Forcing Guide / Rooting Rooms

International
Flower Bulb
Centre

1. Construction and equipment of rooting rooms

Introduction

Storage rooms are used for a variety of purposes, including heat treatments and dry cold storage. They may also be used as rooting rooms for bulbs planted in trays and pots. This places certain demands on the construction of rooting rooms. This section sets out all there is to know about rooting rooms.

Insulation, condensation and thermal bridges

Insulation plays a vital role in the creation and maintenance of the right environment in the rooting room. There are a number of insulation materials available for this purpose, all of which have advantages and disadvantages.
The following factors play a role in the choice of materials

- insulation value
- price
- means of attachment
- stability
- flammability
- fungus resistance
- attraction of vermin (including mice)
- durability
- shrinkage

Insulation

Insulation is a process whereby air trapped in the insulation material prevents the material from conducting heat. The insulation capacity of a particular material should be the first consideration in choosing the right material. The total insulation value, also known as the K-value, is the sum of the insulation capacities of the wall construction and insulation material.

Insulation layer

The walls of the storage room must be properly insulated. Heat conducted in the cold room must be extracted by means of vaporizers. For the heat permeability of the wall a guideline value of maximum 0.2 Watt/m2.K (0.26 kcal/m2h.°C) is maintained.
In practice this means that walls require a minimum layer of 12 cm of Polystyrol (PS) or 10 cm of Polyurethane (PU). Ceilings require thicker insulation (a minimum of 15 cm of PS or 12 cm of PU) due to the higher temperatures directly above the ceiling that are the result of thermal radiation through the roof. Apart from the thickness of the layer, the material itself is of importance. The insulation layer must be hermetically sealed. If this is not done, so-called thermal bridges may occur, causing the cooling system to run for longer periods. This in turn will dry out the soil and crop. This will make it very difficult to maintain consistently high relative humidity (RH) levels. Polystyrol is currently the most widely used insulation material. The material does, however, have one major disadvantage, namely that it will shrink by 1-2% in its first year. Where possible, the use of the more expensive PS or PU sandwich panels is therefore preferred over the use of loose Polystyrol foam panels for rooting rooms. Besides PU foam panels, liquid PU foam may also be sprayed directly onto the wall. The insulation of existing cold rooms may thus be improved.
In newly-constructed cooling rooms it is advisable to also insulate the floor as concrete floors do not provide sufficient insulation. Floor insulation is especially recommended for long-term

storage at temperatures below freezing (freezing of lilies or ice tulips). With regard to pressure resistance, PS 25 (Polystyrol) or similar must be used. A covering layer of 8 cm will suffice, preferably applied as two overlapping layers of 4 cm thick.

Condensation

Maximum humidity levels are determined by the prevailing temperature. The higher the temperature, the more vapour it may contain. Air usually contains less water than its maximum capacity. Humidity is also known as "relative humidity" and expressed as a percentage. A relative humidity of 60% therefore means the air contains 60% of its maximum capacity at that particular temperature.
Relative humidity cannot always be taken as a measure since RH of 60% at 30°C contains more vapour than air at a temperature of 10°C. Similarly, RH levels will rise when air (of a particular humidity) is heated, while they increase when the air is cooled down.
The point at which the air is cooled down to such a temperature where vapour levels equal the maximum air capacity is called the dew point, where relative humidity is 100%.
When the air cools down, the RH will remain 100%, even though the actual amount of vapour contained in the air decreases as a result of condensation on surfaces that are cooling down. The actual vapour contents in the air are expressed as absolute humidity in grammes of vapour per kilogram dry air.

Internal condensation

The following situation is most commonly encountered. The cold room cools down. Condensation causes absolute vapour levels to drop while the RH remains high. The air outside the cold room is (generally) warmer.
As the outside air contains more vapour than the air inside the cold room, no air will enter the room. (Air flows are not directed by relative, but by absolute humidity).
Temperatures in the insulation layer should never fall below the dew point as this will cause vapour to condensate, dramatically decreasing the insulation capacity of the wall. In order to prevent the condensation of moisture in the wall, a waterproof layer must be applied to the warm (!) side of the wall. This layer may for example be made of reinforced aluminium foil applied to the insulation. Special care must be taken of the seams. Damage may be repaired with special tape.
If the cold room is also used as a heating room, the air must flow in the opposite direction, which means a waterproof layer must also be attached to the inside of the room.
Sandwich panels, currently in widespread use, have a steel or aluminium layer on both sides. The panels are usually mounted with H-profiles. To prevent moisture seeping through the seams, all profiles must be treated with moisture-proof kit before mounting.

Surface condensation

Apart from internal condensation, surface condensation may also cause considerable heat loss and even structural damage. This form of condensation occurs in places where heat is conducted relatively easily (i.e. where isolation is poor).
These so-called thermal bridges occur for example at low-level U-profiles in which the wall panels are mounted, at metal bolts between indoor and outdoor walls, etc. The degree of surface condensation will depend on various factors, including:

- low surface temperature
- higher RH
- poor air circulation.

Avoiding surface condensation

Surface condensation may be avoided by constructing walls, roofs, etc., so that only a little heat is transferred. What must be avoided is that construction parts on warm sides getting relatively cold. Critical places, such as corner connections, in particular must be properly isolated. It is moreover advisable to provide a damp-proof shield on the warm side of the construction. A good structural design will avoid any risk of thermal bridges.

Floor: Introduction

The selection of floor materials must allow for transport loads. The floor's own weight, plus that of the construction, must be calculated for a total load of 3000 kg/m2.

Floor: Construction

The insulation material is placed on an 80 cm concrete layer.
To stop moisture from rising up through the floor, a waterproof sheeting (i.e. agricultural sheeting) must be placed between the concrete layer and the insulation material. The sheet must be laid out tightly.
Choose 8 cm thick, solidly pressed Polystyrol (PS 25) or similar for the insulation material (only for long-term storage below 0°C). Stretch a waterproof sheeting across this insulation layer and follow this by a concrete floor of some 120 mm.
To avoid ridges in the floor, the concrete is strengthened with a shrinkage steel mesh reinforcement, set between two concrete layers of 30 mm or more.
A so-called spacer bracket can be used to move the mesh reinforcement in the exact direction of the insulation. To avoid damage to the insulation it is recommended to lay the floor insulation and the concrete floor only after the walls of the cold room have been erected.
If the floor is laid before the walls are erected, thermal bridges may occur at the bottom of the walls.
The concrete floor is then finished off with a hard, wear-resistant layer. The concrete used for this top layer must be densely compacted. A dry cement/sand mixture (1 part Portland cement to 3 parts of sand) is then scattered across the lightly hardened surface, worked in with a float and grated.

Floor: Insulation and drainage

To insulate a floor, it must be dug out deep enough to ensure that the stone floor is level with the surrounding area and that there are no bumps or uneven surfaces that may cause obstructions in transportation.

Floor insulation is only recommended for newly-built cold rooms. Insulation of existing floors is not cost-effective due to the relatively high costs involved. The seams between the concrete floor and the walls may be sealed with kit to prevent water seeping through to the insulation layer. Moisture will affect insulation capacities and may in extreme cases even lead to cracks or frost damage to the stone floor. For floors produced as one layer, make sure that no water seeps through to the walls or underneath the walls to the adjacent rooms. Here, too, all seams must be carefully sealed with kit. Good drainage below the floor may often be required to prevent moisture rising up to the insulation layer, particularly in clay soils. For the drainage of excess water the floor must slope slightly to allow the water to flow freely to the door. Although often quite handy, gullies or sink pits may cause smells, are often blocked or freeze. Consequently, they are not commonly used. Dew or condensation water from the condenser may be drained off by means of a plastic pipe leading outside through the wall or drain into a gravel ditch underneath the floor.

Partition walls: Introduction

Cold rooms are separated from work rooms etc. by means of partition walls. These walls may be made from a variety of materials. Partition walls are preferably made from reinforced insulating materials to prevent damage. The choice of material will depend on various requirements. For example, the greater the difference in temperature and RH, the greater the wall's insulation capacity must be. Rooting rooms must be able to achieve temperatures of -2°C. Relative humidity levels may rise to 95-98% (depending on the temperature). For this reason, only use materials that can withstand high humidity for extended periods of time.
Partition walls should never be load bearing. It must be possible to remove them without affecting the building structure. The wall and floor insulation must provide a close fit to prevent heat entering from other rooms causing the warmer air to condense.

Partition walls: Material

Commonly used insulation materials are panels made of Polyurethane and Polystyrol. Coated with a waterproof layer to avoid damage to the insulating core layer, these panels must meet minimum quality standards the as set by the country of origin. The panels only differ in classification. "Exterieur I" and "WBP", for example, are two different names for the same quality class. Profiled steel panels are becoming increasingly popular.
Aluminium foil may only be used as insulating material if the seams are carefully sealed.
Based on the height of modern cold rooms - up to 4 meters - walls built in stretching bond are too weak to support the building.
Moreover, concrete floors, in particular cellular concrete, has the disadvantage that it absorbs a great deal of moisture, which will seriously impede climate control, particularly in cold rooms.

Partition walls: Sandwich panels

The use of so-called sandwich panels is relatively new. These panels consist of two covering layers of galvanized steel plates, also available with a profile, with a core of insulation material. These prefabricated plates can bridge a span of 6 metres, supported only at either end. They offer a wide range of advantages: fast mounting, clean handling, effortless cleaning and durability, although the price is high compared to that of conventional insulation materials. If sandwich panels are used, make sure that they connect tightly to the floor. Careless construction may soon lead to air gaps and condensation problems.

Cold room doors: Introduction

Swing or sliding doors may be used in cold rooms. Preference will depend on how often access to the cold room is required per day and which means of transport are used.
As a rule of thumb, doors must be at least 1.5 times the width of the transport used. The height of the door will depend on the height of the transport and the stacking height. This is usually at least 3 meters.
Doors must also be properly insulated; heat conductivity should not exceed that of the walls (max. 0.3 W/m2K). Swing doors must be suspended from lever hinges, ensuring that the door on opening is easy to operate to prevent wear and tear at the bottom. The door frame in the cold room, where temperatures are below freezing for extended periods of time, may be equipped with electric heating to prevent the doors from freezing shut.

Cold room doors: Sliding doors

The suspension of sliding doors must allow the door to close tightly against its frame and the floor.
Ensure that the frame of the sliding door is connected to the supportive beam of the building to allow for vibrations caused by closing the door. The doors must have a connecting lock so that it can also be opened from the inside. The great advantage of sliding doors is that they can be opened without taking up any space. However, they are more expensive than swing doors. It must be possible to open hydraulic doors manually.

Ceiling

The ceiling of the room must be level. Protrusions and other objects attached to the ceiling may obstruct the air flow from the vaporizer. For example, light fixtures should never be mounted at an angle to the air flow. If the ceiling is suspended directly below the roof, a thicker insulation layer is recommended. Heat radiation from the roof may increase temperatures above the ceiling considerably.

2. Layout of the rooting room

Ventilation and air circulation: Introduction

Good ventilation is absolutely vital. The supply of fresh air into the rooting room takes place via evaporators or heaters or both. The fresh air inlets must be large enough to allow the air to flow in at a maximum speed of 4 m/s (see Air supply 3.9).
The storage of tulip, narcissus and hyacinth bulbs in pots does not require intensive ventilation. In practice, it will suffice to leave the door to the cold room open when the temperature is checked (twice daily). This will allow sufficient fresh air to enter the room.
Air circulation requirements differ for the cold room and rooting room. Dry storage requires intensive air circulation to keep the RH levels in the vicinity of the bulbs low. High RH levels will increase the risk of a penicillium attack and encourage root growth. However, air circulation must be low in the rooting room to prevent the soil and roots from drying out.

Ventilation and air circulation: For dry storage

The following ventilation is recommended for tulips:

At 20 - 17°C: 10 m3 air/h per 100 1 bulbs; RH max. 75%
At 9°C: 0 m3 air/h per 100 1 bulbs; RH max. 75%
At 5 and 2°C: 0 m3 air/h per 100 1 bulbs; RH max. 80%
(10 m3 of air per hour = 2.8 liter per second)

Ventilation requirements for narcissi are:
At 17°C: 6 m3 air/h per 100 1 bulbs; RH max. 75%
At 9°C: 0 m3 air/h per 100 1 bulbs; RH max. 75%

Ventilation requirements for hyacinths are:
At 25°C:10 m3 air/h per 100 1 bulbs
At 20°C: 60-100 m3 air/h per 100 1 bulbs
At 17°C:10 m3 air/h per 100 1 bulbs
At 9°C:0 m3 air/h per 100 1 bulbs
During cold storage of narcissi at 9°C RH levels may rise to 95% or more. Combined with insufficient air circulation this will lead to premature root growth.
This may be prevented by increasing the air circulation and lowering the RH. RH levels may be dropped by cooling the air down to 7°C. This will condense the vapour in the condenser. The air is then warmed up again to 9°C.

Ventilation and air circulation: Ethylene

Since it is a well known fact that fruit, flowers, tulips affected with fusarium, and combustion engines produce ethylene, ethylene levels in the room must be checked regularly. This can be done with an ethylene measuring device. If ethylene content is too high (0.1 ppm or more) air circulation must be increased. Remove all affected bulbs. It goes without saying that fruit should not be stored with tulips in the cold room. Also make sure that no fumes from combustion engines can enter the cold room. During the 9°C cold period the fusarium fungus produces only small quantities of ethylene.

Air transportation and movement

In order to ensure that the cooled air from the vaporizer reaches the stacked products and to avoid temperature fluctuations in the room, the air must be able to circulate freely among the trays.
Small cold rooms (less than 10 meters in length) will not need an air duct to distribute the cooled air. Generally it will suffice to maintain a steady air flow by means of vaporizer fans.
However, if temperatures vary frequently by more than 0.5°C, the air flow may be stimulated by means of one or more ceiling fans. This will ensure an even vertical and horizontal temperature distribution, provided the air flow is not obstructed by trays. However excessive air circulation during the rooting phase will result in moisture lost from the rooting medium To prevent the soil from drying out, apply water more frequently. In practice this proves to be problematic as it is virtually impossible to supply every single tray with stet sufficient amount of water.
Once the right temperature has been reached, the ceiling fans no longer need to be in constant operation (see Cooling, temperature and relative humidity - Measuring equipment).
In cold rooms of more than 10 meters in length, it is advisable to connect an air duct to the vaporizer to transport the cooled air to the other side of the room.
A 10-cm wide gap must be made at the top of the air duct through which the air can flow along the ceiling to the sides of the room. Place the trays at least 10 cm from the walls to allow the air to flow along the wall to the floor. This ensures an even temperate distribution and moderate air flow. Another possibility is the use of several vaporizers mounted along the side walls of the room.
This will blow the air horizontally into the room, eliminating the need for an air duct. However, the wall must be high enough to make sure that the stacked trays do not obstruct the vaporizers in any way.

For the dry storage of bulbs in small rooms (less than 10 meters in length) the air is circulated by means of ceiling fans. In large rooms the slots in the air duct will not suffice to ensure sufficient air circulation. Openings must therefore be made in the bottom of the duct. Underneath each opening a ceiling fan must be mounted. If the room is then used as a rooting room, the ceiling fans are removed and the bottom openings closed.

Air transportation and movement: Air ducts

The easiest option is to install an air duct in the cold room. However, if the duct is mounted on top of the ceiling (i.e. outside the room), it must be properly insulated. While the bulbs are being cooled down, the ceiling fans must be in continuous operation as cooled air is unable to flow into the room through slits in the duct.
In order to ensure an even air output across the entire length of the duct, the duct must taper. Ideally, the diameter at the end of the duct must be one third of the diameter at the start of the duct. The air flow speed in the duct should not exceed 4m/sec. As RH levels in the room are usually high, the duct must be made of vapour-proof material such as aluminium or waterproof multiply board. Suitable board is available under the name “Exterieur I” or “WBP”. As vaporizers may vary in size according to type, allow for the construction of wide air ducts. After some 2 meters the duct may be tapered such that the air flow speed is approximately 4 m/sec (see Fig.). This is achieved at a diameter of no less than 0.7 cm2 per cubic meter of air per hour.

Lighting

There is usually no need for any work light in a rooting room. Low wattage bulbs like the ones used for emergency lighting in corridors will in practice suffice. All lamps and connections must be splash-proof and meet electricity standards. Use a flashlight to be able to look between the containers during the bulb-cooling phase.
Strip lights are also suitable. These must also be splash- and vapour-proof. As strip lights with starters are unsuitable, only the more expensive models may be considered. Room lights must be placed over the corridor. The operating switches must be located outside the room. For installation inside the room, a splash-proof version will be needed. The installation of a control light outside the room is also recommended.
A lighting strength of 300 Lux is all that is required to enter the room (e.g. one 150-Watt bulb per 20m2 surface area).

Cooling unit: Introduction

Before setting out the requirements all cooling units must meet, we will briefly describe how the cold room and cooling unit work.

Cooling unit: The principle of cold generation

Low temperatures are achieved based on the principle of heat generation. All heat generated in the cold room is extracted and transported by means of a cooling liquid that circulates around the cooling room. Liquids evaporate (boil) as soon as a certain pressure and temperature is reached. Under normal atmospheric pressure water for example will boil at 100°C, ether at 35°C and freon at -30°C. To evaporate a liquid it needs heat. When a liquid is evaporated in a closed room it will extract heat from the air. The resulting cold vapour is sucked up and cooled down outside the room. Here it will condense and form a liquid, releasing the heat stored earlier. When the liquid is returned to the cold room, it will enter the cycle again. This method of cold generation is used for cold storage. In practice, cold generation is a little more complicated as the boiling point is partly determined by pressure. Cooling units used in horticulture are filled with freon, a non-toxic, non-flammable and non-explosive liquid which is not harmful to the bulbs.

Cooling unit: The unit

The cooling cycle therefore involves the following processes: evaporation of cooling liquid, compression of cooled-down vapour, condensation of cooled-down vapour, pressure release of liquid. The entire cold unit comprises the following components:

- humidifier to evaporate the liquid (heat absorption)
- compressor to compress and transport the cooled-down vapour
- condenser to cool down/condense the cooled-down vapour to form a liquid (heat release)
- expansion valve to release the pressure of the cooling liquid.

The vaporizer is located in the cold room. The expansion valve is mounted on it. The compressor and condenser are located outside the cold room.

Cooling unit: Vaporizer and compressor

The cooling liquid is evaporated in the vaporizer. The heat necessary to do this is extracted from the room. This will lower the temperature in the cold room. The vaporizer has a number of copper pipes covered with fins to increase the contact surface. Behind the bar system lie one or more fans that extract the air from the room (see Fig.).
This ensures optimum heat transfer from the air in the room to the evaporation surfaces.
The temperature of the evaporator pipe is a few degrees lower than the temperature of the air in the room.
Part of the vapour in the air condenses onto the pipes. When the evaporation temperature is below freezing, all condensed water freezes. To ensure proper functioning of the evaporator, defrost it regularly and remove all thawed water. Thawing usually takes place with electricity, although hot-gas systems are becoming more popular. This reverses the effect of the cooling unit, i.e. the evaporator is heated and the ice thaws. In order to reduce the risk of fire through overheating during the electric thawing process, the evaporator must be separated from the cooling insulation by means of a fire deflector. The temperature difference between the evaporator and the air in the room is generally 5-6 Kelvin (= 5-6°C). The greater the difference, the more vapour is extracted from the room (and crops). The cooling gas in the evaporator is directed towards the compressor through a suction line where the vapour is compressed and pumped into the condenser.

Cooling unit: Condenser

The condenser shows a great many similarities with the evaporator. For example, it has an extended surface area (pipe with fins) through which air is pumped by means of a fan. However, the process in the condenser is the complete opposite of the process in the evaporator. The hot cooling vapour is cooled down in the condenser. The heat extracted from the cooling room is released into the open air. It is therefore important that the condenser is located somewhere cool, e.g. somewhere in the northeast of the building. When the outside temperature is low, the unit's capacity is often too great, dramatically reducing the pressure in the condenser. As a result there is only a very limited difference in pressure between the vaporizer and the condenser.
This leaves the vaporizer incapable of transporting sufficient cooling liquid, thereby sharply reducing its performance. The condenser has a smaller "counter pressure" and may stall. The condenser performance can be regulated by, for example, turning the fans on or off, or by adapting the rotating speed. The condenser is connected via the storage tank to the expansion valve and the vaporizer by means of a liquid line. The combined construction of a compressor and a condenser is called a cooling generator. A thermostat with temperature guages in the cold room is used to turn the cooling unit on and off.

Cooling unit: Compressor models

a. Closed compressors are used for refrigerators, freezers, etc. They offer low prices and fault-free performance. A drawback is that if the compressor burns out, it must be replaced in its entirety and that the entire cooling system must be cleaned.
b. Open compressors consist of a separate electric motor and a compressor. The revolutions per minute, i.e. the cooling performance, can be regulated by changing the driving wheels, which vary in diameter. Its disadvantages are its high costs and frequent inspections needed.
c. In semi-open compressors the electric motor is connected to the compressor so that replacement presents no problems. They are similar to the closed compressors in all other respects.
Which type is suitable will depend on the company's circumstances.

Cooling unit: Pointers for the purchase of a cooling unit

Before purchasing a cooling unit, calculate the cooling capacity needed.
Include the following specification in the tender to contractors:

- dimensions of the room
- desired storage temperature
- desired humidity
- product volume stored in the cold room
- product volume stored simultaneously in the cold room
- containers used
- time span in which the product must be cooled down
- type of airing (ventilation) required by the product
- thickness and type of insulation used and the wall construction of the cold room
- season in which the storage will take place.

The cooling unit must comprise the following components:

- One switch for every vaporizer fan with "0 - continuous operation - automatic" to regulate air circulation. If desired, a control that turns on the vaporizer fans alternately when the cooling unit is not in operation. Every fan will clock up approximately the same number of operating hours.
- A thawing facility on the vaporizer for storage of products at 2°C or less (electric or hot-gas).
- High or low pressure safeguard.
- Pressure and suction manometer.
- Operation and control thermostat with a maximum deviation of approx. 0.4 Kelvin (°C) at any one time.
- Insulation of the suction pipe.
- Vaporizing fans with a minimum cooling capacity of 0.85m3/h per Watt.
- Silent fans and compressors, if required.
- Operating hour clock on the compressor (a kWh-counter, if required).

Where possible, the condenser must be placed somewhere in the north side of the building. The condenser will be able to release heat into the surrounding area quicker if it is placed in a position where it will not receive direct sunlight. Condensers that are used outdoors must be waterproof.

Cooling unit: Safety measures

People working in the cold room must be protected from all operational risks:

- The electric unit must be waterproof and duly earthed.
- It must be possible to open the cold room doors from the inside.
- It must be possible to operate hydraulic doors manually.

3. Cooling, temperature and relative humidity

Cooling and heating: Introduction

Upon delivery, bulbs are often stored long-term or short-term. The company therefore needs storage rooms that can be heated or cooled. Heating is required in the first stage of the temperature treatment, while cooling is usually needed during the second stage. Even during a cold dry storage period it may be necessary to provide heating to be able to lower humidity levels.
In addition to temperature control, the storage room must also have a ventilation system to ensure the composition of the air (including ethylene content), humidity and temperature meet the bulbs' requirements. The location of the cooling unit and heaters and the position of the air openings will depend on the use and shape of the room or building.

Cooling and heating: Separate heaters and vaporize

Although these units are still in use and are even newly installed, they are not recommended as they suffer a variety of technical problems such as temperature and humidity fluctuations.

Cooling and heating

The use of ceiling fans during the cold period in the rooting room is not recommended as it increases the risk of desiccation. Vaporizer fans will usually ensure an appropriate air circulation in the room. When the temperature is about the same throughout the room after the cooling period, the operating time of the vaporizer fans may be reduced. To determine the right moment, the temperature must be measured in different places around the room. Temperatures in the rooting room should not vary more than 0.5°C.

Cooling and heating: Compact heating and vaporizin

Dry storage of bulbs requires low humidity levels to avoid the risk of mould and root growth. This is achieved by the simultaneous use of cooling and heating.
Part of the vapour will condense onto the cooling vaporizer and is then drained away. As this causes a dramatic drop in humidity levels the air must be heated.
To avoid the creation of air flows of different temperatures in rooms where drying takes place by simultaneous heating and cooling, vaporizers and heaters are combined and built into one block. Air is first led through the vaporizer and then through the heater.
The automatic compact unit features thermostat-controlled cooling and hygrostat-controlled heating. As soon as the hygrostat detects humidity levels that exceed the maximum value (e.g. 85%) the heater will come on. As a result, the thermostat will start to cool and vapour from the air will condense. Humidity levels will drop.
If the compact unit is situated in the room, the same criteria apply as for the installation of heaters in the rooting room.

Cooling and heating: Tower coolers

Large rooms will often require more powerful heating and vaporizing units, which cannot normally be attached to the ceiling. A good alternative is the so-called "tower coolers" (see Fig. and photo). These vertical units suck the air in at the bottom from where it flows upward. To

promote an even air distribution, the vertical duct terminates in a horizontal duct which is led across the ceiling.
This system also uses a switch valve which is located right at the bottom of the vertical pillar. Cooling and heating do not always have to be operated in conjunction, and can be switched on separately. A switch may also be used to operate the thermostat and hygrostat.
A disadvantage of this system is that it takes up valuable floor space. Another disadvantage, which also applies to suspended compact units, is the risk that the heating unit, especially the heating element, freezes. The air is cooled by a few degrees before it is sucked into the heater. Even at a few degrees above freezing this can cause frost damage. This can be avoided if the heater is filled with antifreeze.

Cooling and heating: Units outside the cold room

Air treatment units may also be installed outside the room. This will usually require a structural adaption. In sufficiently high buildings the cooler and heater may for example be installed in a false ceiling above the room. In premises where the rooms are separated by a hallway, the units may be installed over the corridor. To do this, a false ceiling is constructed along the corridor on top of which the air treatment unit is installed. From there the air is transported through a duct into the room.
For a larger extraction duct the loft in which the unit is installed must be sealed hermetically and provided with air grills. It is also recommended to carefully insulate the roof over the loft in view of the heat development.

1. Evaporator with vans which can also provide for ventilation depending on the two-way cabinet position.
2+3 Other evaporators
4. Two-way cabinet for ventilation control
5. Vent grid
6. Door
7. Walls

Cooling and heating: Electric heating

In rooms where the air is heated only occasionally, the installation of electric heating coils in front of the vaporizer will suffice. Provided the mains yields adequate power, the necessary investments are low. There are, however, high usage costs. Because the heating element does not have a ventilation valve, the vaporizer must be equipped with one.

Frost prevention measures

To prevent frost damage to the heater during extreme weather conditions, all water must be extracted immediately and the unit blown through thoroughly. If the heater is installed between two shutter valves, it can be removed in its entirety. This will also prevent rust. A duct connects the supply and extraction pipes.
Another possibility is to fill the entire heater with antifreeze. The amount needed will depend on the desired protection. For further information consult the instruction manual. Regularly check antifreeze levels in the unit. The high costs of filling the entire unit makes this method suitable for small units only. The addition of antifreeze will lead to a reduction of the capacity of the heating element by 5-10%.
In larger units a heat exchanger (counterflow unit) must be placed on the water side to prevent the anti-freeze from flowing into the boiler. This reduces the amount needed considerably.

Air supply

Ventilation air is sucked in through openings in the walls. The size of these openings will depend on the ventilation system to be installed. Make sure that the flow speed does not exceed 4 m/sec. The size of the openings is 0.7 cm2 per cubic meter air per hour.
Example: the maximum air supply needed in a room is 5000 cubic meter per hour. This means that the total opening surface must be no less than 5000 x 0.7 cm2 = 3500 cm2. The net surface of each opening must be 59 x 59 cm or 50 x 70.
The air extraction takes place through openings in the walls or ceiling. In large rooms it is recommended to distribute these openings equally in the ceiling or along the top of the walls. If necessary, air may also be extracted by means of openings at floor level.
All openings must have shutters. Wind entering the building may cause pressure changes which may affect the proper functioning of the ventilation unit. If this is the case, the supply and extraction openings must be installed along the same wall. Make sure that the discharged air is not sucked up again.

Air extraction

The size of the extraction openings must allow for a slight over-pressure. Here, too, a maximum air flow speed of 4m/sec. applies with openings measuring 0.7cm2 per cubic meter of air per hour. Avoid dirt building up on the fans and the heating unit by stretching a fine (fly) grill between the switch valve and the ventilator. It must be possible to take the grill out to be able to clean it occasionally.

Measuring equipment: Introduction

The climate in the rooting room must be appropriate for to the crops stored. Failure to do so may lead to considerable losses, for example due to rejects in forcing. Properly functioning measuring equipment is therefore essential. Temperature and relative humidity are central factors in the environment.

Measuring equipment: Temperature

The temperature can be determined with a mercury thermometer, which must be calibrated every year. Thermometers should preferably have a protective cover and a measuring range suitable to the demands of the products to be stored. In order to permit a careful reading of the thermometer, the scale graduation should be generous enough to read differences of at least 0.2°C easily. Moreover, each room must have at least two thermometers in at least two different places to give an accurate reading of the temperature across the room. In addition to mercury thermometers, remote-controlled thermometers may be used. Their advantage is that they allow temperatures to be monitored in difficult-to-reach places. These thermometers have a metal sensor with a conducting wire to the display cabinet. The display can have more than one sensor.
The equipment must meet the following requirements:

- good readability and measuring accuracy (scaled to 0.2°C or more)
- simple mounting of sensor and cable
- simple calibration

Although this equipment is fairly exact, comparing it regularly against a calibrated thermometer is advisable. Many cold rooms have so-called ‘clock thermometers’ on the wall over the door, which display the temperature without actually entering. We advise against the use of these thermometers as they give an inaccurate reading and are unreliable.

Practice has shown that temperatures will differ across the rooting room. This results in uneven development of the shoots and roots.

With temperature variation of 0.5°C marked as acceptable, the cause of any greater variation must be found as soon as they occur.
Common reasons are:

- poor insulation
- poor stacking of containers affecting the air flow
- containers are too close to the wall
- use of different container types
- containers are too full.

When the elimination of the causes does not lead to the desired temperature, the air circulation may be increased whereby the vaporizer fans are not used for cooling, but for thawing. When this also fails to yield the desired effect, the ceiling fans must be switched on. This will, however, increase the risk of desiccation.

Measuring equipment: Relative humidity

Relative humidity is best measured with a psychrometer made from two (mercury) thermometers mounted side by side on a board.
One of these thermometers must have a cover around the mercury reservoir and be suspended in a bottle of distilled water. This thermometer will record a lower temperature than the one mounted next to it. Based on the temperature difference between the two thermometers, relative humidity can be calculated according to a table. Alternatively, use a psychrometer that gives a direct reading of RH levels. Both thermometers must meet the above requirements, i.e. they must be calibrated every year. Psychrometers must never be mounted in the direct vicinity of an air flow, although the air surrounding the psychrometers should not be stationary. Alternatively, the instrument must be moved up and down a few times before reading it.
The following situations may affect the accuracy of psychrometers:

- the bottle is empty
- the cover has hardened
- there is no distilled water.

These problems may be avoided by regularly topping up the distilled water, checking the cover and replacing it every year. Relative humidity may also be measured with a hair hygrometer. However, we do not recommend this instrument as its measuring accuracy diminishes with time. If a hair hygrometer is used, however, it must be adjusted regularly (several times per season). To do this wrap the instrument in the room in a moist cloth and then turn the calibrating screw to 100%.

Measuring equipment: Thermometer calibration

Thermometers must be calibrated every year to ensure the right temperature in the rooting room. After calibrating the thermometers the variation are recorded on a card which is attached to the thermometer. On reading the temperature the variation on the calibrating card must be taken into account to calculate the actual temperature.

Measuring equipment: Fault reports

Since it will not always be possible to detect the above faults, preventive measures must be taken, including for example the automatic registration of the temperature and humidity. When variation from the target are about to cause serious damage, it must trigger a fault detection, for example through a telephone alarm, an acoustic signal or a warning light. The type of fault detector needed will depend on the circumstances. In newly-constructed rooting rooms computers may be used for registration purposes and fault alarms. The computer program will provide climate control, fault reports and storage of all relevant details.

4. Trays

Types of forcing trays

There is a range of forcing trays available for rooting rooms. Before selecting a particular type, a number of factors must be considered, e.g.

- will the trays also be used for the treatment of dry bulbs?
- which tray size is most suited to the business?
- how much does a filled tray weigh?

For dry storage purposes open trays are preferred, while relatively closed trays are preferred for forcing. Many forcing trays are suitable for both purposes.
A factor of some importance is the weight of the filled trays. Young employees, for example, will find a filled tray of 75 cm x 50 cm far too heavy.

Criteria

Forcing trays must meet a number of requirements, including:

- the internal depth of trays should be no greater than 8 cm for tulips and 10 cm for narcissi. The thinner the layer of soil, the greater the risk the crop and soil will dry out. It also increases the risk that tulips not yet ready for harvesting will fall over while others are being picked.
- when stacking, leave a gap between the top and bottom of the trays of at least 7 cm for tulips and hyacinths and 10 cm for narcissi. If the trays are placed closer together the room temperature must be reduced earlier to keep shoots short. However, this is only possible for tulips. For narcissi and hyacinths the minimum distance must be adhered to to avoid any problems during cultivation.
- in order to avoid the soil and crops from drying out, the bottom of the tray should not contain too many drainage openings, although not enough openings will increase the risk of ‘flooding’ in the accumulated moisture.

Types of trays: Introduction

The current types of trays are mainly:

- plastic trays: dimensions 60 x 40 cm
- wooden trays: dimensions 75 x 50 cm or 37.5 x 50 cm

Types of trays: Plastic trays 60 x 40 cm

The advantage plastic trays have over wooden trays is that they are easy to clean. The number of companies that are changing to plastic trays of 60 x 40 cm is increasing. Their smaller capacity means that they are lighter when filled and are therefore easier to handle than trays measuring 75 x 50 cm.
Plastic trays of 60 x 40 cm are available in a wide variety of models. Many trays have been in use for years without creating any major problems. However, companies may occasionally buy trays that later turn out to be too weak. For this reason, obtain a written guarantee concerning the strength of the trays (stacking pressure) upon purchase. The trays may also be used for dry bulbs providing the stock is free of Fusarium.

Types of trays: Criteria for plastic trays

The following factors must be considered in the purchase of plastic trays:

- the trays must be able to withstand both high and low temperatures. They should not deform or break at temperatures ranging from +40°C to a few degrees below freezing. Ask for a written guarantee from the supplier covering this and other temperature-related characteristics.
- filled trays must be easy to stack. Empty trays must slot into each other. This takes up less room than the cross-method stacking.
- the trays must be easy to lift. For flat trays, which are generally lifted with one hand supporting the bottom, handles are not absolutely necessary. However, if the tray has a handle, it must be positioned at the sides, measuring 10 x 2.5 cm, and not have any sharp edges.
- certain types of trays have broad upright corner braces that obstruct smooth planting and harvesting processes. Similar obstructions must be avoided as they make the positioning and removal of trays more difficult.
- trays must be provided with a row of externally protruding reinforcing ribs at the bottom. This will avoid damage to roots growing through the bottom when the tray is placed on a bench.
- trays that are also used for the storage of dry bulbs must have an open profile. This will, however, increase the risk of desiccation in the rooting room.
- trays with openings in the top half of the sides may cause problems in forcing. If the trays are not filled properly, water may drain through the openings, leaving the soil to dry out.
- is it advisable to have support legs?
- can the trays be stacked with trays with the same dimensions but of a different make?

Types of trays: Wooden crates with slatted bottom

This type of trays is available in two sizes, i.e. the same size as wire woven trays, and in 37.5 x 50 cm. They are more durable than wire-woven trays. The trays are perfectly suitable for forcing purposes and the narrow gaps in the base prevent excessive root growth through the bottom. There is virtually no root growth in the trays, they are not nearly as susceptible to drying out as wire-woven trays. There must be a gap of no less than 1 cm between the slats in the bottom. This allows for expansion of the wood through moisture so that the gaps are not closed off, which would prevent air getting to the roots. Trays with small gaps between the slats are not particularly suitable for dry storage of bulbs.

Desiccation prevention

When bulbs are planted in trays that drain freely the potting soil runs a higher risk of drying out. This may lead to the crops drying out. There are solutions on the market to help stop trays from draining, including closed or perforated inlay plastic sheets or plastic panels. However, since these measures increase the risk of root infestation from e.g. Trichoderma and Botrytis cinerea, we advise against their use.

Tray stacking

Air circulation is vital in both wet or dry cooling. The temperature of the air between the trays must be lowered and maintained at the right temperature to ensure gradual cooling.
The trays must therefore be distributed evenly across the room. Points to consider include:
- the trays should not be stacked directly underneath ceiling fans or extraction openings
- trays must be stacked at least 10 cm from the wall
- do not make the stacks on either side of the corridor wider than 2.20 to 2.50 m. If the room requires wider stacks, ceiling fans are necessary
- the stacking height will depend on the size of the room and air ducts. The space between the bottom of the air duct and the top of the trays must allow room for at least one other tray. In rooting rooms without air ducts the minimum distance between the top tray and the ceiling is 40 cm. Make sure that there are no trays in front of the vaporizer as this will obstruct a free air flow, causing temperature variations in the rooting room.