A SUMMARY OF CA REQUIREMENTS, LIMITATIONS AND RECOMMENDATIONS FOR ORNAMENTALS

Barry A. Eisenberg
Department of Horticulture
University of Illinois
Urbana, IL 61801

Controlled atmosphere storage of ornamentals is an area that has received limited attention in the research community and even less commercially (19). Formal CA work has been limited to fresh flowers and bulbs with the exception of low pressure (LP) storage which has been used on a variety of crops. The majority of ornamentals CA work is actually modified atmosphere (MA) storage which is achieved through box types or polymeric films.

This review will focus on limitations and needs for work in ornamentals CA storage. Therefore, specific references are used rather than reviewing all of the literature in the area. Previously published reviews on the topic (7,13,14,17,20,22,23,27,29,32) are extensive and the work conducted since the last review in 1982 (29) has not added significantly to the area. At first one may find this disappointing, but when examined more closely there does seem to be a rational for why CA of ornamentals has not been studied more intensively.

There is no denying that CA storage work in ornamentals is lacking and for several reasons:

(1) Many of the problems can be solved through proper temperature and humidity controls.
(2) Short-term storage problems are so numerous that long-term storage is being examined with only a few crops.
(3) Due to the large number of cultivars no universal CA environment can be defined.
(4) There is a lack of small scale CA technology.
(5) Products are a mix of leaves, roots, flowers and fruits and each react differently to CA.
(6) In many cases the product has to continue to develop after storage which means that vital chemical processes can not be altered after removal from storage.
(7) Industry funding for CA research is poor when compared to other disciplines within ornamentals.
(8) The use of chemicals to overcome postharvest disorders is a logical alternative to CA given present handling procedures.

The key to understanding why CA storage of ornamentals is limited is in defining how products are handled. There are relatively few instances where extended storage periods are necessary. When they are used it is because production exceeded demand, or the opposite, demand was in excess of inventory especially during holidays or prior to peak production periods. A relatively new area, shipment of ornamentals overseas by ship, is presently being explored. There is some interest in extended storage of fresh flowers and bulbs, but much of this work is MA storage rather than CA. Interest in extended perennial storage is growing and CA may improve crop quality and availability during Spring when the majority of the crop is purchased.

If research in postharvest is to reflect immediate industry needs, then work should focus on short-term storage (less than 5 days) since problems within this time frame are considerable. Leaf yellowing and abscission, flower drop, disease development and poor performance after removal from storage are the major problems (12,13). Many of these problems have been solved through temperature control, but given the number of handling steps it is not often achieved. Most researchers in ornamental postharvest physiology accept this limitation and attempt to avoid postharvest problems either through improved packaging techniques to reduce moisture loss and modify gas mixtures within the film or by the application of chemicals prior to and after storage (13).

The lack of CA ornamental research can also be approached from another viewpoint. Controlled atmospheric storage has been most successful with fruit and vegetable crops that are ethylene sensitive. Controlled atmospheres can also reduce disease development, limit respiration, maintain flavors which are all factors that affect product ripening rates. First, ornamental crops seldom 'ripen' but must continue to develop after storage. Unrooted cuttings must root at a uniform rate, flowers harvested in bud stage have to open and flowers develop normally, bulbs need to expand leaf and flower tissue after storage which are responses that either depend on photosynthetic efficiencies or carbohydrate uptake and utilization, factors not as important with edible crops after storage. Furthermore, ornamentals sensitivity to ethylene and susceptibility to diseases can be controlled with chemicals not used on other crops because ornamental products are not ingested.

Just as with other crops, after storage, ornamentals continue to develop. Potted plant handlers take advantage of this by packaging products in the bud stage because they are less sensitive to ethylene (28). In addition, production practices such as reducing nitrogen fertilization and light levels prior to shipment have been shown to reduce postharvest disorders (6). Production controls similar to these cannot be used with field crops economically due to inherent limitations.

DISCUSSION OF SELECTED CROPS

Cuttings

Several species (gernanium, poinsettia, foliage plants, woody material) of rooted and unrooted cuttings can be successfully stored using

LP storage (2,8,9,18). Low pressure technology will not be discussed here, but those who want more information should read these reviews (7,20). In nearly every instance storage periods can be doubled using LP and low temperatures when compared to normal atmosphere (NA) storage. Yoder Brothers, located in Fort Meyers, Florida, has used LP storage for carnations and chrysanthemums. Ethylene and high rates of respiration can reduce cutting quality, but LP research has not identified which factor is limiting storage life. Further work in this area is being conducted in Europe by Arne Skytt Andersen (unpublished).

There are several reasons why LP storage work is not being explored by more laboratories. First, the technology is expensive and is feasible to only a select group of growers who handle large numbers of cuttings. Consistent results in experimental chambers are also difficult to achieve. In many instances, low temperature/high humidity storage conditions are successful and cost effective. Finally, if research should reflect the primary industry need, then efforts should be focused on short-term uncontrolled temperature storage/shipping experiments. Problems under these conditions are serious and LP technology cannot presently be used to solve these problems.

Modified atmosphere cutting storage is being examined at the University of Illinois. When unrooted geranium cuttings were shipped in sealed styrofoam boxes for 85 hours without temperature controls (range 2 to 32C) the atmosphere within the box contained 6 percent carbon dioxide and 1 ppm ethylene (10). Ethylene concentrations of 1 ppm normally reduce plant quality, but not in this case which may have been due to elevated carbon dioxide levels. Present studies are examining a initial box gasing procedure then allowing the tissue to further modify the box environment.

Foliage Plants

Studies have been limited to the use of polyethylene bags to reduce moisture loss in the retail environment (16). A preliminary study was conducted by the Perishables Research Organization, Nevado, California, in cooperation with the University of Florida using low oxygen levels for simulated overseas shipment of foliage plants (personal communication, George Staby). Plants stored under low oxygen conditions did not differ from plants stored using NA.

Studies at the University of Florida are continuing, using NA to ship foliage plants. Acclimatizing plants by leaching excess nutrients, thinning out growth and shading for 2 to 3 months prior to placement in an adverse environment does effectively reduce leaf yellowing and abscission (6). Therefore, foliage plant CA storage does not appear feasible at this time because altering production practices is simpler, cost effective and by itself, overcome many postharvest problems.

Tissue Cultures

Research has been limited to a comparison of LP and low oxygen callus mass storage to cultures stored using NA (5). Lowering the partial pressure of oxygen to 8 mm Hg was the key to reducing plant growth whether achieved through LP or CA. Further work in this area should not be expected since the advent of freeze preservation techniques for tissue mass storage (3).

Potted Plants

There have been essentially no published CA studies on this topic. Low pressure storage has been evaluated (2) but the benefits could not compensate for the cost. Enclosing plants in plastic bags has been evaluated, but since no atmospheric analysis was done we cannot interpret the results in relation to CA or MA research (16).

Work is in progress at the University of Illinois testing small sealed containers for single plants shipments of flowering gardenias. This is a high priced crop that must arrive after uncontrolled temperature shipment at the home with green leaves and intact flower buds that will open. The approach is to lower oxygen levels with nitrogen gasing to reduce the disorders. Chemicals will also be used with MA treatment.

Bulb Crops

Tulip bulbs have been successfully stored in 3 to 5 percent oxygen and carbon dioxide for 4 weeks at room temperatures (25). In addition, recent work using polymeric films designed to allow bulb tissue to modify the atmosphere have also been successful (26). The growth in this area is encouraging and may be applicable in other areas. Controlled atmosphere storage of gladiolus, easter lily and iris has also been evaluated (22,31). Bulb packaging will not be critically reviewed here since a paper specific to the topic is presented in this proceeding (see Prince, T. A. and R. C. Herner).

Harvested Flowers

For years laboratories around the world have examined CA, MA, NA and LP storage of harvested flowers. Results have been mixed, but generally acceptable. At this time no one is using anything but NA storage for flower storage. Since the introduction of precooling, ethylene inhibitors, pulsing solutions, improved production techniques and the expanded use of floral preservatives many of the problems have been solved with proper NA storage (28). A 'systems approach' to flower handling has been the major factor contributing to improved postharvest life of harvested flowers. The program is referred to as "The Chain of Life" (28).

The majority of the work has been with carnations, roses and chrysanthemums (4,7,8,14,15,17,21,30,32). Various levels of carbon dioxide and oxygen have been used, but they can basically be summed up by a simple recommendation. Carbon dioxide should be between 5 and 10% and oxygen reduced to near 1%. It appears that reduced temperatures (0 to 5 C) are required if quality is to be maintained. Work at the University of California at Davis is examining high carbon dioxide (20%) storage of fresh flowers to control diseases. This project is discussed in this proceedings (see Joyce, D. C. and M. S. Reid).

Many other crops have been examined but very little published information is available since the last review of this topic (29). Daffodil, anthurium, snapdragon, gladiolus, delphinium and tulip storage have been studied (1,17,21,23,24,29). Recommendations are mixed, except for daffodil. It appears that 100% nitrogen is a satisfactory storage treatment (24), but without cultivar evalutions it should not be attempted commercially.

The primary benefits of CA are related to maintaining leaf color, controlling disease and retaining flower quality. In addition, rose blueing (4) and carnation 'sleepiness' can be avoided (13). One problem with CA flower research is that conditions can be formulated to extend flower life, but leaf tissue can be damaged. Therefore, optimizing CA requirements is difficult.

Over the past three years, Perishables Research Organization has been studying CA shipments of fresh flowers. No work has been published, but a review of transportation research is summarized in this proceeding (see, Staby, G. L.).

RECOMMENDATIONS

An original objective of this paper was to define commercial storage recommendations for ornamentals. For reasons outlined earlier and due to previously published literature this will only be done for three cut flower crops.

One major problem is that depending on cultivar, pretreatment, temperature and a host of other factors, success in storage can be altered. In addition, given the growing concern over water loss being of greater importance than previously thought, results need to be reevaluated. It may very well be that differences in storage water vapor may have been the critical factor and not the atmospheric composition, especially when evaluating packaging research. In many instances, CA chambers and product in bags may have a higher relative humidity than the control treatment which creates problems in defining experimental results.

In addition, recommendations cannot be made due to methodology. Many laboratories use flow through systems which is fine for extended CA storage, but is not realistic if the storage goal was to improve shipping quality. During shipment or in most storage situations, static MA systems are more practical unless small CA chambers are developed which are cost effective. Secondly, flowers removed from 0 to 5C and directly evaluated for vaselife can be misleading. Using this method, shipping standard wholesale and retail handling procedures are ignored which must be examined if research is going to be commercially important.

Lastly, if CA, MA and LP recommendations should be made who are they for? Industry is only interested in extended storage of very few ornamental commodities. Harvested flowers and bulbs are of major concern. Foliage plants, tissue cultures and potted plants storage problems are numerous, but CA is not being considered as a means to the solution. Cutting storage under CA and LP conditions is being examined, but again, water loss may be the key which leaves researchers in a quandry about what factors should be evaluated.

FUTURE NEEDS

Applied

If any storage system is going to be successful, it must take into consideration the realities of shipping ornamental products. These have to include uncontrolled temperature shipment. Even though storage research may reflect a growers desire to store crops for extended periods, evaluations must be continued to simulate handling within all channels.

An area that deserves more attention is the use of polymeric films. They can be selected with specific gas diffusion rates to achieve a variety of modified atmospheres. Bulb storage has received the greatest attention and will in the future. Cutting and perennial storage are other areas where films may be of use.

Modifying atmospheres for disease control may have potential. Botrytis limits the storage life of nearly all ornamental crops. Fungicides are effective, but due to tight packing, cool temperatures and high humidity, disease develop usually continues to some degree. Elevated carbon dioxide levels can reduce disease development, but may also alter plant performance after removal from storage. Carbon monoxide may offer some benefits, but the safety factor must be addressed and its use on a small scale needs to be further defined. Insect control is also a subject that is receiving attention, but most ornamental growers control insects during production and spot treat problem crops. Work in this area could be expanded, but on specific problems where chemicals either cause phytotoxicity or are ineffective.

Sealed boxes for short-term shipment should be explored. These are primarily styrofoam boxes. They have not been used due to the high cost when compared to standard cardboard boxes and the problem with heat build up in the box during shipment. Precooling, wrapping plant material in moist paper and incorporating ice into boxes has solved many of the problems. The cost factor is real, but so is the reduction in quality if not used.

Small scale technology is absolutely needed if anything other than NA is going to be used. Advancements need to be made in the treatment of single boxes as well as with small walk-in coolers. Once again, treatments have to reflect industry needs and procedures.

Lastly, any postharvest program should include a 'systems approach', taking into consideration new product handling technology. One major problem with this approach is that every cultivar seems to require a unique set of conditions. This creates a problem that may severely limit CA technology. There is seldom, if ever, a storage facility or a shipment that is comprised of one cultivar. Given this situation, the difficulties in using CA are even greater.

Basic

Ornamental postharvest physiology is in its infancy compared to other disciplines. Storage parameters are still being defined rather than examining what processes are being altered during storage. For example, why can one rose cultivar be successfully stored while another degrades rapidly under the same conditions.

One parameter that must be explored with crops other than harvested flowers is photosynthetic efficiencies after removal from storage. Modified atmospheres may be a blessing or a curse. Supplementing carbon dioxide in greenhouses increases photosynthesis and plant performance. How enzymes and other factors essential for photosynthesis are affected by any storage treatment is not known. If photosynthesis is reduced after removal from storage then CA must be reevaluated.

Respiration is also a factor that should be studied. This has to be examined in relation to photosynthesis. The relationship of the two processes is probably more important than either alone. Special attention should be given to how dark respiration in affected by CA environments.

Phytohormones are another area that should be closely evaluated. Unlike other horticultural crops many of the ornamental products must expand growth or develop new plant parts. Many of these processes are dependent on hormones. Research (unpublished) at the University of Illinois has identified that rooting hormones are essential for rooting of unrooted geraniums after NA storage, while directly rooted cuttings do not require the treatment. Whether the same is true under MA, CA or LP has not been answered. Work is in progress identifying changes in indole acetic acid and abscisic acid during NA and CA storage.

The study of ethylene and its intermediates deserves greater attention. Many crops when removed from storage are in excellent condition, but decline at a rapid rate, which leaves them unacceptable. Whether a build-up of ACC or some other intermediate occurs during storage and is responsible for the disorder is not known. If ACC does build up in storage and if it is further increased by CA then there is little need to examine CA storage.

Basic research in other areas is needed. Once this information is known, chemical versus storage procedures to eliminate storage problems will have a rational. For example, if a chemical change is noted and no chemicals are available to manipulate its level to the desired amount, then environmental controls may be necessary. Again, researchers should have a focus for why they are measuring a physiological parameter, rather than measure a compound simply because they have the equipment.

Controlled atmospheric storage of ornamentals is not feasible by itself with a large number of crops. An intergrated approach using environmental and chemical means is practical and CA may be useful. Regardless, research should be targeted with a clearly defined commercial goal. By improving our approach to CA research, benefits may be identified which can make CA storage at ornamentals practical.

LITERATURE CITED

1. Akamine, E. K. and T. Goo. 1981. Controlled atmosphere storage of Anthurium flowers. HortScience. 16(2):206-207.

2. Anon. 1975. Hypobaric storage and transportation of perishable commodities. Grumman Allied Industries, Inc., Garden City, NY. 23 pp.

3. Anon. 1977. Research summary proceedings environmental conditioning symposium. Horticultural Research Institute, Washington, DC. 25 pp.

4. Bajaj, Y.P.S. and J. Reinert. 1977. Cryobiology of plant cell cultures and establishment of gene-banks. IN: Applied and fundamental aspects of plant cell, tissue and organ culture. J. Reinhart and Y.P.S. (eds), Springer-Verlag, Berlin. 757-777 pp.

5. Bredmose, N. 1979. Influence of subatmospheric pressure on storage life and keeping quality of cut flowers of Belinda roses. Acta Agriculture Scand. 29:287-290.

6. Bridgen, M. P. and G. L. Staby. 1979. Low pressure and low oxygen storage of Nicotiana tabacum and chrysanthemum x morifolium tissue cultures. Plant Science Letters. 22:117-1186.

7. Dilley, D. R. and W. J. Carpenter. 1975. Principles and application of hypobaric storage of cut flowers. Acta Hort. 41:249-268.

8. Dressler, B. and W. Jamieson. 1979. Hypobaric storage of several cut varieties. Grumman Allied Ind. Publication. Oct. 17 pp.

9. Eisenberg, B. A., G. L. Staby and T. A. Fretz. 1978. Low pressure and refrigerated storage of rooted and unrooted ornamental cuttings. J. Amer. Soc. Hort. Sci. 103:732-737.

10. Eisenberg, B. A., J. Gruber and J. Hryhorsak. 1985. Cuttings can become better travelers. Greenhouse Grower. March. pp. 25-28.

11. Gehring, J. M. 1979. Shelf life extension of bedding plants. M.S. Thesis. Virginia Polytechnic Inst. 39 pp.

12. Halevy, A. H. and S. Mayak. 1979. Senescence and postharvest physiology of cut flowers. Part I. Hort. Rev. 1:204-236.

13. Halevy, A. H. and S. Mayak. 1981. Senescence and postharvest physiology of cut flowers, Part II. Hort. Rev. 3:59-143.

14. Hardenburg, R. E., M. Uota and C. S. Parsons. 1969. Refrigeration and modified atmospheres for improving keeping quality of cut flowers. 12th Int. Cong. Refrig. 3:339-347.

15. Hanan, J. J. 1967. Experiments with controlled atmosphere storage of carnations. Proc. Amer. Soc. Hort. Sci. 90:370-376.

16. Harbaugh, B. K. and G. J. Wilfret, A. W. Englehard and W. E. Waters. 1976. Evaluation of 40 ornamental plants for a mass marketing system utilizing sealed polyethylene packages. Proc. Fla. State Hort. Soc. 89:320-323.

17. Hardenburg, R. E., M. Uota and C. S. Parsons. 1969. Refrigeration and modified atmospheres for improving keeping quality of cut flowers. 12th Int. Cong. Refrig. 3:339-347.

18. Jensen, H.E.K. and P. M. Rasmussen. 1979. Lavtryksopbevaring af stiklinger. I. Principper og indledende forsog. (Hypobaric storage of cuttings. I. Principles and preliminary experiments). Tidsskrift Planteavl. 82:623-632.

19. Kader, A. A. 1982. Responses of Horticultural commodities to modified atmospheres: An overview of published literature and future research needs. Controlled Atmospheres for Storage and Transport of Perishable Agricultural Commodities, D. G. Richardson, Editor. p. 229-234.

20. Lougheed, E. C., D. P. Murr, and L. Berard. 1978. Low pressure storage for horticultural crops. HortScience 13:21-27.

21. Marousky, F. J. 1977. Controlled atmosphere and low pressure storage of gladiolus, chrysanthemums and snapdragons. Controlled atmosphere for storage and transport of perishable commodities. Second Natl. Controlled Atmosphere Research Conference. 28:116-121.

22. Marousky, F. S., R. H. Cubbedge and R. O. Magie. 1983. Controlled atmosphere during corm storage of flowering gladiolus. Florists Review. 172:38-40.

23. Nowak, J. and R. M. Rudnicki. 1979. Long term storage of cut flowers. Acta Hort. 90:506-514.

24. Parsons, C. S., S. Asen and N. W. Stuart. 1967. Controlled atmosphere storage of daffodil flowers. Proc. Amer. Soc. Hort. Sci. 90:506-514.

25. Prince, T. A., R. C. Herner and A. A. DeHerogh. 1981. Low oxygen storage of special precooled 'Kees Nelis' and 'Prominence' Tulip bulbs. J. Amer. Soc. Hort. Sci. 106:747-751.

26. Prince, T. A., R. C. Herner, and S. W. Gyeszly. 1982. Storage of special precooled tulip bulbs in controlled atmosphere packages. Controlled Atmospheres for Storage and Transport of Perishable Agricultural Commodities. p. 77-86. D. G. Richardson and M. Meheriuk (eds.). Timber Press, Beaverton, Oregon.

27. Staby, G. L. 1977. Controlled atmosphere and low pressure storage of floral crops-overview. Controlled Atmospheres for the Storage and Transport of Perishable Agricultural Commodities. Second National Controlled Atmosphere Research Conference. p. 69-70.

28. Staby, G. L., J. L. Robertson, D. C. Kiplinger, and C. A. Conover. 1978. Chain of Life. p. 71. Ohio Florists Association, Columbus, OH.

29. Staby, G. L., J. W. Kelly and M. S. Cunningham. 1982. Floral crop storage. Controlled Atmospheres for the Storage and Transport of Perishable Agricultural Commodities. p. 239-266. D. G. Richardson and M. Meheriuk (eds.). Timber Press, Beaverton, Oregon.

30. Staby, G. L., M. Cunningham, C. Halstead, J. Kelly, P. Konjoian, B. A. Eisenberg and B. S. Dressler. 1984. Storage of rose and carnation flowers. J. Amer. Soc. Hort. Sci. 109:193-197.

31. Stuart, N. W., C. S. Parsons and C. J. Gould. 1970. The influence of controlled atmospheres during cold storage on the subsequent flowering of easter lilies and bulbous iris. HortScience 5:356.

32. Uota, M. 1969. Commodity requirements and recommendations for flowers and nursery stock. Controlled Atmosphere for the Storage and Transport of Horticultural Crops. Natl. Controlled Atmosphere Research Conference. 9:109-112.

COMMODITY: Rose VARIETY: (if necessary) see remarks

OPTIMUM TEMPERATURE: 0°C, expected range: 0° to 10°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	.5% - 16% O_2	2 - 16%
Benefits:	Flowers open less rapidly	Flowers open less rapidly

Potential for benefit: Slight when compared to a total postharvest rose program

Injurious level: No data available

Injury symptoms: blueing of red roses, leaf discoloration

Potential for injury: high with specific cultivars

Commercial use or potential:	slight	slight

REMARKS: consistent results difficult, cultivars react differently

SELECTED REFERENCES:

COMMODITY: Chrysanthemum VARIETY: (if necessary) necessary, but no data

OPTIMUM TEMPERATURE: 2°C, expected range: no data

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1.4 - 1.5%	
Benefits:	leaves greener at removal from storage	
Potential for benefit:	slight	
Injurious level:	no data available	
Injury symptoms:	petal browning	
Potential for injury:	no data available	
Commercial use or potential:	slight	

REMARKS: deterioration after storage was faster with CA flowers when compared to nonstored

SELECTED REFERENCES:

COMMODITY: Carnation VARIETY: (if necessary) ______

OPTIMUM TEMPERATURE: 0°C, expected range: 0°C to 20°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	.5% to 2%	0 - 20%
Benefits:	less botrytis less decay	counteracts ethylene at .5 ppm reduces disease
Potential for benefit:	slight	slight
Injurious level:	no data available	
Injury symptoms:	petal discoloration with red and pink cultivars	
Potential for injury:	no data available	
Commercial use or potential:	slight	

REMARKS: no variety work has been conducted

SELECTED REFERENCES:

LIST[1] OF SUPPLIERS OF EQUIPMENT, MATERIALS, AND SERVICES RELATED TO CONTROLLED AND MODIFIED ATMOSPHERE PACKAGING, TRANSPORT, AND STORAGE OF PERISHABLE COMMODITIES.

Item	Supplier(s)
Packaging	
Polymeric films	Cryovac Division W.R. Grace & Company P.O. Box 464 Duncan, SC 29334 [(803) 433-2000]
	E.I. DuPont De Nemours & Company, Inc. Polymer Products Dept. DuPont Building - 6082 Wilmington, DE 19898 [(302) 774-5954]
	Hercules, Inc. Wilmington, DE 19894 [(302) 995-3143]
	RJR Archer, Inc. Reynolds Boulevard Winston-Salem, NC 27102 [(919) 773-5216]
Differentially-permeable fruit coating (Nutri-Save®)	Nova Chem Limited P.O. Box 1030 Armdale Halifax, Nova Scotia B3L 4K9, Canada [(902) 455-4690]

[1]This list includes primarily suppliers in the U.S.A. and those, in other countries, which are international in the scope of their services. No endorsement of listed suppliers or products is intended, nor is criticism implied of similar products which are not mentioned. If you know of any other suppliers and products or services which should be added, please let me know and I will include such information in future editions of this list.

Adel A. Kader
Department of Pomology
University of California
Davis, CA 95616

Item	Supplier(s)
Differentially-permeable fruit coating (Semperfresh ™)	Inotek International Corporation 7528 Auburn Road P.O. Box 348 Painesville, OH 44077 [(216) 357-3242]
CA or MA during transport MA in pallet bags, marine containers, or rail cars	TransFresh Corporation P.O. Box 1788 Salinas, CA 93901 [(408) 424-2911]
Transport vans equipped to use liquid nitrogen for refrigeration and reducing O_2 level	Nhytemp, Inc. P.O. Box 219 Bell Glade, FL 33430
Transport vans equipped to maintain a CA using liquid nitrogen (Nitrol containers)	FEX Leasing P.O. Box 242 Richmond, CA 94807 [(415) 233-1131]
ISO containers equipped to maintain a CA using a nitrogen generating system	International Agritech Corporation and High Tech Transport, Ltd. 5780 Labath Avenue, Suite C Rohnert Park, CA 94928 [(707) 584-1136]
Transport vans equipped with low pressure (hypobaric) system	Interpack, Inc. P.O. Box 92 Glenville Station Greenwitch, CT 06830 [(203) 661-6227]
CA storage facilities Architects and contractors	Food Plant Engineering P.O. Box 9906 1710 South 24th Avenue Yakima, WA 98909 R.S. Cameron & Company 1014 South 3rd Avenue Yakima, WA 98902

Item	Supplier(s)
	Pacific Columbia Corporation P.O. Box 2921 Yakima, WA 98907
	Crowder Refrigeration, Inc. P.O. Box 1188 Okanogan, WA 98840 [(509) 422-3395]
	A & A Mechanical Contractors, Inc. 2943 Daylight Way San Jose, CA 95111
	California Controlled Atmosphere, Inc. 4307 Avenue 404 Dinuba, CA 93618 [(209) 268-4194]
Sealing materials	Gaco Western, Inc. P.O. Box 88698 Seattle, WA 98188 [(206) 575-0450]
	Pentagon Plastics, Inc. 905 North Railroad Avenue West Palm Beach, FL 33401 [(305) 655-2111]
	E.A. Thompson Company 825 Crossover Lane Memphis, TN 38117
	Barrier Systems Box 41044 Cleveland, OH 44141
Breather bags	Fabrico Manufacturing Corporation 4222 South Pulaski Road Chicago, IL 60632 [(312) 890-5350]

Item	Supplier(s)
Atmosphere generating equipment	
Oxygen burners	
Catalytic Oxygen Burner (COB)	Pacific Columbia Corporation P.O. Box 2921 Yakima, WA 98907 [(509) 575-1252]
	Controlled Atmosphere 647 South Second Street Okanogan, WA 98840 [(509) 422-3398]
ISOCELL	Isocell Europa I-39055 Laives Bolzano, Italy (available in the U.S. from Shifletts)
	Shifletts, Inc. 104 11th NE East Wenatchee, WA 98801 [(509) 884-1540]
Nitrogen generators	
Ammonia cracking system (Oxydrain)	Controlled Atmosphere Instrumentation, Inc. Route 2, 106 Tyee Street Okanogan, WA 98840 [(509) 422-6381]
Pressure swing adsorption system	Nitrotec Corporation 15245 Charter Oak Boulevard Salinas, CA 93907 [(408) 633-5825]
	Nitrotec Engineering 7310 Ritchie Highway Glen Burnie, MD 21061 [(301) 766-6595]
	Clifton Percision P.O. Box 4508 Davenport, IA 52808 [(319) 383-6000]

Item	Supplier(s)
GENERON membrane air separation system	Dow Chemical U.S.A. Membranes Department 2030 Williard H. Dow Center Midland, MI 48674
Permeable membrane system	Atmolysair Ltd. P.O. Box 21 71 Chemin Aubrey St-Chrysostome, P.Q. JOS 1RO, Canada
CO_2 scrubbers	
Carcosorb	Pacific Columbia Corporation (see address above)
Scrub-O-Fresh	Shifletts, Inc. (see address above)
ACI Model 250	Atmosphere Control Industries 1110 13-Mile Road Sparta, MI 49345 [(616) 887-7994]
CO_2-Absorber	Isocell Europa (see address above)
	Shifletts, Inc. (see address above)
Molecular Sieve Adsorber	Controlled Atmosphere (see address above)
CA monitoring and control equipment	
Automatic O_2 and CO_2 analyzer	Neogen Food Tech Corporation 241 East Saginaw, Suite 517 East Lansing, MI 48823 [(517) 332-8700]
	Controlled Atmosphere Instrumentation, Inc. (see address above)
	Pacific Columbia Corporation (see address above)

Item	Supplier(s)
	David Bishop Instruments, Ltd. Unit 1, Station Road Industrial Estate Healthfield, East Sussex England, United Kingdom (available in the U.S. from Pacific Columbia Corporation, see address above)
	Isocell Europa (available in the U.S. from Shifletts, Inc., see address above)
Ethylene scrubbers Potassium permanganate beads	Purafil, Inc. P.O. Box 80434 Chamblee, GA 30341 [(404) 451-7146]
	Complete Control P.O. Box 1006 Stafford, TX 77477 [(713) 774-7173]
	Carus Chemical Company, Inc. 1500 Eighth Street LaSalle, IL 61301 [(815) 223-1500]
Catalytic burners	COMINDEX Przedsiebiorstwo Polonijno-Zagraniczne 00-953 Warszawa, ul. Cicha 7 Warsaw, Poland (TELEX 816759)
	Johnson Matthey Chemicals, Ltd. Orchard Road, Royston Hertfordshire SG8 5HE England, United Kingdom
Ethylene gas generators	Catalytic Generators, Inc. 1185 Pineridge Road Norfolk, VA 23502 [(800) 446-8100]