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WeberCooling is a worldwide leader in Vacuum Cooling Technology. In the past few years more and more systems have been installed at flower farms, exporting companies and logistic hubs. The importance of proper temperature and moisture control plays a key role during the entire flower cold chain ensuring adequate quality of flowers. The combination of long-distance transportation and poor temperature control results in flowers with inadequate longevity being sold to consumers. Temperature control plays a key role and Vacuum Cooling is the perfect answer.

## 1. The importance of precooling

Pre-cooling is the rapid removal of field heat from fresh produce. It is among the most efficient quality enhancements available to commercial producers and ranks as one of the most essential value-added activities in the horticultural chain. Precooling is a very important step in the post-harvest stage of the perishable-produce industry as all flowers get into stress after harvesting. This results in transpiration (sweating, resulting in loss of weight and in the building of moisture on the skin of the produce) and respiration (breathing = burning sugars), resulting in loss of life, but at the same time in an increase in product temperature, especially when packed tightly.

Both respiration and transpiration can be greatly reduced by pre-cooling. On average both can be reduced by a factor of 4, 5 or even more, if cooled down from harvesting (on average at 20 – 30$^0$C down to below 5$^0$C). The perfect end temperature is defined by many factors, like produce to be cooled and the post harvesting steps following the pre-cooling. Varieties like Statice benefit from fast pre-cooling after harvesting (plus the benefit of enhanced drying), for Roses pre cooling can best be done after hydrating.

Proper pre-cooling will further:

- prevent wilting;
- minimize the risk of Botrytis infection;
- reduce the rate of ethylene production
- Prevent premature ageing and poor flower opening
- Prevent stem bending

Overall it helps to reduce the loss in quality of produce once it's been harvested. Likewise, precooling increases the vase-life of flowers. Higher quality and longer vase-life will positively affect consumer buying decision and means more profits to produce growers. Vacuum cooling offers an added value and enables expanding your market.

## 2. Available Pre-Cooling Methods

There are different alternative methods for pre-cooling of flowers

- Room Cooling (in a conventional cold storage)
  *There is a trade-off with Room Cooling. It requires relatively low energy but is very slow.*
- Forced Air Cooling (or blast air cooling, forcing cold air through your produce)
  *Forced air will cool faster compared to room cooling, but it will always cool "outside-in" and will reach the core of the flower boxes only after long cooling*
- Vacuum Cooling uses the boiling energy of water to cool down your produce.
  *For the water in the product to boil, the pressure in the vacuum room must be brought down to ultra-low pressures. Cooling to the core of the boxes is easy – and fast.*

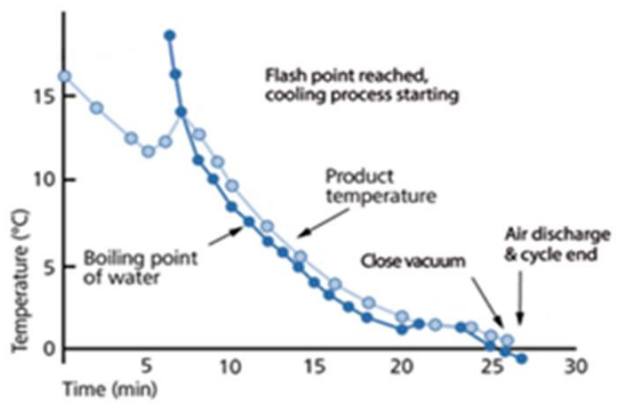
In this document we will tell you more about the technology of Vacuum cooling, the applications and benefits it offers.

## 3. Vacuum Pre Cooling

By far the most important part of maintaining the quality of harvested flowers is ensuring that they are cooled as soon as possible after harvest and that optimum temperatures are maintained during distribution.

Fresh products are usually harvested at relatively high temperatures. As they are living products, they continue to create heat (and moisture). To prevent excessive temperatures, increase shelf and vase life, reduce rejects and achievable prolonged shipping times, quick pre-cooling right after harvesting or packing is vital.

Vacuum cooling is 5 - 20 times faster and more effective than conventional cooling! Only vacuum cooling can cool ultra-fast and uniformly to the core down to 0 - 5°C for most produce within 15 - 20 minutes! The more surface the produce has related to its weight, the faster it can cool, providing you have chosen the right vacuum cooler: depending on the desired end temperature, **flowers can be cooled between 15 - 25 minutes**.




The final cooling temperature plays an important role in the time to cool:

The first stage of cooling, down to around $5^0$C, is always very fast (providing the vacuum cooler is fast enough), cooling down to around freezing requires much more time, as the graph shows.

Other advantages of vacuum cooling methods include that paper and plastic packaging materials in the boxes do not affect the efficiency of cooling, free water is removed, **boxes can be packed tightly** and stacked in any manner in the precooler, and it can work equally well with dry packs and wet packs for cut flowers and greens and for potted plants.

## 4. Vacuum Cooling Technology Explained

Vacuum works with pressure. There is a relation between the pressure level and the boiling point of water. The lower the pressure, the lower the boiling point of water. When introducing a product

recently harvested into the vacuum room, vacuum pumps start evacuating much of the air lowering the pressure inside the room. When the pressure level reaches the product's temperature, a fraction (0,8 – 2%) of the moisture inside the product is being forced to evaporate. This evaporation process extracts energy (=heat) from the product, cooling the in- and outside of the product evenly, from the core. Because of the created vacuum, not only the outside is cooled down, but the product's core as well, as cooling takes place from inside the product.

### *What happens inside the vacuum room and how is the vapor flow handled?*

Vapor flow at final pressure is huge and would require very big vacuum pumps. Using a condenser to trap the vapor flow is more economical! Weber Cooling vacuum coolers operate with very efficient condensers using glycol/water coolant (-5 to -0°C) for a fast cooling. The hot vapor passes through the heat exchanger through which it is re-condensed and drained out of the room. When the cycle is finished, vacuum pumps pump air into the room and the door can be opened again.

*Note: For every 6-7°C reduction in temperature, approximately 1% of the produce weight needs to be turned into water vapor. In an average cycle of 15-25 minutes, weight loss can vary between 2-3%.*

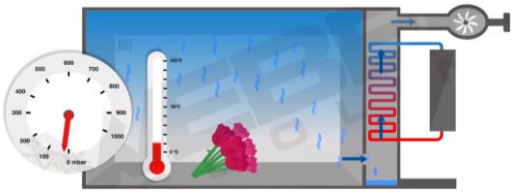
## *CYCLUS*

1. The product is placed in the vacuum room and room is closed.

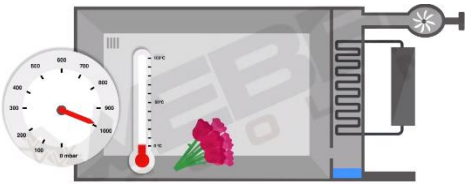
2. The vacuum pump starts and reduces the air pressure in the room from 1000 mbar to the desired pressure.

3. A small amount of water within the product will start boiling when pressure reaches temperature level of the product. This boiling process requires heat that is extracted from the product, enabling the cooling.

4. In the condenser (located in the room) the water vapor is recondensed and the vacuum pump extracts the dry air.



5. The cycle ends when the product is cold and the pressure returns to 1000 mbar.

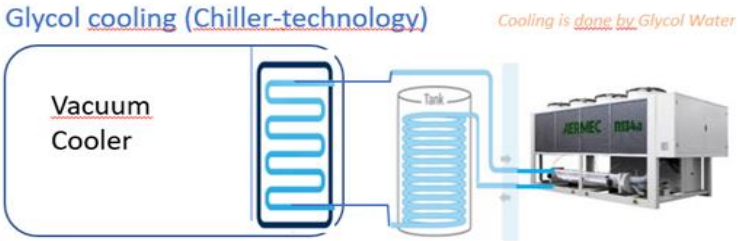


6. The condensed water is drained and the vacuum cooler is ready for the next load.

Table relation pressure/temp

| Pressure mbar | | Boiling point of water | |
|---|---|---|---|
| **mBar** | **Torr** | **°C** | **°F** |
| 1000 | 760 | 100 | 212 |
| 56.2 | 42.2 | 35 | 95 |
| 42.4 | 31.8 | 30 | 86 |
| 31.7 | 23.8 | 25 | 77 |
| 28.4 | 21.3 | 20 | 68 |
| 17 | 12.8 | 15 | 59 |
| 14 | 10.5 | 12 | 53.6 |
| 12.3 | 8.6 | 9 | 48.2 |
| 9.3 | 7.0 | 6 | 42.8 |
| 7.6 | 5.7 | 3 | 37.4 |
| 6.1 | 4.6 | 0 | 32 |

Components of a Vacuum Cooler



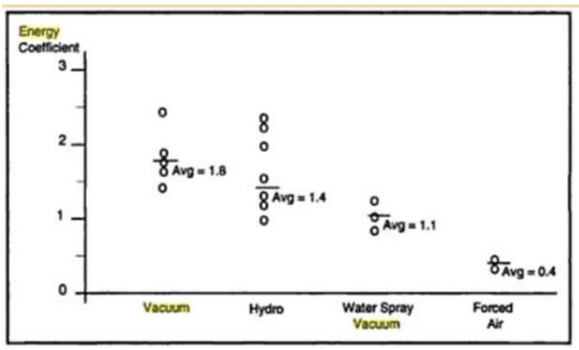

## 5. Energy comparison

There is no discussion about the fact that vacuum cooling is the most energy efficient method for cooling down flowers and can be applied more efficiently than forced air. As a rule of thumb, you can say that due to the difference in energy coefficient, forced air cooling will need up to 4 or 5 times more energy compared to vacuum cooling!

A comparison:

*Average precooling efficiency*:

- Forced air cooling: 30 – 50%
- Vacuum cooling: 140 –250%




To cool down 100 kg of produce in a vacuum cooling, you will need roughly 1 kWh of energy (+/- 20%), to cool down from 23°C down to 3°C. The energy needed will be lowest for flowers and highest for vegetables & herbs (as they have a higher specific heat). With forced air this can be more than 3 kWh! Beside the energy efficiency of vacuum cooling, it also reduces the energy requirement or workload of a cold store system.

## 6. The importance of Cold Chain Management for optimal Logistics & Vase Life

Poor transportation temperature levels reduce vase life, increase respiration rates, and increase heat production. Both time and temperature influence flower and plant quality. Data in the following table shows the effects of temperature on the average respiration rates (heat production) for cut carnations (adapted from Maxie, 1973 and 1974).

| Temperature (degrees F) | Respiration for carnations & roses (mg $CO_2$/kg/hour) | Increase in respiration compared to 32 F (0 C) |
|---|---|---|
| 32 | 10 | - |
| 50 | 30 | 3 times higher |
| 68 | 266 | 27 times higher |
| 86 | 523 | 52 times higher |

At the temperature to which these flowers are commonly exposed (50 F), they respire (and therefore age) about three times faster than at the ideal cold chain temperature (32 F).

A study by Celikel and Reid (2001) also showed that the respiration rates of roses increased by a factor of three when stored at 50 F compared to the proper storage temperature of 32 F. They also showed that there was a strong negative relationship between respiration during storage and subsequent vase life: the higher the respiration, the shorter the vase life. For example, 'Ambiance' roses stored at 32 F for 5 days had a display life of 11.5 days at 68 F, whereas those held at 50 F for 5 days lasted only 7.0 days at 68 F, a 39% decrease in vase life.

Furthermore, higher temperatures during the cold chain can also result in sleeves becoming wet due to the formation of condensation, normally on all surfaces. Too warm temperatures increase respiration rates, which again results in moisture formation on sleeves, often more on the inside. The more moisture, the higher the probability that Botrytis will develop.

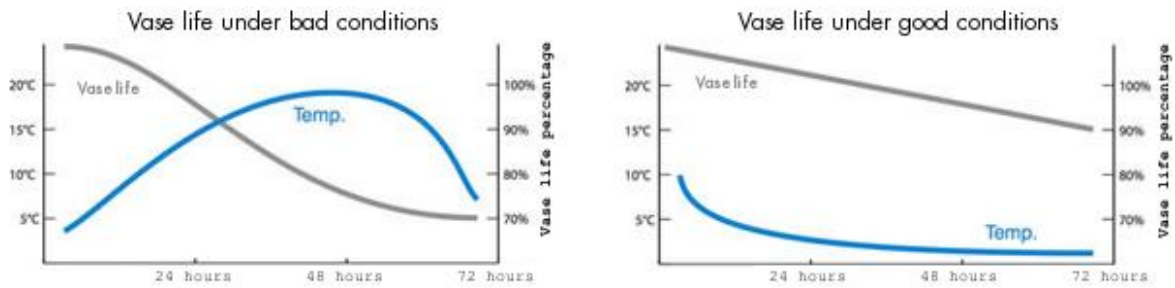
Consequently, cold-chain management has emerged in recent years as a vital success factor in the post-harvest life of fresh flowers. Flowers are delicate, living produce which need optimal storage & shipping conditions to ensure beauty preservation and long vase life. Packed tightly in boxes, flowers generate a lot of heat during storage and transportation which contributes to discolouring, wilting, poor flower opening, and premature ageing. The result is reduced vase life by several days as mentioned in above study and problems associated with Botrytis infection and growth.

Vacuum cooling is the perfect pre-cooling method for (almost) all flowers and has been successfully implemented at all stages of the cold chain, at growers as well as at logistic hubs.

Why is vacuum cooling so perfect? Cooling the flowers to the core is the only way to ensure low temperatures during transportation over large distances.

With vacuum cooling, you can quickly reduce the temperature of flowers down to 4 - 6$^0$C, to the core, normally within around 20-30 minutes. This brings the flower into hibernation, minimizing respiration & transpiration, preserving freshness and maximizing storage and shelf life.

The longer the flowers are exposed to high temperatures, the higher the loss in quality and vase life.




## 7. A calculation model for temperature load during transportation

A central concept has been developed by the Dutch company FlowerWatch 'time temperature exposure´, which is expressed in ***degree hours***. This is the average temperature of your fresh flowers throughout transportation multiplied by the number of hours (1 degree-hour = 1 hour x 1 degree Celsius). The key to successful cold chain performance is to minimise the number of degree hours. This is why maintaining a low temperature of the flowers during the entire cold

chain, keeping the number of "degree hours" within limits will ensure maximum quality preservation and longer vase life.

Basically:
- Amount of "degree-hours" will give indication of freshness of the flower
- You measure temperature after harvesting – each hour – in C – and add the total number
- 500 degree-hours is still good (on average), 750 degree-hours is "funeral flower".
- Say 3 days (72 hour) at average of 5 C, = 72 x 5 – 360 degree-hour, still good

Vacuum Cooling will guarantee an equal low temperature of all the flowers in a shipment as pressure is the same in the vacuum room. When compared to cooling with forced air systems, these systems have difficulty cooling all flowers uniformly and by using cold air, flowers are dried out. Usually only the outside of the flowers is cooled properly, inside stays hot. For tightly packed flowers it does not work, and it takes a lot of time to really reach low temperatures. **This makes Vacuum Cooling the perfect precooling method for shipping flowers by sea.**

Most easy is to use dataloggers on several shipments, see the graph, then you see where you can improve to keep the degree-hours down.

## 8. Vacuumcoolers for Flowers

Flowers have an open structure, allowing for fast vacuum cooling. A wide range of flowers can be cooled with vacuum cooling, but your vacuum cooler will need to run a dedicated cooling program to reach optimal results. The perfect vacuum cooler for flowers is designed to cool down pallets with on average 400 – 500 kg of flowers within 20-30 minutes, down to 1 … 3 $^{0}$C. Parameter settings will be dependent on flower type, packing method and time of cooling. With most vacuum coolers supplied to the flower industry, no other supplier has more knowledge on flower cooling than Weber Cooling!

While research documenting the use of vacuum precooling for floral crops dates back to the 1950s, few such systems have been used commercially. In the past few years however, vacuum coolers have been installed in flower marketing terminals (mostly near airports) but also more and more at growers as a means of removing heat from packed flowers.






## 8.1 Vacuumcoolers at farms

At farms, vacuum cooling is the 'perfect start' of the cold chain. Pre cooling down to 5-7°C is perfect after harvesting before processing the flowers. Respiration & transpiration is reduced by 4 to 6 times. Vacuum cooling can also be used before shipping, lowering flower temperature to 1-2°C ensuring that flowers can start their journey sleeping quietly, while hardly generating any heat, hardly any breathing. Thus preserving their energy. Cooling to very low temperatures becomes vital when shipping flowers by sea. Smaller farms can work with smaller vacuum coolers; with a one pallet system highest cooling speeds can be achieved of 12 – 15 minutes.

With the **Weber Compact ONE,** up to three to four loads per hour can be cooled, or **up to 32 pallets on an eight-hour working day**! With the **Weber Compact TWO** cycle times of around 15 minutes can be achieved. Including logistics, this means cooling up to three loads per hour, or **up to 48 pallets on a normal day**! The **Weber Base Gen & Next Gen** models offer standardized solutions for three up to ten Standard pallets or flower carts (1.000 x 1.200 mm). It's easy to achieve a capacity of **well over 200 pallets per eight-hour shift**. These systems are available with electric sliding or hydraulic swing door.

## 8.2 Vacuumcooling at logistic hubs & Export companies

Even if flowers are shipped at perfect conditions, they will still warm up when shipped over a long distance. Cooling back to the core on arrival - at the airport or logistic hub – is an important step in the cold chain management process. The only efficient and truly effective way of cooling is by vacuum, since no other technology can cool (consolidated) shipments so fast. For higher capacities Weber Cooling offers the Weber AIR range suitable for cooling standard Aircraft pallets. The systems are designed for cooling single or double aircraft pallets per room or double room. Solutions for each demand can be build.

## 8.3 Weber Cooling – Your First Choice

Weber Cooling only builds vacuum coolers – and makes the best systems you can get. All vacuum coolers are designed by our Dutch engineering team, and build using only premium (European) components. As largest producer in the world, with different production locations, we can offer unparalleled value for money.
Our global presence ensures our availability for maintenance and service worldwide. No other supplier has more knowledge and experience on flower (pre-)cooling than Weber Cooling.
For our *Next Gen range* we exclusively work using "**Hydronic Technology**", with which cooled water (generated by a chiller) is used in a secondary cooling system for the "Cold Wall" inside the vacuum cooler. Hydronic Technology offers many advantages: It gives you faster cooling, it reduces the amount of refrigerant in the system and it minimizes maintenance and TCO.
For our export markets we also offer the conventional *Base Gen range*, using **DX (direct expansion) technology**, in which you cool the "Cold Wall" directly with your refrigerant. Simple & effective. Requiring minimum installation, and at lowest cost (especially for smaller systems).

## 8.1 Some of our customers and videos of several installed systems at Farms, Export companies and Logistic hubs, worldwide

https://vimeo.com/showcase/6810111