Frozen in Time Ltd

Manufacturers of Freeze Drying Machines and Vacuum Cold traps

Operating Manual 250KG

Operating Manual

250KG

Order Number:

Serial Number:

In case of enquiries please state the above

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1. General Information

1.1. Introduction

What is freeze drying (lyophilisation)?

Freeze drying means: Removal of water from frozen material. The drying process takes place by direct conversion from ice to vapour. This process is called sublimation. Sublimation happens under vacuum when the temperature in the product is less than -10°C.The aim of freeze drying is to obtain a readily water-soluble product which has the same characteristics as the original product after the addition of water. As the drying process takes place in the frozen state at low temperatures it is possible to dry proteins which will not denature. Most of the other chemical compounds will also remain unchanged. Freeze drying products, of biological origin such as tissues, tissue extracts, bacteria, vaccines and sera transforms them into a dry product. During this process enzymatic, bacterial and chemical changes are largely avoided. Freeze drying is the gentlest process for preserving the biological properties of sensitive tissue and tissue components. Freeze drying can also be used to dry some inorganic products.

1.2. Technical data of freeze dryer

250KG

250kg Freeze Drier Specifications	
Overall Dimensions W x H x L m	**1.95 x 2.4 x 4**
Specimen Chamber Diameter x Length m	**1.4 x 1.6**
Specimen and Condenser Chamber Construction	**304 Stainless Steel (316L Optional)**
Shelf Area m²	**21**
Levels of Shelves	**15**
Shelf Size W x D cm	**0.93 x 1.52**
Distance between shelves cm	**4**
Condenser Chamber Temperature (unloaded)	***-55ºC* (-85ºC *)***
Shelf Temperature Range ºC	**-60 to +80 ºC**
Mobile Temperature Probes	**15**
Condenser chamber Defrost	**Hot gas**
Condenser Ice Capacity	**(250litres / 24hour)**
Refrigerant	**R-23, R-507 & R134A**
Vacuum Pump	**Edwards EH250 & E2M40**
***Isolation Valve* Ø cm**	**40**
Power Requirements	**1ph 240v or 3ph 415v**
Running Power Consumption	**31kw**

Parts supplied with the 250KG

- 1 set of spare door seals
- 2 Vacuum pump exhaust filters
- 20lt Vacuum pump oil
- 2 Operating manuals
- 1 Tube of vacuum grease

1.3. Safety instructions

1.3.1. Disconnect the electricity supply before removing panels

The freeze drier must be securely isolated or unplugged or from the mains supply before the panels are removed or any maintenance work is undertaken.

1.3.2. Solvents

Acidic or high solvent concentration products should not be dried because of corrosion risk and damage to the vacuum pump.

1.3.3. Cleaning and Maintenance of the Unit

For infectious, toxic, pathogenic and radioactive substances, the danger information of the associated safety regulations must be observed.

1.3.4. Freezing of skin to surfaces

Make sure skin does not come into contact with freezing surfaces.

1.4. The 250KG should not be used when:

1. It is not properly installed.

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2. Panels are missing.

3. The operator is not authorized or trained

4. Highly corrosive or solvent substances are present.

5. In hazardous or dangerous locations.

6. The products are explosive or highly flammable.

7. The products are Infectious, toxic, pathogenic or radioactive unless in suitable vessels and in accordance with the relevant safety data.

2. Description of the Freeze Drying Processes

2.1. General Information on Freeze Drying

Freeze drying is the gentlest process for drying products. It uses the process of sublimation, the direct conversion from solid to vapour state. The frozen product is dried under vacuum without thawing. The condenser chamber works as a cryogenic pump as it takes large volumes of vapour and condenses a small amount of ice. The vacuum pump is only intended to remove the air from the drying chamber but not the vapour. In order to start the sublimation process, energy must be supplied to the product. This energy source comes from the heated shelves.
Primary drying removes the most of the water from the product.
Secondary drying removes the last traces of water by means of deep vacuum.

The main components of a freeze dryer are:

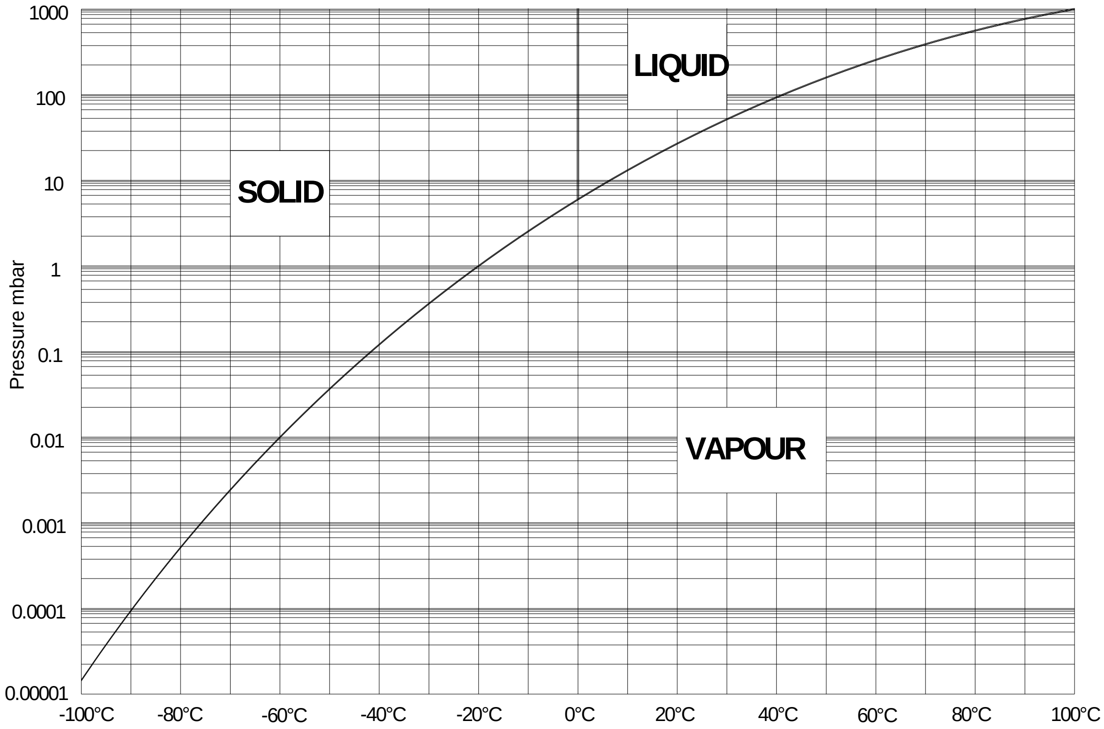
- Vacuum drying chamber with heated shelves
- Vacuum pump to evacuate air.
- Ice condenser with temperature of -55°C to -85°C to condense water vapour.

Sublimation

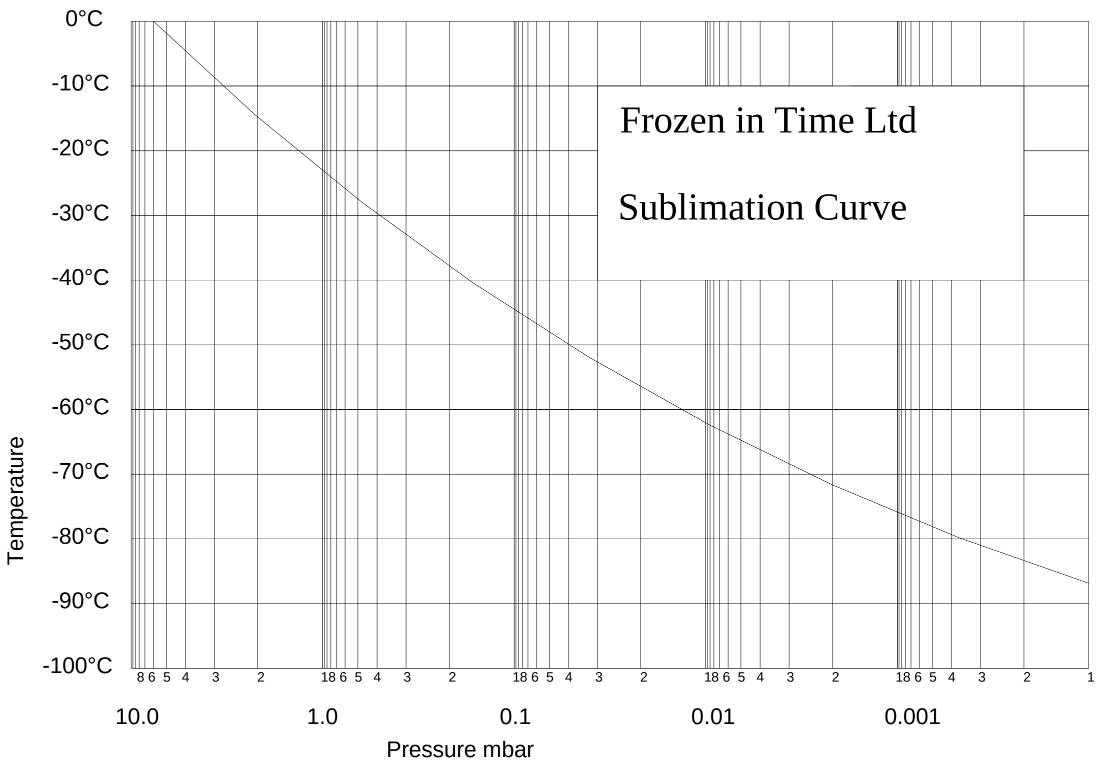
The principle of sublimation is briefly explained using the phase diagram of solid liquid and vapour. If the pressure is higher than 6.1 mbar, water can exist in all three phases (solid, liquid, vapour) when the temperature is lowered or raised. At 6.1 mbar and 0ºC all three lines meet, this is called the triple point where all three phase can occur simultaneously. Below this point when the pressure is lower than 6.1 mbar, the ice is converted directly from a solid to a vapour on reaching the sublimation pressure curve.

The sublimation curve shows the vapour pressure of water as affected by temperature and pressure.

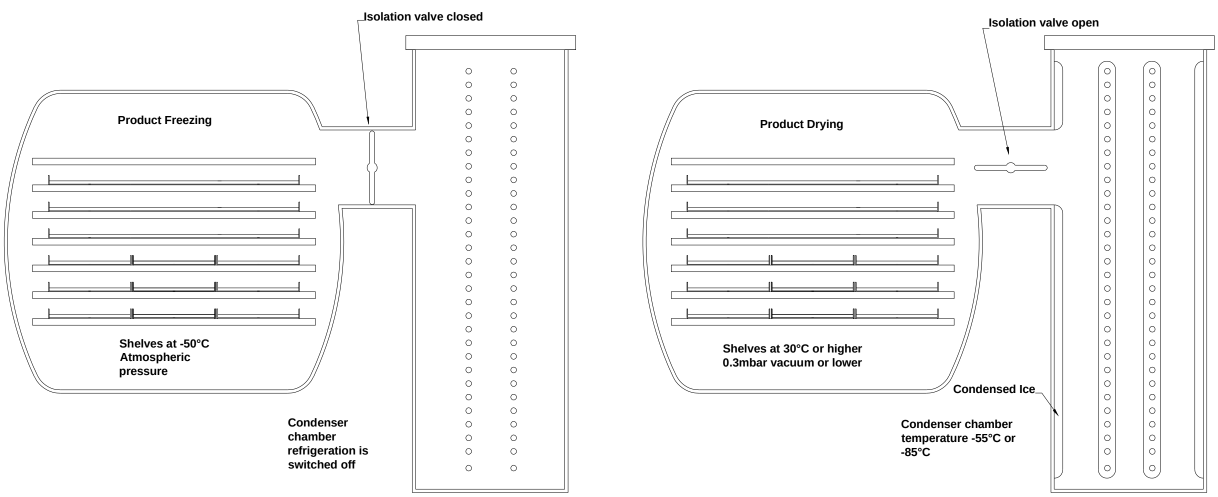
Phase diagram for solid, liquid and vapour



Vapour pressure of ice



Cross sectional diagram of the freeze driers chambers during **Product freezing** and during **Product drying**.



Product Freezing

The Isolation valve is closed and the product is frozen by the low temperature of the shelves.

Product drying

The condenser is frozen to its minimum temperature. As the temperature goes below approximately -30ºC the vacuum pump can be switched on. The isolation valve must be opened and the vacuum is created in both chambers. When the vacuum is sufficient the heating can be applied to the shelves. Sublimation will cause the products on the shelves to dry. Deposition will occur in the condenser chamber as the sublimated vapour re-freezes.

2.2. Freezing the product.

Product can be frozen directly on the shelves of the **250KG**. This is the usual option for product to be freeze dried in trays or vials. The product is placed on the shelves and the shelves are cooled down to the desired temperature. The freezing can be done in stages, at a controlled rate or just as quickly as possible.

2.3. Primary drying

The condenser drops to its operating temperature.
The isolation valve is open
The vacuum pump is switched on.

The duration of the main drying phase depends mainly on:

- the layer thickness of the product,
- the solid content of the product,
- the heat supplied to the product during the drying process,
- the vacuum pressure inside the drying chamber during the drying process.

With increasing pressure the rate of sublimation rises as long as it stays below the vapour pressure of the product. This is because at higher pressures the heat energy reaches the sublimation front of the ice core sooner. Therefore the drying period is shortened. The water vapor generated during the main drying phase is not intended to be removed by the vacuum pump. It is to be collected by the ice condenser. The purpose of the vacuum pump is to lower the partial pressure of the non-condensable gases so that the water vapor can be transported from the product to the ice condenser. However, small quantities of water vapor will be removed by the vacuum pump. The vacuum pump is equipped with a gas ballast valve that when open, removes traces of condensable vapors from the pump. For this reason the gas ballast valve can be open during the main primary phase. The gas ballast valve is not required for secondary drying and closing it will help achieve a lower level of vacuum.

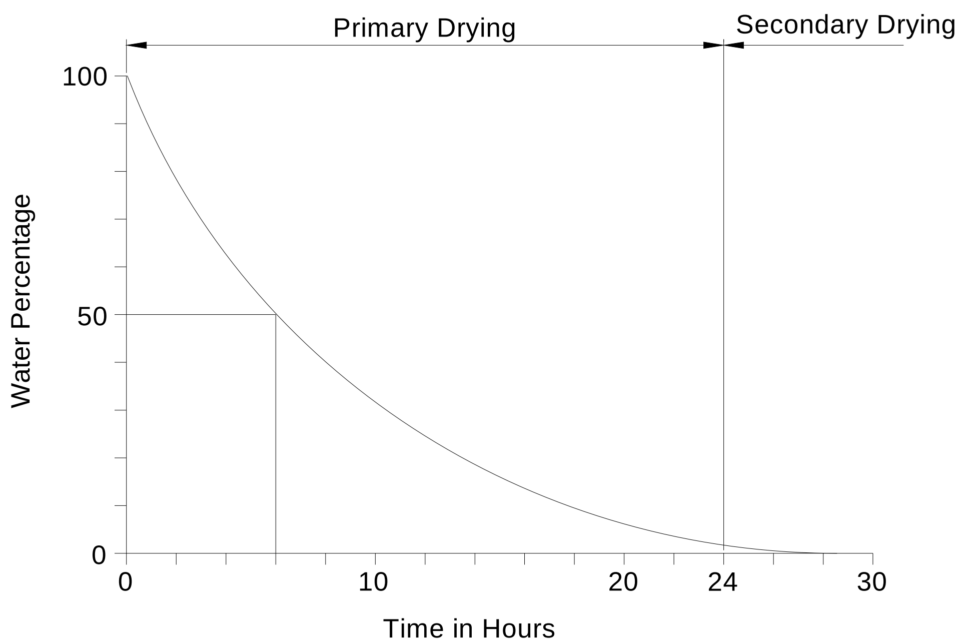
During primary drying the moisture is removed by sublimation and during secondary drying the bound moisture is removed by desorption. The recommended vacuum pump should reach with open gas ballast valve, a vacuum level lower than the relevant water vapour pressure.

Shelf temperatures can be raised in stages, at a controlled rate or set to maximum for fastest heat transfer. The heat input must of course not be enough to damage or melt the product. Too much heat will increase the amount of vapours to a point where the vacuum level diminishes to above the eutectic point of the product.

The residual moisture of the dried product depends mainly on:

- The temperature of the dried product during the final drying process,
- The final vacuum reached during the final drying process.

The end of the primary drying phase is reached when the product temperature is nearly the same as the shelf temperature (temperature difference between shelf and product approximately 3 to 5ºC). Once the primary drying is completed the secondary drying will remove the bound water from the product. The following diagram shows the drying process for a product containing approximately 10 % solid matter. During the first quarter of the primary drying phase approximately 50% of the water content is removed. During the next quarter of the primary drying phase approximately 50% of the remaining water content is removed. This continues until the drying curve approaches the time axis asymptotically. This typical drying curve is due to the fact that the area of sublimation recedes into the product and the remaining water vapour must pass through the already dried layers. During the drying process the resistance increases. The drying curve is determined by the latent heat of sublimation and the amount of vapour transported. In order to increase the specific heat conduction properties of the product and to keep the water vapour volume as low as possible it is necessary that drying takes place as close as possible to the solidification point or eutectic point.



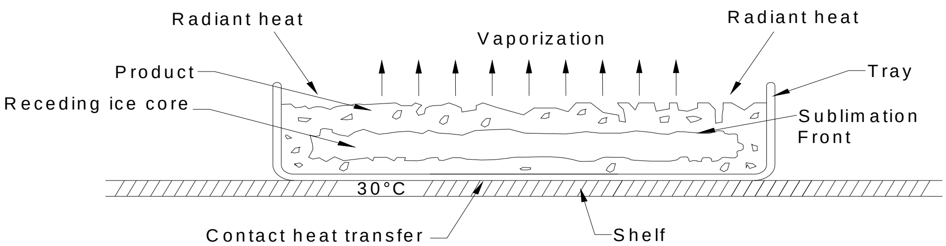
The drying time depends heavily on the vacuum level. The nearer the vacuum to the solidification point in accordance with the vapour pressure curve the shorter the drying time.

Facts regarding ice in a vacuum:

1.0 gram of ice at;
1.0 mbar assumes a volume of 1 m³ vapour
0.1 mbar assumes a volume of 10 m³ vapour
0.01 mbar assumes a volume of 100 m³ vapour

Heat supply during drying
The required heat supply to the product to be dried takes place by;
Conduction through contact in the drying chamber
Mild conduction through low pressure vapour
Radiant heat energy.

Affects of freeze drying of a product in a dish



Heat transfer takes place via the heated shelves by direct contact with the bottom of the tray. At the beginning of sublimation the transfer of heat is very effective from the wall of the tray to the frozen product. However, soon an area develops which is ice-free, porous, dried and has an insulating effect between the wall of the tray and the product. This slows down the heat energy transfer available to the ice core. The porous dried layer enables the passage of vapour from the ice core. If it is restricted the temperature will increase and ice core will thaw rather than sublimate. This applies especially to inhomogeneous products and to great layer thicknesses. During this drying phase it is important to regulate the heat supply and control temperature and pressure precisely.

2.4. Secondary drying

The final pressure in the drying chamber depends on the ice condenser temperature according to the vapor pressure curve above ice :

e. g. 1.030 mbar correspond to -20°C
0.370 mbar correspond to -30°C
0.120 mbar correspond to -40°C
0.040 mbar correspond to -50°C
0.01 mbar correspond to -60°C

The unit is in operating condition if the temperature of the ice condenser is lower than -50°C and the pressure is lower than 0.12 mbar. The final pressure measured when there is no product in the unit and its corresponding ice temperature is determined by the warmest ice surface in the condenser chamber.

2.5. Pressure rise test

The pressure rise test is a good way to confirm that there is no more vaporizing ice in the product. In the automatic cycle, parameters set on the engineering screen of the control system will be followed. It can also be performed manually by the operator. When the secondary dying stage is considered to be finished, a pressure rise test will ensure it is. The shelve temperatures and the vacuum levels will still be in secondary drying conditions. The isolation valve is closed and the operator will watch to see the rate at which the vacuum level in the product chamber increases. The vacuum level will rise even with dry product, however the rate at which it rises when ice is still vaporizing is much greater. The operator must perform tests to become familiar with these rates of pressure rise.

2.6. Air admittance

After the vials have been closed the vacuum in the chamber must be released by admitting air. Air will enter through the air admittance valve until the pressure is equalized and the door will release. This may take a few minutes.

2.7. Defrosting

Defrosting of the ice condenser is carried out manually by pressing the defrost button on the manual screen. Defrost time and temperature is adjustable on the engineering screen of the control system. The drain valve must be opened to allow the water/condensate out.

In the automatic program, defrost must be selected from the post program list. Defrost will perform automatically at the end of the process. It will follow the same conditions set on the engineering screen.

3. Installation and Commissioning of the 250KG Freeze Drier

3.1. Site of installation

If the freeze drier is to be situated in a large open area the heat exchangers can remain on the top of the unit. If it is to be in a smaller room then the heat exchangers will need to be fit outside of the enclosed area, preferably externally.

3.2. Mains power

The operating voltage on the name plate must correspond to the local supply voltage. The **250KG** requires a three-phase power supply 380 to 415 Volts. The freeze dryer must be on a circuit protected with 63 Amp fuses or circuit breaker.

3.3. Air / inert gas admittance

Filtered air can be admitted into the product chamber. If an inert gas is needed such as nitrogen then a supply of this is required usually a gas cylinder.

3.4. Drain valve for condensate

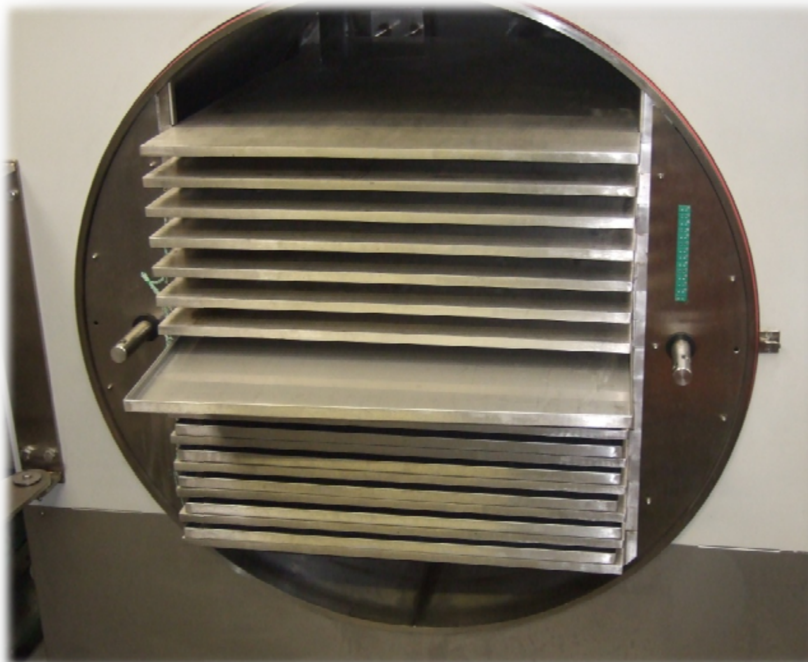
The drain valve can be piped to a floor drain or collecting vessel.

3.5. Vacuum pump exhaust gases

The oil mist has to be discharged outside. A hose can be connected to the exhaust flange of the vacuum pump that leads into the open air or a vent. During installation of the pipe special care must be taken that condensate cannot flow back into the pump.

4. Operating the 250KG

4.1 Loading Trays



4.1.2. Bulk trays

Bulk trays can simply slide onto the shelves. Trays can be supplied in various sizes to suit the application.

4.4. Vacuum Pump

There is a two vacuum pump combination fitted to the 250kg an Edwards EH250 and a E2M40

The EH250 is a mechanical booster pump
The E2M40 is a 2 stage rotary vane vacuum pump

There are several interlocks that prevent the vacuum pump from starting in ways that could cause problems.
These include not allowing the pump to start when:

- There is an insufficient temperature in the condenser chamber
- The drain valve is open
- The condenser chamber defrost is switched on
- Both the Product chamber air admittance and the Isolation valve are open.

In an automatic program the vacuum pump will be controlled completely by the PLC and no user operation is needed or allowed.

The vacuum pump oil should be changed when the pump is warm. The oil level should be visible in the sight glass. The intervals for changing the oil will depend upon the products being freeze dried. With the -80ºC condenser chamber version it will offer better pump protection than the -55 ºC The condenser chamber temperature must be lower than the temperature corresponding to the vapour pressure that the product is going to freeze dried at. In the case of water vapour the following is a good guide:

1.030 mbar correspond to -30°C
0.370 mbar correspond to -40°C
0.120 mbar correspond to -50°C
0.040 mbar correspond to -60°C
0.01 mbar correspond to -70°C
0.003 mbar correspond to -80°C

If the product contains large quantities of chemicals that are more volatile than water then lower temperatures in relation to vacuum levels are required.

An oil mist filter should be fitted to the exhaust port of the vacuum pump.

For extra information on the pump please see the separate operating manual.

4.5. Isolation valve

The Isolation valve can be activated by the extra buttons on the front of the control box when the PC or PLC is switched off. As with the ram and the pump it can be operated by using the controls on the Manual screen. To avoid problems there are two interlocks that prevent the Isolation valve from being opened when:

- The defrost is on
- The vacuum pump is running and the Product air inlet is open.

In an automatic program the Isolation Valve will be controlled completely by the PLC and no user operation is needed or allowed

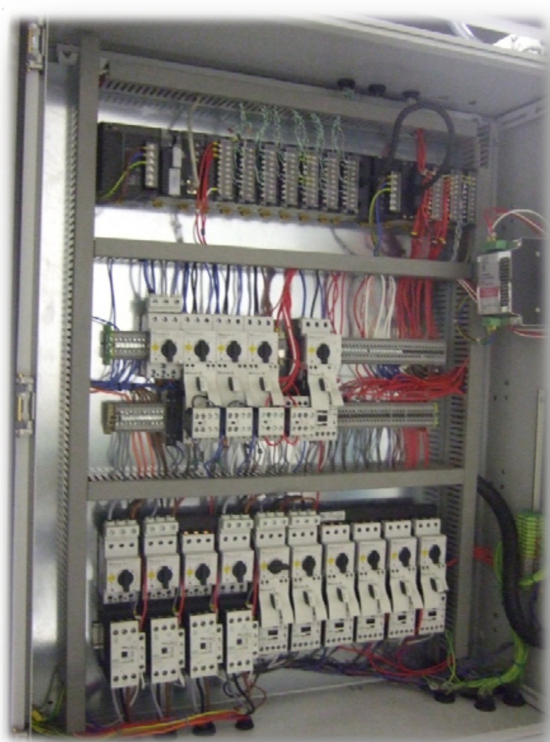
4.6. Air/inert gas admittance valve

Either filtered air or an inert gas can be admitted into the system.

4.7. Condenser drain valve

As with the Isolation valve, vacuum pump and ram, the condenser drain valve can be activated by the extra buttons on the front of the control box when the PC or PLC is switched off. It also can be operated by the controls on the Manual screen. To avoid problems there are two interlocks that prevent the condenser drain valve from being opened when:

- The condenser refrigeration is running
- The vacuum pump is running



4.8. Circuit breakers

The control box has circuit breakers that may trip out in the event of an electrical problem. If a function is not working, this is the first place to check. There are circuit breakers for the following items.

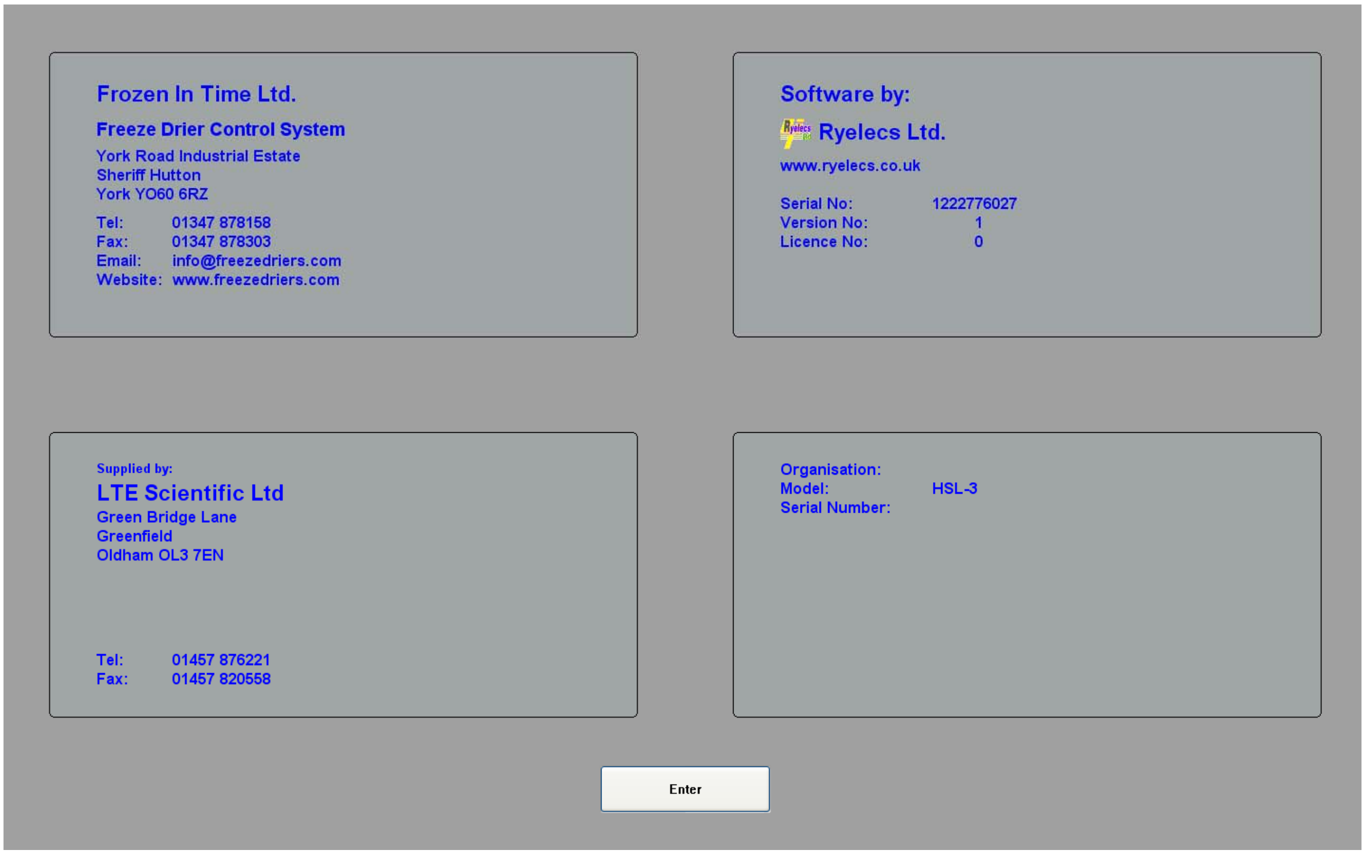
- PLC
- Control circuit
- Heater
- Condenser drain valve
- Isolation valve
- Circulation pump
- Refrigeration compressor 1 to 3
- Refrigeration Fans 1 to 5
- Vacuum pump 1 & 2

Please see wiring diagrams for more detailed information

5. The control system

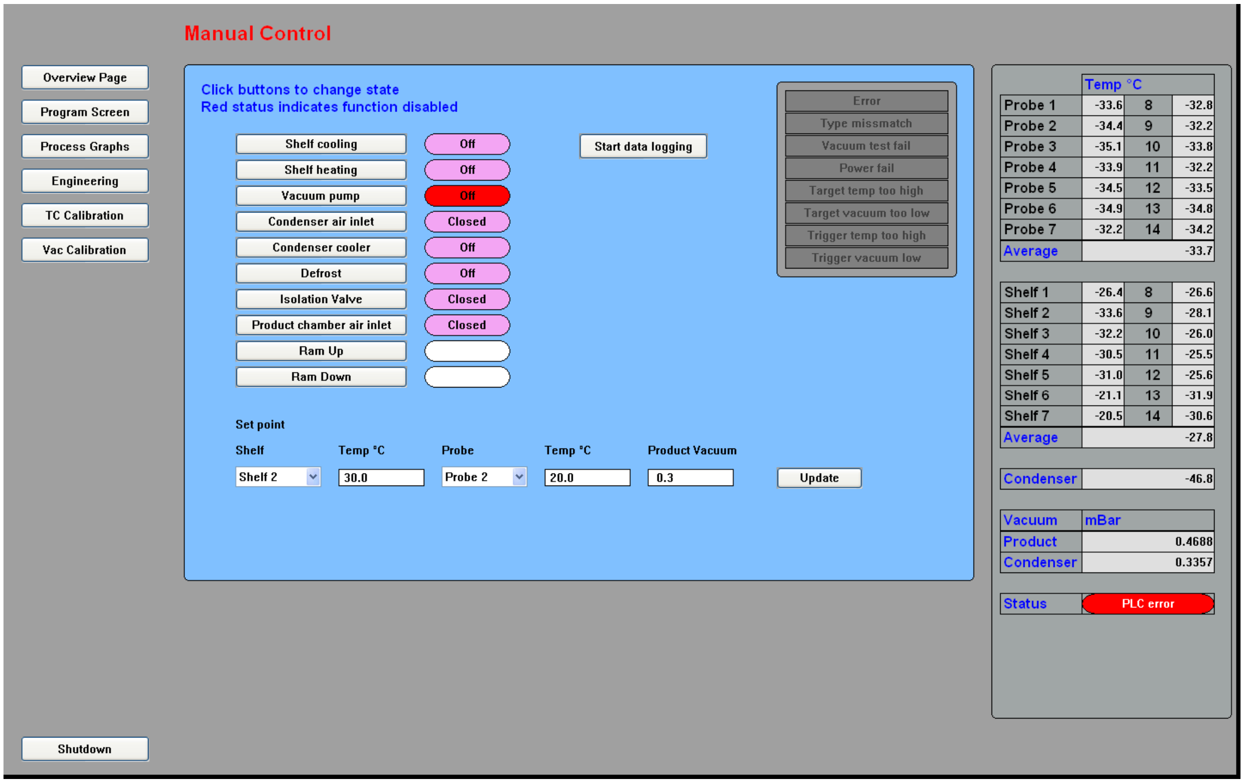
The control system for the freeze drier enables the operator to run the freeze drier fully automatically or manually. All data from the drying processes can be logged, saved and printed. The automatic cycles are easily programmed by the operator and can be saved or edited for later use. There is a manual screen for complete manual control. This is often used when trying out a new product before a program is confirmed. The data logging and programming are done on the PC. The running of the program is looked after completely by the PLC. If there is a power failure the computer will safely shut down with the use of a built in uninterruptable power supply

5.1. Start up Screen



This screen will appear on start up. Details of the machine Manufacturer, software provider and any supply company. The model, serial number and owner details are also on display. Press Enter to start the program.

5.2. Manual Control screen



This screen is for manual control. To change to another screen there are selection buttons the down the left hand side.

- Overview Page
- Program Screen
- Progress Graphs
- Engineering
- Thermocouple Calibration
- Vacuum Calibration

Next are the function buttons that are used to operate the freeze drier. To the right of each button is the function indicator.

Pink means that the function is off but can be activated.
Green means that the function is active.
Red means that the function is off and cannot be activated due to a current lock on the function. During an automatic run all the manual function buttons are locked.
The function buttons include.

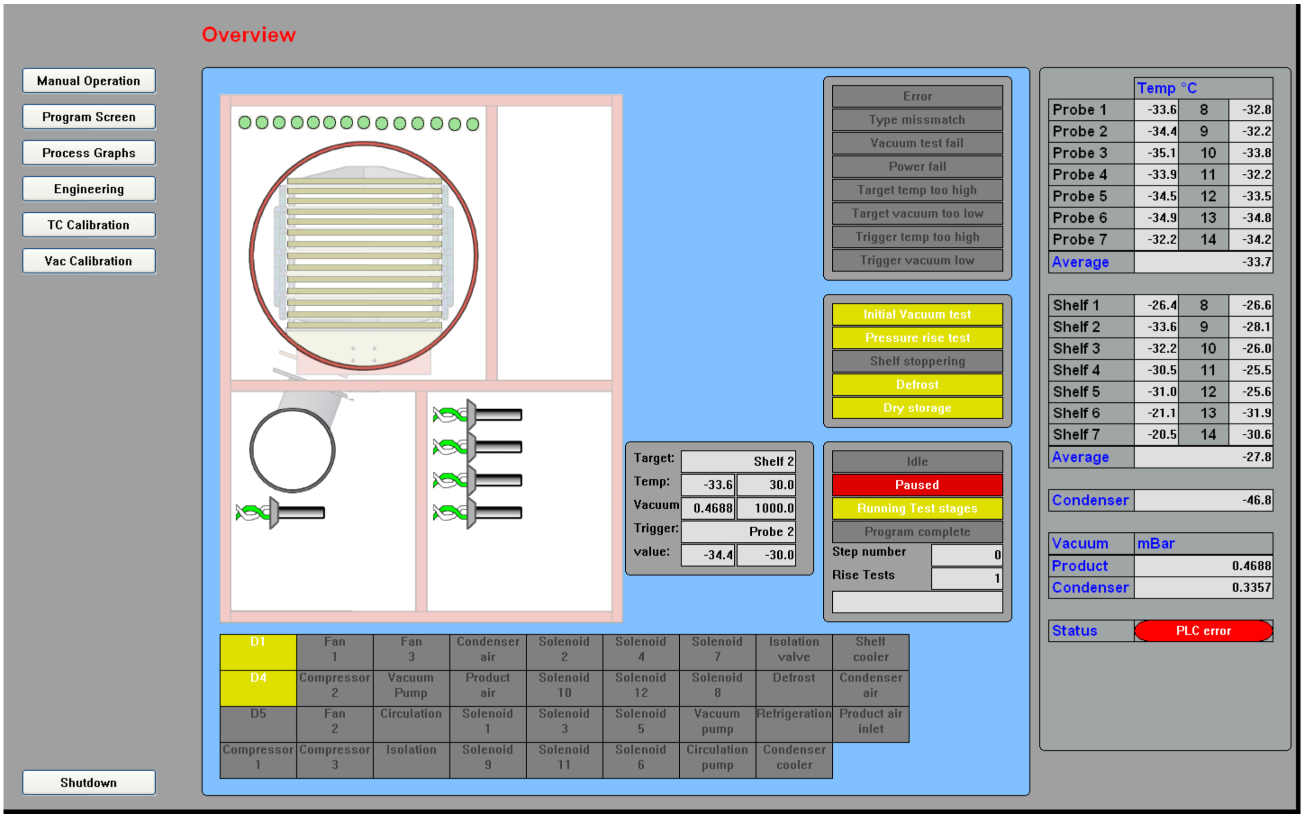
- Shelf Cooling
- Shelf heating
- Vacuum Pump
- Condenser Drain Valve
- Condenser Cooler
- Defrost
- Isolation Valve
- Product chamber air inlet

The ram function buttons require being pressed and held to operate.

On the right there is the graph data logging start/stop buttons. This will activate the recording of temperatures, pressures and time on the graph page.
To the right are the error readings. Please see section Computer error readings for further information.
On the far right are the temperature readouts of the shelves, probes and condenser. Below that are the vacuum levels in millibars of each chamber.

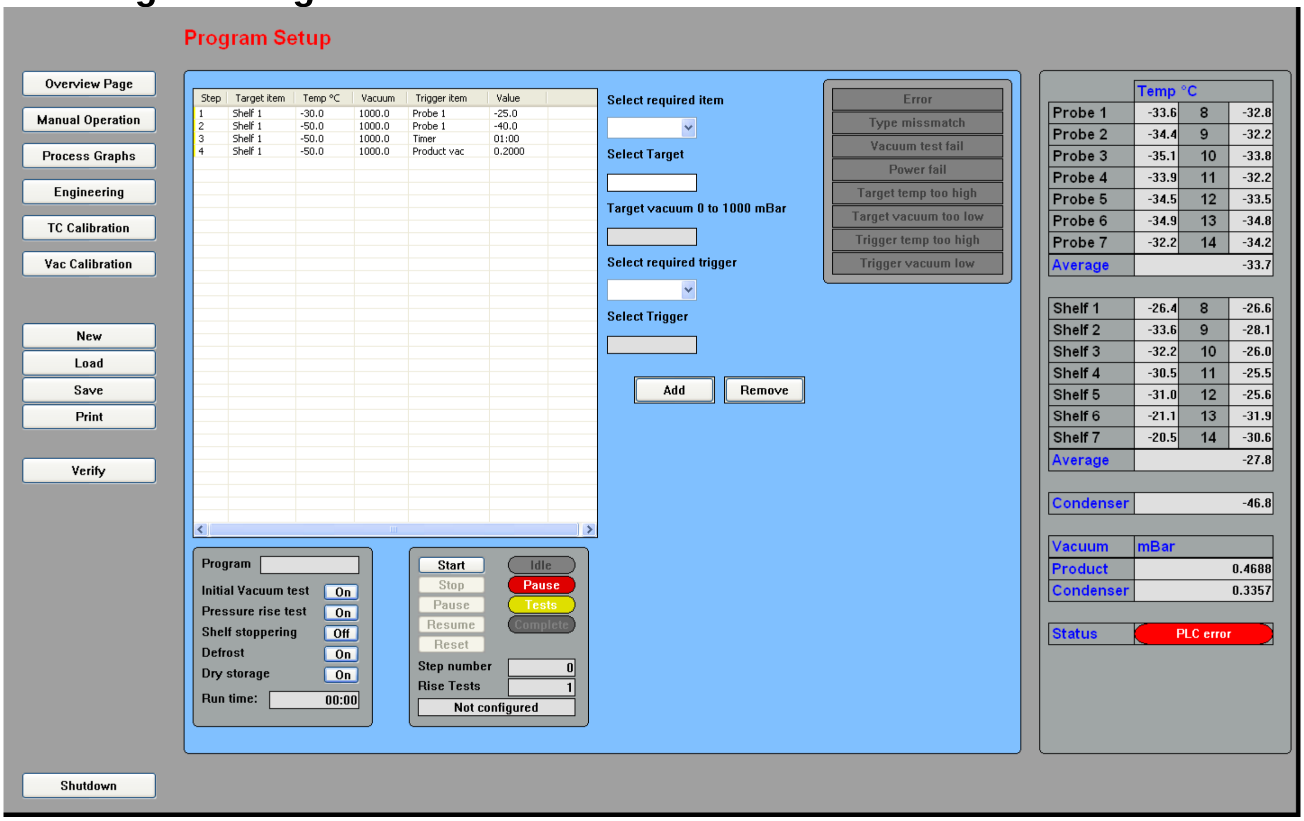
Set points are required to control temperatures and vacuum levels. If the product is to be lowered in temperature then it will be cooled by the shelf. There is a thermal lag between the shelves and the product due to the speed of thermal conduction. For fast cooling set the temperature of the shelf lower than the target temperature of the product probe. Once the product probe temperature has reached its set point or the shelf temperature reaches its set point then the cooling will stop. For example;
The shelf temperature is set at -60ºC and the probe temperature is set at -40ºC.
If the shelf reaches -60ºC before the product probe reaches -40ºC then the shelf will hold at -60ºC until the product probe reaches -40ºC.
If the probe temperature reaches -40ºC before the shelf temperature reaches -60ºC the product probe will control the shelf temperature.
The same principle applies when heating. The shelf can be set higher to allow the product to heat up quicker.
A further control on shelf heating is vacuum level. If vacuum pressure rises above its set point, heating is deactivated. As sublimation slows down the vacuum level will drop below the set point and heating switches back on.

5.3. Overview screen



This screen is for is an overview of the freeze drier it shows what parts of the freeze drier are running.
Vacuum and temperature set points, program step number and running status are also displayed.

5.4. Programming screen



The Program setup screen is for programming the automatic freeze drying cycle. To change to another screen there are selection buttons down the left side as on previous pages.

There are also options for:

- New - creating a new programs
- Load - load an existing program
- Save - save a program
- Print - the details of a program
- Verify – that program is within the capability of the freeze drier.

Next is the program step list. The automatic cycle is made up of programmable steps. The steps are entered using selection boxes directly to the right. There are also 5 pre-programmed steps that can be included in the program.

- Initial vacuum test
- Pressure rise test
- Shelf stoppering
- Defrost
- Dry storage

The selection boxes enable steps to be added. These include:

- Select required item (which shelf or probe to use)
- Select target temperature
- Target vacuum (if a vacuum is to be maintained)
- Select required trigger (time, temp or vacuum)
- Select trigger value (a value time, temp or vacuum)

Steps can be copied, moved, edited or deleted.

The usual indications are given in the error code box. The right side shows the live temperatures and vacuum levels.

To start the program, press the start button. If it is to be stopped during the cycle, press the stop button or the pause button. At this point the cycle can be reset or resume.

The function buttons are used to operate the freeze drier. To the right of each button is the condition of the function.

Pink means that the function is off but can be activated.

Green means that the function is active.

Red means that the function is off and cannot be activated due to a current lock on the function. During an automatic run all the manual function buttons are locked.

The function buttons include.

- Shelf Cooling
- Shelf heating
- Vacuum Pump
- Condenser Drain Valve
- Condenser Cooler
- Defrost
- Isolation Valve
- Product chamber air inlet
- Product chamber gas inlet
- Ram up
- Ram down

The ram function buttons require being pressed and held to operate. On the right there is the graph data logging start/stop button. This will activate the recording of temperatures, pressures and time on the graph screen.

Program setup

The program setup requires the input of a sequence of steps to complete a freeze drying cycle. The operator will define the running conditions within a step and an achievable value to prompt the next step. This value may be a temperature, a vacuum level or a time delay.

When a temperature is entered, the operator will need to specify which temperature probe is to be used.
Each shelf has a built in probe, these probes are listed: Shelf 1, Shelf 2………..
Each shelf has a mobile product probe, these are listed: Probe 1, Probe 2…………
When a vacuum is not required for initial freezing then this box can be left blank.
The following is a simplified example of programming a freeze drying cycle to explain the procedure.

Pre step

The operator may choose to activate the pre step listed as "**Initial Vacuum test**" this ensures that the chambers are going to be vacuum tight before the process is allowed to start.

Entering the first step

This is where a shelf or probe can be chosen for setting a target temperature. A triggering condition is set to initiate the next step.
To freeze the product to -40ºC the operator could do the following:

The first method
Select the required item as a shelf 1 temperature at -50ºC which would allow the shelves to cool down to this point. As the shelves cool down so will the product. The trigger Item would be a product probe 1 set at -40ºC. Upon reaching this the next step will be activated. Depending on the type or quantity of product, the thermal lag between the shelves may vary. In the time it takes the product to reach -40ºC the shelves may or may not reach -50ºC however they will not go below.
The disadvantage of this is:
Setting a minimum shelf temperature gives a constant temperature to absorb heat from the product. As the product temperature gets closer the temperature difference gets less. Therefore the rate of cooling is reduces. Freezing will take longer.
The advantages of this are:
The overall Product temperature will be much more even.
There is less chance of product temperature over shoot.

The second method
Select the required item as a probe 1 temperature at -40ºC. Set the trigger item probe 1 at -40ºC. This way the shelf will cool as cold as is possible for the refrigeration system.
The disadvantages of this are:
The overall Product temperature will be much less even.
There is more chance of product temperature over shoot.
The advantage of this is:
Fastest rate of cooling due to greater temperature differences between product and shelf

Entering the second step

A time step could be used to allow the product to stabilize in temperature. The temperature of the product probe can stay the same so probe 1 is set to -40ºC. If the time step was set to one hour, the next step would be triggered after this time.

Entering the third step

The third step could be to create a vacuum on the product. The temperature of the product would not need further cooling so probe one would remain at -40ºC. A vacuum trigger would be selected next with a value of 0.1mbar. The condenser chamber would be automatically cooled to -30 ºC and the vacuum pump would start.
Once 0.1mbar has been reached the next step would trigger.
As this is the first step that the vacuum is used a value can be into the target vacuum box. This is the vacuum control setting. This setting will prevent the heater from activating while the vacuum level is above the value entered. As the probe 1 temperature is set at -40ºC the system would try and maintain this using heating or cooling. As the vacuum level improves the product will cool by sublimation so the heater would attempt to counter this.
Entering a value into the target vacuum box the same as the trigger value would prevent the heater from activating and allow natural vacuum cooling. The temperature will drop depending upon the level of vacuum created. If the box is left empty or a higher value is entered than the value in the target box then the heater would attempt to maintain probe 1 at the set temperature.
Due to the heat input there will be more sublimation occurring while initial vacuum is being drawn. This will increase the length of time taken to achieve the initial vacuum level.

Entering the fourth step

The fourth step would be to heat the product up to 40ºC while maintaining a vacuum level below a set point. This set point is of most importance at the beginning of the primary drying stage when the sublimation rate is at its highest. If the vacuum level rises above a set value then the ice in the product will start to melt. The vacuum control level will ensure that the ice core of the product stays frozen. To achieve the maximum rate of sublimation the vacuum level must correspond to a vapour pressure of a temperature as close to the eutectic point as is safely possible.

With regards to setting the temperatures similar methods as in the first step can be applied. Set a maximum shelf 1 temperature, reducing the chances of over shoot, but expect heat transfer to take longer. Or allow the shelves to heat up to their maximum temperature allowed (settings are in the engineering page) increasing the heat transfer rate, but also increasing the chances of product temperature overshoot.

Entering the fifth step

The fifth step could be a time step to allow the product to stabilize in temperature.
The temperature of the product probe 1 can stay at 40ºC. If the time step was set to one hour, the next step would be triggered after this time.

Entering the sixth and final step

The sixth step in this example would be secondary drying. This can be considered as another vacuum step.
The temperature of the product does not need further cooling. Select a trigger item as vacuum, with a value of 0.05mbar. When 0.05mbar is achieved it is the end of the programmable steps. If selected there may be some post steps to complete.

Notes:

Usually programming an automated freeze drying process will involve many more steps detailed steps. As there are several shelves it is sometimes important to repeat each temperature step for each shelf or product probe. This will ensure that every probe reaches the set points required.

Post steps

These include;

- Pressure rise test
- Defrost
- Dry storage

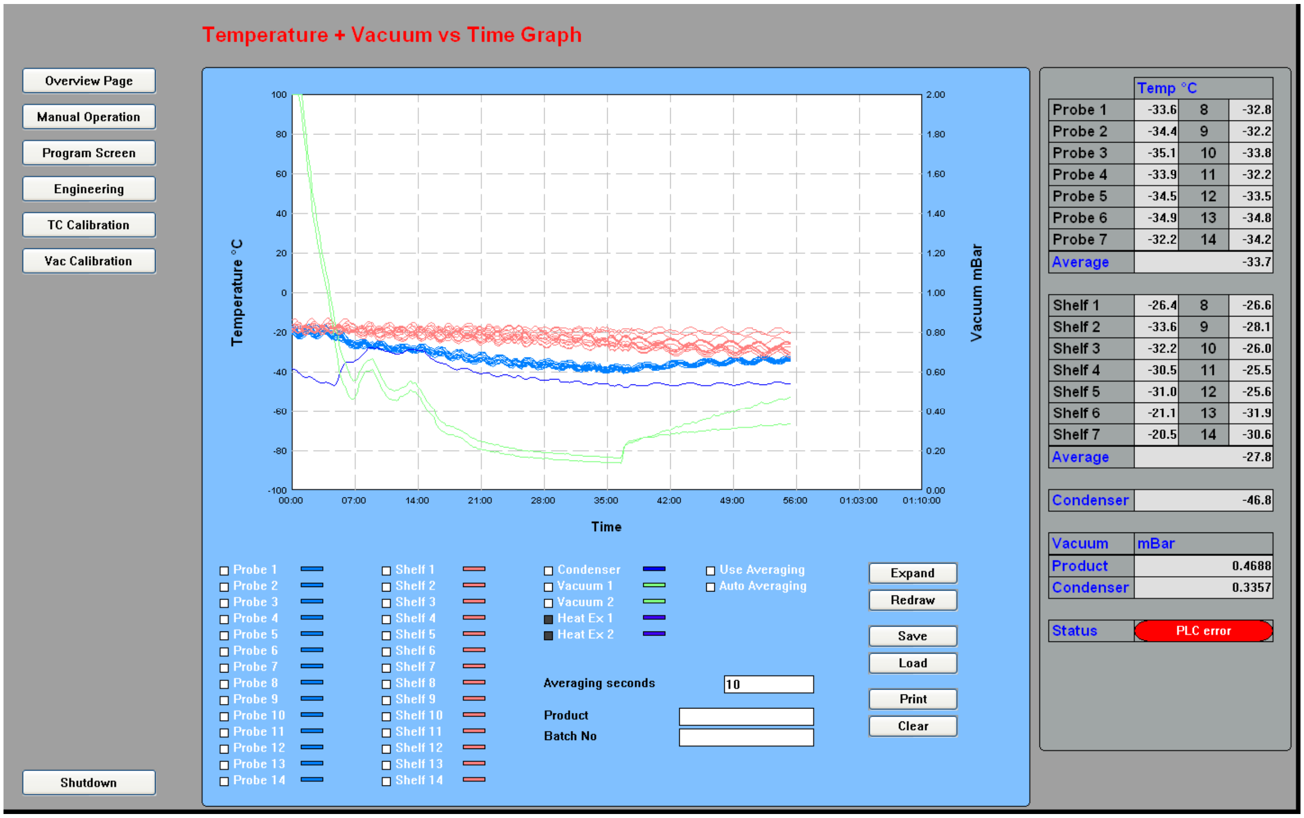
The pressure rise test if selected will occur after the last of the programmed steps has ended. The isolation valve will close. An initial vacuum reading in the product chamber will be taken. After a preset timer has lapsed another vacuum reading will be taken. If the pressure rise is within an allowable range then the next post step will activate. If the pressure rise is too high then the valve will re open and drying will continue for a time span before retesting.

If defrost is selected the condenser drain will open and defrost will activate. It will run for a preset length of time and not exceeding a preset temperature.

Dry storage is a means of storing the product within the freeze drier at a controlled temperature once the process has ended. This is useful if the product finishes its process in the middle of the night and there are no operators to unload it. If products are usually transferred to a fridge after drying then the freeze drier can match these conditions for ideal storage until unloading can take place.

The settings for the post and pre steps can be altered within the engineering screen.

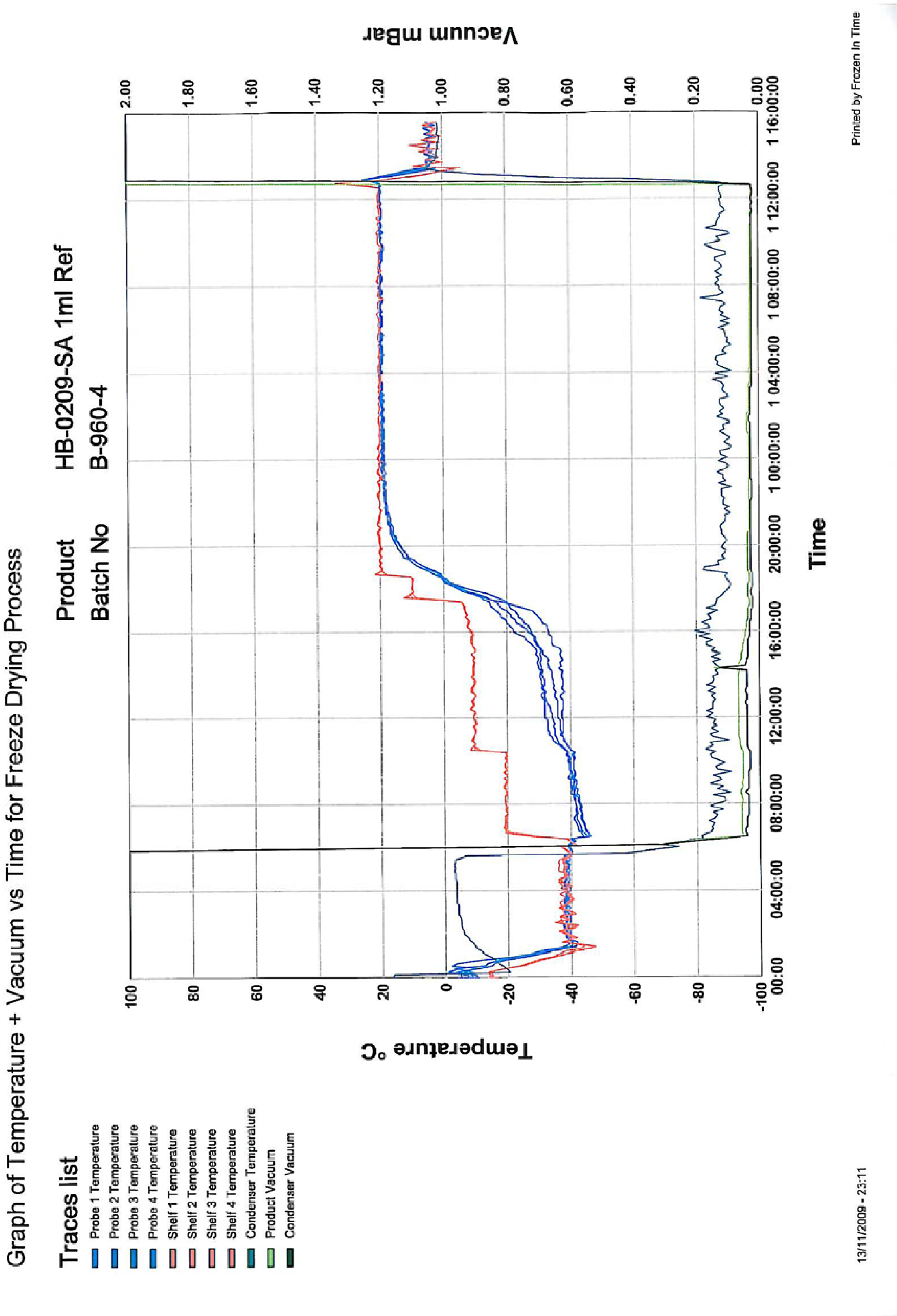
5.5. Progress graph screen



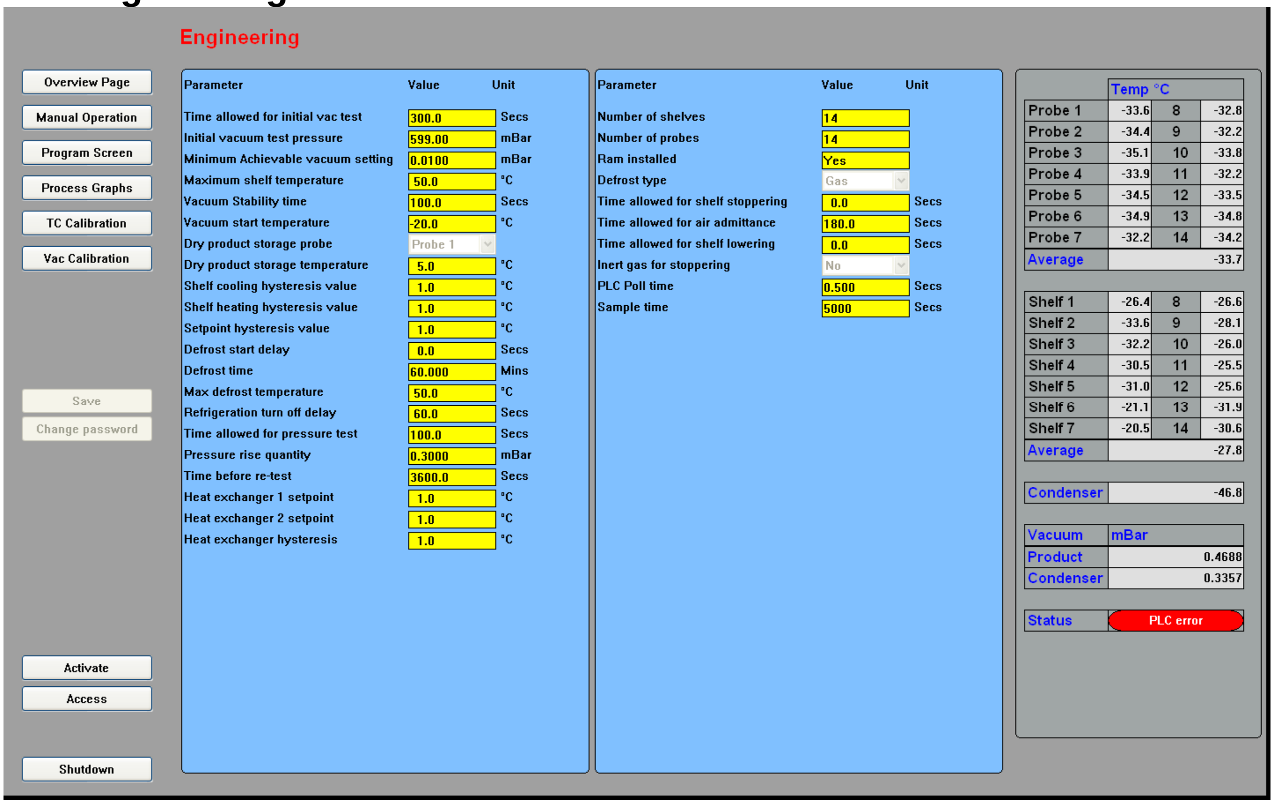
The data logging monitors temperatures of all mobile probes, shelves, condenser and vacuum levels. Information on temperature and vacuum changes becomes very easy to analyze on a line graph. Lines can be hidden to show the lines that are most important. Lines can be given separate colours for easy identification. Zoom and scale are available to pin point curves of most importance. The graph will auto scale as the cycle runs. The information can be saved or printed for records of products and individual batches.

5.6. The Graph print out

Below is an example of a cycle printout. On the left there is a key to identify graph lines. Product and Batch identification appear as the heading.



5.7. Engineering screen



The engineering screen is password protected to stop unauthorized alterations to running parameters. There are two levels of password protection; the first is accessible by an authorized operator who would find it necessary to change settings between different products. The next level is only accessible for equipment setup.

Time allowed for initial vacuum test

This is the time that the vacuum pump will run during an initial vacuum test to confirm the chamber is leak tight before an automated program can start. A moderate vacuum level is set of approximately 600 mbar to confirm doors are closed and the vacuum pump is switched on at the motor. Depending on the volume of the chamber, a sensible time is allowed for this test. As soon as the vacuum level is achieved within the time frame, the test is complete. If the required vacuum is not achieved within the set time the program will not commence. The problem will require investigation.

Initial vacuum test pressure

This is the box were the vacuum level is entered. As mentioned above a sensible setting is 600 mbar, this is only achievable with a leak tight vacuum system. This vacuum level will not adversely affect unfrozen product.

Minimum achievable vacuum setting

This setting is to prevent an operator programming the automated cycle with unachievable vacuum level.

Maximum shelf temperature

This setting is to prevent the temperature of any shelf from exceeding a desired limit. It also prevents any values above this level being entered into the programming steps.

Vacuum stability time
The vacuum pump will only start when the condenser temperature is below a set level (Vacuum start temperature). As the temperature drops in the condenser temperature it may fluctuate around the temperature set point momentarily.
A time delay (vacuum stability time) will stop the pump switching on and off while the temperature hovers around the set point.

Vacuum start temperature
This is the temperature set point that does not allow the vacuum pump to start until the condenser temperature is below it. Usually set at -30ºC. This will stop unfrozen water vapour being drawn into the vacuum pump.

Dry product storage probe
This is the product or shelf probe that is used to control the temperature when the freeze dryer is in dry storage mode. Dry storage can be selected to run after the automated freeze drying cycle has ended if the product is not unloaded straight away. If a cycle ends during the night and the operator cannot unload the freeze drier, preferred conditions such as fridge temperatures can be matched on the shelves. A product or shelf probe may be chosen for this control.

Dry product storage temperature
This is the temperature that dry product will be controlled to if dry product storage is selected.

Shelf cooling hysteresis
To achieve shelf temperature control and eliminate rapid switching between heating and cooling, hysteresis values can be entered. A typical value would be 1ºC would be set at the factory. This could be altered on the engineering screen by the operator.

Shelf heating hysteresis
To achieve shelf temperature control and eliminate rapid switching between heating and cooling, hysteresis values can be entered. A typical value would be 1ºC would be set at the factory. This could be altered on the engineering screen by the operator.

Set point hysteresis
This is a general set point for other thermal controls including defrost and condenser refrigeration.

Defrost start delay
Condenser chamber defrost. This a time delay before the defrost starts.
The defrost is hot gas defrost.

Defrost time
This is the time that the condenser chamber will be heated for. A setting that will give enough time to melt all the condensed ice is required. This can be set by the operator to suit the application of the freeze drier.

Maximum defrost temperature
This is the maximum temperature that the condenser temperature is allowed to reach while defrosting.

Refrigeration turn off delay
The compressors of the refrigeration system will continue to run for a period of time after the refrigeration has been switched off. This will prevent liquid refrigerant being left in areas of pipe work that are exposed to high temperatures.

Time allowed for pressure rise test
The end of the automated cycle has the option a pressure rise test. This is where the product is sealed off in the product chamber to see if sublimation has finished. If the pressure rises above the set limit (pressure rise quantity) it can be considered to not be dry, as sublimation is still occurring. If the pressure rise is within limits the product is dry. For the pressure rise test there is a set time frame that the pressure rise can occur within.

Pressure rise quantity
The end of the automated cycle has the option a pressure rise test. This is where the product is sealed off in the product chamber to see if sublimation has finished. If the pressure rises above the set limit it can be considered to not be dry as sublimation is still occurring. If the pressure rise is within limits the product is dry. For the pressure rise test there is a set vacuum level that is allowable. A rise above this pressure indicates that the product is not dry and the test has failed.

Time before retest
A fail is if the pressure rises beyond the allowable **pressure rise quantity** within the **Time allowed for pressure rise test.** Time before retest is the time that the product will have back under drying conditions before the next test.

Number of shelves
The number of shelves fitted to the machine. This will be set up in the factory. The right hand side live temperatures will rearrange on the screen to evenly fill the space available with the correct number of shelf temperature boxes.

Number of probes
The number of product probes fitted to the machine. This will be set up in the factory. The right hand side live temperatures will rearrange on the screen to evenly fill the space available with the correct number of product probe temperature boxes.

Ram installed
Some freeze driers have a vial closing device and therefore have a hydraulic ram. This will be set up in the factory. If there is no ram installed then NO will be selected. If a ram is installed, YES will be selected.
Screen function buttons will adjust appropriately.

Defrost type
This will have been selected at the factory.

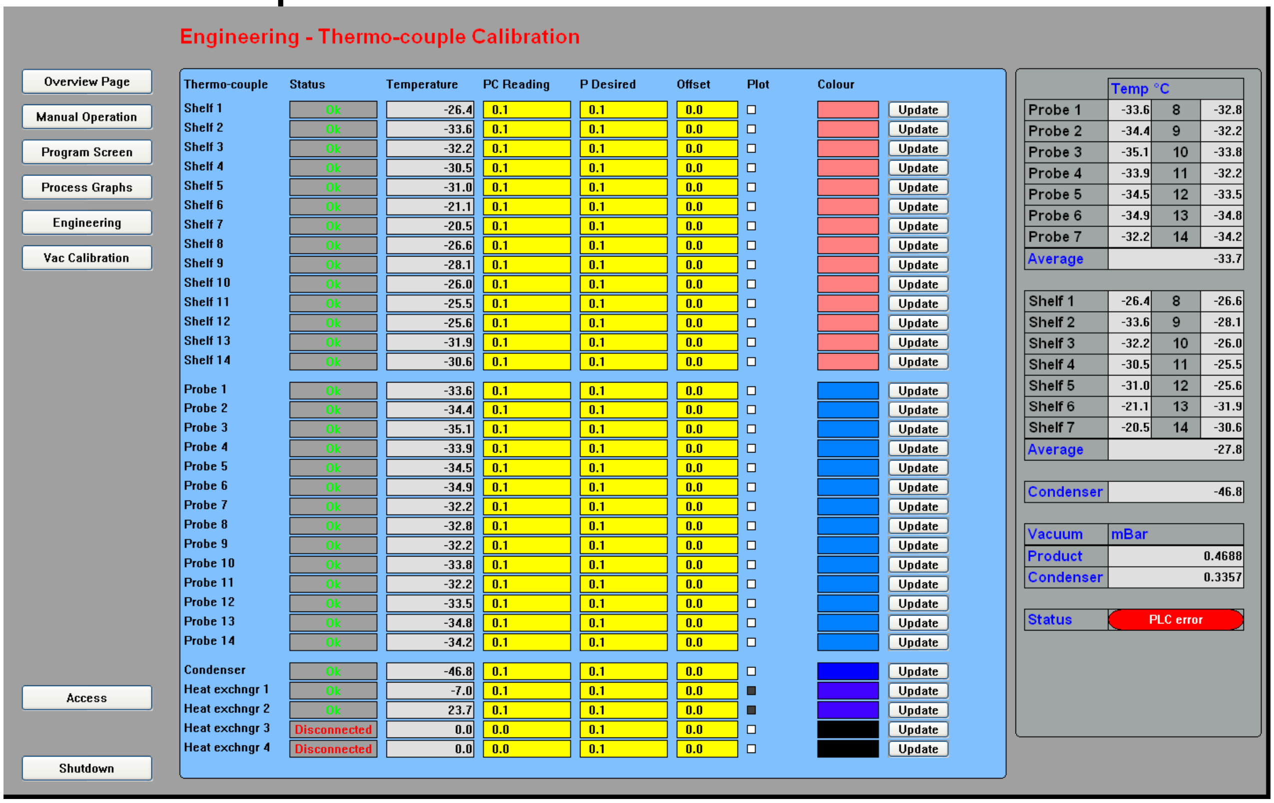
Time allowed for air admittance
Air or an inert gas can be admitted into the product chamber. If the product is to be sealed under vacuum then air should be adequate for back filling the chamber once the vials are sealed. If the vials are to be filled with a partial or full pressure of inert gas, nitrogen for example should enter before the vials are closed. The air or gas enters the chamber through solenoid valves. The valves are quite small and time taken for back filling the chamber can be several minutes. A value is entered that gives enough time for the chamber to reach an appropriate pressure, either partial or full. Tests can be made to help arrive at an ideal time frame. This will be set up initially in the factory.

Inert gas fill
Air or an inert gas can be admitted into the product chamber. If the product is to be sealed under vacuum then air should be adequate for back filling the chamber once the vials are sealed. If the vials are to be filled with a partial or full pressure of inert gas, nitrogen for example should enter before the vials are closed. The air or gas enters the chamber through separate solenoid valves. Select YES for inert gas fill and NO for air fill.

PLC poll time
If displayed this will give the communication speed between the PC and the PLC

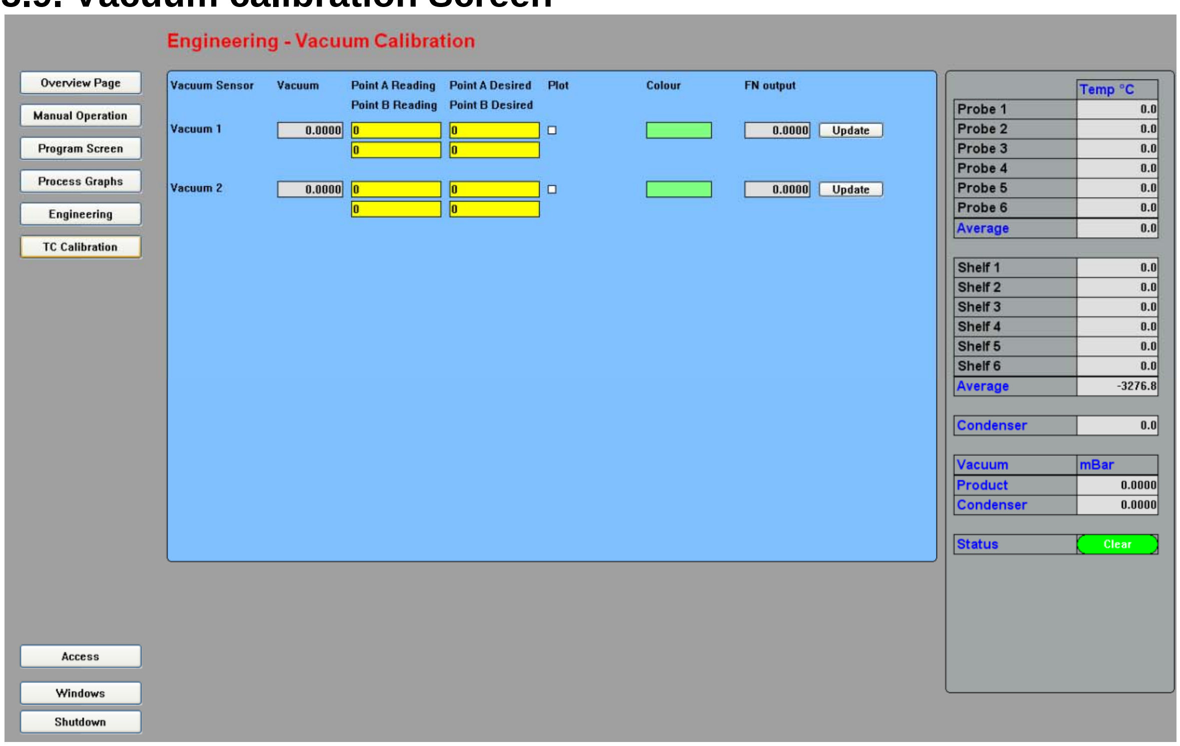
Sample time
If displayed this will show the sampling speed of the temperature and vacuum sensors

5.8. Thermocouple calibration Screen



This screen is for factory setup or periodic temperature calibration. Sensor connection status, PLC temperature reading, correction scaling and offset can be set to give the correct reading.

5.9. Vacuum calibration Screen



This screen is for factory setup or periodic vacuum calibration. Sensor connection status, PLC Vacuum reading, correction scaling and offset can be set to give the correct reading.

6. Troubleshooting

6.1. Power failure

The freeze drier will resume its program or settings after a power failure. In the event of a power failure in the drying phase, the batch may become unusable. Whether the batch can be saved or not depends on the drying phase in which the product was in when the power failure occurred. If power returns within a few minutes then it is unlikely that any damage will have occurred. It is important to distinguish between the primary drying phase and the secondary drying phase. The product is in the secondary drying phase if the residual moisture has reached approximately 5 %. Below this value, the product is generally not damaged by a power failure.
If the product is in the primary drying phase, it is recommended that the product is refrozen.
It is also advisable to defrost the condenser chamber at this point.
If the product is considered to be still usable then freeze drying can restart.

6.2. Insufficient vacuum

Is the vacuum pump is running? If not:

- Check that the pump motor switch is on
- Check that the IEC connection lead is connected
- Check that the vacuum pump circuit breaker has not switched off.
- Check that the contactor is operating.

If the vacuum is sufficient on the condenser chamber but significantly worse on the specimen chamber:

- Check that air admittance and inert gas valves are closed on the overview or manual screen.
- Check all vacuum connections on specimen chamber including door seal. Repair or replace.
- Check for oil leakages from the shelf thermal fluid. Oily residue may collect in the chamber.
- Check for water from cleaning or spilled product residue, this may vaporize preventing vacuum.
- Remove panels and listen for leaks after a vacuum evacuation has been tried.

If the vacuum cannot be achieved in the condenser chamber with the isolation valve closed:

- Check all vacuum connections on condenser chamber including door seal. Repair or replace.
- Check the condition of the isolation valve sealing surface. Glass pieces from broken vials can slit the rubber seal. If there is a doubt about this coat in vacuum pump oil or vacuum grease and test to see if there has been an improvement in the vacuum level.
- Check that there is no suction on the condenser drain hose. This would indicate a leaking valve.
- Check the vacuum pump is pulling an adequate vacuum, test with a separate vacuum sensor.
- Check that the isolation valve is sealing by opening it and pulling a vacuum on the product chamber as well, eliminating the seal of the valve.

If the vacuum pump cannot achieve a sufficient vacuum then replace it or get it repaired.

6.4. Insufficient cooling of the condenser chamber

If the condenser chamber is not reaching the relevant temperature -55ºC or -85ºC
(Please allow 15% for high load conditions)

- Check to see if there is liquid flow in the refrigeration sight glass. Contact the manufacturer, supplier or a local refrigeration engineer.
- Check the circuit breakers for compressor 1, compressor 2 and fans.
- Check that the contactors are operating.
- Check the overview screen to ensure that refrigeration and condenser cooling are operating.

If defrost is not heating up.

- Check the circuit breaker for defrost
- Check that the contactor is operating.
- Ensure that defrost is activated on the overview screen
- Check that the settings in the Engineering screen are allowing its activation
- Check that temperature control is not controlled by a sensor that is malfunctioning and reading an incorrectly high temperature.

6.6. Insufficient cooling of the shelves

If the shelves are not reaching low set points or relevant temperature -45ºC or -70ºC

- Check to see if there is liquid flow in the refrigeration sight glass. Contact the manufacturer, supplier or a local refrigeration engineer
- Check the circuit breakers for compressor 1, compressor 2, fans and circulation pump
- Check that all the contactors are operating.
- Check the overview screen to ensure that refrigeration, shelf cooling and circulation pump are operating.
- Check that temperature control is not controlled by a sensor that is malfunctioning and reading an incorrectly low temperature.

6.7. Insufficient heating of the shelves

If the shelves are not reaching high set points or the relevant temperatures 60ºC to 80ºC.

- Check the circuit breaker for heater and circulation pump.
- Check that all the contactors are operating.
- Ensure that heater and circulation pump are activated on the overview screen.
- Check that shelf temperature control is not controlled by a sensor that is malfunctioning and reading an incorrectly high temperature.
- Check that there is not an unachievable vacuum set point entered preventing the heater from being activated.
- Check that the settings in the Engineering screen are allowing its activation

6.8. Fluctuations in shelf temperatures

If the shelf fluctuations are high it could be due low levels of thermal fluid in the system. Fluid levels should be topped up when the fluid is at its maximum operating temperature. This is when the level is at its highest it will ensure that no over flowing can occur later. Be sure to reconnect the nitrogen blanketing system after the fluid has been accessed.

Shelf fluctuations occurring when the fluid is below 0ºC. This can be caused when water vapour enters the thermal fluid and when it freezes it creates a flow restriction. Please contact the manufacturer, supplier or trained maintenance department. Maintaining a positive nitrogen blanket above the fluid prevents this situation from happening.

Malfunctioning thermocouples can cause sporadic readings or solidly fixed irrelevant readings.

6.9. Defrost will not drain away

If the condenser chamber will not drain away after defrost it could be due to a blocked pipe. However first check that the drain valve is opening.

- Check the overview screen to see if the indicator shows that it is activated.
- Check the circuit breaker for the drain valve
- Check that the contactor is operating.
- Check the valve actuator and see if the indicator dial is reading open.
- Check that the manual handle is turning as the valve is activated.

6.10. Air admittance will not open

If the vacuum cannot be broken in the product chamber the air admittance valve may not be operating. If it is remove the filter or Nitrogen supply line and try again.

6.11. Isolation valve will not open

If the Isolation valve does not operate:

- Check the overview screen to see if the indicator shows that it is activated.
- Check the circuit breaker for the Isolation valve
- Check that the contactor is operating.
- Check the valve actuator and see if the indicator dial is reading open
- Check that the manual orange handle is turning as the valve is activated.

6.12. Doors will not seal under vacuum

If the doors will not seal under vacuum

- Check that the vacuum pump is running
- Close the isolation valve and check that the condenser door is sealing
- Check that the air admittance valves are closed
- Clamp the product chamber door and check that it is pushed up against its seal all around.
- Open the isolation valve and release the door clamps.

Does the door still open?

6.13. Incorrect probe temperature

Incorrect probe temperatures can be due to

- Unplugged probes
- Broken thermocouples
- Thermocouples with loose connections
- Incorrectly calibrated thermocouples

6.16. Trays are distorting

Large trays can have a tendency to distort with high and low temperature. Avoid using large trays where possible. When they are cold they tend to twist and when they are warm they tend to bow. The shelf to tray contact becomes less and freeze drying rates are reduced. If they must be used it is a good idea to clamp the sides down using the shelf closing device. Be careful not to restrict the flow of vapours from the trays to the condenser.

6.17. Computer error readings

On the lower right side of all screens there is a box giving the status of the connection between the PC and the PLC. If it is green and reading clear the connection is good. If it is red and the reading is PLC error the connection is bad or the PLC is switched off.
There is also a box of eight error messages that display on the programming and overview screens.

7. Maintenance

7.1. Condenser chamber

Before each start-up, ensure that condenser chamber is drained.

7.2. Heat exchanger

The refrigeration heat exchanger is used to cool the refrigerant compressed by the refrigeration unit. The heat exchangers are located on each side of the unit and should be kept free of dust or dirt residues. The heat exchanger can be cleaned by brushing, using a vacuum cleaner from the outside or by using compressed air from inside of the unit. Excessive build up on the heat exchanger leads to a decrease in performance and may cause a failure of the unit.

7.4. Rubber seals

Special attention must be paid to the rubber seals. If the seals are dirty, they must be removed, cleaned and slightly greased with vacuum grease. If they show signs of cracking they must be replaced.

7.5. Vacuum pump

Clean up any oil spills on or around the freeze drier from oil changes.
For the maintenance of the vacuum pump, please refer to the separate operating manual.
Additionally:
The oil level of the vacuum pump must be regularly checked at the sight glass (in case of continuous operation at least once a day). Top up oil to the required level via the oil inlet. Due to possible operation with gas ballast, oil consumption cannot be avoided. For topping-up see the operating manual of the pump. The oil change should always be carried out with warm pump.

7.6. Exhaust filter

The exhaust filter should be replaced if it becomes saturated. Where possible there should still be a pipe after the exhaust filter leading into open air. Take care that the condensate in the filter does not rise too high.

7.7. Cleaning

Cleaning the freeze dryer

Use soapy water or other water-soluble, mild cleaning agents to clean the freeze dryer. Avoid corrosive and aggressive substances. Do not use alkaline solutions, solvents or agents with abrasive particles. Remove product residues from the ice condenser chamber using a cloth. It is recommended to open the doors of the freeze drier when it is not in use so that moisture can evaporate.

If there is the risk of toxic, radioactive or pathogenic contamination, special safety measures must be considered and adhered to.

7.8. Checks by the operator

The operator has to ensure the important parts of the freeze dryer and those necessary for safety are not damaged. This especially refers to:

- Doors and hinges
- Seals
- Oil level of vacuum pump
- Heat exchangers
- Exhaust filter