CONTROLLED ATMOSPHERES IN MARINE TRANSPORT - ACHIEVEMENTS AND FUTURE NEEDS

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ABSTRACT

Controlled atmosphere is gaining acceptance as an addition to refrigeration for transport of fresh produce, including bananas. The types of systems in ships and containers are summarised. Results achieved in commercial shipments are presented, which indicate the current capabilities of equipment. Needs for further research and development are discussed.

1. INTRODUCTION

Controlled atmosphere systems are either fitted to containers, land stores and entire refrigerated ships holds. The function of the controlled atmosphere system must be to increase and maintain the nitrogen concentration, remove and maintain the carbon dioxide, remove ethylene as it is produced and maintain the relative humidity. Many aspects of the science and technology were reviewed recently (CRT 1998).

2. TYPES OF CA SYSTEMS

2.1 Modified Atmosphere

Modified atmospheres are a half way house to full atmosphere control and are either a tightly sealed refrigerated space flushed out with an appropriate cocktail of gases or special packaging. The packaging has a differential permeability to gases such as carbon dioxide and oxygen.

2.2 Passive Controlled Atmosphere System

Passive controlled atmosphere systems rely on the refrigerated space being very tightly sealed. The product develops its own atmosphere by consuming oxygen and producing carbon dioxide which can be assisted by the injection of nitrogen. Once the required concentration of oxygen is achieved a valve to the atmosphere can be opened. Carbon dioxide is often removed by adding 1% of the weight of the cargo of cartoned lime. Carbon dioxide concentration can be controlled by encapsulating the lime and using a small fan. Ethylene can be controlled by using sachets of alumina beads coated with potassium permanganate ($KMnO_4$).

2.3 Active Controlled Atmosphere System

Active systems work by flushing the refrigerated space with nitrogen until the required concentrations are achieved. Nitrogen can be obtained either from liquid or compressed gas cylinders or more normally can be separated out from the atmosphere using pressure swing absorption (PSA) or a membrane system.

Carbon dioxide is controlled usually by flushing with nitrogen and with PSA a modification to the absorption cycle. Higher levels can be maintained by retention of metabolic CO_2 or addition from cylinders.

Ethylene can be removed by chemical systems such as $KMnO_4$ or by mechanical systems such as heated catalyst or UV radiation.

3. MEASUREMENT OF GASES

To control these gases naturally is essential to be able to measure their concentration accurately.
This normally carried out in the following way:

Component	Measurement Technique	Accuracy
Oxygen	Chemical or paramagnetic cell	± 0.1%
Carbon Dioxide	Infrared or hot wire	± 0.1%
Nitrogen	Assume balance	
Water	Wet & dry or capacitance	±2.5%
Ethylene	Gas chromatograph	±0.01ppm

4. BASIC REQUIREMENTS

The following are basic requirements for a ship's CA system:

1) Generating a low oxygen atmosphere within 24 hours of loading by the production of nitrogen.
2) Removal of carbon dioxide and ethylene by flushing, chemical or mechanical scrubbing.
3) Addition of water vapour to maintain relative humidity.
4) Instrumentation for control and monitoring.
5) CA ready ship, leak tight compartments, pressure equalisation valves and pipe work for nitrogen injection and sampling.
6) Safety and alarm systems.

In nitrogen generation systems, nitrogen is obtained by separating it out from the atmosphere using pressure swing absorption (PSA) or a membrane system. PSA systems are expensive and removable units and are normally employed.

5.CONTAINER SYSTEMS

Various manufacturers of containers systems exist but basically there are three types, these are the passive system which is used by TransFresh and active systems using either PSA or membrane systems.

5.1 TransFresh System

The TransFresh system is passive and relies on a very tightly sealed container. It has purging ports for initial development of the atmosphere, a door curtain and oxygen valve controller.

5.2 Carrier Everfresh System

This system uses a membrane nitrogen generator and a bottle of carbon dioxide. Control is by a modification to the Microlink controller.

5.3 BOC / Cronos/ Domnick Hunter PSA system.

This system uses PSA to generate nitrogen and has the advantage of being able to retain carbon dioxide. It also has the advantage of being able to control ethylene and relative humidity.

6. SPECIALISED REEFER SHIPS

The modern specialised reefer ship needs to have at least a capability for carrying cargoes under controlled atmosphere. This is especially true, as reefer ships have to compete against refrigerated containers, some of which have a CA capability.

Due to the high capital cost this actually means that the ship needs to be CA ready, having the correct pipe work and valves and hold configuration already in place. The CA generation equipment can then be transported to the ship in a shipping or aeroplane container when a charter with that requirement occurs.

The reefer ship cargo hold has an advantage over its smaller cousin the reefer container in that the surface area to volume to surface area is in its favour. This means that the controlled atmosphere system can use the cargo to help generate the atmosphere.

6.1 Carbon Dioxide and Ethylene Removal

Carbon dioxide is controlled usually by flushing with nitrogen, PSA flushing and a modification to the absorption cycle. It is also possible to scrub using carbon bed scrubbing plants which are fitted to some cold stores. Sometimes the addition of lime is requisite in addition to flushing if very low levels of carbon dioxide are required. If elevated levels are required, it can be maintained by retention of metabolic CO_2 or addition from cylinders.

Ethylene can be removed by flushing as with carbon dioxide or by chemical systems such as $KMnO_4$ or by mechanical systems such as heated catalyst or UV radiation.

6.2 Retrofitting a Ship to Controlled Atmosphere

In converting any ship to be CA friendly the biggest problems are going to be the air tightness of the holds and the positioning of equipment within the holds that the ship's crew would normally have access to. These can include bilge, brine valves or any equipment requiring maintenance during the voyage.

The principal modification that needs to be carried out is to effectively seal the cargo space in order to attain the low oxygen atmosphere. Already a ship's hold is relatively well sealed with each compartment separated by watertight bulkheads with no piercings. Services such as electricity, steam, air and water run in conduits on the deck. However, each hold has cargo hatches, escape hatches, air freshening ducts and bilge pipes which need to be made airtight. Main hatches require little modification other than putty placed on the seal where damaged, bolted down as usual. In some cases it has been necessary to seal with polyurethane foam.

7. RESULTS IN PRACTICE

Results showing the capability and limitations of the TransFresh system in containers are shown in figure 1. With the avocado cargo, a lack of sufficient CO_2 in the initial gas purge delayed establishment of the required level by two days. The persimmons showed that the use of insufficient lime leads to a CO_2 build up later in the voyage. The nectarines demonstrate that reasonable results were obtained in this cargo with no scrubber fitted.

Figure 2 illustrates a number of shipments in developmental "clip-in" PSA systems in containers. These results have been made available to CRT with only limited information, but they illustrate well the sort of control stability achieved with this sort of equipment. Initial CO_2 levels were probably achieved by gas injection.

The control of atmospheric composition in containers is more difficult than in ship's holds, due to the relatively small volume of free space in a container and the proportionally higher leakage rates to be expected. Greater fluctuations will occur as a result of system purges in PSA systems, and it may be unrealistic to expect better than $\pm$ 1% control levels for CO_2 and O_2.

Figure 3 illustrates the rate of achieving conditions in ship's holds carrying bananas during a commercial shipment in 1998. This appears to show that the precise gas concentrations are not too critical for this cargo.

8. CONCLUSIONS

A range of equipment is available, of varying complexity and capability. The challenge of devising a system which provides reliable and accurate simultaneous control and monitoring of temperature and of levels of water vapour, ethylene, CO_2 and O_2 at a commercially viable cost has yet to be met. If it were available, it is not clear that there is sufficient knowledge of precise commodity requirements for it to be applicable in more than a minority of trades.

There is increasing competition from partial systems offering temperature and humidity control, or ethylene control, which may be more economically effective for some commodities.

Some of the technical and commercial difficulties are more easily overcome in reefer ships than in smaller spaces such as containers. In this case, there is a lack of detailed knowledge of commodity tolerance to necessary breaks in atmosphere control at loading and unloading.

Generally, there is more enthusiasm from equipment manufacturers and from cargo owners than there is from carriers who have to pay for the equipment. Nevertheless there is increasing use of CA in transport, and this growth is likely to continue. For it to accelerate, further work to overcome the difficulties identified here is necessary.

9. ACKNOWLEDGEMENTS

Thanks are due to Cronos Containers and to TransFresh Corporation for providing records of shipment conditions for examination.

10. REFERENCE

1) Cambridge Refrigeration Technology, 1998, *Controlled Atmosphere in Marine Transport Refrigeration - CAveat Emptor?,* CRT, Cambridge.

ATMOSPHÈRES CONTROLEES DANS LE TRANSPORT MARITIME : RÉALISATIONS ET BESOINS FUTURS

RÉSUMÉ: On a recours de plus en plus au contrôle de l'atmosphère en tant que technique supplémentaire utilisée avec le froid pour le transport de produits frais, y compris les bananes. On résume les types de systèmes utilisés à bord des bateaux et dans les conteneurs. On présente les résultats obtenus pour les cargaisons commerciales maritimes, qui indiquent les puissances des équipements utilisés actuellement. On expose également des besoins pour de plus amples recherches et développements.

DISCUSSION

Z. KAISER (Czech Republic) - How do you see the future of CA in the road transport?

R.D. HEAP - As road transport tends to be for shorter journeys, I would be surprised to see the development of CA systems for road vehicles.

B. McDONALD (New Zealand) - In the Permea CA system the O_2 level is controlled by the quantity of N_2 purging. However, if the container is not sufficiently gas-tight, excessive N_2 purging does not allow the CO_2 to rise to desirable levels – e.g. 5% CO_2 for Kiwifruit. Is there a container selection process or are containers tested for gas-tightness to overcome this problem?

R.D. HEAP - Gas tightness of containers is very dependant on how they have been handled or misused. It may be necessary to limit the use of some CA systems to newer containers.

J. MOUREH (France) - I want to know if according to your experience, you have any idea about the range of O_2 and CO_2 in the cargo?

R.D. HEAP - I believe that atmosphere composition within the cargo space will be uniform, due to the effects of diffusion and air movement, though we have not attempted to measure this.

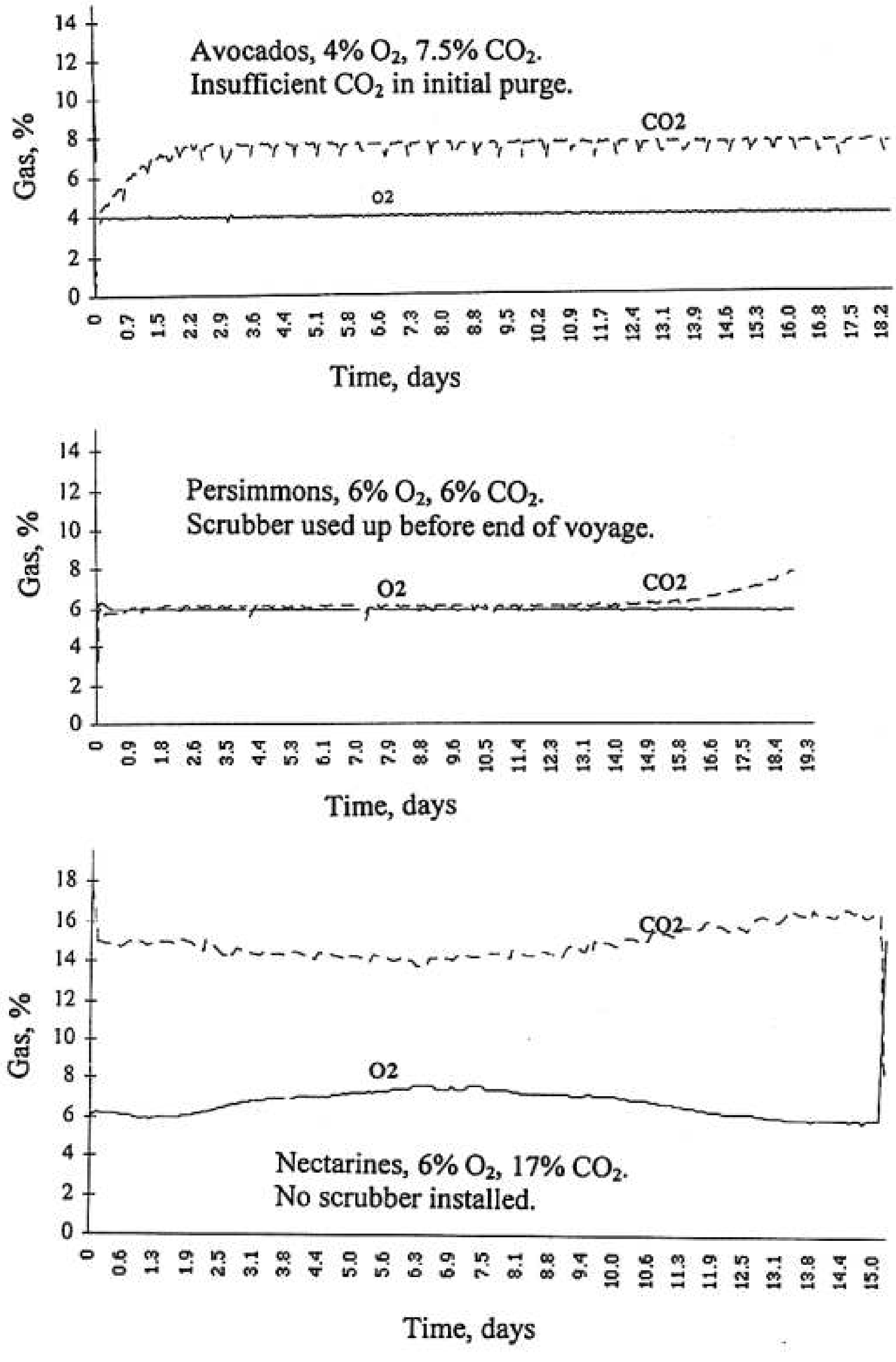


Figure 1. Results using the TransFresh system.

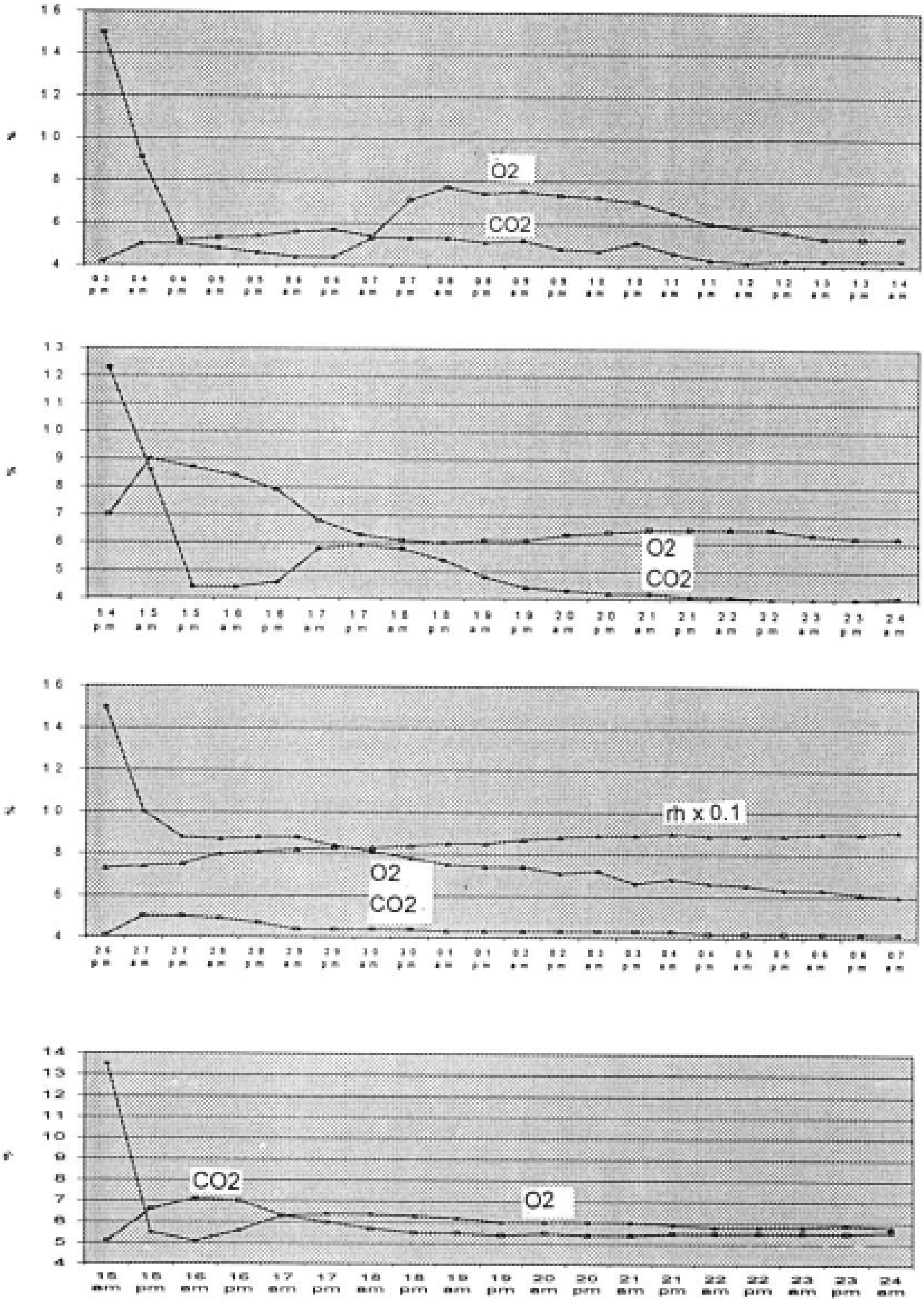
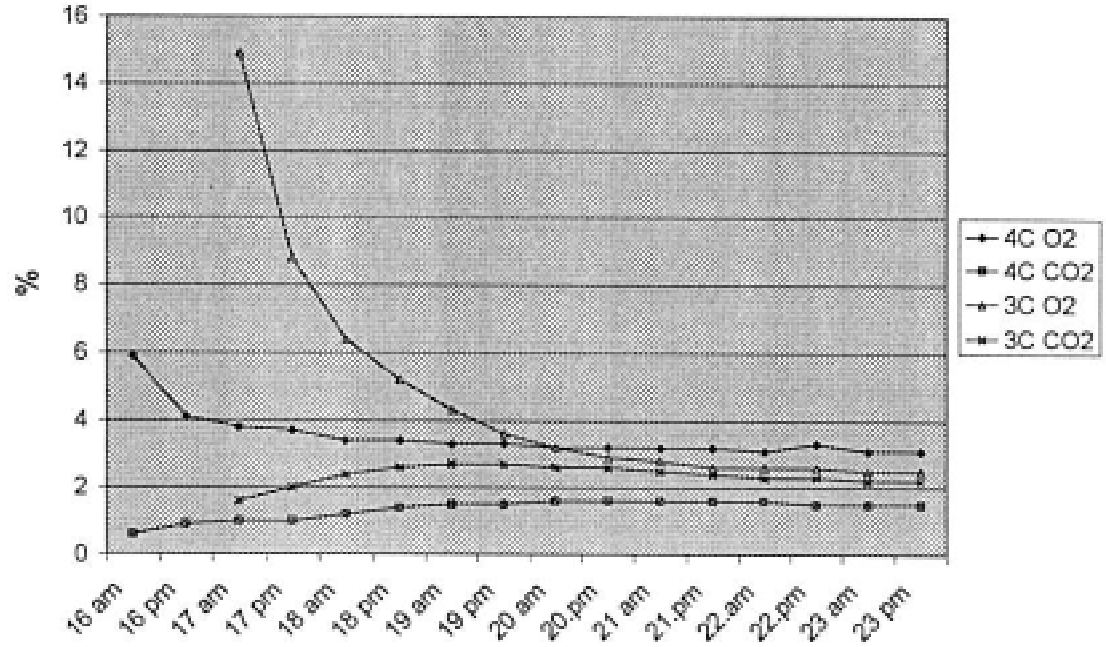


Figure 2. Container developmental p.s.a. system results.



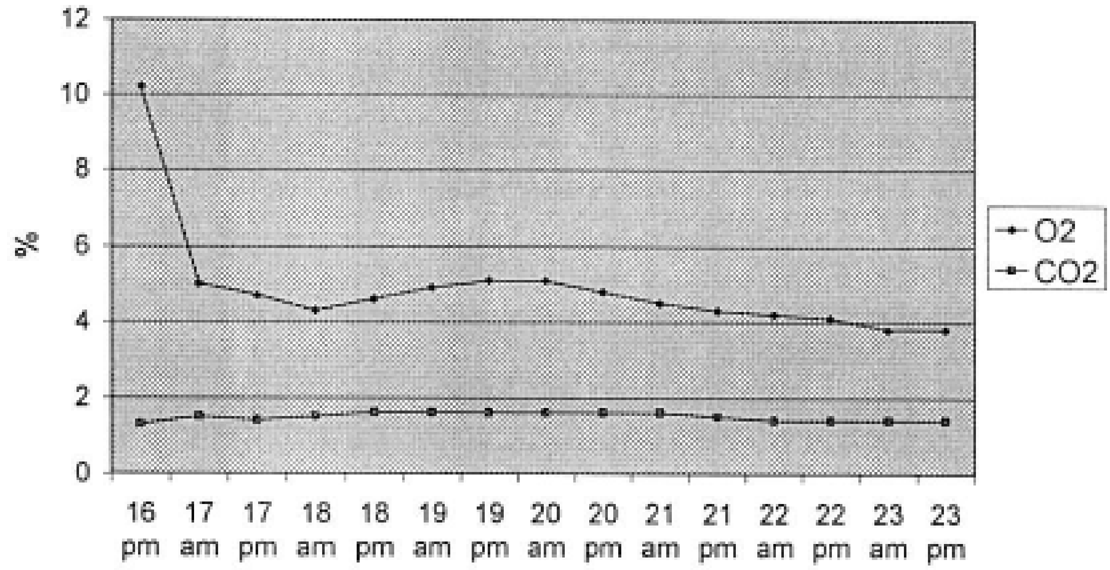


Figure 3. Pulldown for banana shipments, nominally 3 to 4% oxygen, 4 to 5% carbon dioxide.