Controlled Atmosphere Systems

by
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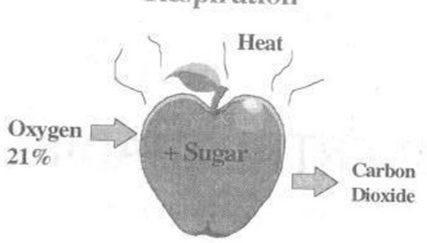
In this article, we examine the basic concept behind CA as a system, the most commonly used form of Controlled Atmosphere system available in the current Reefer market, the various additional components involved and safety considerations.

BASIC CONCEPT

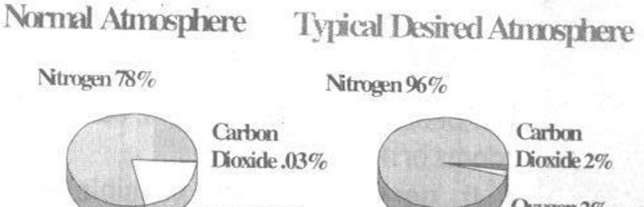
When a fruit or vegetable is harvested from the tree, it is still living, chemical reactions are going one within it with liberation of gases and heat. In other words, it is still respiring. This respiration process contributes to aging or senescence of the fruit.



Respiration Reaction inside fruit

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + Heat$

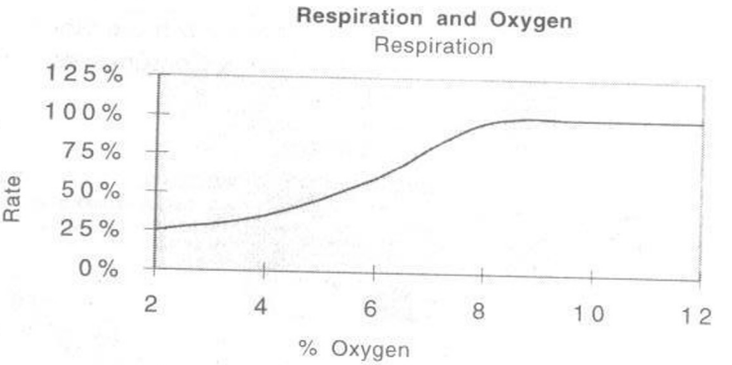
The idea of CA is to ensure conservation of perishables not only by refrigeration but also by changing the gas concentration of the air inside the refrigerated chamber. For the purpose of conservation the oxygen level is reduced to approx. 2 - 3 % (normal air: 21 %) and the carbon dioxide level is increased to 5 - 15 % (normal air: 0.03 %). The gas mixtures that provide the best conservation depend on the crop but may vary with variety, origin and harvest date. The most common fruits that are stored under CA on shore are apples and pears. It is to be remembered that CA is an additional feature provided to supplement Refrigeration.



By changing the atmosphere in the correct way, the respiration of the fruit is reduced and preservation is better. The transit times can therefore be longer, so that fruit, normally transported by air, can be shipped by sea or truck. Another possibility is to harvest riper fruits in order to transport it in better quality than earlier.

The rate of respiration falls rapidly below 9% of oxygen content in the atmosphere. At 2% oxygen level, the rate of respiration is as low as 25%. Most of the products require oxygen content close to 2% for better preservation in addition to refrigeration.

Atmosphere changes must however be made with care as oxygen levels that are too low, as well as carbon dioxide levels that are too high, can result in damage to the fruit. Ethylene, which is a gas that is produced by many fruits, but which also



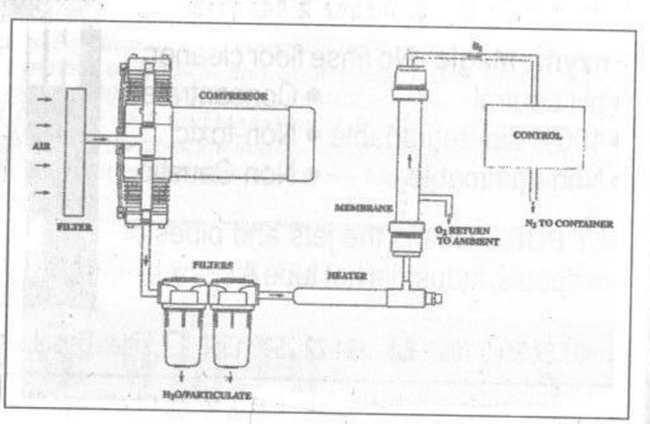
accelerates the ripening process, also has to be removed from the atmosphere (green bananas for example are treated with ethylene in the ripening stages to get them ready for sale).

APPLICATIONS OF CONTROLLED ATMOSPHERE

For several years now, Controlled Atmosphere (CA) has become more and more important in the refrigerated transportation of perishables. While in the beginning CA was almost unknown, it has now become a quite common addition to normal refrigeration in several fruit trades. In the reefer vessel market CA is mostly used by banana companies like Chiquita and Dole for the transport of bananas and other fruits from Latin America to Europe. Apples from New Zealand to Europe and stone fruit (e. g. peaches, nectarines) from Chile to the US are also shipped in reefer containers under CA. Each product has its own requirement of Oxygen and Carbon-di-oxide percentages ranging from 1 to 10% with varying degree of potential benefit, ranging from Slight to Very Good.

Controlled Atmosphere System Of Carrier Transicold

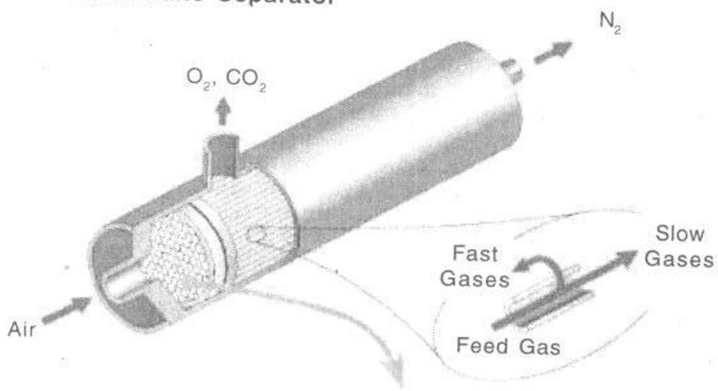
In November 1994 Carrier Transicold unveiled its CA system at the Intermodal exhibition in Amsterdam. The system is based on Carrier's NT reefer machinery and fitted completely into it. The additional weight is 70kg. The system consists of a membrane type nitrogen separator including the necessary oil less air compressor. The membrane itself was developed in conjunction with Medal (DuPont). The controller for atmosphere control is of the same type as for temperature control, so that the two controllers can even be interchanged. The data logger records oxygen and carbon dioxide levels as well as the air humidity inside the container, in addition to the temperature setpoint, supply air and return air temperatures.



System Operation

Atmospheric Air is drawn through an air intake filter to remove contaminants before entering an oil-less Air Compressor. Once it is compressed, air is fed into a condensing line where moisture is removed. It then passes through a filter assembly where the moisture is drained away. To enhance the efficiency of seperation, it is passed through an air heater before entering the membrane seperator. In the membrane seperator, nitrogen is separated from the other gases and delivered inside the container while the other separated gases are simply vented to the outside atmosphere.

Membrane Separator



Principle of Seperation

The membrane seperator contains thousands of small hollow-fibres, approximately twice the diameter of human hair, that make up a semi-permeable membrane bundle. Similar to the shell and tube heat exchanger, the membrane bundle is housed in a cylindrical shell with a feed inlet port at one end and two vent ports-one each at the opposite end and on the side of the housing. Compressed Air used as a supply gas is fed at the inlet of the seperator and flows inside the hollow fibres towards the opposite end vent port. Each of the air components has its own permeation rate that is function of its ability to dissolve and diffuse through a porous medium. This characteristic permeation rate allows fast gases like oxygen to separate out from slow gases like nitrogen.

The ability of a membrane to separate gases is determined by the rate of permeation of each feed gas components, which is a function of the individual components' solubility in the membrane material and the rate of diffusion through the membrane wall. Gases with a higher solubility in the membrane material and are small in molecular size permeate faster than large, less soluble gases. The higher the solubility, the more efficient the seperation process is. The driving force behind the seperation process is the difference between the gas components' partial pressures that make up the feed gas.

Both oxygen and carbon dioxide levels are controlled by flushing with nitrogen. An automatic purity control guarantees the proper function of the system.

It is also possible to connect a CO_2 source to the container (cylinders inside and outside the container). The controller is already designed for CO_2 supply, and a magnetic valve is installed to which the CO_2 source can be connected.

Safety

Since we are dealing with atmospheres which are deficient in oxygen, we need to be very cautious whenever we are working on Controlled Atmosphere systems. Awareness of the ill effects of exposure to Oxygen deficient atmospheres is crucial.

The following are the effects of various degrees of reducing oxygen content in the atmosphere and the affects on human beings.

- 15 - 19% O_2- Co-ordination impaired
- 12 - 14% O_2- Perception and judgement impaired
- 10 - 12% O_2- Performance failure, poor judgement - Onset of Cyanosis
- 8 - 10% O_2- Mental failure, unconsciousness
- 6 - 8% O_2- 100% fatal after 8 minutes exposure
- 4% O_2- Coma in 40secs, convulsions, death

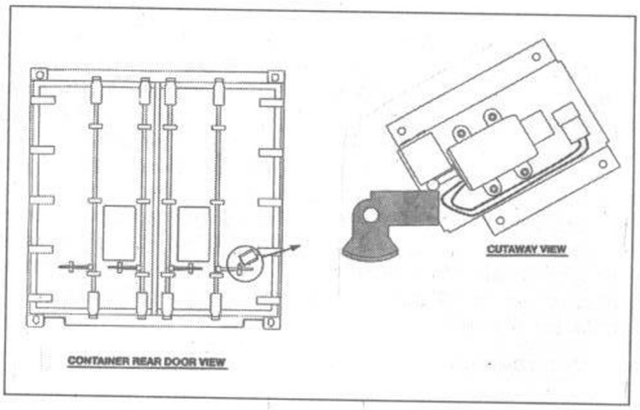
The following precautions are recommended when working on Controlled and Modified Atmospheres

- Never assume the atmosphere is safe
- Vent before entering

-20 minutes minimum
-Remain clear of open doors
-Remain clear of air vents
-Even if safe yesterday

- Work in pairs when entering Modified/Controlled Atmosphere Units

Safety Door Lock



Most of the containers are now equipped with a **safety door lock** which allows the rear doors of the container to be opened only after the oxygen content in the container has reached 20.3% and locks the container at oxygen percentage below 19.8%. The locking and unlocking is achieved through a solenoid valve which pushes out a locking lever and the signal for the same is obtained from the controller based on the sensed value of the oxygen percentage inside the container.

References:

1. www.carrier.transicold.com

2. Dr. Ing. Yves Wild, Overview on Controlled Atmosphere Transportation in Containers, 19th Congress of International Institute of Refrigeration, The Hague, Netherlands, 23rd August 1995.

3. Devon Zagary and Adel A Kader, Controlled Atmosphere Handbook, Carrier Transicold, USA, 1999.

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