for a fixed time or to a given pressure). The chamber then seals and the pressure rise rate is calculated. A graph of the chamber pressure against time is plotted. The test stops when the test time elapses or when the pressure gauge reaches full scale. The chamber is returned to pumping at the end of the test.

The rate-of-pressure rise depends on:

a) The leak rate from atmosphere. Leaks are not improved by more pumping.

b) The outgassing rate from all surfaces.

c) The virtual leak rate from parts of the system furthest from the vacuum pump, especially gas feed pipes.

Outgassing and virtual leaks are reduced by more pumping. Outgassing is increased if the temperature of the whole system is raised.

4.3.8.1 Leak Detection page - general message fields

The general message fields are similar to those of the Process Control page. See **Section 4.3.7.1**. The main difference is that the **Return to Process** button replaces the **Leak Detection** button.

Return to Process button
Select to return to the CHAMBER 1 Process Control page.

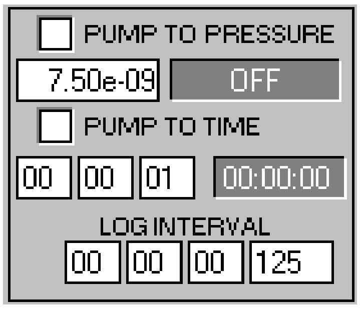
4.3.8.2 Leak Detection page - start/stop panel

This panel is similar to that of the Process Control page (see **Section 4.3.7.2**), except that the **START**, **STOP** and **PAUSE** buttons are used to control leak detection tests.

4.3.8.3 Leak Detection page - recipe status panel

This panel is similar to that of the Process Control page (see **Section 4.3.7.4**).

4.3.8.4 Leak Detection page - PUMP TO PRESSURE panel



PUMP TO PRESSURE checkbox
Select to create a pumping step. A tick indicates that the checkbox is selected. The system will pump down until the demanded pressure is reached. The step will remain active until this condition is met. Both RF generators are automatically switched off during the step. Except for base pressure, all setpoints are automatically set to zero.

Pressure fields
The left field is used to enter the process chamber target pressure. The measured pressure is displayed in the right field.

PUMP TO TIME checkbox
Select to give the initial pumpdown a fixed duration.

NOTE: If both **Pump to Pressure** and **Pump to Time** are selected, then **Pump to Time** takes precedence.

Step Time fields
Enter the required step time (in hours:minutes:seconds) for the duration of the pressure-rise test. While a process is running, the right field displays the time remaining to the end of the step.

LOG INTERVAL fields
Enter the sampling rate for the datalogging log file (in hours:minutes:seconds). If set to zero, no data log will be made.

Gas pod and process chamber mimic
Displays a mimic of the gas pod, process chamber and vacuum system. The pressures read by the chamber Penning and CM gauges are also displayed.

Mass Flow Calibration button
Select to calibrate the MFCs. Calibration is done by clicking on each MFC mimic, then entering the Gas Name, Gas Factor and Mass Flow.

4.3.9 Mass Flow Calibration page

> **DO NOT MIX GASES**
> Some gas mixtures may produce particles in the chamber or gas lines. Check only ONE gas at a time. Allow at least 15 minutes of pumping before and after any chamber fill using Silane or $SiCl_4$.
>
> Caution 4.3

This page is similar to the Leak Detection page (see **Section 4.3.8**), with the addition of setpoint boxes for the mass flow controllers.

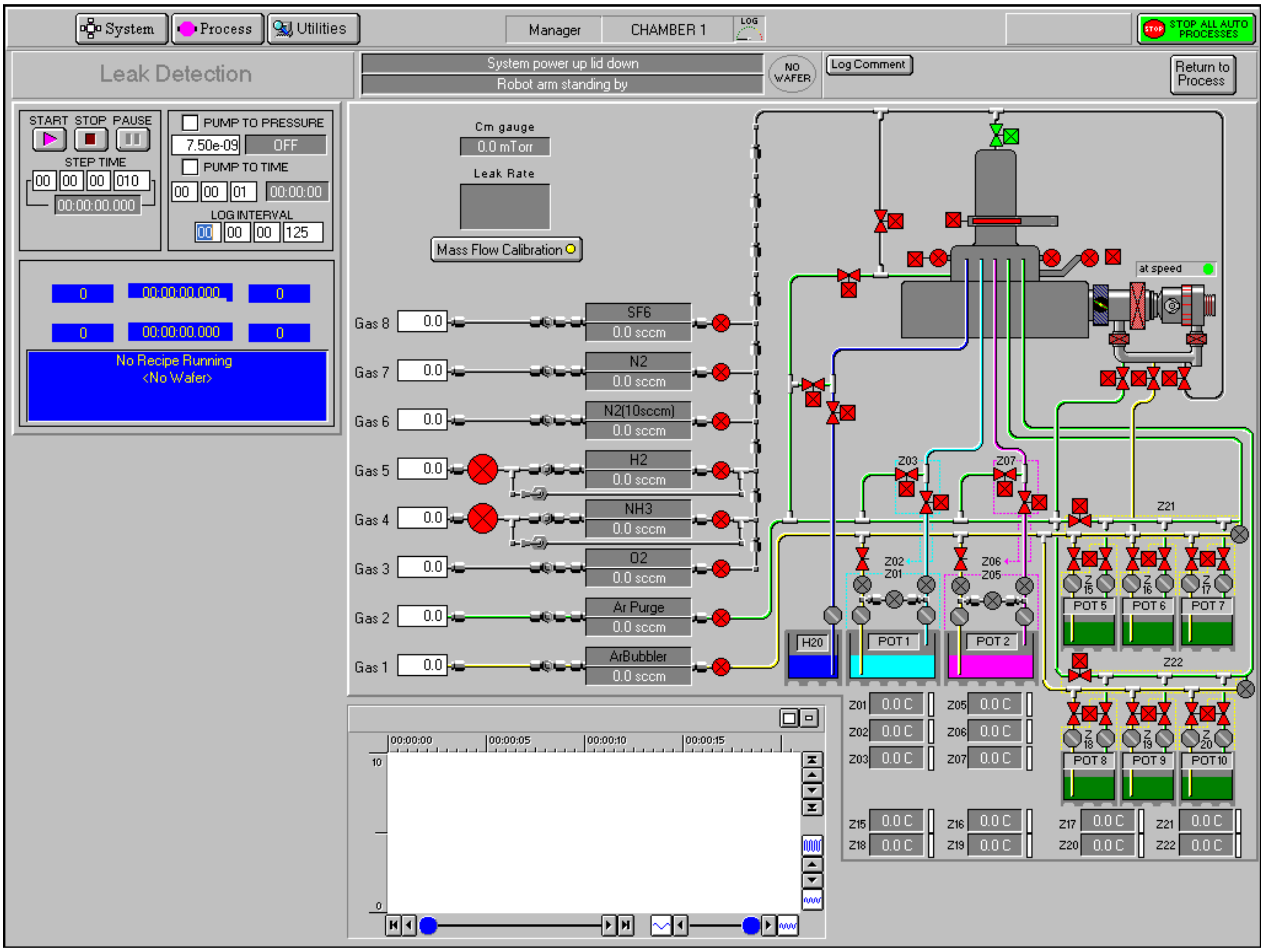


Figure 4-17 MFC Calibration page

Only the **PUMP TO TIME** feature should be selected, because the selected gases will turn on during the initial pumpdown period. If **PUMP TO PRESSURE** is selected with a gas flowing, it is unlikely to reach the target pressure.

When the initial pumping and MFC stabilisation period ends, the chamber seals and fills slowly. The rate-of-pressure rise is calculated and displayed.

NOTE: Chamber pressure depends on the quantity of gas added and the chamber temperature. If a high-power plasma has been run recently, the chamber will be hotter and the rate-of-pressure rise will be greater for the same gas flow.

4.3.10 SERVICE MODE pages

To transfer wafers between chambers in SERVICE mode, click on the wafer mimic in the loadlock or process chamber. The following page opens.

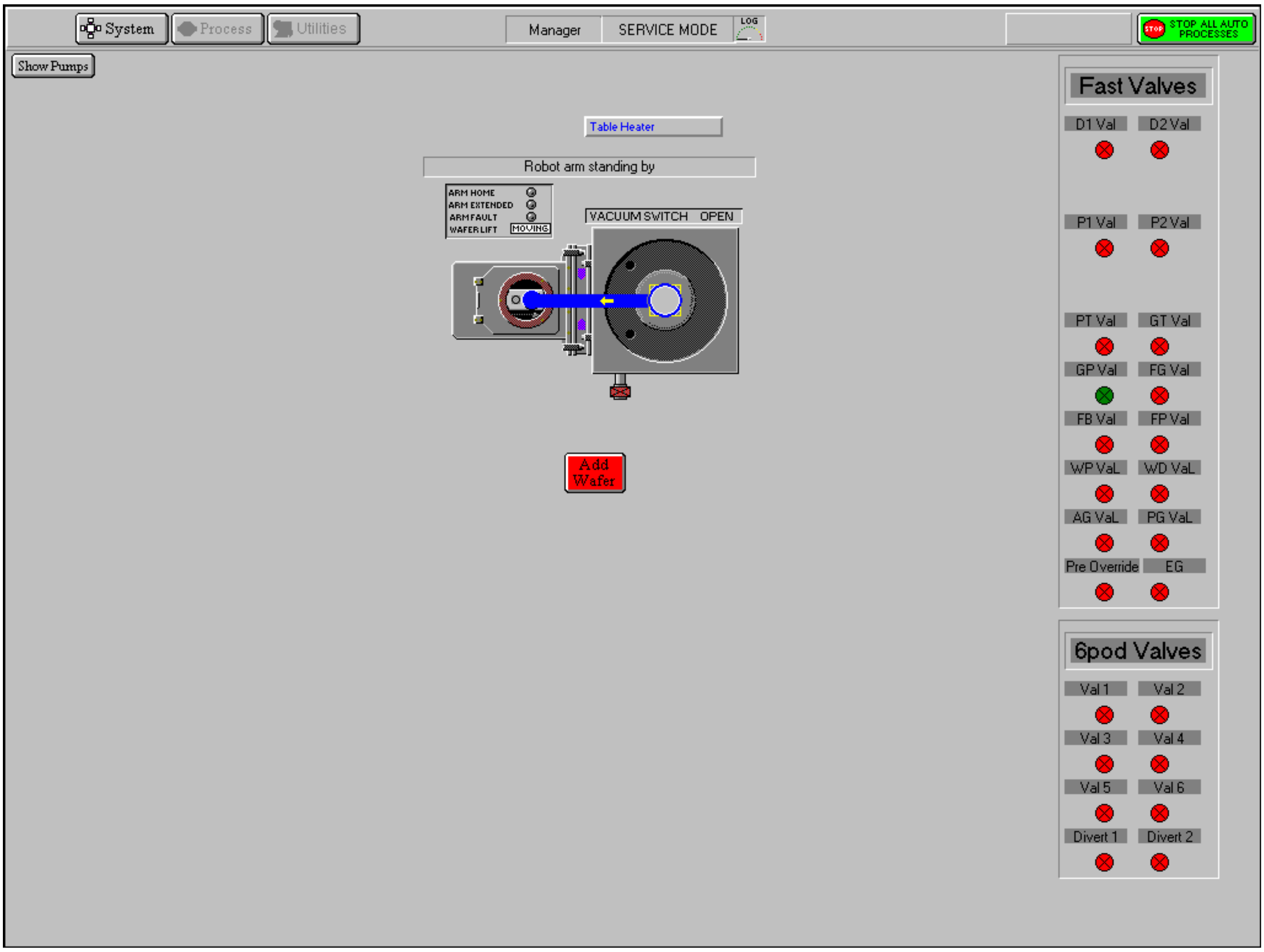


Figure 4-18 Wafer transfer in SERVICE mode

Show Pumps button
Opens the PUMP CONTROL page.

Message field
Displays status messages about the wafer transfer.

Add/Kill Wafer button
The **Add Wafer** button is used to inform the system that a wafer is present. It is used if the machine is powered-up with a wafer in the loadlock. The legend on this button changes to **Kill Wafer** when a wafer is present, enabling the selected wafer to be removed from system memory.

Wafer transfer path
Displayed when the wafer mimic has been clicked. An arrow indicates the direction of the possible transfer. Click the destination to initiate the transfer.

TABLE HEATER button
Initiates auto-tuning of the heating zones.

4.3.11 System Presets page

The System Presets page is accessed by choosing **Configure** from the Utility Menu. It is used to view, set and save system presets.

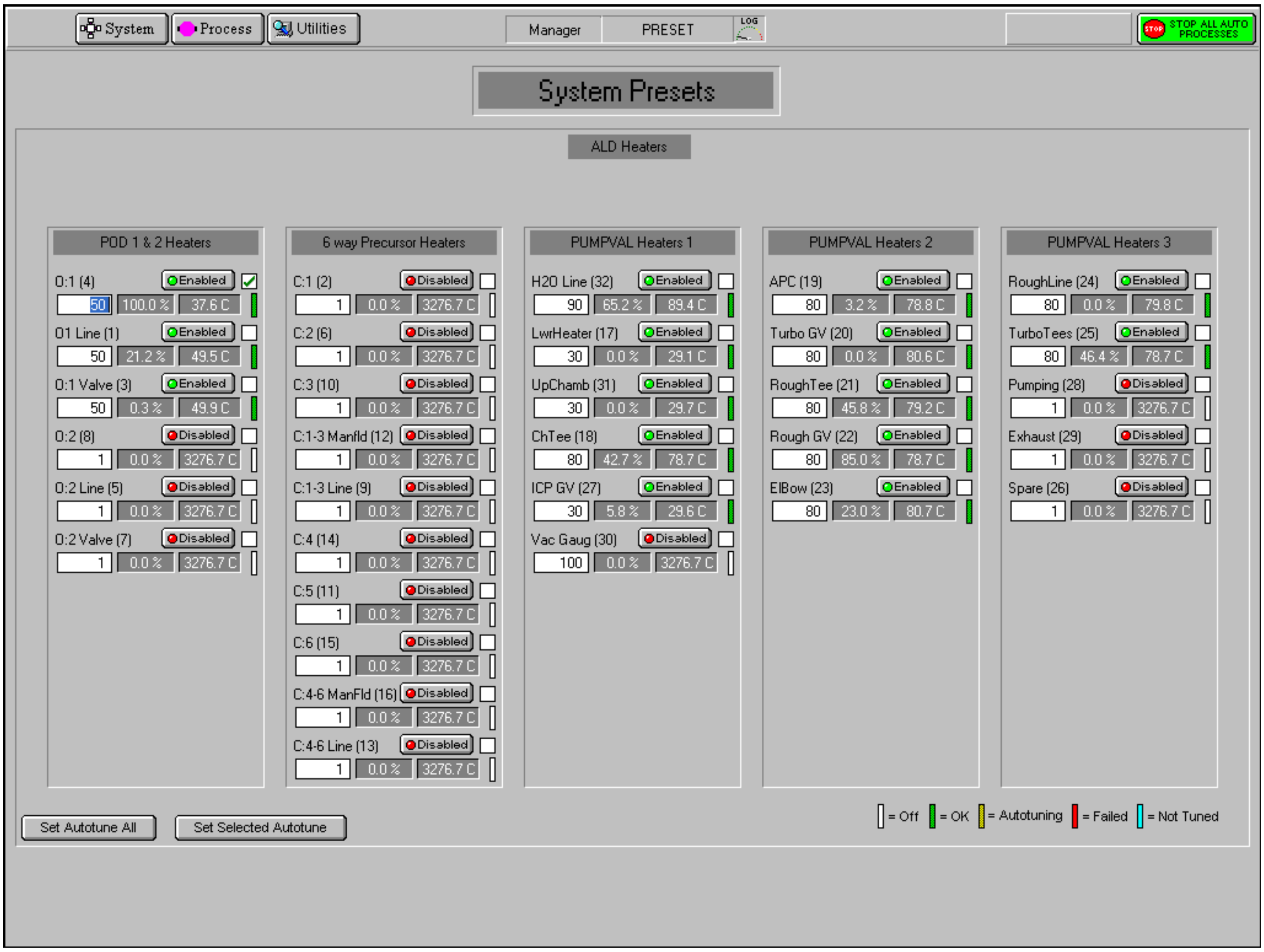


Figure 4-19 System Presets page

The System Presets page presents an array of heating zones for which preset values can be set:

The **Enabled/Disabled** button in each zone enables or disables that heater circuit. The indicator in the button is coloured green when the heater is enabled, and is coloured red when the heater is disabled.

The checkbox to the right of the **Enabled/Disabled** button enables that zone for auto-tuning. The checkbox is marked with a green tick when auto-tuning of the zone is enabled.

The left field in each zone allows you to enter a temperature value for the setpoint.

The centre field shows level of operation of the heater zone, expressed as a percentage. For example 50% means that the heater is operating at half capacity.

The right field shows the current value of the setpoint. Note that the entered setpoint must be 50 degrees higher than the actual temperature.

The indicator beside the right field shows the status of the autotune process. The status indications are explained in the bottom right corner of the page.

All zones can be autotuned simultaneously, or each zone can be autotuned individually.

Set Autotune All button
Click to initiate the autotune of all zones. When the temperature has reached the selected setpoint, wait 30 minutes before continuing.

Set Selected Autotune button
Click to initiate the autotune of a selected zone. When the temperature has reached the selected setpoint, wait 30 minutes before continuing.

4.3.12 TOLERANCES page

The TOLERANCE page is accessed from the Utilities menu. It is used to view, set and load defaults, and to save process tolerances.

> **PROCESS HAZARD**
> Changing parameter values on the TOLERANCE page affects system performance and possibly introduces hazards to personnel. This page must only be edited by trained personnel who are aware of the risks.
>
> Caution 4.4

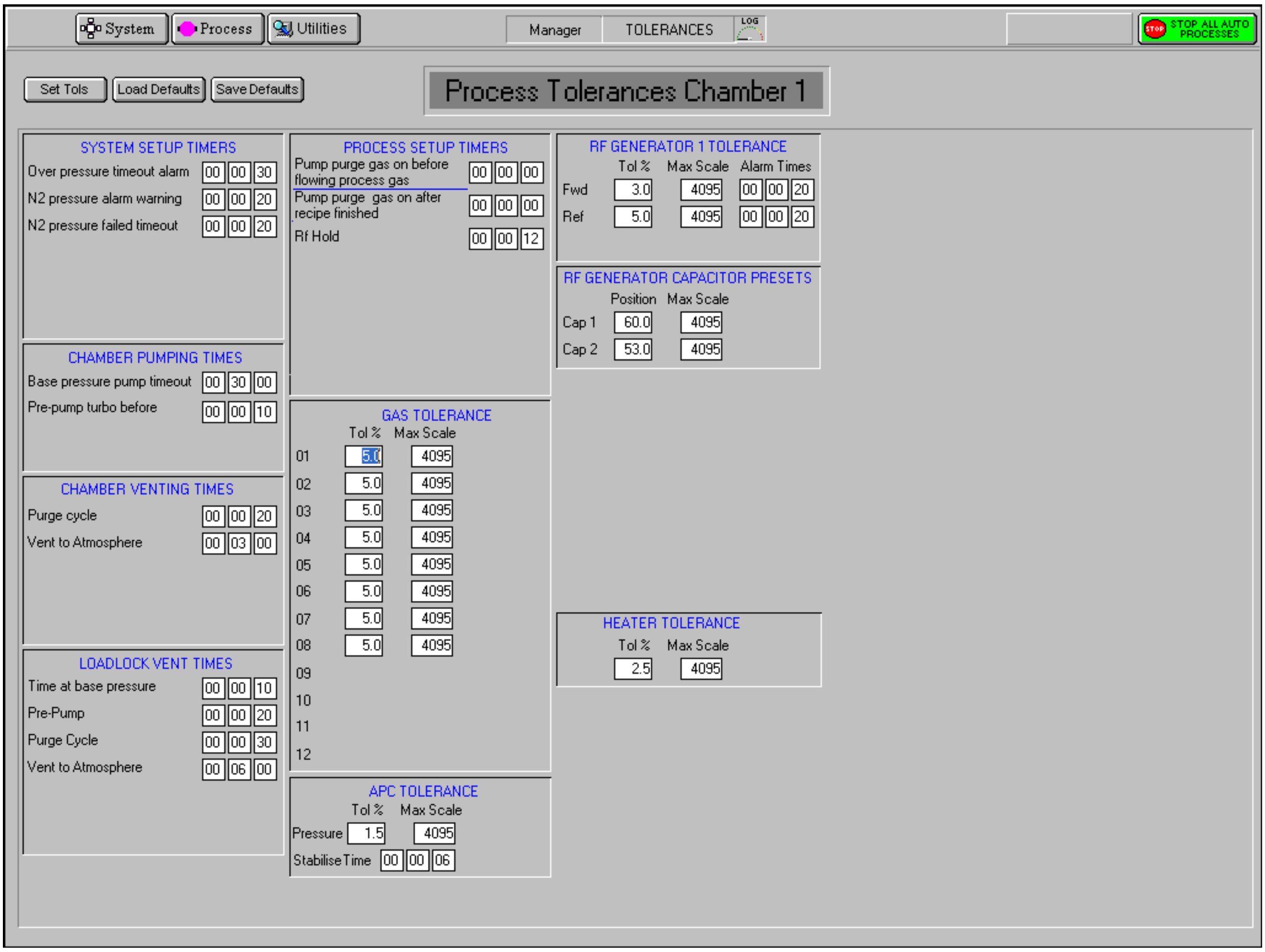


Figure 4-20 TOLERANCES page

4.3.12.1 General field information

In all the **Max Scale** data fields, the displayed value is proportional to a voltage, i.e. 4095 represents 10 V, 2048 represents 5 V, etc.

In the timer panels, each item has three fields:

the left field is used to set hours;

the centre field is used to set minutes;

the right field is used to set seconds.

4.3.12.2 Buttons

Set Tols button
Click to send the current process tolerances to the PLC.

Load Defaults button
Click to load the default tolerance values.

Save Defaults button
Click to save the default tolerance values.

4.3.12.3 SYSTEM SETUP TIMERS panel

Over pressure timeout alarm fields
The duration before an overpressure timeout alarm is triggered via a System Alert.

N2 pressure alarm warning fields
The duration before an N_2 pressure warning is triggered via a System Alert.

N2 pressure failed timeout fields
The duration before an N_2 pressure failed timeout is triggered via a System Alert.

4.3.12.4 CHAMBER PUMPING TIMES panel

Base pressure pump timeout fields
The maximum duration that the process chamber is pumped without reaching customer-defined base pressure before a timeout condition is reached.

Pre-pump turbo before fields
The delay between turbo backing valve and roughing valve operation in evacuation and venting.

4.3.12.5 CHAMBER VENTING TIMES panel

Purge cycle fields
The maximum duration that the process chamber is purged before venting is continued.

Vent to Atmosphere fields
The maximum duration that the process chamber is vented before a timeout condition is reached.

4.3.12.6 LOADLOCK VENT TIMES panel

Time at base pressure fields
The maximum duration that the load lock is at base pressure before a timeout condition is reached.

Pre-Pump fields
The maximum duration before the load lock purge cycle is started.

Purge Cycle fields
The maximum duration that the load lock is purged before venting is started.

Vent to Atmosphere fields
The maximum duration that the load lock is vented before a timeout condition is reached.

4.3.12.7 PROCESS SETUP TIMERS panel

Pump purge gas on before flowing process gas fields
The duration after starting to pump the purge gas before flowing process gas. This field must be set to one minute (00:01:00) before running a process using a precursor.

Pump purge gas on after recipe finished fields
The duration after a recipe has finished before flowing pump purge gas.

RF Hold fields
The duration after a recipe has finished before the RF generator is turned off.

4.3.12.8 GAS TOLERANCE panel

01 to 12 fields

> **Tol%** - percentage of full scale where a difference of more than this value is considered to be an alarm condition.
>
> **Max Scale** – the maximum scale value (sccm). **Do not change.**

4.3.12.9 APC TOLERANCE panel

Pressure fields

> **Tol%** – the percentage difference between the process chamber pressure setpoint and readback before an alarm condition is triggered.
>
> **Max Scale** – the maximum scale value (Torr).

Stabilise Time fields
The maximum duration before the process chamber pressure has stabilised.

4.3.12.10 RF GENERATOR 1 TOLERANCE panel

Fwd fields

Tol% - the percentage difference between the setpoint and readback before an alarm condition is triggered.

Max Scale – the maximum scale value (Watts).

Alarm Times – the duration after an alarm condition is triggered before a Forward Power out-of-tolerance System Alert is raised.

Ref fields

Tol% - the percentage difference between the setpoint and readback before an alarm condition is triggered.

Max Scale – the maximum scale value (Watts).

Alarm Times – the duration after an alarm condition is triggered before a Reflected Power out-of-tolerance System Alert is raised.

4.3.12.11 RF GENERATOR CAPACITOR PRESETS panel

Cap 1 fields

Position – the default position of the capacitor 1 shaft (% of full stroke).
Max Scale – the maximum scale value (reference to voltage). **Do not change.**

Cap 2 fields

Position – the default position of the capacitor 2 shaft (% of full stroke).
Max Scale – the maximum scale value (reference to voltage). **Do not change**.

4.3.12.12 HEATER TOLERANCE panel

Tol%
The percentage difference between the table temperature setpoint and readback before an alarm condition is triggered.

Max Scale
The maximum scale value (scaled degrees C).

4.3.13 SYSTEM LOG pages

All processes are automatically data-logged. The interval between logging events is set in the RECIPE page. The process datalog facility allows you to view process data runs and associated comments. The facility comprises four pages:

- SYSTEM LOG page allows you to view and filter the process data.
- SELECT LOG page allows you to select the process data to view.
- Run Log page lists the selected process data, for all runs except Leak detection runs and MFC calibration runs, with respect to time.
- Leak Detection and MFC Calibration log page displays the leak detection runs and MFC calibration runs in text and graphical formats.

4.3.13.1 SYSTEM LOG page

The SYSTEM LOG page allows logged system events to be viewed. A filter facility allows the viewed events to be displayed by event type and time of occurrence.

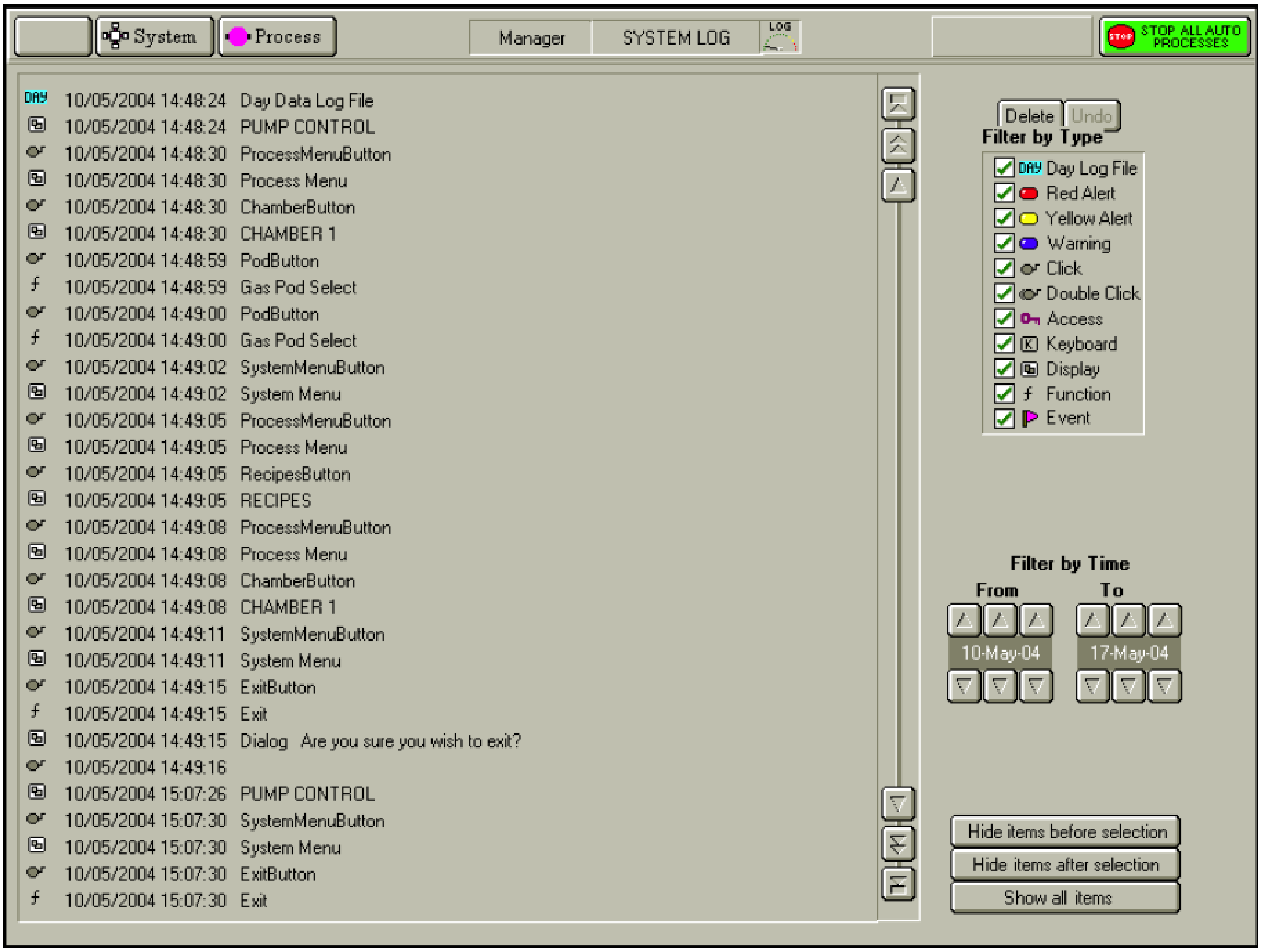


Figure 4-21 SYSTEM LOG page

Event list
A scrollable list of events in date/time order. Each event is categorised by an icon (as shown in the **Filter by Type** panel), and an event description is given.

Use the scrollbar and associated buttons to move the list up or down by a single event, a page of events, or to go to the end of the list.

Delete button
Removes the selected event(s) from the **Event** list.

Undo button
Active only after a **Delete** action. Restores the last deleted event.

Filter by Type panel
A list of event types with associated icons and checkboxes. Use this panel to select the events to display in the **Event** list. In the checkboxes:

a tick indicates that the associated event type will be displayed;
a cross indicates that the associated event type will not be displayed.

Filter by time controls
Use these controls to display only the events that occur in the time range set in the **From** and **To** fields (in hours, minutes and seconds).

Hide events before selection button
Displays all events after and including the highlighted event.

Hide events after selection button
Displays all events before and including the highlighted event.

Show all items button
Displays all previously hidden events.

4.3.13.2 SELECT LOG page

The SELECT LOG page is opened by choosing **Log View** from the Process Menu.

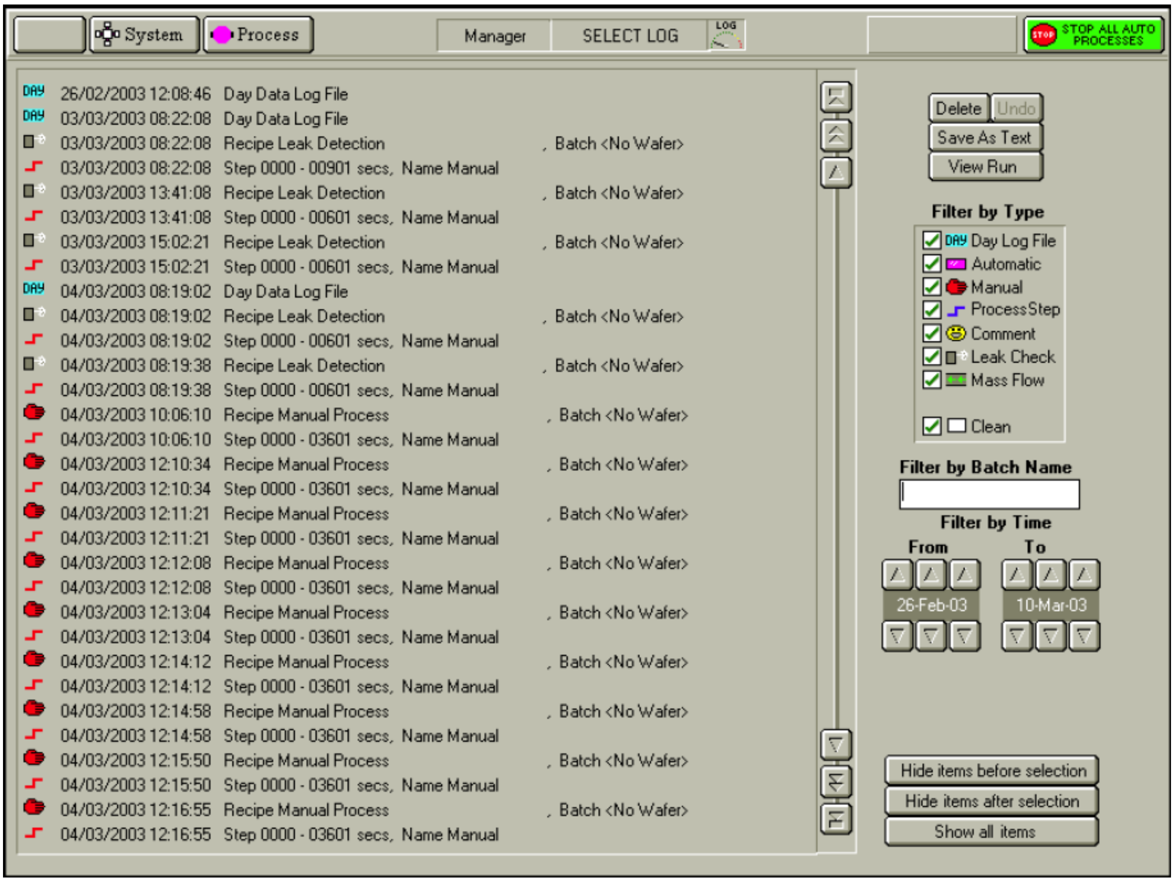


Figure 4-22 SELECT LOG page

The page comprises a list of logged events, which can be filtered by type, batch name and time. When the required events have been selected, they can be viewed on the SYSTEM LOG page.

List of logged events
Displays a list of logged events in a date/time sequence. Each event is identified by an icon, date, time, title, duration, name and comments (if present). An event is selected (highlighted) by clicking on it.

Delete button
Deletes the selected event.

Undo button
Undoes the last action.

Save As Text button
Saves the selected event as a text file for use in spreadsheets etc.

View Run button
Opens either the Run Log page (see **Section 4.3.13.3**) or, if either a Leak detection run or MFC calibration run is selected, the Leak Detect and MFC calibration log page (see **Section 4.3.13.4**) with the selected log data displayed.

Filter by Type list
A list of event types with associated checkboxes. Use this panel to select the events to display in the Event list. A checkbox showing a cross indicates that the associated event type will not be displayed. A checkbox showing a tick indicates that the associated event type will be displayed.

Filter by Batch Name field
Enter a batch name to list only logged events associated with that batch.

Filter by time fields and buttons
Use these controls to select events occurring in a time range to be displayed.

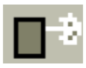
Hide items before selection button
Displays all events after and including the highlighted event.

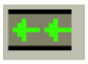
Hide items after selection button
Displays all events before and including the highlighted event.

Show all items button
Displays all previously hidden events.

4.3.13.3 Run Log page

The Run Log page is accessed from the SELECT RUN page by clicking **View Run** with any process other than a leak detection run or MFC calibration run selected. It displays the parameters, demands and readbacks for selected log data.

 Leak detection run symbol

 MFC calibration run symbol.

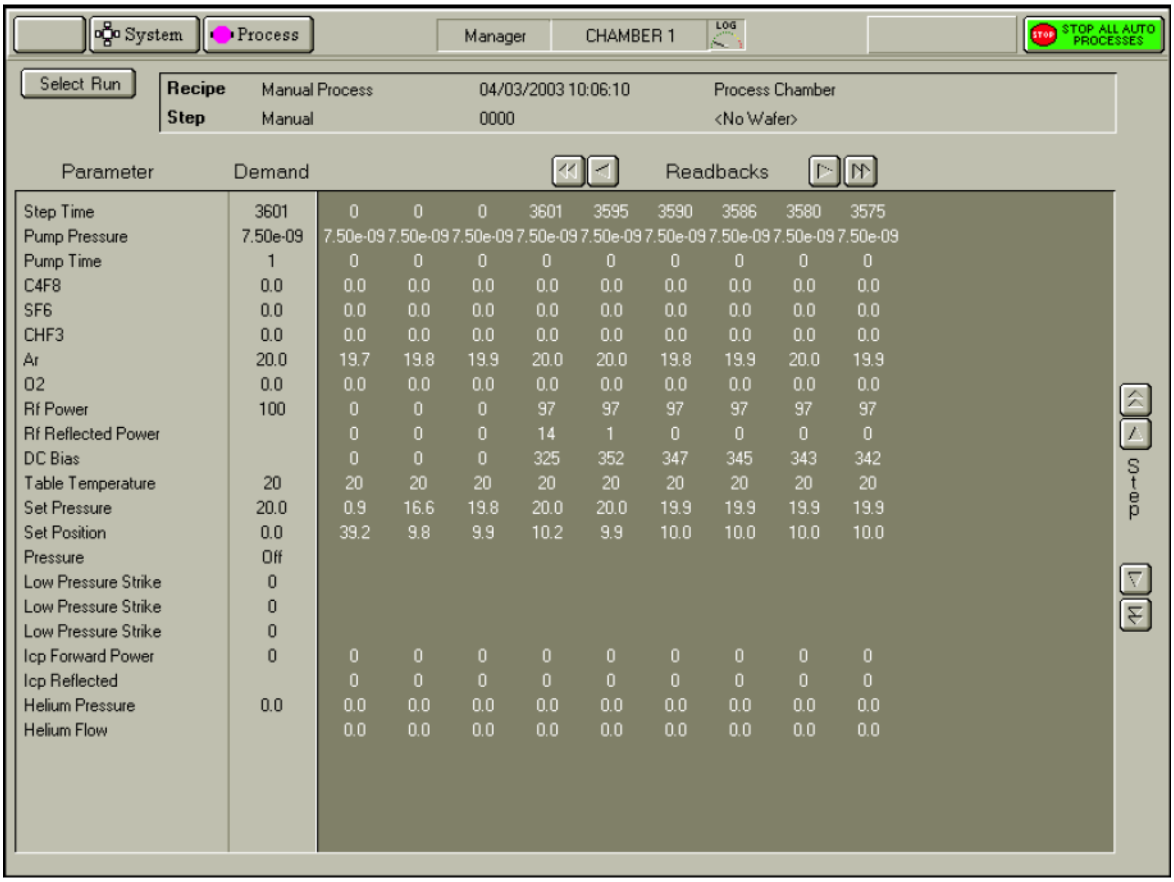


Figure 4-23 Run Log page

Select Run button
Displays the Select Log page.

Log information panel
Displays details about the selected log data.

Parameter list
Lists the logged parameter names

Demand list
Displays the demanded parameter value

Readbacks list
Displays the logged parameter values with respect to time at the log intervals specified for the process run. The list can be scrolled horizontally either by single readbacks or by page. The list can also be scrolled vertically to display further steps (for multi-step recipes).

4.3.13.4 Leak Detection and MFC Calibration Log page

The Leak Detection and MFC Calibration Log page is accessed from the SELECT RUN page by selecting a leak detection run or an MFC calibration run and clicking **View Run**.

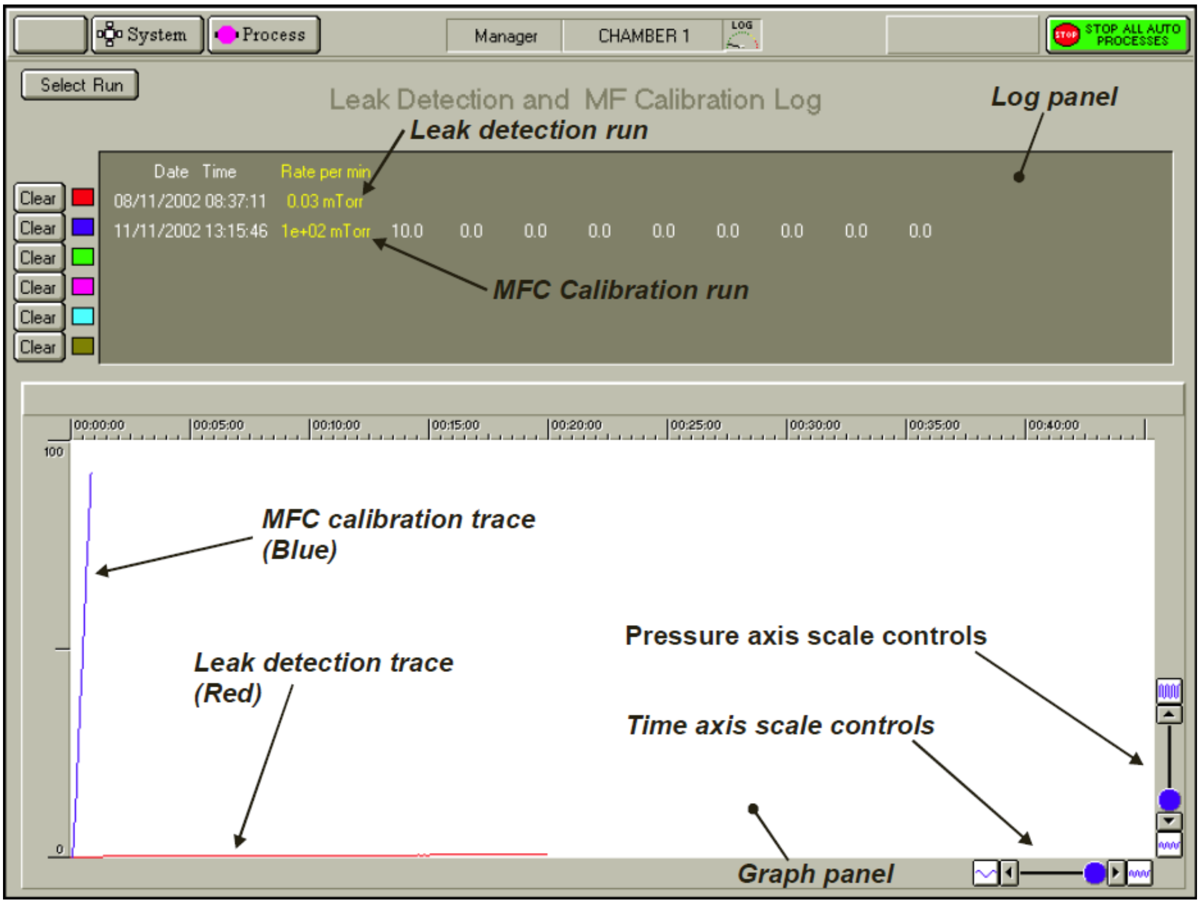


Figure 4-24 Typical leak detection and MFC calibration log page

This page is used to view details of up to six leak check runs and/or MFC calibration runs. Figure 4-24 shows details of a leak test (red trace) and an MFC calibration run (blue trace).

Select Run button
Opens the SELECT RUN page.

Clear buttons
Select to remove the associated data from the log panel and graph panel. Note that to re-display the cleared data, you must return to the Select Run page and re-select it.

Log panel
Displays details of each run in text format.

Graph panel
Displays a plot of each run (pressure versus time). Each run is represented by a coloured trace as indicated by the palette displayed adjacent to the run data in the Log panel. The graph can be scaled in each axis by the controls located at the bottom-left corner of the graph.

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5 OPERATING INSTRUCTIONS

This chapter describes how to operate the **FlexAL®** tool. These procedures must only be performed by personnel with the appropriate skills and training.

The procedures described here include:

- **Emergency shutdown procedure**
- **Starting up and shutting down the system**
- **Production mode operation**
- **Maintenance or engineering operation**
- **Manager operation**
- **Pumping, venting and opening the system**
- **Creating and editing recipes**
- **System alerts**
- **Loss of services**
- **Datalog pages**
- **Operator adjustments**
- **Service mode**
- **Log files**
- **Operating the PDMs**

5.1 Emergency shutdown procedure

In an emergency, press the red **EMERGENCY STOP** button on the control panel (see **Figure 4-1**). Once operated, the button latches in the OFF position to ensure that power is removed from the system.

The **EMERGENCY STOP** button is intended for use when electrical power must be immediately removed from the system to prevent personal injury or an immediate hazard. The button must also be operated if the building is being evacuated because of fire, earthquake, flood or other major event.

> **Caution 5.1**
>
> **EMERGENCY STOP**
>
> Use the **EMERGENCY STOP** button only if an immediate hazard is perceived. Repeated use of the button can degrade system hardware, resulting in premature failure.

It must be noted that pressing the **EMERGENCY STOP** button does not remove all potential hazards from the system. Refer to **Section 1.6.1.1** for a list of hazards that may still be present after pressing the **EMERGENCY STOP** button.

When the emergency has been rectified and it is safe to operate the system, perform the start-up sequence described in **Section 5.2.9** to recover from the shut-down.

5.2 Starting up and shutting down the system

This section only applies to users with *MANAGER*, *MAINTENANCE* or *USER* privilege.

5.2.1 System power-up procedure

This section describes how to start up the system when it is fully powered down. It is assumed that the system is switched off at the facility safety isolation box.

WARNING 5.1

POTENTIALLY HAZARDOUS EQUIPMENT
The FlexAL® system can produce various hazards if it is not installed and operated correctly. These hazards can cause death or serious injury. Before applying power to the system, ensure that all relevant personnel have read and understood Chapter 1 of this manual (Health and safety). If you have any concerns or questions, contact Oxford Instruments Plasma Technology before proceeding with the installation.

WARNING 5.2

POTENTIALLY HAZARDOUS EQUIPMENT
The FlexAL® system can produce various hazards if it is not installed and operated correctly. These hazards can cause death or serious injury. Before applying power to the system, ensure that the system is installed correctly and is in a fit state to be operated.

5.2.1.1 Pre-start checks

Before attempting to power-up the system, check the following:

- The maintenance log, to ensure that the system is fit to be operated.
- The history of the system gas bottles and gas lines. Particularly, check if any gas lines have been recently opened or if any gas lines may contain air.
- All the system covers are correctly fitted and the doors are closed.
- There is no visible damage to the system.

Caution 5.2

COOLING
Running the system without adequate cooling can cause permanent equipment damage. Always ensure that all heater/chiller units provided are switched ON when the system is powered up.

5.2.1.2 Starting up the system

1 Ensure that the cooling water isolation valves are ON.

2 Switch ON the heater/chiller unit (if fitted).

3 Check that the cooling water pressures and flows are within specification.

4 Ensure that the system compressed air supply is turned ON, and that the pressure is within specification.

5 Check that the **Slit Valve Lockout** knob and the **Precursor Lockout** knobs are unlocked and pushed home. See **Figure 4-1**.

6 If it can be confirmed that all gas lines do not contain air, turn ON all manually operated gas isolation valves, including any cylinder valves. If one or more gas lines may contain air, leave the valves closed and display a clear note of why this has been done.

7 If the system turbo pump requires bearing purge, adjust the bearing purge gas pressure regulator to the manufacturer's recommended value (see **Section 7.7.3**).

8 Open the door of the system base unit. Set all **Remote/Local** switches on the panel mounted units to **Remote**. These units include the turbo pump controller, the RF generator, etc.

9 Switch ON all the panel mounted units.

10 Rotate the **EMERGENCY STOP** button to check that it is out (see **Figure 4-1**).

11 Apply power to the system by switching on the facility safety isolation box.

12 Operate the **SYSTEM ON** button (coloured green or with the **I** legend), located on the console. See **Figure 4-1**.

13 Switch on the remote PC system controller. Check that the controller boots up correctly and that the Access Control window opens (see **Figure 5-1**).

14 The system is now powered up. If any gas lines are shut off because they may contain air, evacuate the gas lines before turning on the process gas supply (see **Section 8.3.1**).

5.2.2 Logging on

The login procedure is the same for all login levels.

When the PC2000 application is first started, the Access Control window is opens automatically. This page can also be opened at any time from the System Menu (see Figure 4-2).

Figure 5-1 Access Control window

To log on to the controller, perform the following steps:

1. Type your account user name in the **Enter Name** field.
2. Type your account password into the **Enter Password** field. The password is case-sensitive: for example, **Password** and **pAsswOrd** are different passwords.
3. Ensure that the **Demonstration** button is NOT selected.
4. Click **Verify**.
5. If the information entered is correct, the log-in status is displayed in the **Current User** and **Access Level** fields.
6. Click **OK**. The PC2000 application now loads and displays the PUMP CONTROL page or the RECIPES - Production Mode page, depending on your access level.
7. If the login information is not verified correctly, re-enter your name and password and click **Verify**.

5.2.3 Switching off screen-savers and power-saver options

PC screen savers and power-saver options can cause the PC to lose communications with the system. It is important to turn screen-savers and power-saver options on the PC off.

Caution 5.3

SCREEN SAVERS

When running the PC 2000 software, using a screen saver or allowing the PC to enter any of the power saver modes can cause the PC to lose communications with the PLC. Before starting the PC 2000 software, ensure that screen savers and all power saver options are turned OFF.

1. Right-click anywhere in a clear area on the Windows desktop then, on the displayed menu, select the **Properties** option. The Display Properties dialogue box opens.
2. Select the **Screen Saver** tab.
3. In the **Screen Saver** drop-down list, select **None**.
4. Click **OK**.
5. On the taskbar, select the **Start** button, then the **Settings** option. Then select **Control Panel**. The control panel opens.
6. Select **Power Options**. The Power Options Properties dialogue opens.
7. Ensure that all power scheme options are set to **Never**. If necessary, use the dropdown lists to select the **Never** option.
8. Click **OK**.
9. Close the control panel.

5.2.4 Overview of shutdown procedures

> **Caution 5.4**
> AVOID CONDENSATION OF PRECURSORS
> When the system is shut down, heated parts of the precursor delivery system cool down. This can cause precursor to condense inside the delivery system. Ensure that precursor has been evacuated from all such areas before shutting the system down. If condensation has occurred inside the delivery system, use **Section 5.2.10** to recover the system.

There are three different shutdown procedures that can be performed, depending on the reason for the shutdown:

- **Venting the process chamber for a short period**
  This is appropriate if the process chamber is to be vented for a short period only, e.g. to remove a mishandled wafer (see **Section 5.2.5**).
- **Partial shutdown**
  This is appropriate for most maintenance or repair activities, except if the maintenance will disturb gas lines, the gas pod, precursor lines, or precursor delivery modules (see **Section 5.2.6**).
- **Full shutdown**
  This is appropriate if the system is to be shut down for a long period or is to be moved. It must also be used if it is necessary to work on gas lines, the gas pod, precursor lines, or precursor delivery modules (see **Section 5.2.7**).

5.2.5 Venting the process chamber for a short period

This procedure is only suitable if the process chamber is to be opened for a brief period (e.g. to remove a mishandled wafer). If the process chamber must be vented for more than a few minutes, or if maintenance work is required, perform the partial shutdown procedure (see **Section 5.2.6**) or the full shutdown procedure (see **Section 5.2.7**) as required.

1. **Close all precursor valves (six-way precursor cabinet)**
2. **Close all precursor valves (single-precursor oven)**
3. **Pump the process chamber (all systems)**
4. **Vent and open the process chamber (all systems)**
5. **Perform maintenance (all systems)**
6. **Close the process chamber lid (all systems)**
7. **Evacuate and leak-check the process chamber (all systems)**
8. **Open the ampoule manual valves as required (six-way precursor cabinet)**
9. **Open housekeeping valves as required (single-precursor oven)**

5.2.5.1 Close all precursor valves (six-way precursor cabinet)

Perform this section only if a six-way precursor cabinet is fitted.

1. Wearing heat resistant gloves open the precursor cabinet door and close all the manual ampoule valves. In accordance with good practice close the inlet first and outlet second. Record which valves were open and which were closed for future reference.
2. Open the Process Control page and close all the pneumatic precursor valves.

5.2.5.2 Close all precursor valves (single-precursor oven)

Only perform this section if a PDM with a single-precursor oven is fitted.

1. Wearing heat resistant gloves open the oven door and close the manual ampoule valves. In accordance with good practice close the inlet first and outlet second.

> **Caution 5.5**
>
> **DO NOT LEAVE THE OVEN DOOR OPEN**
>
> Opening the oven door interrupts electrical power to the heater circuit. If the power is interrupted for more than 5 minutes the PLC disables the heater zone and raises a fault condition. It will then be necessary to enable and disable the heater zone.

2. Close all housekeeping valves.

5.2.5.3 Pump the process chamber (all systems)

Perform this section for all system configurations. If a six-way precursor cabinet is fitted, this procedure evacuates the delivery lines back to the precursor cabinet.

> **Caution 5.6**
>
> **CONDENSATION RISK**
>
> If the delivery lines cool, precursor can condense inside them. This condition can be difficult to diagnose. Maintain all delivery lines at their operating temperature throughout this procedure.

1. Start the system pumping.
2. Pump until the CM gauge reads base pressure (usually when the penning gauge is in the 10^{-3} range).

5.2.5.4 Vent and open the process chamber (all systems)

Perform this section for all systems.

1. Put on suitable personal protective equipment.

> **WARNING 5.3**
>
> **TOXIC VAPOUR**
>
> **Exposure to toxic vapour can cause death or serious injury. Ensure that all precursor lines are evacuated before opening the process chamber. Wear suitable personal protective equipment.**

2. Open the PUMP CONTROL page (see **Figure 4-4**).

3 Click on the **VENT** button in the process chamber control panel to vent the process chamber.

WARNING 5.4

TOXIC GASES
Contact can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

4 If toxic or hazardous gases have been used in the previous process, evacuate the process chamber without opening the lid.

5 Repeat the previous two steps (vent and evacuate) as many times as necessary to remove all traces of toxic gases and precursors. It is the customer?s responsibility to assess the hazards presented by each precursor and to use appropriate procedures to mitigate those hazards.

6 Undo the precursor delivery lines at the process chamber and hinge back the process chamber lid (see **Figure 5-2**).

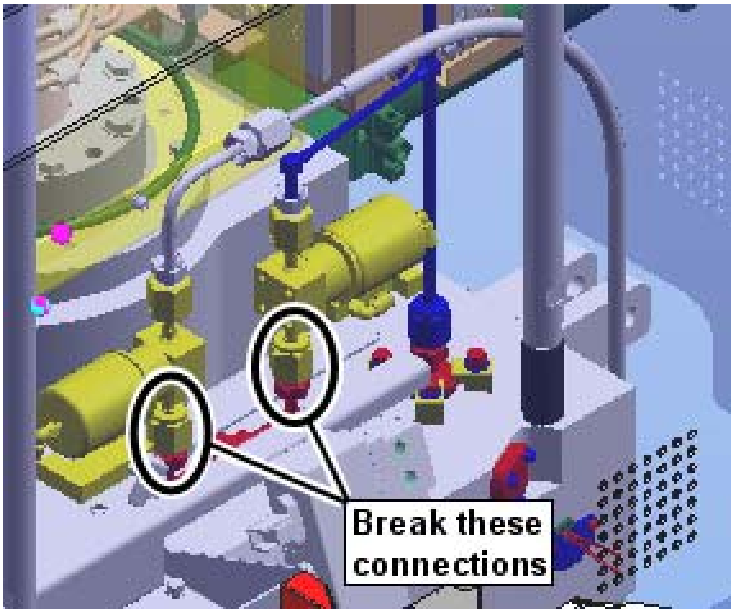


Figure 5-2 Precursor line connections at the process chamber

5.2.5.5 Perform maintenance (all systems)

Perform this section for all systems.

1 Perform the minor maintenance that is required. Do not leave the process chamber open for more than a few minutes. Do not turn off electrical power or service the gas lines or precursor lines.

5.2.5.6 Close the process chamber lid (all systems)

Perform this section for all systems.

1. Close the process chamber lid.
2. Re-connect all the delivery lines that were disconnected, using new VCR gaskets.

5.2.5.7 Evacuate and leak-check the process chamber (all systems)

Perform this section for all systems.

1. Evacuate the process chamber (see **Section 5.6.3**). This evacuates the delivery lines that were opened in **Section 5.2.5.4**.
2. Open the Process Control page and check that all precursor pneumatic valves are still closed.
3. Open the Leak Detection page (see **Figure 4-16**).
4. Check that the leak rate with all precursor pneumatic valves and housekeeping valves closed is less than 0.2 mTorr/min.

5.2.5.8 Open the ampoule manual valves as required (six-way precursor cabinet)

Only perform this section on systems fitted with a six-way precursor cabinet.

1. Open the manual ampoule inlet and outlet valves according to the required delivery mode.

5.2.5.9 Open housekeeping valves as required (single-precursor oven)

Only perform this section on systems fitted with a single-precursor oven.

1. Open the housekeeping and manual ampoule valves according to the delivery mode.

5.2.6 Partial shutdown procedure

Before opening the process chamber, the precursor must be evacuated from the space between the ampoule pneumatic outlet valve and the ampoule manual outlet valve on all ampoules. This ensures that there are two closed valves between any reservoir of precursor and the process chamber.

After completing this procedure the following conditions will be true:

- All electrical power is removed from the system.
- The compressed air supply to the system is turned off.
- The water supply to the system is turned off.
- All gas valves are turned off, but process gas is still present in the gas lines.
- All precursors are isolated, using the ampoule manual valves.
- All condensable precursors are pumped to the system base pressure. This is necessary because the line-heating is turned off, which can cause precursors to condense in the lines.

NOTE: This procedure is not suitable if the system is to be moved, or if access to the gas or precursor lines is required. In these events, perform the procedure described in **Section 5.2.7**.

This procedure assumes that all processing has completed and all process wafers have been removed from the chamber.

To shut down the system for maintenance or repair:

1 If manual point-of-use gas valves are fitted, turn them OFF. These valves isolate the lines between the gas bottles and the gas pod. They are normally located next to the gas pod.

2 If manual point-of-use gas valves are not fitted, close the gas bottle valves.

3 Shut down all the precursor modules fitted to the system (see **Section 5.2.8**).

4 Vent the loadlock (see **Section 5.6.2**).

5 Vent the process chamber (see **Section 5.6.4**). This procedure evacuates the precursor delivery modules.

WARNING 5.5

TOXIC GASES

Contact can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

6 If toxic or hazardous gases have been used in the previous process, evacuate the process chamber without opening the lid.

7 Repeat the previous two steps (vent and evacuate) as many times as necessary to remove all traces of toxic gases and precursors. It is the customer?s responsibility to assess the hazards presented by each precursor and to use appropriate procedures to mitigate those hazards.

8 Click the **STOP ALL AUTO PROCESSES** button. This opens the Automatic Process Shutdown dialogue (see **Figure 5-3**).

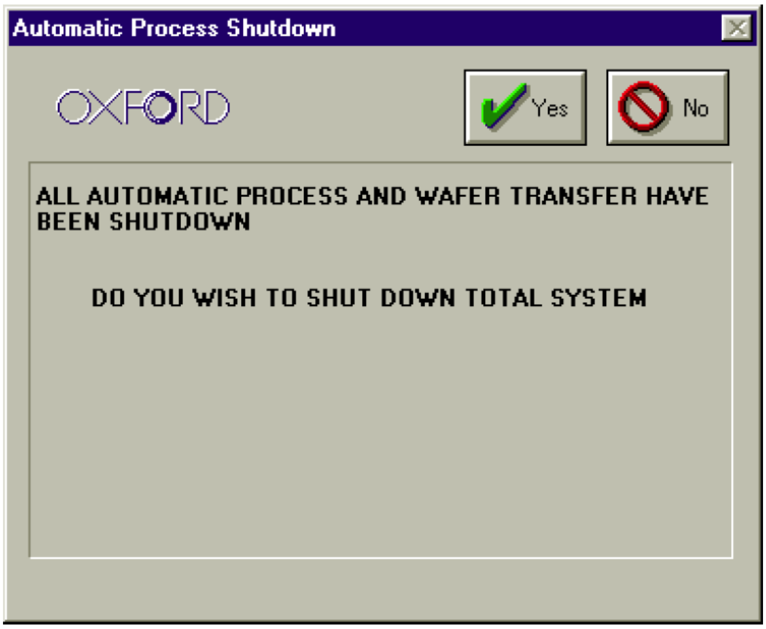


Figure 5-3 Automatic Process Shutdown window

9 Click **Yes**. This switches off the vacuum pumps and shuts down the system.

10 Click on the **System** button on the PC Controller page.

11 Select the **Exit** menu option. This shuts down the PC2000 application.

12 Shut down the Windows operating system by clicking the **Start** icon and then the **Turn Off Computer** icon.

13 Switch off the power switch on the PC controller.

14 Press the red **OFF** button on the system control panel (see **Figure 4-1**).

15 Switch off the main system isolator on the power box.

16 Switch off and lockout the facility safety isolation box.

17 At the system control panel, set the **SLIT VALVE LOCKOUT** valve to its OFF position by pulling the red control knob fully outwards. Lock the valve using the padlock provided.

18 At the system control panel, set the **PRECURSOR LOCKOUT** valve to its OFF position by pulling the red control knob fully outwards. Lock the valve using the padlock provided.

19 Turn off and lockout the compressed air supply to the machine.

20 Allow time for all heated components to cool to ambient temperature. Then turn off and lockout the cooling water supply to the machine.

> **HAZARDOUS VOLTAGE**
> **WARNING 5.6**
> **Contact can cause severe injury or death. Any work requiring the removal of covers or panels must only be performed by authorised personnel who are aware of the hazards involved. Before removing any covers or panels, power down the system and lock out the power source.**

21 Wait at least five minutes before removing any panels or covers. This ensures that any stored electrical energy has decayed to a safe level.

22 Attach a notice to the machine, explaining its status. In particular, emphasise that the gas lines have not been evacuated.

5.2.7 Full shutdown procedure

Perform the following steps to shut down the system for a long term, or if the system is to be moved. After completing this procedure the following conditions will be true:

- All electrical power is removed from the system.
- The compressed air supply to the system is turned off.
- The water supply to the system is turned off.
- All gas lines are evacuated.
- All gas valves are turned off.
- All precursor ampoules are isolated and are removed from the system.
- All precursor lines are purged and leak-checked.

This procedure assumes that all processing has completed and all process wafers have been removed from the chamber.

1 Referring to **Section 8.3.1**, evacuate all the gas lines. Consider the reason for shutting down the system and decide whether to evacuate the gas lines back to the point-of-use valves, or back to the gas bottle valves. If in doubt, evacuate the gas lines back to the bottles as further evacuation cannot be performed once the system is shut down.

2 Shut down the precursor modules (see **Section 5.2.8**).

3 Referring to **Section 7.7.9**, remove all precursor ampoules from the six-way precursor cabinet.

4 Referring to **Section 7.7.11**, remove all precursor ampoules from the single-precursor ovens.

5 Vent the loadlock (see **Section 5.6.2**).

6 Click on the **VENT** button in the process chamber control panel to vent the process chamber.

WARNING 5.7

TOXIC GASES
Contact can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

7 If toxic or hazardous gases have been used in the previous process, evacuate the process chamber without opening the lid.

8 Repeat the previous two steps (vent and evacuate) as many times as necessary to remove all traces of toxic gases and precursors.

9 Click the **STOP ALL AUTO PROCESSES** button. This opens the Automatic Process Shutdown dialogue (see **Figure 5-3**).

10 Click **Yes**. This switches off the vacuum pumps and shuts down the system.

11 Choose **Exit** from the System Menu. This shuts down the PC2000 application.

12 Shut down the Windows operating system by clicking the **Start** icon and then the **Turn Off Computer** icon.

13 Switch off the power switch on the PC controller.

14 Press the red **OFF** button on the system control panel (see **Figure 4-1**).

15 Switch off the main system isolator on the power box.

16 Switch off and lockout the facility safety isolation box.

17 At the system control panel, set the **SLIT VALVE LOCKOUT** valve to its OFF position by pulling the red control knob fully outwards. Lock the valve using the padlock provided.

18 At the system control panel, set the **PRECURSOR LOCKOUT** valve to its OFF position by pulling the red control knob fully outwards. Lock the valve using the padlock provided.

19 Turn off and lockout the compressed air supply to the machine.

20 Allow time for all heated components to cool to ambient temperature. Then turn off and lockout the cooling water supply to the machine.

WARNING 5.8

HAZARDOUS VOLTAGE
Contact can cause severe injury or death. Any work requiring the removal of covers or panels must only be performed by authorised personnel who are aware of the hazards involved. Before removing any covers or panels, power down the system and lock out the power source.

21 Wait at least five minutes before removing any panels or covers. This ensures that any stored electrical energy has decayed to a safe level.

22 Attach a notice to the machine, explaining its status.

5.2.8 Shutting down the precursor modules

The exact procedure depends on which precursor delivery options are fitted to the system. Some of the steps listed only apply to one option. This is clearly indicated in the title and text of the step.

Each six-way precursor cabinet contains two manifolds. Ampoules must be installed so that all precursors on the same manifold are chemically compatible. Because of this restriction, the precursor can be evacuated from all three ampoule outlets on a manifold at the same time.

Perform the steps described in this section if the system is operating normally and can run recipes. If the system cannot run recipes (for example if a wafer is trapped in the slit valve), use the procedure described in **Section 8.2.3**.

WARNING 5.9

TOXIC GASES
Contact can cause death or serious injury. When starting up the system after an unscheduled shutdown, the process chamber must be subjected to at least two vent cycles before the chamber lid is opened. Wear personal protective equipment as necessary.

Referring to the relevant section for details of each step, perform the following steps in turn to open the process chamber for maintenance:

1. **Close all precursor valves (six-way precursor cabinet)**
2. **Close all precursor valves (single-precursor oven)**
3. **Pump the process chamber (all systems)**
4. **Evacuate and purge the ampoules on each manifold (six-way precursor cabinet)**
5. **Evacuate and purge the delivery lines (single-precursor oven)**
6. **Cool down the delivery lines (all systems)**

5.2.8.1 Close all precursor valves (six-way precursor cabinet)

Perform this section only if a six-way precursor cabinet is fitted.

1. Wearing heat resistant gloves open the precursor cabinet door and close all the manual ampoule valves. In accordance with good practice close the inlet first and outlet second. Record which valves were open and which were closed for future reference.
2. Open the Process Control page and close all the pneumatic precursor valves.

5.2.8.2 Close all precursor valves (single-precursor oven)

Only perform this section if a PDM with a single-precursor oven is fitted.

1 Wearing heat resistant gloves open the oven door and close the manual ampoule valves. In accordance with good practice close the inlet first and outlet second.

> **Caution 5.7**
>
> **DO NOT LEAVE THE OVEN DOOR OPEN**
>
> Opening the oven door interrupts electrical power to the heater circuit. If the power is interrupted for more than 5 minutes the PLC disables the heater zone and raises a fault condition. It will then be necessary to enable and disable the heater zone.

2 Close all housekeeping valves.

5.2.8.3 Pump the process chamber (all systems)

Perform this section for all system configurations. If a six-way precursor cabinet is fitted, this procedure evacuates the delivery lines back to the precursor cabinet.

> **Caution 5.8**
>
> **CONDENSATION RISK**
>
> If the delivery lines cool, precursor can condense inside them. This condition can be difficult to diagnose. Maintain all delivery lines at their operating temperature throughout this procedure.

1 Start the system pumping.

2 Pump until the CM gauge reads base pressure (usually when the penning gauge is in the 10^{-3} range).

5.2.8.4 Evacuate and purge the ampoules on each manifold (six-way precursor cabinet)

Only perform this section if a six-way precursor cabinet is fitted. Repeat this section for all precursor manifolds fitted to the system.

1 At the Process Control page, open the pneumatic valves on all the precursors in the selected manifold. This pumps the section of pipe between the ALD dose valve and the ampoule or VCR blanking fitting. Pump the system for at least 15 minutes (see **Figure 5-4**).

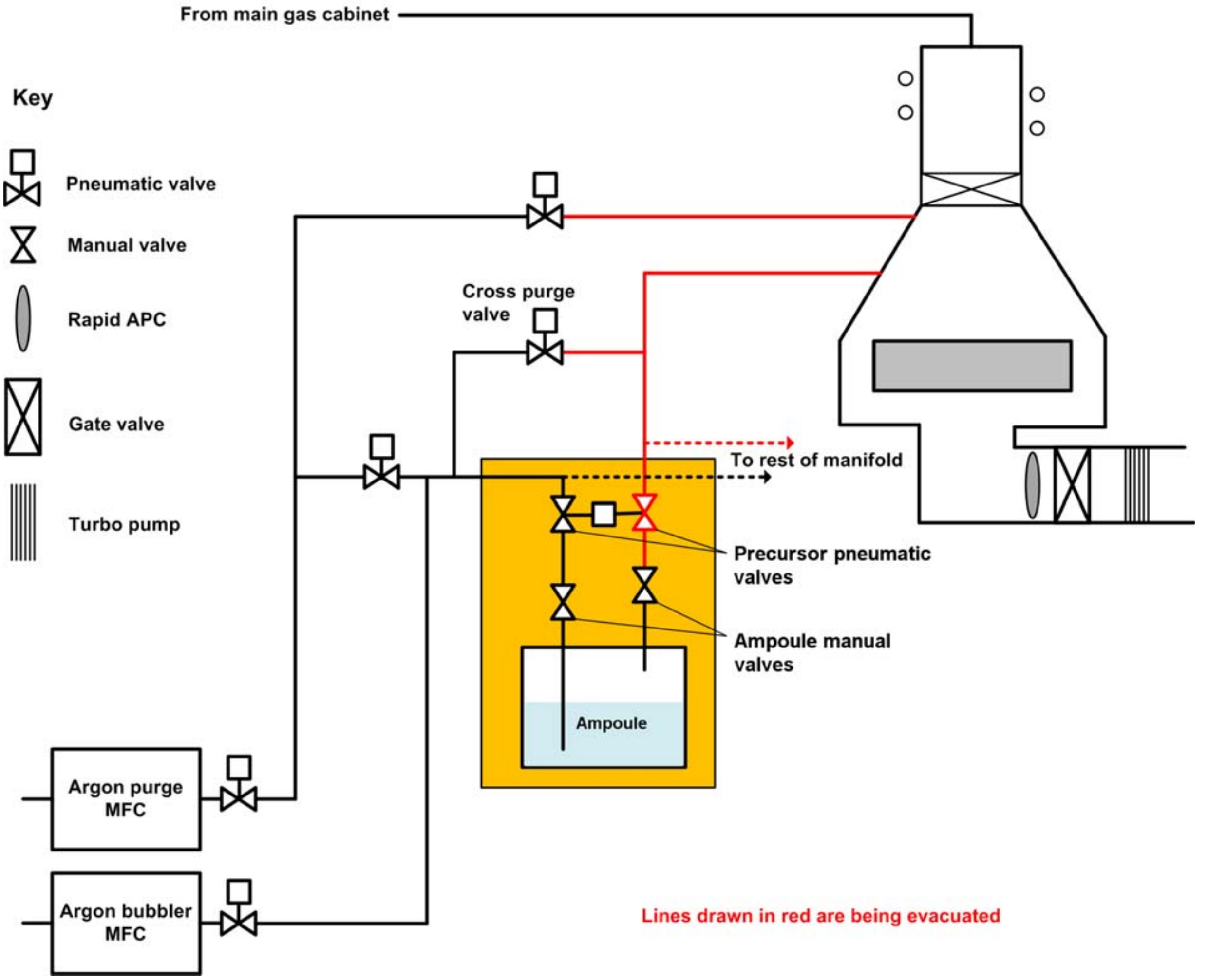


Figure 5-4 Opening all the outlet precursor valves on a manifold

2 Using the keyswitch, open the cross-purge valve on the selected manifold (see Figure 5-5). This enables the inlet or purge manifold to be pumped. Re-start this section if an over-pressure alarm shuts down the process. If more than three over pressure alarms occur consecutively, investigate for a vacuum leak on the ampoule fittings.

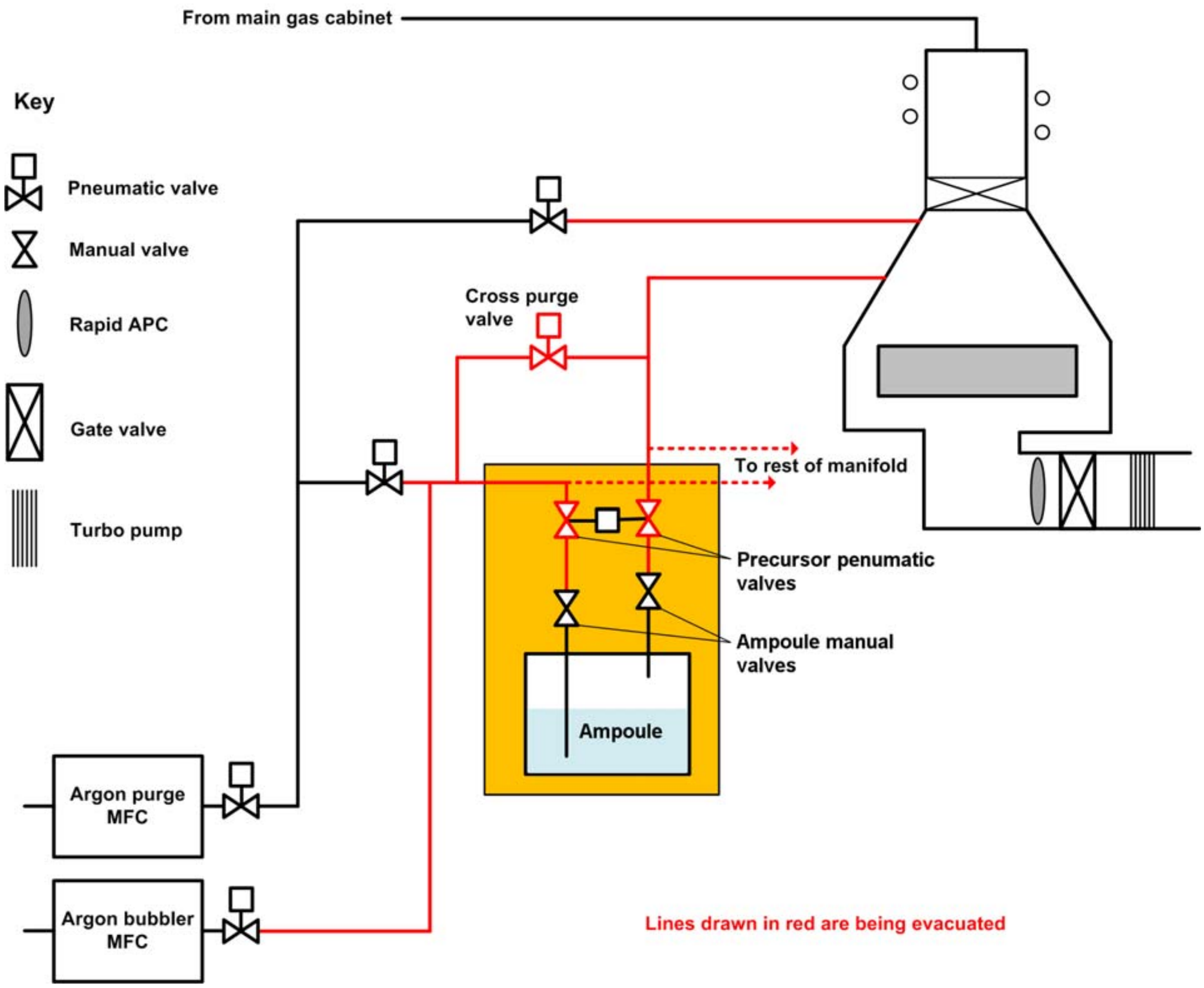


Figure 5-5 Pumping and purging the delivery lines on a manifold

3 Run the following recipe to pump and purge the delivery line:

1) Pump the line for 1 minute with the pneumatic precursor valves open.

2) Purge the line for 30 seconds with 200 sccm Ar (bubbler), precursor pneumatic valves open, Pressure 80 mT.

4 Repeat this sequence at least 45 times.

NOTE: Because the ampoule manual valves are closed, this procedure purges the lines between the precursor pneumatic valves and the ampoule manual valves.

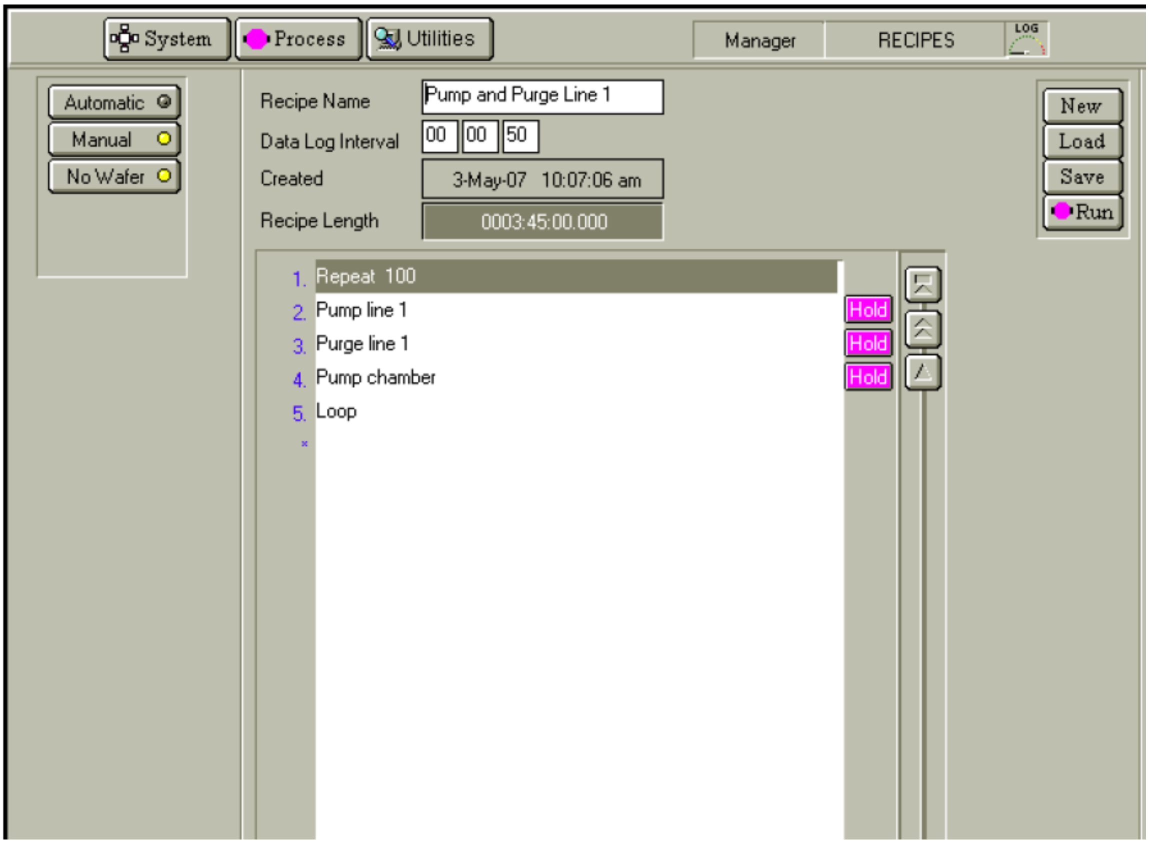


Figure 5-6 Sample recipe for purging the delivery lines

5. Open the Leak Detection page (see **Figure 4-16**).
6. Perform a leak check of the process chamber with all the pneumatic precursor valves closed.
7. Open the pneumatic valves on all the precursors in the manifold that is being checked. Perform a leak check of the chamber and precursor delivery lines. The leak up rate of the delivery system should be <0.2 mT/min higher than the leak rate of the chamber alone. If the leak rate is too high, investigate and fix any faults before proceeding.
8. Close the cross-purge valve, using the keyswitch. Remove the key and store it in a secure place.
9. Close the pair of ALD precursor valves.
10. Repeat this section for every manifold on the system.

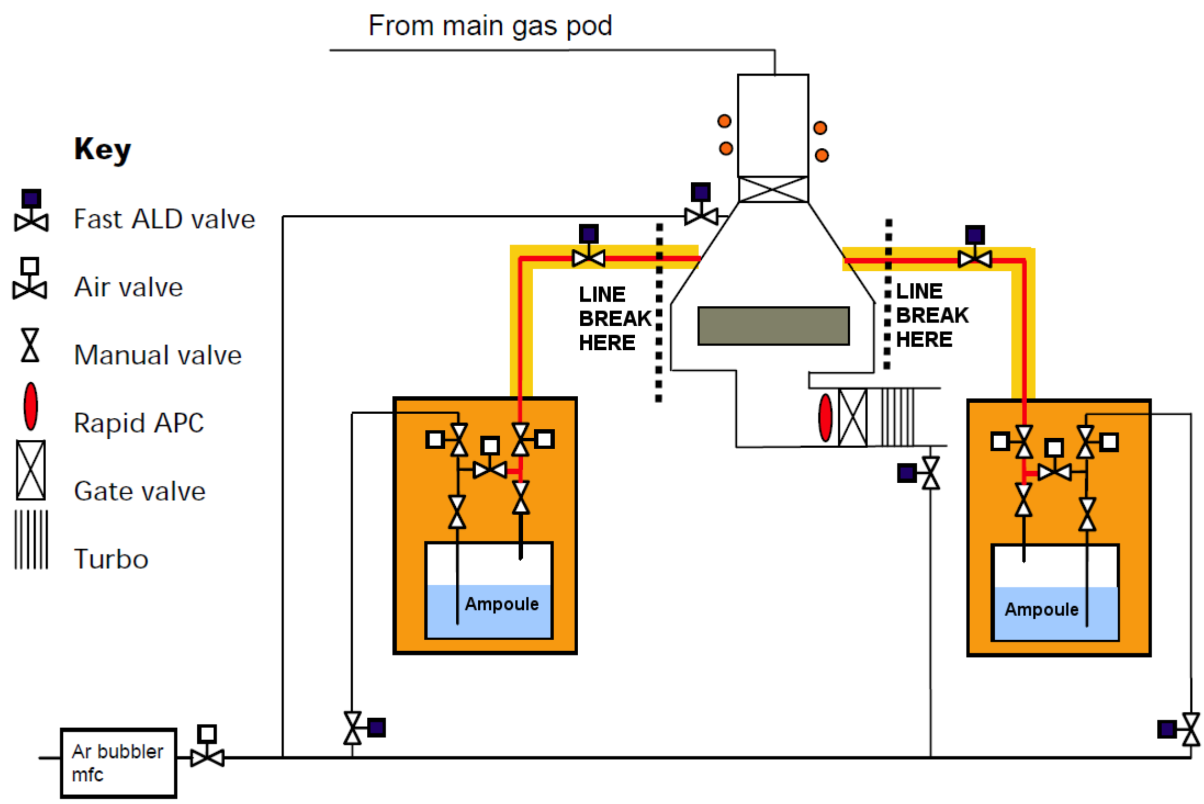
5.2.8.5 Evacuate and purge the delivery lines (single-precursor oven)

Only perform this section if a PDM with a single-precursor oven is fitted.

1. Access the Leak Detection page (see **Figure 4-16**).
2. Check the leak rate of the process chamber with all precursor delivery valves closed.
3. Check the leak rate of the precursor delivery system. This leak rate should be <0.2 mT/min higher than the chamber alone.
4. If all the precursor lines pump to normal base pressure (usually 2 to 5 $x10^{-6}$ Torr) and pass the leak check, then it is acceptable to go to step **13**.
5. Open and close the fast ALD valve and the pressure difference should be less than 4 x 10^{-6} Torr. It is always a good idea to elevate line temperatures to achieve this. By skipping the following sections the time to pump out the precursor lines will be reduced since the oven pipe work down stream of the outlet housekeeping valve is not being pumped. Should an ultra low vapour pressure liquid or solid be used it is always recommended to pump and purge the lines.

Open the outlet housekeeping valve and pump

6. Open the outlet housekeeping valve and pump the system for at least 15 minutes.

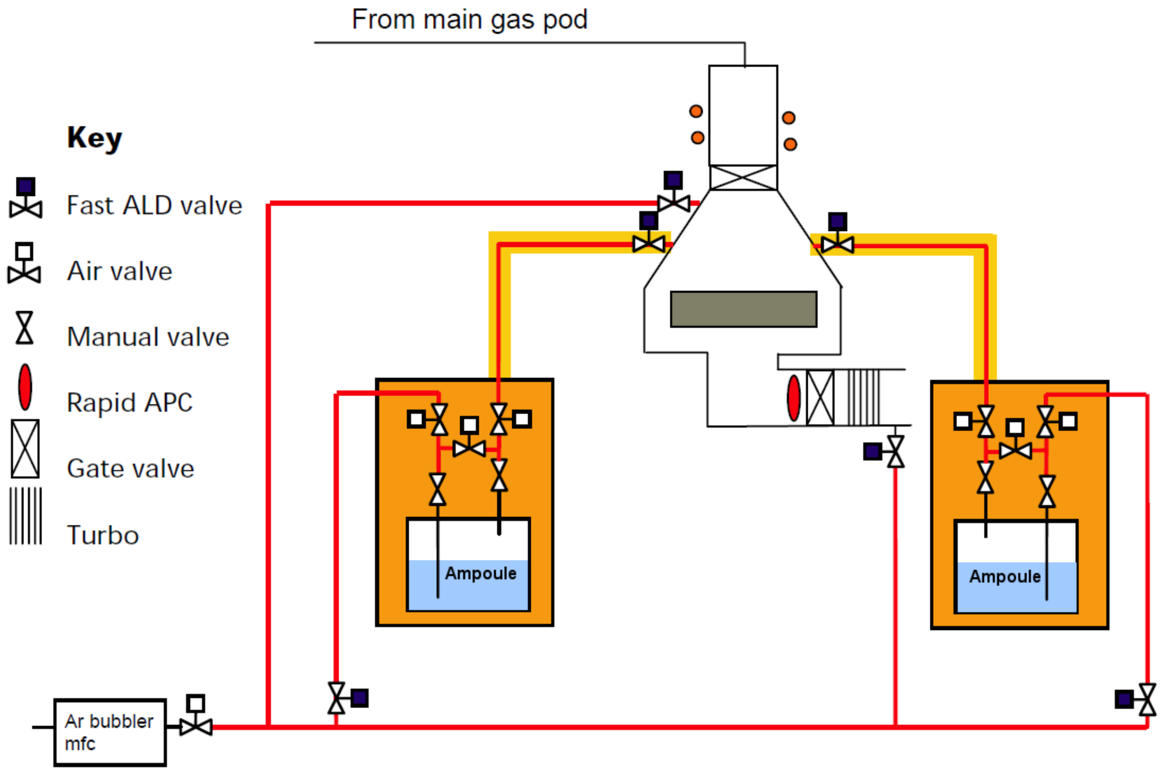


The red lines indicated the sections of line being pumped at this stage in the procedure.

Figure 5-7 Opening the outlet housekeeping valves

Pump and purge the delivery lines

7 Open the inlet and cross-purge housekeeping valves. It is now safe to open the cross purge valve, since the precursor has mostly been removed from the line and the manual ampoule valves are closed (see **Figure 5-8**).



The red lines indicated the sections of line being pumped at this stage in the procedure

Figure 5-8 Pumping and purging the delivery lines

8 Run the following recipe to pump and purge the delivery line:

1) Pump Line 1 for 1 minute with Line 1 valve open.

2) Purge Line 1 for 30 seconds with 200 sccm Ar (bubbler), Line 1 valve open, Pressure 80 mT.

9 Repeat this sequence at least 45 times.

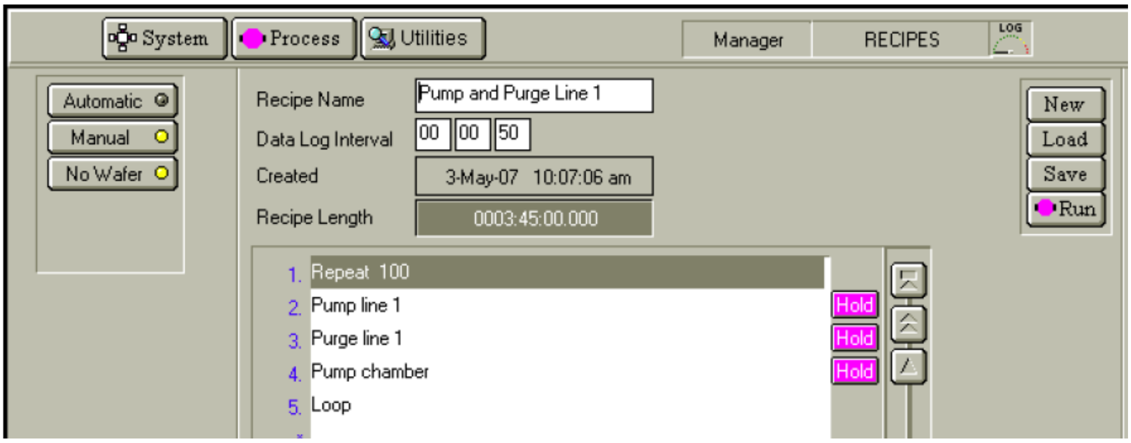


Figure 5-9 Sample recipe for purging the delivery lines

Leak check the delivery lines

10 Ensure that all housekeeping valves are still open.

11 Use the software leak up feature (see **Figure 4-16**).

12 The leak up rate of the delivery system should be <0.2 mT/min higher than the chamber alone.

Close all housekeeping valves

13 Close all the housekeeping valves.

5.2.8.6 Cool down the delivery lines (all systems)

Perform this section for all systems.

1 Set all the delivery line temperatures to 1°C.

2 Set the process chamber temperature to 1°C.

NOTE: The ampoule heaters in a six-way precursor cabinet, and the ovens in a PDM, can be left at their operating temperature, if required.

5.2.9 Start-up after an unscheduled system shut-down

If electrical power is lost from the system, precursor vapour will be trapped in the process chamber and precursor delivery lines. Without electrical power for heating, these parts of the system will cool down, and precursor will condense inside the system. Condensed precursor can block valves.

Ensure that this recovery procedure is followed to ensure that all condensed precursor is removed from the system.

To start up the system after an emergency stop, power failure, or software abort:

1 Determine the reason for the unscheduled shut-down of the machine.

2 Determine if there are any process wafers in the machine.

3 Determine whether there may be process gas in the chamber: for example if the machine was shut down during a process run.

4 Confirm that the reason for the shut-down has been resolved and it is safe to re-start the machine.

5 If an **EMERGENCY STOP** button has been pressed, rotate the button to release it.

6 Turn on the main system isolator on the power box, if it is not turned on already.

7 Identify all precursor bubbler ampoules that are fitted to the system (bubbler ampoules have two manual valves attached to the ampoule).

8 Close the manual inlet valve on all precursor bubblers. This isolates the trapped argon in the bubbler and minimises back-migration of precursor.

NOTE: Leave the ampoule manual outlet valves open to allow any condensed precursor to drain back into the ampoule.

---

9 Press the green **ON** button on the system control panel (see **Figure 4-1**). If a robot arm is fitted, it should move slowly to its home position.

10 Press the red **OFF** button on the system control panel (see Note).

11 Press the green **ON** button on the system control panel. If cassette loadlock(s) are fitted, their elevators will move to find the end positions.

NOTE: Once the PLC reboots, all PLC controlled heating zones will immediately start heating. The PLC retains the setpoints that were active when the system shut down. It is not necessary to re-start the PC in order to re-start these heaters.

---

12 Log on to the system (see **Section 5.2.2**).

13 A user with access to the SERVICE mode can then use the facilities to add wafers to the mimic page so that the system controller knows where any wafers are.

NOTE: The double on and off routine (in steps **9** to **11**) is essential only for a system with a Hine robot arm and vacuum cassettes. If the arm has stopped inside the cassette and both are initialised together, then the arm and the cassette contents will be damaged. Therefore the Hine arm will go to its home position when power is applied, but the cassettes will initialise ONLY if the Hine arm is already at home position when power is applied.

---

14 Evacuate the process chamber (see **Section 5.6.3**).

15 Evacuate the loadlock (see **Section 5.6.1**).

16 Vent the loadlock without opening the lid.

17 Evacuate and vent the loadlock twice more. This step must always be performed as a precaution, even if the loadlock is expected to be free of hazardous gas residues.

WARNING 5.10

TOXIC GASES

Contact can cause death or serious injury. When starting up the system after an unscheduled shutdown, the loadlock must be subjected to at least two vent cycles before the loadlock lid is opened. Wear personal protective equipment as necessary.

18 Open the loadlock and remove any process wafers that may be present.

NOTE: System and data log files may be corrupted. Refer to **Section 5.13** for details.

19 Remove all precursor from the chamber by performing a pump and purge recipe and ensuring base pressure and/or leak up rates have returned to normal levels (with a turbo <10-6 Torr base pressure, without a turbo leak up rate < 2 mTorr/min).

20 If the system has been powered down for longer than five minutes, perform the precursor recovery procedure (see **Section 5.2.10**). This procedure removes any precursor that may have condensed in the delivery lines.

5.2.10 Precursor recovery procedure

1 Leave all ALD valves closed. This prevents contact between droplets of precursor and the valve seats.

2 Wait until ALL heater zones have reached their operating temperatures. This includes heaters on the precursor lines, ALD valves, chamber walls, and the foreline.

3 Wait for 60 minutes once the heater zones have reached their operating temperatures.

4 Close all precursor-ampoule manual-valves in the six-way precursor cabinet (see **Section 5.2.8.1**).

5 Close all precursor-ampoule manual-valves in the single-precursor ovens (see **Section 5.2.8.2**).

6 Evacuate the precursor lines in the six-way precursor cabinet as follows:

a) At the Process Control page, open the pneumatic valves on all the precursors in the first manifold.

b) Monitor the process chamber pressure while the line is pumping. The pressure should drop smoothly. If the pressure drops then randomly increases again, precursor has probably condensed in the line.

c) If precursor has condensed in the line, open the purge valve to clear it.

d) Close the purge valve and continue monitoring the process chamber pressure.

e) Wait until the process chamber pressure is less than 5 mTorr.

f) Perform a rate of rise leak check. If the leak rate is less than 1 mT /min, continue to the next step. If the leak rate is too high, continue pumping the line.

g) Close the pneumatic valves on the first manifold.

h) At the Process Control page, open the pneumatic valves on all the precursors in the second manifold.

i) Close the pneumatic valves on the second manifold.

7 Evacuate the precursor lines to each of the single-precursor ovens as follows:

a) At the Process Control page, open the fast ALD valve.

b) Monitor the process chamber pressure while the line is pumping. The pressure should drop smoothly. If the pressure drops then randomly increases again, precursor has probably condensed in the line.

c) If precursor has condensed in the line, open the cross-purge valve to clear it.

d) Close the purge valve and continue monitoring the process chamber pressure.

e) Wait until the process chamber pressure is less than 5 mTorr.

f) Perform a rate of rise leak check. If the leak rate is less than 1 mT /min, continue to the next step. If the leak rate is too high, continue pumping the line.

g) Close the fast ALD valve.

8 Open the manual valves on all the precursor ampoules.

5.2.11 Logging off

1 Choose **Exit** from the System Menu. The Close Down Cluster System dialogue box opens.

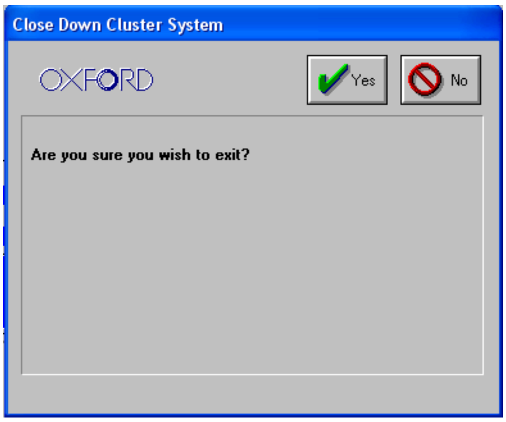


Figure 5-10 Close Down Cluster System dialogue box

2 Click **Yes**. This shuts down the PC2000 application (see **Figure 4-20**).

5.3 Production mode operation

The production mode facility is provided to make operation of the system as simple as possible. In this mode a special recipe page is provided, which allows you to load and run a recipe and then vent the automatic loadlock.

1. Ask your supervisor to log on as a *MANAGER* and to evacuate the process chamber. Do not evacuate the automatic load lock at this stage.
2. Choose **Password** from the System Menu.
3. Log on with an appropriate user name and password for the *PRODUCTION* mode. The Production Mode page opens (see **Section 4.3.6**).
4. Open the lid of the automatic loadlock and place the wafer to be processed on the transfer arm.
5. Close the loadlock lid.
6. At the Production Mode page, click **Load**, select the required recipe from the displayed list, then click **OK**.
7. Enter a batch identity.
8. Click **Run**. The loadlock will automatically pump down and the recipe will run. This button becomes active only when a recipe has been loaded, a batch identity has been entered, and the associated indicators are coloured green.
9. When the **Process Complete** message is displayed, click **Vent** to vent the loadlock. The **Vent Time Remaining** counter indicates venting progress.
10. When the loadlock has vented, open the lid and remove the processed wafer.
11. Repeat steps **4** to **10** to process further wafers. If running the same recipe again, skip step **6**. If a new recipe is required, load another recipe.
12. When all processing is complete, ask your supervisor to log on as a *MANAGER* and return the system to the required state.

5.4 Maintenance or engineering operation

The processing options available to a user with *MAINTENANCE* privilege are:

Single button automatic process run
This method of operation allows a multi-step recipe to be run and is suited to production or high volume processing. However it assumes the user has some system knowledge as the user must navigate between several pages.

Manual process run
This operating method requires the user to manually enter all of the processing parameters for the run. A recipe is not used, so only a single process step can be performed at a time. This method is designed for engineering use or for process development.

5.4.1 Single button automatic process run

This section describes a single button automatic process run, which allows a complete process to run automatically once the wafers have been loaded into the chamber.

Before performing a single button automatic run, the following conditions must be true:

- The system must be started up, with all vacuum pumps running (see **Section 5.2.1**).
- The process chamber must be evacuated (see **Section 5.6.3**).
- The loadlock must be vented (see **Section 5.6.2**).

To perform a single button automatic run:

1. Open the lid of the loadlock.
2. Place the process wafer on the transfer arm.
3. Close the lid of the loadlock.
4. Click the **menu** icon at the top left corner of the PC Controller page.

5 Select the **Recipes** menu option. The RECIPES page opens.

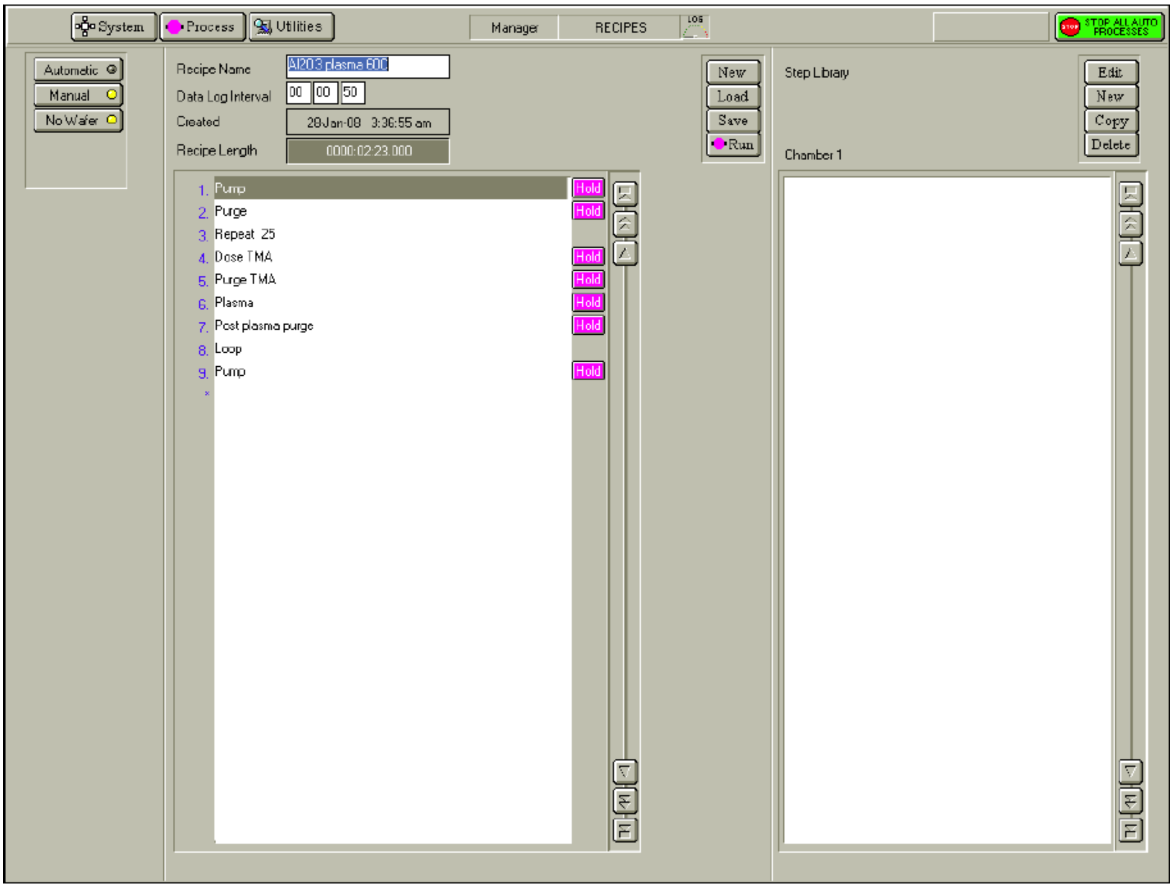


Figure 5-11 RECIPES page

6 Find the required recipe from the list in the **Recipe Library** panel.

7 Drag the required recipe into the **Recipe Editor** panel.

8 Inspect the list of recipe steps in the **Recipe Editor** panel to confirm that the correct recipe has been loaded.

9 If running a recipe without loading a wafer, click **no wafer**. The colour of the button changes to yellow to confirm that it has been selected. The **no wafer** button might be selected if testing a recipe or running a clean recipe.

10 Click **Run** (see Figure 5-11). This initiates the following automatic sequence:

1) The Process Control page is displayed to allow you to monitor the progress of the run.

2) The loadlock is evacuated.

3) The wafer is transferred into the process chamber.

4) When the process chamber reaches its base pressure, the process starts.

5) When the process has completed, the wafer is transferred back into the loadlock.

11 To pause the process at any stage, click **PAUSE** on the Process Control page. This immediately switches off the plasma RF power and freezes the step time at its current value.

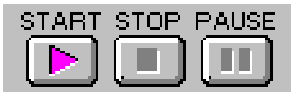


Figure 5-12 Control buttons on the Process page

12 To re-start the process, click **PAUSE** again. This switches on the plasma RF power and re-starts the step timer from its current value.

13 To stop the process, click **STOP**. This causes the process to abort and resets the step timer to zero. The message **Process Complete** is also displayed. It is then possible to run the same process or a different process, if required.

NOTE: Do not click on the large red **Stop All Auto Processes** button near the top right of the page.

---

14 Wait until the process has completed.

> WARNING 5.11
>
> **TOXIC GASES**
>
> **Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be properly evacuated before transferring the wafer into the loadlock. Ensure that the automatic pumping sequence is allowed to complete.**

15 Click the **menu** icon.

16 Choose **Pumping** from the System Menu. The PUMP CONTROL page opens.

17 Vent the loadlock (see **Section 5.6.2**).

18 Open the loadlock lid and remove the wafer.

19 Repeat the steps in this section to process further wafers.

20 When all wafers have been processed, evacuate the loadlock (see **Section 5.6.1**).

5.4.2 Manual process run

Because a manual process run does not use a recipe, the operator must monitor the process parameters during the run.

To transfer a wafer from the loadlock to the process chamber to carry out a manual process:

1 On the PUMP CONTROL page, click on the loadlock wafer mimic. The blue arrowed path is displayed, showing the available destination.

2 Click on the process chamber wafer indicator. The wafer is transferred to the process chamber.

To transfer a wafer from a process chamber to the loadlock on completion of a manual process:

1 Click on the process chamber's green wafer indicator. The blue arrowed path is displayed showing the available destination.

2 On the loadlock mimic, click on the wafer indicator. The wafer is transferred to the loadlock.

To perform a manual process run:

1 Insert the wafer into the automatic load lock. (If necessary, vent the automatic loadlock by selecting the **STOP** button then the **VENT** button).

2 Close the lid of the loadlock.

3 Select the EVACUATE button for the loadlock. A dialogue box opens, allowing you to enter a wafer name (if any).

4 Check that the system has pumped down to base pressure. The process chamber message panel should display **Base Pressure Reached**.

5 Choose **Chamber 1** from the Process Menu. Set the parameters as required: e.g. Step Time, RF generator power, chiller temperature, chamber pressure, and gas demands.

6 Check that the green ready for transfer indicators are displayed on both the loadlock and process chamber pumping page panels (see **Figure 5-13**).

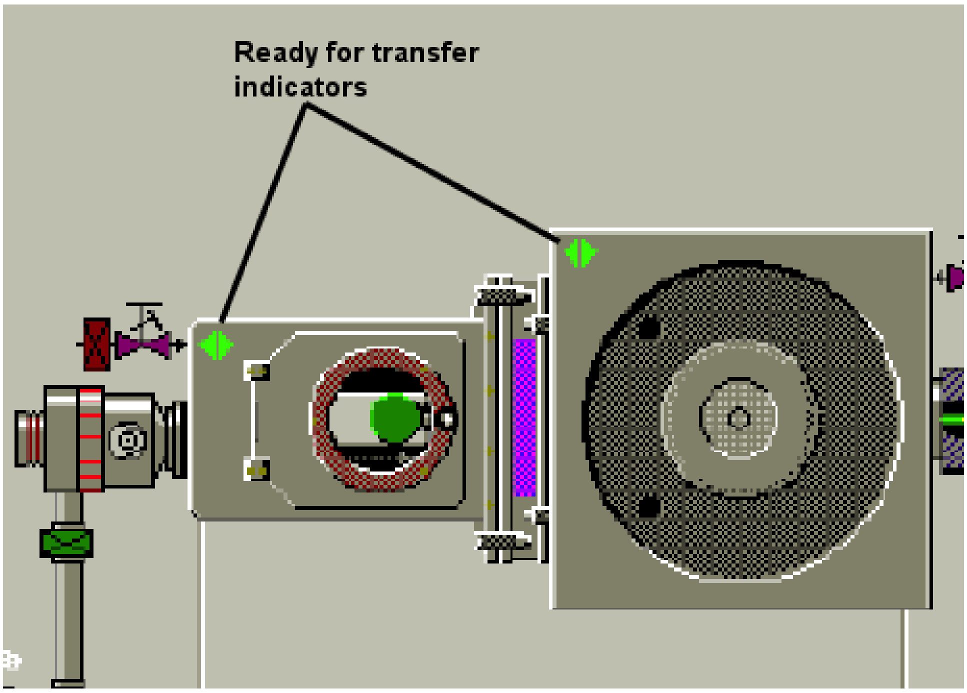


Figure 5-13 Ready for transfer indicators

7 On the PUMP CONTROL page, click on the loadlock wafer mimic. The ROBOT CONTROL page opens.

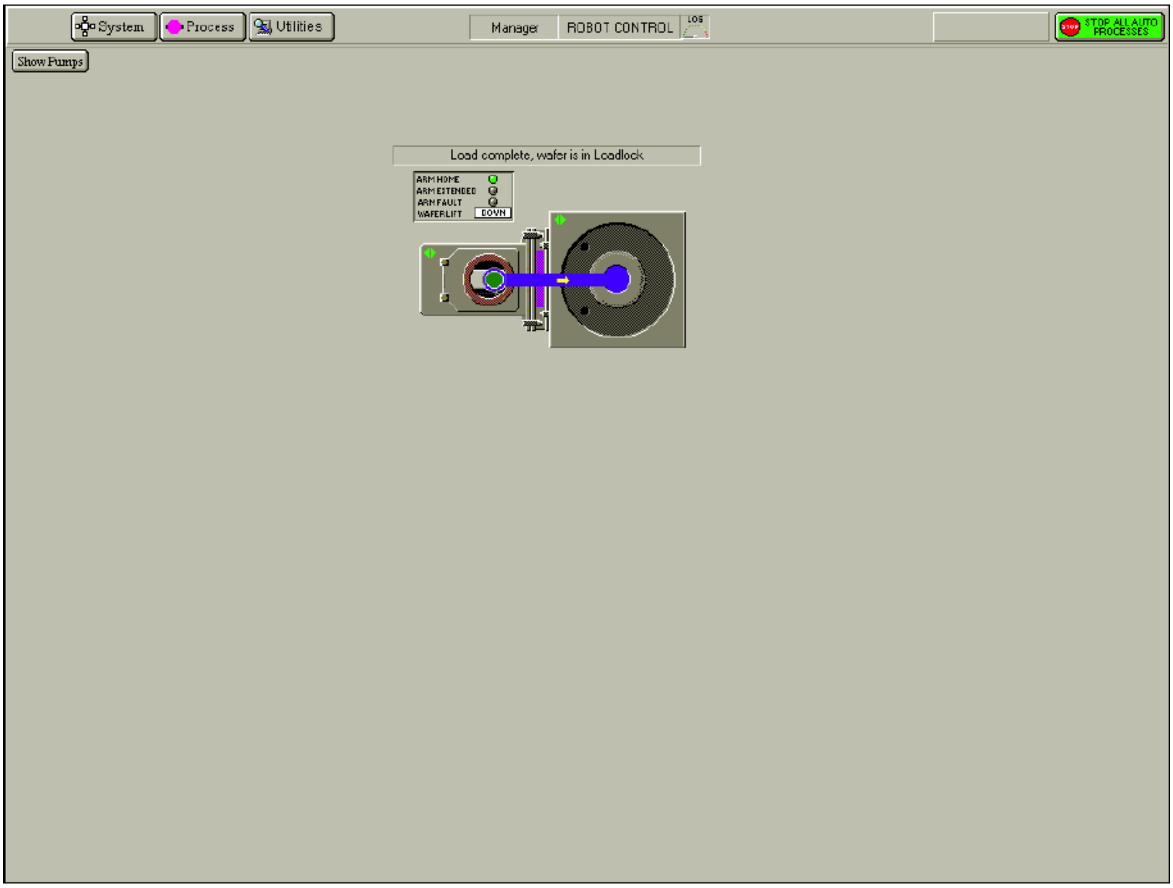


Figure 5-14 ROBOT CONTROL page

8 Click on the process chamber wafer mimic. The wafer is transferred from the automatic loadlock into the process chamber.

9 On the Process Control page, check that the set parameters are correct for the required process.

10 Before running a process which uses a precursor, ensure that the process pump purge is set to one minute on the TOLERANCES page (see **Section 5.5.2.1** and **Section 4.3.12**). This allows the precursor pod line sufficient time to settle before the process starts.

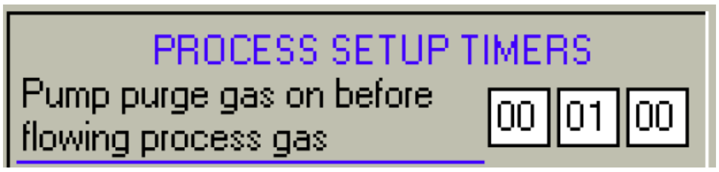


Figure 5-15 Process setup timers

11 Click the **START** button (see **Figure 5-12**). (If this button is not active, the chamber has not reached base pressure.) The process will commence.

12 To pause the process at any stage, click **PAUSE** on the Process Control page. This immediately switches off the plasma RF power and freezes the step time at its current value.

13 To re-start the process, click **PAUSE** again. This switches the plasma RF power on and re-starts the step timer from its current value.

NOTE: It is possible to change process parameters when the process is paused. However the changes do not take effect until the **START** button is pressed.

---

14 To stop the process, click **STOP** (see **Figure 5-12**). This causes the process to abort and resets the step timer to zero. The message **Process Complete** is also displayed. It is then possible to run the same process or a different process, if required.

Because this method of operation does not use a recipe, the **JUMP** button is not active.

15 When the **Process Complete** message is displayed, select the PUMP CONTROL page and move the wafer from the process chamber to the loadlock using the same method as the transfer in.

WARNING 5.12

TOXIC GASES

Contact can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Wear personal protective equipment as necessary.

16 Open the lid of the loadlock and remove the wafer.

17 If required, the system can now be vented, see **Section 5.6.4**.

5.5 Manager operation

A user with *MANAGER* privileges can perform the same functions as a user with *MAINTENANCE* privileges. Refer to **Section 5.4** for a description of these functions. This section describes the additional tasks that can only be performed by a user with *MANAGER* privilege.

5.5.1 Account setup and management

User accounts can only be created or amended by a person with *MANAGER* privilege. To add a new user, or to amend a current user's account, perform the following steps:

1 Log on as a *MANAGER* (see **Section 5.2.2**).

2 Click the **menu** icon.

3 Select the **User Log In** menu option. The Access Control dialogue opens. Notice that the **Edit Users** button is active because a user with *MANAGER* privileges is logged in.

4 Click **Edit Users**. The Edit User List dialogue opens.

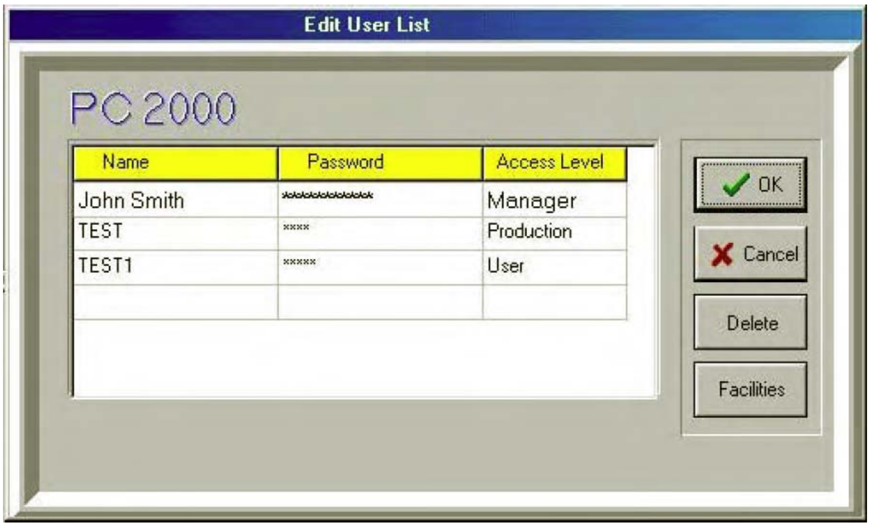


Figure 5-16 Edit User List

Refer to the following sections for instructions on creating, editing and deleting user accounts.

5.5.1.1 Creating a new account

To add a new user account:

1 Click the **Name** field in the first empty row in the table.

2 Type a name for the new user. The name can be of any length.

3 Click in the **Password** field and type a password for the new user. The password can be of any length and is case-sensitive. Make sure that you record the password for future reference.

4 Click on the **Access Level** field.

5 Select an access level for the new user from the drop-down list. The following options are displayed:

Quit
Grants the user the ability to view all pages and recipes but not to activate any controls. This user is not able to exit the PC2000 application.

View_Only
Grants the user the ability to view all pages and recipes but not to activate any controls. This user is able to exit the PC2000 application.

User
Grants the user a subset of all possible functions. This subset can be configured by the manager for each individual user name.

Production
Grants the user *PRODUCTION* mode access to the system.

Maintenance
Grants the user *MAINTENANCE* mode access to the system. This level of access has its own recipes and recipe steps. However it does not allow access to production recipes and steps, nor access to the system log.

Manager
Grants the user access to all possible functions.

6 If the access level is set to *USER*, click in the **Name** field and then click **Facilities** to set up the facilities for this particular user. The Edit User Facilities dialogue opens (see **Figure 5-17**).

Figure 5-17 Edit User Facilities dialogue

7 Check the appropriate boxes to grant particular facilities to this user. Once all of the required facilities have been selected, click **OK** to save the user facilities and close the dialogue.

NOTE: The enabled facilities are assigned to a particular user name, not to the USER access level in general. It is possible for two people with USER access level to have different sets of facilities enabled. Click **OK** in the Edit User List window to complete the action.

8 To check that the new account operates as expected, it is recommended that the manager should log off, then and log on as the newly added user.

5.5.1.2 Modifying an existing account

To modify the account of an existing user:

1 To change a user's password, click on the **Password** field and type a new password. Passwords are case-sensitive.

2 To change the access level for a user, click on the **Access Level** field. Then select an access level from the drop-down list.

NOTE: If the access level is changed from USER to another option, the customized set of facilities selected for the user is lost.

3 If the access level is set to *USER*, click **Facilities** to set up the facilities for this user. The Edit User Facilities dialogue opens (see **Figure 5-17**).

4 Check the appropriate boxes to grant particular facilities to this user. When all required facilities have been selected, click **OK** to save the user facilities and close the dialogue.

NOTE: The enabled facilities are assigned to a particular user name, not to the USER access level in general. It is possible for two people with USER access level to have different sets of facilities enabled.

5 Click **OK** in the Edit User List window to complete the action.

5.5.1.3 Deleting a user account

To delete the account for a user:

1 Click in the **Name** field of the user account that is to be deleted.

2 Check that the correct account has been selected for deletion.

Caution 5.9

DELETING MANAGER ACCOUNTS
Deleting all the *MANAGER* accounts permanently removes all account management capability. Take care not to delete all the *MANAGER* accounts.

3 Click **Delete**. This immediately deletes the selected user account from the window. There is no confirmation request once the **Delete** button has been pressed.

NOTE: If all the MANAGER accounts are accidentally deleted, contact Oxford Instruments Plasma Technology for advice.

4 If an account has been accidentally deleted, click **Cancel** to exit the window without saving the change.

5.5.2 System configuration

Users with *MANAGER* privilege can configure the PC2000 application.

5.5.2.1 Configuring system tolerances

The PC2000 application uses a list of parameter tolerances to decide when to raise a deviation alarm for a particular process parameter. The application also uses a list of times to control pumping and venting operations, and to decide when to raise certain timeout alarms.

A default set of process parameter tolerances and preset times is programmed into the PC2000 application at the factory. These tolerances and times may be edited by a user with *MANAGER* privilege, if required.

1 Choose **Tolerances** item from the System Menu. The TOLERANCES page opens (see **Figure 4-20**).

2 To change a tolerance or time, click in any field on the page and enter a new value. Then click **save** to save the changes. Refer to **Section 4.3.12** for a description of all the fields.

5.5.2.2 Configuring gas lines

Gas lines must only be configured if a process gas has been changed, of if a mass flow controller has been exchanged for one with a different flow range.

CAUTION
Altering the configuration of a gas line can cause process variations and possible damage to process wafers. Take care when changing mass flow controller values.
Caution 5.10

1 Open the Process Control page.

2 Click the MFC icon that is to be configured in the Process gas mimic. The **Gas Factor Editor** dialogue opens (see **Figure 5-18**).

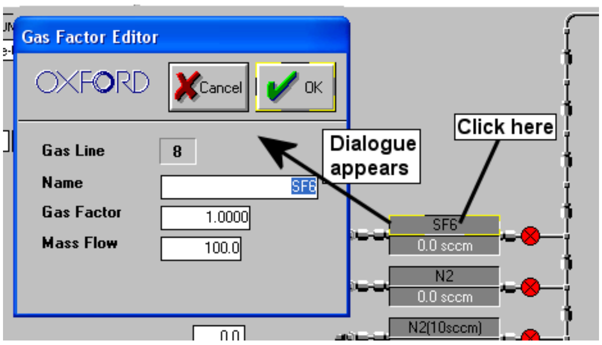


Figure 5-18 Configuring a process gas line

3 Click the value to be changed and enter a new value. The values have the following effect:

Name
The name of the process gas. Altering this value does not affect the operation of the gas line.

Gas Factor
Leave this set to 1.0.

Mass Flow
The full scale flow rate of the mass flow controller in sccm. This value must match the maximum flow rate that is marked on the body of the mass flow controller.

5.5.2.3 Configuring the entire system

The PC2000 application provides a page for configuring the software to match the system hardware (the **Interface** option in the Utility Menu). This configuration is performed at the factory and must only be changed by qualified Oxford Instruments Plasma Technology personnel.

5.6 Pumping, venting and opening the system

This section describes how to evacuate, vent, open and close the loadlock and process chamber. The information only applies to users with *MANAGER*, *SUPERVISOR*, *MAINTENANCE* or *USER* privilege.

5.6.1 Evacuating the loadlock

1 Choose **Pumping** from the System Menu. The PUMP CONTROL page opens.

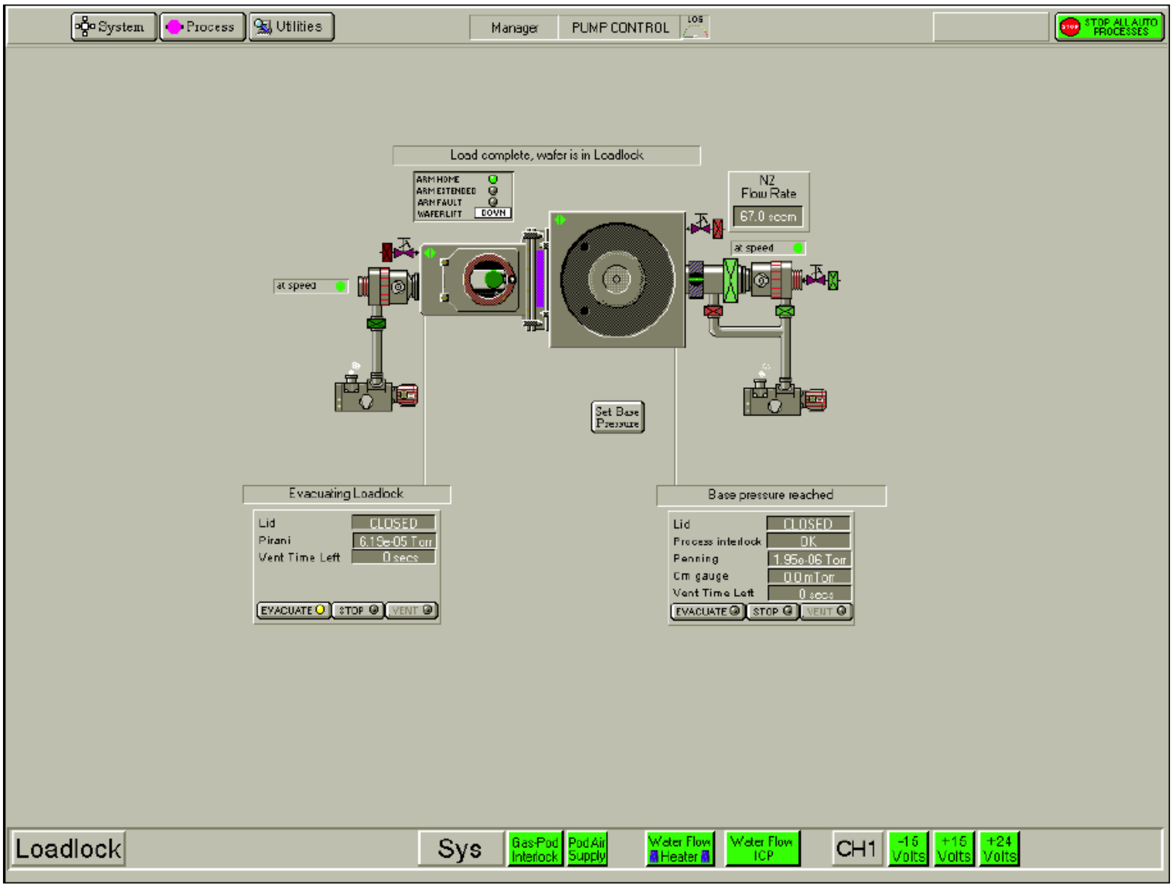


Figure 5-19 Typical PUMP CONTROL page

2 Check that the **Process interlock** field displays the message **OK**.

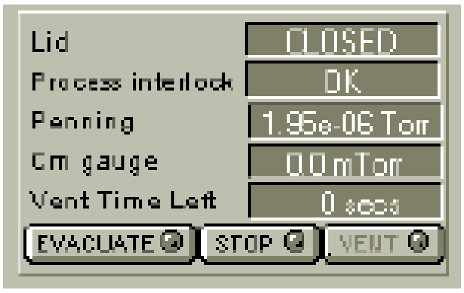


Figure 5-20 Process interlock field on PUMP CONTROL page

3 If it is intended to perform a manual or automatic process run, lift the loadlock lid and load the process wafer on to the transfer arm.

4 Close the loadlock lid.

5 Check that the **Lid** field on the PUMP CONTROL page indicates that the loadlock lid is **CLOSED**.

Figure 5-21 Indication of loadlock lid position on PUMP CONTROL page

6 Click **EVACUATE**. You are prompted for a wafer identity. If a process wafer has been loaded into the chamber, enter a wafer identity and click **OK**. If there are no wafers in the chamber, click **Cancel**.

The system now automatically actuates all the relevant valves to evacuate the loadlock to its specified base pressure.

7 When the base pressure has been reached, the loadlock status field on the PUMP CONTROL page displays the message **Base pressure reached**.

5.6.2 Venting the loadlock

1 Choose **Pumping** from the System Menu.

2 On the PUMP CONTROL page, select the **STOP** button then the **VENT** button for the loadlock. The vent sequence is controlled by a timer to allow time for the turbo pump (if fitted) to spin down.

3 When the **Vent Time Left** timer has decremented to zero, the loadlock pump has been switched off automatically, and the loadlock has been vented.

4 Check that the loadlock **Vacuum Status** field on the PUMP CONTROL page displays the **FAULT** message, which indicates that the loadlock vacuum switch has changed state.

5 Open the loadlock lid, if required.

The vent valve remains open for a short time after the loadlock is opened to ensure that the system has fully vented.

5.6.3 Evacuating the process chamber

1 Choose **Pumping** from the System Menu. The PUMP CONTROL page opens (see **Figure 5-19**).

2 Check that the **Process interlock** field displays the message **OK**.

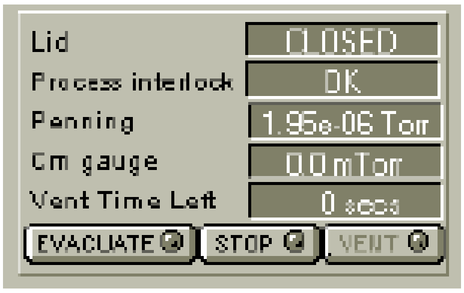


Figure 5-22 Process interlock field on the pumping page

3 Close the process chamber lid.

4 Check that the **Lid** field indicates that the process chamber lid is closed (see **Figure 5-22**).

5 Click on the **Base Pressure** field.

6 Enter the required process chamber base pressure in Torr, if it is different to the displayed value.

7 Click **EVACUATE**. The system now automatically actuates all the relevant valves to evacuate the process chamber to its specified base pressure.

8 When the base pressure has been reached, the status field on the PUMP CONTROL page displays the message **Base pressure reached**.

5.6.4 Venting the process chamber

See **Section 5.2.4** for an explanation of the various procedures for venting the process chamber.

5.7 Creating and editing recipes

A recipe consists of one or more process steps that are automatically executed in sequence. The RECIPES page is used to assemble and store all the set points and instructions which make up a recipe for an automatic or production run (see **Figure 5-23**). Only users with *MANAGER*, *MAINTENANCE* or *USER* privilege can create recipes.

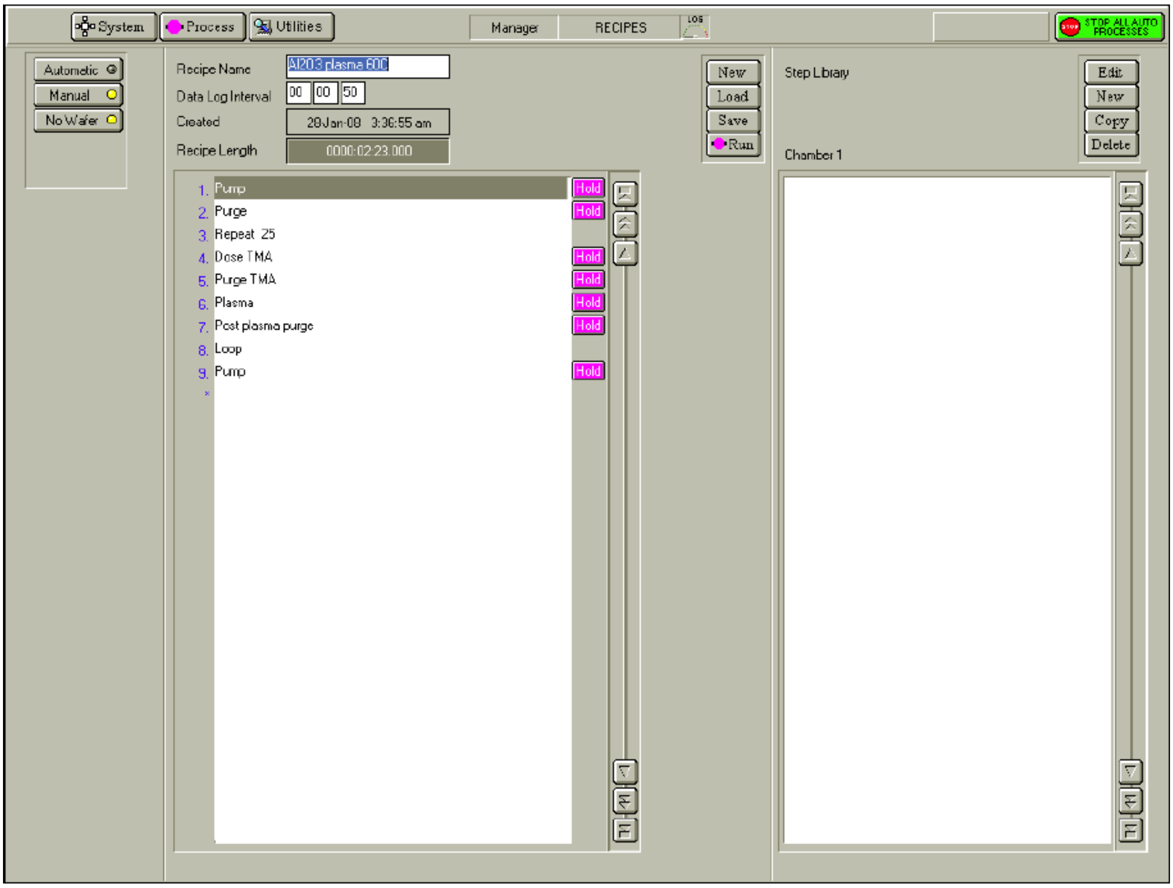


Figure 5-23 Recipes page

A recipe consists of a sequence of individual process steps, each of which runs for a programmed time.

A recipe is created by selecting recipe steps from the step library by using a drag and drop feature. Refer to **Section 5.7.4** for information on creating new recipe steps for the library.

NOTE: Personnel who create recipes must make sure that they understand the operation of key components of the system to ensure that recipes proceed as expected.

5.7.1 Recipe creation features

Recipes are created by assembling existing recipe steps and can be edited as required. Steps can be manipulated by using the editing buttons in the **Step Commands** pop-up panel. Click in the Recipe step list to open the panel (see **Figure 5-24**)

Figure 5-24 Recipe editing buttons

The recipe editing buttons provide the following options:

Edit Step
Enables the selected (highlighted) step to be edited.

Repeat Step
Repeats all subsequent steps until a **Loop** step is reached. This group of steps can be repeated any number of times. (When you select this option, you are prompted to enter the number of times the group of steps is to be repeated.)

Loop Step
Terminates a repeat step group.

Insert Step
Creates an empty row above the selected step to allow another step to be dragged into the list.

Delete Step
Deletes the selected step from the list.

Cancel
Closes the Step Commands pop-up panel.

5.7.2 Creating a new recipe

1 In the **Recipe** panel, click **New**.

2 Click a recipe step in the **Step Library** list. Then hold down the left mouse button, drag the mouse pointer to the **Step Name** field next to the asterisk (*), and release the mouse button. The step name is displayed in the **Step Name** field.

3 If desired, the recipe step can be edited, as described in **Section 5.7.3**. For example the step time or any of the process parameters can be changed.

4 Continue dragging recipe steps into the recipe as required until the recipe is complete. When the **Step Name** field has been filled, the recipe step list can be scrolled. This allows a maximum of 1000 steps to be added.

5 To remove a step from the list, click on the step to highlight it, then click **Delete Step**. All subsequent steps ascend the list by one place to fill the gap that has been created.

6 To insert a step before an existing step, click on the existing step, then click **Insert Step**. The selected step, and all succeeding steps, ascend the list by one place. Another step can then be dragged from the **Step Library** list into the vacant row.

7 When all steps have been added, enter the required data log interval time into the **Data Log Interval** field.

8 Type a name for the recipe in the **Recipe Name** field. The name should contain enough information so that the recipe can be identified without examining the steps it contains.

9 Click **Save** to save the recipe.

5.7.3 Editing an existing recipe

1 Click **Load** and select the recipe to be edited from the list that appears.

2 Highlight the step to be edited in the recipe.

3 Click **Edit Step** in the Step Commands panel and edit the process parameters as required. Note that editing a step in a recipe does not affect the corresponding step in the library.

4 To remove a step from the recipe, click on the step to highlight it, then click **Delete Step**. All subsequent steps ascend the list by one place to fill the gap that has been created.

5 To add a step before an existing step, click on the existing step and click **Insert Step**. The selected step, and all succeeding steps, descend the list by one place. You can then drag another step from the **Step Library** list into the vacant row.

6 If desired the recipe can be saved with a different name to preserve the original version.

5.7.4 Creating a new recipe step

1. In the **Step Library** panel, click **New**. The **Step Edit** page opens.
2. Enter the step parameters as required, then click on OK. The step is automatically saved.).

5.7.5 Editing an existing recipe step

1. In the **Step Library** panel, highlight the recipe step to be edited and click **Edit**. The **Step Edit** page opens, showing the parameters of the existing recipe step.
2. Edit the process parameters as required, then click **OK** to store the changes. This action overwrites the existing recipe step in the step library. However, any existing recipes that use this recipe step are not updated with the changes.

5.7.6 Copying an existing recipe step

1. In the **Step Library** panel, highlight the recipe step to be copied and click **Copy**. The Copy Step window opens.
2. Type a name for the new recipe step to be created.
3. Click **OK**. A copy of the existing recipe step is added to the step library.
4. If desired, the new recipe step can now be edited as described in **Section 5.7.5**.

5.8 System alerts

This section applies to all users.

A system alert is displayed when the PC2000 application detects an event that requires the attention of the user. Each alert is automatically categorized depending on its severity and the level of response required by the user. Details of the three possible alert categories are shown in **Table 5-1**.

Table 5-1 System alert categories

Alert Category	Description	Example	Action
Blue	A warning. This indicates that a service parameter is out of tolerance but the process is continuing.	Low flow of cooling water.	Resolve the issue as soon as possible. If necessary pause the process after the current wafer has completed.
Yellow	Hazard.	Not currently used.	
Red	A process abort. This indicates that a fault is so severe that the process must be aborted.	High reflected RF power.	Resolve the issue immediately.

A typical system alert is shown in **Figure 5-25**.

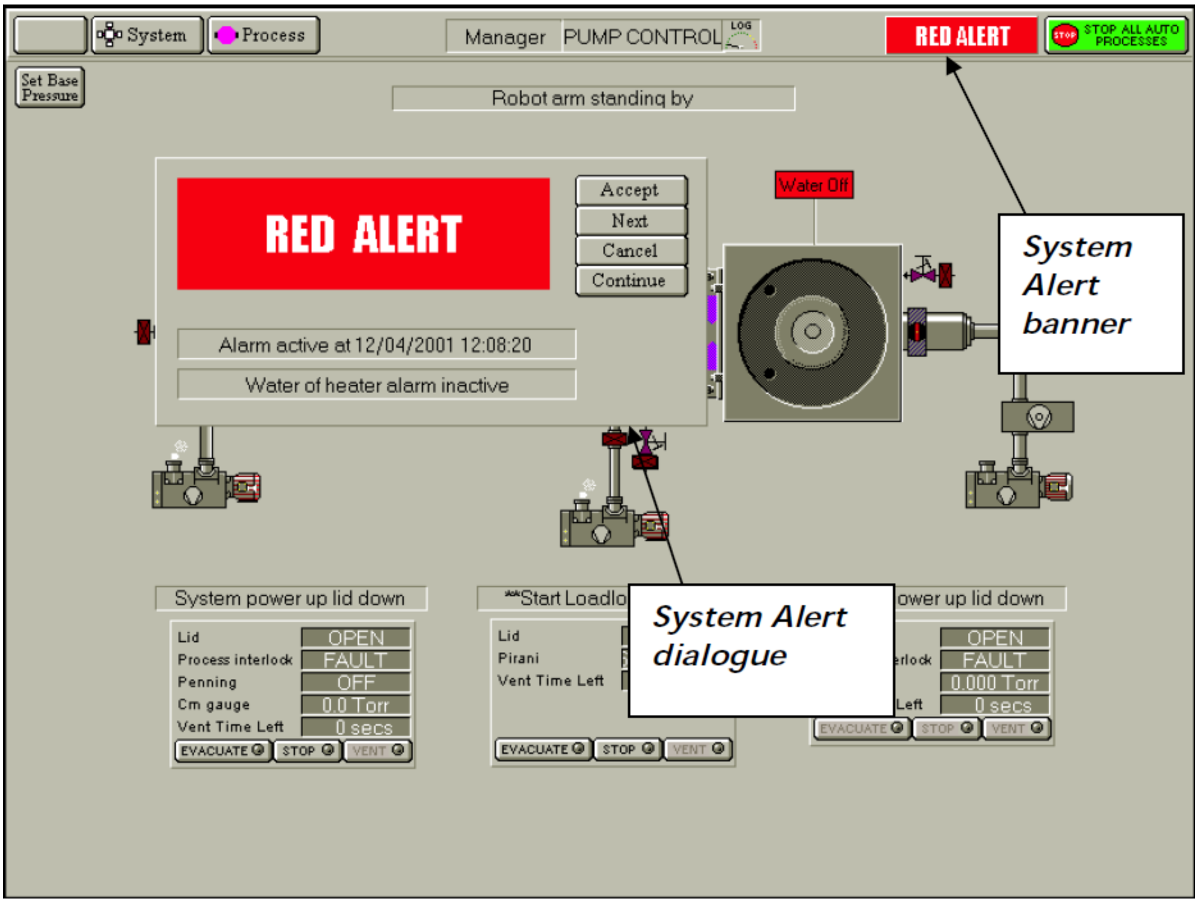


Figure 5-25 Typical system alert

Observe the following features:

- The system alert banner remains active as long as there is one or more active alert.
- The system alert dialogue shows details of the alert and provides possible actions that can be taken.

5.8.1 Responding to an alert

A user logged in at any access level can close the alert dialogue, but only a user logged on as a system *MANAGER* can clear the alert banner from the menu bar.

The possible actions presented by the dialogue are given in **Table 5-2**.

Table 5-2 Possible responses to an alert

Button	When Active	Resulting Action
Accept	Available to system managers only.	Clears the alert and logs it.
Next	Available only when more than one alerts is active.	Displays the next alert.
Cancel	Available to system managers only.	Closes the alert but does not log it.
Continue	Always.	Closes the alert dialogue. The alert banner remains active.

The alert message contains a description of the event that caused it. If the cause is a service fault (e.g. wafer flow, gas pressure, etc.), resolve the issue as soon as possible. Depending on the severity of the fault, it may be possible to continue the current process with the fault present. Do not start a new process until the fault has been completely resolved.

A red alert usually indicates that a process parameter has been out of tolerance for too long. This causes the process to pause automatically.

5.9 Loss of services

This section applies to all users and describes how ALD **FlexAL**® responds to the loss of one or more services. Refer to **Chapter 8** for troubleshooting and repair information.

5.9.1 Loss of electrical power

If all electrical power is lost, the following events occur:

- The process run stops.
- All vacuum pumps stop.
- All pneumatic valves close.

If only one phase of the three phase electrical supply is lost, the following events occur:

- The process aborts.
- The backing pump stops.
- All pneumatic valves close.

NOTE: If the phase powering the system controller remains live, then the controller retains the current system status.

5.9.2 Loss of compressed air

If the system compressed air supply is lost, the following events occur:

- All pneumatic gas and vacuum valves close. As a result all flow of process gas is stopped and the chamber is isolated from the vacuum pumps.
- RF power is turned off as soon as the loss of gas flow is detected. This usually occurs within five seconds.
- Loadlock wafer transfer valves are in an undefined state.
- Rotational movement of the air-operated 4-way loadlock stops (if this item is fitted).

5.9.3 Loss of cooling water

If the system cooling water supply is lost, the following events occur:

- A blue level alert is raised.
- If the water flow is lost for an extended time, vacuum pumps may shut down due to their internal temperature alarms. This will cause any process that is running to abort.

5.9.4 Loss of turbo pump nitrogen purge

The nitrogen supply to the turbo pump purge is monitored by a flow meter. If the nitrogen pressure is lost, the following events occur:

- The process aborts.
- All pneumatic valves close.
- A red alert is displayed.

NOTE: It is important that the turbo pump purge supply is separated from the chamber vent supply. If the pressure of the turbo pump purge supply fluctuates when the chamber vent valve opens, this interlock could be triggered.

5.9.5 Loss of process gas

The failure of a particular process gas is detected when the relevant mass flow controller can no longer maintain the demanded gas flow. If this happens, the following events occur:

- The active process is paused and the plasma power is turned off.
- All gas flows remain active.

NOTE: If the gas supply is restored, then the process resumes automatically.

5.9.6 Failure of a vacuum pump

An auxiliary electrical circuit in the power box detects pump failure caused by overload or a short circuit. If this happens, the following events occur:

- The process is aborted.
- All process gas valves are closed.

It is possible that a vacuum pump could stop for some reason that does not trigger the auxiliary circuit. In this case, the following events occur:

- The process is aborted.
- Gas continues to flow into the chamber until the vacuum pressure exceeds 600 mbar. Then all gas flows are shut down.
- The system controller shows the interlock status as **fault**.

5.10 Datalog pages

This section only applies to users with *MANAGER*, *MAINTENANCE* or *USER* privilege.

All processes run on the **FlexAL**® system are automatically data-logged. The interval between logging events is set in the recipe, using the RECIPE page (see **Section 5.7.2**).

System events, such as alerts, are also automatically logged.

There are two types of log files that are stored on the PC:

Process log
This log stores data logged from process runs.

System log
This log stores details of events and alerts that have occurred.

This section describes how to view datalog data.

5.10.1 Viewing process log data

The Process Datalog facility allows you to view process data runs and associated comments. Refer to **Section 4.3.13** for detailed information on the log fields and functions.

5.10.1.1 Viewing a log

1 Choose **Log View** from the Process Menu. The SELECT LOG page opens (see **Figure 4-22**).

5.10.1.2 Running a log

1 With the SELECT LOG page open, clicking **View Run** while any process other than a leak detection run or MFC calibration run selected. The RUN LOG page opens (see **Figure 4-23**).

5.10.1.3 Running a leak detection and MFC calibration log

1 With the SELECT LOG page open, choose a leak detection run or an MFC calibration run and click **View Run**. The Leak Detection and MFC Calibration Log page opens (see **Figure 4-24**).

5.10.1.4 Saving a log file as text for use in another application

---

NOTE: OIPT now supplies customers with comprehensive software to view or analyse PC2000 log files. The software, LogViewer, is provided on the system PC. For full details of LogViewer, refer to its manual by following the shortcut on the desktop of your system PC.

Any logged process run can be saved at text and then opened in Microsoft® Excel® for viewing, analysis, etc.

1 On the Select Log page, select the required process run (any multiple steps will be automatically highlighted).

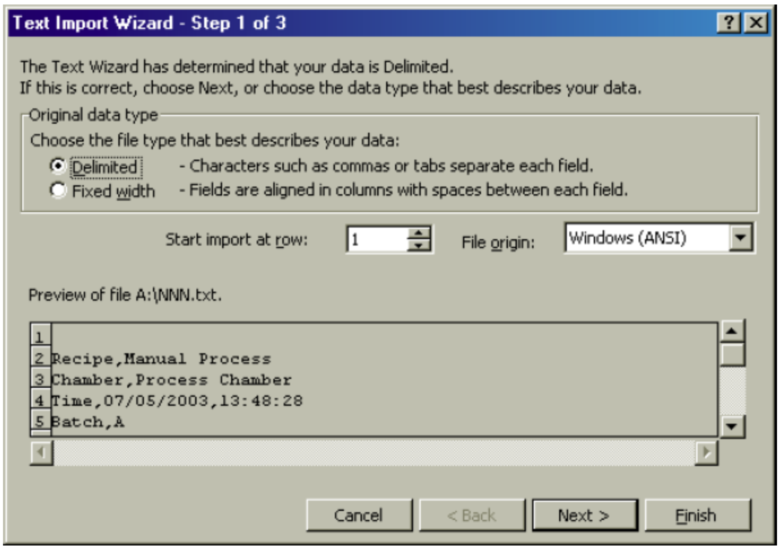
2 Click **Save As Text**. The Save As dialogue opens.

3 Navigate to the target location for the log text file, enter a filename and, in the **Save as type:** field, choose **Log Text Files (*.Txt)** from the drop-down list. If saving to a CD, label it and insert into the drive now.

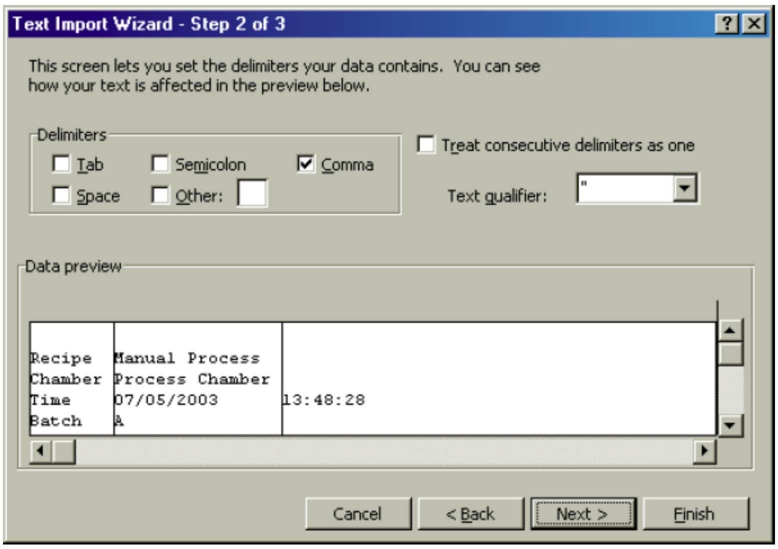
4 Click **Save**. The text file is saved in your chosen location.

5 Start Excel and then in the File menu, select the **Open** option. The Open dialogue is displayed.

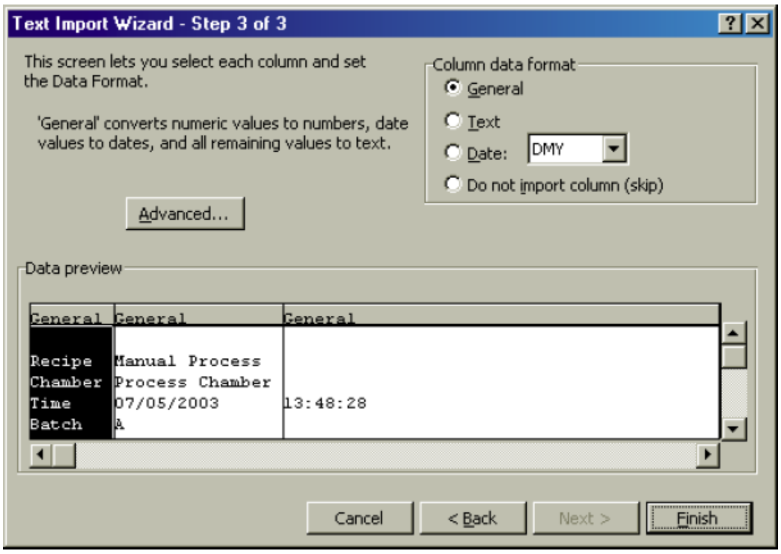
6 Navigate to the location of the saved text file and in the **Files of type:** field, select **All Files (*.*)** from the drop-down list. Select the required text file and then click **Open**. The first dialogue of the Text Import Wizard opens.



7 In the **Original data type** panel, click the **Delimited** radio button, then click **Next**. The second dialogue of the Text Import Wizard opens.



8 In the **Delimiters** panel, select the **Comma** checkbox, then click **Next**. The third and final dialogue of the Text Import Wizard opens.



9 In the **Column data format** panel, ensure that the **General** option is selected, then click **Finish**. The process run log data is now displayed in the Excel worksheet.

10 Adjust the column widths so that all text is visible and then save the spreadsheet.

5.11 Operator adjustments

5.11.1 Adjusting the nitrogen regulator outlet pressure

NOTE: Refer to **Section 2.8.1** for a description of the nitrogen vent distribution circuit.

The regulator outlet pressure should not usually require adjustment from its factory setting. However, if adjustment is necessary, proceed as follows.

WARNING 5.13

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. This procedure requires the removal of covers or panels with electrical power applied to the system. This procedure must only be performed by authorised personnel who are aware of the hazards involved.

1 Remove system panels as necessary to gain access to the regulator.

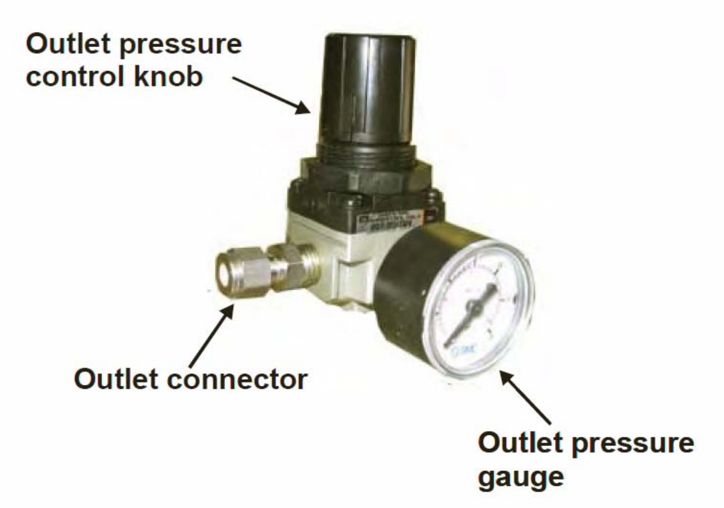


Figure 5-26 Nitrogen pressure regulator

2 Adjust the regulator outlet pressure control knob to set the outlet pressure to the maximum which will not open the check valve; normally 0.5 to 0.7 bar gauge as indicated on the regulator gauge.

NOTE: Setting the outlet pressure too low will extend system venting times excessively, and may compromise the purge gas flow to the turbo pump if fitted. Setting the outlet pressure too high will open the check valve and waste gas, but will not reduce venting times.

3 Refit all system covers.

4 Carry out a simple process to check that the vent sequence operates correctly.

5.11.2 Adjusting the purge flow rate of the backing pump

NITROGEN PURGE
If the rotary/dry pump's N_2 purge flow rate is inadequate, damage to the pump could occur. Ensure that the flow rate is set to the value recommended by the pump manufacturer.

Caution 5.11

The N_2 purge flow rate of the rotary/dry pump is set at the factory before system shipment and should not need adjustment. However, the pump purge rate must be confirmed on installation, and at any time the purge gas supply pressure changes significantly.

5.11.2.1 Setting the required purge flow rate of rotameters

The following procedure is for setting N_2 purge flow rates for pumps. A similar procedure can be used for other applications, e.g. etch cleaning, glove box purging, etc.

The rotameter scale is graduated in the range 0 to 6. These graduations do not represent flow rates in sccm or slpm. To set the required flow rate, use the following procedure:

1 Refer to the pump manufacturer's literature or to the relevant OIPT installation data document to obtain the required N_2 flow rate.

2 Check the tube number (marked on the rotameter tube). Then refer to the relevant graph in **Figure 5-27** and note the required scale reading.

3 Ensure that the N_2 supply meets the mandatory requirements for nitrogen supplies as stated in the OIPT services specifications document.

4 Adjust the flow-setting knob of the rotameter so that the centre of the ball float is aligned with the required scale reading.

Rotate the knob in the counter-clockwise direction to increase flow.

Rotate the knob in the clockwise direction to reduce flow.

Graphs of flow rate versus rotameter scale readings

Refer to the following graphs when setting a rotameter.

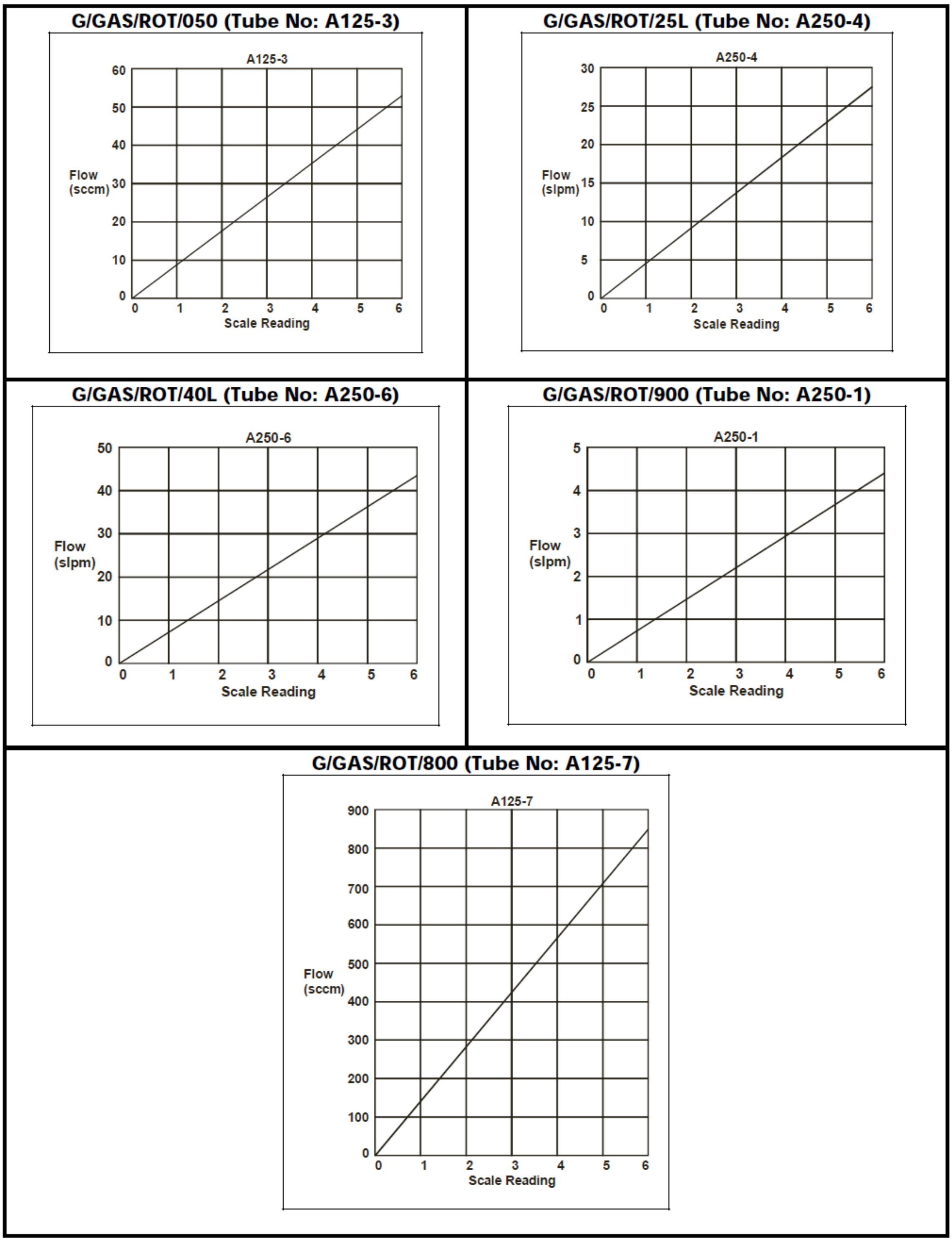


Figure 5-27 Rotameter calibration graphs

5.11.3 Adjusting the AMU

WARNING 5.14

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. The following procedure involves working with the panels removed, and must only be performed by authorised personnel who are aware of the hazards involved.

5.11.3.1 DC bias/peak-to-peak switch setting

The **DC bias/Peak-to-peak** switch is located on the front panel of the AMU (see Figure 2-8). The switch selects one of two sensing output signals from the AMU.

DC bias

This switch setting is the default position. The output is a scaled DC voltage proportional to the RF-induced self-bias on the electrode, sometimes called the DC bias. This is a negative offset voltage on the electrode with respect to ground, which is inverted and conventionally referred to as a positive value, typically within the range 100 V DC to 600 V DC. Normal scaling can read up to 1000 V DC. This signal is read by the software with correct scaling on OIPT tools.

Peak to peak

The output is an unscaled DC voltage related to the peak-to-peak value of the RF signal at the output of the automatch. This can be useful when the scaled DC bias is inaccessible, for example if the electrode has no DC contact to the plasma because a quartz carrier plate masks the entire electrode. The value displayed on the PC screen is arbitrary, not a true peak-to-peak value, but can still be a useful monitor.

NOTE: The software has no knowledge of the switch setting and is scaled only for the DC bias setting.

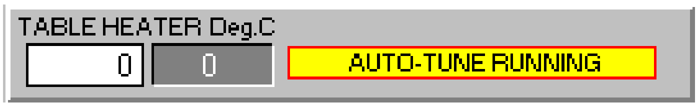
5.11.4 Setting up the autotune of the temperature controller

The table heater is controlled by a proportional integral derivative (PID) loop via the PLC. To set the table heater temperature, an auto-tune set-up software sequence is carried out.

The temperature controller auto-tune is set up by OIPT prior to system shipment. However, if required, it can be done by using the following procedure.

NOTE: The temperature controller auto-tune set-up procedure takes between one hour and one hour twelve minutes to complete.

1 On the Process Control TABLE HEATER panel of the Process Control page, enter the heater setpoint into the data field. For the PID to auto-tune, the value entered must be 80 to 100 degrees higher than the actual temperature.



2 On the Process Control page, click the **START** button and then the **STOP** button to download the setpoint to the PLC.

3 Choose **Services** from the System Menu to open the SERVICE MODE page.

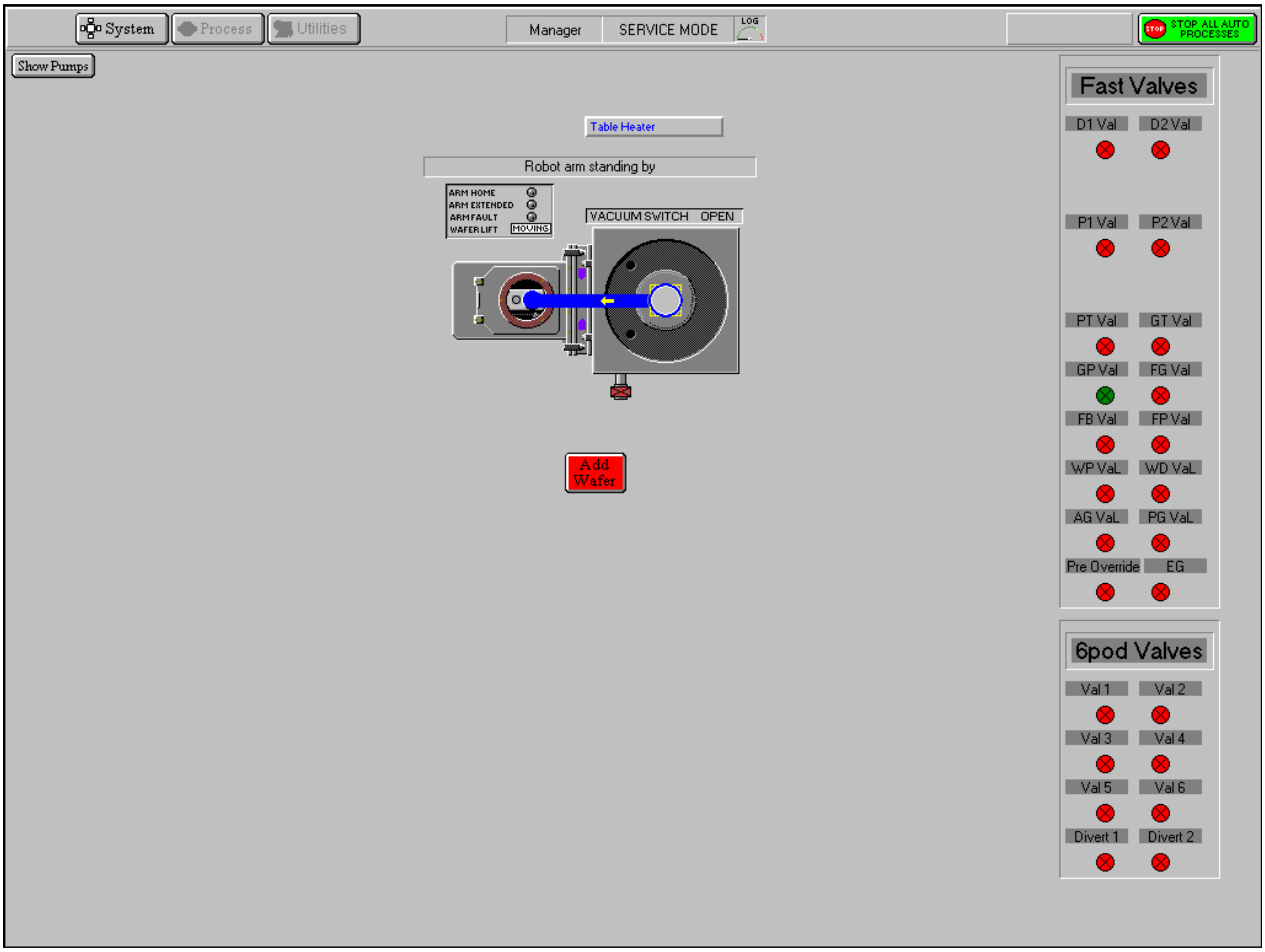


Figure 5-28 Typical SERVICE MODE page showing Table Heater button

NOTE: Once the auto-tune sequence has been started, it cannot be stopped except by switching the system off.

4 Click **Table Heater**. A confirmation prompt opens.

5 Click **Yes**. The message **CALIBRATION STARTED** opens.

6 Exit SERVICE mode.

7 Choose **Chamber 1** from the Process Menu. The Process Control page opens. In the TABLE HEATER panel, the message **AUTO-TUNE RUNNING** is displayed. The actual temperature value will increase towards the set-point value. On completion of auto-tune, the message **HEATER READY** is displayed (this will take approximately one hour to one hour and twelve minutes).

NOTE: If the water flow switch or thermo snapswitch (if fitted) fail while auto-tune is running, the message **HEATER FAIL** will be displayed. If this occurs, investigate and fix the fault and then re-start this procedure from step 1.

If the water flow switch or thermo snapswitch (if fitted) fail temporarily during heating (i.e. when **HEATER READY** is displayed), the message **PLEASE TUNE ME** will be displayed. When the flow switch/snapswitch recover, the **HEATER READY** message is displayed again. The heater is again ready for use – do not re-tune the heater.

5.12 Service mode

SERVICE mode allows low level operation of the system, and is used during certain maintenance activities. *SERVICE* mode can only be accessed by personnel with *MAINTENANCE* or *MANAGER* login level.

All personal safety interlocks are still active in *SERVICE* mode, but many equipment interlocks are not active. It is the user's responsibility to determine that a particular operation will not cause equipment damage before initiating it.

5.12.1 Accessing service mode

To access *SERVICE* mode:

1 Login as a user with *MAINTENANCE* OR *MANAGER* privilege.

2 Choose **Service** from the System Menu. The SERVICE MODE page opens (see **Figure 4-18**).

> **Caution 5.12**
>
> **SERVICE MODE**
> *SERVICE* mode allows direct access to low level machine functions. Incorrect use of *SERVICE* mode can cause damage to process wafers or to the system hardware. Only use *SERVICE* mode if you have a suitable level of training and experience.

3 Click any item on the page to allow direct control. A confirmation dialogue opens to confirm that the state of the selected item is to be changed.

4 Moving the mouse pointer over the item that you want to adjust. A box is displayed around the item, indicating that it can be manually controlled.

Manual control of the following items is available. Confirmation is requested before any action is carried out:

Process chamber wafer lift.

Process chamber vent valve.

Process chamber turbo pump.

Process chamber gate valve.

Process chamber APC valve.

Process chamber roughing valve.

Process chamber isolating valve and purge valve.

Process chamber rotary vane/dry pump.

Automatic load lock isolating valve.

Automatic load lock vent valve.

Automatic load lock rotary vane/dry pump.

Slit valve.

NOTE: The **Table Heater** button is used to calibrate the table heater PID controller. As this has been carried out during final test of the system before shipment, it should not need re-calibration. However, if a message is displayed indicating that table heater calibration is required (during system operation), refer to **Section 5.11.4**.

The Fast Valves panel provides control of the individual fast valves – click on a valve to open it – its colour will change to green.

5.12.2 Transferring wafers in service mode

Perform the following steps to transfer wafers between chambers in service mode:

1 Click on the wafer mimic in the loadlock or process chamber. The following page opens:

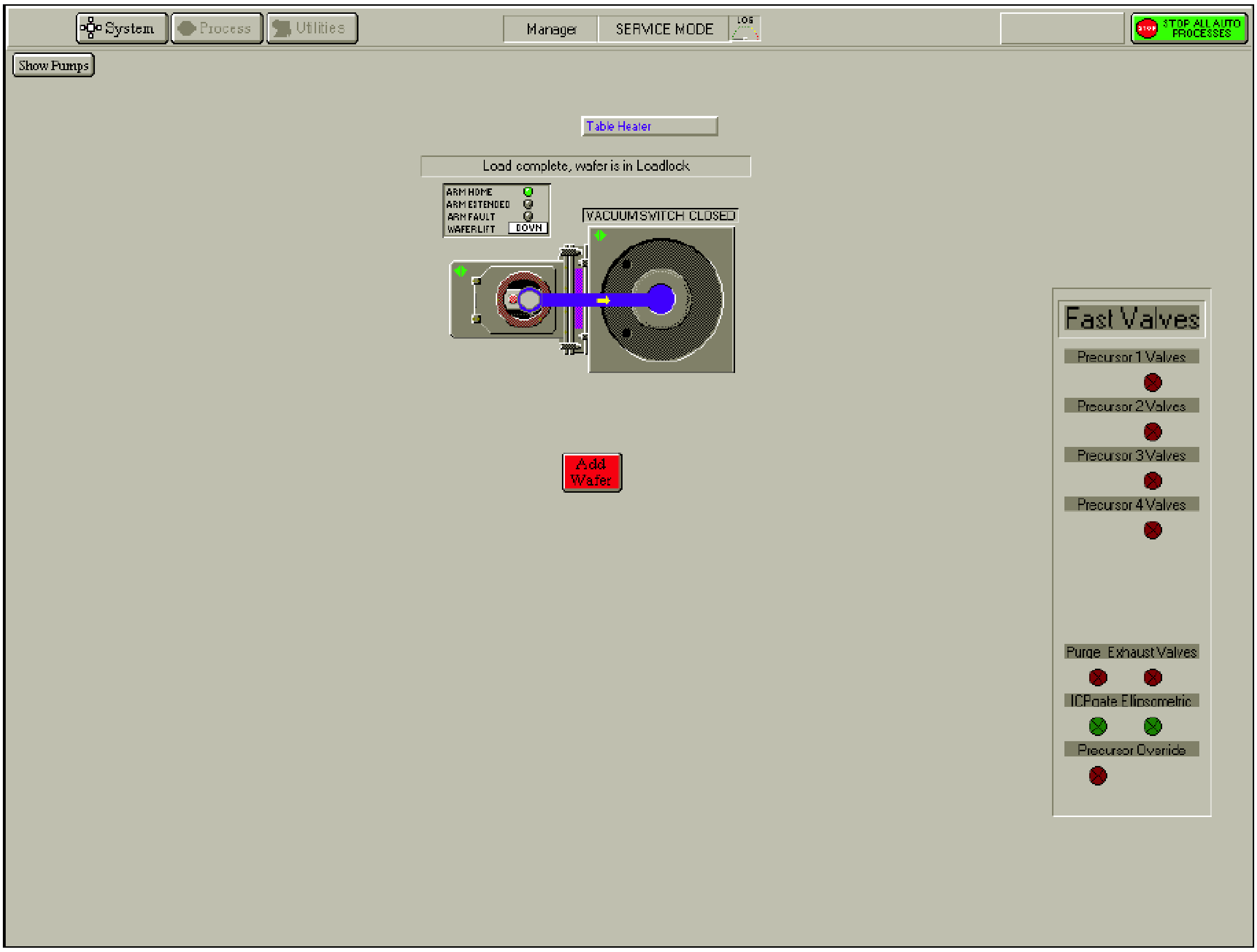


Figure 5-29 Wafer transfer in service mode

2 Click on the wafer destination. The wafer will be transferred.

5.12.3 Exiting service mode

1 Confirm that the system is in a suitable state to exit *SERVICE* mode.

2 Choose **Exit** from the System Menu.

3 A confirmation dialogue opens.

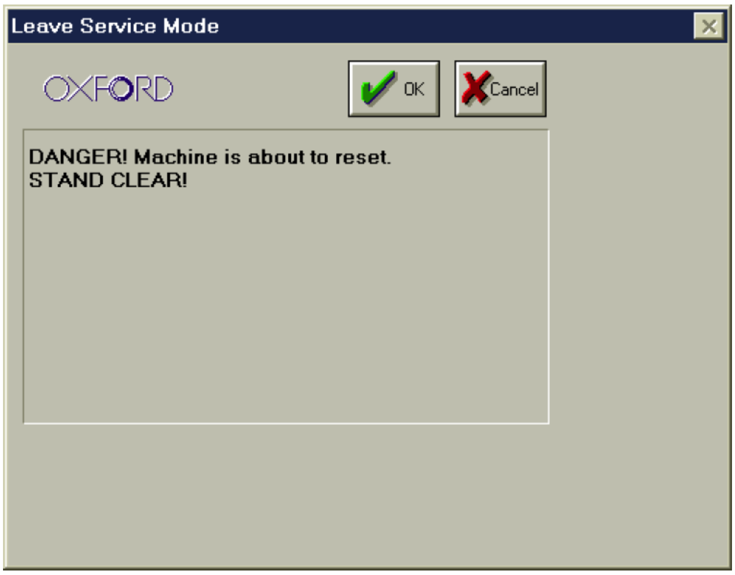


Figure 5-30 Exiting service mode dialogue

4 Click **OK** to exit *SERVICE* mode.

5 Click **Cancel** to remain in *SERVICE* mode.

After exiting from service mode, the system configuration will depend on which service mode facilities were used as follows:

a) If no service mode facilities were used, e.g. no valves were open or closed; the system configuration will be the same as it was before entering service mode.

b) If the service facilities were used, the system configuration will depend on which of the facilities were used as follows.

To prevent damage to the system, any chamber which had any of its features altered in SERVICE mode, e.g. valves opened/closed, pumps turned on/off etc., will have its pumping stopped. All other chambers will continue to be pumped.

To return the chamber which had its pumping stopped to the pumping or vent state, click on the associated **STOP** button, and then on the **EVACUATE** button or the **VENT** button as required. The chamber will then pump down or vent.

5.13 Log files

While PC2000 is running, two log files are maintained, one for the system log and the other for the data log. These files are stored on your hard disk in the folder **C:\Optsyslg**. Details of the log files are as follows.

System log file
The filename for this file is of the form s0Caabb where aa represents the month, e.g. 06 (for June) and bb represents the day of the month, e.g. 11 (for the eleventh day).

Data log file
The filename for this file is of the form p1caabb where aa represents the month, e.g. 06 (for June) and bb represents the day of the month, e.g. 11 (for the eleventh day).

When PC2000 is shut down correctly (select the System Menu, then the Exit option), both log files are automatically saved and closed. If PC2000 is then started again, the files are automatically opened and their data is available via the System Log page and the Select Log Data page.

If PC2000 is not shut down correctly, e.g. the PC is switched off or the PC hangs etc., one or both of the log files can become corrupted. If this happens, the next time PC2000 is started the corrupt log file(s) will be detected and reported on-screen by an error dialogue. To correct this problem, use the following procedure:

1. Close PC 2000.
2. Use Windows Explorer to navigate to **C:\Optsyslg**.
3. Delete the reported log file.
4. Re-start PC2000.

5.14 Operating the PDMs

5.14.1 Overview of precursor operation

FlexAL systems can include a six-way precursor cabinet. Systems may also include up to two single-precursor ovens. The operation of these two units is different and is described separately.

5.14.1.1 Important notices

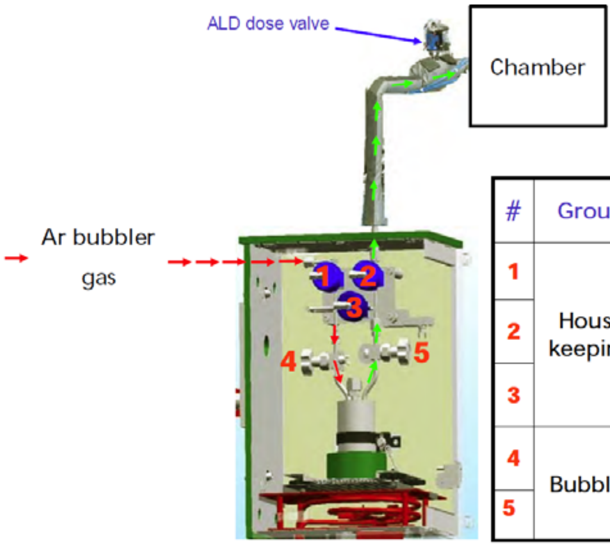
The following notices must be read and understood.

- This is a general recommended procedure that is used by Oxford Instruments Plasma Technology.
- When considering health and safety procedures at other sites the, advice contained within this manual must be carefully reviewed to determine its applicability and adjusted accordingly.
- This manual does not cover additional PPE that may be required to perform this operation under local regulations and for specific precursor types.
- This manual is written with typical ALD precursors in mind. It must always be reviewed for non-standard precursors.
- OIPT engineers are not trained in the health and safety procedures in place at a particular customer site and are not authorised to perform these operations. They can however offer advice to aid understanding. If in doubt, please contact OIPT.

5.14.1.2 Definition of terms

Important definitions used in the following procedures:

Manual ampoule valves (see **Figure 5-31**)
These are supplied as part of the ampoule. They are usually rotating handle valves.



Valve nomenclature

#	Group	Valve Name	Operated by
1	House keeping	Inlet	Pneumatic
2		Outlet	
3		Cross purge	
4	Bubbler	Inlet	Manual
5		Outlet	

Figure 5-31 PDM module valve nomenclature

Ar bubbler mfc
This mfc is located inside of the main system frame; although it is controlled from the gas pod electronics.

Ar purge mfc
This mfc is located inside the main system frame; although it is controlled from the gas pod electronics.

Bubbler
A precursor ampoule with two connectors. The inlet pipe (dip tube) extends almost to the bottom of the container and is used to bubble argon through a low vapour pressure liquid or solid to increase vapour transport to the chamber (rather like blowing air through a straw into a drink) (see **Figure 5-32**).

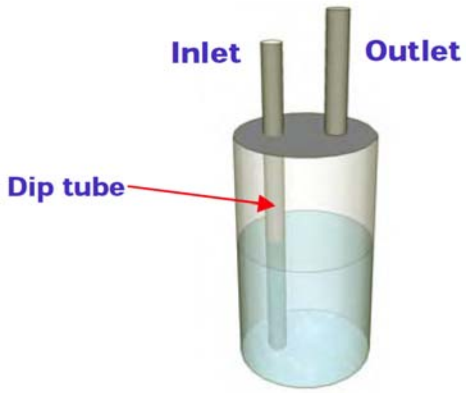


Figure 5-32 PDM bubbler

Precursor Pot or ampoule
A generic term to describe a container of precursor that may be a bubbler or a single outlet canister.

5.14.1.3 Using ALD precursors

Unknown precursor operating temperature

Precursor operating temperatures are described in the process conditions sheet. If a precursor operating temperature is not known, refer to **Figure 5-33** and perform the following steps to decide how to operate the precursor:

1. Contact the precursor manufacturer to gain as much information as possible about the precursor vapour pressure and decomposition rates with respect to temperature.
2. If using the precursor in bubbler mode, set the ampoule temperature to produce a vapour pressure of less than 0.1 Torr. Ensure that the selected temperature is well below the decomposition temperature of the precursor. If this condition cannot be satisfied, the precursor is deemed to be unstable (see below).

3 Set the temperature of the delivery pipe-work between 10°C and 20°C higher than the temperature of the liquid reservoir.

NOTE: It is important that the liquid source is the coolest part of the delivery system. If any part of the vapour delivery system is cooler than the liquid source, liquid precursor will condense there. This can block the pipe.

4 Referring to **Table 5-3**, select a delivery method for the precursor.

Table 5-3 Selecting a precursor delivery method

Condition	Delivery method
The vapour pressure exceeds 1 Torr at temperatures well below the decomposition limit.	Use vapour draw (see **Section 5.14.5.2**).
The vapour pressure does not exceed 1 Torr until the temperature is close to the decomposition limit.	Use a bubbler (see **Section 5.14.5.1**).

Using unstable precursors

A precursor is deemed to be unstable if any of the following conditions are true:

- The decomposition rate of the precursor exceeds 0.05% per month at the selected operating temperature.
- The decomposition rate of the precursor is unknown.
- The precursor material is known to be unstable.

Perform the following steps when using unstable precursors:

1 Try using an ampoule temperature that is well below the decomposition limit.

2 If the deposition rate per cycle is unsatisfactorily low, increase the ampoule temperature and repeat the experiment.

When the precursor is not in use, perform the steps described in **Section 5.14.1.4**.

Consider the following points when using unstable precursors:

- Allow 1 hour for a precursor to reach temperature once the air temperature has been reached.
- Precursor decomposition rates often increase exponentially with respect to increasing temperature. Some precursors can be stable almost indefinitely at a certain temperature, but have a high decomposition rate at a temperature that is 10ºC higher.

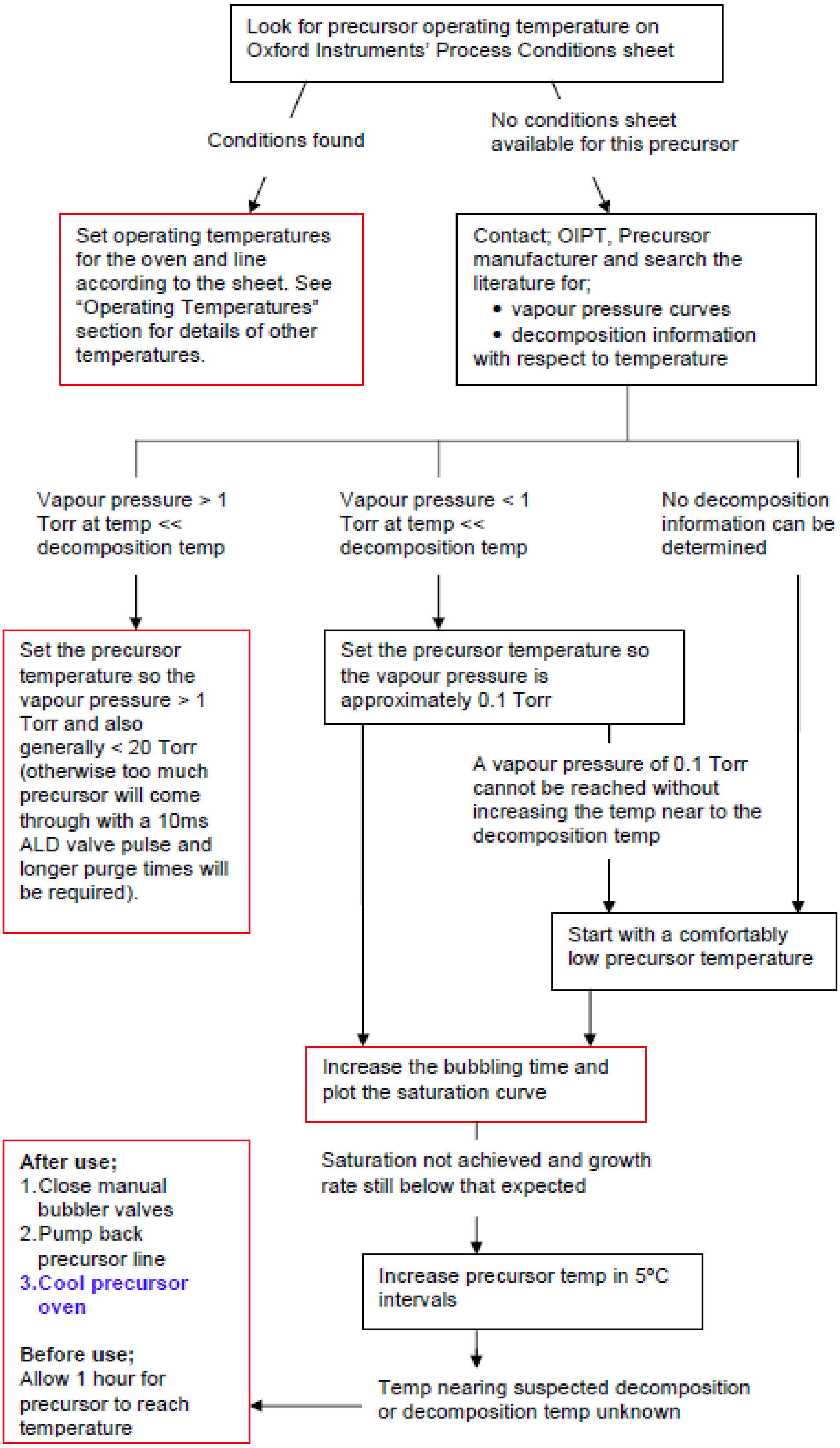


Figure 5-33 Precursor operation flowchart

5.14.1.4 Unused ampoules

If an ampoule contains precursor material and it is not to be used for more than 1 week, perform the following steps:

1. Close the ampoule manual inlet and outlet valves.
2. Evacuate the delivery line back to the ampoule outlet valve.
3. Cool the ampoule down to room temperature.

5.14.1.5 Storing precursors

Precursors must be stored inside approved cabinets, for example a flame proof cabinet for pyrophoric precursors.

You must always keep the original chemical drum or container and its packaging for returning the ampoule to the precursor manufacturer once empty for refilling.

5.14.1.6 Monitoring precursor usage

Method 1: monitoring precursor pressure

Perform the following steps every week to monitor precursor usage:

1. Run the recipe shown in Figure 5-34.

- Repeat 4

Step 1; Time: 1 minute; APC: 90; ICP Gate: closed
Step 2; Time: 5 seconds; APC: 0; ICP Gate: closed
Step 3; Time: 20 milli seconds; APC: 0; ICP Gate: closed; Precursor dose
Step 4; Time: 5 seconds; APC: 0; ICP Gate: closed
Step 5; Time: 1 minute; APC: 90; ICP Gate: closed

- Loop

Figure 5-34 Recipe to monitor precursor usage

2. Compute the average pressure in the chamber over each of the four recipe steps.

3 Check that the pressure values measured for each of the last three recipe steps are repeatable. Ignore the pressure value measured during the first step as this will generally be higher than the other three (see Figure 5-35).

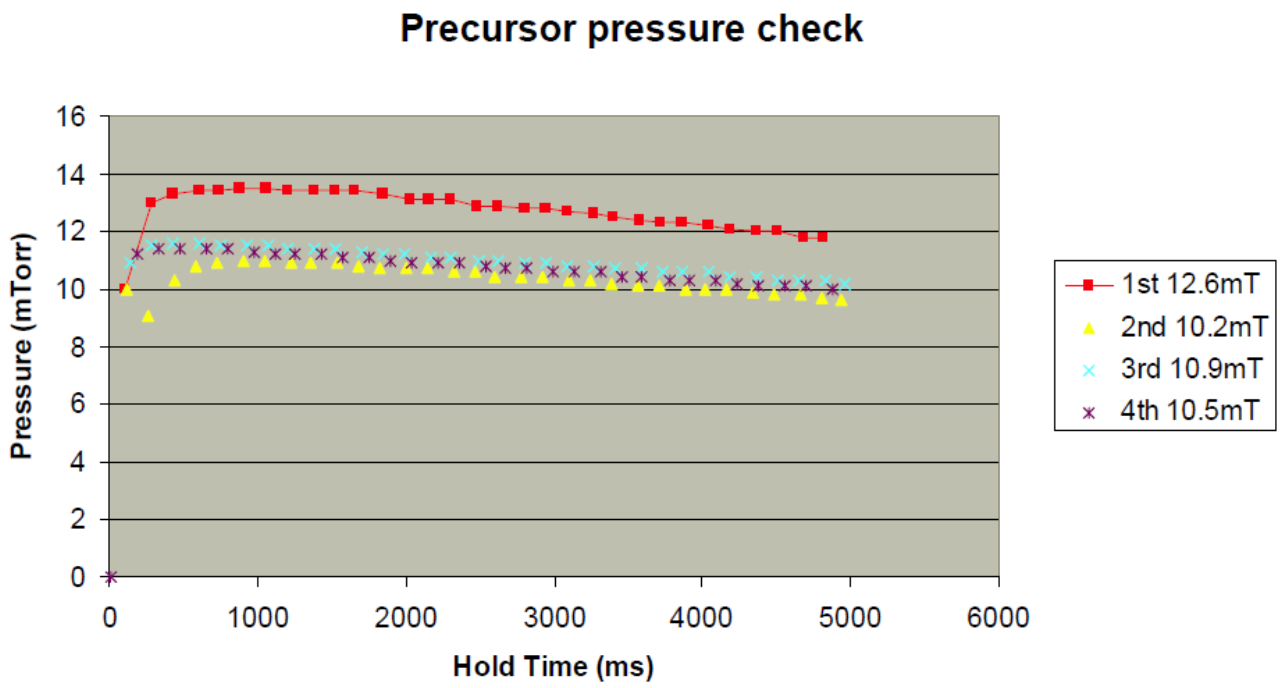


Figure 5-35 Typical results for the precursor usage monitoring recipe

Method 2: for low vapour pressure precursors

For low vapour pressure precursors it is not possible to use the pressure monitoring method to check precursor consumption. In this event, a diagnostic check such as a differentially pumped RGA or mass spectrometer can be used.

Method 3: weighing precursors

Precursors must be weighed in and out of the precursor module to keep an eye on consumption. A digital balance with a 5 kg range and a 0.01 g resolution is recommended.

5.14.1.7 Cross-contamination issues

Caution must be taken when running thermal oxide processes involving water when using halides as precursors or when using ammonia with water. Take the following precautions to prevent cross-contamination:

If using chlorine based metal precursors (e.g $HfCl_4$ and H_2O):

1 Carefully purge the system to remove water after each ALD cycle.

2 Use the lowest possible concentrations of both $HfCl_4$ and H_2O.

3 Ensure each precursor is fully purged out before introducing the other.

4 Consider using O_2 plasma processes in these cases.

If using ammonia after a water-based thermal ALD process:

1 Ensure the base pressure has returned to the 10^{-6} Torr range before flowing NH_3.

2 If possible, heat the walls of the process chamber. This produces an aluminium oxide layer on the chamber walls, reducing attack by the solution of NH_3 in H_2O.

If the chamber walls cannot be heated for any reason, take extreme care to purge the chamber thoroughly.

5.14.2 Operating the precursor delivery module

The following caution and warning notices must be observed before using the system.

WARNING 5.15	**TOXIC GASES** **Exposure to toxic gases can cause death or serious injury. Do not disconnect the precursor or undo any internal joint unless all residual precursor has been removed from the system. Wear personal protective equipment as necessary.**

WARNING 5.16	**HOT SURFACES** **Contact with hot surfaces can cause serious injury and burns. Do not fit the glove box front unless the oven temperature is below 40°C.**

Caution 5.13	**SUCKBACK RISK** Operating the bubbler with low flow of carrier gas can cause precursor to enter the inlet pipe. Do not operate in bubbler mode with low flows, below 50 sccm. The flow must be sufficient to maintain the pressure upstream of the inlet valve above the backpressure of liquid and vapour: of order 30 mbar for water.

Caution 5.14	**RISK OF VACUUM PUMP DAMAGE** Before using a precursor, ensure that the Rotary pump purge is running.

5.14.3 Precursor delivery modes

There are two principle modes of operation:

- **Vapour draw mode**
  Used for precursors that have a vapour pressure greater than 1 Torr.
- **Bubbling mode**
  Argon is flowed through the precursor ampoule to extract precursor vapour. Bubbler mode must only be used for precursors with a vapour pressure less than 1 Torr.

The following sections describe how to configure a six-way precursor cabinet and a single-precursor oven for each mode.

NOTE: These procedures assume that the ampoules have been connected, leak-checked and de-gassed. Refer to **Section 7.7.9**, **Section 7.7.10**, **Section 7.7.11** and **Section 7.7.12** to perform these steps.

5.14.4 Operating a six-way precursor cabinet

Each of the six ampoules contained within the cabinet can be configured for either bubbling mode or vapour-draw mode.

5.14.4.1 Configuring an ampoule for bubbling mode of operation (6-way)

In bubbling mode, argon flows into the ampoule inlet and out of the ampoule outlet. Only use bubbling mode with precursors that have a vapour pressure less than 1 Torr. To operate a precursor in bubbling mode, perform the following steps:

1 Confirm that the ampoule has been connected, leak-checked, and de-gassed.

2 Confirm that the system is not running a recipe or manual process.

3 Confirm that all the heater zones associated with this precursor have been set to, and have reached, appropriate temperatures.

4 Put on suitable personal protective equipment.

TOXIC VAPOUR
Exposure to toxic vapour can cause death or serious injury. Wear suitable personal protective equipment whenever the precursor cabinet doors are opened.
WARNING 5.17

5 Open the precursor cabinet doors.

6 Locate the ampoule that contains the precursor to be operated in bubbler mode.

7 Open the manual outlet valve on the ampoule.

8 If the precursor has not been used for some time, vapour may have built up in the ampoule. This vapour can cause increased precursor dose during the first process run. Perform the following steps to perform a limited degas procedure:

a) Close the precursor cabinet doors.

b) Pump the precursor line until the pressure in the process chamber stabilises. If the precursor has a low vapour pressure, use the Penning gauge to monitor the pressure.

c) If the pressure has not stabilised after 30 seconds, stop pumping the precursor line.

d) Open the precursor cabinet doors.

9 Open the manual inlet valve on the ampoule (see **Figure 5-36**).

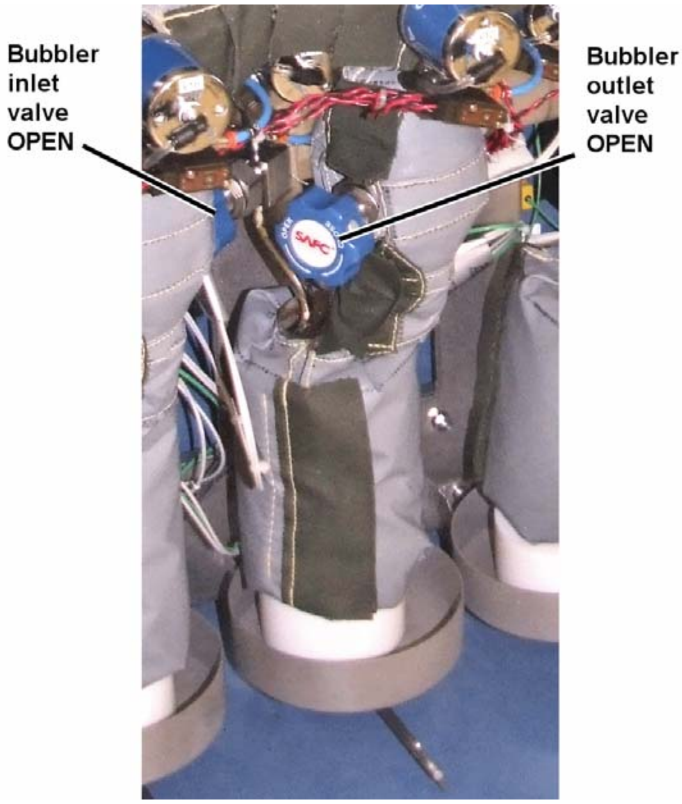


Figure 5-36 Ampoule manual valves set for bubbler mode

10 Close the precursor cabinet doors.

11 Run the process with a flow of argon set on the argon bubbler MFC, and no flow on the argon purge MFC (see **Figure 5-37**).

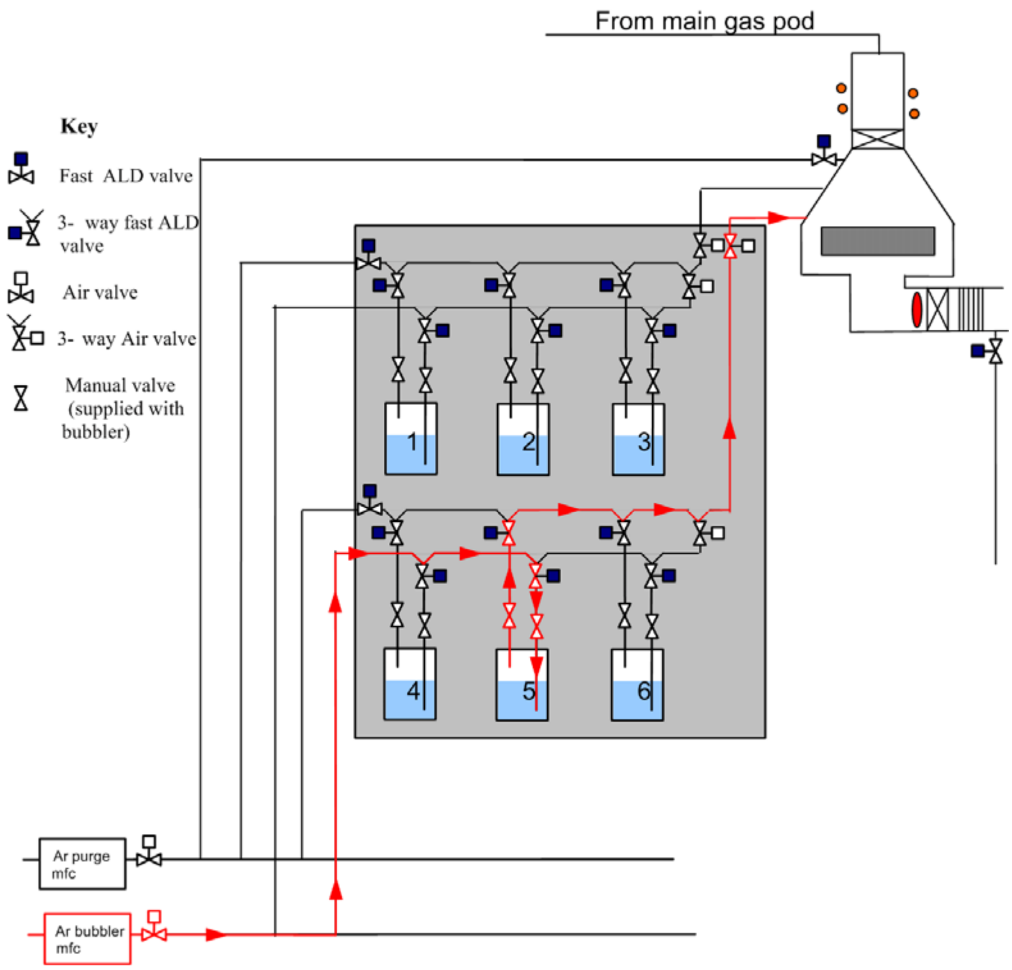


Figure 5-37 Schematic showing bubbling mode of operation

5.14.4.2 Configuring an ampoule for vapour-draw mode of operation (6-way)

In vapour-draw mode, the vapour pressure above the liquid is sufficient to deliver enough precursor to the reactor without assistance.

Vapour-draw is normally used for precursors whose vapour pressure exceeds 1 Torr.

To operate a precursor in vapour-draw mode, perform the following steps:

1 Confirm that the system is not running a recipe or manual process.

2 Put on suitable personal protective equipment.

WARNING 5.18

TOXIC VAPOUR
Exposure to toxic vapour can cause death or serious injury. Wear suitable personal protective equipment whenever the precursor cabinet doors are opened.

3 Open the precursor cabinet doors.

4 Locate the ampoule that contains the precursor to be operated in vapour-draw mode.

5 Open the manual outlet valve on the ampoule.

6 Close the manual inlet valve on the ampoule (see **Figure 5-38**).

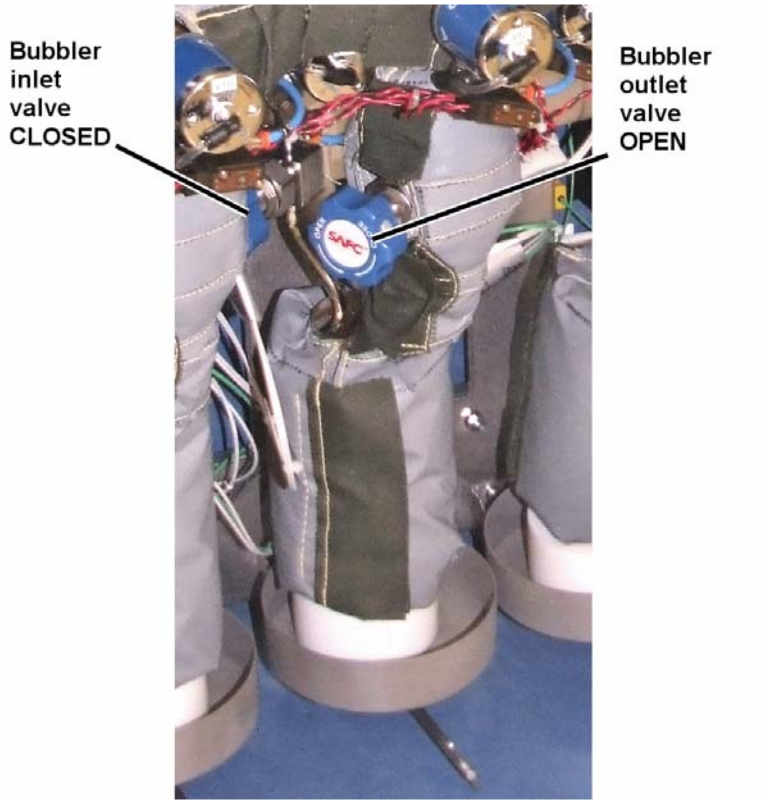


Figure 5-38 Bubbler manual valves set for vapour draw mode

7 Close the precursor cabinet doors.

8 Run the process with a flow of argon set on the argon purge MFC, and no flow on the argon bubbler MFC (see **Figure 5-39**).

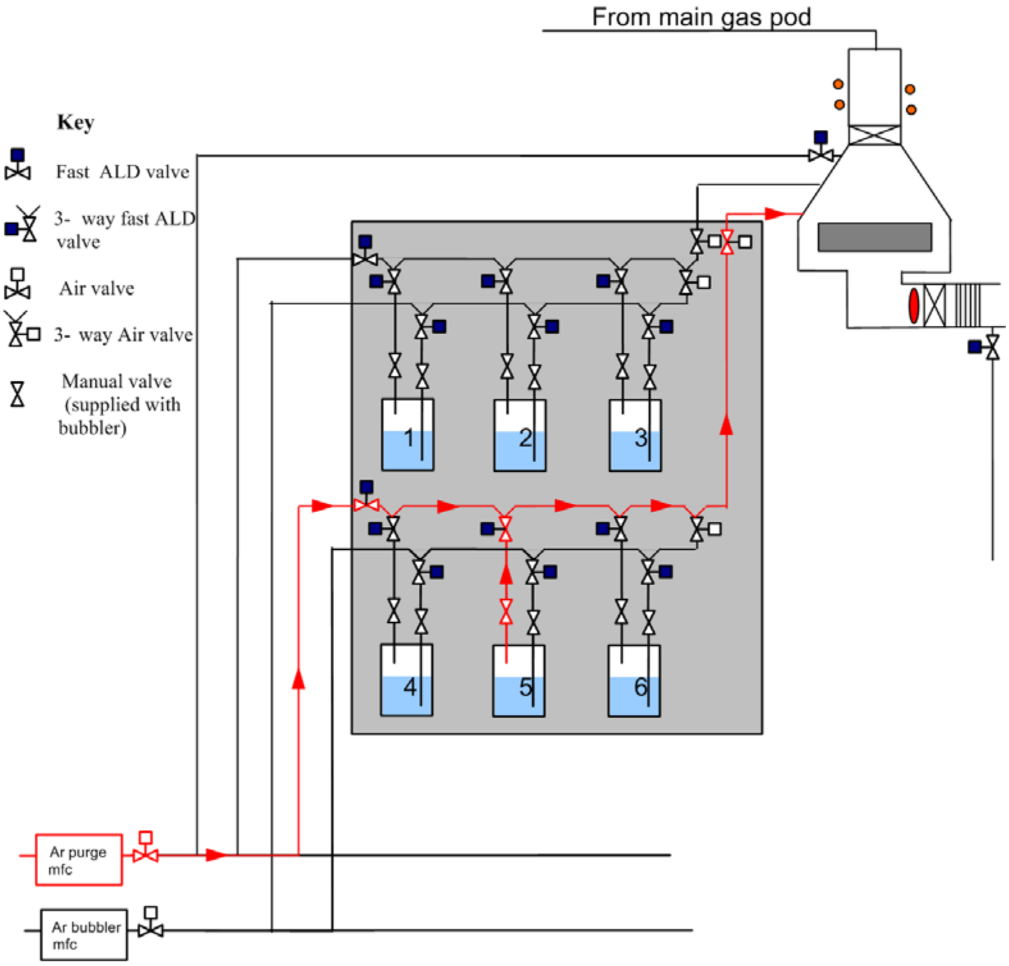


Figure 5-39 Schematic showing vapour draw mode of operation

5.14.5 Operating the PDM with a single-precursor oven

There are two principal modes of operation; vapour draw and bubbling. On a single-precursor oven the modes are controlled by the settings of the housekeeping valve switches and the manual ampoule valves.

5.14.5.1 Bubbling mode of operation (single)

Perform the following steps to operate the PDM in bubbling mode:

1. Check that the manual inlet valve on the precursor ampoule is open (see **Figure 5-40**).
2. Check that the manual outlet valve on the precursor ampoule is open.

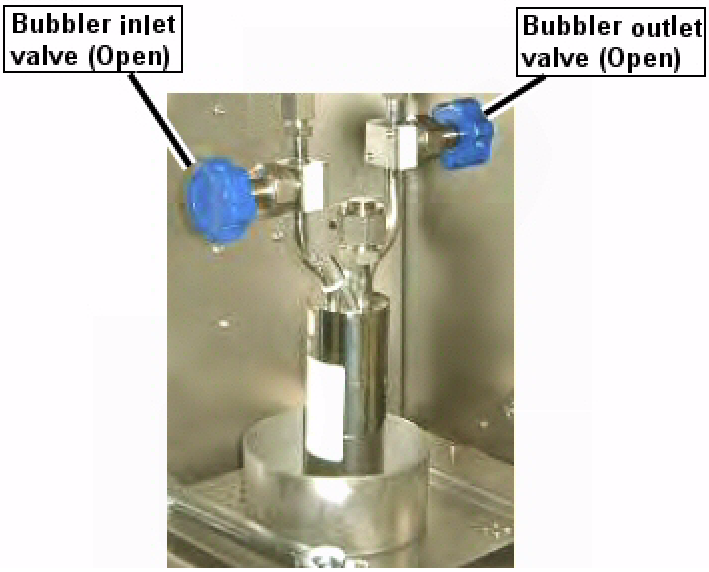


Figure 5-40 Ampoule manual valves set for bubbling mode

3. Open the outlet housekeeping valve (see **Figure 5-41**).

Figure 5-41 PDM controls set for bubbler mode

4 If the precursor has not been used for some time, vapour may have built up in the ampoule. This vapour can cause increased precursor dose during the first process run. Perform the following steps to perform a limited degas procedure:

a) Pump the precursor line until the pressure in the process chamber stabilises. If the precursor has a low vapour pressure, use the Penning gauge to monitor the pressure.

b) If the pressure has not stabilised after 30 seconds, stop pumping the precursor line.

5 Open the inlet housekeeping valve see **Figure 5-41**).

5.14.5.2 Vapour-draw mode of operation (single)

Vapour-draw is where the vapour pressure above the liquid is sufficient to deliver enough precursor to the reactor without assistance. Vapour-draw is normally used for precursors whose vapour pressure exceeds 1 Torr.

1 Check that the manual ampoule inlet valve is closed (see **Figure 5-42**).

2 Check that the manual ampoule outlet valve is open.

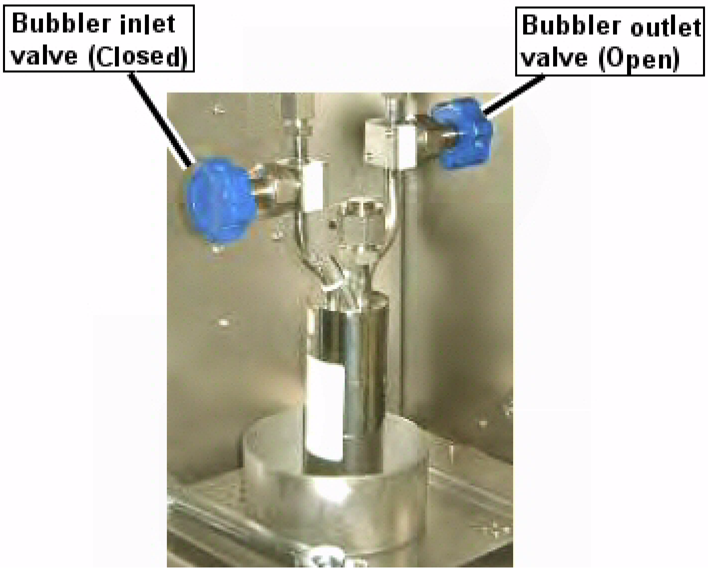


Figure 5-42 Ampoule manual valves set for vapour draw mode

1 For vapour-draw open the outlet housekeeping valves only (see Figure 5-43).

Figure 5-43 PDM controls set for vapour-draw mode

5.14.6 Precursor leak checking

An essential part of any precursor changeover is the leak up check. This check verifies all gas pipe connections have been successfully made and all precursor or air has been removed from the gas pipe. Please see the software section of this manual for a more detailed overview of the automated software leak up feature.

DO NOT EVACUATE THE OZONE GENERATOR
Do not evacuate the ozone generator (if fitted), as this can cause permanent damage to the unit.
Caution 5.15

The following specifically applies to leak checking when precursors are involved;

- Remember very low vapour pressure liquids and solids can barely register on leak checks and often have little effect on base pressure. The base pressure of the chamber and gas line should be no more than 4*10-6 Torr higher than the base pressure of the chamber alone.
- Perform a leak check of the chamber and a leak check of the gas line. The two readings should not differ by more than 0.2 mT/min.
- The main sign of trapped or condensed liquid is purging with argon and then noting a sluggish pump down to base pressure compared to normal after flowing argon. The pressure decrease will also not be smooth, and occasional sudden increases in the pressure reading will be seen.
- Do not evacuate the ozone generator, as this can permanently damage the unit.

6 PROCESS GUIDE

This chapter is the OIPT Process Guide for **FlexAL**®.

The chapter is logically divided into general information and specific information relevant to the main process types (etch and deposition) and is generally applicable to all **FlexAL**® systems. Where information is applicable to a specific system only, e.g. the ALD **FlexAL**® , this is stated.

Material presented within this guide is aimed at users who have knowledge of plasma processes and the terms used. However, if you encounter an unfamiliar term, please refer to the **GLOSSARY**.

The chapter is divided into the following sections:

6.1 About the process guide

This guide gives information about plasma processes based on OIPT's extensive experience in the semiconductor industry.

The scope of the guide is to provide a general introduction to process strategies and common process problems, and has not been prepared for a particular version of hardware. The information is presented to help users obtain optimum results from their specific process applications using **FlexAL**® systems.

To ensure that the information is as comprehensive and up-to-date as possible, it has been collated from the following sources within OIPT:

- **In-house Applications Laboratory**[1] (process laboratory reports, manager's notes, customer feedback etc.).
- **Service Department** (customer feedback, on-site experience etc.).
- **Technology Department** (external information sources, design reviews, customer liaison, etc.).

1. The Application Laboratory is a purpose-built clean room facility housing examples of all of our systems for research and development purposes. Each of these systems is installed in accordance with our standard installation data documents supplied to customers for each system type.

6.2 Health and safety

For detailed health and safety information, see **Chapter 1**.

The customer is always responsible for:

- Delivery of process gases to the tool.
- Removal of exhaust gases from the tool.
- Maintaining a safe system of work for using and maintaining the tool.

6.3 The clean room

It is recommended that OIPT process tools are installed in a clean room that meets the following requirements:

- Air conditioning system is fitted with high efficiency particulate air (HEPA) filters. Ideally the system should produce laminar flow conditions.
- Clean room walls, ceiling and flooring are constructed from low particulate materials.
- Work areas to be kept free of waste materials.
- Covered waste containers to be provided and emptied regularly.
- Gangways to remain clear at all times.
- Access to health and safety and COSHH (control of substances hazardous to health) data sheets to be maintained at all times.
- Access to fire protection equipment to be maintained at all times.
- Appropriate warning labels to be provided where required.
- Samples to be covered where practicable, particularly at the end of a working shift.
- No eating, drinking or smoking is to be permitted in the clean room or laboratory.
- Restricted access to be maintained and a list of authorised persons to be displayed outside the processing areas. All other persons entering the area to be escorted at all times.
- Items entering the processing area must be inspected for cleanliness prior to entry.
- Non-essential items to be excluded from the processing areas.
- Non-essential equipment or documentation must not be stored on the floor area.
- Prior to entering the processing rooms, protective clothing must be worn. The minimum recommended clothing items are over-shoes, coat and hat. These items must be made available within the laboratory access room and must be replaced at a controlled frequency. A bench must be provided to aid dressing with protective clothing. The bench area immediately adjacent to the entry door to the laboratory must contain a tack mat to further prevent contamination ingress. Over-shoes must not come into contact with the area that has been used for day shoes.
- Cleaning of the processing areas must be performed with suitably filtered vacuum equipment.
- A cleaning programme must be established and evidence of compliance maintained for audit purposes.
- All samples in current use, or in temporary storage, within the area must be identified.

- Non-conforming samples must be identified and physically segregated from acceptable work.
- Gloves must be worn when handling unprotected samples.
- Unused tooling and equipment must be stored in a manner to prevent damage and deterioration.
- It remains the responsibility of the users to ensure that tooling and equipment remains suitable for its intended purpose.

For health and safety guidelines, refer to **Chapter 1**.

For a list of required services, refer to **Chapter 10**.

6.4 Processes

6.4.1 General

The scheduled maintenance tasks listed in **Chapter 7** must be performed regularly to ensure the consistency of etch or deposition processes.

6.4.2 Etch processes

6.4.2.1 RIE operating parameter ranges

For an RIE tool the typical process operating ranges are:

Total gas flows = 10 to 150 sccm.

The maximum flow depends on the type of pumps fitted to the system i.e. their maximum flow capacity, their pumping performance, and the required operating pressure. It may be necessary to use lower flow rates than these if a particular process requires a low vacuum pressure.

Pressure = 5 to 500 mTorr.

With process pressures below 50 mTorr, the plasma may not strike easily, or it may be unstable, depending on the process gas and power levels used. It is important to check this and adjust the process accordingly, since operating the system without a plasma can cause permanent equipment damage.

The ‘low pressure strike’ feature in the PC2000 application can be used to help the plasma strike for low pressure processes.

The APC may not be able to maintain a constant pressure for certain flow/pressure combinations. The gas flow or pressure settings may need to be adjusted accordingly.

RF power = typically 20 W to 400 W (or up to 1200 W for RIE System133 or RIE 800 Plus).

A plasma may not strike easily when using low power levels with certain gases. It is important to check this and adjust the process accordingly, since operating the system without a plasma can cause permanent equipment damage.

It is always important to have a cover plate (typically quartz or graphite) on the RIE electrode to protect it from sputter etch damage, particularly when operating with high RF powers and therefore high DC biases.

Helium pressure (if applicable) = 0 to 30 Torr.

The optimum helium pressure depends on the cooling efficiency required and the maximum tolerable helium leakage. Some processes benefit from no cooling.

Temperature is limited by the operating range of the electrode or its heater/chiller, depending on type of electrode or heater/chiller used.

NOTES:

1 The system base pressure must be close to 10^{-6} Torr when measured using the Penning gauge. However, the time taken to reach this pressure depends on whether the chamber has recently been vented to atmosphere and the cleanliness of the chamber walls. Systems with an anodised process chamber or electrodes take longer to outgas compared with systems that have bare metal surfaces.

2 Operating with chlorine-based processes can cause damage to the electrode unless it is protected with a cover plate (or dummy wafer in a tool with wafer clamping).

3 Operating with a high reflected power (>5% of forward power) is not advised, as this will cause damage to the matching unit or RF generator. To reduce the high reflected power, adjust the process parameters or re-tune the matching unit.

6.4.2.2 ICP operating parameter ranges

For an ICP source the typical process operating ranges are:

Total gas flows = 10 to 200 sccm.

The maximum flow depends on the type of turbo pump, i.e. its maximum flow capacity, and the required operating pressure. It may be necessary to use lower flow rates than these if a particular process requires a low vacuum pressure.

Pressure = 1 to 60 mTorr.

With process pressures below 5 mTorr and above 20 mTorr, the plasma may not strike easily, or it may be unstable, depending on the process gas and power levels used. It is important to check this and adjust the process accordingly, since operating the system without a plasma, either on the substrate electrode or in the ICP tube, can cause permanent equipment damage.

The low pressure strike feature in the PC2000 application can be used to help the plasma strike for low pressure processes.

The APC may not be able to maintain a constant pressure for certain flow/pressure combinations. The gas flow or pressure settings may need to be adjusted accordingly.

ICP power = approximately 200 W to 2500 W (or 4000 W for ICP 380).

The minimum power level that can be used depends on how easily the plasma strikes for certain gases. It is important to check this and to adjust the process accordingly. Operating the system without a plasma, either on the substrate electrode or in the ICP tube, could cause damage.

The maximum ICP power that can be used depends on the power rating of the RF generator. However, most processes perform well with only moderate ICP power levels, which also helps to avoid excessive substrate heating.

Substrate electrode RF power = typically 5 W to 400 W.

A plasma may not strike easily when using low power levels with certain gases. It is important to check this and adjust the process accordingly, since operating the system without a plasma, either on the substrate electrode or in the ICP tube, can cause permanent equipment damage.

Helium pressure = 0 to 30 Torr.

The optimum helium pressure depends on the cooling efficiency required and the maximum tolerable helium leakage. Some processes benefit from no cooling.

Temperature is limited by the operating range of the electrode or its heater/chiller, depending on type of electrode or heater/chiller used.

NOTES:

1 The system base pressure must be close to 10^{-6} Torr when measured using the Penning gauge. However, the time taken to reach this pressure depends on whether the chamber has recently been vented to atmosphere and the cleanliness of the chamber walls. Systems with an anodised process chamber or electrodes take longer to outgas compared with systems that have bare metal surfaces.

2 Operating with chlorine-based processes can cause damage to the electrode unless it is protected with a cover plate (or dummy wafer in a tool with wafer clamping).

3 Operating with a high reflected power (>5% of forward power) is not advised, as this will cause damage to the matching unit or RF generator. To reduce the high reflected power, adjust the process parameters or re-tune the matching unit.

6.4.2.3 Low pressure strike facility

Striking a plasma is difficult when the vacuum pressure is low. This is because the concentration of free electrons being produced is not high enough to start and maintain the ionisation chain reaction, or avalanche, which is required to initiate the plasma.

The low pressure strike feature is provided in the PC2000 application to improve plasma striking for low pressure RIE or ICP processes. When activated, the system increases the chamber pressure during the first few seconds of the process step to enable the plasma to strike. The pressure is then reduced to the required process pressure. Using the low pressure strike feature has minimal impact on the process because the time taken to strike the plasma at the higher pressure is very short, compared to the total process time.

6.4.2.4 DC bias

The DC bias voltage displayed on the GUI is measured on the lower electrode. If there is good electrical contact between the wafer and the electrode, this measurement is close to the DC bias voltage seen by the wafer. Any insulating barrier on the electrode can reduce the measured DC bias value. Possible causes of this reduction include:

- Quartz cover plate (or any other insulating cover plate material).
- Electrode surface anodisation.
- Polymer coating on electrode surface generated by process.
- Any other insulating coating generated by plasma.

In all of these cases, the measured DC bias value is inaccurate due to the lack of DC contact to the plasma. If the electrode is completely insulated, or there is minimal contact between the exposed areas of the electrode and the plasma, the measured DC bias value may be close to zero.

It is important to understand that these conditions do not reduce the sheath potential (or ion energy). However it may be impossible to obtain reliable DC bias measurements during certain processes. In these situations it is recommended that the DC bias is initially measured with a bare electrode (e.g. prior to loading the quartz cover plate).

If it is suspected that there has been polymer deposition on the electrode, it may be necessary to clean off the polymer (with an O_2 plasma or by mechanical cleaning) to allow an accurate measurement of the DC bias.

Electronegative gas mixtures

Strongly electronegative mixtures, such as SF_6 gas above 10 Pa (70 mTorr), may produce DC bias values that are close to zero. This is not a fault, but is due to the formation of negative ions in the plasma. A DC bias is created because of the difference in mobility between the negative and positive charges in the plasma. When both charge carriers are heavy ions, both polarities of carrier have similar mobilities and the DC bias collapses.

ICP sources

The DC bias on the lower electrode can be a strong function of the power in any auxiliary plasma source, for a fixed lower electrode RF power. At low ICP power, there can be a rise in DC bias reading, because of the increase in the effective area of the grounded electrode. As the ICP power rises, the DC bias is reduced, as ions from the source begin to dominate the ion flux at the electrode. This reduction in DC bias is a strong indicator that plasma from the source is reaching the lower electrode.

DC bias polarity

The surface of the RF driven electrode acquires a negative bias with respect to the plasma. However, the literature and the industry tend to refer to DC bias as a positive quantity. OIPT follows this convention in their equipment.

DC bias control

The DC bias value depends on all the process parameters and several aspects of the machine condition. If the DC bias value is important to the correct operation of the process, it is possible to program DC bias as the recipe parameter, and allow the system to control the RF power to achieve the programmed DC bias value. The control mode (power or bias) can be selected on the GUI. Before using DC bias control mode, it is important to consider the potential causes of inaccurate bias measurements that are described in the preceding sub-sections.

DC bias reproducibility

DC bias is a very sensitive indicator of the state of the plasma tool. While this makes it a useful parameter to measure and record, it also makes it difficult to ensure that the value is consistent from day-to-day on the same machine, and between nominally identical systems.

OIPT has deliberately omitted any DC bias scaling in the PC2000 application. Some customers have requested this feature to allow DC bias readings to be normalised across different tools, but OIPT has found that it is better to know the actual value.

Refer to **Section 8.4** for information on fault-finding DC bias problems.

6.4.2.5 Arcing/pitting

Refer to **Section 6.4.4** for information on fault-finding arcing and pitting problems.

6.4.2.6 Etch process chamber cleaning recipes

There are a number of plasma cleaning strategies currently in use:

Polymer processes

For polymer processes (any process containing C_4F_8, CHF_3, or CH_4, e.g. C_4F_8/O_2, CHF_3/Ar, CH_4/H_2, CHF_3/Ar), use an O_2 based etch to remove the polymer. The etch rate can often be increased by adding 10-20% SF_6 (this is more common in cleaning recipes for ICP chambers).

Typical examples of cleaning recipes are:

RIE chamber:

O_2: 100 sccm.

Pressure: 100 mT.

Electrode: 200 W.

Time:* 1-2 hours, but dependent on total process time since last clean.

Period:* After every 3-10 hours etching.

* These parameters depend on the process gases, conditions and chamber wall temperature and are subject to change.

ICP chamber:

O_2: 40 sccm.

SF_6: 10 sccm (optional, if not available).

Pressure: 10 mT.

ICP Power: 1500 W.

Electrode: 150 W.

Backside He: 0 mbar.

Time:* 1-2 hours, but dependent on total process time since last clean.

Period:* After every 3 to 10 hours etching.

* These parameters depend on the process gases, conditions and chamber wall temperature and are therefore subject to change.

Inorganic film

For processes which deposit an inorganic film, e.g. a-Si, SiO_2, BO_x etc from $SiCl_4$, or BCl_3 it is necessary to use an etch gas that is specific to that type of film, for example:

SF_6: 50 sccm.

Pressure: 20 mT.

ICP Power: 1500 W.

Electrode: 150 W.

Backside He: 0 mbar.

Etched material and mask layer

For processes which deposit a combination of etched material and mask layer (e.g. GaAs and sputtered photoresist during GaAs via hole etching), it is common to use a mixed chlorine/fluorine chemistry:

RIE chamber:

SF_6: 85 sccm.

Cl_2: 50 sccm.

Pressure: 45 mT.

Power: 150 W.

Temperature: 20°C.

Quartz carrier plate.

ICP chamber:

Step1: 40 sccm Cl_2, 20 sccm SF_6, 50 mT, 500 W ICP, 200 W RF, 22°C, 0 Torr He, 20 mins to remove GaAs and PR residues (may need to be longer after lots of 'via hole etching').

Step2: 50 sccm O_2, 20 mT, 2000 W ICP, 200 W RF, 22°C, 0 Torr He, 30 mins.

Step3: 50 sccm O_2, 60 mT, 2000 W ICP, 200 W RF, 22±C, 0 Torr He, 30 mins.

6.4.2.7 Processing small samples of pieces of wafer

It is quite a common requirement to process small samples or pieces of wafer. If the process requires cooling, either to improve the etch profile or to allow use of resist mask at high power levels, then the small pieces of wafer must be glued or fixed to a carrier wafer which is in turn clamped to the cooled substrate table.

Processing small samples that need cooling

There are several ways of attaching the small pieces of wafer to the carrier:

- **Vacuum grease or vacuum oil**
  After etching has been completed, remove the vacuum grease from the back of wafer using isopropyl alcohol (IPA) or acetone.
- **Thermal heatsink compound**
- **A thermally conductive elastomer pad.**
  Refer to the **EMI Shielding** and **Thermal Management Solutions** sections on the Parker Chomerics website **http://www.chomerics.com/** for suitable pads.
- **Photoresist**
  Spin a few microns of photoresist onto a carrier wafer, place the sample on top while the resist is still wet, push the sample down well into the resist, and then bake the resist.

With the first three methods it is important that the sample completely covers the bonding material, so that no bonding material is exposed to the plasma. If the plasma contacts the bonding material it re-deposits it on the wafer.

With all these methods it is necessary to clamp the carrier wafer and to apply helium pressure to the back of the carrier wafer to provide cooling of the sample. Gluing the sample to a carrier does not provide cooling unless the carrier is itself cooled.

Processing small samples that do not require cooling

If the process does not require cooling (e.g. most low power RIE-only processes), then it is not necessary to bond the sample to carrier. To prevent the sample from sliding off the carrier, it is possible to glue pieces of silicon to the carrier to act as locating lugs. This method avoids the need to glue the sample and minimises contamination of the sample.

6.4.2.8 Use of the helium backing system

The helium backing system can be used for effective temperature control of the substrate during processing.

It is important to ensure that there is a good seal between the substrate and the table. If helium is leaking out from behind the wafer, the thermal contact to the temperature-controlled table is degraded. The wafer then heats up more than expected, which may degrade the process. For example, in SiO_2 etching the profile may become partially isotropic or the photoresist masking layer may degrade.

Checking helium backing

The PC2000 application displays the measured helium flow into the substrate table. If the wafer seals perfectly against the table, this measured flow should be zero when a wafer is present. In practice there is always some leakage, but the flow reduction when a wafer is present can be used to evaluate the effectiveness of the wafer to table seal.

Perform the following steps to check the helium backing system:

1. Evacuate the system with no wafer on the substrate table.
2. Set a range of helium pressures and note the measured helium flows.
3. Load a blank substrate of the correct size and note the measured helium flows for the same range of set helium pressures.
4. Load a typical customer wafer (e.g. with a thick SiO_2 layer) and note the helium flows for the same range of set helium pressures.
5. Record the results in the following table:

Table 6-1 Checking helium backing

Set He/Torr	He Flow/sccm No Wafer	He Flow/sccm Si Wafer	He Flow/sccm Customer Wafer
7			
10			
15			
20			

6 Compare the measured flow values with and without a wafer present. The flow values with a wafer present should be less than those with no wafer. Acceptable criteria are still being evaluated, but a recent example with acceptable results is shown in **Table 6-2**.

Table 6-2 Recent helium backing evaluation example

Set He/Torr	He Flow/sccm No Wafer	He Flow/sccm Si Wafer	He Flow/sccm Customer Wafer
7	4.2 sccm	<3.9 sccm [1]	
10	7.2 sccm	<6.5 sccm [2]	

1. These were the maximum values observed (usually occurring for wafers with thick SiO2 layers) and cooling was thought to be adequate because profiles were acceptable.

2. The Application Laboratory is a purpose-built clean room facility housing examples of all of our II systems for research and development purposes. Each of these systems is installed in accordance with our standard installation data documents supplied to customers for each system type.

If there is little or no difference between the flows with and without a wafer present, then the seal is ineffective.

If blank silicon wafers produce a good seal but the customer wafers do not, the problem is with the customer wafers. Possible problems include:

- The wafers are warped.
- The wafers are too flexible or too thin. Try reducing the helium pressure to reduce flexing of the wafers.
- The wafers are not being clamped properly, possibly because they are too thin.

Troubleshooting poor helium sealing

If the wafer to table seal is inadequate:

1 Check the backs of wafers for excessive contamination, scratching, curvature or bowing.

2 Vent the chamber and check the surface of the substrate table for particles, scratches, or erosion. Check that the table is very flat and clean and that it has no bumps or grooves eroded into it.

3 Check that the wafer is positioned centrally in the clamping ring.

4 Check the wafer clamp integrity and wafer clamping force. A simple test is to try to move the wafer using a gloved finger when it is clamped. If the wafer is thin it may be necessary to temporarily modify the clamping ring by adding strips of PTFE or aluminium foil to make it press down on the wafer.

5 Press down on the wafer in various places and see if it flexes. If the wafer flexes, this indicates that the wafer is not sitting down flat on the electrode. Try polishing away any bumps.

6 Check that the measured helium pressure is correct. A faulty helium pressure gauge could cause excessive pressure to be applied to the back of the wafer. Typical CM gauge pressure when the wafer is clamped and helium pressure is applied (APC fully open and no other gases flowing) is in the range 0.3 to 2 mT for the range of Helium pressures given above.

6.4.2.9 Gases with a low vapour pressure

Gases with a low vapour pressure (e.g. $SiCl_4$, BCl_3) present unique problems for the gas supply system, e.g. temperature dependence of gas pressure, condensation in the gas lines, and low line pressure. Refer to **Section 10.2.7.1** for more information on using low vapour pressure gases.

6.4.2.10 Endpoint detection techniques

Endpoint detectors are used in etch processes to detect the point where all of the etched film has been removed. Accurate endpoint detection is important to avoid etching the layer below the etched film.

Oxford Instruments Plasma Technology produces equipment to utilise two endpoint techniques:

- **Optical emission spectroscopy (OES)**.
- **Laser interferometry**.

These techniques are described in the following sections.

Optical emission spectroscopy (OES)

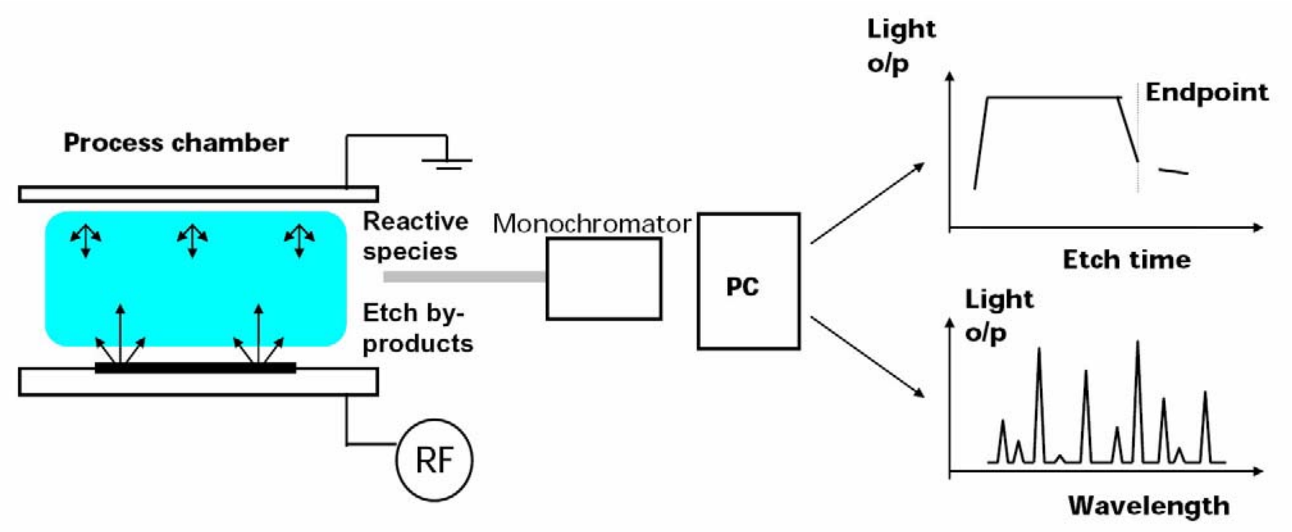


Figure 6-1 Optical emission spectroscopy

This technique monitors the optical spectrum produced by the plasma during processing. When the desired layer is being etched, the reactive species or etch by-products produce optical emissions at specific wavelengths. When the layer has been etched, these spectral lines reduce in amplitude.

Features:

- Monitoring of reactive species or etch by-products provides the endpoint signal.
- Detection of the endpoint relies on an etch stop layer below the layer being etched.
- Scanned monochromator allows full spectrum analysis.

Laser interferometry

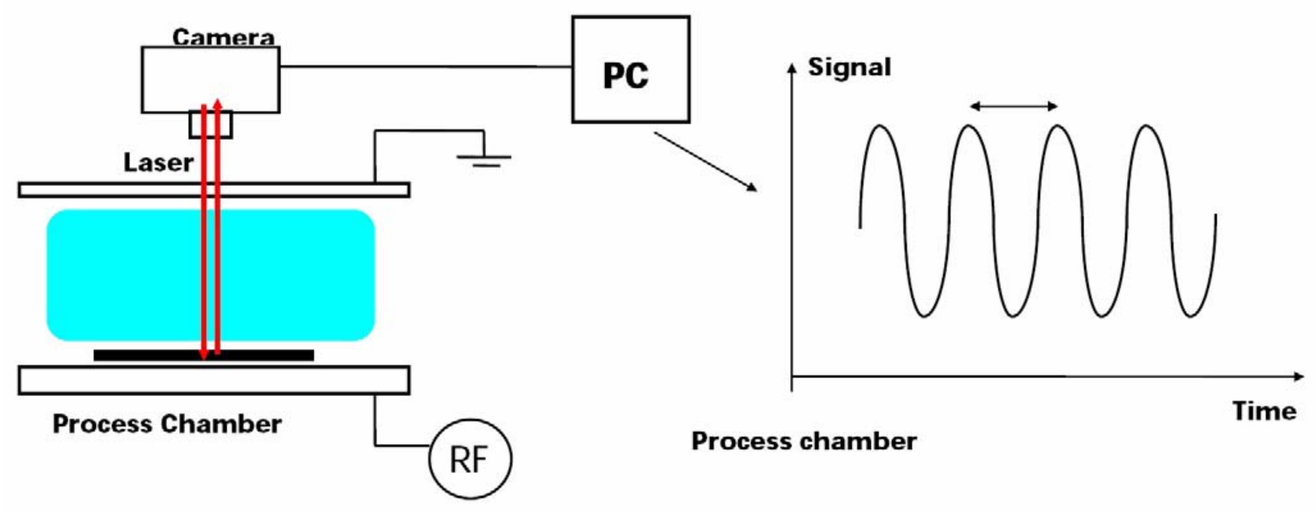


Figure 6-2 Laser interferometry

Laser interferometry uses the interference between reflected laser signals from the top and the bottom of the etched film to measure the thickness of the film.

Features:

- In-situ etch rate monitoring.
- Endpoint detection does not require an etch stop layer.
- The endpoint can be chosen anywhere within the layer once the etch rate has been established.

Comparison of OES and laser endpoint techniques

The laser interferometer (LI) endpoint system works best with a flat transparent layer (or stack of layers) on a reflective substrate. The technique has the following benefits:

- It gives very precise measurement of etch depth in the etched layer, or layers.
- It can be used on very small pieces of wafer.
- It can either determine when the etch reaches an interface between differing materials (by detecting a change in slope of the laser reflectance signal with time), or it can measure the etch depth when partially etching through a layer (by counting the interference ripples).
- It can often be used to identify multiple interfaces when etching through different layers in a multilayer stack of materials (through the changes in reflectance of the materials in question).

The laser interferometer system has the following disadvantages:

- The laser spot needs to be aligned every time to a suitable measurement point on the wafer (i.e. an etched area, not a masked area).
- The system only measures a single point, so any process non-uniformity will result in a range of etch depths across the wafer or batch.

The optical emission spectroscopy (OES) system has the following benefits:

- The system does not require alignment for every run, as it monitors optical emission from the whole plasma.
- OE can give a qualitative idea of uniformity since the length of the transition of the signal from before to after endpoint indicates the quality of etch uniformity.
- The endpoint is more accurate for the whole (average) of the wafer rather than a single point on the wafer.

The optical emission spectroscopy (OES) system has the following disadvantages:

- Larger wafers or a larger etched area (>2 cm^2) is necessary to effectively determine the endpoint.
- The size of the etched area needed for good OE endpoint depends on the materials being etched, since the emission lines for certain materials can be very faint. Also, if the etch rate of the material is low, the concentration of etch species will be low.
- OE can only detect a change in the strength of a particular emission line (or group of emission lines), so can only detect when the etch passes through an interface between differing materials.

Typical OES endpoint wavelengths

Table 6-3 Typical OES endpoint wavelengths

Material etched	Gas species detected	Wavelength (nm)	Rise/fall at endpoint
Si	F	704	Rise
Si	SiF	440, 777	Fall
Si	SiCl	287	Fall
SiO_2	F	704	Rise
SiO_2	CO	483	Fall
Resist, polyimide	O	843	Rise
Resist, polyimide	CO	483	Fall
Resist, polyimide	OH	309	Fall
Resist, polyimide	H	656	Fall
Si_3N_4	N_2	337	Fall
Si_3N_4	CN	387	Fall
Si_3N_4	N	674	Fall
W	F	704	Rise
Al	Al	391, 394, 396	Fall

Endpoint algorithm examples

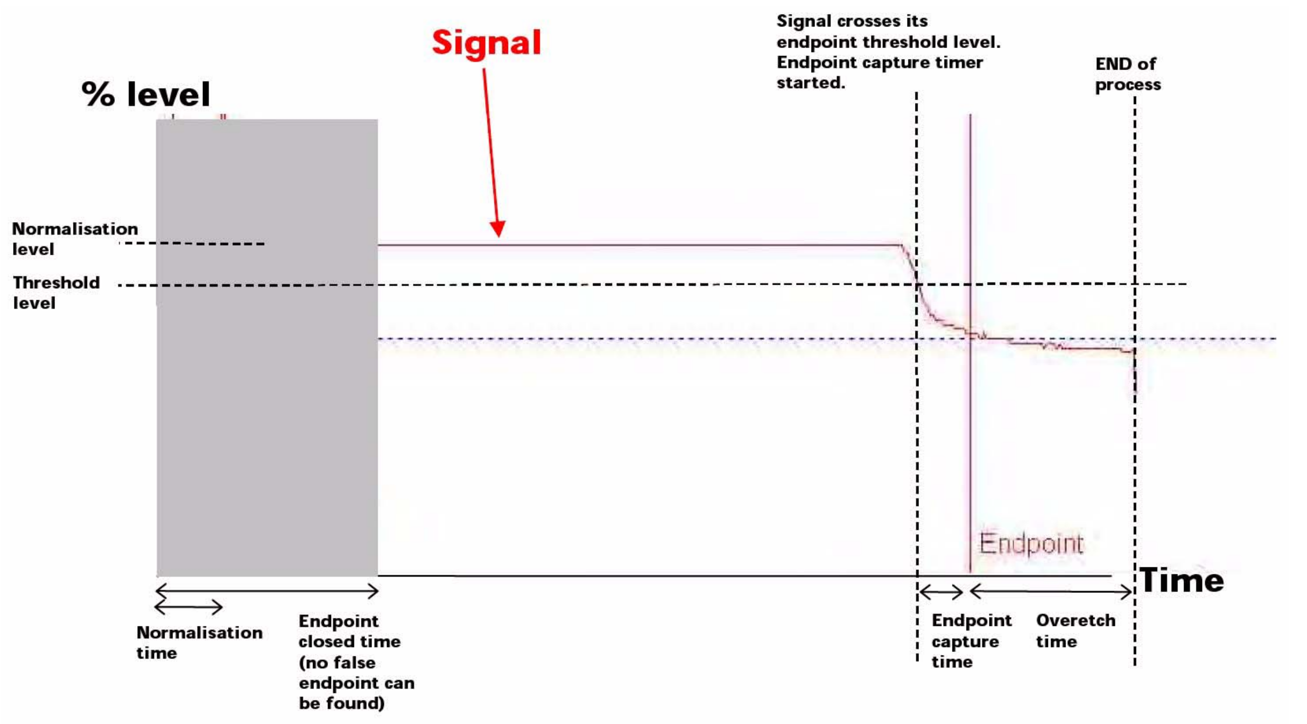


Figure 6-3 Endpoint trace (signal falling)

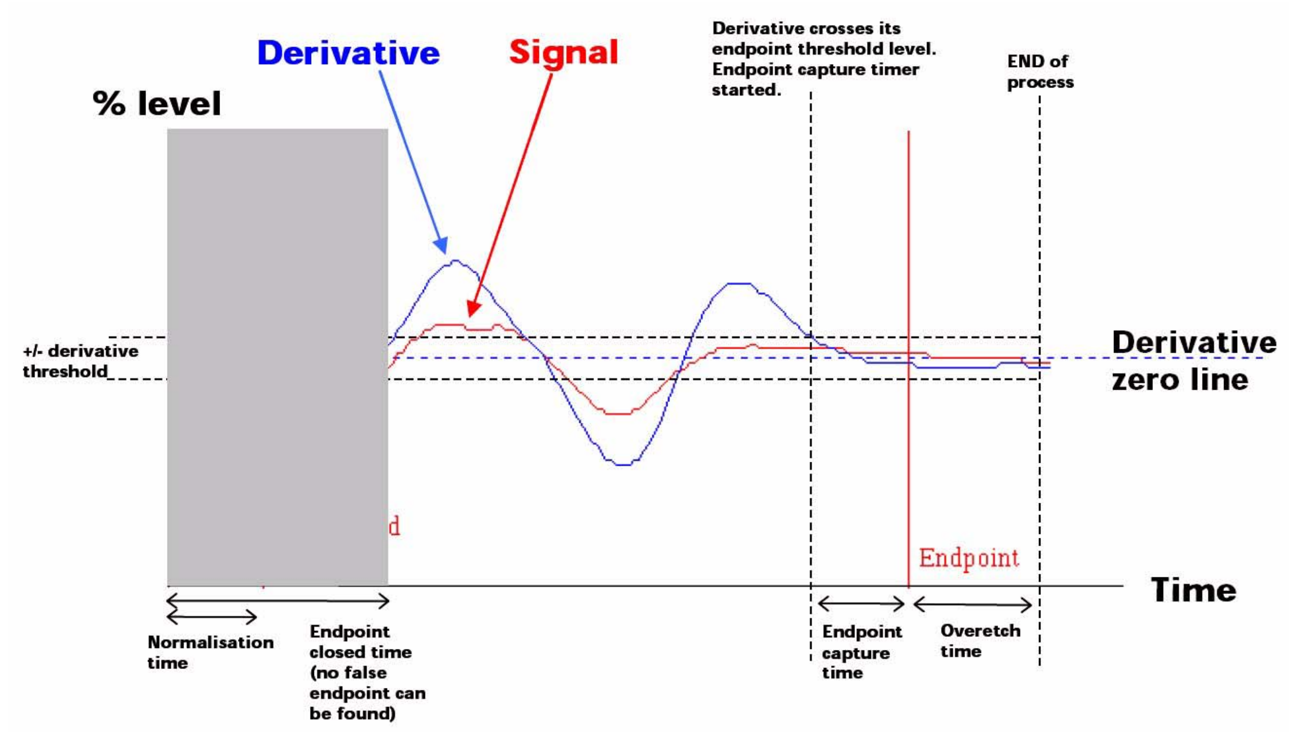


Figure 6-4 Endpoint trace (derivative, less than)

6.4.2.11 Gas calibration factors

OIPT systems are supplied with MFCs that are calibrated for, and compatible with, the gases specified by the customer. The customer must also contact OIPT for advice before changing the gas type.

It is possible to use MFCs with chemically compatible gases that they have not been calibrated for. See the MKS Instruments OEM manual for details of gas correction factors. However certain gases (e.g. H_2 or He) have gas calibration factors that are far from unity, and must only be used with MFCs that have been calibrated for them.

6.4.3 Deposition processes

6.4.3.1 PECVD operating parameter ranges

For a PECVD tool the typical process operating ranges are:

Total gas flows = 150 to 3000 sccm.

The maximum flow depends on the type of pumps fitted to the system i.e. their maximum flow capacity, their pumping performance, and the required operating pressure. It may be necessary to use lower flow rates than these if a particular process requires a low vacuum pressure.

Pressure = 200 to 2000 mTorr.

With process pressures below 300 mTorr the plasma may not strike easily, or it may be unstable, depending on the process gas and power levels used. It is important to check this and adjust the process accordingly, since operating the system without a plasma can cause permanent equipment damage.

The low pressure strike feature in the PC2000 application can be used to help the plasma strike for low pressure processes.

The APC may not be able to maintain a constant pressure for certain flow/pressure combinations. The gas flow or pressure settings may need to be adjusted accordingly.

RF power = typically 20 W to 300 W.

A plasma may not strike easily when using low power levels with certain gases. It is important to check this and adjust the process accordingly, since operating the system without a plasma can cause permanent equipment damage.

Temperature = room temperature to 400°C (or up to 700°C for a 700°C stainless steel electrode).

Film quality and density degrade when deposited at lower temperatures. It is therefore recommended to operate the process at the maximum temperature that the substrate allows.

PECVD chambers are usually not fitted with a Penning gauge. In these system the capacitance manometer gauge is used to measure the base pressure. It must be noted that CM gauges are only accurate to within a few mTorr at low pressures.

Operating with a high reflected power (>5% of forward power) is not advised as this will cause damage to matching unit or generator. The process parameters should be adjusted to reduce the reflected power to less than 5% of the forward power.

6.4.3.2 Low frequency deposition

The uniformity of films (e.g. silicon nitride) deposited using a low frequency power source is usually worse than films deposited using a high frequency source. This is because the low frequency signal is much more sensitive to the electrical conductance between the upper electrode, plasma, wafer, and substrate table (thin insulating areas act as capacitors at high frequencies). Any insulating deposits on the chamber or table are likely to be non-uniform, which will in turn cause the deposited film to be non-uniform.

The following procedure is recommended to improve the uniformity of low frequency, or mixed frequency, deposition:

1. Clean the substrate table and showerhead back to bare aluminium. Initially use a plasma clean, followed by mechanical cleaning of any remaining deposits.
2. Perform a brief deposition of a few hundred nanometers with no wafers in the system.
3. In all subsequent deposition runs, ensure that dummy wafers or aluminium blanks are placed over any unused wafer positions. This maintains the thickness of the initial film that has been deposited.
4. Run regular cleaning plasma, again with dummy wafers or aluminium blanks placed over the wafer positions to protect the initial film.
5. If mechanical cleaning of the chamber is required, use dry wipes with the system at room temperature.

Another possible cause of non-uniformity is the wafer material. For example GaAs is less conductive than silicon, so films deposited on large GaAs wafers are less uniform than similar films deposited on silicon wafers. This effect can be counteracted to some degree by increasing the LF frequency, but there is a trade-off with matching (i.e. the reflected power is generally higher at higher frequency).

For LF depositions, ensure that the system controls load power, as this is the power that actually reaches the plasma. Matching is often quite poor for LF plasmas, and it may be necessary to adjust the low frequency matching unit to minimise the reflected power. High reflected power does not affect the process unduly, as the LF generator increases its output to maintain the specified load power. However high reflected power can cause overheating of the LF generator.

6.4.3.3 Premature flaking

Premature flaking of the chamber wall or showerhead material can occur for a number of reasons:

1) For new systems the showerhead may need several deposition/clean cycles before it reaches its best film adhesion performance. This can be improved by bead blasting the showerhead.
2) Temperature cycling of showerhead and chamber walls can cause flaking. It is important that chamber walls are set to a stable temperature, e.g. 60°C, and that the showerhead cooling water is flowing properly. It is also important that the electrode temperature is maintained at a constant value as this affects the showerhead temperature.
3) Temperature cycling can cause flaking. The system should be left pumping, with the electrode maintained at deposition temperature, when not in use.
4) Incomplete cleaning during a previous clean cycle can lead to premature flaking.
5) Wiping of the chamber and or showerhead with water or IPA can leave residues, which subsequently causes early flaking of deposited films.
6) Wiping of chamber walls or showerhead while they are hot can leave residues, which cause premature flaking.
7) Repeated venting of the chamber causes flaking. It is recommended that a cleaning plasma is run on the **FlexAL**® system after every 5 to 10 microns of film deposition, or more often if mixed films or deposition temperatures are used. (Loadlocked systems can be cleaned less often than this).
8) Mixed deposition of silicon oxide, nitride, and oxynitride films can cause increased stresses in deposited films and hence premature flaking.
9) Changes to standard recipes can also cause increased stress and hence premature flaking.

6.4.3.4 PECVD particles

It is recommended that PECVD wafers are regularly sampled and examined for particles. If a dedicated particle detector system is not available, visually examine the wafer using a strong light source at various angles of incidence. If particles are found on a sample wafer, all wafers since the last clean sample must be checked.

Table 6-4 lists common problems that may cause particles.

Table 6-4 PECVD particles

Particle Descriptions	When They Most Often Occur	Possible Causes	Remedy/Quick Fix - Test
Small particles less than 5 µm, which appear in concentrated, clusters. These clusters appear in a pattern, which mirrors that of the showerhead holes. They are concentrated mainly in one focal plane of the microscope and appear to be at the bottom of the film.	The first run after a clean.	Running the machine too soon after the completion of a clean process. Silane forms particles when it reacts with residual oxygen in the gas lines (remember all of the gas line up to the gas selection valve is incorporated in the chamber vacuum and needs to de-gas at the end of a long clean run).	Wait 30 minutes after running a cleaning plasma before running a deposition process using silane. Alternatively perform several pump/purge cycles of the chamber before running the deposition process.
	The first run after a long period of machine disuse (say overnight).	A small leak in the silane line, producing a build-up of silica dust. This dust is then blown though on to the first wafer.	Fix the leak in the silane line. After a significant period of machine disuse, flow silane through the system without a wafer in the chamber to clear the dust.
Small particles less than 5 µm, which appear in concentrated clusters. These clusters appear in a pattern, which may or may not mirror that of the showerhead holes. They appear in many different focal planes under the microscope, at regular intervals throughout the film.	Every run.	A leak in the gas inlet assembly or a severe leak in the silane line. Plasma forming behind the showerhead or in the gas inlet assembly.	Leak-check the chamber and the gas line. If both items have a leak rate less than 1 mT per minute, contact the OIPT service department and give this description. If either item has a leak rate greater than 1 mTorr per minute, take apart the gas inlet assembly and clean the O-rings and PTFE parts.
Flakes or larger non-metallic particles.	The first run after a clean.	Residual particles that were not etched during the cleaning process.	Cool the system to room temperature and clean the inside of the chamber using dry wipes and a vacuum cleaner.
	After a power failure, or other reason, which caused a significant drop in table temperature.	When the lower electrode cools, deposited film may crack, particularly around the edges or the electrode. Flakes may then be blown onto the wafer during subsequent deposition runs.	Clean the chamber.
	After a certain amount of deposition on the chamber, but at an unpredictable frequency.	If films of differing chemistries and stresses are being deposited, particularly those with high stress, then the film may flake off much earlier than expected.	Clean the chamber more regularly.

Table 6-4 PECVD particles

Particle Descriptions	When They Most Often Occur	Possible Causes	Remedy/Quick Fix - Test
	After a certain amount of deposition but the frequency seems to be reducing after every clean.	The films are not adhering to the showerhead very well. The showerhead has been cleaned using solvent, leaving behind a residue that is giving poor adhesion for the deposited films. The showerhead has become dirty and the clean process is unable to remove all the deposit. The showerhead is ready for its periodic maintenance.	Bead blast the showerhead.
Metal particles, which shine under normal clean room light and are greater than 20 μm in maximum dimension.	Most of the time	There may be arcing around the showerhead holes, or the holes may have become damaged due to normal wear and tear.	Bead blast the showerhead.
Particles or marks, which appear randomly on the wafer, but look as if they are underneath the film.	Every run	The wafer has been cleaned using solvents, which have not been properly washed off with de-ionised water.	Use a new wafer that has been cleaned properly.

Clean the showerhead. The use of solvents and ultra-sonic baths is strongly discouraged. Scrubbing with abrasive pads is also not recommended. OIPT are not be able to provide process support if these alternative cleaning methods are used.

Recommended bead blasting specification

Bead blast using alumina powder (aluminium oxide beads) of 180 grit size or less - for example 120. Do not use any solvents. Clean the showerhead after bead blasting using compressed air only. Hold the showerhead up to the light to check that none of the holes are blocked by grit from the bead blasting. Clean out any holes that are blocked with a length of suitable steel wire.

6.4.3.5 Enlarging of showerhead holes

PECVD showerhead holes can become enlarged during use. This is caused during high-power processing, for example during plasma cleaning. Any holes, which have slightly sharper edges, will form an intense discharge over the hole (due to the high fields generated by the sharper edges). These discharges can be seen as bright spots of flashes in the plasma during the clean process.

These discharges can cause some erosion and widening of the hole opening (on the outlet side only). Typically the erosion eventually removes the sharp edges and the bright spots disappear. This process may occur with several holes during the initial run-up of the system, until the showerhead is conditioned. The effect of hole enlargement on the deposition results should be minimal, since this effect only enlarges the outlet of the hole which should not affect the gas flow.

The bright spots may also produce some black/brown polymer deposition around the holes, which can cause premature flaking of deposited films. It is recommended that the showerhead is bead-blasted to remove such residues.

Bright spots should not be observed during low power (<50 W) deposition processes. If they are, it is recommended that the showerhead is plasma cleaned and bead-blasted until the bright spots are eliminated. If bright spots are still present after cleaning, the showerhead should be replaced.

6.4.3.6 PECVD process chamber cleaning recipes

A CF_4/N_2O or CF_4/O_2 plasma cleaning recipe is typically recommended for PECVD processes.

6.4.3.7 Optical emission endpoint detector for chamber clean

Oxford Instruments Plasma Technology has integrated its optical emission spectroscopy (OES) end-point detector with the **FlexAL**® standard PC2000 operating software. This provides a real-time display of detector signal, and allows for automatic process end-point detection or user terminated end-point.

Part No. 81-12-70

The end-point detector is a fixed, single wavelength detector with a narrow bandpass optical filter and high sensitivity photodiode. The kit includes a KF40 process window and detector mount assembly.

The system monitors the 704 nm wavelength (atomic fluorine) emission. This fluorine is consumed while the deposited material in the chamber is clearing.

When most of the material has been removed, the fluorine emission rises, indicating the completion of the chamber plasma cleaning process. An example of clearing a thick film (100 µm) deposition is shown in **Figure 6-5**.

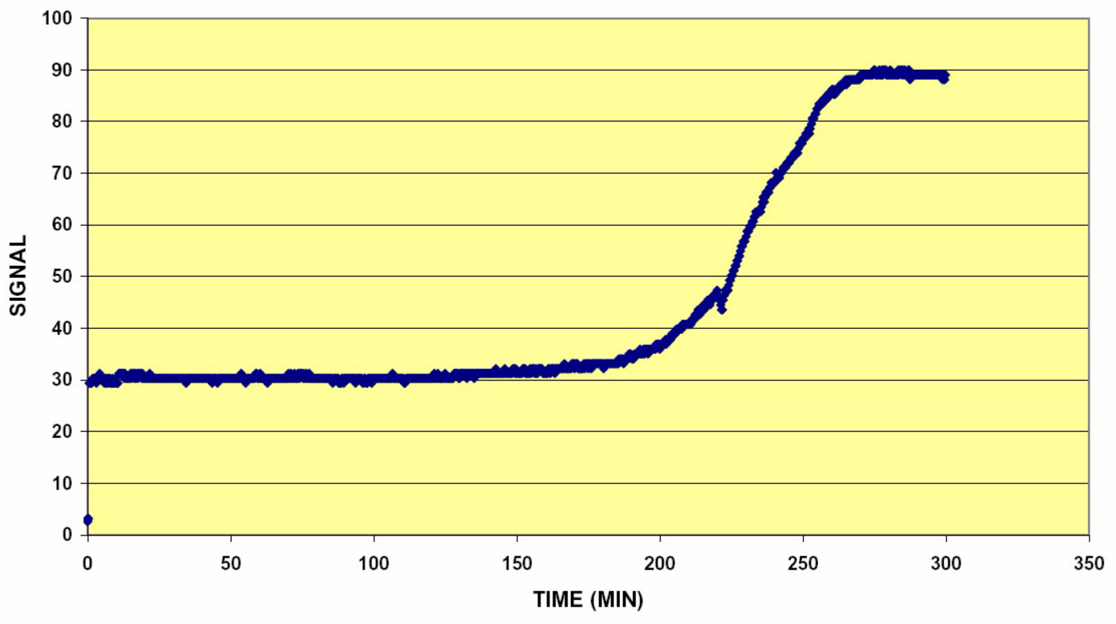


Figure 6-5 End point signal, SiO_2 cleaning (100 microns deposition)

6.4.3.8 Running deposition processes on an HDP system

For an HDP tool the typical process operating ranges for deposition are:

Total gas flows = 10 to 200 sccm.

The maximum flow depends on the type of pumps fitted to the system i.e. their maximum flow capacity, their pumping performance, and the required operating pressure. It may be necessary to use lower flow rates than these if a particular process requires a low vacuum pressure.

Pressure = 1 to 60 mTorr.

With process pressures below 5 mTorr and above 20 mTorr the plasma may not strike easily, or it may be unstable, depending on the process gas and power levels used. It is important to check this and adjust the process accordingly, since operating the system without a plasma can cause permanent equipment damage.

The *low pressure strike* feature in the PC4000 application can be used to help the plasma strike for low pressure processes.

The APC may not be able to maintain a constant pressure for certain flow/pressure combinations. The gas flow or pressure settings may need to be adjusted accordingly.

ICP power = approximately 30 W to 200 W.

The minimum ICP power that can be used depends on how easily the plasma strikes for certain gases. It is important to check this and to adjust the process accordingly. Operating the system without a plasma, either on the substrate electrode or in the ICP tube, could cause equipment damage.

The maximum ICP power that can be used depends on the power rating of the RF generator. However, most processes perform well with only moderate ICP power levels, which also helps to avoid excessive substrate heating.

Substrate electrode RF power = typically 5 W to 400 W.

ICP-PECVD processes are usually operated with a substrate electrode RF power of 0 W. In this case, a brief plasma strike step using a low substrate RF power may be required to start the plasma. Adding substrate power to the ICP-PECVD process can be used to provide ion bombardment of the film during growth and hence control certain film properties.

Helium pressure = 0 to 30 Torr.

The optimum helium pressure depends on the cooling efficiency required and the maximum tolerable helium leakage. Some processes benefit from no cooling.

Temperature

The table temperature is limited by the operating range of the electrode or its heater/chiller, depending on type of electrode or heater/chiller used.

6.4.4 Process troubleshooting

6.4.4.1 Partial process failure

A partial process failure may produce one or more of the following symptoms:

- The etch rate has dropped.
- The etch selectivity has reduced.
- The etch profile is no longer anisotropic.
- Non-uniform etching (or deposition).

Table 6-5 Possible causes of partial process failure

Possible Cause	Recommended Actions
The hardware has changed.	Review any maintenance tasks that have been performed recently. Possible causes are a new gas cylinder, a new cover plate, or a faulty RF or grounding connection.
A vacuum leak.	Perform a vacuum leak-check (see **Section 4.3.13.4**).
A faulty MFC.	Check the calibration of the MFCs (see **Section 4.3.13.4**).
The process pressure is incorrect or is varying.	Fault-find the APC, MFCs and pumping system (see **Chapter 8**).
Incorrect RF power reaching the plasma.	Fault-find the RF generator and matching unit (see **Chapter 8**).

Table 6-5 Possible causes of partial process failure

Possible Cause	Recommended Actions
Incorrect gas mixture.	Check that the correct gas species and flows have been selected. Check the calibration of the MFCs (see **Section 4.3.13.4**).
Incorrect or non-uniform wafer temperature.	Check the wafer clamping and cooling. Faulty helium cooling system (if used). Investigate possible causes of poor thermal contact between the wafer and the substrate table (e.g. contaminated or damaged table, poor sample adhesion to its carrier).
The chamber is dirty.	Clean the chamber more frequently.
Poor process regime.	Try making small variations in various process parameters. A poorly designed process may produce large effects on the wafer in response to a small change in a certain process parameter. This effect is often referred to as a knife edge or cliff process.
	Check that the process includes sufficient pumpdown time, preheat time or pre-clean time.
	The process may be sensitive to a different process that has been run immediately before it. Investigate if a transition process is required.
The incorrect hardware has been used for the given process.	Check that the correct cover plate, electrode gap and temperature setting have been used.

6.4.4.2 Total process failure

Refer to **Chapter 8** if the plasma does not strike or if there is a different major failure.

7 PERIODIC MAINTENANCE

This chapter provides instructions for the scheduled maintenance tasks that must be performed on the **FlexAL**® system. They include:

- **Daily maintenance tasks**.
- **Weekly maintenance tasks**.
- **Monthly maintenance tasks**.
- **Three-monthly maintenance tasks**.
- **Six monthly maintenance tasks**.
- **Annual maintenance tasks**.
- **Unscheduled maintenance tasks**.

WARNING 7.1

POTENTIALLY HAZARDOUS EQUIPMENT
The FlexAL® system can produce various hazards if maintenance work is not performed correctly. These hazards can cause death or serious injury. Before maintaining the system, ensure that all relevant personnel have read and understood Chapter 1 of this manual (Health and safety). If you have any concerns or questions, contact Oxford Instruments Plasma Technology before proceeding with the maintenance task.

7.1 Daily maintenance tasks

7.1.1 Check the turbo pump temperature

1 Ensure that the turbo pump temperature is sufficiently high, i.e. >50ºC. The turbo pump temperature can be monitored on the turbo pump controller's display (ATH400M), or via the dedicated software and RS232 cable (ATH500M). Refer to the pump manufacturer's manual for details. If the turbo pump temperature is too low, adjust the manually-operated flow valve to reduce the flow rate of the turbo pump cooling water.

7.2 Weekly maintenance tasks

7.2.1 Check the base unit

1 Examine the exterior of the machine for damage or signs of overheating and for failed indicator lamps.

2 If the system is fitted with a closed loop (recirculating) cooling system, top up with an appropriate coolant. Contact OIPT for the part number of an appropriate coolant.

Refer to **Chapter 10** for the warranty impact of not using a recommended coolant product.

7.3 Monthly maintenance tasks

7.3.1 Check the base unit

1. Monitor the vacuum integrity of the system by pumping thoroughly, isolating the process chamber and noting the rate of pressure rise. An abnormally high value (i.e. > 2 mTorr/minute) may indicate a leak or heavy contamination of the process chamber. (The chamber can be isolated by clicking the Stop button on the corresponding Pump Control page.)
2. Monitor the backing pump(s)' condition by timing how long it takes to pump from atmosphere to 0.1 Torr (without a turbomolecular pump turned on). An increase in time may indicate deteriorating pump performance. If a foreline trap is fitted, an increase in time may indicate the filters inside the trap require changing.
3. Check the zero setting of the capacitance manometer (CM) gauge. Note that the CM gauge output does not stabilise until it has been switched on and under vacuum for at least 15 minutes. A turbo pumped system will have a base pressure well below 0.1 mTorr, so the zero point can be adjusted readily in this case (see manufacturer's data). A Roots/rotary combination should give a base pressure below 1 mTorr, and can be used to set the zero point of a 10 Torr gauge. A rotary pump should give a base pressure below 10 mTorr, so a true zero pressure cannot be set in this case. Either the gauge should be set to the same arbitrary reference level (e.g. 10 mTorr), or it should be set to zero on another vacuum system with a known base pressure, and carefully re-installed.
4. Monitor the performance of each mass flow controller, by noting the system pressure with 10%, 50% and 100% flow setpoints and the throttle fully open. A change may indicate a deterioration in MFC performance or a change in pumping speed.
5. Check the safety interlock chain is functioning by cycling each of the interlock devices in turn (identified in **Section 1.6.2.1**).

7.3.2 Check the process chamber

WARNING 7.2

ITEMS CAN MOVE UNDER AUTOMATIC CONTROL
The ICP isolation gate valve can operate without warning. This could can cause severe injury. Ensure that electrical power to the system is locked out before working near the gate valve. Ensure that the compressed air supply to the system is locked out before working near the gate valve. Ensure that the compressed air lockout valve on the system front panel is pulled out and padlocked before working near the gate valve.

WARNING 7.3

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

7.3.2.1 Inspect and clean the process chamber

1. Perform a partial shutdown of the system (see **Section 5.2.6**).
2. Open the Slit valve and ICP valve, then isolate and lockout the compressed air. Use a lint-free cloth and IPA to clean the O-ring and its sealing face.

> **PINCH POINT**
> **The slit valve is a pinch point, which could cause severe injury. Lockout the compressed air supply to the machine before working near the slit valve.**
> **WARNING 7.4**

3. Visually examine the interior of the chamber for contamination. Any necessary cleaning must be carried out using a lint-free cloth moistened with Isopropyl Alcohol (IPA). Tougher deposits can be removed using an abrasive pad first.

> **FLAMMABLE LIQUID**
> **Isopropyl alcohol is highly inflammable (flammable). Do not use it near a naked flame or energised electrical equipment.**
> **WARNING 7.5**

4. Examine the exterior of the chamber and its fittings for damage.
5. Examine the lid and seals for any damage or deterioration.
6. Examine the heating/cooling water flow system for signs of leakage.
7. Purge the process chamber for thirty minutes with dry nitrogen if IPA has been used for cleaning.
8. Visually examine the top electrode for contamination. Any necessary cleaning must be carried out using a lint-free cloth moistened with Isopropyl Alcohol (IPA).
9. Examine the top electrode and its integral gas and water fittings for damage.
10. Examine the seals for signs of deterioration.

7.3.2.2 Check the process chamber O-rings

The O-rings must be checked monthly but replaced as and when necessary.

Replacement O-rings must be constructed of an appropriate high-temperature compatible material (not viton). They must be pre-baked to 150°C to minimise the risk of water vapour from the O-rings. The chamber lid O-ring does not have to be removed unless it leaks. Clean the O-ring in situ using a lint-free cloth wetted with Isopropyl Alcohol.

To change the lid O-ring (use gloves):

1. Perform a partial shutdown of the system (see **Section 5.2.6**).
2. Remove the O-ring, being careful not to damage the retaining groove.
3. Use a lint-free cloth and IPA to clean the O-ring sealing face on the chamber.
4. The new O-ring, cleaned with IPA, must be inserted with no twists. Stretch the O-ring evenly as it is inserted to avoid local regions of stretching.

7.3.3 Check the upper electrode

1 Perform a partial shutdown of the system (see **Section 5.2.6**).

WARNING 7.6

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

2 Visually examine the upper electrode for contamination. If necessary, clean the electrode by using a lint-free cloth moistened with Isopropyl Alcohol (IPA).

WARNING 7.7

FLAMMABLE MATERIALS
Some materials used in, and resulting from, deposition and etching processes can be flammable. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Only use appropriate materials when cleaning flammable coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.

3 Examine the upper electrode and its integral gas and water fittings for damage. Carefully inspect the gas inlet showerhead plates for signs of plasma concentrating in a hole and enlarging the hole.

4 Examine the seal for signs of incipient deterioration.

7.3.4 Check the lower electrode

1 Perform a partial shutdown of the system (see **Section 5.2.6**).

WARNING 7.8

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. After a processing run, the process chamber must be subjected to at least two vent cycles before any maintenance work is carried out. Ensure that the gas lines have been purged before removing or loosening components. Wear personal protective equipment as necessary.

2 Visually examine the substrate table for contamination. Any necessary cleaning must be carried out using a lint-free cloth soaked in Isopropyl Alcohol (IPA).

WARNING 7.9

FLAMMABLE MATERIALS
Some materials used in, and resulting from, deposition and etching processes can be flammable. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Only use appropriate materials when cleaning flammable coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.

3 Examine the table and its integral heating and/or cooling systems for signs of damage.

7.4 Three-monthly maintenance tasks

7.4.1 Check the base unit

1 Heater/chiller unit (on closed loop cooling systems). If the condenser on the refrigeration circuit is air-cooled, it must be kept clean enough to allow the free flow of air through it. Dirt can be removed by brushing or vacuum cleaning.

2 Carry out the RF radiation leakage tests as detailed in Section 7.4.2.

7.4.2 Check the RF generators and AMU

WARNING 7.10

RF AND MICROWAVE RADIATION
Exposure to RF and microwave emissions can cause severe injury or burns. This section includes all the current requirements for the measurement of radio frequency and microwave emissions from the Oxford Instruments Plasma Technology FlexAL®II range of products. Ensure that all personnel involved have read and understood this entire section and that the tests specified in this section are performed and recorded every three months.

Oxford Instruments Plasma Technology **FlexAL**® systems are tested for the emission of RF and microwave energy prior to shipment. Each system must be subsequently tested every three months during use, or more frequently if local safety standards require it.

Systems must also be tested for RF and microwave emissions after maintenance, if the maintenance has disturbed any RF shielding components (such as covers and viewports), or components in the process chamber (such as feedthroughs and vacuum gauges).

Systems with RF generators in the frequency range of 0.1 MHz to 81 MHz must be tested for emissions by separately measuring both the electric (E) and magnetic (H) field strengths. Either field can be a safety hazard, hence the need to test both.

Suitable test meters are the Narda[1] 8511 for 1.7 MHz to 2.1 MHz and the Narda 8512 for 13.56 MHz and 27.12 MHz. Equivalent meters from other vendors are acceptable. The test meter MUST have a current calibration certificate. If an alternative 13.56 MHz meter is used, it must be able to detect the presence of 27.12 MHz as well as 13.56 MHz.

The viewports have been identified by OIPT as a particular risk area. The acceptable radiation limit at viewports, and within a 20 cm radius hemispherical region centred on the viewport, is 40% of the general acceptable level.

7.4.2.1 Tools and equipment

The following item is required to perform this task:

- A suitable test meter to match the frequency of the RF generator on the system.

7.4.2.2 Procedure

To test the RF and microwave emissions from a system:

1. Ensure that the system is in its normal operating configuration, with all covers and components in place.
2. Evacuate the system to its base pressure.
3. Turn on all system RF generators and set the output power of each generator to its maximum operating value.
4. Measure the emitted field strength 50 mm (2 inches) away from the system, at all points that can be reached by hand with the probe. If parts of the system are inaccessible from the ground, a stepladder must be used to allow access.

   The probes of the recommended meters are designed so that the correct measurement distance is obtained if the head of the probe is touching the system. Particular attention must be given to viewports, doors and flanges, the auto matching unit, and the whole length of RF power cables. If viewports are fitted with shutters, then tests must be made with the shutter both open and closed. Cables that connect to gauges or feedthroughs on the process chamber can radiate RF energy, even if they are not directly connected to the RF power feed. Check all such cables along their entire length. Also check the pumping system and the power box.
5. Strike a plasma in the system and repeat the previous measurement step.
6. Compare the measured values against the equipment specification (see Table 7-1). The **General** column lists acceptable limits for most parts of the system. The **Viewports** column lists acceptable limits for a hemispherical region 20 cm in radius, centred on the viewport. Readings must be equal to or less than the levels shown in Table 7-1 at all points. Exceptions are only be permitted in certain special circumstances. These exceptions are clearly documented in the system instructions. In all other situations, these standards must be strictly met.

1. The Narda Microwave Corporation, Plainview, New York 11803.

If any measurement exceeds the permitted radiation, investigate and cure the cause of the emission before returning the equipment to service.

Table 7-1 Maximum permitted RF field strengths

Frequency (MHz)	Electric Field (E)		Magnetic Field (H)	
	V/m		A/m	
	General	Viewports	General	Viewports
0.1	87.0	34.8	2.19	0.88
0.05 to 0.46	87.0	34.8	2.19	0.88
0.4	87.0	0.1	1.83	0.73
2	43.5	17.4	0.37	0.15
13.56	12.1	4.86	0.073	0.03
60	5.5	2.2	0.034	0.01
81	5.5	2.2	0.021	0.01

It is strongly recommended that the operation of all safety interlocks must be tested at the same time, whenever an RF leakage test is performed.

7.4.3 Check the precursor delivery modules

7.4.3.1 Verify the operation of the housekeeping valves (for single-precursor ovens).

1. Close the manual ampoule valves.
2. Pump and leak check the line according to steps listed in the precursor removal procedure.
3. Open all housekeeping valves.
4. Flow argon down the precursor line into the chamber and note the pressure rise.
5. Close each housekeeping valve in turn and confirm the pressure in the chamber reaches base pressure.
6. Flow argon for no more than 30 seconds at 100 sccm with the valve closed.
7. An over pressure alarm will be generated when opening the housekeeping valve after this test due to the pressure build up.

7.4.3.2 Oven maintenance

1. Check the calibration of the oven and the temperature of the heated gas lines.
2. Inspect the oven, heated lines and nearby components for signs of hot spots or overheating.

7.4.3.3 Six-way precursor cabinet checks

1 Check that all heater jackets are tightly wrapped around pipes and valves. Ensure that the velcro straps remain tight.

NOTE: When fitting heater jackets around bends in pipe-work, start fitting the heater jacket at the bend and work outwards.

7.4.3.4 Check the extraction system

1 Ensure the extraction system is operational and that the air flow is with specified limits.

7.5 Six monthly maintenance tasks

7.5.1 Check the upper electrode (for tools with a system showerhead)

1 Perform a partial shutdown of the system (see **Section 5.2.6**).

2 Check the condition of the gas inlet isolation assembly for any signs of brown discolouration of the white PTFE.

The white PTFE sometimes changes to brown in colour before failing with a major enlargement of the through-holes.

7.5.2 Check the vacuum system

7.5.2.1 Check the active Pirani gauge

Refer to the manufacturer's literature in Volume 3 for details of:

a) Atmosphere and vacuum adjustment.

b) Filter cleaning.

7.5.2.2 Check the capacitance manometer gauge

1 Perform a partial shutdown of the system (see **Section 5.2.6**).

2 Remove the capacitance manometer from the process chamber.

FLAMMABLE LIQUID
Isopropyl alcohol is highly inflammable (flammable). Do not use it near a naked flame or energised electrical equipment.
WARNING 7.11

3 Carefully pour a measure of Isopropyl Alcohol (IPA) at room temperature into the pressure-measurement cavity. Do not allow IPA to come into contact with electronic components.

4 Agitate the solvent carefully and then pour it out.

FRAGILE COMPONENT
Because the diaphragm in the gauge is thin tensioned metal, it can be destroyed by sudden changes in temperature or by clumsy handling.
Caution 7.1

5 Re-install the gauge, allowing sufficient time for outgassing of the cavity and diaphragm prior to operation.

NOTE: Refer to the manufacturer’s manual for calibration adjustments.

7.5.2.3 Check the Penning gauge

The following applies to an Edwards Active Inverted Magnetron gauge. If a different Penning gauge is fitted, refer to the manufacturer's literature.

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. Perform the recommended lock out / tag out procedure before disconnecting or dismantling the Penning gauge.
WARNING 7.12

Dismantling the body tube

The body tube assembly can be removed from the gauge by gripping the magnet housing and twisting the body tube flange clockwise to unlock the bayonet fitting. The tube can then be completely withdrawn from the gauge electronics / magnet housing.

The electrode can be removed from the body tube for cleaning / replacement as follows:

1 Using the flat spanner provided with the spares kit, locate the two lugs in the end of the collar and rotate anti-clockwise to completely unscrew. Once the collar is removed, the anode assembly and O-ring can be withdrawn.

2 The two cathode cups are removed from the flange end of the body tube by releasing the circlip using a pair of circlip pliers. Note the correct orientation of the cups. The cup with the reduced central hole size must be closest to the O-ring end of the body tube.

3 Re-assembly is the reverse procedure, taking care not to bend the anode, and ensuring that it is centralised in the body tube when tightening the threaded collar.

Cleaning the Penning gauge

FLAMMABLE MATERIALS
Some materials used in, and resulting from, deposition and etching processes can be flammable. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Only use appropriate materials when cleaning flammable coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.
WARNING 7.13

The cathode cups, body tube and anode assembly can be cleaned by firstly degreasing in a proprietary degreasing agent, and then thoroughly soaking in a laboratory detergent. After soaking, the parts must be thoroughly rinsed in clean water and then in Isopropyl Alcohol, to remove all traces of water. The parts must be dried thoroughly.

7.6 Annual maintenance tasks

7.6.1 Check the base unit

1. Replace or clean the filters used in the compressed air supply system.
2. Replace the filters in the cooling water system.
3. Where closed loop (recirculating) water cooling systems are used, drain the system and replace the coolant with a suitable product. Contact OIPT for details of approved coolants.
4. Refer to **Chapter 10** for the warranty impact of not using an approved coolant product.

7.6.2 Check the upper electrode

This inspection is for tools with access to the gas inlet isolation assembly from the top side only.

1. Perform a partial shutdown of the system (see **Section 5.2.6**).
2. Check the condition of the gas inlet isolation assembly for any signs of brown discolouration of the white PTFE.

   The white PTFE sometimes changes to brown in colour before failing with a major enlargement of the through-holes.

7.6.3 Check the gas handling system

WARNING 7.14

TOXIC GASES
Exposure to toxic gases can cause death or serious injury. Before attempting any maintenance work on the gas handling system, electrically isolate the system by switching off the wall-mounted electrical isolation box. Adopt the correct purging procedures before removing or loosening components in the gas system. Wear appropriate personal protective equipment.

7.6.3.1 Check the wall-mounted gas pod

1. Ensure that the gas pod and its fixings are secure.

NOTE: OIPT gas pods typically weigh >40 kg. Ensure the wall and gas pod fixings are sturdy enough to bear at least four times the weight of the gas pod.

7.6.3.2 Check the mass flow controller

If it is necessary to clean, repair or re-calibrate the valves:

1. Perform a full shutdown of the system (see **Section 5.2.7**).
2. Make sure the valve has been thoroughly purged before removal.
3. Arrange with the vendor for the return of the mass flow controllers for service work. Inform the vendor if hazardous gases have been used.

7.6.3.3 Check the gas line filters

The process gas filter elements must be exchanged for new items at intervals that depend on the nature and purity of the process gases, and of other materials that come into contact with them. It may be necessary to change the filters annually, more frequently than annually, or less frequently than annually.

1. Perform a full shutdown of the system (see **Section 5.2.7**).
2. Make sure the line has been thoroughly purged before removal.
3. Unscrew the union nut and remove the filter assembly.
4. Using a a fibre mallet, tap the filter element lightly on the side to loosen and remove the element.
5. Fit a new element.
6. Re-assemble and fit the filter assembly.

7.7 Unscheduled maintenance tasks

This sub-section provides instructions for periodic maintenance tasks that occur on an event basis. The tasks described here include:

- **Changing the gas bottles**
- **Etch cleaning**
- **Turbomolecular pump maintenance**
- **Cleaning the process chamber liners.**
- **Servicing the ICP gate valve**
- **Adjusting the automatic loadlock end-effector for different wafer sizes**
- **Opening the process chamber for maintenance**
- **Removing, exchanging and fitting ampoules**
- **Preparing the six-way precursor cabinet to fit an ampoule**
- **Fitting an ampoule into the six-way precursor cabinet**
- **Preparing the single-precursor oven to fit an ampoule**
- **Fitting an ampoule into a single-precursor oven**

7.7.1 Changing the gas bottles

The operator should be aware that certain process parameters may change as the process gas bottles pressure drops. For example, inert gas bottles which are normally filled to about 3000 psi, should be changed when the pressure drops below 400 psi. The inlet pressure should be 25 psia to 35 psia. Before disconnecting the empty bottle it is advisable to thoroughly evacuate the gas line (by closing the gas bottle tap and pumping the line via the MFC). The line should then be filled with dry N_2 if available.

Once the new bottle has been connected, monitor the vacuum integrity of the gas line before opening the bottle by setting a high flow on the MFC, pumping the line thoroughly (via the MFC), isolating the process chamber and noting the rate of pressure rise. An abnormally high value (>2 mTorr/minute) may indicate a leak in the gas line or the regulator to bottle connection.

During normal operation the bottle pressure and line pressure on the cylinder regulator must be regularly checked for loss of pressure during periods when the gas bottle tap is turned off (during shut-down periods, overnight or over a weekend). This will indicate a leak from the gas line or the regulator.

7.7.2 Etch cleaning

Where the system is used for Plasma Enhanced Chemical Vapour Deposition (PECVD), the manual processing runs should be interspersed with etching processes as an efficient method of cleaning the electrodes and chamber walls.

The etching processes may be optimised to suit particular processing requirements; however, the following recommendations may be used as a starting point.

The etch cleaning should be performed each time the aggregate of the deposition layers reaches ~10 microns.

The recommended clean process is:

CF_4/O_2 8% or 20%, 700 mTorr, 200 W, 30 minutes

This process is optimised for rapid electrode cleaning. If it is found that the cleaning rate of the chamber walls is too slow with the above process, then a low pressure process can also be used:

CF_4/O_2 8% or 20%, 350 mTorr, 200 W, 30minutes

The two processes can be alternated until the chamber and electrodes are etched clean.

A chamber conditioning step (using the normal deposition conditions in the empty chamber to deposit 0.2 to 0.5 μm) is recommended before processing wafers.

7.7.3 Turbomolecular pump maintenance

Refer to the manufacturer’s literature in Volume 3 for details of maintenance required.

7.7.3.1 Maintenance of all turbo pumps

TURBOMOLECULAR PUMP FAILURE
Premature failure of turbomolecular pumps can be caused by failure to observe the recommendations given below.

Caution 7.2

a) Always follow the maintenance and operating instructions contained in the manufacturers' manuals, copies of which are provided within the system manuals. Note that with some types of pump the lubricant should be replaced when the total running time reaches 500 hours.

b) When corrosive process gases are being used always purge the turbo pump with dry nitrogen during a processing run. If the process chamber is to be vented adequate time must first be allowed for the process gases to be pumped away.

c) If corrosive process gases are used in a system with no gate valve between the turbo pump and the process chamber and the system is to be left for more than one hour with the turbo pump not running, proceed as follows:

Procedure

1 Turn off all the manual gas taps on the process gas lines. Also turn off the gas taps on the process gas cylinders.

2 Close the chamber door.

3 Pump the process chamber and turbo pump down to approximately 1 x 10^{-4} millibars.

4 Vent the process chamber and turbo pump to atmospheric pressure with dry nitrogen. Do not allow the chamber door to open.

5 Repeat steps **3** and **4** three times.

6 Seal the process chamber and turbo pump.

If corrosive process gases are used in a system with a gate valve between the turbo pump and the process chamber and the system is to be left for more than one hour with the turbo pump not running, proceed as follows:

1 With the exception of the Argon and Nitrogen lines, turn off all the manual gas taps on the process gas lines and also turn off the gas taps on the process gas cylinders.

2 Close the chamber door.

3 Run a process sequence (without any samples loaded), using only Argon or Nitrogen as process gases for at least 10 minutes.

4 Vent the process chamber and vent the turbo pump to atmospheric pressure with dry nitrogen. Do not allow the chamber door to open.

5 Pump the process chamber and the turbo pump down to 1 x 10^{-4} millibars and then vent them with dry nitrogen.

6 Repeat step **5** three times.

7 Seal the process chamber and the turbo pump.

7.7.3.2 Maintenance of Alcatel ATP/ACT turbo pumps only

Re-greasing of process chamber turbo pumps

The following instruction applies to conventionally greased bearing turbo pumps, e.g. the Alcatel ATP series. It does not apply to Maglev turbo pumps.

To prevent damage to turbo pumps fitted to process chambers, OIPT strongly recommends that bearing re-greasing is carried out periodically after every 2500 hours of pump running time.

Details of re-greasing are given in the following section.

Turbo pump lubrication (2000 to 8000 hours) (3 to 12 months)

MAINTENANCE
Failure to perform regular pump maintenance will result in the pump warranty being suspended.

Caution 7.3

Refer to the manufacturer’s manual in Volume 3 of this manual.

Alcatel ATP series turbo pumps are conventional greased bearing pumps. Periodically, these bearings need to be re-greased.

The re-greasing interval depends on a number of factors; Refer to the graph in the Maintenance section of the manufacturer’s manual to establish the re-greasing interval for the pump in your system. Remember that turbo pumps fitted to process chambers must be re-greased at 2500 hour intervals. The re-greasing interval for turbo pumps fitted to load locks and transfer chambers is not so critical, therefore the manufacturer’s recommendations can be used.

The ATP turbo pumps are supplied with series ACT intelligent controllers which are menu driven. The SET-UP menu allows the re-greasing interval to be set so that a visual warning with an optional audible alarm is displayed at the relevant time. Note that this visual warning does not require any action immediately; it only indicates that the bearing should be regreased at the next available opportunity. If required, the visual warning and audible alarm can be disabled via the SET-UP menu.

When the pumps are supplied, the ACT controller is pre-set with a 5,000 hour re-grease interval. If the pumps are running continuously, the visual re-grease warning will be automatically triggered after approximately seven months.

The customer is advised to use the SET-UP menu to set the re-greasing interval for the pump fitted to his system. Refer to the pump manufacturer’s manual. Note that this change takes approximately five minutes.

When the re-greasing time is reached, lubrication is carried out using a pre-loaded syringe to apply a metered quantity of a specific grease to one point on the bearing. Refer to the pump manufacturer's manual. The Alcatel part numbers of the syringes are:

Table 7-2 Alcatel syringes part numbers

Pump Type	Pre-loaded Syringe Part Number
ATP80	056993
150C/400HPC/900HPC	101924

Note that the grease syringe has a limited shelf life so shouldn't be ordered from the Alcatel service centre until it is needed. Alcatel exercises strict stock control on this item to ensure that the grease is always in good condition.

Once the grease has been applied to the bearing, it needs to be evenly distributed around the bearing. This is done automatically by using the ACT controller's 'RUNNING IN' menu.

NOTE: The grease distribution takes approximately 2.5 hours.

7.7.3.3 Alcatel turbo pumps fitted with bake-out collars

Some systems incorporate a bake-out collar fitted to the turbo pump to assist heating the process chamber to approximately 50ºC - 60ºC.

If the flow rate of the cooling water to the turbo pump is too high, the pump will be over cooled, thus reducing the heating effect of the bake-out collar.

7.7.3.4 Vacuum pump lubricants

Caution 7.4

VACUUM PUMP LUBRICANTS

When changing or topping-up the lubricating oil in a pump, always use oil of the same brand and type. If a change of brand or type is contemplated, refer to Oxford Instruments Plasma Technology for advice.

The lubricating oils used for pumps where the oil comes into contact with the pumped gases, i.e. oil-sealed pumps such as rotary vane types, must be chosen to meet the specific characteristics necessary for the process involved.

The vapour pressure must be low at the temperatures reached at the rubbing surfaces. Viscosity should not vary significantly over the temperature range involved, and the water absorption rate and content must be low.

Lubricating oils generally fall into one of two categories: mineral (hydrocarbon) based oil or synthetic oil such as perfluorinated polyether. The synthetic oils are normally used where they come into contact with strong oxidants such as nitrogen dioxide, oxygen, or one of the halogens.

Perfluorised polyethers

Perfluorised polyether (PFPE) lubricants have the following properties:

a) They are stable up to 350°C, i.e. they do not decompose below this temperature.

b) They are chemically inert. They will, however, react with Lewis acids (BCl_3, $AlCl_3$ etc.) at temperatures over 100°C.

c) They do not polymerise under the impact of high-energy radiation.

d) Since they tend not to keep contaminants suspended, pumps using these lubricants must always be fitted with suitable oil filters.

e) They do not age and therefore, if used correctly, need not be replaced during the lifetime of the pump.

f) Any contaminants in the lubricant may be removed by fitting clean filters and letting the pump run for several hours with inert gas ballast, the intake port having been closed.

g) They do not protect metal surfaces against corrosion. Pumps must therefore always be flushed with inert gas. Pumps using PFPE should be allowed to run continuously.

h) PFPE is incompatible with hydrocarbon oils, i.e. mineral oils, conventional greases and cleaning agents.

i) If a pump uses PFPE lubricant only Freon 113 or Frigen 113 may be used as a cleaning agent, and only PFPE grease may be employed.

j) If it should become necessary to change from PFPE to mineral oil lubrication or vice versa, the pump must be completely disassembled, freed of lubricant and fitted with new gaskets and vanes.

k) At temperatures over 350°C, hazardous gaseous decomposition products are formed. Therefore do not smoke in rooms where PFPE is used, and make sure that no tobacco comes into contact with PFPE.

l) When handling PFPE, protective clothing must be used.

m) Do not mix PFPE with used oil. Dispose of them separately.

n) PFPE is normally odourless and colourless. Cloudiness or odour is a sign of contamination.

Hydrocarbon lubricants

Where mineral oils are used, the rate of oil deterioration for a particular pump and process must be established at an early stage, and oil changes based upon this information.

7.7.3.5 Backing pump maintenance

Refer to the manufacture’s literature for details of the maintenance required.

7.7.4 Cleaning the process chamber liners.

Clean the inner process chamber liners after every 3 to 5 microns of deposition.

7.7.5 Servicing the ICP gate valve

Service the ICP gate valve after cleaning the process chamber liners two to four times.

1. Open the ICP gate valve.
2. Perform a partial shutdown on the system (see **Section 5.2.6**). Ensure the ICP gate valve remains open.
3. Lockout the compressed air dump valve.
4. Unscrew the two screws that secure the ICP gate valve in place (see **Figure 7-1**).

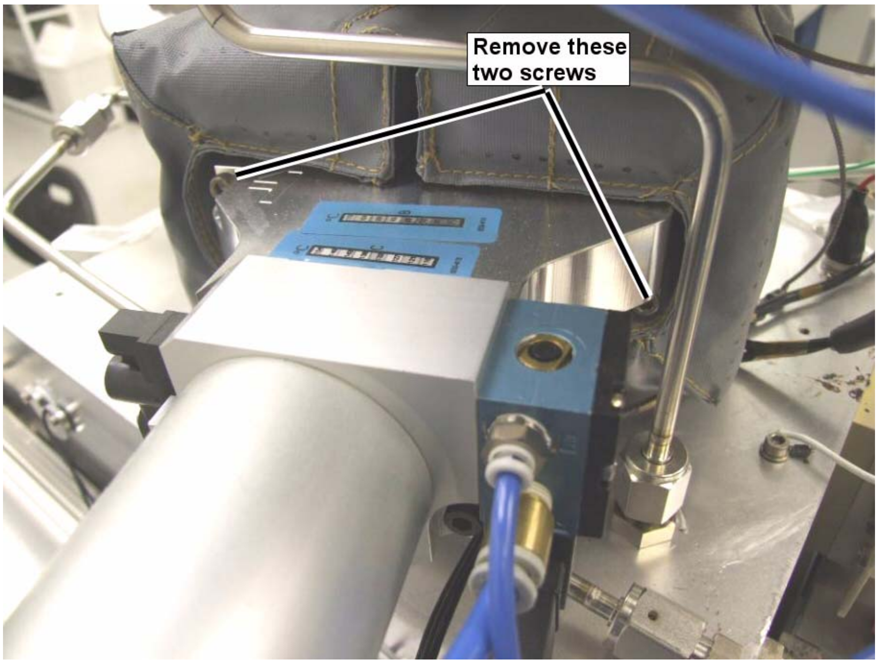


Figure 7-1 Removing the ICP gate valve

5. Clean the gate valve actuator using a vacuum cleaner that is suitable for toxic use.
6. Wipe the actuator using a lint-free wipe moistened with isopropyl alcohol.
7. Refit the gate valve, in the open position.
8. Refit the two fixing screws (see **Figure 7-1**).
9. Start up the system.
10. Open and close the gate valve several times, to check it is operating correctly.
11. Open the gate valve and flow gas through the ICP tube. Check that the process chamber pressure rises.

7.7.6 Adjusting the automatic loadlock end-effector for different wafer sizes

The automatic load lock end effector can accommodate wafer diameters of 3” to 8”. This is achieved using a series of pairs of holes appropriately spaced for the different wafer sizes into which concentric cams are secured. See **Figure 7-2**.

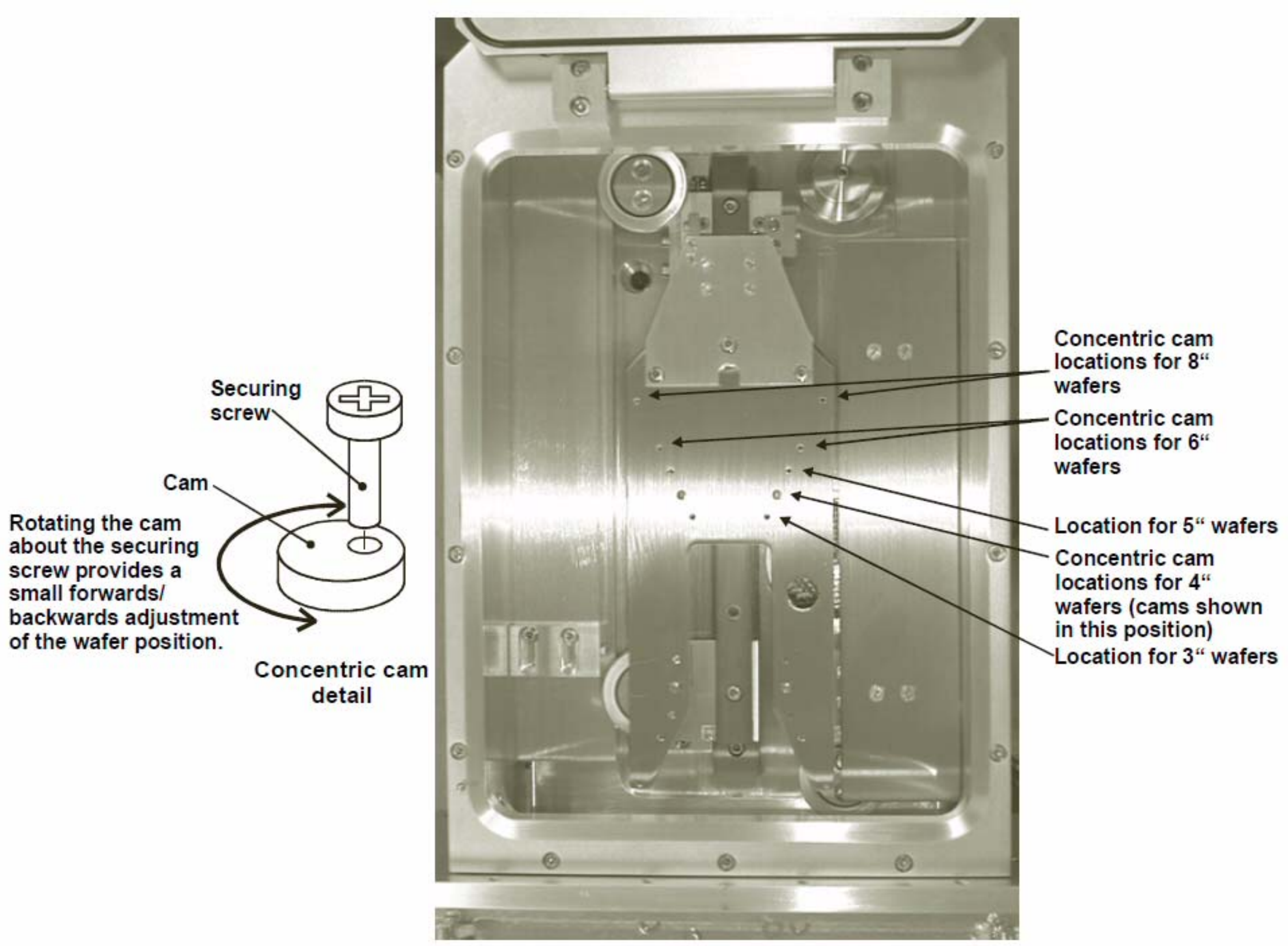


Figure 7-2 End-effector wafer size adjustments

To set up the end effector for a wafer size different to that previously processed, use the following procedure:

1. If necessary, vent the automatic load lock.
2. Open the automatic load lock’s lid.
3. Wearing powder-free gloves, remove both concentric cams/securing screws from the end effector, then fit them into the appropriate holes for the wafer size to be processed (see **Figure 7-2**).
4. Close the automatic load lock’s lid, then carry out a test wafer load into a process chamber. Ensure that the wafer is located centrally on the lower electrode. If necessary, rotate the concentric cams until the wafer is located centrally.

7.7.7 Opening the process chamber for maintenance

See **Section 5.2.4** for details.

7.7.8 Removing, exchanging and fitting ampoules

There is a different set of procedures for removing, exchanging and fitting ampoules for the six-way precursor cabinet and for the single-precursor oven:

Ampoule procedures for the six-way precursor cabinet:

- Shut down the precursor modules (see **Section 5.2.8**).
- Prepare the cabinet to fit an ampoule (see **Section 7.7.9**).
- Fit the ampoule and return the system to service (see **Section 7.7.10**).

Ampoule procedures for the single-precursor oven:

- Shut down the precursor modules (see **Section 5.2.8**).
- Prepare the oven to fit an ampoule (see **Section 7.7.11**).
- Fit the ampoule and return the system to service (see **Section 7.7.12**).

7.7.9 Preparing the six-way precursor cabinet to fit an ampoule

7.7.9.1 Fit the glove box to the six-way precursor cabinet

1 Confirm that the precursor contained in the ampoule to be fitted is chemically compatible with the other precursors on the same manifold.

> **CONTAMINATION RISK**
> Only install precursors that are chemically compatible on the same manifold.
> Caution 7.5

2 Check that the keyswitch operated cross-purge valve is closed.

3 Check that the pair of ALD precursor valves is closed. This is indicated by the Process page of PC2000 and the absence of a red LED on the solenoid pilot valve.

4 Put on suitable personal protective equipment.

> **TOXIC VAPOUR**
> **Exposure to toxic vapour can cause death or serious injury. Wear suitable personal protective equipment whenever the precursor cabinet doors are opened.**
> WARNING 7.15

5 Open the precursor module doors. Place the ampoule to be fitted, spanners, VCR gaskets and other tools that may be required inside the cabinet.

6 Fit the glove box to the front of the precursor cabinet (see **Figure 7-3**).

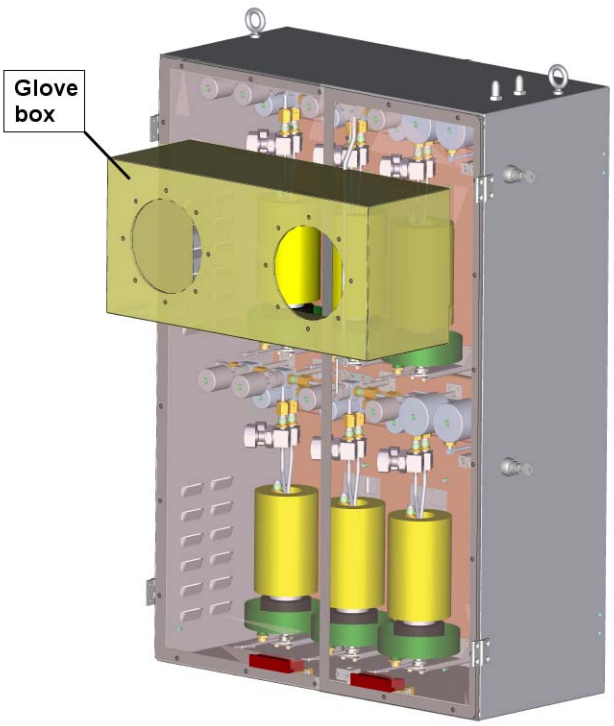


Figure 7-3 Glove box fitted to the six-way precursor cabinet

7.7.9.2 Turn on the extraction

1 Turn on the extraction to the glove box and purge the glove box for five minutes.

7.7.9.3 Removing the existing ampoule

If an ampoule not fitted, the ends of the ampoule connections will have VCR blanks on them. Perform the following steps to remove the ampoule or blanks.

1 Leave the extraction and nitrogen purge running.

2 Insert both hands into the gloves on the glove box.

3 Using the correct VCR spanners, disconnect the VCR fittings on the ampoule (or the VCR blanks).

4 Remove the ampoule and place it in a suitable location in the cabinet.

5 If a replacement ampoule is to be fitted immediately, fit new VCR gaskets on the delivery lines.

6 If a new ampoule is not to be fitted immediately, fit blank VCR fittings on the ends of the delivery lines.

7.7.10 Fitting an ampoule into the six-way precursor cabinet

This procedure describes how to fit an ampoule into the six-way precursor cabinet. Before performing this procedure, ensure that the relevant precursor line has been evacuated and purged, the glove box is fitted to the precursor cabinet, and the cabinet extraction is turned on (see **Section 7.7.9.1**).

Referring to the relevant section for details of each step, perform the following steps in turn to fit an ampoule into the six-way precursor cabinet:

1 **Connect the ampoule**

2 **Pump the delivery line start the system pumping.**

3 **Pump and purge the delivery line**

4 **Leak check the delivery line** (KEY STEP)

5 **Degas the ampoule** (KEY STEP)

6 **Remove the glove box and set the temperatures**

NOTE: The indicated key steps are crucial to maintain system integrity.

7.7.10.1 Connect the ampoule

1. Leave the extraction and nitrogen purge running.
2. Insert both hands into the gloves on the glove box.
3. If there are VCR blanking fittings on the ends of the delivery lines, remove them using the correct VCR spanners.
4. Using the correct VCR spanners, remove the VCR end caps from the ampoule.
5. Place the ampoule on the thermal isolation disc that sits on the height adjustable drip tray (see **Figure 7-4**).

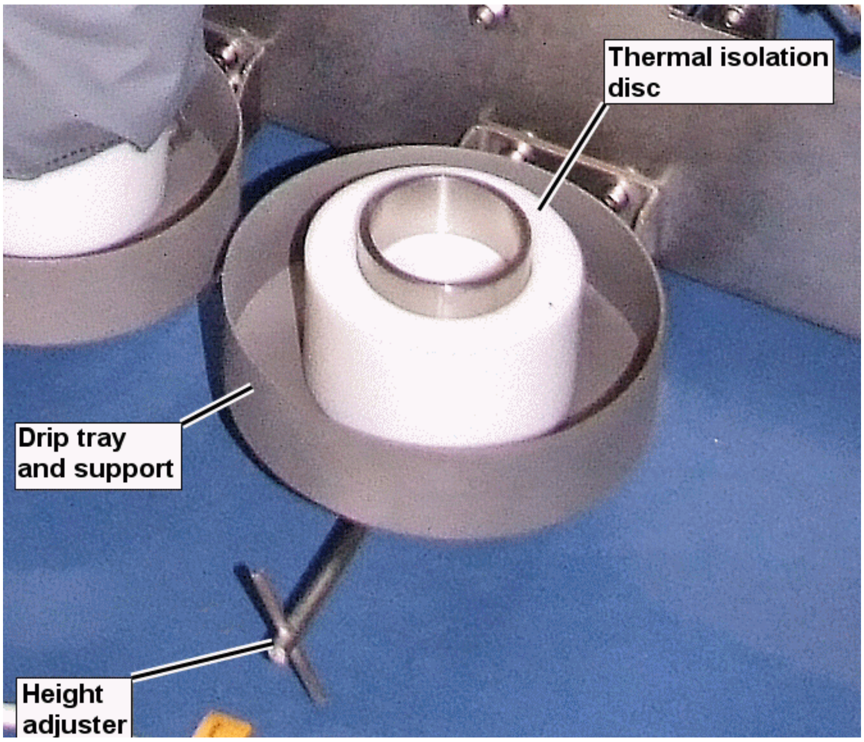


Figure 7-4 Fitting the ampoule

Figure 7-5 Ampoule heater jacket

6 Adjust the height of the drip tray until the ampoule connections are touching the module's pipe work.

7 Tighten the VCR nuts according to the manufacturer's instructions.
DO NOT OPEN THE MANUAL VALVES ON THE BUBBLER YET.

7.7.10.2 Pump the delivery line start the system pumping.

Leave the glove box in place for this procedure.

1 Open the Process Control page and open the pair of ALD precursor valves on the precursor that has just been fitted (see **Figure 7-6**). This evacuates the air that has been introduced between the precursor outlet pneumatic ALD valve and the ampoule outlet manual valve. **DO NOT OPEN THE MANUAL AMPOULE VALVES YET**. Refer to **Figure 7-6** for an explanation of the pumpdown sequence.

Caution 7.6	**CONTAMINATION RISK** It is important to observe a pressure rise when opening the outlet ALD valve for the first time after connecting an ampoule. This pressure rise is the ONLY indication that the ALD valve has opened. If a pressure rise is not seen, check the ALD valve before proceeding. Continuing with this procedure will contaminate the precursor.

2 Confirm that the process chamber pressure rises when the outlet ALD valve is opened. If it does not, check the operation of the ALD valve before proceeding. A failed ALD valve will fail to pump away the air trapped between the ALD valve and the ampoule manual outlet valve. Continuing with the procedure will cause this air to mix with the precursor in the ampoule.

3 Open the key-operated cross-purge valve on the manifold that the ampoule is connected to. This evacuates the air that has been introduced between the precursor pneumatic inlet valve and the ampoule manual inlet valve. **DO NOT OPEN THE MANUAL AMPOULE VALVES YET**.

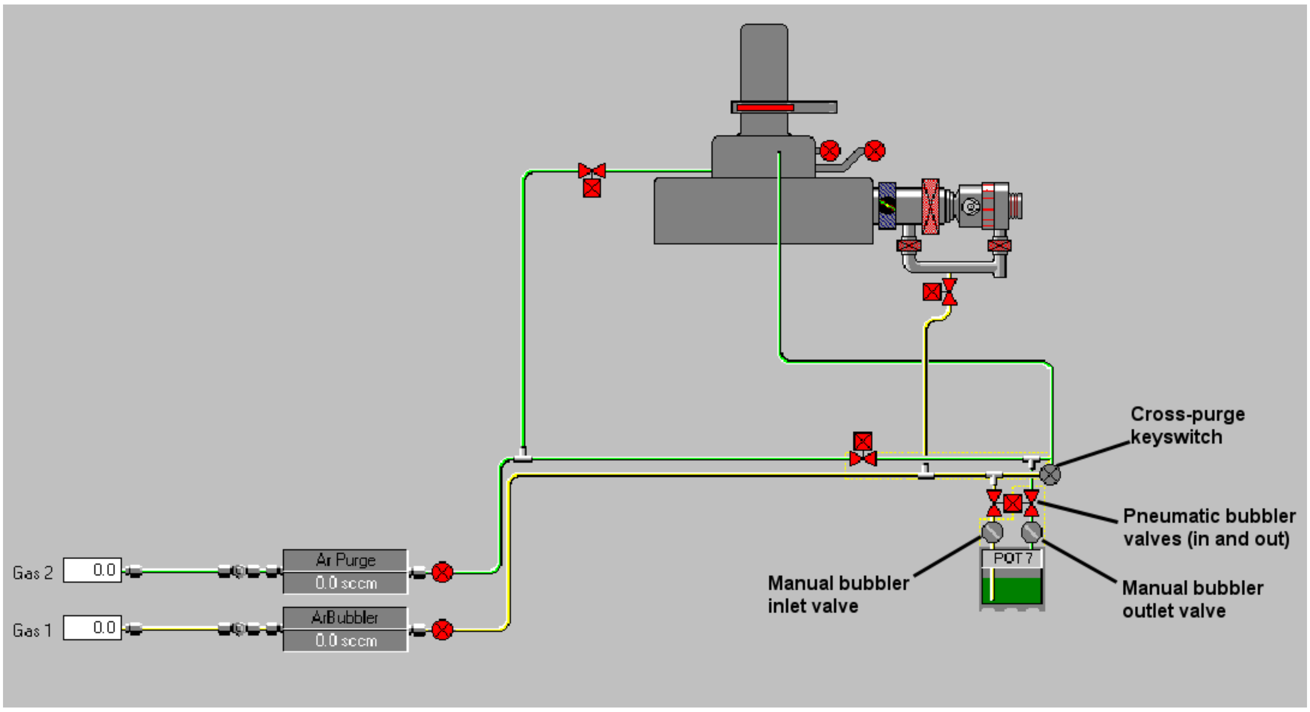


Figure 7-6 Simplified Process Control page showing the precursor valves

4 When opening the ampoule valves and cross-purge valve, a pressure rise will be observed in the process chamber because air has been introduced into these sections of pipe work. An over pressure alarm may be generated. Repeat the procedure until the lines have been evacuated.

Caution 7.7

CONTAMINATION RISK

It is important to observe a pressure rise when opening the cross-purge valve for the first time after connecting an ampoule. This pressure rise is the ONLY indication that the cross-purge valve has opened. If a pressure rise is not seen, check the cross-purge valve before proceeding. Continuing with this procedure will contaminate the precursor.

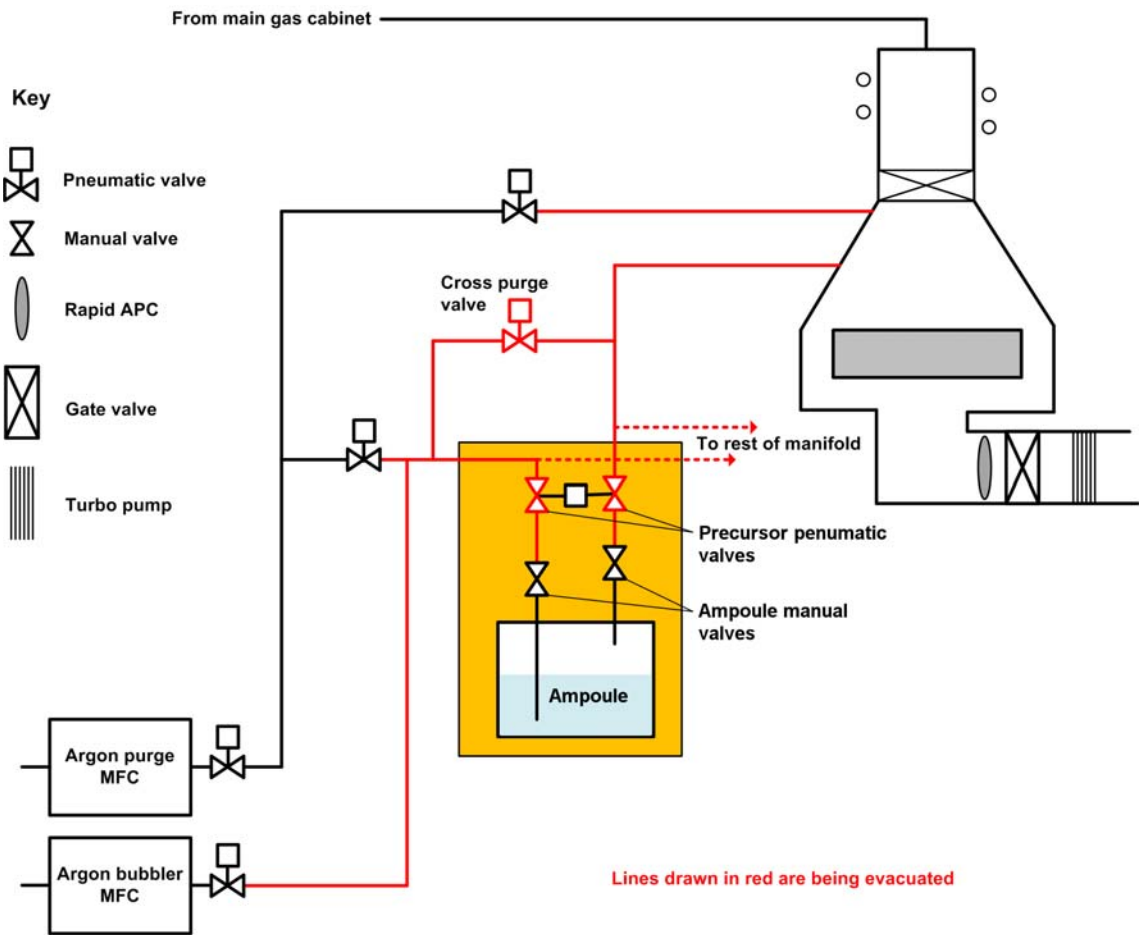


Figure 7-7 Pumping the delivery line

7.7.10.3 Pump and purge the delivery line

Leave the glove box in place for this procedure.

1 Run the following recipe to pump and purge the precursor delivery line:

1) Pump the precursor that has just been fitted for 1 minute with the pneumatic precursor valves open.

2) Purge the precursor for 30 seconds with 200 sccm Ar (bubbler). The pneumatic precursor valves are still open and the process chamber pressure should be set to 80 mT.

2 Repeat this sequence at least 45 times.

NOTE: Because the ampoule manual valves are still closed, this recipe purges the delivery lines up to the manual valves.

7.7.10.4 Leak check the delivery line

Leave the glove box in place for this procedure.

1. Open the pneumatic valves on the precursor that has just been fitted, using the Process page. **DO NOT OPEN THE MANUAL AMPOULE VALVES YET**.
2. Ensure the cross-purge valve is still open.
3. Open the Leak Detection page (see **Figure 4-16**).
4. Check the leak up rate of the process chamber with the precursor valves open. The measured leak rate should be <0.2 mT/min higher than the leak rate of the chamber alone. If the measured leak rate is too high, investigate and fix any problems before proceeding.
5. Close the cross-purge valve, using the keyswitch. Remove the key and store it in a suitable location.
6. Close the precursor pneumatic valves from the Process Control page.

7.7.10.5 Degas the ampoule

Leave the glove box in place for this procedure.

A new ampoule must be degassed before use, to prevent liquid being forced into the delivery pipework. If you are uncertain about the history of an ampoule, assume it has not been used and follow this degassing procedure.

An ampoule is usually filled with precursor in a nitrogen purged environment. Since the inlet line is under vacuum, opening the inlet before opening the outlet will result in a differential pressure of 1 Bar between the outlet and inlet. This will force liquid up the dip tube and into the cold argon delivery pipe work (see **Figure 7-8**).

It is normally best to degas the ampoule with all heating turned off. However it may be best to degas non-sticky solids after melting them. Consult OIPT for advice.

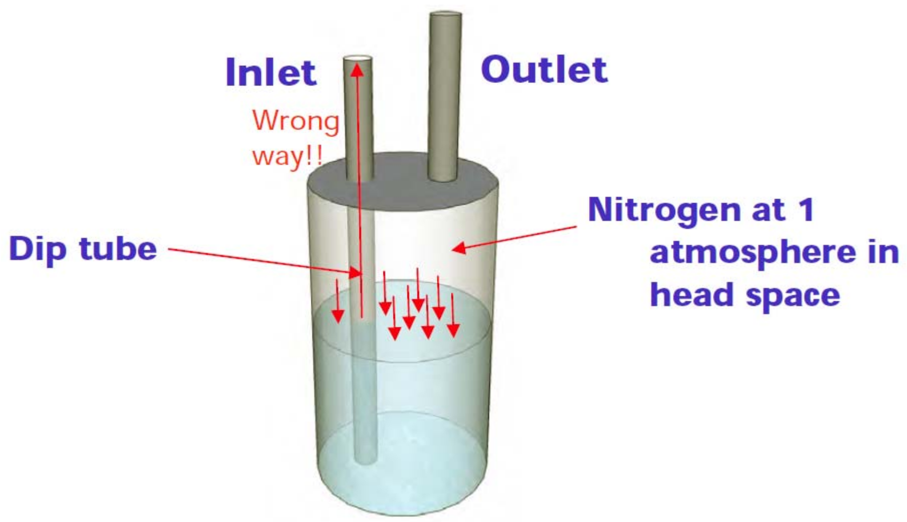


Figure 7-8 Explanation why ampoule degassing is necessary

To degas the ampoule:

1 At the Process Control page, close the pneumatic precursor valves and cross-purge valve.

2 If an ICP source is fitted, close the ICP gate valve.

3 Slowly open the manual ampoule outlet valve. It is best to open the valve until movement just occurs and then close it using gentle pressure. Then slowly open the valve again, taking 10 seconds or longer to open it fully.

4 Run the following recipe to degas the ampoule:

a) Repeat for 200 steps.

b) Open the ALD dose valve for 10 mS.

c) Close the ALD dose valve.

d) Evacuate the process chamber for 30 seconds.

e) Loop.

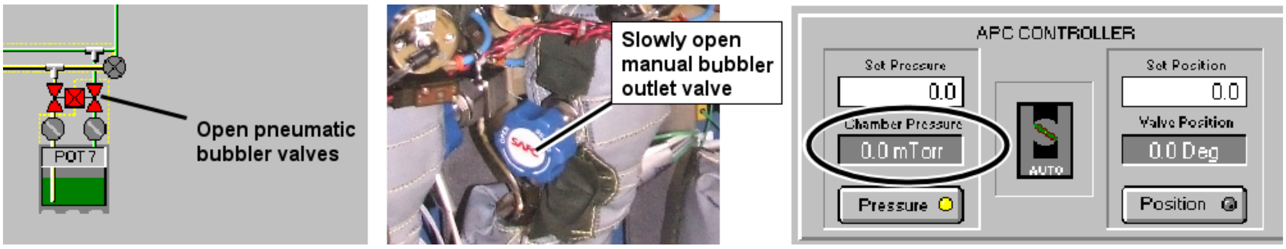


Figure 7-9 Degassing the ampoule

5 Monitor the process chamber during the degas recipe. If the maximum pressure rise is 50 mT or less, stop the recipe and change the open time of the ALD dose valve to 100 mS.

6 Run the amended recipe until the maximum pressure rise is again 50 mT or less. Then change the dose valve time to 200 mS, then 500 mS.

7 When the peak pressure rise does not increase, even though the ALD dose valve time has been increased, stop the degas recipe.

Caution 7.8

CONTAMINATION RISK

Only use precursors with a vapour pressure below 5 Torr in a bubbler. Precursors with a vapour pressure above 5 Torr can flow into the dip tube, contaminating the argon delivery pipe. (For example TMA has a density of 0.7g/cm^3 and a vapour pressure of 10 Torr, It's vapour pressure will lift precursor ~20 cm up the dip tube.)

8 If the precursor is to be used in bubbling mode, open the manual inlet valve on the ampoule. If the precursor is to be used in vapour draw mode, leave the manual inlet valve closed.

NOTE: It is good practice to always open the outlet first and then open the inlet, even for a used ampoule.

7.7.10.6 Remove the glove box and set the temperatures

1 Turn off the precursor cabinet nitrogen purge and extraction.

2 Put on suitable personal protective equipment.

TOXIC VAPOUR
Exposure to toxic vapour can cause death or serious injury. Wear suitable personal protective equipment whenever the precursor cabinet doors are opened.
WARNING 7.16

3 Remove the glove box and close the precursor module doors.

4 Fit the heater jacket on the ampoule, ensuring that the thermocouple and heater electrical connections are correctly made (see **Figure 7-5**).

5 Set the precursor cabinet temperatures according to **Table 7-3**.

Table 7-3 PDM temperatures after an ampoule has been fitted

Item	Temperature
Ampoule jacket	According to the precursor
Manifold	At least 10°C hotter than the coldest ampoule that is fitted to the manifold.
Line	At least 20°C hotter than the coldest ampoule that is fitted to the manifold.
Walls	120°C to 150°C, depending on the process recipe.

6 When the ampoule heater has reached the programmed temperature, wait at least 1 hour more to allow the temperature of the precursor inside the ampoule to stabilise.

7.7.11 Preparing the single-precursor oven to fit an ampoule

7.7.11.1 Prepare to exchange the ampoules

1 Close all the house keeping valves. This minimises the amount of air introduced into the pipe-work.

2 Set the oven temperature to 1°C.

7.7.11.2 Fit the glove box

1 Wait until the oven temperature is less than 40°C.

HOT SURFACES
Contact with hot surfaces can cause serious injury and burns. Do not fit the glove box front unless the oven temperature is below 40°C.
WARNING 7.17

2 Remove the precursor module door.

Figure 7-10 Removing the precursor module door

3 If connecting a replacement ampoule, this can be placed inside of the cabinet before fitting the glove box. If the operator feels the amount of space available is too tight with both ampoules inside of the glove box this operation can be split into two halves and the glove box removed to take out the old ampoule and put in the new and then refitted.

If leaving the precursor module empty, it is recommended to fit VCR blanks on the end of the connectors and pump out the pipe work. In this event, place the blanks inside the cabinet before fitting the glove box. Note that it is perfectly acceptable to leave the blanks permanently inside the oven.

4 Fit the glove box (see **Figure 7-11** and **Figure 7-12**).

Figure 7-11 Fitting the glove box

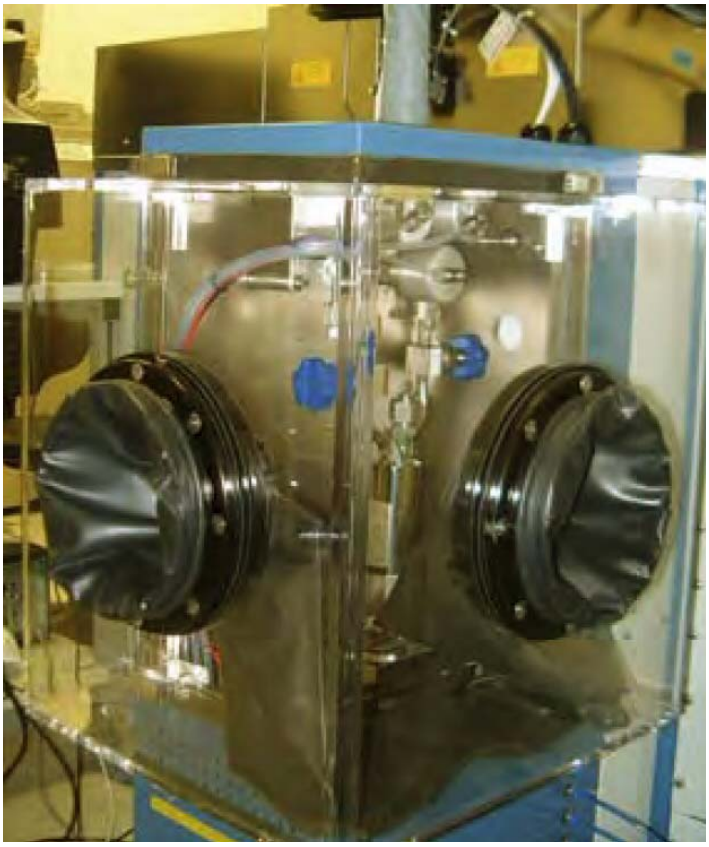


Figure 7-12 Glove box fitted

7.7.11.3 Turn on the extraction

1 Turn on the extraction to the glove box and purge the glove box for five minutes.

7.7.11.4 Remove the existing ampoule

1 Ensure all housekeeping valves and the ampoule manual valves are closed.

2 Disconnect the ampoule VCR connections.

3 Lower the height adjusting plate.

4 Tighten the end caps on the ampoule.

5 If a new ampoule is to be fitted immediately, leave the end of the delivery lines uncovered.

6 If a new ampoule is not to be fitted immediately, place VCR blanks on the pipe work.

7 Tighten the VCR nuts using the correct spanners.

Figure 7-13 Fitting the ampoule

7.7.12 Fitting an ampoule into a single-precursor oven

This procedure describes how to fit an ampoule into the single-precursor oven. Before performing this procedure, ensure that the relevant precursor line has been evacuated and purged, the glove box is fitted to the precursor cabinet, and the cabinet extraction is turned on (see **Section 7.7.11.1**).

Referring to the relevant section for details of each step, perform the following steps in turn to fit an ampoule into the six-way precursor cabinet:

1 **Fitting the ampoule**
2 **Pump the delivery lines**
3 **Pump and purge the delivery lines**
4 **Leak check the delivery lines**
5 **Degas the ampoule**
6 **Refit the oven door and set the temperatures**

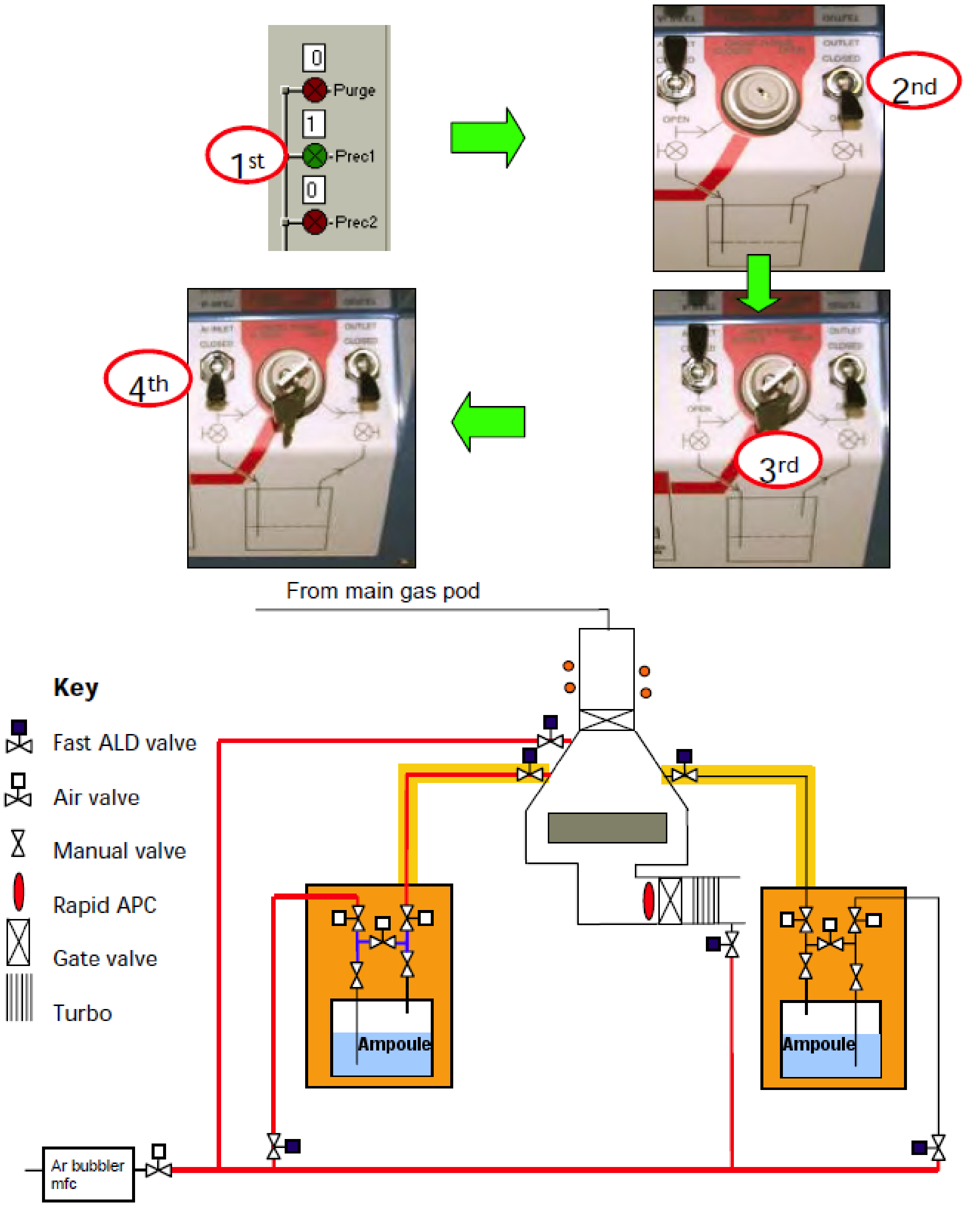
7.7.12.1 Fitting the ampoule

1 Remove the VCR end caps from the ampoule to be fitted.
2 Place the ampoule on the height adjustable support.
3 Spin the support until the ampoule connections are touching the module's pipe work.
4 Tighten the VCR nuts by hand.
5 Tighten the VCR nuts using spanners. **DO NOT OPEN THE MANUAL VALVES YET**.

7.7.12.2 Pump the delivery lines

1 Start the system pumping.
2 Check that the ampoule manual valves are closed.
3 Open all house keeping valves in turn (see **Figure 7-14**).
4 When opening outlet and cross purge a pressure rise will be observed since air has been introduced into these sections of pipe work. An over pressure alarm may be generated.

5 When opening inlet there should be no pressure change.



Blue lines indicate air introduced into the pipe work from the bubbler connection.

Figure 7-14 Pumping the delivery lines

7.7.12.3 Pump and purge the delivery lines

1 Run the following recipe to pump and purge the delivery line:

a) Pump Line 1 for 1 minute with Line 1 valve open.

b) Purge Line 1 for 30 seconds with 200sccm Ar (bubbler), Line 1 valve open, Pressure 80mT.

2 Repeat this sequence at least 45 times.

7.7.12.4 Leak check the delivery lines

1. Ensure all housekeeping valves are still open.
2. Use the software leak up feature (see **Figure 4-16**).
3. Check that the leak rate with all housekeeping valves open is less than 0.2 mTorr/ min.

7.7.12.5 Degas the ampoule

It is important to properly degas a new ampoule.

> **CONTAMINATION RISK**
> Failure to properly degas a ampoule before using it can result in powder or liquid blowing down the delivery line.
> **Caution 7.9**

Bubblers that have previously been used for ALD processing can be opened straight away. Open the outlet first. If bubbling (see later note on bubbled precursors) open the inlet second.

If you are uncertain always assume a ampoule has not been used and follow this degassing procedure.

A ampoule is usually filled with precursor in a nitrogen purged environment. Since the inlet line is under vacuum, opening the inlet before opening the outlet will result in a differential pressure of 1 Bar between the outlet and the inlet. This will force liquid up the dip tube and into the cold argon delivery pipe work (see **Figure 7-15**).

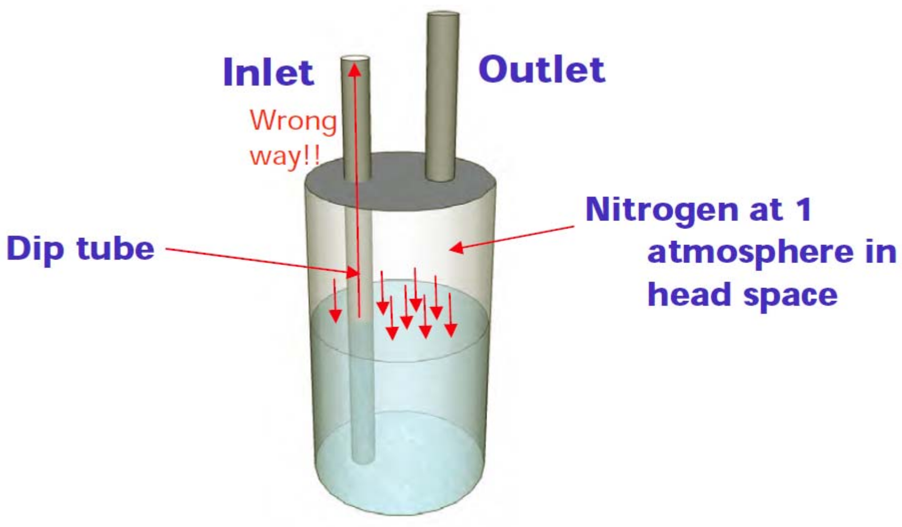


Figure 7-15 The effect of opening the inlet valve before the outlet valve

To degas the ampoule:

1. Close all housekeeping valves and manual ampoule valves.
2. Open the outlet house keeping valve (continue to use the glove box).
3. Start the system pumping.

4 Slowly open the manual ampoule outlet valve ensuring the pressure in the chamber does not rise above 50 mT. It will take approximately 1 to 2 minutes to remove the nitrogen from the head space. Failure to do this slowly may result in powder or liquid blowing down the delivery line. For low vapour pressure liquids or solids, the pressure in the chamber drops almost to zero and it is obvious the nitrogen has been removed. For high vapour pressure liquids, their partial pressure could be such that full pumping of the raw vapour may give a pressure rise in the chamber of 30 mTorr. In this event, stop the degassing procedure as soon as the ampoule manual valve is open.

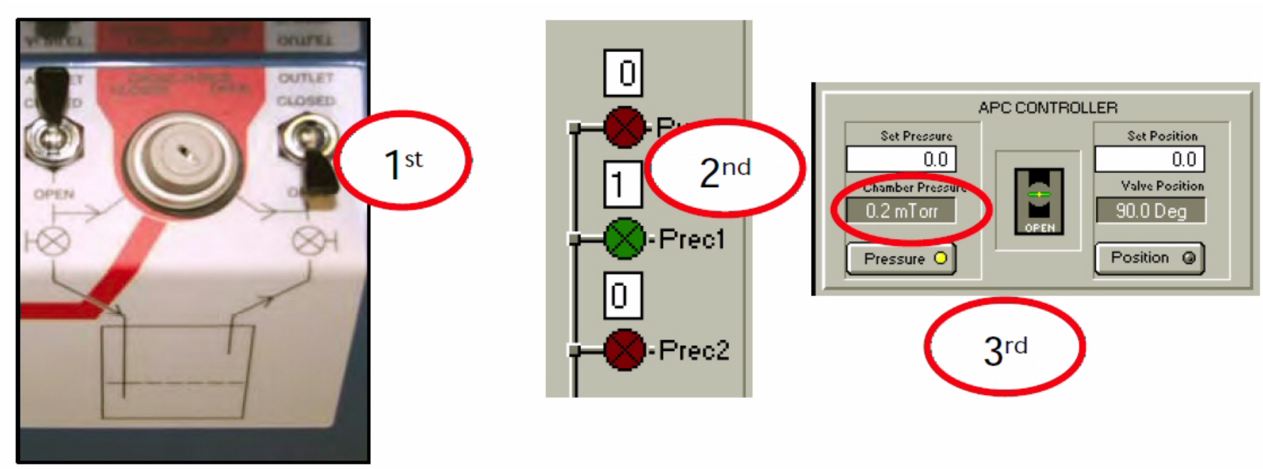


Figure 7-16 Degassing the ampoule

> **Caution 7.10**
>
> **CONTAMINATION RISK**
> Only use precursors with a vapour pressure below 5 Torr in a bubbler. Precursors with a vapour pressure above 5 Torr can flow into the dip tube, contaminating the argon delivery pipe. (For example TMA has a density of 0.7g/cm^3 and a vapour pressure of 10 Torr. Its vapour pressure will lift precursor ~20cm up the dip tube.)

5 For bubbled precursors it is now safe to open the inlet valve.

NOTE: It is good practice to always open the outlet first and then open the inlet, even for a used ampoule.

7.7.12.6 Refit the oven door and set the temperatures

1 Refit the oven door (see **Figure 7-17**).

Figure 7-17 Refitting the oven door

2 Set the PDM temperatures according to **Table 7-4**.

Table 7-4 PDM temperatures after an ampoule has been fitted

Item	Temperature
Oven	According to the precursor
Line	At least 20°C hotter than the oven
Valve	At least 20°C hotter than the oven
Walls	120°C

3 Allow at least 1 hour for the precursor inside of the ampoule to reach temperature once the desired oven air temperature is achieved.

8 TROUBLESHOOTING AND REPAIR

This chapter provides information for troubleshooting faults on the **FlexAL**® system and effecting repairs. **FlexAL**® is designed for ease of maintenance and repair. This chapter describes how to repair various parts of the system in the event of failure. The general repair philosophy is to exchange the faulty component for an identical new item.

The topics discussed here are:

- **Customer support**
- **Troubleshooting the PDMs**
- **Gas pod repair**
- **Troubleshooting the AMU**

8.1 Customer support

Oxford Instruments Plasma Technology has global customer support facilities to provide a coordinated response to customer's queries. All queries are recorded on our support database and dealt with as quickly as possible. If we are not able to answer the query immediately, we will contact you as soon as possible.

Before contacting a customer support facility, please ensure that you have referred to the appropriate section of your system manual, OEM manuals and electrical drawings.

Please direct all queries through your nearest support facility (see below) and have the following details available.

System type - e.g. **FlexAL**®.

Works order number – this can be found on the front cover of this System Manual.

Contact information – your name, company and how we can contact you.

Details of your query – nature of the problem, part numbers of spares required, etc.

8.1.1 Customer support contact information

CHINA Beijing Tel: +86 106518 8160 Email: pt.support@oichina.cn Shanghai Tel: +8621 6360 8530 Email: pt.support@oichaina.cn	USA 300 Baker Avenue, Suite 150 Concord, MA 01742 Phone: +1 978-369-9933 Toll Free: +1 800-447-4717 Fax: +1 978-369-8287 Email: pt.usa@oxinst.com	UK Customer Support Hotline: +44(0) 1934 837070 (0800 – 2000 UK local time) Fax: +44(0) 1934 837071 Email: pt.support@oxinst.co.uk
GERMANY Tel: +49 6122 937 161 Email: plasma@oxford.de	JAPAN Tel: +81 3 5245 3591 Email: oikkpt@oxinst.co.jp	SINGAPORE Tel: +65 6337 6848 Email: pt.support@oxford-instruments.com.sg
TAIWAN Tel: +886 3 5788696 Email: pt.support@oxford-instruments.com.tw		

8.2 Troubleshooting the PDMs

8.2.1 PDM faults

Faults that typically occur in a PDM are.

- Residual vapour or liquid in the line:

  Use a glove box with extraction to mitigate the risk.

- Vapour or liquid travelling into the wrong part of the line (e.g. up an un-heated gas line).

  If you suspect this has taken place;

  a) Immediately close all valves (including the manual ampoule valves)

  b) Write down the sequence of valves that have been operated up to this point, ideally by referring to your checklist.

  c) Identify where the problem might be, consulting OIPT if necessary (+44 1934 837 070 or **ptsupport@oxinst.com**)

  d) Open the valves up to the point of the suspected problem starting with the dose ALD valve and working down stream (valves 2>3>1). Perform a leak check after opening each valve.

  e) Look out for leak rates of greater than 1mT/min.

  f) If you see high leak rates and sluggish pump down times and you suspect there is liquid trapped in the lines consult OIPT for advice, giving as much information as possible.

8.2.2 PDM troubleshooting

Finding a fault within a stainless steel pipe requires logical detection work. The easiest way to do this is as follows:

1. Print a copy of the gas layout.
2. Close all valves on the system.
3. Open the valve nearest to the chamber and monitor for a pressure rise.
4. On the printed copy of the gas layout, mark the valve as OK or faulty.
5. Work progressively upstream, repeat steps **3** and **4**.
6. Check the sections of pipe that are under suspicion.

Table 8-1 PDM troubleshooting

Symptom	Possible Causes	Remedy
The line is slow to pump down, or there is a high rate of pressure rise after an ampoule change	Nupro valves not having enough air pressure.	Ensure 2 bar of pressure is available to open valves V1, V2 and V3.
	Missing or misplaced VCR gasket, or a loose joint.	Fit the gasket correctly; tighten the joint hand-tight and then a further 1/8 turn.
	Normal – line can take >20 minutes to pump out.	Pump longer. Heat the lines to enhance bakeout.
Pressure fluctuations in the chamber during vapour flow	Vapour is degassing more as it is heated.	Redo the degassing procedure with the ampoule at working temperature.
	Vapour is condensing in the supply line.	Reduce the oven temperature; increase the line and chamber temperature.
	APC or MFC instability.	Check MFC and APC function with the vapour source isolated.
No deposition during a vapour-draw process	Valves are set incorrectly	See Operating Instructions.
	Bubbler is empty.	Run a precursor pressure check (see earlier). Change the ampoule.
	Oven is too cold.	Set to the operating temperature.
	Outlet valve is blocked.	Run a precursor pressure check (see earlier). Consult OIPT.

Table 8-1 PDM troubleshooting

Symptom	Possible Causes	Remedy
No deposition during a bubbling process	Valves are set incorrectly	See operating instructions.
	Bubbler ampoule is empty.	Close manual inlet valve to the ampoule. Compare difference of pressure rise line causes in chamber with and without the ampoule manual outlet valve open.
	Oven is too cold.	Set to operating temperature.
	Argon mfc failure.	Flow argon down purge line and check for pressure rise in the chamber.
	Blockage in the argon feed to the bubbler ampoule	As above. Then close manual ampoule valves. Pump out line. Open cross purge valve. Flow argon and check for pressure rise.
	Blockage in the ampoule manual valves	Perform all the above tests in this category, then attempt to flow argon into the bubbler ampoule and watch for pressure rise in chamber. If no pressure rise observed in chamber immediately close the manual ampoule inlet and outlet valves and run the ampoule removal procedure.
Oscillating pump down of precursor line	Condensation in the line.	Increase the line temperature and run pump and purge recipe.

8.2.3 Opening the process chamber when unable to run recipes

This section describes how to open the process chamber when the system is unable to run recipes (e.g. if a wafer is stuck in the slit valve). Because pneumatic precursor valves cannot be opened, it is impossible to evacuate precursor beyond the pneumatic precursor inlet valves.

> **WARNING 8.1**
>
> **TOXIC GASES**
> **Exposure to toxic gases can cause death or serious injury.**
> **Perform this procedure on all precursor lines before opening the chamber.**

Referring to the relevant section for details of each step, perform the following steps in turn to open the process chamber:

1. **Close the manual ampoule valves and housekeeping valves for all connected precursors**
2. **Pump the precursor out of all the delivery lines**
3. **Leak check the delivery lines**
4. **Cool down the delivery lines**
5. **Vent and open the process chamber**
6. **Perform maintenance**
7. **Close the lid**
8. **Leak check the delivery lines**
9. **Open housekeeping valves as required**

8.2.3.1 Close the manual ampoule valves and housekeeping valves for all connected precursors

1. Wearing heat resistant gloves open the oven door and close the ampoule manual valves. In accordance with good practice close the inlet first and outlet second.

> **Caution 8.1**
>
> **DO NOT LEAVE THE OVEN DOOR OPEN**
> Opening the oven door interrupts electrical power to the heater circuit. If the power is interrupted for more than 5 minutes the PLC disables the heater zone and raises a fault condition. It will then be necessary to warm start the heater PLC.

2. Close all the housekeeping valves.

8.2.3.2 Pump the precursor out of all the delivery lines

CONDENSATION RISK

Caution 8.2

If the delivery lines cool, precursor can condense inside them. This condition can be difficult to diagnose. Maintain all delivery lines at their operating temperature throughout this procedure.

1. Note the current base pressure.
2. Start the system pumping by entering service mode and opening the appropriate ALD valves.
3. All precursor lines must pump to original base pressure prior to pumping precursor lines. Open and close the fast ALD valve and the pressure difference should be less than 5 x 10^{-6} Torr.
4. Should base pressure not be reached increase the line temperatures to maximum.

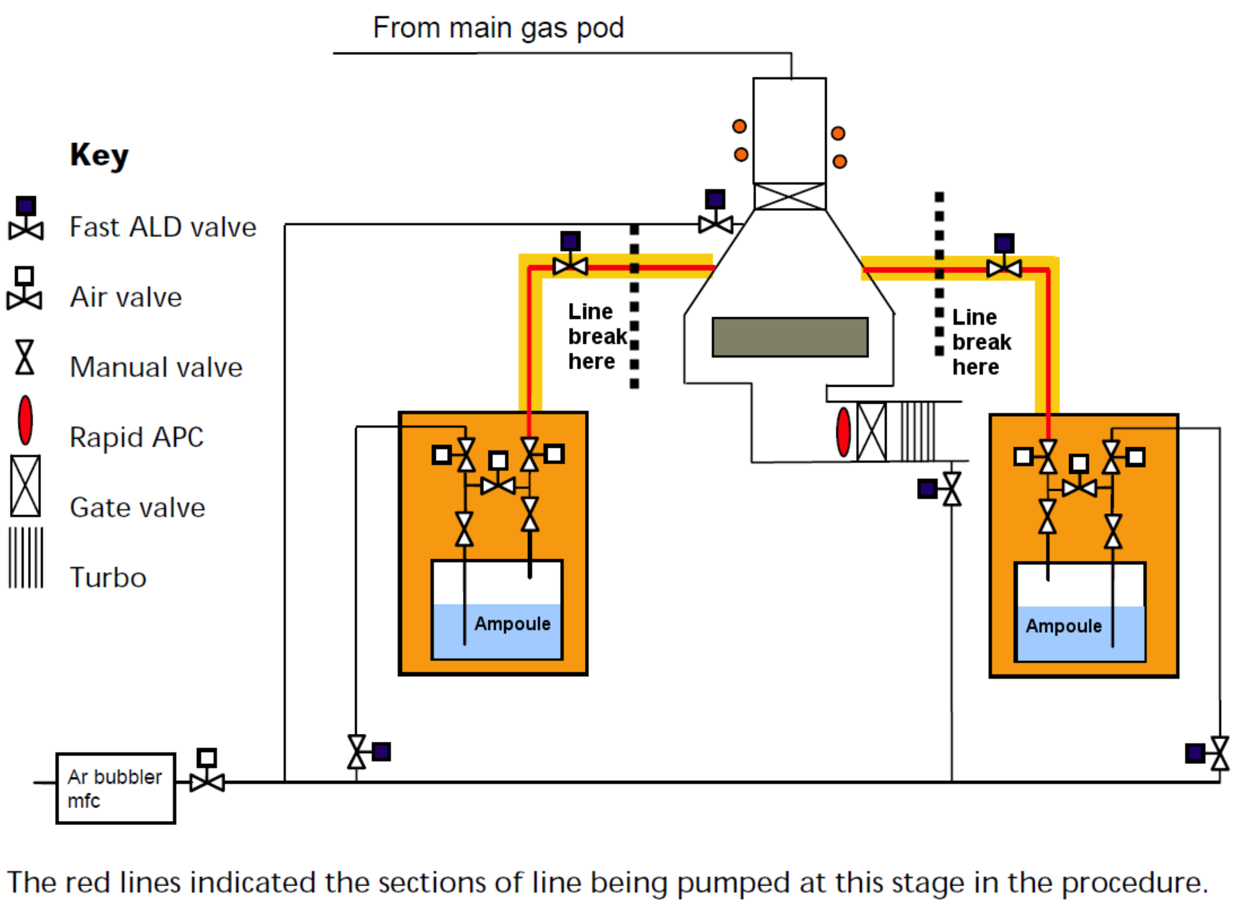


Figure 8-1 Pumping delivery lines

8.2.3.3 Leak check the delivery lines

1. Using service mode with the ALD valves open, close the gate valve and perform a manual (with a watch) leak up rate. The leak up rate of the delivery system should be <0.2 mT/min higher than the chamber alone.

8.2.3.4 Cool down the delivery lines

1. Set the delivery line temperatures to 1°C.
2. Set the chamber temperature to 1°C.

NOTE: Note the ovens should still be left at operating temperature since the precursor has not been pumped out of these sections of pipe.

8.2.3.5 Vent and open the process chamber

1. Wearing appropriate PPE break the precursor delivery lines above the precursor modules and hinge back the lid and pipe work (see **Figure 8-2**).

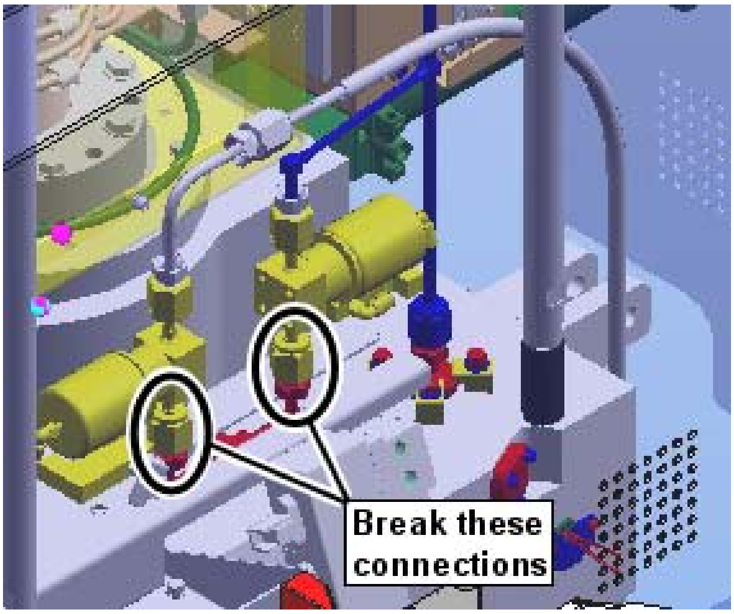


Figure 8-2 Precursor line connections at the process chamber

8.2.3.6 Perform maintenance

1. Referring to **Chapter 6**, perform the required maintenance activities.

8.2.3.7 Close the lid

1. Close the lid.
2. Re-connect all the delivery lines that were disconnected, using new VCR gaskets in all joints that have been disturbed.

8.2.3.8 Pump the delivery lines

1 Start the system pumping.

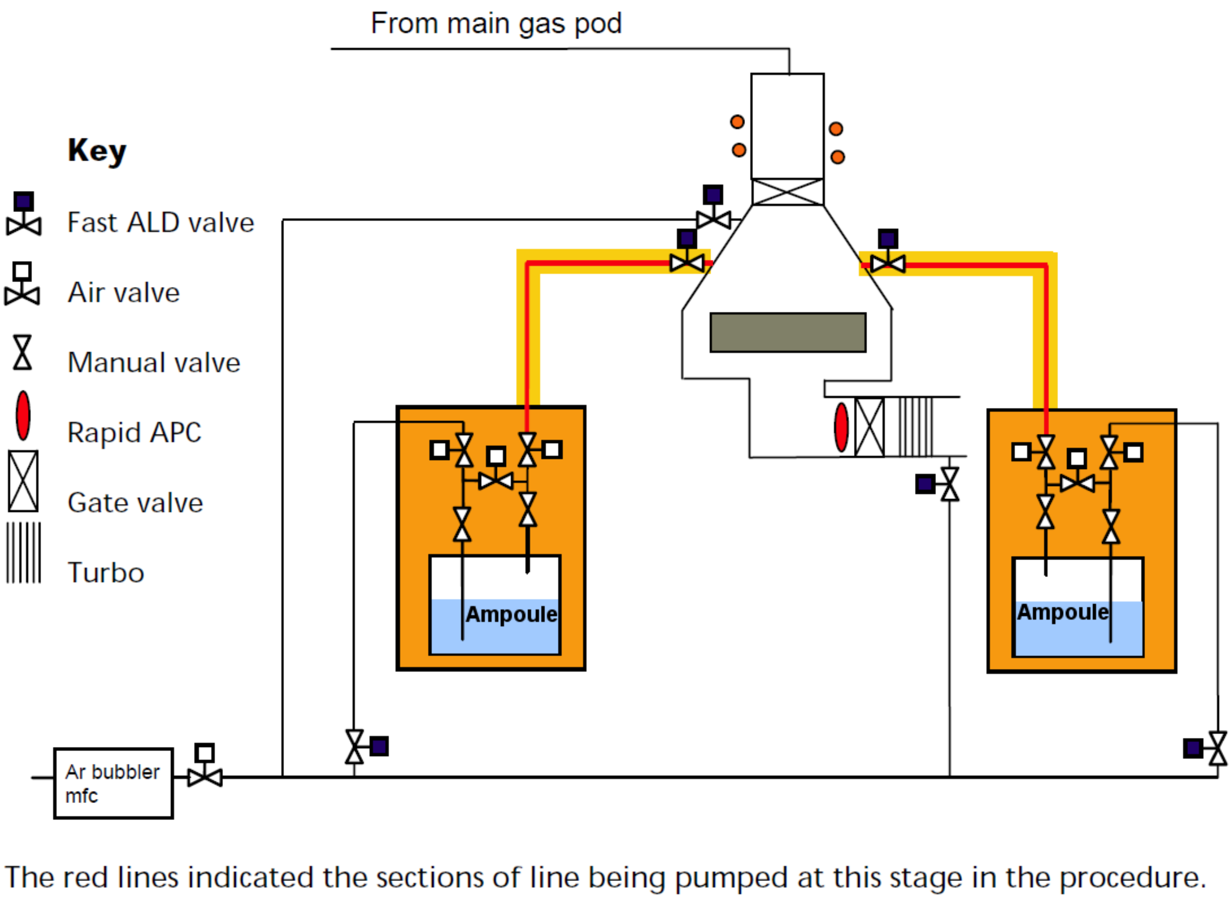


Figure 8-3 Pumping the delivery lines

8.2.3.9 Leak check the delivery lines

1 Ensure all housekeeping valves are still closed.

2 Use the software leak up feature (see **Section 4.3.8**).

3 Check that the leak rate with all housekeeping valves open is less than 0.2 mTorr/min.

8.2.3.10 Open housekeeping valves as required

1 Open the housekeeping and manual ampoule valves according to the delivery mode.

8.3 Gas pod repair

8.3.1 Evacuating and leak checking a gas line

It may be necessary to evacuate a gas line in the following circumstances:

- Before leak-checking a gas line.
- Before repairing or replacing a component of a non-hazardous gas line.
- Before changing a non-hazardous gas bottle.

8.3.1.1 Evacuating a gas line to the point-of-use valve or bottle.

This section describes how to evacuate a gas line to the point-of-use valve or gas bottle.

A gas line must be evacuated before any part of the gas line is opened to the atmosphere.

Tools and equipment

No special tools and equipment are required to perform this task.

Procedure

To evacuate a gas line:

1 If the gas line is to be evacuated to the gas bottle, close the relevant gas bottle valve.

2 If the gas line is to be evacuated to the point-of-use valve, close the point-of-use valve on the relevant gas line.

3 Evacuate the process chamber (see **Section 5.6.3**).

4 Check that the **Process interlock** field on the PUMP CONTROL page is displaying the message **OK**. This ensures that the gas pod mixing manifold is evacuated.

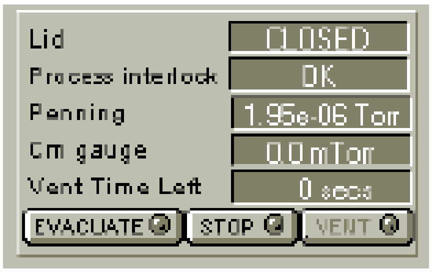


Figure 8-4 Process interlock field

5 Start a manual process with the following conditions:

- ignore tolerance box is ticked;
- setpoints of all RF generators are set to zero;
- pressure setpoint of 0 Torr is set (APC fully open);
- high gas flow of the relevant gas is selected.

6 Run this process until the process chamber pressure has fallen below 5E-5 mTorr.

7 Continue to run this process for at least 10 minutes.

8 Stop the process. The gas line is now evacuated.

8.3.1.2 Leak checking a gas line

It is good practice to leak check a gas line after any maintenance task or gas bottle change has been performed.

Gas lines containing toxic, corrosive or flammable gas must be leak checked in the following situations:

- After changing a gas bottle, before the bottle valve is turned on.
- After maintaining the gas line, before the bottle valve is turned on.

Tools and equipment

No tools and equipment are required to perform this task.

Procedure

To leak-check a gas line:

1 Perform the steps described in **Section 8.3.1.1** to evacuate the gas line.

2 Referring to **Section 4.3.13.4**, perform a leak check of the process chamber for ten minutes. Record the measured leak rate.

3 Referring to **Section 4.3.13.4**, perform a mass flow controller calibration of the required gas line for ten minutes. Because the gas line has been evacuated there should be zero flow displayed in the MFC. Record the measured leak rate.

4 Calculate the leak rate of the gas line, which is the difference between the leak rates measured in the previous two steps. The leak rate for non-toxic gas lines should be <1 mTorr/min. The leak rate for toxic, corrosive of pyrophoric gases should be <<1 mTorr/min.

8.4 Troubleshooting the AMU

WARNING 8.2

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. Any work requiring the removal of covers or panels must only be performed by authorised personnel who are aware of the hazards involved. Before removing any covers or panels, power down the system and perform the recommended lock out / tag out procedure.

8.4.1 Fault diagnosis chart for the AMU

Use the following chart to locate and identify faults. Note that the chart lists typical fault symptoms and is not exhaustive.

Table 8-2 AMU fault diagnosis chart

Symptom	Possible Causes	Action
Drive motors do not respond to automatic or manual control.	Fuse FS2 blown. Fuse FS1 or FS101 tripped.	Investigate and repair fault, which caused the fuse to blow. Then renew the fuse. Investigate and repair the fault, which caused the fuse to trip. (The fuses will automatically reset once the fault is repaired.) Note that these components are semiconductor fuses which respond to an increase in current above their rating (approximately 200 mA) by increasing their internal resistance significantly. The voltage drop across each of these components under non-fault conditions is approximately 0.5 V. When tripped by high current, the voltage drop is almost the full supply voltage i.e. 24 V. After power is removed, the devices require 20 seconds to cool down and reset.
C1 or C2 drive to min or max.	C1 or C2 starting too far from final match position.	Adjust park potentiometers (see Section 8.4.4).
	Match position is out of accessible range.	Change process conditions
		Change component fit in AMU (skilled personnel only). Refer to Section 8.4.3.
C1 or C2 drive to min or max and do not return manually.	Capacitor has travelled past an electrical limit.	All vane capacitors only: Continue manual travel in the same direction (to max if capacitor is at max). The capacitor will turn fully until it passes the opposite limit.
		Readjust limit settings.
Plasma does not strike even though the reflected power is low.	Gas pressure is too low or too high.	**Caution: do not run for > 2 minutes in this condition.** Change gas pressure to 20 - 200 mTorr range (RIE), or 0.5 - 1.5 Torr range (PECVD)

Table 8-2 AMU fault diagnosis chart

Symptom	Possible Causes	Action
C1 or C2 oscillate close to match	Amplifier gain too high.	See **Section 8.4.1.2**.
	C1 or C2 spindle thread dirty.	Remove capacitor, clean and re-lubricate capacitor's spindle thread and bearing. Realign; see **Section 8.4.1.3**.
Drive motor shafts rotate but capacitor spindles do not.	Coupling between the motor shafts and capacitor spindles has become disengaged or loose.	See **Section 8.4.1.3**.
End stops don't work, motor drives through.	Park potentiometers have broken.	Check park potentiometers behind AMU control panel and replace if necessary.
Error signal pots don't adjust the error signal or both adjust one signal only.	Links placed incorrectly.	Check links LK6, 7, 10 & 107 to ensure they are in the correct position. If link is open end type, ensure that metal insert is still present.

8.4.1.1 AMU troubleshooting hints and tips

The following hints and tips may be useful:

- Do not remove anything from the motor control board without removing the power (JP2) first.
- When in AUTO mode RV1 and RV2 found on the side of the AMU casing can be used to make fine adjustments to the match position.

8.4.1.2 Amplifier gain adjustment procedure

When adjusting the amplifier gain, initially adjust the associated variable resistor (RV101 for C1 or RV1 for C2; see **Figure 2-8** for locations). These variable resistors provide a fine adjustment. If required, a coarse adjustment is available by using links LK102 and LK2 as shown in **Figure 8-5**.

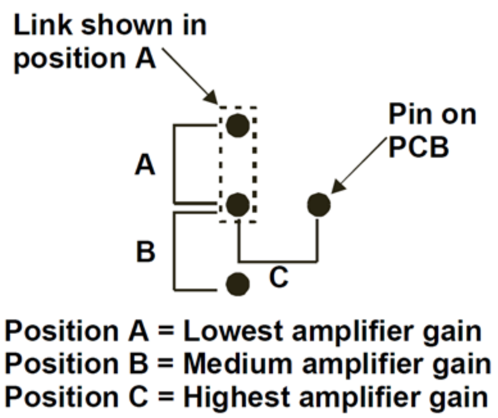


Figure 8-5 LK102 and LK2 settings

8.4.1.3 Drive motor shaft to capacitor spindle alignment

If the coupling between the motor shafts and capacitor spindles, has become disengaged or loose, use the following procedure to align the shafts/spindles to their correct relative positions.

1. Tighten the shaft and spindle grub screws.
2. Loosen the two bolts securing the motor/gear assembly to the AMU casing.
3. Carefully slide the motor/gear assembly away from the fan housing to disengage the gear wheels from the capacitor.
4. Align the gear wheels to the capacitor, depending on the AMU version. See **Table 8-3**.

Table 8-3 AMU gear alignment by version

AMU Version	Procedure
Air spaced AMUs	**1** Set the relevant capacitor to MANUAL mode. **2** Set the relevant capacitor to MAX, so that the motor drives the read-back potentiometer to its upper limit, without driving the capacitor itself. **3** Fully mesh the capacitor vanes.
Vacuum capacitor AMUs for RIE/PECVD applications	**1** Set the relevant capacitor to MANUAL mode. **2** Set the relevant capacitor to MAX, so that the motor drives the read-back potentiometer to its upper limit, without driving the capacitor itself. **3** Set the relevant capacitor to maximum by rotating its shaft anti-clockwise until the shaft becomes loose and starts to unscrew from the capacitor body, then rotate the shaft one turn clockwise.
Vacuum capacitor AMUs for the ICP 180 application	For C1, use the following steps: **1** Set the relevant capacitor to MANUAL mode. **2** Set the relevant capacitor to MAX, so that the motor drives the read-back potentiometer to its upper limit, without driving the capacitor itself. **3** Set the relevant capacitor to maximum by rotating its shaft anti-clockwise until the shaft becomes loose and starts to unscrew from the capacitor body, then rotate the shaft one turn clockwise.
	For C2, use the following steps: **1** Set C2 to MANUAL mode. **2** Set the C2 to MIN so that the motor drives the readback potentiometer to its lower limit, without driving the capacitor itself. **3** Set C2 to minimum by rotating its shaft clockwise until the physical end stop is reached, and then rotate the shaft one turn anti-clockwise.
Vacuum capacitor AMUs for RF ion source applications	**1** Set the relevant capacitor to MANUAL mode. **2** Set the relevant capacitor to MIN so that the motor drives the readback potentiometer to its lower limit, without driving the capacitor itself. **3** Set relevant capacitor to minimum by rotating its shaft clockwise until the physical end stop is reached, and then rotate the shaft one turn anti-clockwise.

4 On completion of capacitor alignment in step 4, re-engage the motor/gear assembly to the capacitor and tighten the securing bolts.

5 Check the capacitor travel.

8.4.2 Link settings

Incorrect link settings can cause the AMU to malfunction. The factory default settings are given in the following table:

Table 8-4 AMU link settings

Link	Air Spaced Capacitor	Low Power Vacuum Capacitor	High Power Vacuum Capacitor	Notes
LK1	A	A	A	Setting **A** enables park position. Setting **B** disables park.
LK2	B	A	B	Coarse gain setting for C2: **A** low **B** medium **C** high
LK3	A	A	A	Setting **B** simulates RF on signal (for testing only).
LK4	B	A	A	Incremental Gain Signal. LK4 in position **A** enables extra gain when in position control. This is used when driving a vacuum capacitor.
LK5	A	A	A	Panel/PLC Controller. Position **B** for AMU controlled by PLC.
LK6	A	A	B	Changes the biasing on the input amplifier for C2 motor.
LK7	B	B	A	Changes the biasing on the input amplifier for C2 motor.
LK101	A	A	A	Setting **A** enables park position. Setting **B** disables park.
LK102	B	A	B	Coarse gain setting for C1 **A** low **B** medium **C** high
LK104	B	A	A	Incremental Gain Signal. LK104 in position **A** enables extra gain when in position control. This is used when driving a vacuum capacitor.
LK105	A	A	A	Panel/PLC Controller. Position **B** for AMU controlled by PLC.
LK106	A	A	B	Changes the biasing on the input amplifier for C1 motor.
LK107	A	A	B	Changes the biasing on the input amplifier for C1 motor.

8.4.3 Changing RF components

This may be necessary to match a process beyond the normal operating range.

WARNING 8.3

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. Any work requiring the removal of covers or panels must only be performed by authorised personnel who are aware of the hazards involved. Before removing any covers or panels, power down the system and perform the recommended lock out / tag out procedure.

1 Turn off the RF generator completely before removing the smaller L-section cover. This reveals the ends of the two variable capacitors and mounting positions for extra fixed capacitors.

Caution 8.3

RISK OF COMPONENT DAMAGE
Only fit components that are rated for RF power service. Low power circuit devices will fail.

Suitable components are given in the following table:

Table 8-5 Fixed padding capacitor types

OIPT Part Number	Capacitance	Rating
94-ECC1209	90 pF	1 kV
94-ECC1218	180 pF	2 kV

2 Change components according to the following table:

Table 8-6 RF component selection

Symptom	Remedy	Notes
C1 going maximum.	Add fixed capacitance in parallel with C1.	See following note.
C1 going minimum.	Remove fixed capacitance in parallel with C1.	Minimum is zero fixed capacitance.
C2 going maximum.	Add fixed capacitance in parallel with C2.	See following note.
	Increase coil inductance.	
C2 going minimum.	Remove fixed capacitance in parallel with C2.	Minimum is zero fixed capacitance.
	Decrease coil inductance.	

NOTE: Variable capacitors C1 and C2 have a maximum capacitance of 1000 pF and 500 pF respectively. For each of these variable capacitors there are three positions for fitting parallel 'padding' capacitors. Therefore, a maximum of 3 x 180 pF padding capacitors could be fitted but usually there is no need to fit more than one padding capacitor (i.e. 180 pF).

8.4.4 Adjustment of capacitor park positions

The capacitors drive automatically to the park positions if:

- the AMU is set to Auto.
- the RF is OFF.
- the circuit board links enable parking.

The park positions can be adjusted when all of these conditions are satisfied, by altering the corresponding potentiometer with a small flat-bladed screwdriver. The capacitor will move when the potentiometer is adjusted, and the park position is displayed as the capacitor position.

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9 DECOMMISSIONING

This chapter provides guidance on decommissioning the **FlexAL®** tool prior to moving it to another location or disposing of it. The chapter also provides guidance on system disposal.

The guidance contained within this chapter is, by necessity, of a general nature. The exact details of any decommission procedure must be customised to suit the nature of the customer's site and installation.

WARNING 9.1	**SYSTEM HAZARDS** **The system contains several potential hazards. Before decommissioning the system, ensure that all personnel who will be involved have read and understood the health and safety section of this manual.**

The chapter consists of the following sections:

- **Health and safety considerations**
- **Decommissioning the system**
- **Disposal of the system**

9.1 Health and safety considerations

It is the customer's responsibility to perform suitable risk assessments before shutting down, decommissioning or moving a system. This section includes a list of health and safety items that must be considered, but this list may not be exhaustive, and does not absolve the customer of any responsibility.

The following health and safety items must be considered before decommissioning or moving a system:

- **Hazardous gases**
  If the system has been used with toxic, corrosive or flammable gases, all gas components must be fully purged before shutting down the system.
- **Hazardous residues**
  All plasma systems may contain toxic, corrosive or flammable residues. Perform a risk assessment to decide the level of decontamination that is required and the best method for performing the cleaning.
- **Vacuum**
  Ensure that all vacuum chambers are vented before shutting down the system.
- **Pressurised gas**
  Ensure that all trapped volumes of pressurised gas are relieved before shutting down the system.
- **Water**
  Ensure that all trapped volumes of water are safely drained before decommissioning the system (see **Section 9.2.3**). Be aware that trapped water could be under pressure, and adopt suitable precautions.

- **High and low temperatures**
  Some parts of the system may be hot or cold when the system is shut down. Ensure that all such items are given sufficient time to reach safe temperatures before the system is moved.

9.2 Decommissioning the system

9.2.1 General considerations for shutting the system down

The method used for shutting the system down will vary depending on whether the system is to be moved and re-installed, stored, or disposed of. In general the following items need to be considered:

- The length of time the system is to be shut down.
- Whether the system is to be re-installed or scrapped.
- Check that all necessary support frames are available.
- Check that all necessary lifting equipment is available.
- Check that all necessary blanking flanges and components are available.

If the system is to be shut down for more than a few days, the pumps must be comprehensively purged to avoid corrosion. Refer to the manufacturer's instructions for purging information.

If the system is to be re-installed, the vacuum system must be vented, backfilled with dry nitrogen, and sealed.

9.2.2 Shutting the system down

1. Run a chamber or ion source cleaning recipe, according to the most recent use of the tool.
2. Referring to **Section 7.7.8**, evacuate all precursor lines and remove all precursor containers from the system.
3. Referring to **Section 8.3.1**, evacuate all of the process gas lines to the cylinder.
4. Purge all gas lines that contained toxic, flammable or corrosive gases with dry nitrogen.
5. Pump the system for an extended period, according to the criteria shown in **Table 9-1**.

Table 9-1 Chamber pumping criteria

Chamber Pump Type	Shutdown Period	Pumping Regime
Turbo pump	Less than or equal to 2 days.	Pump the system for 3 hours before shutting it down.
	Greater than 2 days.	Pump the system for one hour with a small flow of nitrogen into the chamber.
		Pump the system with no nitrogen flow for a further 12 hours.
Non turbo pump	Any period	Pump the system for one hour with a small flow of nitrogen into the chamber.
		Pump the system with no nitrogen flow for a further hour.

6 Vent the loadlock, process chamber and transfer chamber (if applicable) with dry nitrogen.

7 Fit a blank fitting on the process gas inlet to the chamber to seal it.

8 Referring to Section 5.2.4, shut down the system.

9 Turn off the **Slit Valve lockout** knob and fit a padlock to secure it in the OFF position.

10 Turn off and lockout the main system isolator.

9.2.3 Disconnecting the services

1 Ensure that all covers and panels are fitted to the system.

2 Attach notices to the system indicating that the system is not ready for service.

WARNING 9.2

HAZARDOUS VOLTAGE
Contact with hazardous voltage can cause death, severe injury or burns. Ensure the main system electrical supply is turned off and locked out before disconnecting it.

3 Turn off and lockout the main electrical feed to the system.

WARNING 9.3

PNEUMATIC PRESSURE
Pneumatic valves or components can move unexpectedly, causing severe injury. Lockout the compressed air supply, and release the stored pressure, before working near pneumatic items.

4 Turn off and lockout the compressed air feed to the system.

5 Turn off and lockout the nitrogen feed to the system.

6 Turn off and lockout the cooling water supply to the system. Ensure that both the supply and return valves are closed.

7 Disconnect the electrical supply from the PC.

8 Disconnect the electrical supply from the safety isolation box to the system base unit.

9 Disconnect the monitor, keyboard and mouse from the PC.

10 Disconnect the control cable(s) from the PC to the system base unit.

11 Disconnect the safety earth (ground) between the system and the gas pod, if the gas pod is not bonded to the system.

12 Drain the system cooling circuit.

13 Disconnect the cooling circuits from the system base unit. Do not seal the cooling circuits tightly.

14 Disconnect the gas outlet line(s) and control cable from the gas pod to the system services panel.

15 Check that all the process supply gas valves to the gad pod are closed.

16 Disconnect the gas supplies to the gas pod.

17 Disconnect the compressed air supply from the system services panel(s) and from the gas pod.

18 Disconnect the nitrogen purge lines to the system services panel(s) and the backing pump(s).

19 Disconnect the backing pump(s) from the system and cap the pump ports and the system vacuum ports.

20 Disconnect the backing pump exhaust line.

21 Disconnect the extraction collars on the process chamber (e.g. ICP process chambers) and the gas pod from the extraction systems.

9.2.4 Decontaminating the system

The system must now be decontaminated before moving it. Remove any hazardous residues/deposits from the process chamber, ion sources, pumps and pump lines, gas lines and mass flow controllers in accordance with local safety regulations. Refer to equipment manufacturer's manuals as necessary.

If the system is to be moved a short distance, it may be acceptable to perform a limited decontamination procedure. It is the customer's responsibility to ensure that all local and national safety regulations are complied with.

9.2.4.1 Preparation for decontamination

1 Ensure the area around the system is free from all other work in progress.

2 Quarantine the area around the system using yellow hazard posts and chain or similar barrier.

3 Ensure all personal protective equipment, tools; cleaning materials and blanking devices are available within the system quarantine area.

9.2.4.2 Assessment of the system

1. Inspect the system history & maintenance record. Record any abnormalities or non-functionality that may affect evaluation and decontamination, e.g. pump failure.
2. Inspect the external surfaces of system. Record any visible residues including liquids, powders, flakes, or films.
3. Carefully open the chamber lid and inspect the internal surfaces of system. Record any visible residues including liquids, powders flakes, or films.
4. All visible indicators of hazardous materials must be assumed to be hazardous unless otherwise determined and documented by appropriate test, analysis or evaluation.
5. Complete Goods Return Form QCF60 and fax or mail it to Oxford Instruments Plasma Technology before taking further action.
6. If assistance is required during the assessment, please contact Oxford Instruments Plasma Technology.

9.2.4.3 Removal of hazardous residues and deposits from the process chamber

1. Carefully open the chamber lid.
2. Use a vacuum cleaner to remove any loose material.

WARNING 9.4

FLAMMABLE MATERIALS
Some materials used in, and resulting from, deposition and etching processes can be flammable. Before working on the process chamber, or its associated components, consult a competent authority to ascertain the nature of any coatings. Only use appropriate materials when cleaning flammable coatings. Wear appropriate protective clothing, e.g. hand and eye protection, as necessary.

3. Harder deposits maybe removed with Scotchbrite and IPA.
4. Any broken wafers must be carefully removed and placed in the sharps bin provided.
5. Where system parts are routinely removed and replaced, e.g. filters or O-rings, these parts must be removed and replaced with clean parts.

9.2.5 Dismantling the system components

It is the customer's responsibility to ensure that all items are removed, transported and stored in a safe manner. Oxford Instruments Plasma Technology supplies support frames for certain items, but is the customer's responsibility to ensure the frames are adequate for the action that is to be performed. The absence of a support frame does not necessarily mean that an item can be manoeuvred without external support.

WARNING 9.5

HEAVY OBJECT
Incorrectly lifting heavy objects can cause severe injury. Use the appropriate lifting equipment, operated by fully trained personnel, when handling heavy system components. When handling heavy rack-mounted components, ensure that the weight is safely distributed between sufficient personnel.

1. Remove the backing pump from its mounting and prepare it for transport in accordance with the pump manufacturer's instructions.
2. Remove the gas pod from its mounting and prepare it for transport.
3. Prepare the system PC for transport.
4. Disconnect the system frames from the transfer chamber (if fitted) and fit castor assemblies onto the frames.

9.2.6 Transport of system and system components

If the contaminated item is a sub-assembly or sub-component, e.g. mass flow controller or pump, of the system which will not be otherwise decontaminated, the contaminated item must be removed, sealed and transported separately in accordance with the requirements of this subsection.

Ensure Goods Return Form QCF60 has been completed and faxed or mailed to Oxford Instruments Plasma Technology. Await approval to ship component from Oxford Instruments Plasma Technology.

Ensure a copy of the completed QCF60 is securely attached in a clear, waterproof bag to the component shipping container.

Note that if the system is to be moved and re-installed within the customers facility, it may be acceptable to purge the gas lines/mass flow controllers and ion sources (if fitted) with dry nitrogen and seal all connections before moving the system.

9.3 Disposal of the system

This sub-section gives guidance for disposing of the system at the end of its life. The disposal must be carried out in accordance with local and national safety and environmental regulations.

To dispose of the system:

1. Decommission the system as described in **Section 9.2**.
2. Locate, remove and dispose of any hazardous materials in accordance with local and national safety and environmental regulations. Refer to the relevant manufacturer's manuals for information on disposing of pumps etc.
3. Contact Oxford Instruments Plasma Technology to arrange for a visit to disassemble the system if additional assistance is required.
4. Locate and remove the mass flow controllers. These can be returned to the manufacturer for refurbishment.
5. Locate and remove the vacuum pumps (and pump controller). These can be returned to the manufacturer for refurbishment.
6. Locate and remove the vacuum valves. These can be returned to the manufacturer for refurbishment.
7. Locate and remove the vacuum gauges. These can be returned to the manufacturer for refurbishment.
8. Locate and remove the RF generator. This can be returned to the manufacturer for refurbishment.
9. Locate, remove and dispose of any O-rings attached to the vacuum chamber or vacuum pipe work. Place the O-rings in sealed plastic bags and label as hazardous material. Dispose of O-rings in accordance with local safety regulations.
10. Locate, remove and dispose of any oil within vacuum pumps. Store the oil in sealed hydro-carbon resistant containers and label as hazardous material. Dispose of oil in accordance with local safety regulations.
11. Locate, remove and dispose of any glycol based fluids heater/chiller units. Store the fluid in sealed containers and label as hazardous material. Dispose of fluid in accordance with local safety regulations.
12. The system process chamber and process chamber base plate are aluminium and can be recycled in accordance with local safety regulations.
13. The system console frame is stainless steel and can be recycled in accordance with local safety regulations.
14. Dispose of the remainder of the system in accordance with local and national safety and environmental regulations.

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10 TECHNICAL SPECIFICATIONS

This chapter contains a technical specification of the **FlexAL**® system.

10.1 System specifications

This section contains qualitative specifications for all of Oxford Instruments Plasma Technology's plasma and ion beam systems.

Note that all dimensions shown in these data sheets are typical; precise dimensions depend on the actual equipment fit. All dimensions are given in millimetres unless otherwise stated.

NOTE: All information, services, dimensions, etc. refer only to the ALD **FlexAL**® system: i.e. plasma processing at up to 200 mm wafers in MESC compatible chambers.

Oxford Instruments Plasma Technology conducts a programme of continual product development, and reserves the right to change the design and/or specification of equipment without notice. The details contained in this document were correct at the time of printing but must be confirmed immediately prior to delivery. Details of the clean room interface will be advised at the time of delivery.

10.1.1 FlexAL® system dimensions

System dimensions are given in **Figure 10-1**, **Figure 10-2** and **Figure 10-3**.

Gas handling component dimensions are given in **Figure 10-5**, **Figure 10-6**, and **Figure 10-7**.

Dimensions for commonly used vacuum pumps are given in **Table 10-12**. Consult the relevant manufacturer's manual for any pump types that are not listed.

Dimensions for commonly used heater/chillers are given in **Table 10-13**. Consult the relevant manufacturer's manual for any heater/chiller types that are not listed.

10.1.2 FlexAL® system component weights

Typical weights of system components:

Table 10-1 Component weights

Item	Weight
Main system	475 kg
12-line gas pod	70 kg
Precursor pod	50 kg
208/415 V transformer	220 kg
Pumps	See manufacturer's information.
Heater/chillers	See manufacturer's information.

10.1.3 Heat load

The typical heat load for the clean room installation is:

Table 10-2 Heat load information

System State	Heat Load
Operating	8 kW
Passive	4 kW

NOTE: These specifications do not include externally sited components such as pumps, heater/chillers, transformers, etc.

10.1.4 Sound level

Typical sound levels (measured 500 mm above the backing pump): 75 db.

10.1.5 System dimension diagrams

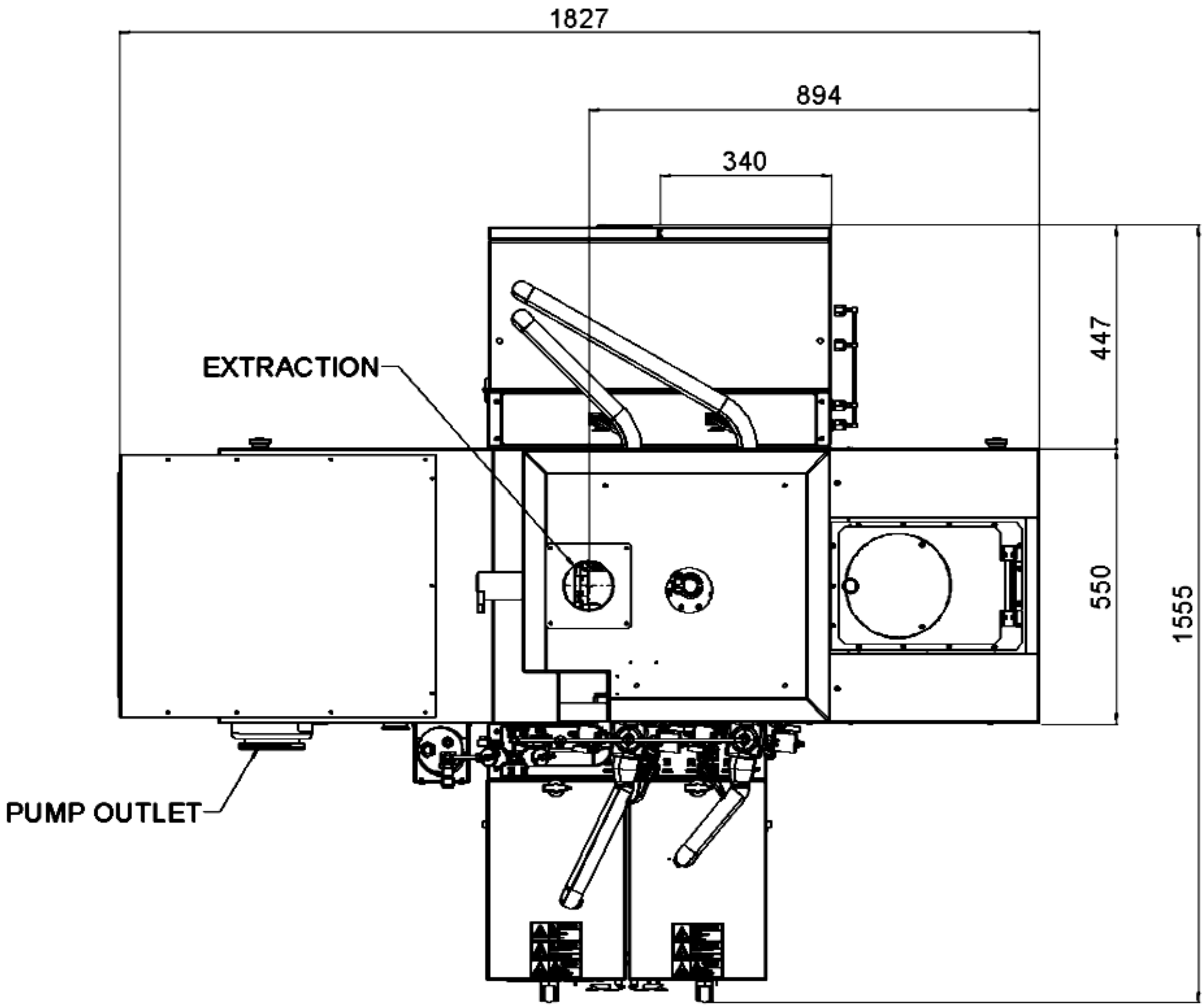


Figure 10-1 FlexAL® floorplan

NOTE: OIPT recommends that service access space of at least 600 mm is allowed between any obstacle (e.g. walls, partitions, etc), serviceable items (e.g. the power distribution unit), and items that require routine access (e.g. the precursor modules).

FlexAL®II

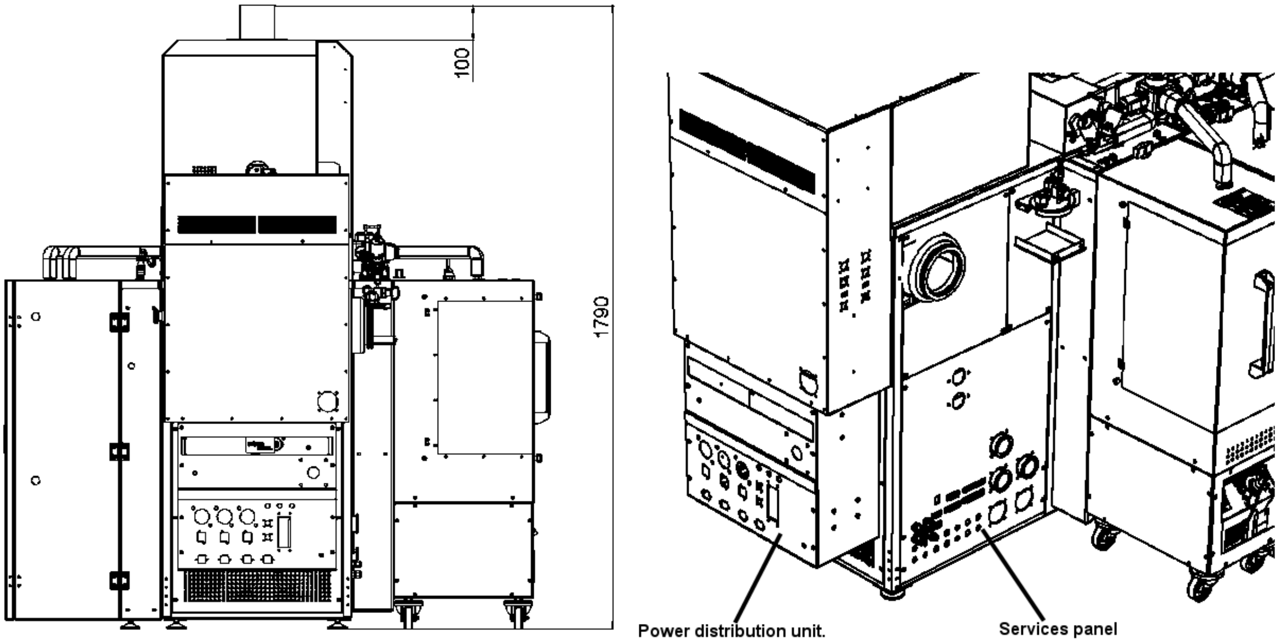


Figure 10-2 FlexAL® system view

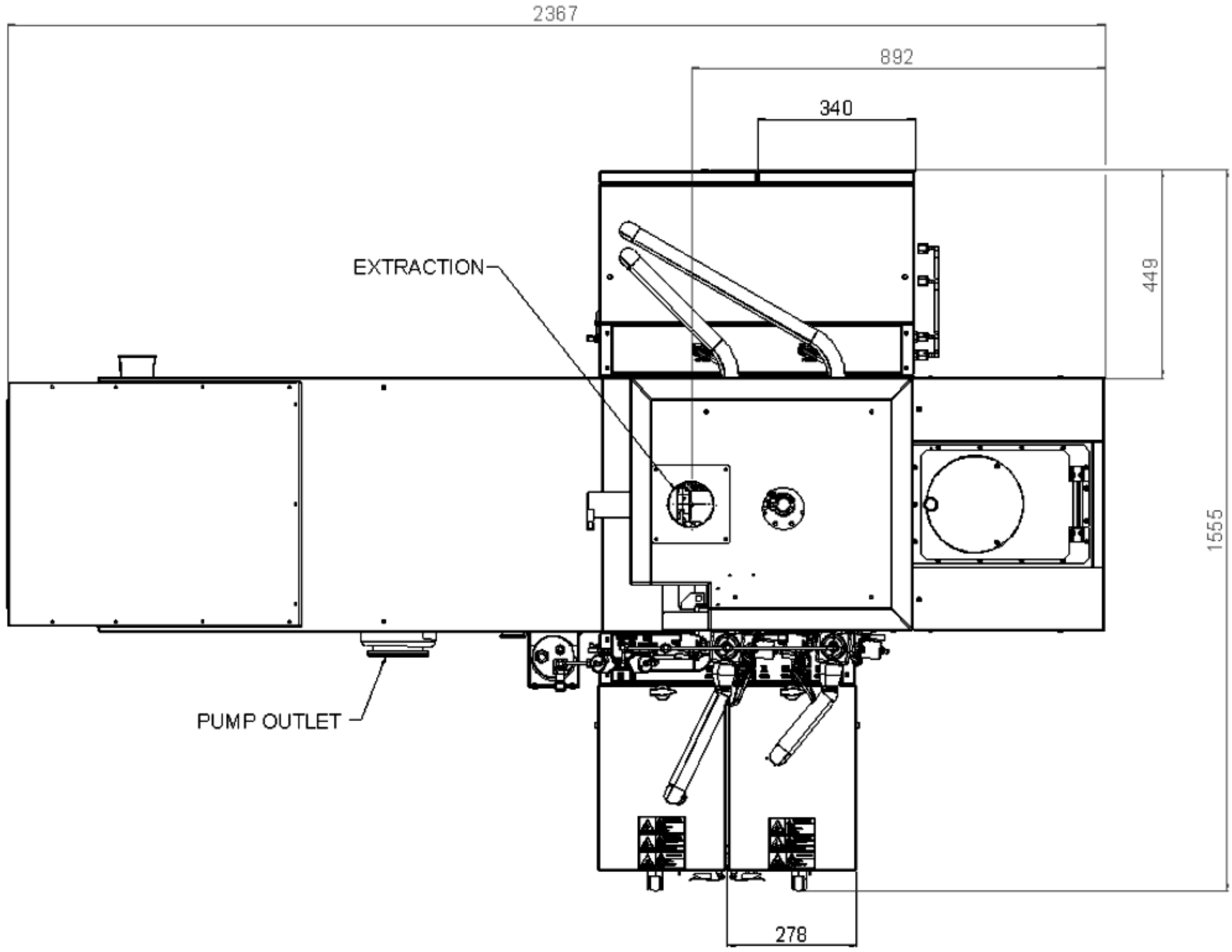


Figure 10-3 Floorplan of FlexAL® system with overhanging loadlock

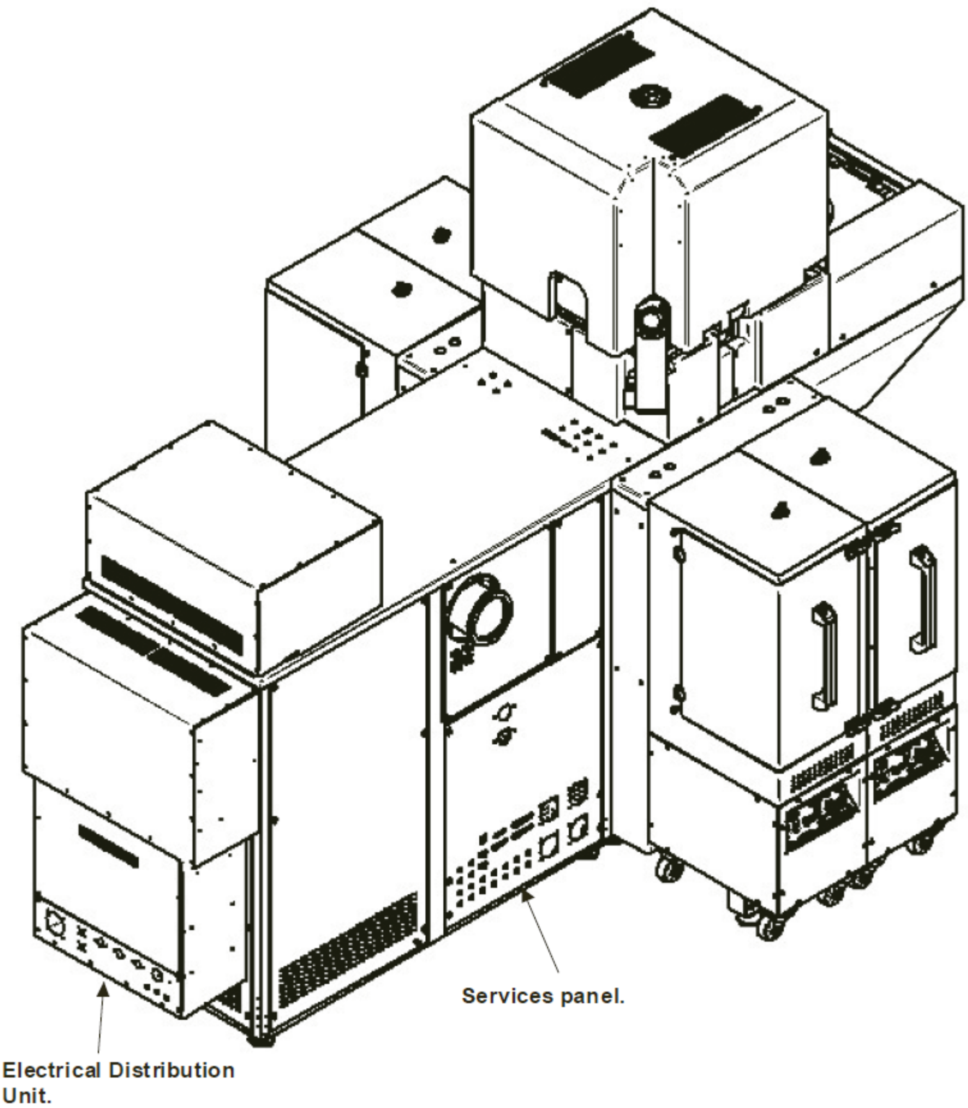


Figure 10-4 View of FlexAL® with overhanging loadlock

10.1.6 Gas handling system

NOTE: OIPT gas pods typically weigh >40 kg. If you intend to fix your gas pod to a wall, ensure that the wall and the gas pod fixings are sturdy enough to bear at least four times the weight of the gas pod. Periodically (e.g. annually), check that the gas pod and its fixings are secure.

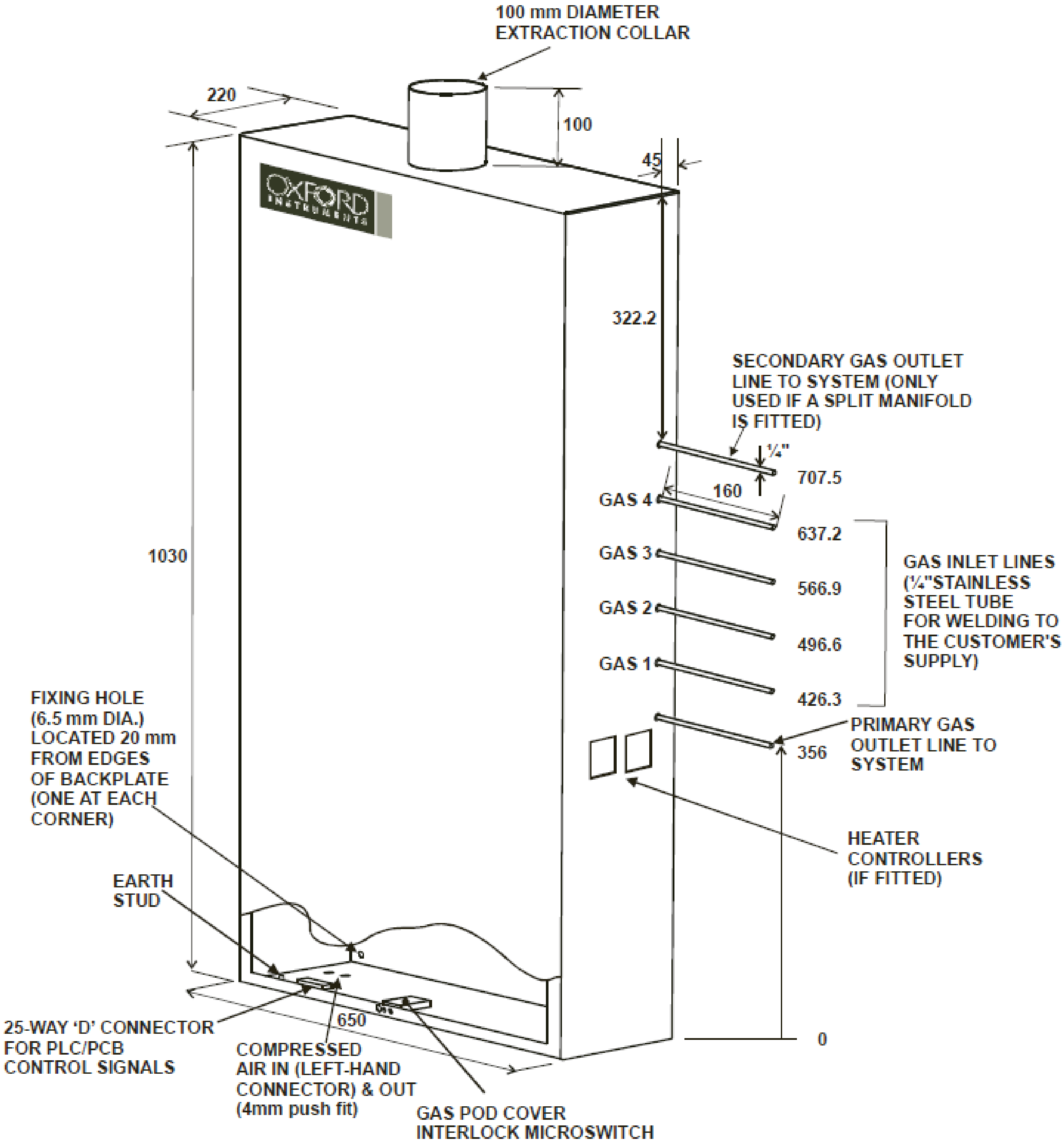


Figure 10-5   4-line gas pod

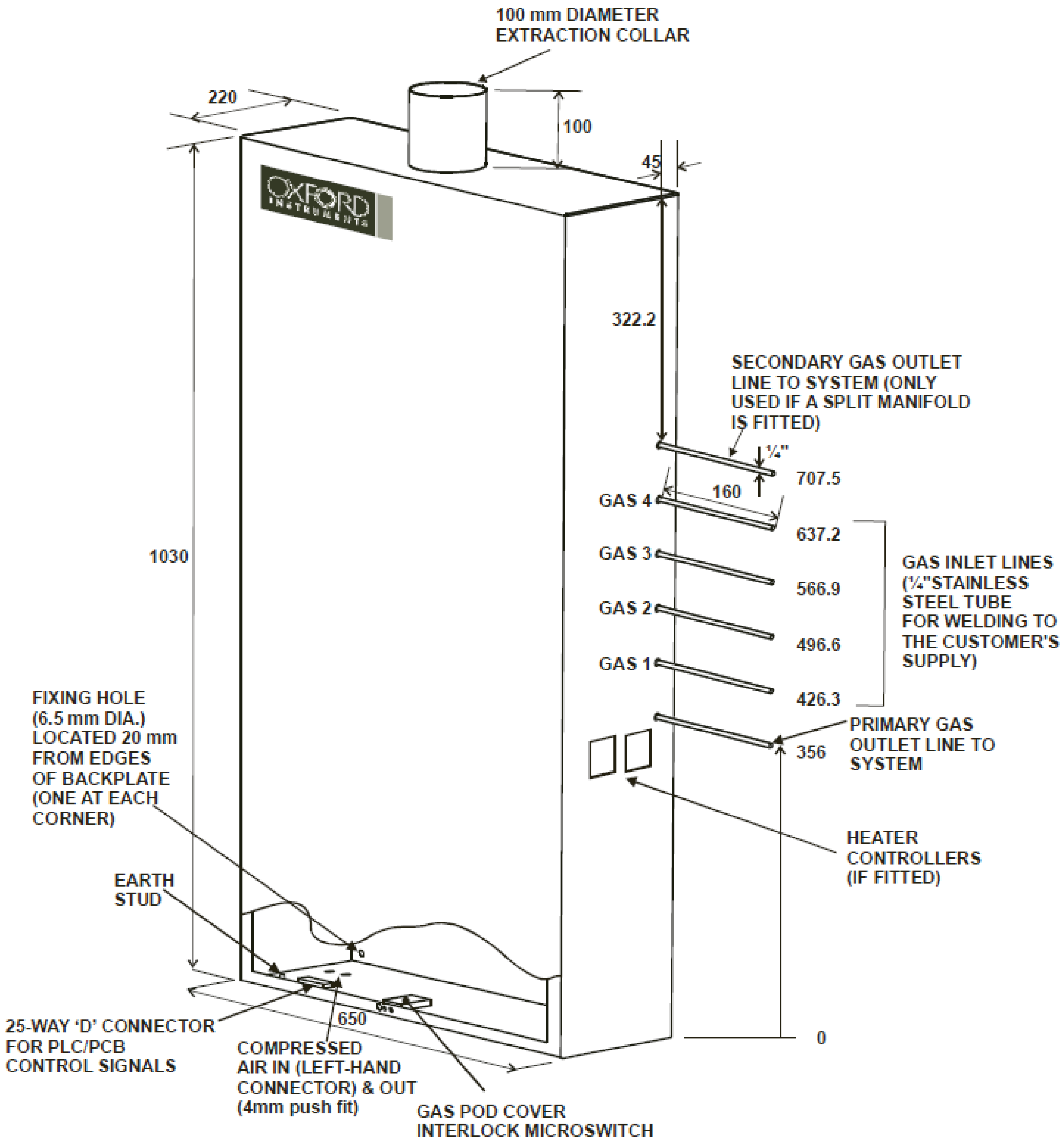


Figure 10-6 8-line gas pod

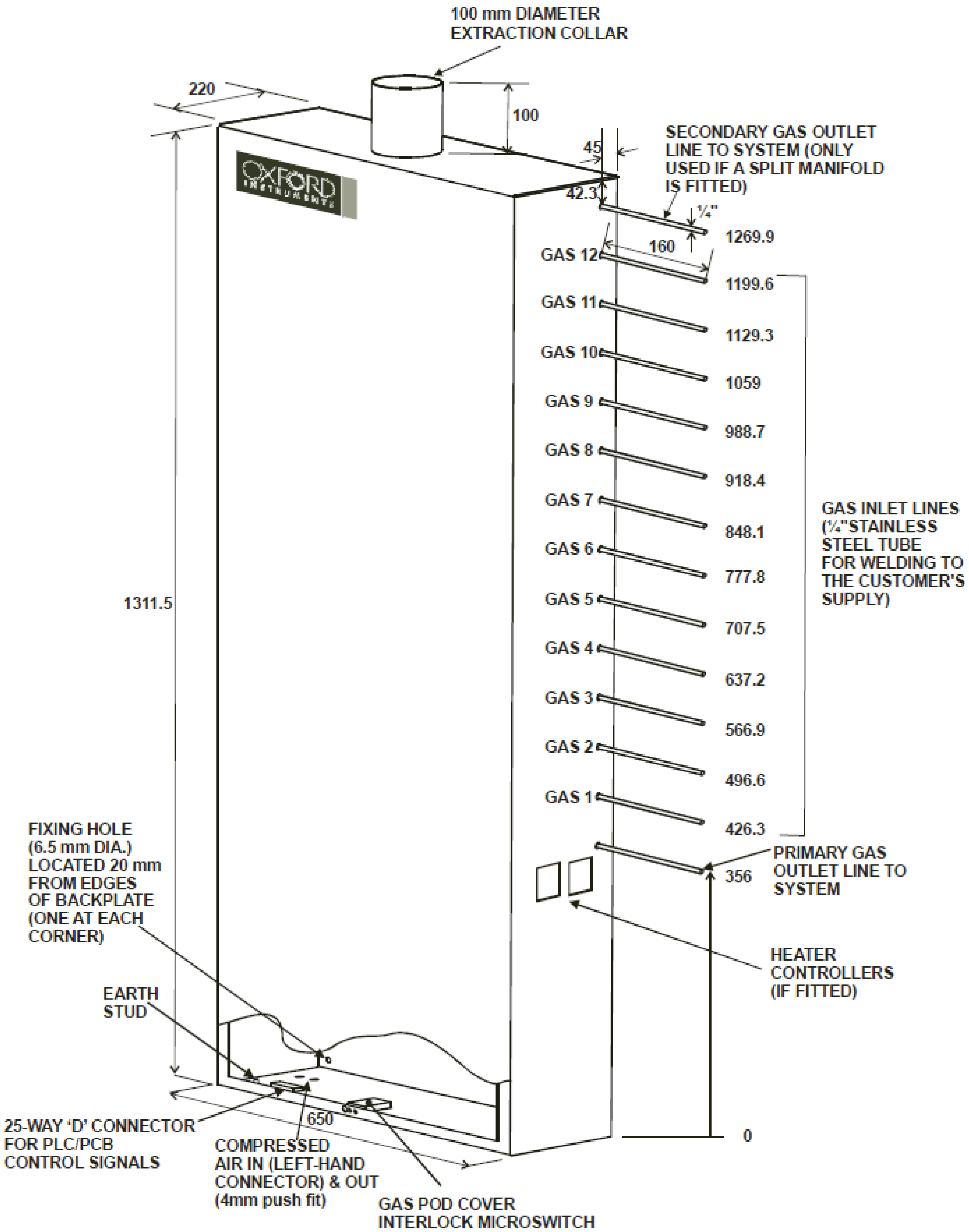


Figure 10-7 12-line gas pod

10.1.7 Services panel

Figure 10-8 shows a typical **FlexAL**® services panel.

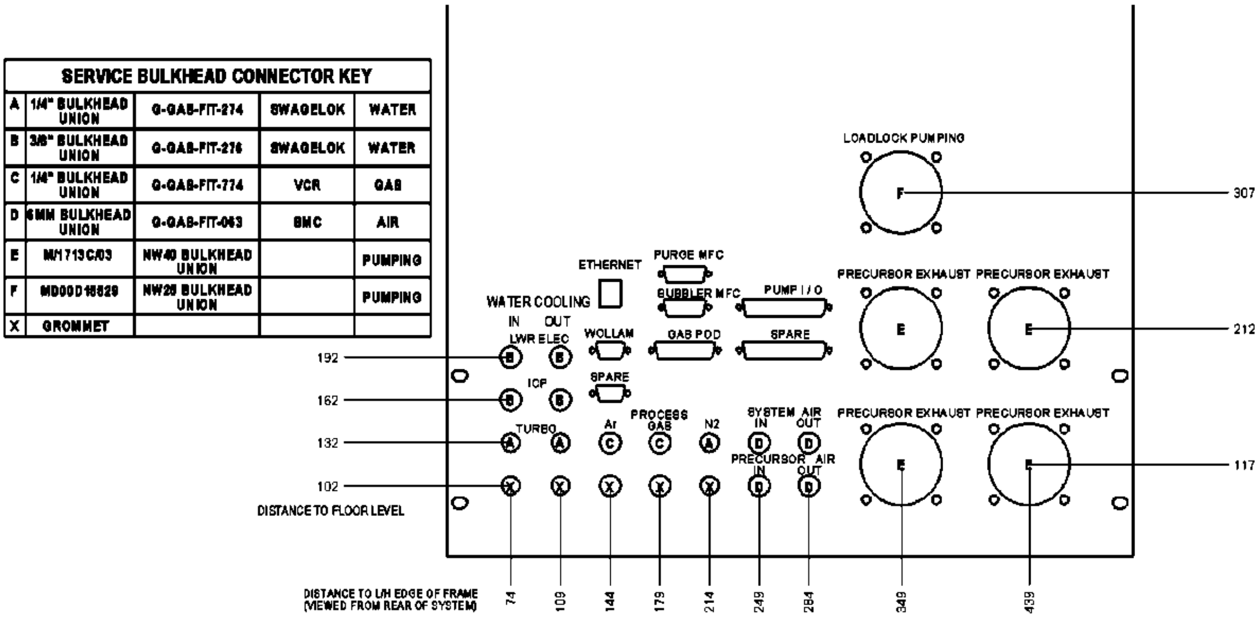


Figure 10-8 Typical FlexAL® services panel

10.2 Services specifications

This section gives the specifications of the services required for the **FlexAL**® system. For details of cooling flow rates and electrical supply ratings, see the relevant system installation data sheets.

Customers must ensure that the services as specified are available at the time of delivery to reduce system commissioning time and potential problems.

Unless other arrangements have been made in writing with Oxford Instruments Plasma Technology, it is a requirement that services meet the following specifications. If they do not meet these specifications then the system warranty and process guarantees may be made invalid.

If you suspect that you may fail to meet ANY of these specifications, please contact Oxford Instruments Plasma Technology immediately so that we can discuss the problem with you.

Oxford Instruments Plasma Technology conducts a programme of continual product development, and reserves the right to change the design and/or specification of equipment without notice. The details contained in this document were correct at the time of printing but must be confirmed immediately prior to delivery.

WARNING 10.1

POTENTIALLY HAZARDOUS EQUIPMENT
The FlexAL® system can produce various hazards if it is not installed correctly. These hazards can cause death or serious injury. Before installing the system services, ensure that all relevant personnel have read and understood Chapter 1 of this manual. If you have any concerns or questions, contact Oxford Instruments Plasma Technology before proceeding with the installation.

10.2.1 Water cooling system

10.2.1.1 General description of water systems

There are two acceptable methods of applying cooling/warming water to an OIPT system:

Recirculation
Water is pumped through the system by a dedicated heater/chiller unit or a heat exchanger unit. The heater/chiller or heat exchanger adds or removes heat from the water that is recirculating through the system in order to maintain the supply water at the required temperature.

*Many customers have a water recirculation facility shared by several systems. This shared facility seldom provides water of suitable quality, and so cannot usually be used for cooling any part of the OIPT system without the use of a heat exchanger dedicated to the OIPT system.

Total Loss Cooling
Municipal water flows through the system from a mains supply. The water exiting the system is fed to a drain for disposal.

Water failing to meet the recirculation or total loss cooling specifications must not be put into the system without close consultation with OIPT.

In some circumstances, it may be appropriate to use a combination of recirculation cooling and total loss cooling in one system.

It is recommended that customers use a dedicated heater/chiller for the entire system, or at least for the critical components.

NOTE: Chillers, which cool only, can give problems with condensation on chamber components in some environments. This is a particularly important consideration for production systems of the batch-load type. In severe cases, they can produce sufficient condensation to damage components such as RF power supplies, ferrofluidic seals and automatch units. Any damage so caused cannot be covered by the system warranty.

If a heater-chiller is used to provide warm water (above 30°C) for heated parts of the system, then items such as the turbo pump will require an independent water supply.

Items such as turbomolecular pumps can be cooled with total loss cooling if they are of stainless steel construction and if the water is suitable. If the water is not suitable, then a heat exchanger may be necessary.

Total loss cooling cannot be used on any components that have aluminium in direct contact with the coolant.

10.2.1.2 Water cooling specifications

The system requires cooling water in accordance with the specifications in **Table 10-3**.

Table 10-3 System water cooling specification

Function	Connection	Parameter	Specification
Chamber turbo pump	1/4” stainless steel Swagelok®	Flow	1 lpm (0.27 gpm (US))
		Temperature	15°C to 25°C. (59°F to 77°F)
Baseplate cooling	3/8” stainless steel Swagelok®	Flow	2 lpm (0.53 gpm (US))
		Temperature	10°C to 25°C. (50°F to 77°F)
ICP and AMU	3/8” stainless steel Swagelok®	Flow	1 lpm (0.27 gpm (US))
		Temperature	15°C to 25°C. (59°F to 77°F)
Loadlock turbo pump (if required)	1/4” stainless steel Swagelok®	Flow	1 lpm (0.27 gpm (US))
		Temperature	15°C to 25°C. (59°F to 77°F)

10.2.1.3 Recirculating water configuration

WARNING 10.2

COLD SURFACES
Contact with cold objects can cause serious injury to the skin and can cause the skin to adhere to the cold object. Chiller units contain components which could become cold enough to cause serious injury. Read the manufacturer’s manual before installing, operating or maintaining chiller units. Ensure that suitable protective clothing is worn.

Recirculation water is used in systems where the user does not wish to consume water at a high rate, or where it is wished to supply water to the system at a constant temperature.

Some systems contain aluminium in direct contact with coolant. These are the systems fitted with tables or turbomolecular pumps with plain aluminium cooling channels. Certain aluminium chambers are also included.

In these aluminium-containing systems, it is **MANDATORY** that the approved coolant is used at all times. If the approved coolant and installation are not used, the system warranty will not cover any damage to the system or any other equipment caused, directly or indirectly, by the coolant.

It is the customer's responsibility to comply with the above requirement. If the customer has any doubt as to whether their system falls into this category, they must contact OIPT for further advice.

In systems that do not contain aluminium components, severe corrosion can still sometimes occur: water will collect corrosive chemicals, and will be lacking in the oxygen that protects stainless steel.

OIPT strongly recommends that the approved coolant is used. If an alternative product or water is used, then it is entirely the customer's responsibility to check for any signs of corrosion or contaminated water.

If the customer's coolant has not been approved in writing by OIPT, then the system warranty will not cover any damage to the system or any other equipment caused, directly or indirectly, by the coolant.[1]

The approved installation and coolant are shown in **Mandatory specifications for recirculated water systems**, and in **Figure 10-9**. Note that the total water flow meter and the isolation valves are recommended for cooling monitoring and ease of maintenance.

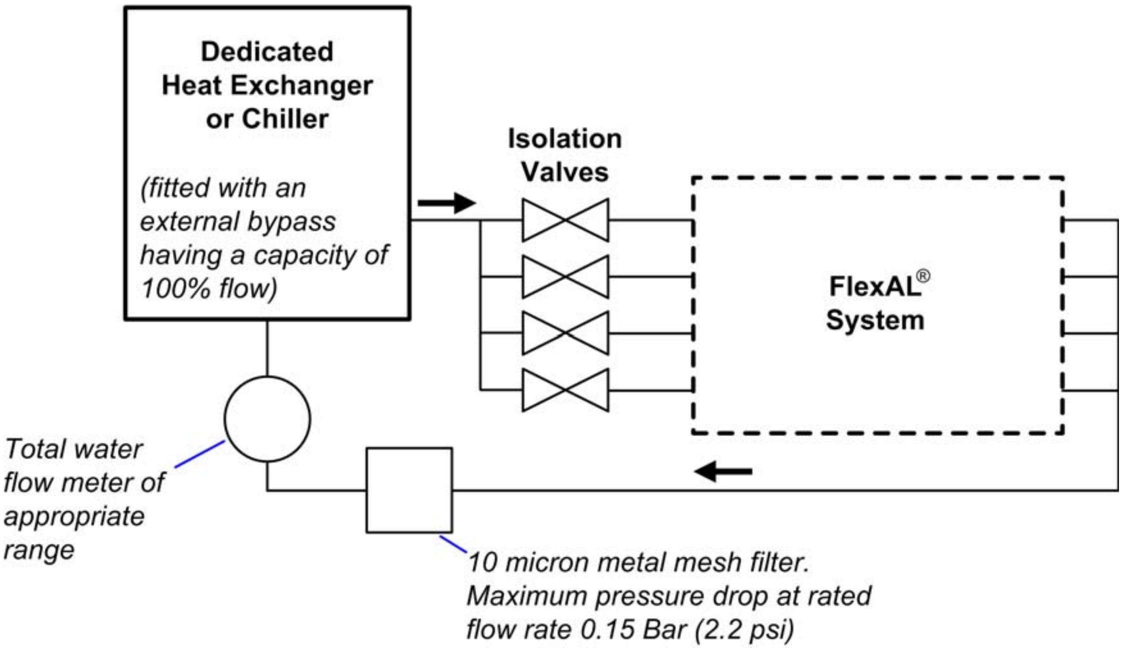


Figure 10-9 Recommended basic recirculation installation

Mandatory specifications for recirculated water systems

Caution 10.1	**RISK OF BLOCKAGE** If clear (i.e. transparent) tubing is exposed to sunlight, algal growth can develop, which can restrict coolant flow. It is **MANDATORY** that clear tubing is not used in any part of the cooling system. OIPT recommends the use of either black or dark green tubing.

1. Customers must note, for example, that certain types of inhibitor will damage the pumps of heater/chiller units, and that the use of municipal (drinking water) or deionized water can introduce harmful chemicals into the system. If plain water is used, distilled water is by far the safest option.

Caution 10.2

OVER PRESSURE RISK
It is the customer's responsibility not to exceed a pressure of 4.2 bar, or other limit that has been set for the system. Exceeding this safe pressure may cause irreparable damage to system components.

The water must be kept warm enough to prevent condensation on chamber surfaces and outside system components. This applies to those parts of the system inside the clean room and those parts in a service area. Condensation can damage components such as RF power supplies, ferrofluidic seals and automatch units. Any damage so caused cannot be covered by the system warranty.

Pressure	Adjustable 0.7 to 4.2 bar (10 to 60 psi). Chiller / heat exchanger to be fitted with a bypass having a capacity of 100% of rated flow.
Temperature range	See system installation data sheets.
Minimum flows	See system installation data sheets.
Cooling capacity	See system installation data sheets.
Coolant	Hexid A40 (OIPT Part No. G/WATER/SUN/007 for 15 litres)[1]. This product is propylene glycol based, and is pre-diluted ready for use.
Filtration	10 micron metal mesh water filter. Maximum pressure drop 0.15 bar (2.2 psi) at rated flow. For example, filter element Balston SMC-100-12-10.

1. To order replacement fluid, check the capacity of the model of heater/chiller to be fitted to the system. Also allow at least 5 litres for the system and connecting lines, or more if necessary.

10.2.1.4 Total loss cooling

Municipal (drinking) water may be used in total loss cooling of the system in situations where clean water is freely available, but only if the water meets the specification in **Mandatory specifications for total loss cooling systems**. If in doubt, obtain the water specification from the water utility company, and consult OIPT. It is not practical to use total loss cooling where the water temperature is critical.

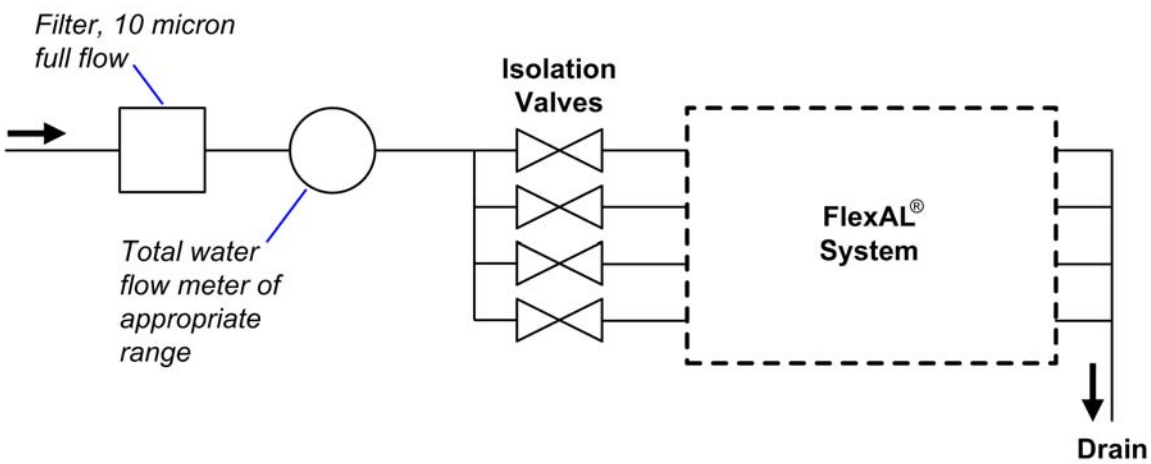


Figure 10-10 Recommended basic total loss installation

Mandatory specifications for total loss cooling systems

Caution 10.3

RISK OF BLOCKAGE
If clear (i.e. transparent) tubing is exposed to sunlight, algal growth can develop, which can restrict coolant flow. It is MANDATORY that clear tubing is not used in any part of the cooling system. OIPT recommends the use of either black or dark green tubing.

Caution 10.4

OVER PRESSURE RISK
It is the customer's responsibility not to exceed a pressure of 5 bar, or other limit that has been set for the system. Exceeding this safe pressure may cause irreparable damage to system components.

If total loss cooling with municipal water (drinking quality water) is used in the system or in the pumps, the water quality must meet the following specifications. Note that increased maintenance will be required if this water is used directly in the system as well as in the pumps.

The water must be kept warm enough to prevent condensation on chamber surfaces and outside system components. This applies to those parts of the system inside the clean room and those parts in a service area. Condensation can damage components such as RF power supplies, ferrofluidic seals and automatch units. Any damage so caused cannot be covered by the system warranty.

Pressure	4 to 5 bar (58 to 73 psig) The back-pressure from the drain must be less than 1 bar (15 psig).
Temperature	10°C to 25°C (50°F to 77°F)
pH	7 to 8
Oxygen	Greater than 4 mg/litre
CO2 and NH3	Less than 10 mg/litre
Chloride	Less than 100 mg/litre
Calcium carbonate	Less than 75 mg/litre
Filtration	To 0.9 micron at full flow

10.2.2 Electrical power supply

NOTE: It is the users responsibility to purchase and organise the installation of a wall-mounted electrical safety isolation box that meets the local electrical regulations. The isolation box must be easily accessible and mounted as close to the system as possible.

The system requires one of the following electrical supplies:

Table 10-4 Electrical supply specification

Function	Connection	Parameter	Specification
System electrical supply (for a 208 V system)	Cable (4 metres long)	Voltage	208 VAC ±10%
		Current	75 A
		Frequency	50/60 Hz
		Phases	3 phase + E
System electrical supply (for a 415 V system)	Cable (4 metres long)	Voltage	380 VAC -10% to 415 VAC +6%
		Current	40 A
		Frequency	50/60 Hz
		Phases	3 phase, N + E

NOTE: See **Section 10.2.13.3** for electromagnetic compatibility requirements.

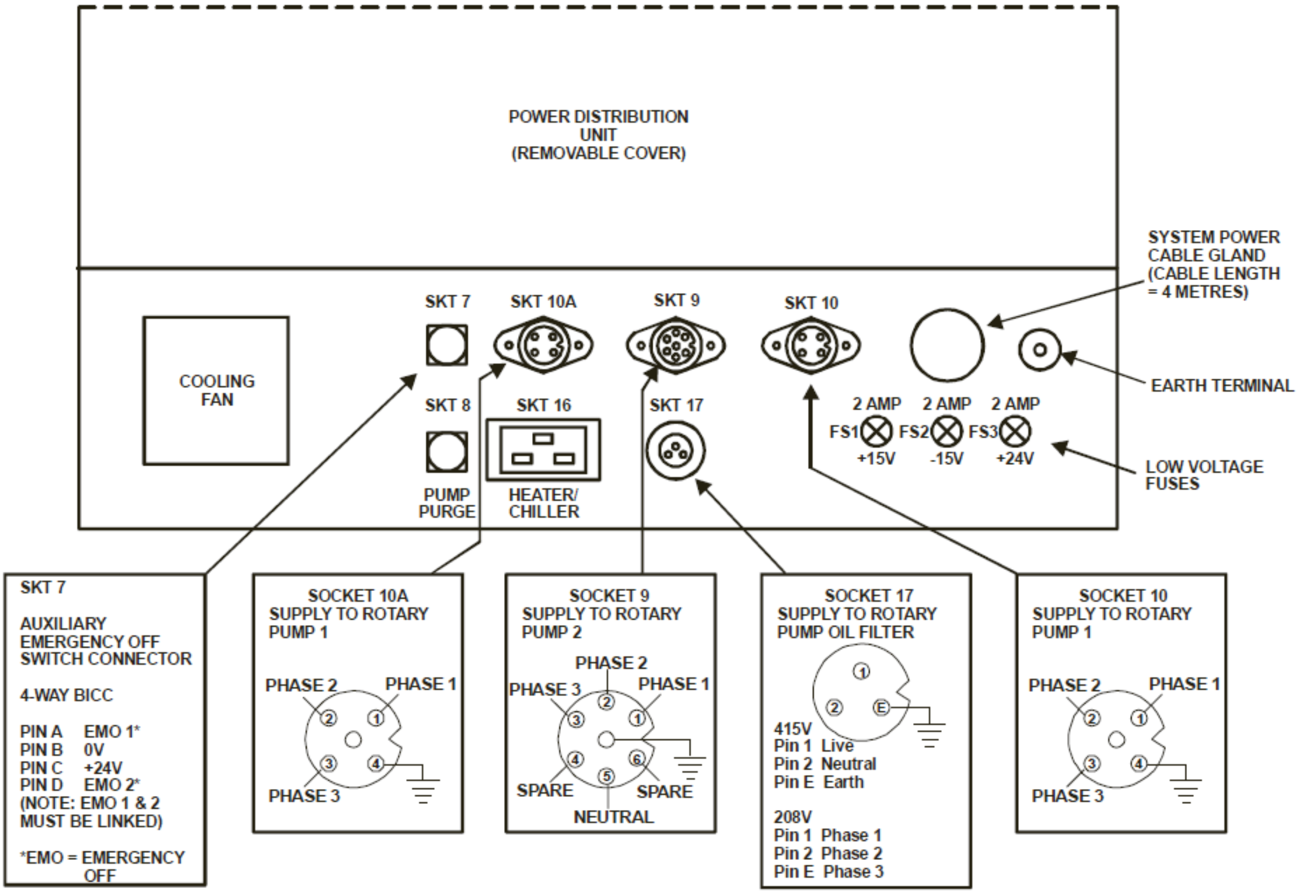


Figure 10-11 Electrical connections

10.2.2.1 Earth connection

WARNING 10.3

HAZARDOUS VOLTAGE
Hazardous voltages can appear on the chassis if the system is not earthed. These voltages can cause death, severe injury or burns. It is essential that the system is connected to earth before the electrical power connections are made.

It is essential that the system earth must be connected before the electrical power connections. An earth continuity test is required for all permanently connected equipment, using suitable safety test equipment.

To meet international standards for RF interference, our systems are fitted with filtration on the mains supply inputs. As a result, there is significant leakage to earth (ground) from the mains supply.

An earth continuity test is required for all PERMANENTLY CONNECTED EQUIPMENT, using a CLARE tester or similar equipment.

International standard IEC950, section 5.2, requires that a label is attached at the point where the system is connected to the factory electricity supply: either to the safety isolation box, or to the transformer, or to the electrical supply outlet socket. This label must contain the following text:

Warning

High leakage current.

Earth connection essential before connecting supply.

10.2.2.2 Residual current circuit breakers

Fitting a residual current circuit breaker (RCCB), also known as an earth leakage circuit breaker (ELCB, or ELB), to the electrical supply of the system is NOT recommended. This is because the equipment contains filters on the power lines. These filters create a small leakage current, which can cause spurious trips of the RCCB.

NOTE: The leakage current caused by the filters is in accordance with International standard IEC 60950-1Ref:[16].

Oxford Instruments Plasma Technology accepts no responsibility if the customer fits an RCCB, which then proves unsuitable.

10.2.3 Emergency stop connection for auxiliary equipment

Auxiliary equipment, e.g. gas detection and minimum air flow monitors, can immediately shut the system down by using the circuit shown in Figure 10-12. Note that when no auxiliary equipment is used, SKT 7 pins A and D must be shorted together.

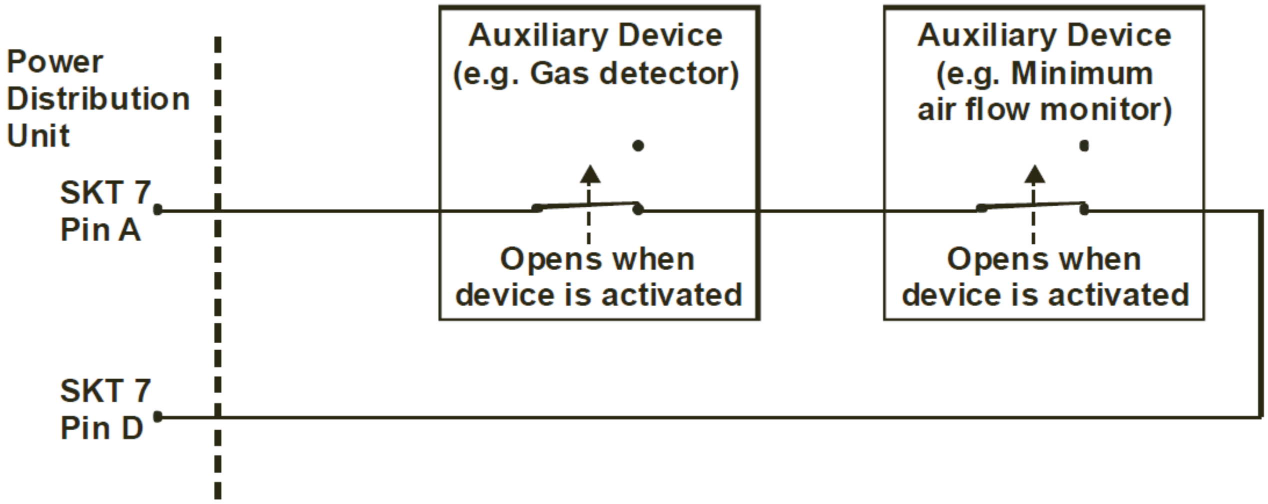


Figure 10-12 Auxiliary equipment emergency stop connection

10.2.4 Compressed air requirement

Compressed air must be supplied via a filter and oil mist separator, as shown in Figure 10-13.

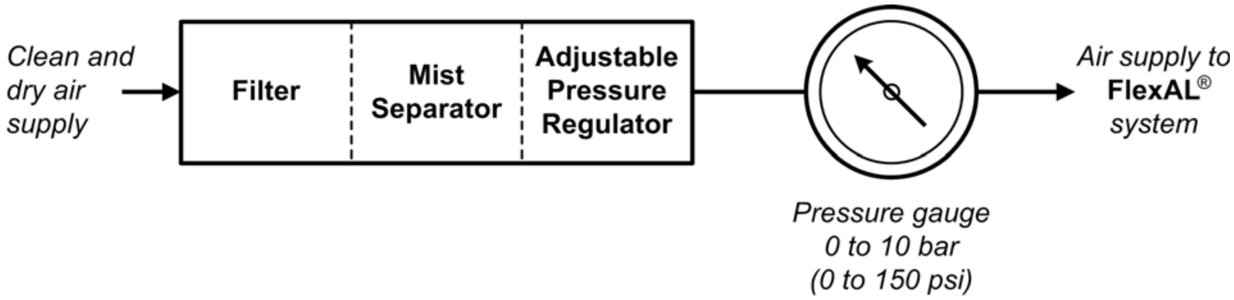


Figure 10-13 Compressed air supply

The following air filter/mist separator/pressure regulator unit components are recommended:

Air filter: SMC AF2000-02D with filter element 1129116A.

Mist separator: SMC AFD2000-02D with filter element 63092. This filter element must be changed annually. Note that as this item is not supplied by OIPT, its maintenance is not included in the system manuals.

Regulator with gauge: SMC AR2001-02G.

Spacers: 2 off SMC Y20L.

The system requires compressed clean, dry air (CDA) in accordance with the specifications given in Table 10-5.

Table 10-5 System compressed air specification

Function	Connection	Parameter	Specification
CDA inlet to filter/mist separator/regulator unit	Customer specific	Minimum pressure	6 bar (90 psig)
CDA inlet to system	6 mm push-fit connector	Maximum flow rate	5 lpm (0.2 cfm). (This flow is in addition to the gas pod flow)
		Regulated pressure	3.0 to 6.0 bar. (45 to 90 psi)
		Pressure monitoring	0 to 10 bar. (0 to 150 psi)
		Oil content	Less than 10 ppm
		Maximum moisture content (dew point)	-3°C (25°F)
		Filtration	Maximum particle size of 0.3 microns

Table 10-5 System compressed air specification

Function	Connection	Parameter	Specification
CDA inlet to gas pod	6 mm push-fit connector	Flow	5 lpm (0.2 cfm). (This flow is in addition to the system flow)
		Pressure	4.0 to 6.0 bar. (60 to 90 psi)
CDA inlet to each precursor module	6 mm push fit connector	Flow	1.25 lmp (0.05 cfm) per module
		Pressure	6.0 to 7.0 bar (60-90 psi)

NOTE: The CDA inlet pressures to the system must be limited to 6 bar (90 psi).

10.2.5 Nitrogen requirement

Compressed nitrogen must be supplied via a filter and semiconductor grade regulator, as shown in **Figure 10-14**. All tubing used in the installation must be electropolished stainless steel. All pipe-work fittings and pressure regulators must be semiconductor grade.

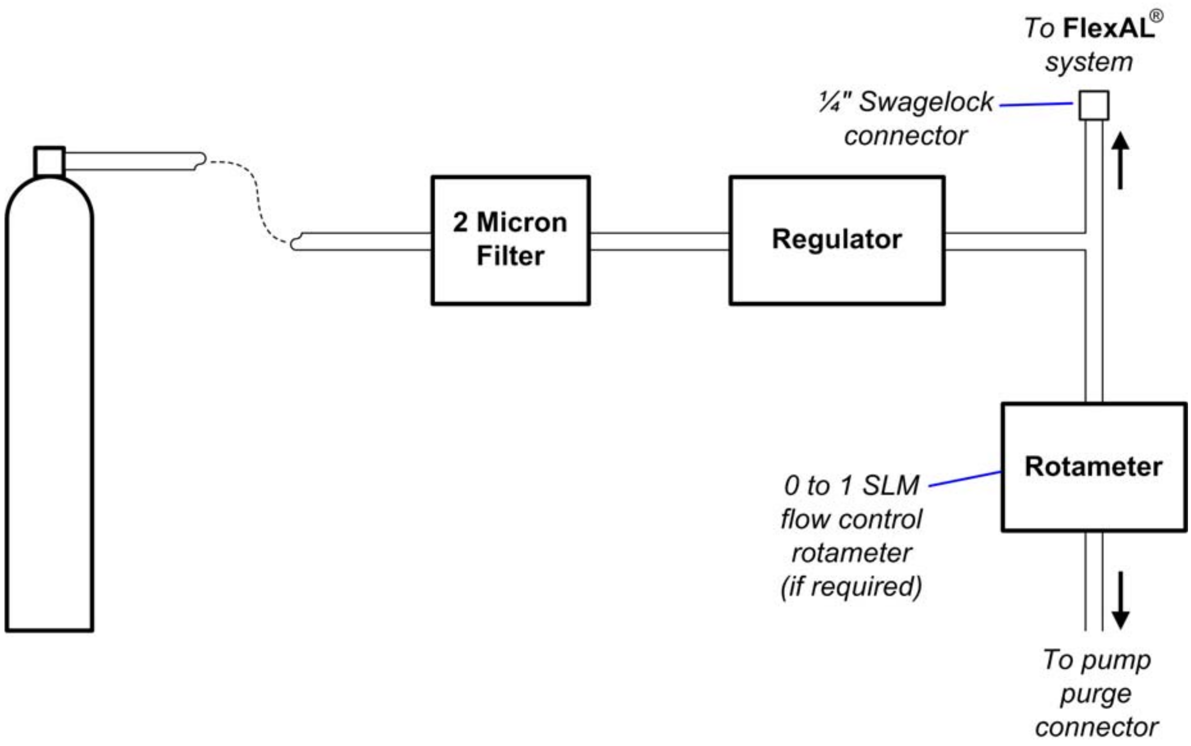


Figure 10-14 Nitrogen supply to the system

Purge supplies to turbo pumps are supplied by OIPT as part of the system. It will usually be necessary for the customer to fit a purge to the rotary pump.

The system requires nitrogen in accordance with the following specification:

Table 10-6 System nitrogen specification

Function	Connection	Parameter	Specification
Regulated N_2 inlet to system	1/4” stainless steel Swagelok®	Flow	5 lpm (0.2 cfm)
		Pressure	3.0 bar (45 psi) minimum
		Regulation	0.5 bar to 5 bar (7.5 to 75 psig)
		Filtration	2 micron filter mounted adjacent to the system
		Purity	Better than 99.99% to satisfy process requirements
		Minimum pressure at input to system	3 bar (45 psig). Certain pumps, for example Edwards Drystar pumps, may need up to 5 bar (75psig) to ensure satisfactory purging. Check with the vendor's instructions.
Regulated N_2 inlet to each precursor module	1/4” stainless steel Swagelok®	Flow	10 lpm (0.4 cfm) per module
		Pressure	3.0 bar (45 psi) minimum
Backing pump purge	It is the customer’s responsibility to ensure that a rotary pump purge connection is fitted and used correctly. The purge flow is necessary to protect the pumping system from the customer's process, and may also be required by local safety regulations. Customer requirements vary, so special kits can be supplied on request. It may be safe to omit this feature on certain systems running inert gas processes. However, unless the customer has written agreement on this point from OIPT, any damage caused by the omission cannot be covered by the system warranty.		

10.2.6 Helium requirement (if helium option is fitted)

If helium is required, it must be supplied via a local regulator, as shown in Figure 10-15. All tubing used in the installation must be electropolished stainless steel. All pipe-work fittings and pressure regulators must be semiconductor grade.

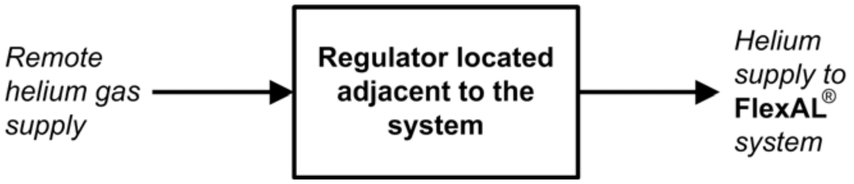


Figure 10-15 Helium supply to the system

If the **FlexAL**® tool has the helium substrate cooling option fitted, the system requires compressed helium in accordance with the specification given in Table 10-7.

Table 10-7 Helium supply specification

Function	Parameter	Specification
Helium supply	Pressure	2 bar (30 psig) minimum 3.5 bar (43 psig) maximum
	Regulation	0.5 to 5 bar (7.5 to 75 psig)
	Purity	At least 99.99% to satisfy process requirements
	Filtration	A 2 micron filter is fitted to each gas line, as part of the gas pod. Other grades of filter can be fitted, if required.

Caution 10.5

OVER PRESSURE RISK
The maximum pressure at the inlet to the pressure controller must not exceed 3.5 bar (43 psig). The helium pressure controller can be destroyed by higher pressures.

10.2.7 Process gas requirement

Process gas is supplied to the gas pod from an external supply. All tubing used for process gas supply must be electropolished steel. All pipework fittings and regulators must be semiconductor grade.

The customer must fit manual shut-off valves on all gas lines as close to the gas pod inlets as possible. Each valve must be clearly labelled with the gas it controls. These valves are sometimes referred to as *point-of-use* valves. **Figure 10-16** shows a typical installation for these valves.

Figure 10-16 Gas supply point-of-use valves

All process gas supplies must conform to the specification given in **Table 10-8**.

Table 10-8 Process gas supply specification

Function	Parameter	Specification
Process gas supplies	Pressure	2.0 to 3.0 bar (30 to 45 psig)[1]
	Regulation	0.5 to 5 bar (7.5 to 75 psig)
	Purity	At least 99.99% to satisfy process requirements
	Filtration	A 2 micron filter is fitted to each gas line, as part of the gas pod. Other grades of filter can be fitted, if required.

1. Low vapour pressure gases can be used (see **Section 10.2.7.1**), but they require special consideration to prevent unwanted condensation of material in the gas lines. It may be necessary to heat the gas lines and the gas handling equipment in the gas pod. Contact Oxford Instruments Plasma Technology for advice.

The system requires a pipework connection between the gas pod and the system gas inlet. This connection must comply with the specification given in **Table 10-9**.

Table 10-9 Process gas connection specification

Function	Connection	Parameter	Specification
Process gas in	1/4" electropolished stainless steel pipe, welded at the gas pod	Pressure	2.0 to 3.0 bar (30 to 45 psi)
	1/4" stainless steel VCR at the system		

10.2.7.1 Installation of low vapour pressure gases

Special precautions must be taken if low pressure gases (such as $SiCl_4$, BCl_3 or C_4F_8) are used. The low vapour pressure can lead to condensation in the gas supply lines, particularly where the gas passes through a cooler region of pipework. This condensation can result in a build up of liquid in the gas pipe, usually at the low points or U-bends in the gas line. Liquid build-up can produce unstable gas flows, especially if liquid condenses or flows into the MFC.

The gas pressure at the system can be very low if the gas cylinder is cold, e.g. if it is kept outdoors in the winter. Observe the following guidelines if using low vapour pressure gases:

a) Keep the gas cylinder indoors (in an extracted gas cabinet) to avoid loss of line pressure when the outside temperature is cold.
However, do NOT heat the gas cylinder with a heated jacket as this can cause condensation when the gas passes through the cooler gas lines.

b) Maintain a positive temperature gradient from the cylinder to the MFC. This is best achieved by positioning the gas pod close to the system, which results in short pipe runs. If this is not possible, then the gas lines must be heated by wrapping a suitable heater tape around them.

The MFC in the gas pod may also need to be heated. OIPT offers a heated MFC kit for use with low vapour pressure gases.

The MFC temperature should be maintained above the temperature of the gas line, which should in turn be maintained at a higher temperature than the gas cylinder. A typical setup might be MFC 40°C (104°F) or above, gas line 30°C to 40°C (86°F to 104°F), and gas cylinder at room temperature (see **Figure 10-17**).

c) If condensation problems are suspected, it is necessary to pump out the gas lines completely, optimise the heater tape arrangement and temperature setpoints, and then refill the gas line.

d) For $SiCl_4$ it is important to use a dedicated $SiCl_4$ MFC.

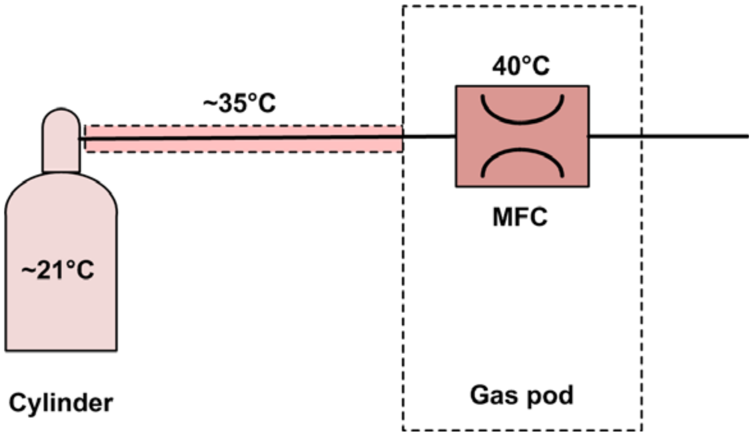


Figure 10-17 Typical heated gas line showing the temperature gradient

10.2.8 Extraction requirements

The system requires air extraction for the pump exhausts and gas pod. If toxic, flammable or corrosive gases are to be used on the system at any time, the extraction system must be designed accordingly.

The following mandatory requirements describe the extraction systems recommended by OIPT. While these recommendations may be regarded as good practice, they are not a complete definition of the safety standards required when handling toxic, corrosive or otherwise hazardous gases. It is the customer's responsibility to ensure that the installation meets all relevant local safety regulations and OIPT accepts no responsibility in this respect.

For detailed information about the safety aspects of gas handling and pumping systems, the customer must consult the relevant manufacturer/supplier of the gases and pumps to be used.

The extraction system must comply with the following specifications:

Table 10-10 Extraction specifications

Function	Connection	Parameter	Specification
Gas pod	100 mm (4") diameter tube	Flow	6-line gas pod : 1 m^3/hour (0.6 cfm)
			12-line gas pod: 3 m^3/hour (1.8 cfm)
Backing pump exhaust	Refer to the manufacturer's information		
Precursor modules	1 x 40 mm diameter tube for every 2 precursor modules	Flow	1 or 2 modules fitted : 1 m^3/hour (0.6 cfm)
			3 or 4 modules fitted: 2 m^3/hour (1.2 cfm)
ICP source screening box	1 x 40 mm diameter tube.		5 m^3/hour (3 cfm)

Precursor pod extraction is required to remove any hazardous vapours from the precursor pod(s) in the event of an accidental release. It is the **FlexAL**® owner's responsibility to install any gas detection or minimum air flow monitoring devices their risk assessment may deem is necessary. For details of emergency stop connections, refer to **Section 10.2.3**.

10.2.8.1 Mandatory requirements for backing pump extraction

The installation must provide an extraction system that matches the backing pump exhaust and which conforms to local safety standards. In particular all fittings and pipework connected to the backing pump exhaust must be made from industry standard stainless steel, in accordance with local safety regulations.

Specialised equipment, such as scrubbers and furnaces, may be needed to dispose of hazardous gases. The routing of the pump exhaust line must be arranged so that condensates cannot flow back into the pump.

Note that there is a risk of damage from cross-contamination if backing pumps share the same exhaust system. This applies whether the pumps are on the same system or on different systems. Damage caused by any cross-contamination is not covered by the system warranty.

Care must be taken to route mutually incompatible exhaust gases through separate exhaust ducts. In particular, oxygen enriched exhaust gases must not be mixed with exhausts from mineral oil pumps, as this can cause an explosion.

10.2.8.2 Mandatory requirements for gas pod extraction

The gas pod must be connected to the customer's gas extraction system via a 100 mm (4”) diameter pipe collar, to provide cabinet extraction with a minimum flow rate of 1 m^3/hour (0.6 cfm). An extraction vacuum of approximately 500 Pa relative to local atmospheric pressure (0.07 psig) is required.

It is the customer’s responsibility to ensure that the gas extraction system, including any necessary gas sensors, meets local safety regulations.

10.2.8.3 Mandatory requirements for cryogenic pump extraction

WARNING 10.4

TOXIC GASES AND VAPOUR

Exposure to toxic gases or vapour can cause death or serious injury. Cryo pumps fitted to systems with hazardous gas collect the gas during normal operation. If the pump is regenerated, or the electrical power fails, the has is then released through the pump’s pressure relief valve. Connect the pressure relief valve on all cryo pumps to a suitable exhaust system.

If a cryogenic pump is used to pump toxic, corrosive, or flammable gases, a written action plan is required. This must be prepared in consultation with OIPT and other competent bodies. Specialised equipment such as scrubbers and furnaces may be needed to dispose of hazardous gases.

If the pumped gases contain more than 20% oxygen, a vent pipe must be fitted to the system’s cryo pump outlet connector. The vent pipe must be routed to a safe place outside of the clean room and conform to local safety standards.

If a cryogenic pump is used to pump gases containing more than 20% oxygen, the associated roughing pump(s) must be lubricated with a PFPE fluid, e.g. Fomblin or Krytox.

10.2.9 Liquid nitrogen requirements (if fitted)

WARNING 10.5

EXPLOSION
Explosion hazard caused by the boil-off of liquid nitrogen. Ensure that all liquid nitrogen facilities are designed to avoid pressure build-up.

WARNING 10.6

COLD OBJECTS
Contact with cold objects can cause serious injury to the skin and can cause the skin to adhere to the cold object. Components carrying liquid nitrogen are cold enough to cause serious injury. Allow sufficient time for cold components to return to room temperature before carrying out maintenance. If cold objects must be handled, ensure that suitable protective clothing is worn.

WARNING 10.7

ASPHYXIATION
Liquid nitrogen produces nitrogen gas, which can displace the oxygen from air. This can cause death. Ensure that adequate ventilation is provided. Take care to avoid spilling liquid nitrogen.

10.2.9.1 Mandatory requirements for liquid nitrogen systems

The liquid nitrogen facilities must comply with the following specifications:

Table 10-11 Liquid nitrogen installation specifications

Function	Requirement
Liquid nitrogen connection to system	3/8" Swagelok® connector
System design	Adequate precautions must be taken to prevent pressure build-up (e.g. pressure relief valves).
	All liquid nitrogen carrying components must be thermally insulated. Components must also be covered to prevent accidental touching by personnel.
Inspection	The liquid nitrogen installation must be inspected by a specialist to confirm that it is safe to use.

10.2.10 Pump set information

Caution 10.6

EMERGENCY STOP FACILITY
Where the rotary vane or Roots pumps are powered from a mains supply separate from the **FlexAL**® system, a separate 'emergency stop' facility must be provided by the customer.

Table 10-12 lists information about various vacuum pumps that may be fitted to the system.

Table 10-12 Vacuum pump information

Location	Available Pump Options	Length (mm)	Width (mm)	Height (mm)	System Flange	Pump Exhaust Flange[1]	Weight (kg)	Power Consumption (kW)	Min. N_2 Purge (l/min)
Loadlock	Alcatel 2015C2	462	188	240	NW25	NW25	27	0.45 (50 Hz) 0.55 (60 Hz)	2
Chamber	Alcatel 2063C2 (mineral oil only)	819	264	397	DN40	DN40	98	2.2 (50 Hz) 2.6 (60 Hz)	2
Loadlock	Alcatel ACP28G	609	185	310	DN25	ISO KF	33.5	1.2	1.05
Loadlock	Alcatel ACP15G	514	202	276	DN25	DN16	23	0.52 (50/60 Hz)	n/a
Chamber	Alcatel A300H	844	310	323	DN63	DN25	165	1.5 (50/60 Hz)	15

1. All fittings and pipework connected to the rotary pump exhaust must be made from industry standard stainless steel.

10.2.10.1 Backing pump purging

The requirements for rotary pump purging depend on the process used. Customers must consult the pump manufacturer for their recommendations.

For Alcatel 2033 and 2063 rotary pumps, the recommended minimum N_2 purge rate is 2 litres/minute at a pressure of 2 bar to 5 bar. For highly corrosive or pyrophoric gases, 4 litres/minute is recommended.

10.2.10.2 Foreline heating tape recommendation for FlexAl® systems

External connectors located on the facilities panel below the foreline outlet port are provided for foreline heating.

We recommend using heater tape similar to the following;

RS 379-744 (www.rswww.com)

20 metres of heating tape at 20 /m (total wattage 400).

Wrap this around the foreline such that it heats 3 metres of pipe (in other words order 20 metres of heater tape for every 3 metres of foreline).

This should be able to heat the foreline to approximately 80ºC.

This heater tape is also available as a kit with the connectors already wired from OIPT, please consult your sales representative for a quotation.

10.2.11 Heater/chiller information

Table 10-13 Heater/chiller information

Available Heater/ Chiller Options	Length (mm)	Width (mm)	Height (mm)	Typical Operational Temperature Range[1]	Water Connections	Weight (kg)	Electrical Requirements
Betta-Tech CU600	620	450	500	-10°C to +70°C	1/4" Swagelok® fitted	70	240 V 50 Hz 8.5 A or 110 V 60 Hz 15 A, single phase

1. Standard control range, for other temperature ranges please consult the factory.

RISK OF EQUIPMENT DAMAGE
Heater/chillers should be filled/topped up with a suitable coolant. Refer the OIPT Services Specifications document, sub-section 2.1, for the warranty impact of not using a recommended product.
Caution 10.7

Some customers may prefer to use a chiller to control the temperature of system hardware, e.g. turbo pumps and AMUs. The following table lists recommended chillers and fluids.

Table 10-14 Chiller information

Component	Recommended Chiller	Part Number	Recommended Fluid	Part Number
Turbo pump	Bettatech CU600	94-G-G-WTR-SUN-610	Hexid A4	94-G/WTR/SUN/007
Baseplate	Bettatech CU600	94-G-G-WTR-SUN-610	Hexid A4	94-G/WTR/SUN/007
ICP and AMU	Bettatech CU600	94-G-G-WTR-SUN-610	HFE 7500	94-G-G-WTR-SUN-609

10.2.12 Precursor connections

Initial precursor pot installation is to be completed by the installation and commissioning engineer.

10.2.12.1 Precursor amounts

Please see **Table 10-15** for recommended ordering quantities for precursors.

Table 10-15 recommended precursor quantities

Quantity of Precursor	Recommended Use
50 g	Researching a new material or developing a new process and running a few samples for measurements
100 g	Running 2-3 months of medium duty sample work
200 g	Running 4-6 months of fairly intensive processing

10.2.13 Environment

10.2.13.1 Statement of intended use

This equipment is intended to be used by skilled and trained personnel for processing materials within a controlled access environment.

10.2.13.2 Mandatory specifications for the system environment

The **FlexAL**® system is rated for use in a pollution degree 1 installation category environment (laboratory or clean industrial environment).

Table 10-16 lists the mandatory environmental specifications.

Table 10-16 Mandatory environmental specifications

Item	Specification
Operating temperature	5°C to 25°C (41°F to 77°F)
Storage temperature	0°C to 50°C (32°F to 122°F)
Maximum humidity	80%[1]
Minimum humidity	10%[2]
Electrostatic build-up	Low static environment [2]
Ambient light level	300 lux minimum
Altitude	Up to 2000 m (6562 ft)
Cleanliness	Clean room class 10,000 or better

1. High humidity has a progressively significant effect on system performance. At humidity greater than 50%, the rate of chamber pump-down after venting the chamber is affected significantly, and at humidity greater than 65%, the rate of chamber pump-down may not meet system specifications.
2. Low humidity introduces a risk of electrostatic build-up, with subsequent discharge to the system producing a malfunction or damage. The systems are tested to EN 61000-4-2:1995**Ref:[4]** + A1:1998, + A2:2001. OIPT recommends the use of an environment, which protects against electrostatic build-up, and extra precautions are necessary at low humidity.

10.2.13.3 Recommended seated workstation dimensions

The following table gives the criteria and recommended dimensions for a seated workstation. Refer to **Figure 10-18**.

Table 10-17 Recommended seated workstation dimensions

Criteria	Dimension
Workstation height (A) (assumes hands are primarily at work surface height)	76 m maximum 71 cm minimum
VDT height (B) (single monitor, measured to centreline)	119 cm maximum 94 cm minimum
Work surface thickness	5 cm minimum
Work surface edge radius	0.65 cm minimum
Vertical leg clearance (C)	67 cm minimum
Horizontal leg clearance – depth at knee level (D)	51 cm minimum
Horizontal leg clearance – depth at foot level	66 cm depth minimum x 25 cm vertical clearance
Horizontal leg width clearance	61 cm minimum

Note that recommend dimensions are based on the assumption that a footrest and an adjustable chair are provided.

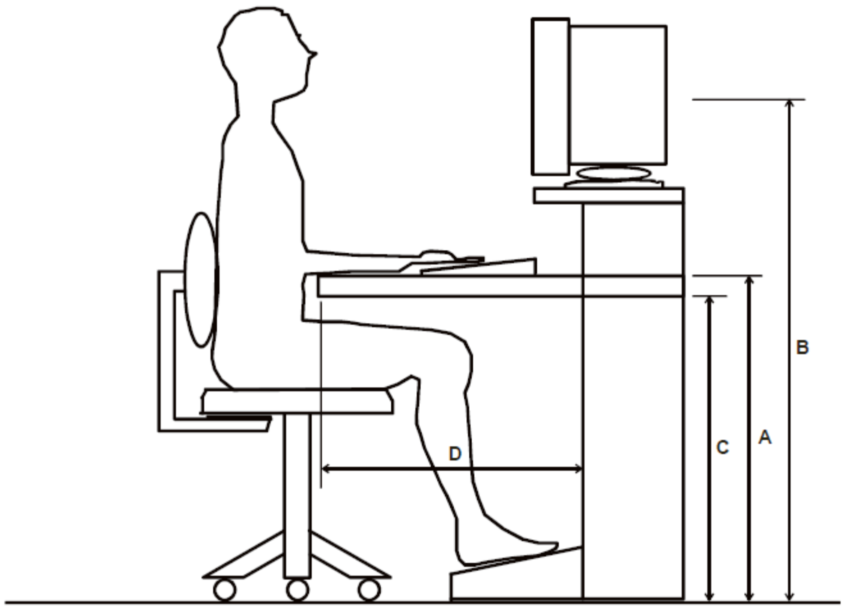


Figure 10-18 Seated workstation dimensions

10.3 Services diagrams

This section contains services diagrams for a typical system.

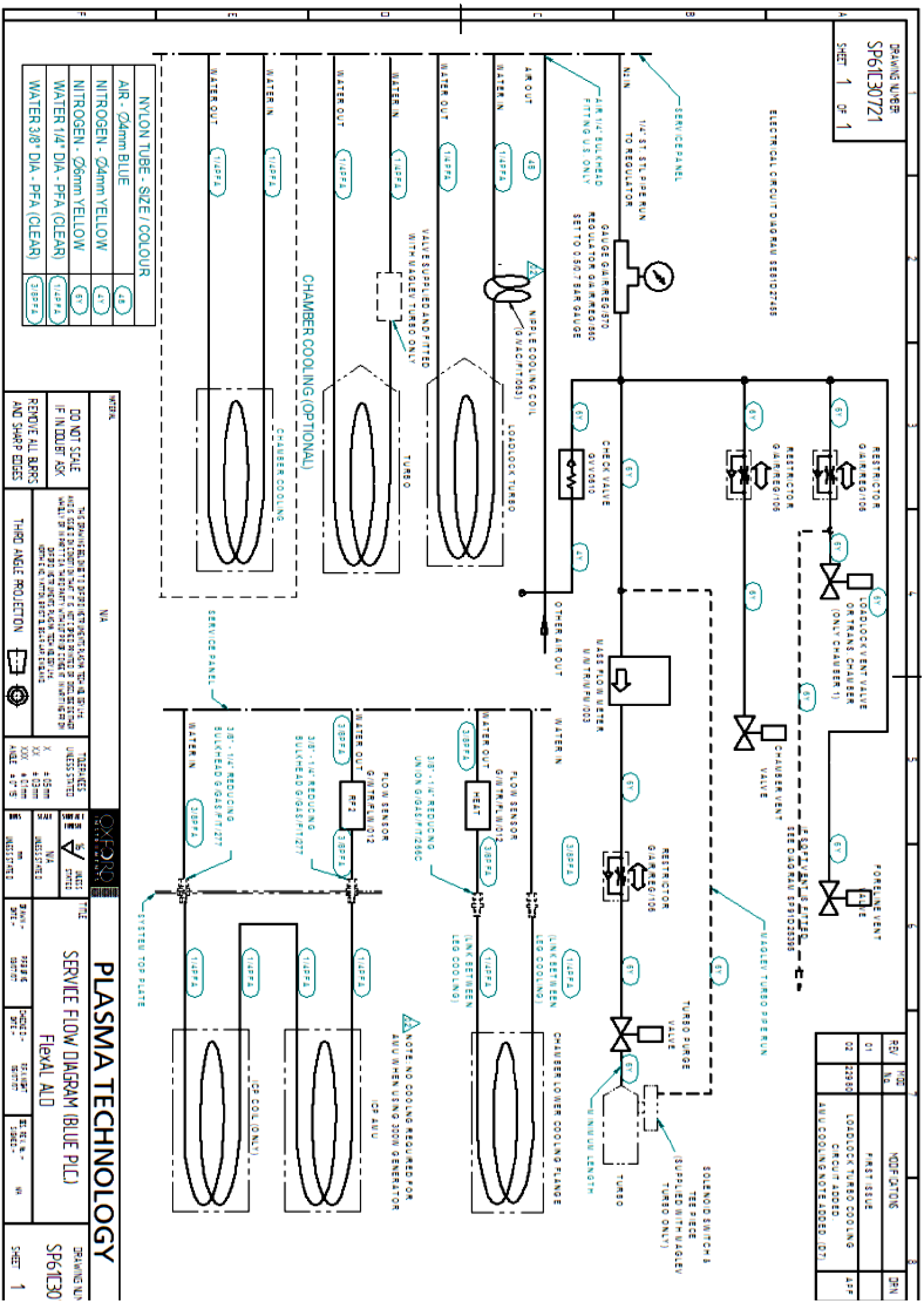


Figure 10-19 FlexAL® services flow diagram

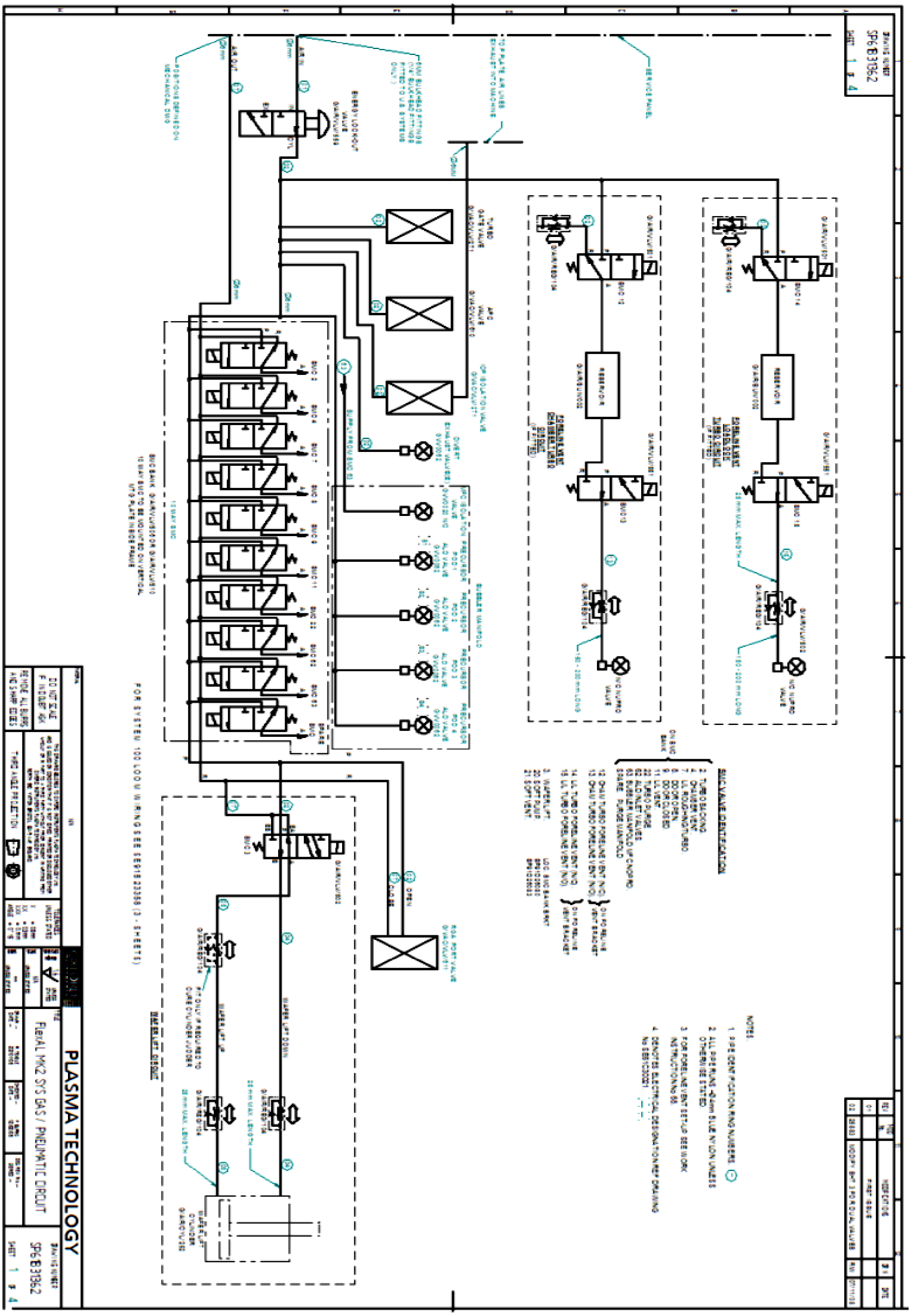


Figure 10-20 FlexAL® pneumatic circuit

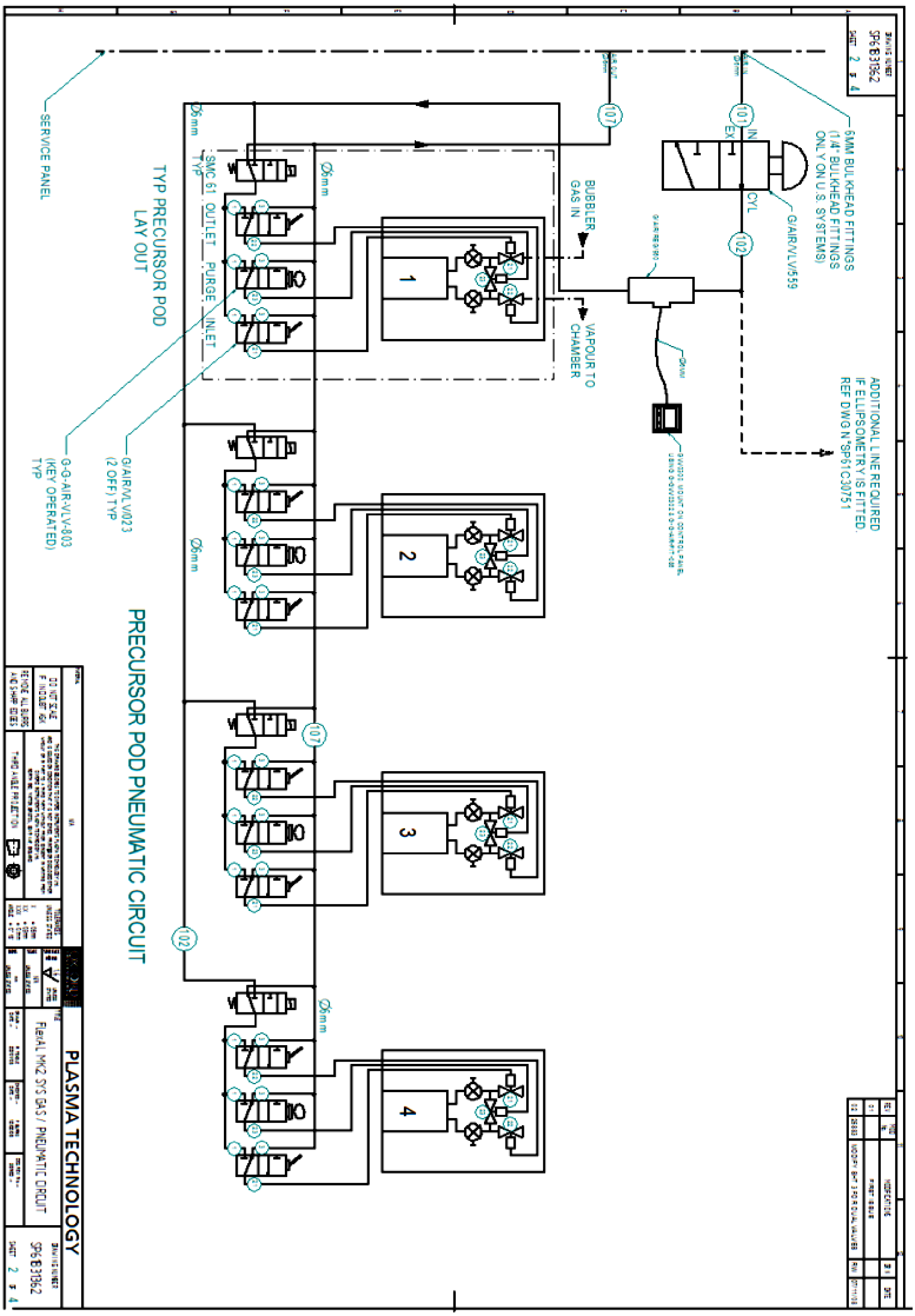


Figure 10-21 FlexAL® precursor pod pneumatic circuit

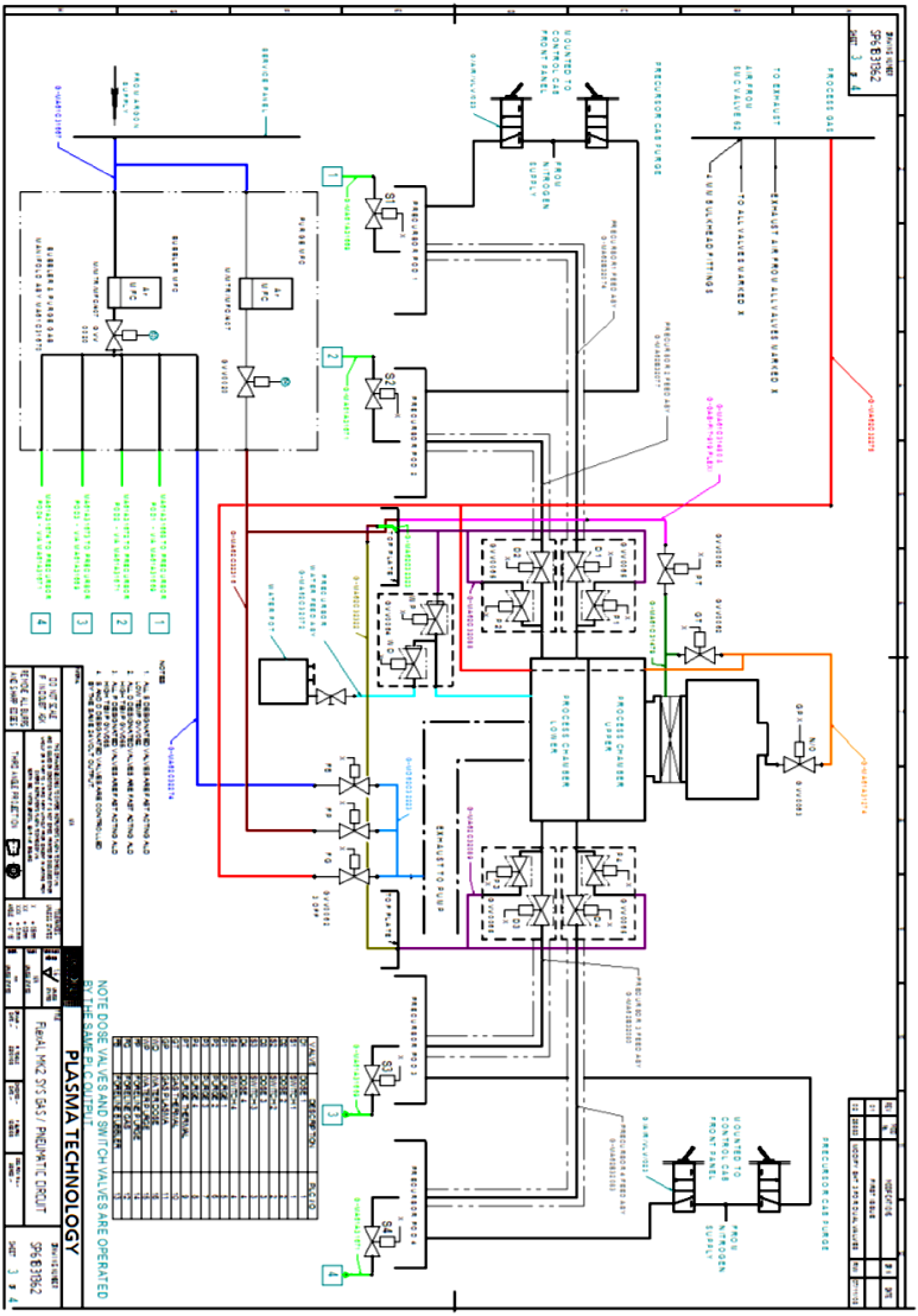


Figure 10-22 FlexAL® gas and pneumatic circuit

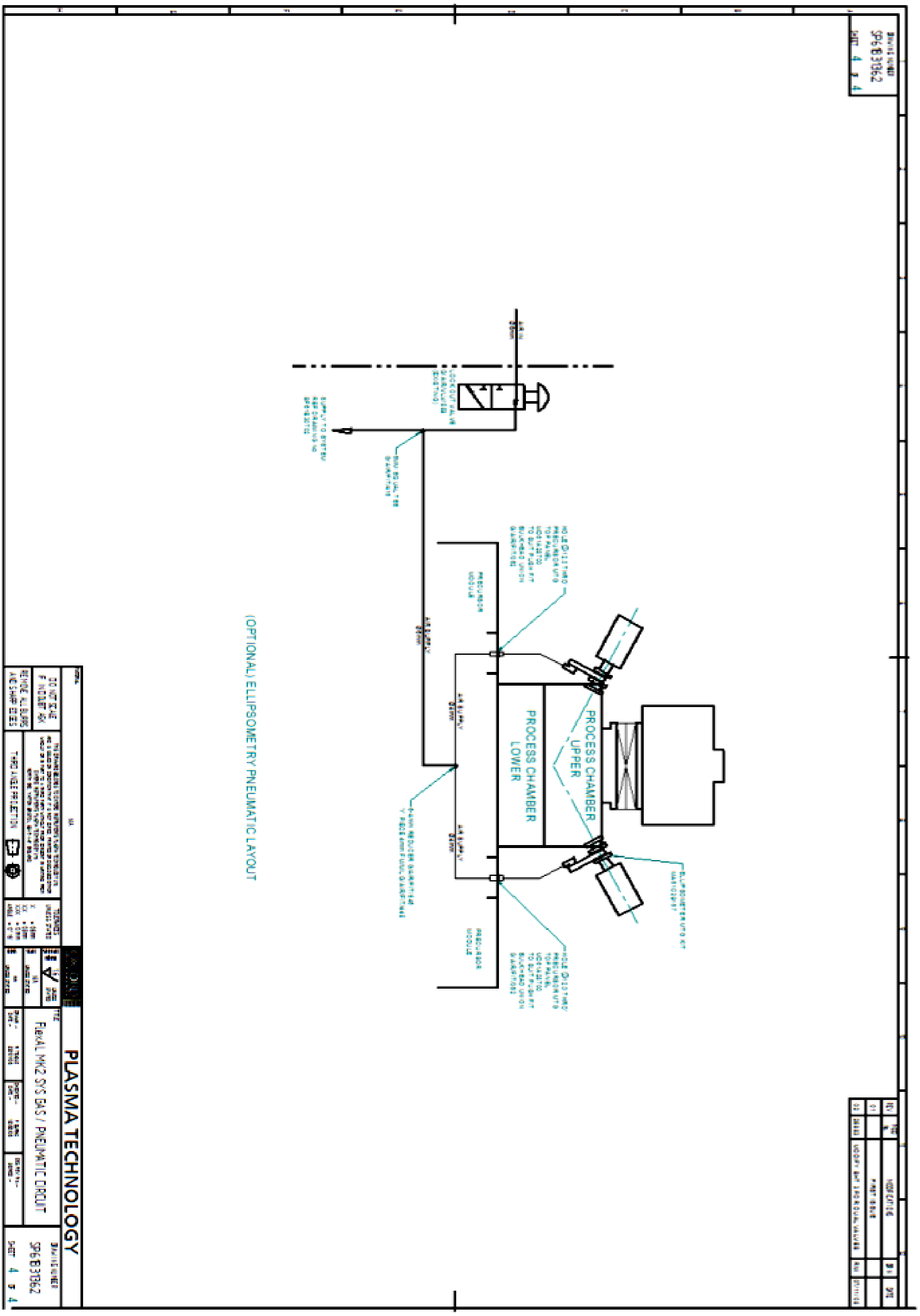


Figure 10-23 FlexAL® ellipsometer pneumatic circuit

APPENDIX A CERTIFICATION AND QUALITY FORMS

This appendix contains copies of the formal certification document for this **FlexAL**® and Oxford Instruments Plasma Technology quality control forms (QCF).

The documents included here are:

- **Declaration of Conformity QCF 185d** - CE certificate.
- **Goods Return Form QCF 60** - to be completed and attached to the outside of the package of any returned parts.
- **Certificate of Pre-Acceptance and Certificate of Acceptance QCF 61** - to be completed and returned if the customer is absent from acceptance.
- **System Readiness Form QCF 89** - to be completed and returned prior to the commissioning visit.

QCF – 185 D

Rev: 02

Plasma Technology
North End
Yatton, Bristol BS49 4AP UK
Tel: +44 (0) 1934 837000
Fax: +44 (0) 1934 837001
Email: Plasma.technology@oxinst.co.uk
www.oxford-instruments.com

OXFORD INSTRUMENTS

CE

Declaration of Conformity - IonFab, FlexAL, OpAL and PlasmaLab

Oxford Instruments Plasma Technology declares that *IonFab, FlexAL, OpAL, PlasmaLab 80+, 800+, 100, 133 & 400* comply with the following European Directives and Standards:

Machinery Directive	2006/42/EC
Low Voltage Directive	2006/95/EC
EMC Directive	2004/108/EC

Statutory Instrument 1597 (The Supply of Machinery (Safety) Regulations 2008)

BS EN 61010-1:2001	Safety requirements for electrical equipment for measurement, control and laboratory use. General requirements
EMC	EMC Technical Files created and reviewed by Notified Body, SGS UK, South Industrial Estate, Bowburn, County Durham, DH6 5 AD.

Responsible person: Mr P. Bray

Position within the company: Engineering Director

Signature: P Bray.

Date: 7-5-10

Certificate Issued by: Mr D.Shergold

Position within the company: Compliance Engineer

Signature:

Date: 07/05/10.

CELEBRATING 50 YEARS

Page 1 of 1

QCF60 issue 5 Date; 15/06/07

Environmental Agency
Producer Registration Number
for WEEE: WEE/AE0116XU

Returns No :

Goods Return Form

- This form must be completed and a copy sent to Oxford Plasma Technology Service Department by fax or mail before return of any goods to the factory. (Fax No : + 44 (0) 1934 837071)
- If return to the factory is approved a Returns Authorisation Number will be issued. This should be written in the box provided on this form and the completed form returned with the goods as part of the shipping documentation**.** ***It must be possible to read this form without opening the packaging containing the goods, therefore the form should not be enclosed within the packaging but affixed to the container.***
- Once the Returns Authorisation Number is issued goods should be returned within one month. OPT reserve the right to invoice the full value of parts if not returned.
- All sections below must be completed. If any section does not apply, mark that section "not applicable". If the information requested is not known, mark that section "not known".
- ***Any goods returned to the factory without a copy of this form carrying a Returns Authorisation Number will be considered hazardous and may be disposed of at the sender's expense. Mark the returns number on all packages and supporting shipping documentation.***

Equipment description.	**Serial number or identifying marking**	
	Original OPT order No :	**Date of order :**
Reason for return of part/s.	**Description of fault/s.**	
Chemical names of all materials which have come into contact with the goods.	**Precautions which must be taken when handling these materials.**	
Nature of hazard(s) presented by contact with these materials.	**Action to be taken in the event of human contact or spillage of these materials.**	
Details of any decontamination carried out prior to shipping	**Levels of residual substances left in or on the returned goods.**	
Name and address of person to be contacted in case of query.	**Tel No :** **Fax No :**	**Ext :**

Declaration

Please strike through the section a) or b) which does not apply and sign the declaration.

a) I hereby confirm that the equipment detailed above has not come into contact with any hazardous substance and has been drained of any lubricant.

b) I hereby confirm that the only hazardous materials to which the equipment detailed above has been exposed are listed above and that the following precautions have been taken.

1. The equipment has been drained of any lubricant
2. All ports have been sealed and the equipment has been securely packed and labelled in accordance with Oxford Instruments Plasma Technology recommendations (available on request)
3. The carrier has been informed of the nature of the consignment.

Signed. . . . . Date. . . . .

Name . . . . Position. . . . .

QCF 61a Issue 2

Guidelines for Customer Pre-Acceptance Visit In Respect of Test

Scope: This document provides the outline for a visit by the customer to carry out pre-acceptance checks on their machine. It covers the technical and material requirements in order for the customer and the presenting Test Engineer to fulfil their expectations.

Annex A – Schedule presented to customer prior to arrival at OIPT
Annex B – Flow Chart for process

Schedule: The Engineer presenting the Equipment should ensure the following is complete: *(As most visits occur in the morning all these preparations should be carried out on the previous day)*

The area in which the system is located is clean and tidy.
There are enough chairs for the visitors.
The build file is up to date and correct.
The system is complete in all respects.

1. **Inventory Check**

When the customer has arrived invite him to check that the system is what he expected, in respect of units, pumps, ancillaries etc. If there is a problem inform the Test Manager/Sales Manager.

2. **Hardware Familiarisation**

System layout, services required for installation, hardware dimensions, footprints etc.

3. **P.C. & Operating System**

Including screens and options, service mode, compiling and running recipes.

4. **Mechanical Operation**

Wafer loading, mechanical components movement and handling system.

5. **Demonstration of the Overall System**

Pumping down and striking a plasma.

These are the core items that customers will require, there may be instances of non-standard testing. These should be discussed with the Test Engineer before the visit commences. These non-standard tests should also be highlighted in the Build File.

Special Test and Processes
Any special test requirements will be agreed before the commencement of the Pre-Acceptance.

Pre-Acceptance sign off
The pre-acceptance certificate should be filled in and signed, note any issues agreed upon which need to be completed prior to shipment.

Wash Up Meeting
Once the customer's requirements have been satisfied inform the Test, Sales and relevant Product Manager in order to obtain the customer's feedback.

Annex A

Visit Agenda

The purpose of the pre-acceptance inspection is to ensure that the customer is entirely satisfied that the system is complete in accordance with their order and working to their satisfaction. It also serves to highlight any deficiencies or defects that the customer and OIPT agree will be addressed before the system is shipped.

The inspection will consist of:

1. Inventory check

A confirmation that all the features and options have been incorporated into the system as detailed in the customer's original order.

2. Hardware familiarisation

Explanation of the layout of the major system components and the connectivity of the system to its peripherals. Also hardware dimensions, footprint, service requirements and all safety features

3. PC Operating System

Full explanation of the screens and displays of the PC operation system, including Service Mode, compiling and running recipes and data logging.

4. Mechanical operations

Method of loading wafers.
Mechanical wafer-handling system

5. Full demonstration of a typical automatic process (using inert gases)

Including:
Pump-down to vacuum
Plasma strike

6. Additional procedures

Any other operations that the customer wishes to see in addition to the standard pre-acceptance checks.

Pre-acceptance form

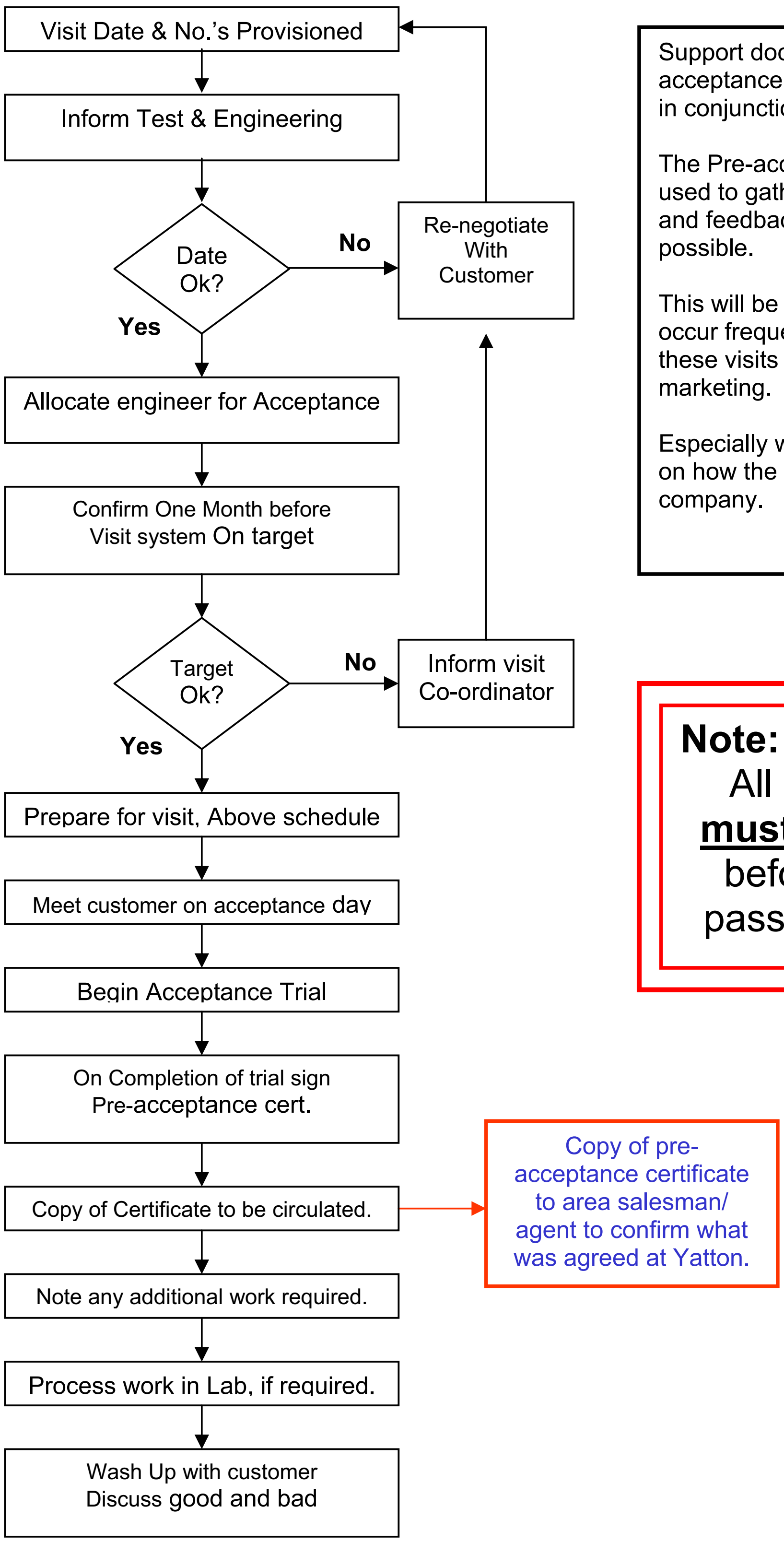
At the end of the inspection OIPT and the customer will both sign the Pre-Acceptance Form, which will also detail any work to be completed before shipping. Both the customer and OIPT will retain a copy for their reference.

Further discussions with specialists

The customers may also wish to discuss any aspect of the installation procedure at their installation site.
Please let me know if there are any questions about the required services, gases, connections, or any other aspect of their system.

Annex B

Flowchart for Pre-Acceptance visit



Support documents for test acceptance schedule should be used in conjunction with this document.

The Pre-acceptance visit should be used to gather as much information and feedback from the customer as possible.

This will be an opportunity that will not occur frequently, information from these visits should be fed to sales and marketing.

Especially with regards to information on how the customer perceives the company.

Note:
All agreed items **must** be completed before product is passed to Shipping

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09/11/07

Environmental Agency Producers Registration Number for WEEE: WEE/AE0116XU

SYSTEM READINESS FORM

This form is provided in order for us to record the level of work that you have conducted, to support the installation of your new Oxford Instruments system. The system should be installed, within the parameters listed below and the form returned to your supporting Oxford Instruments office. Returning this form signifies that you have completed the installation of the system, in accordance with the Services and Specifications data sheet and that the installation conforms with all of the requirements listed within. Should you not have a copy of the afore-mentioned "Services & Specifications" data sheet, you should contact your supporting Oxford Instruments office immediately and obtain a copy.

Should this form be received, an engineer dispatched to start commissioning and any of the facilities requirements not be met, Oxford Instruments reserves the right to terminate that commissioning visit and charge the customer for a return visit, once the facilities have been fully completed.

Company Name :		**Company Contact Name:**	
System Serial Number :		**System Type:**	

Please tick appropriate box	YES	NO	Detail					
1. Has the system been sited ? Attach site plan if available.								
2. Has the system been installed in a clean room ?								
3. Are there any special requirements for gaining access into the clean room ? ie. clearance, training, citizenship etc.. If so please list below.								
4. Have pumps been sited and the cables between each pump and system power box been connected?								
5. Has the gas pod been sited, connected to the system and connected in to the appropriate gas delivery and exhaust extraction systems, in accordance with local safety regulations?								
6. If the system has a heater chiller, has this been sited, connected to the lower electrode cooling circuit and filled with Hexid A40?								
7. Has AC power been connected to the system? Measure the voltages between each phase and neutral.			**Phase 1 to Neutral**		**Phase 2 to Neutral**		**Phase 3 to Neutral**	
8. Has compressed air been connected to the system? Inlet pressure must be 6 Bar (90PSI). Note Pressure.			**Compressed Air Inlet Pressure**					
9. Has cooling water been connected to the system? Differential pressure between inlet and outlet must be 3 - 4 Bar (45 – 60PSI). Water supply should be connected to each			**Inlet Water Pressure**		**Outlet Water Pressure**			

Environmental Agency Producers Registration Number for WEEE: WEE/AE0116XU

inlet/outlet on the system in parallel and not series. Note Inlet and Outlet Pressure.				
10. Has N2 vent been connected to the system? Inlet must be able to maintain a pressure of 3 Bar (45psig). Note Pressure.			Vent Nitrogen Inlet Pressure	
11. Has N2 purge been connected to the system? Inlet must be able to maintain a pressure of 3 Bar (45psig). Note Pressure.			Purge Nitrogen Inlet Pressure	
12. If the system is configured with cryogenic cooling, is an LN2 Dewar, filled with LN2 available? Is the Dewar connected to the system via 3/8" Swagelock connections and is the pipe work adequately insulated to prevent a safety hazard?			Is the pipe work adequately insulated to prevent a safety hazard?	
12. Have all of the gas pod connections been made to the appropriate gas supply or system connection. Have they been leak checked?				

13. All process gasses should be available for the system commissioning. Please verify that each gas, as it is laid out in the gas pod is connected, available for process and that the gas line has been leak checked.		Name of Gas	Inlet Pressure	Heated?	Leak Rate		Name of Gas	Inlet Pressure	Heated?	Leak Rate
	Gas 1					Gas 7				
Please record the leak rate for each gas line. If there is no line fitted please enter N/A.	Gas 2					Gas 8				
Process gas inlet pressure should be set at 3 Bar (45psig). Minimum acceptable inlet pressure: 2 Bar (30psig). Maximum acceptable inlet pressure: 5 Bar (75psig).	Gas 3					Gas 9				
If the gas line is to be used for BCl3, SiCl4 or TEOS, has the gas line been wrapped with trace heater wire and insulated? Failure to do so could result in condensation of the gas, within the line during processing.	Gas 4					Gas 10				
	Gas 5					Gas 11				
	Gas 6					Gas 12				

	Yes	No	Detail
14. Have the rotary pump exhaust lines been connected to an exhaust extraction system that meets all local safety standards?			
15. If the system is fitted with a cryo pump, which is used for toxic gasses, has an action plan been discussed and implemented for connection of the pump outlet connector?			
16. Has the rotary pump purge been connected to the pumps and nitrogen supply?			

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17. Have the rotary pumps been filled with oil of the correct type for the pump in use?			
18. Is the gas pod extraction connected with a minimum flow rate of 1m3/hour (6 line gas pod) or 3 m3/hour (12 line gas pod). Does the extraction system meet all local safety regulations?			
19. Do you believe that that demonstration of process has been included in the purchase of your tool?			
19.a. Please state, which processes require to be demonstrated.			
19.b. Are the required samples and measurement equipment available for the process work to follow on from hardware acceptance?			

Name :		**Position Within Company:**		
Signature:		**Date:**	/ /0	
Preferred Date for Commissioning Commencement:			/ /0	

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Environmental Agency Producers Registration Number for WEEE: WEE/AE0116XU

Please return the completed form to your nearest Oxford Instruments Support Office, detailed below:

USA & Canada
Oxford Instruments America Inc
Plasma Technology Support Manager
300 Baker Avenue, Suite 150
Concord
MA 01742
Tel: +1 800 447 4717
Fax: +1 978 369 8287
Email: mailto:pt.usa@oxinst.com

DE, NE, B, SE, FI,DK
Oxford Instruments GmbH
Plasma Technology
Postfach 4509
65035 Wiesbaden
Germany
Tel: +49 6122 937161
Fax: +49 6122 937175
Email: Plasma@oxford.de

Eastern Territories
Oxford Instruments Pte. Ltd
Raymond Wong
371 Beach Road
#02-07 Keypoint
Singapore 199597
Tel: +65 6337 6848
Fax: +65 6337 6286
Email: Raymond.Wong@oxford-instruments.com.sg

U.K. and all Other Territories
Oxford Instruments Plasma Technology
Global Support Manager
North End
Yatton, Nr Bristol
BS49 4AP. U.K.
Tel: +44 1934 837070
Fax: +44 1934 837071
Email: Support.PT@oxinst.co.uk

APPENDIX B PATENT ACKNOWLEDGEMENTS

B.1 Patent rights

This product exploits technology that is licensed from ASM and is protected by patents. A label is attached to the system base unit indicating that the ASM licence covers the system.

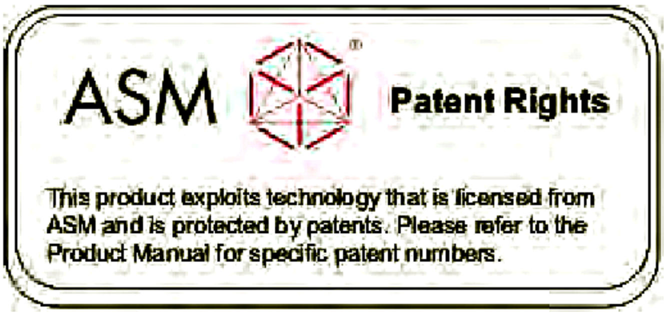

Figure B-1 ASM patent rights label

Details of the specific patent numbers are listed on the pages that follow.

ASM Patents Licensed / Sub-Licensed to Oxford Instruments 281

Case	Extension	Title	ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
g.002	KR	Method for forming a metal film	KR 1998/35911	01-Sep-1998	2000/18353	06-Apr-2000	332364	30-Mar-2002	Issued	ASMG
g.004	EP	Method for forming a three component nitride film containing metal and silicon	EP 1999/941865	10-Sep-1999	1044288	18-Oct-2000	1044288	19-Mar-2003	Published& Gr	ASMG
g.004	JP	Method for forming a three component nitride film containing metal and silicon	JP 1999/570818	10-Sep-1999	2002/525432	13-Aug-2002			Published	ASMG
g.004	US	Method for forming a three component nitride film containing metal and silicon	US 09/554443	10-Sep-1999			6426117	30-Jul-2002	Issued	ASMG
g.004	WO	Method for forming a three component nitride film containing metal and silicon	WO PCT/KR98/4	10-Sep-1999	0016377	23-Mar-2003			Published	ASMG
g.009	EP	Method of Forming a Thin Film	EP 2000/915582	06-Apr-2000	1092233	18-Apr-2001			Published	ASMG
g.009	JP	Method of Forming a Thin Film	JP 2000/612991	06-Apr-2000	2003/521579	15-Jul-2003			Published	ASMG
g.009	KR	Method of Forming a Thin Film	KR 1999/11877	06-Apr-1999	2000/49298	05-Aug-2000	273473	15-Nov-2000	Issued	ASMG
g.009	US	Method of Forming a Thin Film	US 09/719103	06-Apr-2000			6645574	11-Nov-2003	Issued	ASMG
g.009	WO	Method of Forming a Thin Film	WO PCT/KR00/0	06-Apr-2000	0063957	26-Oct-2000			Published	ASMG
g.010	EP	Chemical Deposition Reactor and Method of Forming a Thin Film using the Same	EP 2000/940951	19-Jun-2000	1125321	22-Aug-2001			Published	ASMG
g.010	JP	Chemical Deposition Reactor and Method of Forming a Thin Film using the Same	JP 2000/505047	19-Jun-2000	2003/502501	21-Jan-2003			Published	ASMG
g.010	KR	Chemical Deposition Reactor and Method of Forming a Thin Film using the Same	KR 1999/23078	19-Jun-2000	2001/1007431	26-Jan-2001			Published	ASMG
g.010	US	Chemical Deposition Reactor and Method of Forming a Thin Film using the Same	US 09/763238	19-Jun-2000			6539891	01-Apr-2003	Issued	ASMG
g.010	WO	Chemical Deposition Reactor and Method of Forming a Thin Film using the Same	WO PCT/KR00/0	19-Jun-2000	0079576	28-Dec-2000			Published	ASMG
g.015	EP	Thin Film Forming Method	EP 2001/937028	08-Jun-2000	1292970	19-Mar-2003			Published	ASMG

Case	Extension	Title	ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
g.015	JP	Thin Film Forming Method	JP 2001/000503	08-Jun-2001	2003/536272	02-Dec-2003	3687651	17-Jun-2005	Published	ASMG
g.015	US	Thin Film Forming Method	US 2003/000297	15-Jul-2003	2004/0009307	15-Jan-2004			Published	ASMG
g.015	WO	Thin Film Forming Method	WO PCT/KR01/0	08-Jun-2001	0199166	27-Dec-2001			Published	ASMG
g.017	EP	Plasma Enhanced ALD equipment and Method of forming a Conducting Thin Film	EP 2001/000957	06-Aug-2001	1421606	26-May-2004			Published	ASMG
g.017	JP	Plasma Enhanced ALD equipment and Method of forming a Conducting Thin Film	JP	06-Aug-2001	2005/502784	27-Jan-2005			Published	ASMG
g.017	KR	Plasma Enhanced ALD equipment and Method of forming a Conducting Thin Film	KR 2001/46802	02-Aug-2001		11-Feb-2003			Published	ASMG
g.017	US	Plasma Enhanced ALD equipment and Method of forming a Conducting Thin Film	US 10/486311	06-Aug-2001	2004/0231799	25-Nov-2004			Published	ASMG
g.017	WO	Plasma Enhanced ALD equipment and Method of forming a Conducting Thin Film	WO PCT/KR01/0	06-Aug-2001	03023835	20-Mar-2003			Published	ASMG
g.018	KR	Apparatus for Depositing	KR 2001/69598	08-Nov-2001	2003/0038168	16-May-2003			Published	ASMG
g.018	US	Apparatus for Depositing	US 10/495156	08-Nov-2002	2005/0034664	17-Feb-2005			Published	ASMG
g.018	WO	Apparatus for Depositing	WO PCT/KR02/0	08-Nov-2002	03041141	15-May-2003			Published	ASMG
g.019	AUS	Method for Forming Thin Film	US 10/495157	08-Nov-2002	2005/0037154	17-Feb-2005			Published	ASMG
g.019	EP	Method for Forming Thin Film	EP 2002/000788	08-Nov-2002	1454347	08-Sep-2004			Published	ASMG
g.019	JP	Method for Forming Thin Film	JP 2003/000543	08-Nov-2002	2005/509093	07-Apr-2005			Published	ASMG
g.019	KR	Method for Forming Thin Film	KR 2001/69597	08-Nov-2001	3038167	16-May-2003			Published	ASMG
g.019	WO	Method for Forming Thin Film	WO PCT/KR02/0	08-Nov-2002	03041142	15-May-2003			Published	ASMG
I.052	AUS	LPCVD with ALD preconditioning	US 09/611602	07-Jul-2000		09-Apr-2003	6592942	15-Jul-2003	Issued	ASMI
I.052	DE	LPCVD with ALD preconditioning	DE	09-Jul-2001	1299572	09-Apr-2003	60104426	21-Jul-2004	Issued	ASMI
I.052	EP	LPCVD with ALD preconditioning	EP 1952051.9	09-Jul-2001	1299572	09-Apr-2003	1299572	21-Jul-2004	Published& Gr	ASMI
I.052	FR	LPCVD with ALD preconditioning	FR	09-Jul-2001	1299572	09-Apr-2003	1299572	21-Jul-2004	Issued	ASMI

Case	Extension	Title	ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
I.052	GB	LPCVD with ALD preconditioning	GB	09-Jul-2001	1299572	09-Apr-2003	1299572	21-Jul-2004	Issued	ASMI
I.052	JP	LPCVD with ALD preconditioning	JP 513963/02	09-Jul-2001	2004/504496	12-Feb-2004			Published	ASMI
I.052	PCT	LPCVD with ALD preconditioning	PCT 2001/095205	09-Jul-2001	1299572	09-Apr-2003			Published	ASMI
I.053	AUS	ALD in hot wall batch reactor	US 09/611536	07-Jul-2000			6585823	01-Jul-2003	Issued	ASMI
I.053	JP	ALD in hot wall batch reactor	JP 2001/198085	26-Jun-2001	2002/060947	28-Feb-2002			Published	ASMI
I.100	00	Valve block for ALD	EP 03076812.1	11-Jun-2003	1486707	15-Dec-2004			Published	ASMI
I.100	00	Valve block for ALD	US 10/864260	09-Jun-2004	2004/0250853	16-Dec-2004			Published	ASMI
I.100	00	Valve block for ALD	JP 2004/171168	09-Jun-2004	2005/51205	24-Feb-2005			Published	ASMI
MC.004	AUS	Active thermal insulation	US 08/682704	25-Sep-1996		05-Jan-1999	5855680	05-Jan-1999	Issued	ASMI
MC.004	DE	Active thermal insulation	DE 19581484.3	25-Jul-1996	19581484	02-Jan-1997			Published	ASMI
MC.004	FI	Active thermal insulation	FI 945610	28-Nov-1994		29-May-1996	97730	10-Feb-1997	Issued	ASMI
MC.004	JP	Active thermal insulation	JP 518299/1996	29-Jul-1996	1997/508889	09-Sep-1997			Published	ASMI
MC.004	KR	Active thermal insulation	KR 10/1996/0704	29-Jul-1996		12-Feb-1997	255429	14-Feb-2000	Issued	ASMI
MC.004	PCT	Active thermal insulation	WO /FI95/00657	28-Nov-1995		06-Jun-1996			Published	ASMI
MC.005	AUS	Pump between pulses	US 08/682705	25-Sep-1996		18-Jan-2000	6015590	18-Jan-2000	Issued	ASMI
MC.005	C1US	Pump between pulses	US 09/482625	14-Jan-2000	6572705	03-Jun-2003	6572705	03-Jun-2003	Issued	ASMI
MC.005	C2US	Pump between pulses	US 09/855321	14-May-2001	2002/0041931	11-Apr-2002			Published	ASMI
MC.005	DE	Pump between pulses	DE 19581483.5	25-Jul-1996		02-Jan-1997			Published	ASMI
MC.005	FI	Pump between pulses	FI 945611	28-Nov-1994		11-Jun-1996	100409	28-Nov-1997	Issued	ASMI
MC.005	JP	Pump between pulses	JP 518300/1996	29-Jul-1996		09-Sep-1997			Published	ASMI
MC.005	KR	Pump between pulses	KR 10/1996/0704	29-Jul-1996		12-Feb-1997	255430	14-Feb-2000	Issued	ASMI
MC.005	PCT	Pump between pulses	WO /FI95/00658	28-Nov-1995	9617107	06-Jun-1996			Published	ASMI
MC.006	AUS	Flow restriction	US 08/682703	26-Jul-1996		27-Jan-1998	5711811	27-Jan-1998	Issued	ASMI

Case Extension	Title		ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.006 DE	Flow restriction	DE	19581482.7	25-Jul-1996		02-Jan-1997			Published	ASMI
MC.006 FI	Flow restriction	FI	945612	28-Nov-1994		29-May-1996	97731	10-Feb-1997	Issued	ASMI
MC.006 JP	Flow restriction	JP	1996/517343	26-Jul-1996		09-Sep-1997	3349156	13-Sep-2002	Issued	ASMI
MC.006 KR	Flow restriction	KR	10/1996/0704	29-Jul-1996		12-Feb-1997	255431	14-Feb-2000	Issued	ASMI
MC.006 PCT	Flow restriction	WO	/FI95/00659	28-Nov-1995	9617969	13-Jun-1996			Published	ASMI
MC.008 EP	Functional surfaces	EP	97660037.9	02-Apr-1997	799641	08-Oct-1997			Published	ASMI
MC.008 FI	Functional surfaces	FI	961512	03-Apr-1996		04-Oct-1997	107533	31-Aug-2001	Issued	ASMI
MC.008 JP	Functional surfaces	JP	84939/1997	03-Apr-1997	1998/53609	24-Feb-1998			Published	ASMI
MC.009 CP1US	Flow distributor, US CIP	US	09/686613	04-Jan-2000	6630030	07-Oct-2003	6630030	07-Oct-2003	Issued	ASMI
MC.009 JP	Flow distributor	JP	506497/1999	28-Dec-1999		12-Mar-2002			Published	ASMI
MC.009 KR	Flow distributor	KR	10/2000/7000	04-Jan-2000		15-Mar-2001			Published	ASMI
MC.009 PCT	Flow distributor	WO	/FI98/00571	03-Jul-1998	9901595	14-Jan-1999			Published	ASMI
MC.010 AUS	Coating inner surfaces of equipment	US	09/581020	07-Jun-2000	6416577	09-Jul-2002	6416577	09-Jul-2002	Issued	ASMI
MC.010 FI	Coating inner surfaces of equipment	FI	974472	09-Dec-1997		10-Jun-1999	104383	14-Jan-2000	Issued	ASMI
MC.010 PCT	Coating inner surfaces of equipment	WO	/FI98/00955	09-Dec-1998		17-Jun-1999			Published	ASMI
MC.011 FI	Ba and Sr source materials	FI	981959	11-Sep-1998		12-Mar-2000	108375	15-Jan-2002	Issued	ASMI
MC.011 JP	Ba and Sr source materials	JP	2000/570387	12-Mar-2001		13-Aug-2002			Published	ASMI
MC.011 KR	Ba and Sr source materials	KR	10/2001/7003	12-Mar-2001		22-Aug-2001			Published	ASMI
MC.011 PCT	Ba and Sr source materials	WO	/FI99/00741	13-Sep-1999		23-Mar-2000			Published	ASMI
MC.012 AUS	Single wafer ALCVD™ reactor	US	09/568077	10-May-2000	6562140	13-May-2003	6562140	13-May-2003	Issued	ASMI
MC.012 C1US	Single wafer ALCVD™ reactor	US	09/769562	25-Jan-2001	2001/0009140	26-Jul-2001	6579374	17-Jun-2003	Issued	ASMI
MC.012 C2US	Single wafer ALCVD™ reactor	US	10/383291	06-Mar-2003	2003/0150385	14-Aug-2003			Published	ASMI
MC.012 EP	Single wafer ALCVD™ reactor	EP	00660085.2	10-May-2000	1052309	15-Nov-2000			Published	ASMI

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MC.012 FI	Single wafer ALCVD™ reactor	FI	991078	10-May-1999	991078	11-Nov-2000			Published	ASMI
MC.012 JP	Single wafer ALCVD™ reactor	JP	2000/137175	10-May-2000	2001/20075	23-Jan-2001			Published	ASMI
MC.012 KR	Single wafer ALCVD™ reactor	KR	10/2000/0024	10-May-2000	2001/20831	15-Mar-2001	415475	06-Jan-2004	Issued	ASMI
MC.012 TW	Single wafer ALCVD™ reactor	TW	89107029	14-Apr-2000	527433	11-Apr-2003	175825	08-Aug-2003	Issued	ASMI
MC.013 AUS	High surface area trap	US	09/619820	20-Jul-2000	6506352	14-Jan-2003	6506352	14-Jan-2003	Issued	ASMI
MC.013 C1US	High surface area trap	US	10/205296	24-Jul-2002	2002/0187084	12-Dec-2002			Published	ASMI
MC.013 FI	High surface area trap	FI	991628	20-Jul-1999	991628	21-Jan-2001	110311	31-Dec-2002	Issued	ASMI
MC.013 JP	High surface area trap	JP	2000/220782	21-Jul-2000	2001/62244	13-Mar-2001			Published	ASMI
MC.013 TW	High surface area trap	TW	89114140	14-Jul-2000	555585	01-Oct-2003	188294	09-Feb-2004	Issued	ASMI
MC.015 AUS	Metal compounds as oxygen sources	US	09/687355	13-Oct-2000	6632279	14-Oct-2003	6632279	14-Oct-2003	Issued	ASMI
MC.015 C1US	Metal compounds as oxygen sources	US	10/618429	10-Jul-2003	2004/0007171	15-Jan-2004			Published	ASMI
MC.015 FI	Metal compounds as oxygen sources	FI	992223	14-Oct-1999	992223	14-Apr-2001			Published	ASMI
MC.015 JP	Metal compounds as oxygen sources	JP	2000/315409	16-Oct-2000	2001/172767	26-Jun-2001			Published	ASMI
MC.015 KR	Metal compounds as oxygen sources	KR	10/2000/0060	14-Oct-2000	2001/40090	15-May-2001			Published	ASMI
MC.016 AUS	Yttrium stabilized ZrO2	US	09/835737	16-Apr-2001	2002/0042165	11-Apr-2002	6548424	15-Apr-2003	Issued	ASMI
MC.016 C1US	Yttrium stabilized ZrO2	US	10/410718	08-Apr-2003	2003/0215996	20-Nov-2003	6777353	17-Aug-2004	Issued	ASMI
MC.016 JP	Yttrium stabilized ZrO2	JP	2001/117318	16-Apr-2001	2001/355070	25-Dec-2001			Published	ASMI
MC.016 TW	Yttrium stabilized ZrO2	TW	90108955	13-Apr-2001	567584	21-Dec-2003	193372	20-Apr-2004	Issued	ASMI
MC.017 AUS	Ozone for silicon/metal oxides	US	10/148525	27-Aug-2002	2003/0188682	09-Oct-2003			Published	ASMI
MC.017 C1US	Ozone for silicon/metal oxides	US	10/678766	02-Oct-2003	2004/0065253	08-Apr-2004			Published	ASMI
MC.017 EP	Ozone for silicon/metal oxides	EP	00987492.6	04-Apr-2000	1248865	16-Oct-2002			Published	ASMI
MC.017 JP	Ozone for silicon/metal oxides	JP	2001/542604	04-Dec-2000	2003/515674	07-May-2003			Published	ASMI
MC.017 KR	Ozone for silicon/metal oxides	KR	10/2002/7006	30-May-2002	2002/63196	01-Aug-2002			Published	ASMI

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MC.017 PCT	Ozone for silicon/metal oxides	WO	/FI00/01072	04-Dec-2000	0140541	07-Jun-2001			Published	ASMI
MC.020 AUS	Batch ALCVD™ reactor with load lock	US	09/749329	27-Dec-2000	2001/0013312	16-Aug-2001	6447607	10-Sep-2002	Issued	ASMI
MC.020 D1US	Batch ALCVD™ reactor with load lock	US	10/205297	24-Jul-2002	2002/0185060	12-Dec-2002	6689210	10-Feb-2004	Issued	ASMI
MC.020 TW	Batch ALCVD™ reactor with load lock	TW	89127892	26-Dec-2000	546400	11-Aug-2003	184030	18-Dec-2003	Issued	ASMI
MC.021 AUS	Batch type holder with angle variation.	US	09/749339	27-Dec-2000	2001/0014371	16-Aug-2001	6551406	22-Apr-2003	Issued	ASMI
MC.021 C1US	Batch type holder with angle variation.	US	10/365926	13-Feb-2003	2003/0140854	31-Jul-2003	6835416	28-Dec-2004	Issued	ASMI
MC.021 JP-U	Batch type holder with angle variation.	JP-U	2000/9189	27-Dec-2000	2001/3079231	10-Aug-2001	3079231	23-May-2001	Issued	ASMI
MC.021 KR-U	Batch type holder with angle variation.	KR-U	20/2000/0036	28-Dec-2000	2001/0224419	15-May-2001	224419	07-Mar-2001	Issued	ASMI
MC.021 TW	Batch type holder with angle variation.	TW	89127893	26-Dec-2000	524876	21-Mar-2003	174871	25-Jul-2003	Issued	ASMI
MC.023 AUS	In situ reduction of source materials	US	10/110598	11-Apr-2002	6767582	27-Jul-2004	6767582	27-Jul-2004	Issued	ASMI
MC.023 EP	In situ reduction of source materials	EP	00969585.9	14-Mar-2002		14-Aug-2002			Published	ASMI
MC.023 FI	In situ reduction of source materials	FI	992233	15-Oct-1999		15-Apr-2001			Published	ASMI
MC.023 JP	In situ reduction of source materials	JP	2001/529475	15-Apr-2002	2003/511560	25-Mar-2003			published	ASMI
MC.023 KR	In situ reduction of source materials	KR	10/2002/7004	15-Apr-2002		30-May-2002			Published	ASMI
MC.023 PCT	In situ reduction of source materials	WO	/FI00/00884	12-Oct-2000		19-Apr-2001			Published	ASMI
MC.023 TW	In situ reduction of source materials	TW	89121351	12-Oct-2000	008261 sep 200	01-Sep-2002	162686	27-Dec-2002	Issued	ASMI
MC.024 AUS	Tungsten nitride	US	10/110730	13-Oct-2000			6863727	08-Mar-2005	Issued	ASMI
MC.024 DE	Tungsten nitride	DE	09695966	15-Mar-2002	1242647	25-Sep-2002	60004566	18-Aug-2003	Issued	ASMI
MC.024 EP	Tungsten nitride	EP	00969596.6	15-Mar-2002	1242647	25-Sep-2002	1159313	13-Aug-2003	Published& Gr	ASMI
MC.024 FI	Tungsten nitride	FI	19992234	15-Oct-1999		15-Apr-2001			Published	ASMI
MC.024 FR	Tungsten nitride	FR	09695966	15-Mar-2002	1242647	25-Sep-2002	1242647	13-Aug-2003	Issued	ASMI
MC.024 GB	Tungsten nitride	GB	09695966	15-Mar-2002	1242647	25-Sep-2002	1242647	18-Aug-2003	Issued	ASMI
MC.024 JP	Tungsten nitride	JP	2001/529476	15-Apr-2002	2003/511561	25-Mar-2003			published	ASMI

Case Extension	Title	ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.024 KR	Tungsten nitride	KR 10/2002/7004	15-Apr-2002		30-May-2002			Published	ASMI
MC.024 PCT	Tungsten nitride	WO /FI00/00895	13-Oct-2000		19-Apr-2001			Published	ASMI
MC.024 TW	Tungsten nitride	TW 89121352	12-Oct-2000	541351	11-Jul-2003			Published	ASMI
MC.025 AUS	Selective coating	US 09/644636	23-Aug-2000	6391785	21-May-2002	6391785	21-May-2002	Issued	ASMI
MC.025 C1	Selective coating (IMEC)	US 10/123492	15-Apr-2002	2002/0155722	24-Oct-2002	6664192	16-Dec-2003	Issued	ASMI
MC.025 C2US	Selective coating (IMEC)	US 10/731656	08-Dec-2003	2004/0121616	24-Jun-2004	6852635	08-Feb-2005	Issued	ASMI
MC.025 EP	Selective coating (IMEC)	EP 000955875	24-Aug-2000	1206799	22-May-2002			Published	ASMI
MC.025 JP	Selective coating (IMEC)	JP 2001/519484	24-Aug-2000	2003/508897	04-Mar-2003			Published	ASMI
MC.025 PCT	Selective coating (IMEC)	WO /US00/23252	24-Aug-2000	01/15220	01-Mar-2001			Published	ASMI
MC.025 TW	Selective coating (IMEC)	TW 89117141	24-Aug-2000	478045	01-Mar-2002	151092	30-May-2003	Issued	ASMI
MC.027 EP	Nitride nanolaminates on sensitive surfaces	EP 00973583.8	16-Oct-2000	1221178	10-Jul-2002			Published	ASMI
MC.027 JP	Nitride nanolaminates on sensitive surfaces	JP 2001/531142	15-Apr-2002	2003/524888	19-Aug-2003			Published	ASMI
MC.027 PCT	Nitride nanolaminates on sensitive surfaces	WO /US00/28654	16-Oct-2000	01/29893	26-Apr-2001			Published	ASMI
MC.027 TW	Nitride nanolaminates on sensitive surfaces	TW 89121517	13-Oct-2000	550306	01-Sep-2003	185093	07-Jan-2004	Issued	ASMI
MC.027 US	Nitride nanolaminates on sensitive surfaces	US 10/049125	20-Aug-2002			6902763	07-Jun-2005	Issued	ASMI
MC.028 AUS	Metals with boron compound	US 09/687205	13-Oct-2000	6475276	05-Nov-2002	6475276	05-Nov-2002	Issued	ASMI
MC.028 C1US	Metals with boron compound (ALD)	US 10/210715	30-Jul-2002	2002/0187256	12-Dec-2002	6821889	23-Nov-2004	Issued	ASMI
MC.028 FI	Metals with boron compound (ALD)	FI 19992235	15-Oct-1999		15-Apr-2001			Published	ASMI
MC.029 AUS	TMA and O3	US 10/003749	23-Oct-2001	2002/0106451	08-Aug-2002	6743475	01-Jun-2004	Issued	ASMI
MC.029 C1	TMA and O3	US 10/829894	21-Apr-2004	2004/0197476	07-Oct-2004	6884465	26-Apr-2005	Issued	ASMI
MC.029 JP	TMA and O3	JP 2001/324382	23-Oct-2001	2002/161353	04-Jun-2002			Published	ASMI
MC.029 TW	TMA and O3	TW 89122263	23-Oct-2000	548239	21-Aug-2003	185773	14-Jan-2004	Issued	ASMI
MC.030 AUS	Solid source for Pulsar™	US 09/854706	14-May-2001	2001/0042523	22-Nov-2001	6699524	02-Mar-2004	Issued	ASMI

Case Extension	Title	ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.030 C1US	Solid source for Pulsar™	US 10/695269	28-Oct-2003	2004/0086642	06-May-2004			Published	ASMI
MC.030 JP	Solid source for Pulsar™	JP 2001/145256	15-May-2001	2001/323374	22-Nov-2001			Published	ASMI
MC.030 TW	Solid source for Pulsar™	TW 89111644	14-Jun-2000	524875	21-Mar-2003	174786	24-Jul-2003	Issued	ASMI
MC.031 AUS	CVD of metalloid thin films	US 09/764692	18-Jan-2001	2001/0009695	26-Jul-2001	6599572	29-Jul-2003	Issued	ASMI
MC.031 C1US	CVD of metalloid thin films	US 10/394309	20-Mar-2003	2003/0186495	02-Oct-2003	6794287	21-Sep-2004	Issued	ASMI
MC.033 AUS	Liquid source system for ALD applications	US 10/615332	08-Jul-2003	2004/0079286	29-Apr-2004			Published	ASMI
MC.033 VJP	Liquid source system for ALD applications	JP 2003/274331	14-Jul-2003	2004/36004	05-Feb-2004			Published	ASMI
MC.033 VTW	Liquid source system for ALD applications	TW 92118177	03-Jul-2002	2004/02774	16-Feb-2004			Published	ASMI
MC.035 AUS	Active CVD-zone for ALD	US 09/836674	16-Apr-2001		15-Aug-2002			Published	ASMI
MC.035 JP	Active CVD-zone for ALD	JP 2001/117413	16-Apr-2001		18-Dec-2001			Published	ASMI
MC.035 TW	Active CVD-zone for ALD	TW 89107028	14-Apr-2000	496907	01-Aug-2002	160775	27-Nov-2002	Issued	ASMI
MC.036 AUS	ALCVD™ reactor equipped with filter and hot drain	US 09/835931	16-Apr-2001	2001/0054377	27-Dec-2001	6783590	31-Aug-2004	Issued	ASMI
MC.036 FI	ALCVD™ reactor equipped with filter and hot drain	FI 20000900	14-Apr-2000		15-Oct-2001			Published	ASMI
MC.036 JP	ALCVD™ reactor equipped with filter and hot drain	JP 2001/117468	16-Apr-2001		09-Jan-2002			Published	ASMI
MC.036 KR	ALCVD™ reactor equipped with filter and hot drain	KR 10/2001/0020	14-Apr-2001		08-Nov-2001			Published	ASMI
MC.036 TW	ALCVD™ reactor equipped with filter and hot drain	TW 89107027	14-Apr-2000	576873	21-Feb-2004	197419	17-Jun-2004	Published	ASMI
MC.037 AUS	CuO reduction / plasma radicals	US 09/291807	14-Apr-1999	6342277	29-Jan-2002	6342277	29-Jan-2002	Issued	ASMI
MC.037 C1US	CuO reduction / plasma radicals	US 09/974162	09-Oct-2001	2002/0031618	14-Mar-2002	6616986	09-Sep-2003	Issued	ASMI
MC.037 C2	CuO reduction / plasma radicals	US 10/683727	10-Oct-2003	2004/0076751	22-Apr-2004			Published	ASMI
MC.037 D1US	CuO reduction / plasma radicals	US 09/866156	24-May-2001	2001/0028924	11-Oct-2001	6652924	25-Nov-2003	Issued	ASMI
MC.037 D2	CuO reduction / plasma radicals	US 10/692243	22-Oct-2003	2004/0083949	06-May-2004			Published	ASMI

Case Extension	Title		ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.037 EP	CuO reduction / plasma radicals	EP	00922268.8	14-Apr-2000	1183406	06-Mar-2002			Published	ASMI
MC.037 JP	CuO reduction / plasma radicals	JP	2000/610879	12-Oct-2001	2002541332	03-Dec-2002			Published	ASMI
MC.037 PCT	CuO reduction / plasma radicals	WO	/US00/10267	14-Apr-2000	0061833	19-Oct-2000			Published	ASMI
MC.038 AUS	Licenced Sherman patent	US	08/699002	16-Aug-1996		29-Jun-1999	5916365	29-Jun-1999	Issued	ASMI
MC.039 EP	Conductance ratio	EP	19581099	18-Nov-2002	1322797	02-Jul-2003			Published	ASMI
MC.039 JP	Conductance ratio	JP	2002/513966	20-Jul-2001	2004/504497	12-Feb-2004			Published	ASMI
MC.039 KR	Conductance ratio	KR	10/2003/7000	20-Jul-2001	2003/24787	26-Mar-2003			Published	ASMI
MC.039 PCT	Conductance ratio	WO	/FI01/00680	20-Jul-2001	0208488	31-Jan-2002			Published	ASMI
MC.039 TW	Conductance ratio	TW	90117837	20-Jul-2001	576874	21-Feb-2004	197452	17-Jun-2004	Issued	ASMI
MC.039 US	Conductance ratio	US	10/333521	20-Jul-2001	2003/0224107	04-Dec-2003	6881263	19-Apr-2005	Issued	ASMI
MC.043 AUS	Sullivan ALE-reactor (radicals and purging)	US	09/392371	08-Sep-1999	6511539	28-Jan-2003	6511539	28-Jan-2003	Issued	ASMA
MC.043 C1US	Sullivan ALE-reactor (radicals and purging)	US	10/317275	10-Dec-2002	2003/0089308	15-May-2003	6764546	20-Jul-2004	Issued	ASMA
MC.043 D1US	Sullivan ALE-reactor (radicals and purging)	US	10/317266	10-Dec-2002	2003/0101927	05-Jun-2003			Published	ASMA
MC.043 EP	Sullivan ALE-reactor (radicals and purging)	EP	00963326.4	08-Sep-2002	1216106	26-Jun-2002			Published	ASMA
MC.043 JP	Sullivan ALE-reactor (radicals and purging)	JP	2001/521471	07-Mar-2002	2003/508932	04-Mar-2003			Published	ASMA
MC.043 PCT	Sullivan ALE-reactor (radicals and purging)	WO	/US00/24586	08-Sep-2000	0117692	15-Mar-2001			Published	ASMA
MC.043 TW	Sullivan ALE-reactor (radicals and purging)	TW	89118222	06-Sep-2000	527224	11-Apr-2003	175152	29-Jul-2003	Issued	ASMA
MC.044 AUS	Graded barriers	US	09/800757	06-Mar-2001	2001/0041250	15-Nov-2001	6534395	18-Mar-2003	Issued	ASMI
MC.044 C1US	Graded barriers	US	10/253859	23-Sep-2002	2003/0032281	13-Feb-2003	6933225	23-Aug-2005	Issued	ASMI
MC.044 D1US	Graded barriers	US	10/329658	23-Dec-2002	2003/0129826	10-Jul-2003	6703708	09-Mar-2004	Issued	ASMI
MC.044 EP	Graded barriers	EP	01918295.5	02-Mar-2001	1266054	18-Dec-2002			Published	ASMI
MC.044 JP	Graded barriers	JP	2001/565432	02-Mar-2001	2003/526218	02-Sep-2003			Published	ASMI
MC.044 PCT	Graded barriers	WO	/US01/06746	02-Mar-2001	0166832	13-Sep-2001			Published	ASMI

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MC.044 TW	Graded barriers	TW 90105107	06-Mar-2001		11-Jun-2002	157886	14-Sep-2002	Issued	ASMI
MC.045 AUS	Dual damascene	US 09/644416	23-Aug-2000	6727169	27-Apr-2004	6727169	27-Apr-2004	Issued	ASMI
MC.045 D1US	Dual damascene	US 10/737315	15-Dec-2003	2004/0130029	08-Jul-2004			Published	ASMI
MC.045 EP	Dual damascene	EP 00957751.1	26-Feb-2002	1221177	10-Jul-2002			Published	ASMI
MC.045 PCT	Dual damascene	WO /US00/23213	24-Aug-2000	0129891	26-Apr-2001			Published	ASMI
MC.045 TW	Dual damascene	TW 89117142	24-Aug-2000		01-Mar-2002	151592	27-Jun-2002	Issued	ASMI
MC.046 AUS	Low k	US 09/843518	26-Apr-2001	2001/0054769	27-Dec-2001	6482733	19-Nov-2002	Issued	ASMI
MC.046 C1US	Low k	US 10/303355	21-Nov-2002	2003/0134508	17-Jul-2003	6699783	02-Mar-2004	Issued	ASMI
MC.046 CP1US	Low k	US 10/303293	22-Nov-2002	2003/0143839	31-Jul-2003	6759325	06-Jul-2004	Issued	ASMI
MC.046 D1US	Low k	US 10/237526	06-Sep-2002	2003/0054631	20-Mar-2003	6686271	03-Feb-2004	Issued	ASMI
MC.046 JP	Low k	JP 2001/144436	15-May-2001	2002/9078	11-Jan-2002			Published	ASMI
MC.046 WO	Low k	PCT PCT/US/03/4	22-Nov-2003	04049432	10-Jun-2004			Published	ASMI
MC.047 AUS	Shallow trench	US 09/887199	21-Jun-2001	2003/0015764	23-Jan-2003	6861334	01-Mar-2005	Issued	ASMI
MC.048 AUS	Capacitor dielectrics	US 09/452844	03-Dec-1999			6780704	24-Aug-2004	Issued	ASMI
MC.048 D1US	Capacitor dielectrics	US 09/791072	22-Feb-2001	2001/0024387	27-Sep-2001	6831315	14-Dec-2004	Issued	ASMI
MC.048 JP	Capacitor dielectrics	JP 2000/368569	04-Dec-2000		24-Jul-2001			Published	ASMI
MC.048 TW	Capacitor dielectrics	TW 89125655	01-Dec-2000		11-May-2002	155059	27-Aug-2002	Issued	ASMI
MC.049 AUS	Oxidation moderation	US 09/791167	22-Feb-2001	2001/0031562	18-Oct-2001	6492283	10-Dec-2002	Issued	ASMI
MC.049 C1US	Oxidation moderation	US 10/281418	25-Oct-2002	2003/0060057	27-Mar-2003	6794314	21-Sep-2004	Issued	ASMI
MC.050 AUS	Metal oxide reduction	US 10/276663	15-Nov-2002	2004/0038529	26-Feb-2004	6921712	26-Jul-2005	Issued	ASMI
MC.050 EP	Metal oxide reduction	EP 01934057.9	20-Sep-2002	1282911	12-Feb-2003			Published	ASMI
MC.050 JP	Metal oxide reduction	JP 2001/584473	15-Nov-2002	2003/533880	11-Nov-2003			Published	ASMI
MC.050 KR	Metal oxide reduction	KR 10/2002/7015	13-Nov-2002	2003/7612	23-Jan-2003			Published	ASMI

Case Extension	Title	ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.050 PCT	Metal oxide reduction	WO /FI01/00473	15-May-2001	188972	22-Nov-2001			Published	ASMI
MC.050 TW	Metal oxide reduction	TW 90111584	15-May-2001	508658	01-Nov-2002	166237	18-Mar-2003	Issued	ASMI
MC.051 AUS	Metals via or through oxide intermediate	US 09/858820	15-May-2001	2002/0004293	10-Jan-2002	6482740	19-Nov-2002	Issued	ASMI
MC.051 C1US	Metals via or through oxide intermediate	US 10/300169	19-Nov-2002	2003/0096468	22-May-2003	6887795	03-May-2005	Issued	ASMI
MC.051 CP1US	Liquid phase reduction of metal oxides	US 10/394430	20-Mar-2003	2004/0005753	08-Jan-2004			Published	ASMI
MC.052 AUS	Nitrogen source material	US 10/100500	15-Mar-2002	2002/0182320	05-Dec-2002	6706115	16-Mar-2004	Issued	ASMI
MC.052 FI	Nitrogen source material	FI 20010539	16-Mar-2001			109770	15-Oct-2002	Issued	ASMI
MC.056 AUS	Aluminum oxide sandwich	US 09/945463	31-Aug-2001	2002/0115252	22-Aug-2002	6660660	09-Dec-2003	Issued	ASMI
MC.056 D1	Aluminum oxide sandwich	US 10/653737	02-Sep-2003	2004/0043557	04-Mar-2004			Published	ASMI
MC.056 JP	Aluminum oxide sandwich	JP 2002/535166	11-Sep-2001	2004/535166	15-Apr-2004			Published	ASMI
MC.056 PCT	Aluminum oxide sandwich	WO /US01/42167	11-Sep-2001	0231875	18-Apr-2002			Published	ASMI
MC.056 TW	Aluminum oxide sandwich	TW 90124227	02-Oct-2001	516168	01-Jan-2003	169832	07-May-2003	Issued	ASMI
MC.057 AUS	Low temperature gate stack	US 10/227475	22-Aug-2002	2003/0049942	13-Mar-2003	6806145	19-Oct-2004	Issued	ASMI
MC.057 PCT	Low temperature gate stack	WO /US02/27230	26-Aug-2002	03041124	15-May-2003			Published	ASMI
MC.057 TW	Low temperature gate stack	TW 91119485	28-Aug-2002	559916	01-Nov-2003	189726	02-Mar-2004	Issued	ASMI
MC.058 AUS	Transition metal carbides	US 09/687204	13-Oct-2000	6482262	19-Nov-2002	6482262	19-Nov-2002	Issued	ASMI
MC.058 C1US	Transition metal carbides	US 10/246131	17-Sep-2002	2003/0031807	13-Feb-2003	6800552	05-Oct-2004	Issued	ASMI
MC.058 JP	Transition metal carbides	JP 2001/532259	11-Apr-2002	2003/512527	02-Apr-2003			Published	ASMI
MC.058 PCT	Transition metal carbides	WO /US00/28537	16-Oct-2000	0129280	26-Apr-2001			Published	ASMI
MC.058 TW	Transition metal carbides	TW 89121518	13-Oct-2000	527429	11-Apr-2003	175854	08-Aug-2003	Issued	ASMI
MC.059 AUS	Magnetic RAM	US 09/997396	28-Nov-2001	2002/0076837	20-Jun-2002			Published	ASMI
MC.059 EP	Magnetic RAM	EP 19952456	26-Nov-2001	1340269	03-Sep-2003			Published	ASMI
MC.059 PCT	Magnetic RAM	WO /US01/44350	26-Nov-2001	0245167	06-Jun-2002			Published	ASMI

Case Extension	Title		ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.059 TW	Magnetic RAM	TW	90129481	29-Nov-2001	527700	11-Apr-2003	175767	07-Aug-2003	Issued	ASMI
MC.060 AUS	Magnetic heads	US	10/136095	30-Apr-2002	2002/0196591	26-Dec-2002	6759081	06-Jul-2004	Issued	ASMI
MC.060 DV1	Magnetic heads	US	10/781574	17-Feb-2004	2004/0161636	19-Aug-2004			Published	ASMI
MC.060 JP	Magnetic heads	JP	2002/135407	10-May-2002	2003/59016	28-Feb-2003			Published	ASMI
MC.064 AUS	Limited film growth on walls	US	09/801542	07-Mar-2001	2002/0157611	31-Oct-2002	6939579	06-Sep-2005	Issued	ASMI
MC.064 JP	Limited film growth on walls	JP	2002/60518	06-Mar-2002	2002/353154	06-Dec-2002			Published	ASMI
MC.065 AUS	Active pulse shape monitoring	US	10/066169	30-Jan-2002	2003/0143747	31-Jul-2003			Published	ASMI
MC.066 AUS	Divider plate	US	10/222005	14-Aug-2002	2003/0075273	24-Apr-2003	6820570	23-Nov-2004	Issued	ASMI
MC.066 PCT	Divider plate	WO	/US02/26192	15-Aug-2002	03016587	27-Feb-2003			Published	ASMI
MC.072 AUS	Rare earth oxides	US	10/067634	04-Feb-2002	2003/0072882	17-Apr-2003	6858546	22-Feb-2005	Issued	ASMI
MC.072 JP	Rare earth oxides	JP	2001/236874	03-Aug-2001	2003/55093	26-Feb-2003			Published	ASMI
MC.073 AUS	Ruthenium thin films	US	10/066315	29-Jan-2002	2003/0165615	04-Sep-2003	6824816	30-Nov-2004	Issued	ASMI
MC.073 JP	Ruthenium thin films	JP	2003/19678	29-Jan-2003	2003/226970	15-Aug-2003			Published	ASMI
MC.073 KR	Ruthenium thin films	KR	10/2003/0004	24-Jan-2003	2003/0065343	06-Aug-2003			Published	ASMI
MC.073 TW	Ruthenium thin films	TW	91101473	29-Jan-2002	556314	01-Oct-2003	188712	12-Feb-2004	Issued	ASMI
MC.075 AUS	Removable container closure	US	10/187142	28-Jun-2002	2003/0075925	24-Apr-2003	6889864	10-May-2005	Issued	ASMI
MC.075 EP	Removable container closure	EP	2744752.3	28-Jun-2002	1404890	07-Apr-2004			Published	ASMI
MC.075 PCT	Removable container closure	PCT	PCT/US02/20	28-Jun-2002	03/004723	16-Jan-2003			Published	ASMI
MC.075 TW	Removable container closure	TW	91114123	27-Jun-2002	539822	01-Jul-2003	181018	28-Oct-2003	Issued	ASMI
MC.076 AUS	CuO reduction prior to SiC.	US	09/975466	09-Oct-2001	2002/0098685	25-Jul-2002	6878628	12-Apr-2005	Issued	ASMI
MC.077 AUS	Low temperature WNC.	US	10/242368	12-Sep-2002	2003/0082296	01-May-2003			Published	ASMI
MC.077 EP	Low temperature WNC.	EP	2798955.7	10-Sep-2002	1425435	09-Jun-2004			Published	ASMI
MC.077 PCT	Low temperature WNC.	WO	/US02/29032	10-Sep-2002	03025243	27-Mar-2003			Published	ASMI

Case Extension	Title		ApplicationNo	FilingDate	PublicationNo	Publication Date	PatentNo	Issue Date	Status	Assgnee
MC.077 TW	Low temperature WNC.	TW	91120831	12-Sep-2002	559890	01-Nov-2003	189730	02-Mar-2004	Issued	ASMI
MC.078 AUS	Stuffed diffusion barrier	US	10/007304	05-Dec-2001	2002/0187631	12-Dec-2002	6936535	30-Aug-2005	Issued	ASMI
MC.078 JP	Stuffed diffusion barrier	JP	2002/566544	05-Dec-2001	2004/525510	19-Aug-2004			Published	ASMI
MC.078 KR	Stuffed diffusion barrier	KR	10/2000/0074	06-Dec-2000	2003/0386034	02-Jun-2003	0386034	02-Jun-2003	Issued	ASMI
MC.078 PCT	Stuffed diffusion barrier	WO	/US01/47592	05-Dec-2001	02067319	29-Aug-2002			Published	ASMI
MC.087 AUS	Enhanced thermal conduction	US	10/463309	16-Jun-2003	2003/0232138	18-Dec-2003			Published	ASMI
MC.087 VJP	Enhanced thermal conduction	JP	2003/171797	17-Jun-2003	2004/134741	30-Apr-2004			Published	ASMI
MC.087 VTW	Enhanced thermal conduction	TW	92116365	17-Jun-2003	2004/04912	01-Apr-2004			Published	ASMI
MC.094 AUS	Source vapour pressure monitor	US	10/285348	30-Oct-2002	2004/0083787	06-May-2004	6779378	24-Aug-2004	Issued	ASMI
MC.094 JP	Source vapour pressure monitor	JP	2003/370625	30-Oct-2003	2004/149925	27-May-2004			Published	ASMI
MC.098 AUS	Molecular bridges	US	10/696244	28-Oct-2003	2004/0092096	13-May-2004			Published	ASMI
MC.098 PCT	Molecular bridges	WO	2003/033214	21-Oct-2003	2004/040642	13-May-2004			Published	ASMI
MC.108 AUS	Adjusting electronegativities and work function	US	10/430703	05-May-2003	2004/016261	03-Jun-2004			Published	ASMI
MC.108 JP	Adjusting electronegativities and work function	JP	2003/404434	03-Dec-2003	2004/186693	02-Jul-2004			Published	ASMI
MC.109 AUS	Barrier layers for metal gates and electrodes	US	10/430811	05-May-2003	2004/0104439	03-Jun-2004	6858524	22-Feb-2005	Issued	ASMI
MC.110 AUS	Enhanced CMOS process flow	US	10/601037	19-Jun-2003	2004/0106249	03-Jun-2004			Published	ASMI
MC.145 AUS	HfSiON with one reactor	US	10/652851	29-Aug-2003			6818517	16-Nov-2004	Issued	ASMI

APPENDIX C ALD OZONE DELIVERY SYSTEM

The ALD Ozone Delivery System (ODS) is intended for use in conjunction with Oxford Instruments Plasma Technology **FlexAL**® and **OpAL**® tools. The topics in this appendix are:

C.1 Other Equipment Manufacturer manuals

These OEM manuals are applicable to the ODS:

- Atlas 25 ozone generator.
- C-30ZX ozone monitor.

C.2 Health and safety information for the ODS

This section contains specific health and safety information for operating and maintaining the ODS. The section must be read in conjunction with **Chapter 1** of this manual.

C.2.1 Hazard information for ozone

C.2.1.1 Characteristics of ozone

WARNING C.1

TOXIC SUBSTANCE
Ozone is a toxic substance that is hazardous to health if inhaled or in contact with the eyes or skin. Exercise caution when working with the ODS. Seek medical attention if inhalation or contact with ozone occurs.

WARNING C.2

RISK OF EXPLOSION
Ozone is an unstable gas which, at normal temperatures, decomposes to diatomic oxygen. At elevated temperatures and in the presence of certain catalysts such as hydrogen, iron, copper and chromium, ozone decomposition may be explosive. Moreover, ozone reacts with non-saturated organic compounds to produce ozonides, which are unstable and may decompose with explosive violence.

At room temperatures, ozone is a colourless gas with a characteristic sharp, irritating odour. It is a powerful oxidizing agent. Oxidation reactions involving ozone evolve more heat than similar reactions involving oxygen, and can usually be initiated at lower temperatures than similar reactions involving oxygen.

All personnel who install, maintain or operate the ODS must fully understand the hazards associated with ozone before commencing work. All such personnel must read and understand the appropriate Material Safety Data Sheet (MSDS).

C.2.1.2 Potential health effects of ozone

When inhaled, ozone irritates the nose, throat, and chest and also causes dryness of the mouth. Ozone may cause difficulty in breathing, headache, and fatigue. The characteristic sharp, irritating odour is readily detectable at low concentrations (0.01 ppm to 0.05 ppm).

Ozone irritates the eyes causing pain, lacrimation, and general inflammation.

Before operating the ODS, consult the appropriate MSDS to understand what first-aid measures may be required.

C.2.2 Hazard information for the Ozone Delivery System

WARNING C.3

HEAVY WEIGHT
The cabinet of the ODS is a heavy object with a centre of gravity above its mid-point. Exercise caution when lifting and installing the cabinet.

WARNING C.4

LETHAL VOLTAGES
High voltages are present inside the cabinet of the ODS.
Isolate the mains electrical supply to the cabinet before attempting to open the cabinet.
Exercise extreme caution when in the vicinity of high voltages.
There are no user serviceable parts inside the cabinet of the ODS.

Caution C.1

Damage to the Ozone Delivery System
The ozone generator is not designed to pump down to vacuum.
Do not evacuate the ODS, otherwise damage to the ozone generator may occur.

C.2.3 Safety features of the Ozone Delivery System

C.2.3.1 Safety interlocks

When the door of the ODS cabinet is opened, the following interlock actions occur:

- Electrical power to the ozone generator is interrupted, which stops ozone production.
- The compressed air supply to the cabinet is disabled, which closes the isolation and ALD dose valves.

C.2.3.2 Ozone monitoring

There is an ozone detector within the ODS cabinet. Ozone is denser than air, so the detector is located near the bottom of the cabinet. The detector has an LED display that illuminates to indicate the measured ozone concentration. See Table C-1.

Table C-1 Ozone detector LEDs

Ozone Concentration (ppm)	LED Colour
0 to 0.05	Green
0.05 to 0.1	Yellow
Greater than 0.1	Red

If the ozone detector measures unsafe concentrations of ozone, it performs the following actions:

- Electrical power to the ozone generator is interrupted, which stops ozone production.
- The compressed air supply to the cabinet is disabled, which closes the isolation and ALD dose valves.
- An alarm is displayed on the PC2000 pages on the **FlexAL**® or **OpAL**® system controller. This stops the recipe that is running on the controller.
- Electrical power to the ozone generator remains OFF, even if ozone concentrations return to safe levels.

C.3 Services requirements for the ODS

C.3.1 Quantitative requirements

C.3.1.1 Facilities inlet connections

Compressed air with a pressure of >5 bar.

Oxygen with a pressure of between 2 bar and 3 bar.

C.3.1.2 Outlet connections

Compressed air exhaust.

Ozone supply to the ALD chamber.

Ozone outlet to the exhaust (atmospheric pressure side of pump).

C.3.1.3 Connections between the ODS and the ALD system

AC electrical power.

24 VDC control signals.

Compressed air to drive the remote isolation valve (**OpAL**® systems only).

C.4 Description of the ODS

The ODS is used in Oxford Instruments Plasma Technology **FlexAL**® and **OpAL**® tools. The system provides the oxidant for ALD processes and is designed to deliver short pulses of ozone (~ few seconds) to the ALD chamber.

The unit is a complete ozone delivery system housed in a steel cabinet. The cabinet is continuously monitored to ensure that the concentration of ozone is within safe levels.

C.4.1 Features of the ODS

- Ozone generator, which outputs ~10% w/w ozone concentration.
- Ozone destruction unit.
- Forward pressure regulation.
- Oxygen flow regulator.
- Ozone flow-restriction to regulate ozone delivery to the ALD chamber.
- A Swagelok® rapid ALD dose valve.

C.4.2 Main parts of the ODS

The ODS is housed in a stainless steel cabinet with a sealing door containing a glass viewing window to enable set-up (see **Figure C-1**).

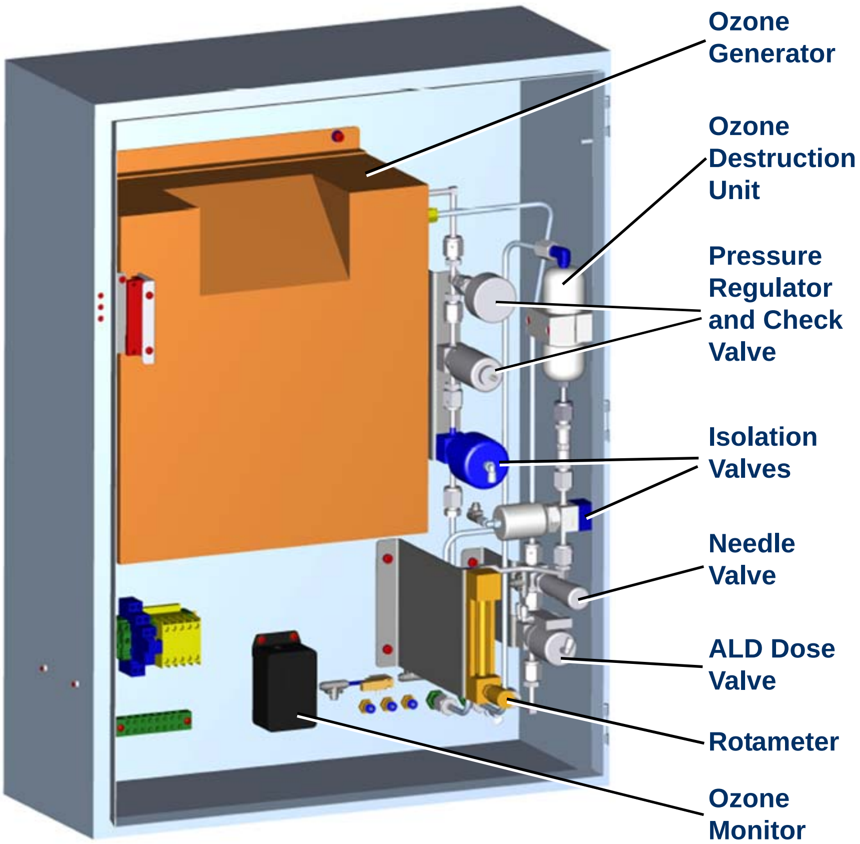

Figure C-1 ODS cabinet

The main components of the ODS cabinet are:

Ozone generator
Absolute Ozone® Atlas 25 ozone generator.

Ozone destruction unit
Uses a catalyst to convert ozone to oxygen before sending it to the exhaust system.

Pressure regulator and display
Adjusts the pressure of oxygen fed into the ozone generator. The pressure in the generator must be greater than the pressure in the exhaust.

Check valve
Prevents backflow from the exhaust into the generator, if the exhaust pressure becomes greater than the generator pressure.

Isolation valves
Closed when the unit is idle or an interlock is tripped. These valves provide protection in the event of a leak or failure.

Needle valve
Regulates the flow into the ALD chamber.

ALD dose valve
Switches the flow to the ALD chamber.

Rotameter
Regulates the flow of oxygen through the ozone generator. This flow determines the percentage of ozone in oxygen that flows into the process chamber.

Ozone monitor
Model C-30ZX monitor interrupts the interlock chain if an ozone leak is detected in the cabinet.

C.4.3 Functional description of the ODS

Figure C-2 shows a functional diagram of the ODS.

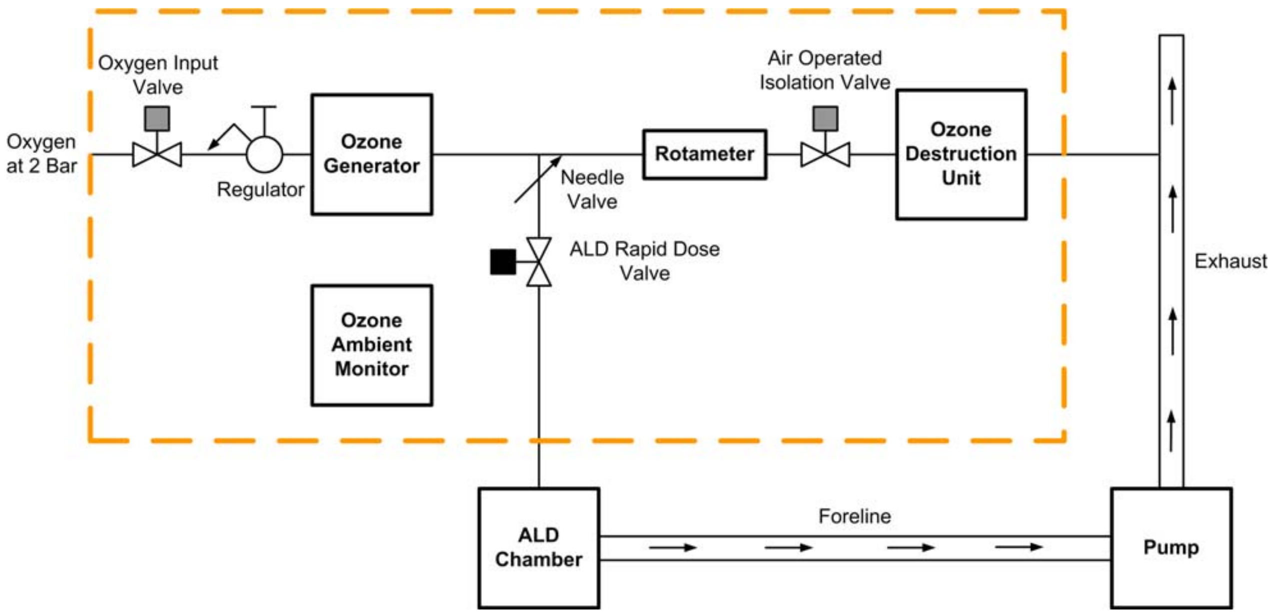

Figure C-2 Functional diagram of the ODS

When the ODS is not in use, the three pneumatic valves are closed. This minimises the risk of oxygen leaking from the system.

When the oxygen input valve opens, oxygen enters the ozone generator. Some of the ozone produced by the ozone generator passes through the isolation valve into the ozone destruction system. This converts ozone into oxygen, which then passes into the facility exhaust. When the ALD rapid dose valve is open, ozone also passes through a needle valve into the ALD process chamber.

C.4.4 Pneumatic control circuit of the ODS

Figure C-3 shows the pneumatic control circuit.

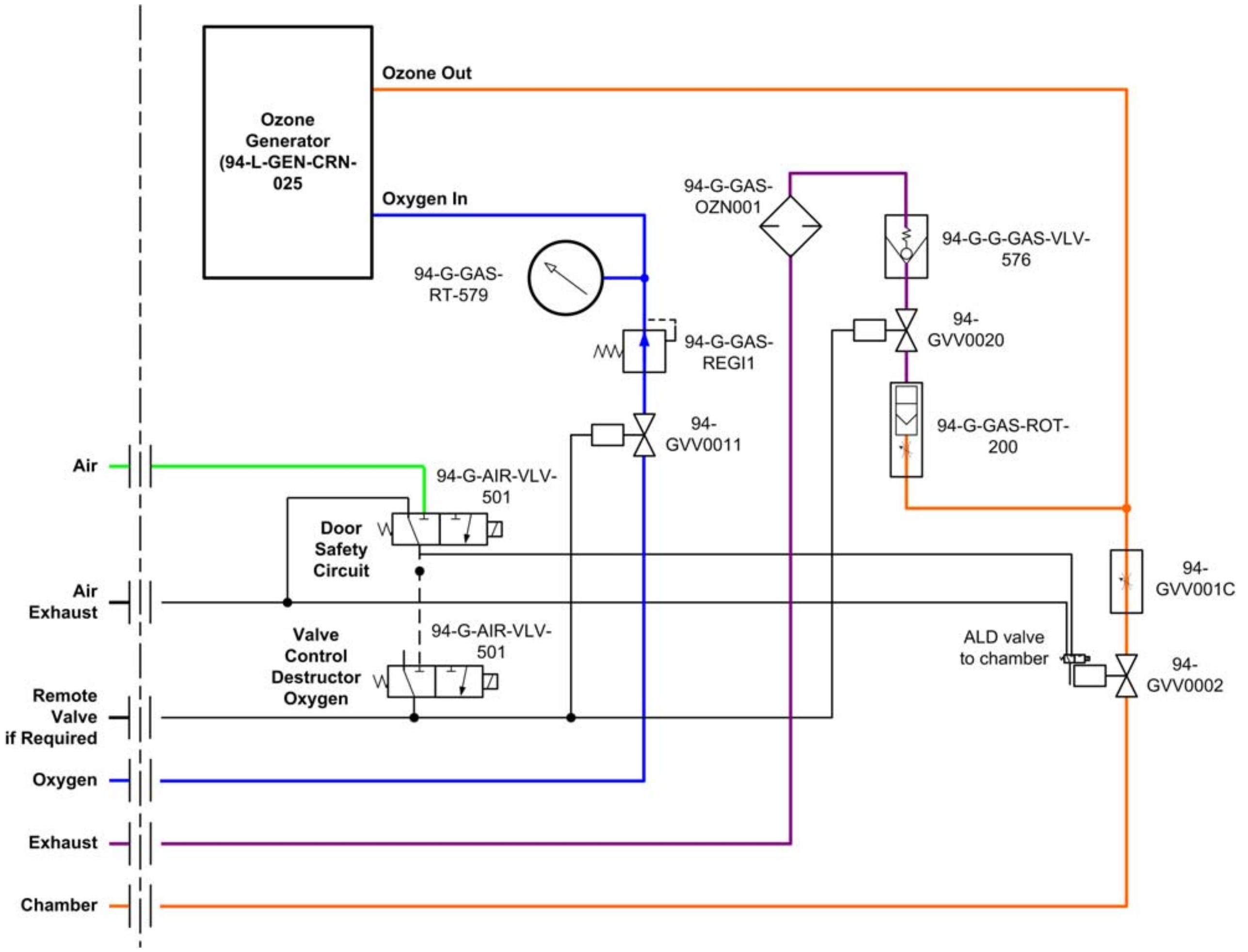

Figure C-3 ODS pneumatic control circuit

C.4.5 ODS electrical schematic

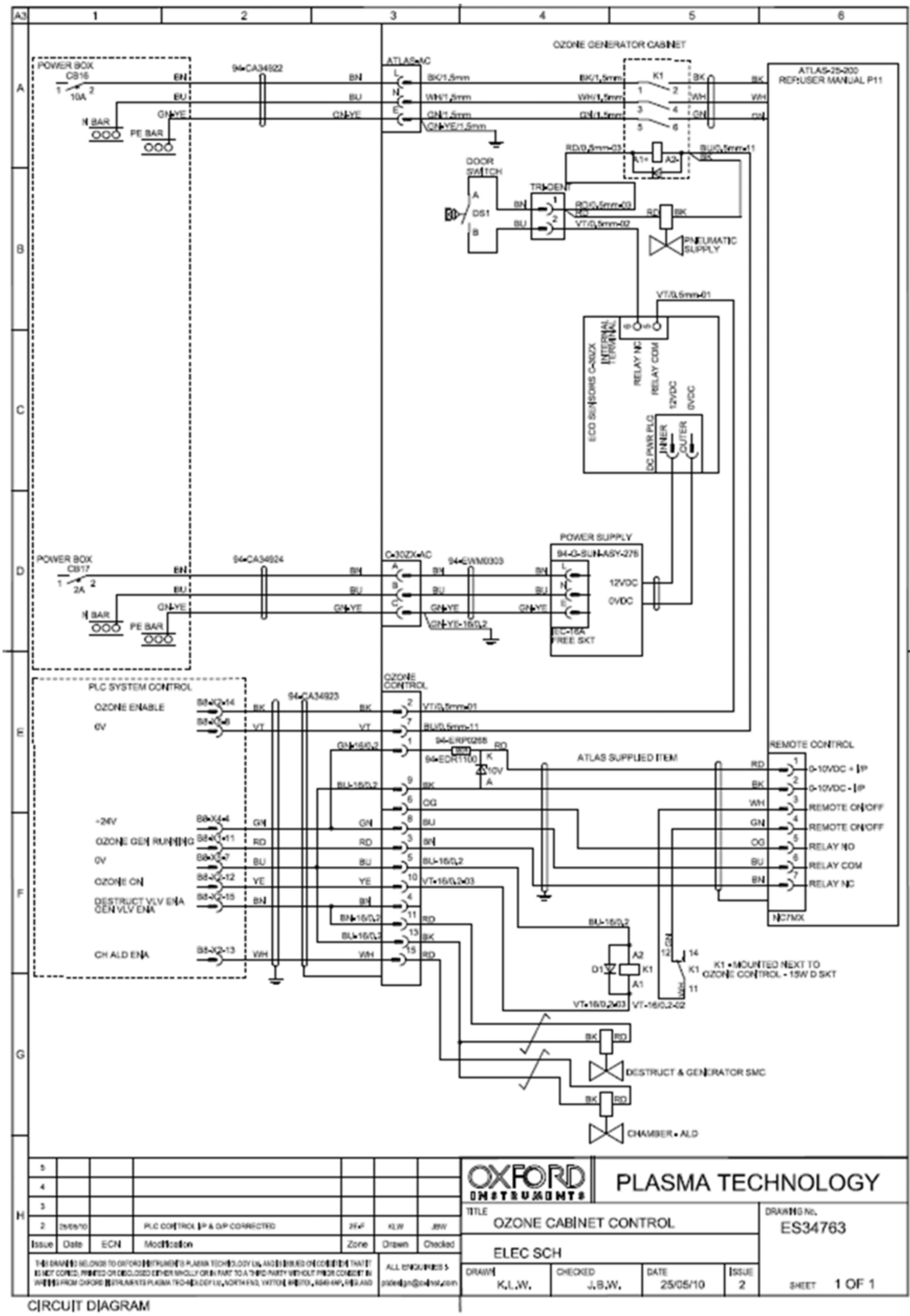

Figure C-4 Electrical schematic diagram of the ODS

C.5 Installing the ODS

C.5.1 Mounting the ODS

C.5.1.1 Mounting the ODS to a FlexAL® tool

If the ODS is supplied with a **FlexAL**® system, the cabinet is mounted on the **FlexAL**® system frame as shown in **Figure C-5**.

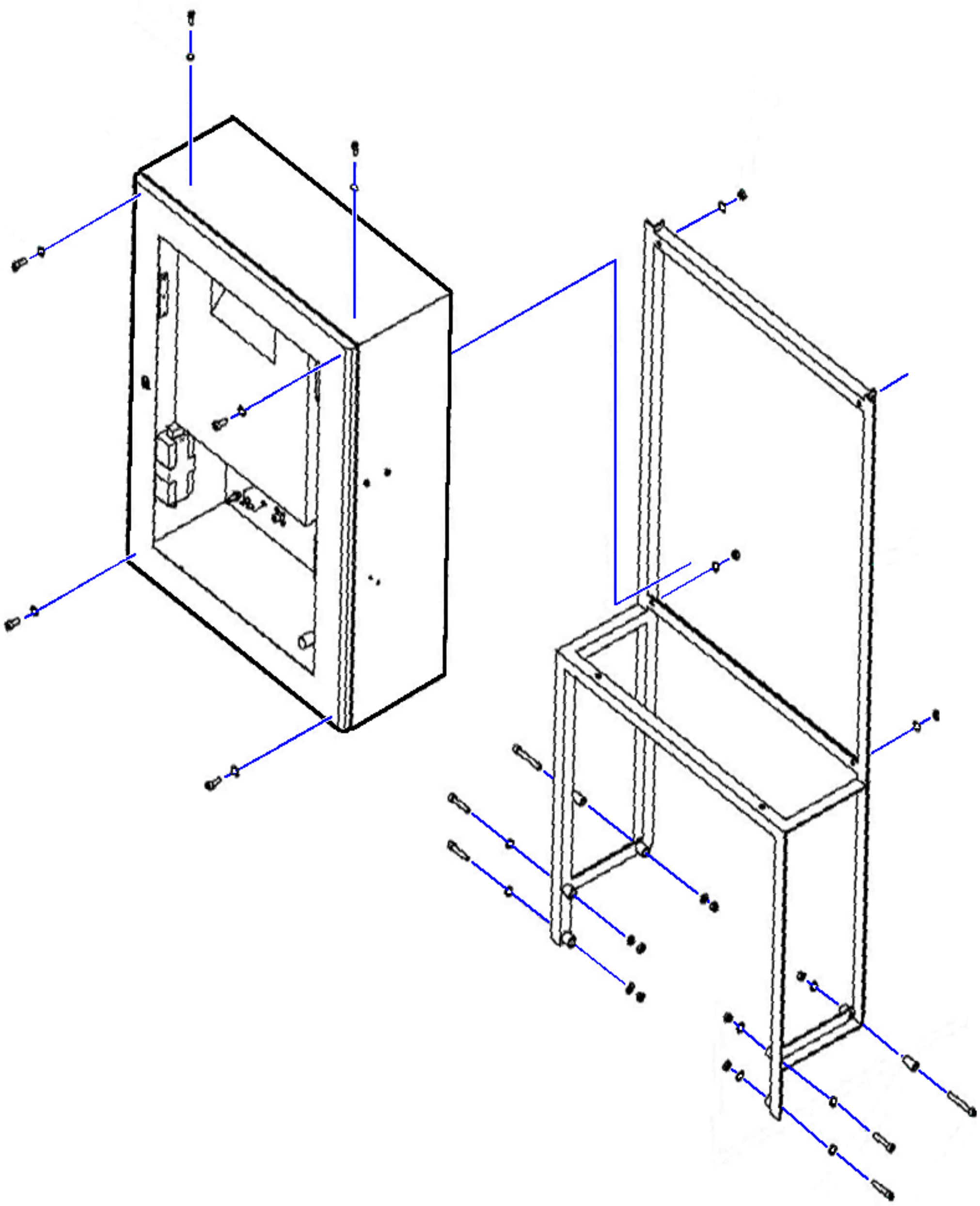

Figure C-5 Mounting the ODS to a FlexAL® tool

C.5.1.2 Mounting the ODS to an OpAL® tool

If the ODS is supplied with an **OpAL**® system, the cabinet is mounted on a wall as shown in **Figure C-6**.

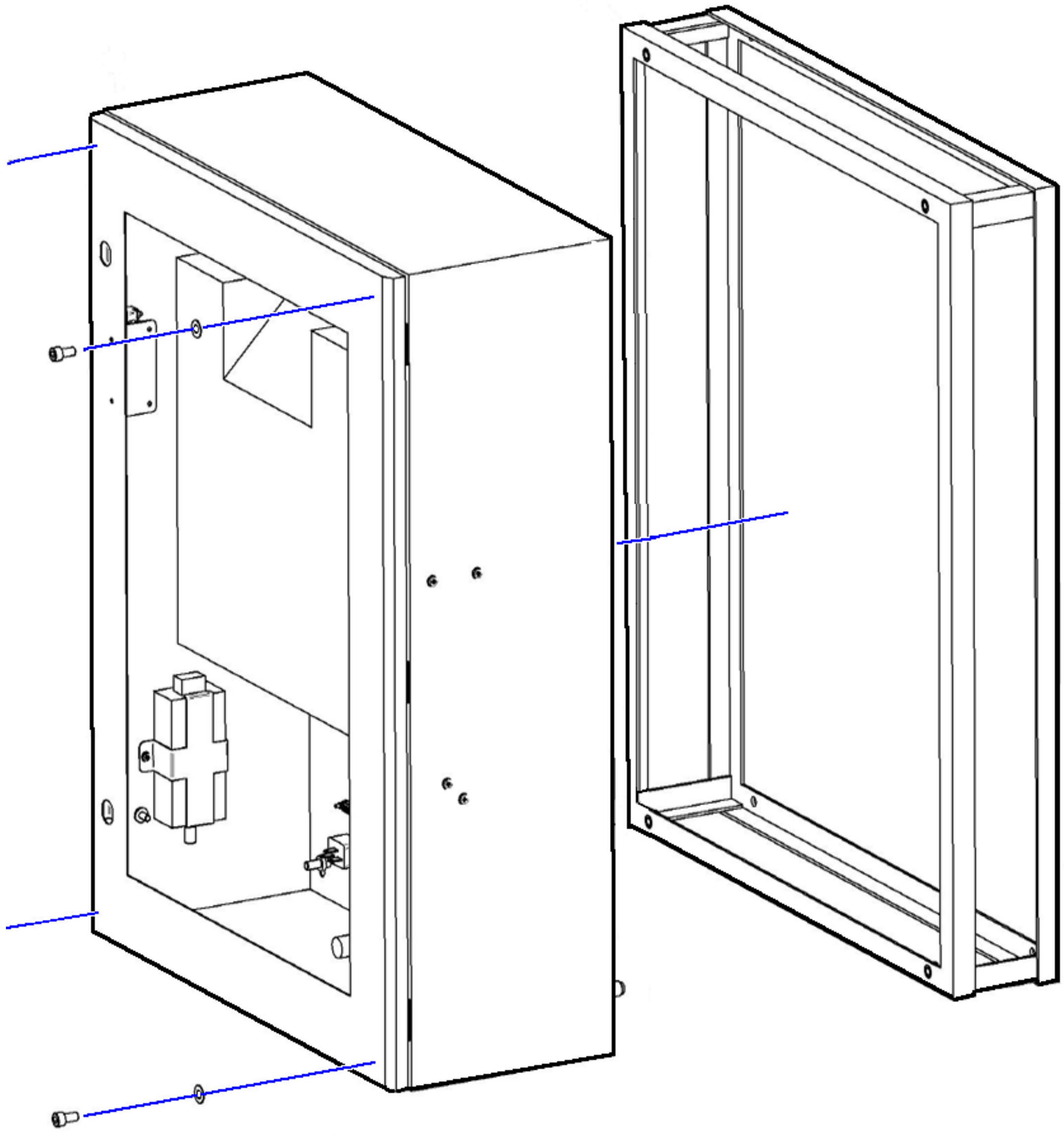

Figure C-6 Mounting the ODS to an OpAL® tool

Refer to **Section C.3** for information on the required services.

C.5.2 Commissioning the ODS

C.5.2.1 Initial power-up

WARNING C.5

LETHAL VOLTAGES
High voltages are present inside the cabinet of the ODS.
Isolate the mains electrical supply to the cabinet before attempting to open the cabinet.
Exercise extreme caution when in the vicinity of high voltages.
There are no user serviceable parts inside the cabinet of the ODS.

When electrical power is first connected to the cabinet, the ozone monitor unit displays a high alarm reading for between 30 and 60 minutes. This is normal behaviour. Do not attempt to use the ODS until the high alarm has disappeared.

If electrical power to the system is interrupted for less than 5 minutes, the ozone monitor will only require approximately 5 minutes to warm up. If electrical power is interrupted for more than five minutes, the high alarm reading may persist for between 30 and 60 minutes.

C.5.2.2 Initial set-up procedure

Adjust the pressure regulator

1. Open the door of the ODS cabinet.
2. Set the **Power** knob on the control panel of the ozone generator to the OFF position.
3. Rotate the control knob on the pressure regulator fully clockwise.
4. Close the door of the ODS cabinet to enable the interlock switch.
5. Switch the ozone generator ON from the process page on the main system PC2000 application. This opens the ozone isolation valves. The ozone generator will not activate as it is switched OFF.
6. Open the door of the ODS cabinet.
7. Rotate the control knob on the pressure regulator by one quarter-turn in the counter-clockwise direction.
8. Close the door of the ODS cabinet and note the pressure displayed on the regulator display.
9. Repeat steps **6** to **8** until the regulator displays a value of 1.5 bar above atmospheric pressure.

Adjust the rotameter

1. Note the flow rate on the rotameter inside the ODS cabinet.
2. Open the door of the ODS cabinet.
3. If the flow rate is greater than 0.1 slpm, rotate the control knob on the rotameter by a small amount in the clockwise direction.

4 If the flow rate is less than 0.1 slpm, rotate the control knob on the rotameter by a small amount in the counter-clockwise direction.

5 Close the door of the ODS cabinet and wait several seconds until the flow rate through the rotameter is stable.

6 Repeat steps **2** to **5** until the flow rate through the rotameter is 0.1 slpm.

Adjust the needle valve

1 Open the door of the ODS cabinet.

2 Rotate the control knob on the needle valve fully clockwise to close it.

3 Close the door of the ODS cabinet.

4 Access the PC2000 application on the main system controller.

5 Evacuate the ALD chamber and leave the system pumping.

6 Open the ALD dose valve from the PC2000 application.

7 Note the chamber pressure indicated on the PC2000 Pumping page.

8 Open the door of the ODS cabinet.

9 Rotate the control knob on the needle valve slightly in the counter-clockwise direction.

10 Close the door of the ODS cabinet and wait until the indicated chamber pressure is stable.

11 Repeat steps **8** to **10** until the chamber pressure is 30 mTorr (for **FlexAL**®) or 75 mTorr (for **OpAL**®).

Prepare the ozone delivery system for use

1 Access the PC2000 application on the main controller.

2 Stop the ozone generator and close the ALD valve.

3 Open the door of the ODS cabinet and set the **Power** knob on the control panel of the ozone generator to the ON position.

4 Close the door of the ODS cabinet.

The ODS is now ready for use.

C.6 Operating the ODS

The ODS is controlled from the PC2000 application on the main system controller.

C.6.1 Representation on the PC2000 pages

Figure C-7 shows the panel used to control the ODS.

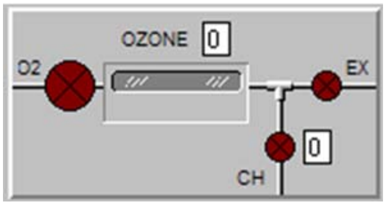

Figure C-7 Ozone panel on the PC2000

The **OZONE** panel contains the following controls and indicators:

O2 valve
Switches the oxygen supply to the ozone generator.

Ex valve
Switches ozone to the exhaust system.

CH valve
This fast ALD valve switches ozone to the ALD process chamber.

Status panel
Displays status messages.

Ozone generator ON/OFF field
Enter 1 to switch the ozone generator ON. Enter 0 to switch the ozone generator OFF.

C.6.2 Using the ODS in a recipe

The ozone generator must be switched ON from the PC2000 controller at least five minutes before delivering ozone in a process step. This period allows the ozone output of the generator to optimise (see Figure C-8).

1 If running a recipe, switch the ozone generator ON during the first recipe step.

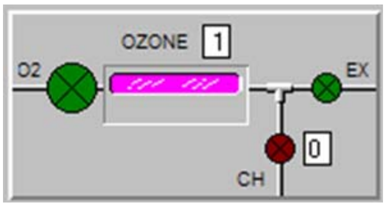

Figure C-8 Ozone generator is switched ON

2 Switch the fast ALD valve (CH) ON to admit ozone to the process chamber (see Figure C-9). For most processes, use a one-second pulse of ozone.

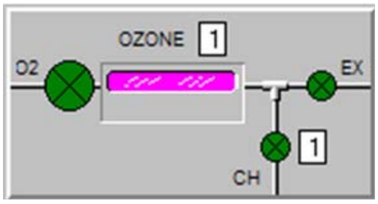

Figure C-9 Fast ALD valve is open

C.7 Maintaining the ODS

Perform the following periodic maintenance checks at regular monthly intervals:

1. Open the door of the ODS cabinet.
2. Observe the colour of the granules in the ozone destruction unit. If the crystals have changed colour, contact Oxford Instruments Plasma Technology for advice. The crystals change colour when they are contaminated with moisture.
3. Check that all VCR and Swagelok® connections within the ODS cabinet are secure.

C.8 Troubleshooting the ODS

C.8.1 Fault displayed on the PC2000 page

Figure C-10 shows the OZONE panel of the PC2000 if a fault in the ODS has occurred.

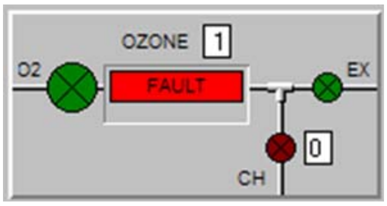

Figure C-10 Fault in the ODS indicated on PC2000 OZONE panel

A red alert message is generated if the ozone generator is switched ON but the generator does not return an OK message within 30 seconds. The red alert stops the process that is running. The alert message is:

The ozone generator output has failed, please check the generator, power connections and the ozone monitor.

C.8.2 Elevated ozone concentration

WARNING C.6

TOXIC SUBSTANCE
Ozone is a toxic substance that is hazardous to health if inhaled or in contact with the eyes or skin. Exercise caution when working with the ODS. Seek medical attention if inhalation or contact with ozone occurs.

If the ozone monitor displays an elevated ozone concentration, DO NOT attempt to open the ODS cabinet. Wait until the monitor indicates a safe ozone concentration before opening the cabinet. Depending on the levels of ozone within the cabinet, this may take several hours.

If the ozone concentration has not decayed to a safe level after several hours, it is possible that the ozone monitor has failed. Perform the following steps to recover the situation:

1. Check that the ozone generator is powered off.
2. Put on appropriate personal protective equipment.
3. Ensure that the area around the ODS cabinet is well ventilated. If necessary, install temporary extraction for the area.
4. When it is safe to do so, open the door of the ODS cabinet and check the ozone monitor for faults.

C.8.3 Troubleshooting guide

Symptom	Possible Cause	Solution
Ozone generator cannot be switched ON from the PC2000 page.	Ozone generator is switched OFF at the front panel.	Check that the ozone generator is switched ON.
	The ODS cabinet door is open.	Close the ODS cabinet door.
	The front panel switch of the ozone monitor is OFF.	Switch the ozone monitor ON.
Ozone generator displays a FAULT message on the PC2000 page.	Ozone monitor is displaying a high reading.	Check the ozone monitor for faults.
	Exhaust pressure is too high.	Correct the fault.
ODS has recently been powered OFF and the ozone monitor is displaying a high reading.	Ozone monitor is warming up.	Wait 60 minutes and attempt to switch ON the ODS again.
System has been powered ON for more than 60 minutes and the ozone monitor is displaying a high reading.	Ozone level inside the ODS cabinet is high.	Wait for the ozone level to decay to a safe level. Then leak-check the ODS.
	Ozone monitor is faulty.	Wait for 60 minutes. If the ozone reading has not decreased, check the ozone monitor for faults.
Rotameter is showing zero flow	Exhaust pressure is too high.	Correct the fault.
	Needle valve is open too far.	Adjust the needle valve.
Rotameter flow is incorrect but not zero.	Rotameter is incorrectly adjusted.	Adjust the rotameter.

GLOSSARY

This glossary explains the acronyms, abbreviations and special terms used in this System Manual. The entries are presented in alphanumeric order.

The glossary includes a list of references to the standards and codes of practice and other documents referred to in this System Manual.

List of references

[1] Uniform Fire Code Article 51.

[2] The Safe Storage, Handling & Use of Special Gases in the Micro-Electronics Industry, British Compressed Gases Association code of practice 18.

[3] BS EN ISO 14121: 2007 (Safety of Machinery - Risk Assessment part 1).

[4] BS EN 61000 4-2: 1995 (Electromagnetic Compatibility (EMC). Testing and Measurement Techniques).

[5] BS EN 61000 6-2: 1995 (Electromagnetic Compatibility (EMC) - Part 6-2: Generic Standards - Immunity for Industrial Environments).

[6] BS EN 61010-1:2001 (Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use. General Requirements).

[7] BS EN 61326-1:2006 (Electrical Equipment for Measurement, Control and Laboratory use. EMC Requirements. General Requirements).

[8] BS 6206:1981 (Specification for Impact Performance Requirements for Flat Safety Glass and Safety Plastics for use in Buildings).

[9] BS EN 55011:2007 (Industrial, Scientific and Medical (ISM) Radio-frequency Equipment - Electromagnetic Disturbance Characteristics - Limits and Methods of Measurement).

[10] ANSI/IEEE C95.1 (IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz).

[11] SEMI S2: Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment.

[12] DIRECTIVE 2008/46/EC of The European Parliament And Of The Council of 23 April 2008.

[13] Machinery Directive: 89/392/EEC (amended 98/37/EEC).

[14] Low Voltage Directive: 2006/95/EC.

[15] Electromagnetic Compatibility (EMC) Directive: 2004/108/EC.

[16] International Electrotechnical Commission standard IEC60950-1: Safety of information technology equipment.

[17] Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2008 (RoHS).

Acronyms and abbreviations

ALD	atomic layer deposition
APC	automatic pressure controller
CAN	controller area network
CM	capacitive manometer
DC	direct current
EMO	emergency off
FlexAL	flexible automatic layer deposition
Hz	Hertz
ICP	inductively-coupled plasma
IPA	Isopropyl Alcohol
LED	light emitting diode
MESC	Modular Equipment Standards Committee
MFC	mass flow controller
MHz	Megahertz
mm	millimetre
ms	millisecond
MSDS	materials safety data sheet
ODS	Ozone Delivery System
OIPT	Oxford Instruments Plasma Technology
PC	personal computer
PCB	printed circuit board
PDM	precursor delivery module
PLC	programmable logic controller
ppm	parts per million
PSU	power supply unit
RF	radio frequency
sccms	standard cubic centimetre millisecond
slpm	standard litres per minute
SMC	SMC Corporation of America
TLV	threshold limit value
V	volts
w/w	TBA

Glossary of terms

Flammable

Flammability is the ease with which a substance will ignite, causing fire or combustion. Those substances that ignite spontaneously when exposed to ambient environment are termed pyrophoric.

ICP 65

A model of inductively-coupled plasma ion source. The number 65 denotes the diameter of the insulating tube in the ion source. Other models in OIPT systems are ICP 80, ICP 180 and ICP 380.

Precursor

A substance from which another substance is formed. A precursor could be a solid, liquid or gas. In ALD it is generally transported to the reactor in vapour form.

Precursor module

The blue cabinet that houses the ampoules containing the precursor. The cabinet is constructed of stainless steel and is fitted with an extraction port. The cabinet is fan air heated to increase the vapour pressure of the precursor stored inside.

Pyrophoric

A pyrophore is a substance that ignites spontaneously: that is, its autoignition temperature is below room temperature. Most pyrophoric materials react with their environment rather than self decompose. Typical reactions are with oxygen, water and moisture in the air.

Vapour pressure

All solids and liquids have a tendency to evaporate into a vapour form. Gases have a tendency to condense. In equilibrium, this is the vapour pressure.

OIPT locations worldwide

United Kingdom
Oxford Instruments Plasma Technology
North End, Yatton,
Bristol, BS49 4AP
Tel: +44(0)1934 837000
Fax: +44(0)1934 837001
Email: plasma-sales@oxinst.com (sales)
Email: ptsupport@oxinst.com (support)
Web: www.oxford-instruments.com

Americas
Oxford Instruments
300 Baker Avenue, Suite 150
Concord, MA 01742
Phone: +1 978 369 9933
Toll Free: +1 800 447 4717
Fax: +1 978-369 6616
Email: info@ma.oxinst.com (sales & support

People's Republic of China (Beijing)
Oxford Instruments China
Room 714, Henderson Centre
No. 18 Jianguomennei Ave,
Dongcheng District,
Beijing 100005
Tel: +86 10 6518 8160
Fax: +86 10 6518 8155
Email: info@oichina.cn (sales)
Email: china.ptsupport@oxinst.com (support)
Web: www.oichina.cn

People's Republic of China (Shanghai)
Oxford Instruments China
Room 14-F, No.1 Plaza No.800
Nanjing East Road
Shanghai 200001
Tel: +86 21 6360 8530/1/2/3
Fax: +86 21 6360 8535
Email: info@oichina.cn (sales)
Email: china.ptsupport@oxinst.com (support)
Web: www.oichina.cn

Singapore
Oxford Instruments Pte. Ltd
10 UBI Crescent
#04-81 Lobby E
UBI TECHPARK
Singapore 40854
Tel: +65 6337 6848
Fax: +65 6337 6286
Email: oipt.sales@oxford-instruments.com.sg (sales)
Email: oipt.support@oxford-instruments.com.sg (support)

Japan
Oxford Instruments K.K.
Haseman Building
2-11-6 Tomioka
Kotoku
Tokyo 1350047
Tel: +81 3 5245 3261
Fax: +81 3-5245 4472
Email: info.jp-pt@oxinst.com (sales & support)
Web: www.oxinst.co.jp

Europe
Oxford Instruments GmbH
Otto-von-Guericke Ring 10,
D-65205 Wiesbaden
Tel: +49 6122 937 161
Fax: +49 6122 937 175
Email: plasma@oxford.de (sales & support)

Rest of the World
Oxford Instruments Plasma Technology
North End, Yatton,
Bristol, BS49 4AP
Tel: +44 (0)1934 837000
Fax: +44 (0)1934 837001
Email: plasma-sales@oxinst.com (sales)
Email: ptsupport@oxinst.com (support)
Web: www.oxford-instruments.com