Apples O.S.

# THE PROFITABILITY OF

# CONTROLLED ATMOSPHERE STORAGE OF APPLES

# IN THE ORANGE AREA OF NEW SOUTH WALES

# A BENEFIT - COST STUDY

G. R. GRIFFITH



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# THE PROFITABILITY OF CONTROLLED ATMOSPHERE STORAGE OF APPLES IN THE ORANGE AREA OF NEW SOUTH WALES: A BENEFIT-COST STUDY

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## Metric Conversion

Throughout this bulletin the following metric conversion is applicable:

1 bushel of apples = 40 lb.
= 18.14 kg.

CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# CHAPTER 1

## INTRODUCTION

Apples are seasonally produced but face a year-round demand. Without storage, production would have to be marketed within only a few months. The usual tendency would be for depressed prices during and immediately following harvesting, and higher prices out-of-season. Refrigerated air storage[1] has long been the means by which Australian apple producers store their fruit for sale later in the year to take advantage of higher prices. The expected price differential between sales at harvesting and sales later in the year has almost always exceeded the cost of storage for this period, so orchardists have raised their net farm income.

A technique recently introduced into the Orange district, and into some other N.S.W. apple producing areas as well, supplements refrigerated air storage. This innovation is known as controlled atmosphere (C.A.) storage, and simply involves manipulating the composition as well as the temperature of the storage atmosphere. Hall[2] referred to C.A. storage of apples as "...probably the most significant technological advance since the advent of mechanical refrigeration".

Advantages of C.A. storage include an increase in the storage life by up to 25 per cent, maintenance of better quality during storage, longer post-storage shelf life, and reduced rotting, yellowing, spotting and shrivelling of the fruit.[3] Consumers are willing to pay premium prices for this higher quality. C.A. storage is however more expensive to install and operate and requires greater skill and care by the

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1 Where apples are stored at just above freezing point to reduce respiration and hence increase the period during which they can be stored. Storage temperature and storage life vary from variety to variety.

2 Hall, E.G., "Principles of Controlled Atmosphere Storage" in <u>Proceedings of an Extension School on C.A. Storage of Apples and Pears</u> (Sydney: N.S.W. Department of Agriculture, March 1969), p. 5.

3 For greater detail on these points see "Longer Life for Apples", <u>Rural Research in C.S.I.R.O.</u>, No. 34, (December 1960), p. 14; and "Advantages and Disadvantages of C.A. Storage", <u>Victorian Horticultural Digest</u>, 13 (1), (February 1969), pp. 14-19.

orchardist.

Thus there is a problem in balancing the costs of and the gains from C.A. storage, and this provided the underlying basis for the study reported herein.

## 1.1 JUSTIFICATION OF THE STUDY

The rapid increase in the use of C.A. storage by N.S.W. orchardists over the past seven years has resulted in a large flow of investment funds into the orchard sector. Contact with several growers suggested that while many of the orchardists installing C.A. facilities did carefully examine the economics of such an investment, many did not. Attractive premiums obtained during the initial years of marketing C.A. fruit decided many orchardists, and little thought was given to future profit margins.

Preliminary reviews of the literature revealed a great deal of technical and physiological information on C.A. storage, but little emphasising economic factors. Furthermore, the economic information which was available generally suffered two deficiencies.

First, most reports looked only at a section of the complete storage process[4] and only one study[5] went as far as to actually compute the net returns from C.A. storage.

Second, the economic research done was invariably presented in terms of "dollars per bushel case per annum". Although the orchardist often requires per bushel case figures for comparison with market reports, his major concern is whether an investment in C.A. storage will add to his net farm income. Thus criteria emphasising total returns from the store appear more suitable. Furthermore, the long-term nature of C.A. storage investments demands the use of some measure other

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4 See for example, Holligan, P.J., An Open Flame Controlled Atmosphere Generator (N.S.W. Department of Agriculture, Agricultural Engineering Centre, Glenfield: Technical Report No. 1/73, 1973); Blanpied, G.D., Estimated Apple Storage Costs (Cornell University: Agricultural Economics Research Report No. 87, June 1962); and Thomas, O.R. and W.P. Jensen, "Controlled Atmosphere Storage: Costs and Compensations" (Paper presented to American Society of Agricultural Engineers, Utah State University, June 1968).

5 Thomas and Jensen, op.cit., p. 10.

than "dollars...per annum", so criteria emphasising not only total benefits but also the time aspect, were required.

C.A. storage can be used for other fruits and vegetables as well as for apples, but apples were chosen as the only fruit studied because (1) specifying only a single product reduced the complexity of the analysis, (2) apples represent about 85 per cent of all fruit stored under C.A. conditions, and (3) in terms of value, apples are the most important fruit traded at the City of Sydney Wholesale Markets.[6]

The Orange district was selected as the region for the study because of the dominant position of the district in the supply of C.A. stored apples to the Sydney Markets (see Table 1) and the recent and continuing boom there in the construction of C.A. stores (see Table 2).

TABLE 1

N.S.W. C.A. Storage Capacity, 1972/73[7]

| District (a) | Grower Stores | | Co-op. Stores | | Total | |
|---|---|---|---|---|---|---|
| | No. | Bushel Capacity | No. | Bushel Capacity | No. | Bushel Capacity |
| Orange | 30 | 418,200 | 1 | 110,000 | 31 | 528,200 |
| Batlow | 4 | 102,800 | 2 | 234,000 | 6 | 336,800 |
| N.S.W. (a) | 34 | 521,000 | 3 | 344,000 | 37 | 865,000 |

(a) The New England district did have one 10,500 bushel co-operative C.A. store, but this has recently been dismantled.

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6 In 1968/69, the latest year in which comparative figures are available, apples comprised $12.3 million of a total fruit turnover value of $52.8 million.

7 The Division of Horticulture, N.S.W. Department of Agriculture provided the information for both Tables. Approximately 30,000 bushels of C.A. capacity has been added up until December 1973. Some 20,000 bushels of this was in the Orange area.

TABLE 2

C.A. Storage Construction in the Orange District: Cumulative

| Season | No. Private C.A. Stores | Bushel Capacity |
|---|---|---|
| 1967/68 | 2 | 15,000 |
| 1968/69 | 3 | 25,000 |
| 1969/70 | 9 | 101,500 |
| 1970/71 | 20 | 220,250 |
| 1971/72 | 24 | 367,250 |
| 1972/73 | 30 | 418,200 |

## 1.2 OBJECTIVES OF THE STUDY

For the orchardist contemplating increasing his fruit storage capacity this study attempts to provide information to help him make such a decision. Major questions asked were (1) is refrigerated air storage of apples in the Orange district of N.S.W. profitable, (2) does the addition of C.A. facilities increase profitability, and if so, which systems are the most profitable, (3) do economies of size exist in both refrigerated air storage and C.A. storage, and (4) how sensitive is profitability to changes in discount rates, decision criteria, length of run, and price changes?

# CHAPTER 2

# PRINCIPLES OF CONTROLLED ATMOSPHERE STORAGE

## 2.1 BIOLOGICAL BASIS

Biochemical reactions, including respiration, continue in apples after they are harvested. These reactions must be inhibited if the fruit is to be stored without cell breakdown and subsequent microbial attack. Cool room (refrigerated air) storage achieves this by a reduction in the storage temperature. C.A. storage utilizes an additional three methods to inhibit respiration, namely (1) reducing the oxygen ($O_2$) content of the storage atmosphere, (2) increasing the carbon dioxide ($CO_2$) content of the storage atmosphere, and (3) increasing the relative humidity of the storage atmosphere. Obviously, a store as air-tight as possible is required for effective atmosphere control.

## 2.2 TECHNICAL BASIS

The technical aspects of C.A. storage have been relatively well documented and information on both theoretical bases and overseas applications have been available for some time. Reviews of developments in Australia and overseas have been done by Holligan[8] and Dalrymple[9] respectively.

C.A. storage has been practised in Britain and Europe for many years but the method used was to store apples in an airtight but uncooled room, letting the fruit itself generate a low $O_2$ - high $CO_2$ atmosphere by respiration. This method is unsuitable for N.S.W.

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8 Holligan, P.J., "The Design, Construction and Operation of Controlled Atmosphere Cool Stores for Fruit - Part II" (Paper presented to a meeting of the Agricultural Engineering Branch, Institute of Engineers, Australia, Sydney, July 1971).

9 Dalrymple, G.A., "The Development of an Agricultural Technology - Controlled Atmosphere Storage of Fruit", <u>Technology and Culture</u>, 10 (1), (March 1969), pp. 35-48.

as the need for refrigeration reduces the respiration rate too quickly for the required atmosphere in the store to develop.

Several related events contributed to the introduction of C.A. storage into N.S.W. in the late 1960's: (1) research in Britain[10] and Australia[11] showed that the optimum atmospheric composition was 2.5 per cent $O_2$, 2.5 per cent $CO_2$ and 95 per cent nitrogen ($N_2$), and that this composition should be achieved within 4-5 days of room sealing; (2) development of mechanical "low oxygen generators"[12] to achieve the required atmosphere within 5 days and to maintain the correct concentration if the room leaks; and (3) the release of diphenylamine (DPA) in Australia as a scald inhibitor.[13]

Since each volume of $O_2$ removed from the interior atmosphere results in the addition of one volume of $CO_2$ (no matter which generator system is chosen) some means must be found of removing the excess $CO_2$ above 2.5 per cent from the air. A wide range of such "scrubbing" materials is available but dry slaked lime is generally most popular because of lower cost per unit scrubbing capacity.[14]

The main advantages of mechanically generated C.A. storage have been outlined in detail elsewhere.[15] In summary they are: (1) the optimal storage atmosphere can be achieved within the required 5 days; (2) fruit harvested at different times can be put into the same room and the atmosphere regenerated; (3) fruit can be removed for sale at different

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[10] Fidler, J.C., "Controlled Atmosphere Storage of Apples", The Journal of Refrigeration, 8 (8), (August 1965), pp. 265-273.

[11] Hall, op.cit., p. 6.

[12] All C.A. storage facilities in the Orange district are equipped with external mechanical generators. Two types are used - "flushing" (two brands) or "recirculating", (one brand). See Appendix I for descriptions of these generators.

[13] Australian apple varieties, especially Granny Smiths, are highly susceptible to superficial scald during C.A. storage. DPA dipping before storage reduces the incidence of this disorder to commercially acceptable levels.

[14] Usually 0.5 kg dry slaked lime per bushel case will maintain $CO_2$ below 5 per cent in a gas-tight room for a whole season. Other scrubbing materials used are water, brine solution, caustic soda, and activated charcoal.

[15] Victorian Horticultural Digest, op.cit., pp. 14-16.

times and the atmosphere regenerated, (4) a leaky room can be maintained at the correct atmospheric content; and (5) they provide an insurance against a gas-tight room developing a leak.

# CHAPTER 3

## CONTROLLED ATMOSPHERE STORAGE SYSTEMS

C.A. storage requires a gas-tight room, and this can be achieved by either building a new rigid gas-tight room or modifying an existing cool room to make it gas-tight.

### 3.1 RIGID ROOM SYSTEM

For larger orchards the erection of a rigid gas-tight C.A. room has been thought to allow better utilisation of expensive refrigeration and generating equipment. Experience however has brought to light two drawbacks of such rooms.

First, movement in relative air pressures and temperatures inside and outside these rooms have resulted in the development of leaks in the gas seal which should keep the room air-tight. Thus the cost of maintaining C.A. conditions rises.

Second, the rectification of these leaks usually involves sealing the insides of the room walls, which has the effect of moving the water vapour barrier from outside to inside the insulation. This reduces the technical efficiency of cooling and the cost of maintaining low temperatures increases.

Recent research[16] has revealed new materials and construction techniques which make the room more gas-tight. However, the above problems still occur to some degree, so in the following analysis, two situations will be examined: (a) the extreme case of a perfectly gas-tight room, and (b) the more general case of some leakage (requiring twice weekly lowering of the $O_2$ level).

At present rigid C.A. rooms may be as large as 50,000 bushel capacity, however the most popular sizes in the Orange district have been around 10,000, 15,000 and 25,000 bushel capacities. Generally the larger the room the lower the per bushel case construction costs, but some of these savings may be cancelled by the need to have extremely reliable refrigeration equipment and large capacity generators such as the Tectrol

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[16] See D.A. Hull Pty. Ltd., "Australia's Most Advanced Design in Controlled Atmosphere Stores" (D.A. Hull Pty. Ltd. technical paper, Sydney, April 1971).

and Capco models.

## 3.2 MODIFIED ROOM SYSTEM

The high initial capital costs of new rigid C.A. rooms have prevented many of the smaller orchardists from installing C.A. storage. A compromise usually involves converting an existing cool room to a gas-tight C.A. room. By far the most successful of these conversions has been the plastic tent - jacketted-room design developed jointly by C.S.I.R.O. and the N.S.W. Department of Agriculture. This principle is explained in detail by Holligan,[17] but simply, a jacketted room involves a gas-tight plastic "tent" erected inside an existing cool room. An open-flame generator and dry slaked lime scrubber are usually attached to the tent (although a Capco generator could be used) and fans provide a homogeneous atmosphere within the tent. The tent also provides a barrier between the fruit and the refrigeration equipment.

Plastic tent modified C.A. rooms have several advantages over rigid C.A. rooms:

(1) lower initial cost;
(2) the flexible plastic allows the volume of air inside the tent to respond to changes in temperature and pressure, reducing the possibility of leaks and the resultant increased cooling and generating costs,
(3) refrigeration equipment is accessible for maintenance,[18]
(4) the relationship of the tent to the refrigeration coils means a higher relative humidity inside the tent, reducing shrivelling and weight loss in the stored fruit,
(5) since a greater bushel capacity is able to be maintained in C.A. conditions when the room is gas-tight, it is often worthwhile having several small tents inside a large room all serviced by the one generator. (This utilises generating and refrigeration equipment more efficiently and also enables different varieties of

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[17] Holligan, 1971, loc.cit. See also K.J. Scott, "Some Principles in the Operation of C.A. Storage Rooms", (Unpublished N.S.W. Department of Agriculture mimeo, Sydney, 1969).

[18] If the refrigeration equipment in a rigid room breaks down, the room has to be flushed out with normal air before repairs can commence, and often a period of several days has to elapse before the equipment is working again.

fruit to be stored in, and marketed from, different tents without disturbing other fruit),

(6) it is generally operationally easier to use gas-tight plastic tents as it involves less worry about leakage of the contents.

## 3.3 ADDITIONAL EQUIPMENT

Apart from suitable generating and scrubbing equipment, operation of C.A. facilities requires some additional capital expenditure.

Accurate and reliable instruments are necessary to measure the storage temperature and atmospheric content. A propane gas supply system and D.P.A. dipping equipment are also required, and in leaky rooms, a water tower and pump are often needed to maintain pressure in Capco and Tectrol units. Additionally, since the atmosphere within C.A. rooms will not support life, many orchardists have on hand breathing apparatus in case of emergencies.

## 3.4 THE STORAGE ALTERNATIVES STUDIED

Because of the many different combinations of equipment, storage systems, and capacities of C.A. storages which may be employed, it was necessary to consider a range of alternative storages. This study estimates the profitability of 24 C.A. storages which vary by room size, by storage system, by generator type, and for rigid rooms, by whether the room was gas-tight or leaky, and by whether the Capco generator was attached to a Capco scrubber or a lime scrubber. The selection of these 24 C.A. possibilities was based largely on survey data (see 5.1). Additionally, 5 refrigerated air storage rooms of various sizes were included to complete the analysis. The 29 different storages studied are listed in Table 3.

TABLE 3

Alternative Storages Studied

| Room Size (bushels) | Type of Storage System | | | | |
|---|---|---|---|---|---|
| | Refrigerated Air Storage | Controlled Atmosphere Storage | | | |
| | | Generator Type | Rigid Room C.A. | | Modified Room C.A. |
| | | | Gas-tight | Leaky | |
| 3,000 | x | Open flame | | | x |
| | | Capco + lime scrubber | | | x |
| 6,000 | x | Open flame | | | x |
| | | Capco + lime scrubber | | | x |
| 10,000 | x | Open flame | | | x |
| | | Tectrol | x | x | |
| | | Capco + Capco scrubber | x | x | |
| | | Capco + lime scrubber | x | x | x |
| 15,000 | x | Tectrol | x | x | |
| | | Capco + Capco scrubber | x | x | |
| | | Capco + lime scrubber | x | x | |
| 25,000 | x | Tectrol | x | x | |
| | | Capco + Capco scrubber | x | x | |
| | | Capco + lime scrubber | x | x | |

# CHAPTER 4

## METHODOLOGY

Investment in orchard cool storage is of a long term nature and involves variable cash flows of benefits and costs over the life of the asset. Benefit-cost analysis[19] has therefore been used as the appropriate methodology for this study. This technique has been applied to some farm development projects[20] but not previously to orchard cool storage. As we are looking at profitability only in relation to the orchardist making the investment, the question of indirect benefits and costs does not arise.

### 4.1 PLANNING HORIZON

Most orchardists interviewed were of the opinion that the economic life of C.A. and cool rooms and associated equipment should be set at considerably less than the physical life of these structures, on the grounds of anticipated obsolescence. Consequently a planning horizon of 10 years was adopted. Allowance was made for the replacement of plastic tents after 5 years and unexpended physical life in all assets was allowed for by a 10 per cent salvage valuation.

### 4.2 DECISION CRITERIA

As Prest and Turvey[21] point out, the choice of investment criteria depends upon whatever it is to be maximised and on the relevant constraints. Since capital constraint was only of minor relevance to orchardists in the Orange area and the objective function to be maximised was net benefits from

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19 For an excellent coverage of this topic see Mishan, E.J., Cost-Benefit Analysis - An Informal Introduction (London: Allen and Unwin, 1971).

20 See for example Harrison, S.R. et.al., Evaluation of Farm Development Projects, and Discounted Cash Flow Analysis of Beef Development Projects (Qld. Department of Primary Industries: Technical Bulletins No. 7 and No. 8, 1970).

21 Prest, A.R. and R. Turvey, "Cost Benefit Analysis - A Survey" Economic Journal 75 (300) (December 1965), p. 703.

the investment over the length of the planning horizon, Net Present Value (N.P.V.) was selected as the decision criterion. This criterion also had the additional benefit of reflecting changes in the scale of investment.

## 4.3 DISCOUNT RATE

Consideration of on- and off-farm opportunity costs of capital and the rate for borrowings led to the selection of a 10 per cent discount rate for the analysis, and this rate corresponded fairly closely to the views of the majority of orchardists interviewed. A few growers did state however that they had received in excess of 20 per cent return on capital per annum, while others had difficulty in achieving a 5 per cent return.

## 4.4 TAXATION EFFECTS

Although the effects of taxation payments and deductions are important factors in primary production investment,[22] they were excluded from this analysis because individual orchardist differences in origin and amount of income, and allowable deductions could not be adequately accounted for. Hence before tax analysis was used as a common basis for evaluation of alternative storage profit abilities.

## 4.5 BENEFITS NOT ACCOUNTED FOR

Some of the benefits resulting from storage are difficult to assess and therefore have not been accounted for in the analysis. These benefits include the ability to: meet customers' requirements quickly; manage labour more efficiently (especially in the packing shed); and take advantage of short-term peaks in demand.

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[22] These effects would include: (1) taxation at the marginal tax rate on increased profits; (2) investment allowances; and (3) special depreciation which may be allowable on some items of new equipment. Current details are available from the Australian Taxation Office.

## 4.6 EFFECTS OF VARYING PLANNING HORIZON, DISCOUNT RATE AND DECISION CRITERIA

The assumptions regarding planning horizon, discount rate and decision criteria are obviously only one such combination, so these assumptions were varied in Chapter 7 to examine the sensitivity of relative profitabilities to another criterion (internal rate of return), to time and to discount rate.

# CHAPTER 5

## DATA COLLECTION

Most of the price data and much of the cost data required was derived from external sources such as technical and marketing bulletins, and suppliers quotes. To obtain the remainder of the data and to supplement and validate external sources, a survey of Orange district orchardists owning C.A. facilities was conducted.

### 5.1 ON-FARM SURVEY

Information supplied by the N.S.W. Department of Agriculture[23] indicated that 20 orchardists operated C.A. facilities in the Orange district in 1970-71. Of these, 10 had constructed new rigid C.A. rooms and the remaining 10 had modified existing space using plastic tents. All operated refrigerated air storage. Because of the small number, all 20 were interviewed. A pilot set of questions was shown to one of the orchardists and on the basis of his criticisms the final questionnaire was formulated. Useful data was obtained from 13 orchardists; 7 relating to rigid rooms and 6 to plastic tents.[24]

### 5.2 OTHER COST DATA

Some previous research was available for the costs of refrigerated air storage in other areas,[25] so these results were used to supplement and modify the survey data, where

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23 N.S.W. Department of Agriculture, Fruit Growers of the Orange District, 1970 (N.S.W. Department of Agriculture, Division of Horticulture: May 1970).

24 The survey was neither repeated nor extended during the revision for this bulletin as the original sample was still deemed reasonably representative. If some figures did require revision, this was done on information from other sources.

25 Hamilton, C.P. "Economics of Cool Storage" (Paper presented to a Qld. Department of Primary Industry Cool Storage Symposium, Stanthorpe, 1965). Also see Board, G.H., "The Economics of Cold Storage of Fruit" (unpublished Farm Management report, University of New England, 1965).

applicable, to derive figures for the Orange area. These costs are given in Appendix III.

For C.A. storage systems, a different approach was used. Information obtained from suppliers, contractors, and technical bulletins, as well as the survey, allowed the use of the "synthetic firm" or "economic engineering" method of synthesising the costs of the stores.[26] This type of analysis was made easier in the case of new rigid room stores as most materials, construction techniques and equipment is standard for each room size. Many of the operating costs are also similar, so synthetic costing can be used to advantage. These assumptions are also listed in Appendix III. General assumptions of the analysis are given in Appendix II.

## 5.3 PRICE DATA

Collection of price data presented some problems. The only sources which list separate C.A. and normal apple prices by varieties are Weekly Marketing Notes and Monthly Average Prices,[27] but because they are average prices for a wide size range, they are necessarily general and incomplete. A further deficiency is the short time in which historical price data for C.A. apples has been available - the first marketing of C.A. apples was in October 1967. With experience of only 6 seasons of marketing C.A. apples, price premiums have only partially stabilized.

However, because they are the only price data available, average 1967-73 prices, for both C.A. and normal storage, have been used in this analysis. Additionally, the survey indicated that all orchardists installing C.A. facilities examined past prices as at least part of the basis for profitability expectations from their investment. Together with assumed marketing strategies for normally and C.A. stored fruit derived from survey results, expected benefits from the various

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26 See for example Tuck, I.D., "The Synthetic Firm Approach to Estimating Cost-Size Relationships in Agriculture", (paper presented to the Annual Conference of the Australian Agricultural Economics Society, Adelaide, February 1971), and C.C. Dennis et.al., An Analysis of Apple Packing Costs in Michigan, (U.S.D.A.: Market Research Report No. 786, 1964).

27 N.S.W. Department of Agriculture, Weekly Marketing Notes, and Monthly Average Prices, (N.S.W. Department of Agriculture, Division of Marketing and Economics: July 1967 to March 1973).

storage alternatives have been calculated for each room size. These assumptions are listed in Appendix IV.

A further assumption was necessary to cover spatial price differences. Growers participating in the survey sent on average 10 per cent of their apples to the Brisbane markets. However, since data in the form required was unavailable for the Brisbane wholesale markets, it was assumed that the only difference in net returns from the two markets was that due to transport cost differentials.

# CHAPTER 6

## RESULTS

The operation of a cool storage enterprise is a complex situation to describe quantitatively. Many of the factors determining profitability are located off the farm, some change over time, and others are highly variable in nature. Hence, simplifying assumptions were used to ease specification and computation burdens. As noted above, these are outlined in Appendices II to IV.

Using these assumptions, and the methodology and selected parameter values specified in Chapter 4, cash flows for each storage alternative were derived and discounted. An example of the cash flow calculations is given in Appendix V. A summary of results for the specified parameter values (discount rate of 10 per cent, planning horizon of 10 years, and a N.P.V. decision criterion) is given in Table 4.

Even though the results were more or less as expected, several important conclusions can be drawn from this summary, and they are outlined below in their respective storage type classifications.

### 6.1 REFRIGERATED AIR STORAGE

The first point is that, given all the assumptions are valid, investment in a 3,000 bushel capacity refrigerated air store is not a recommended action when the discount rate is 10 per cent. Profits are made however if capital is invested in the four larger-sized rooms.

The second important result relates to economies of size. As can be seen from Figure 1,[*] N.P.V. for refrigerated air storage increases with room size, but at a constant rate indicating no economies of size are in existence. This is somewhat unexpected as the price and marketing strategy assumptions cause price returns to increase proportionally to size, while some of the capital and operating costs were assumed to decrease on a per bushel basis as room size increases. Overall though the relationship between benefits and costs meant that returns to room size were constant.

(*) Figure 1 (pp.21,22) comprises three graphs which show the relationship between N.P.V.and room size for the three types of storage.

TABLE 4

N.P.V. ($) for Alternative Storage Systems Studied; 10 Per Cent Discount Rate and 10 Year Planning Horizon

| Room Size (bushels) | Refrigerated Air Storage | Type of Storage System | | | |
|---|---|---|---|---|---|
| | | Controlled Atmosphere Storage | | | |
| | | Generator Type | Rigid Room C.A. | | Modified Room C.A. |
| | | | Gas-tight | Leaky | |
| 3,000 | -890 | Open flame | | | 3499 |
| | | Capco + lime scrubber | | | 1021 |
| 6,000 | 9380 | Open flame | | | 14942 |
| | | Capco + lime scrubber | | | 12693 |
| 10,000 | 22607 | Open flame | | | 30314 |
| | | Tectrol | 63301 | 62933 | |
| | | Capco + capco scrubber | 70359 | 70083 | |
| | | Capco + lime scrubber | 71988 | 71822 | 28586 |
| 15,000 | 39030 | Tectrol | 110170 | 109650 | |
| | | Capco + capco scrubber | 114340 | 113920 | |
| | | Capco + lime scrubber | 118910 | 118670 | |
| 25,000 | 72028 | Tectrol | 208570 | 207710 | |
| | | Capco + capco scrubber | 216610 | 215910 | |
| | | Capco + lime scrubber | 217370 | 216930 | |

The general conclusions then are that refrigerated air storage of apples in the Orange district is basically profitable for all but the smallest room size studied, and that no economies of size in cool rooms exist.

## 6.2 RIGID ROOM C.A. STORAGE

In this class of cool room, eighteen alternative storage configurations were analysed. As shown in Table 3, distinctions were made between three different room sizes, three storage systems, and finally whether the rooms were gastight or leaky.

The N.P.V.'s in Table 4 indicate the following. All eighteen alternatives are highly profitable. The greater technical efficiency and lower initial costs of recirculating generators (Capco - as discussed in Appendix I) contribute to the slightly higher N.P.V.'s of these systems. Choice of scrubbing unit also affects profitability to a slight degree. The presence of leaks in the C.A. room did not however diminish profitability to any appreciable extent, and economies of size of cool rooms are again non existent.

Table 4 also illustrates the increased profitability of any rigid room C.A. alternative over a refrigerated air storage room of the same size. Rigid C.A. rooms are approximately three times as profitable as their refrigerated air storage counterparts.

Generally, then, for the assumed costs, returns and strategies, rigid room C.A. storage of apples is highly profitable and is a better investment than refrigerated air storage for comparable room sizes; economies of size are again not evident; and choice of generator system and scrubbing apparatus marginally affects profitability.

### 6.3 MODIFIED ROOM C.A. STORAGE

The profitability of modifying the three smallest room sizes to C.A. storage was examined. A choice of two generator systems was assumed - a flushing type and a recirculating type.

As expected, the results indicated that all six stores analysed would yield economic returns, although the N.P.V.'s for the smallest room at $1,000 and $3,000 were not really encouraging. Reflecting lower initial outlays, flushing generator systems exceeded the recirculating types in N.P.V., but only by a fairly constant $2,000. Some very small economies of room size were in evidence.

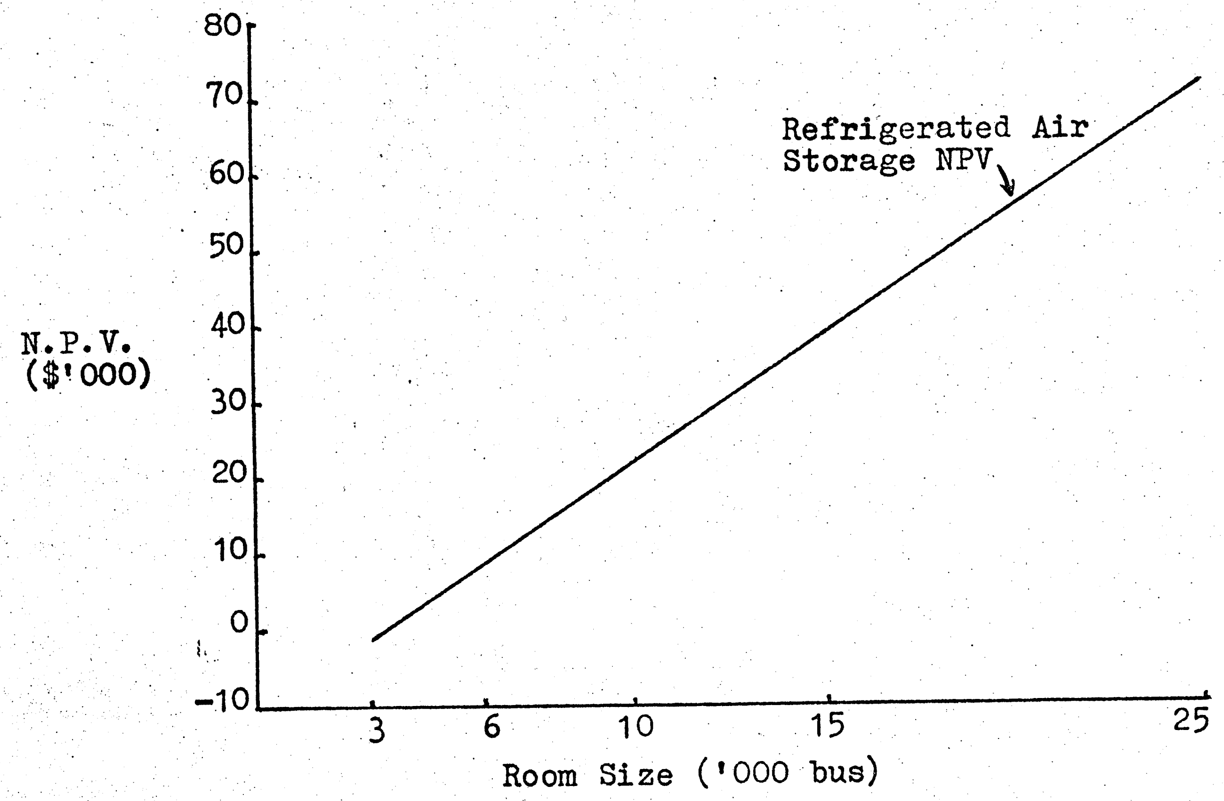
Comparing modified C.A. storage with refrigerated air store for the three smallest room sizes, shows that the former is always more profitable than the latter under the specified set of assumptions.

For the 10,000 bushel room size where all 3 types of storage are analysed, the order of profitability is rigid room C.A., modified room C.A. and refrigerated air storage.

FIGURE 1

N.P.V.-Room Size Relationships at 10 Per Cent Discount Rate

(a) Refrigerated Air Storage




(b) Rigid Room C.A. Storage (Leaky)

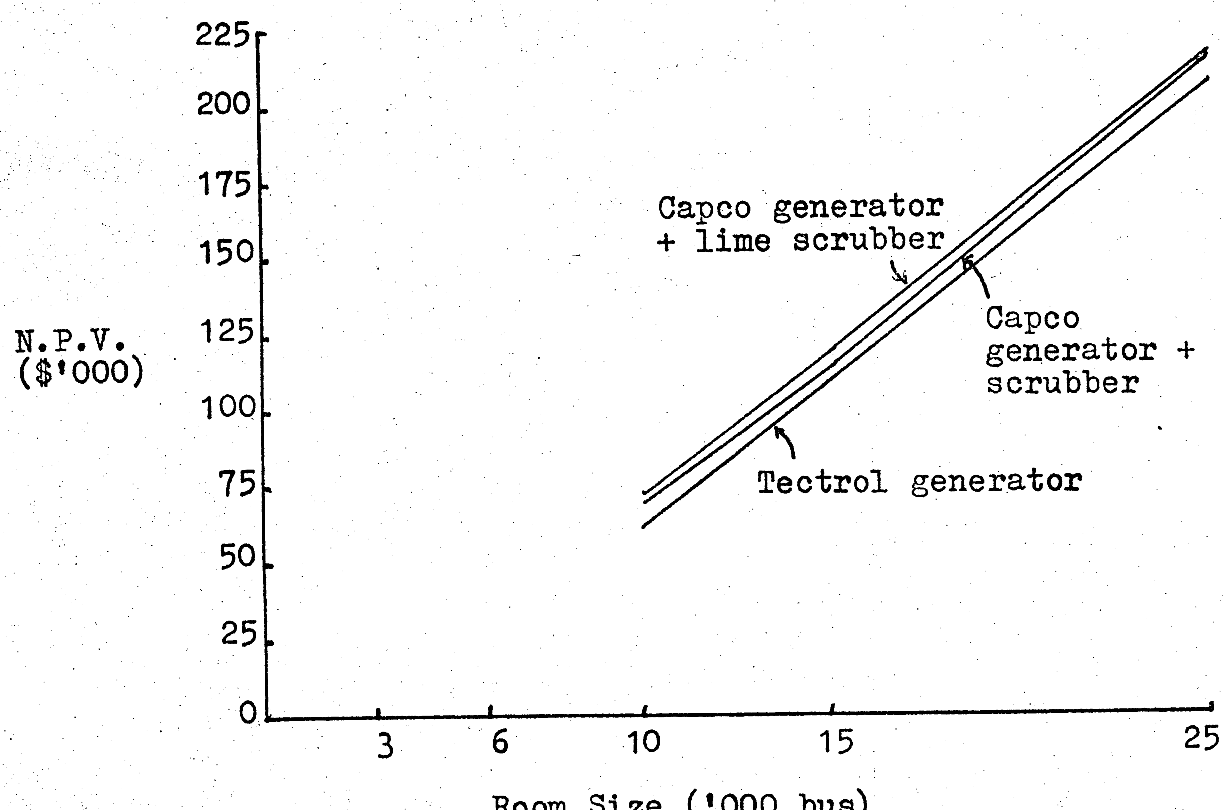
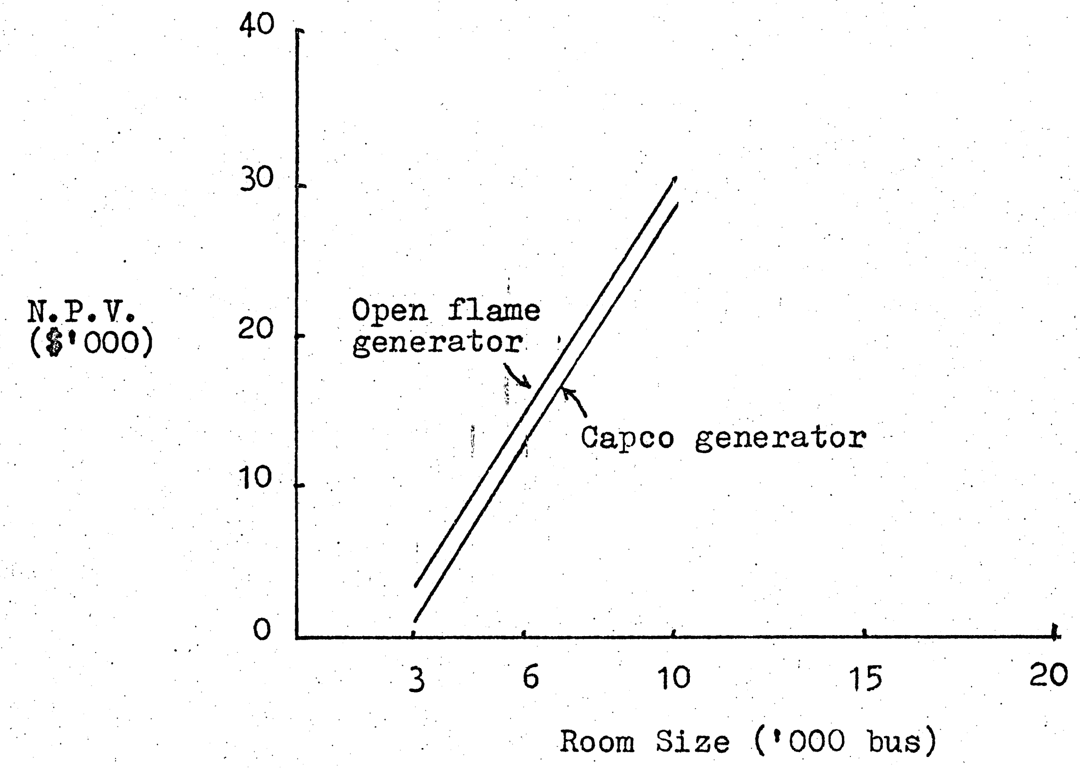


FIGURE 1 (Contd)

(c) Modified Room C.A. Storage




## 6.4 GENERAL CONCLUSIONS

In terms of the objectives of this study listed in the Introduction (see Section 1.2 and the assumptions given above), the general conclusions of the analysis are: (1) refrigerated air storage of apples in the Orange district of N.S.W. is economically sound for all room sizes except the 3,000 bushel capacity; (2) the erection of rigid room C.A. facilities is more profitable for all room sizes studied; (3) converting existing cool rooms to C.A. by plastic tent results in an increase in profitability; (4) economies of size of cool rooms are not generally evident for any system studied; (5) choice of generator units and scrubbing material, and whether the C.A. rooms are gastight or not, affects the N.P.V.'s achieved, but not to a large extent.

These results conformed fairly well to a priori notions, particularly where the form of the assumptions made indicated a bias towards acceptance of a viewpoint. Obviously, the results would be altered if the underlying structure of the analysis was modified, so some of these assumptions will be relaxed in the following chapter. Other assumptions could not for reasons of time and space be relaxed - the price returns and marketing strategies are examples in this case.

Overall though, the assumptions made were probably fairly realistic. Two reasons can be advanced to substantiate this claim. First, a lower level of about 5,000 bushel room capacity is being recommended for new C.A. and refrigerated air storage installations.[28] Thus some dissatisfaction with profitability levels of smaller rooms has been voiced, and this fits in with the negative and small positive N.P.V.'s obtained for 3,000 bushel refrigerated and modified C.A. rooms respectively.

Secondly, Tectrol generators are no longer marketed in N.S.W. and this would reflect the greater technical and economic efficiency of recirculating generators of the Capco type.[29]

Hence practical experience is partly validating the synthetic results of this analysis.

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[28] Holligan, P.J. (Personal communication, June 1973).

[29] *ibid*.

# CHAPTER 7

## SENSITIVITY ANALYSIS

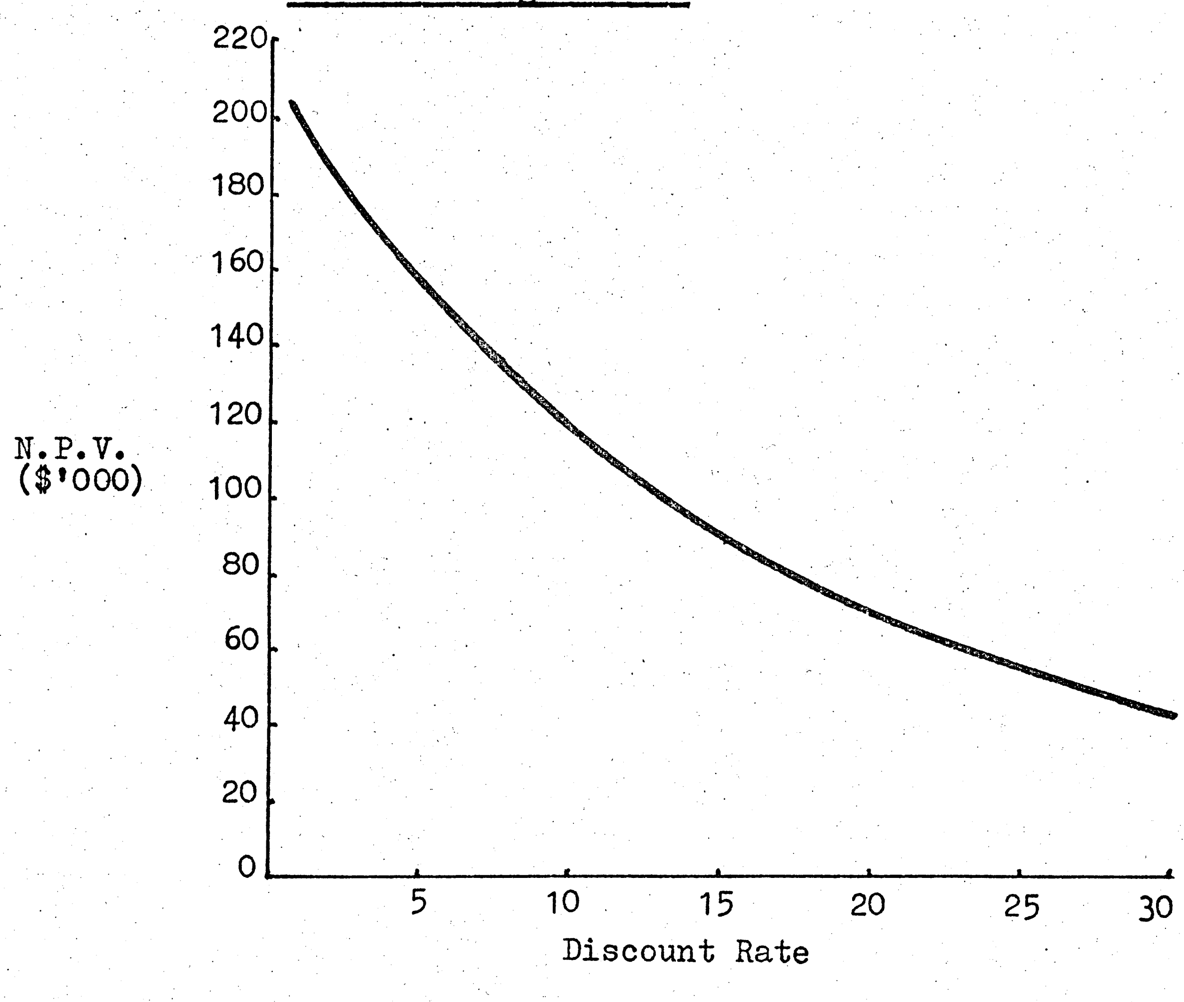
This section examines the sensitivity of the derived profitabilities to discount rate selected, alternate decision criteria, and the length of the planning horizon.

### 7.1 DISCOUNT RATE

Holding the planning horizon constant at 10 years and maintaining a N.P.V. decision criterion, discount rates were varied in 1 per cent intervals from 0 per cent to 30 per cent. The results of this exercise are presented in Figure 2 for a representative storage system, namely the 15,000 bushel leaky rigid C.A. room with a Capco generator and lime scrubber.

FIGURE 2

N.P.V. Curve; 1 Per Cent - 30 Per Cent Discount Rate, for 15,000 Bushel Leaky Rigid C.A. Room with Capco Generator and Lime Scrubber; and 10 Year Planning Horizon



It can be seen that the N.P.V. decreased from a high of $204,110 at 1 per cent to $118,670 at 10 per cent but at a decreasing rate, enabling the N.P.V. at 30 per cent to be maintained at a healthy $40,598.

This general hyperbolic N.P.V. function was a common feature of all alternative systems studied with the exception of the four, smaller refrigerated air storage rooms. In these cases, the N.P.V. curve became zero below the 30 per cent discount rate, indicating a limit on profitability. Additionally the N.P.V. for the 25,000 bushel refrigerated air storage was only marginally positive at 30 per cent.

Profitable investment in C.A. storage systems is thus fairly independent of the discount rate chosen. The level of profitability obviously varies inversely with the discount rate (and this is expected from the nature of the cash flows), but essentially all the C.A. storage systems examined were profitable up to a 30 per cent discount rate.

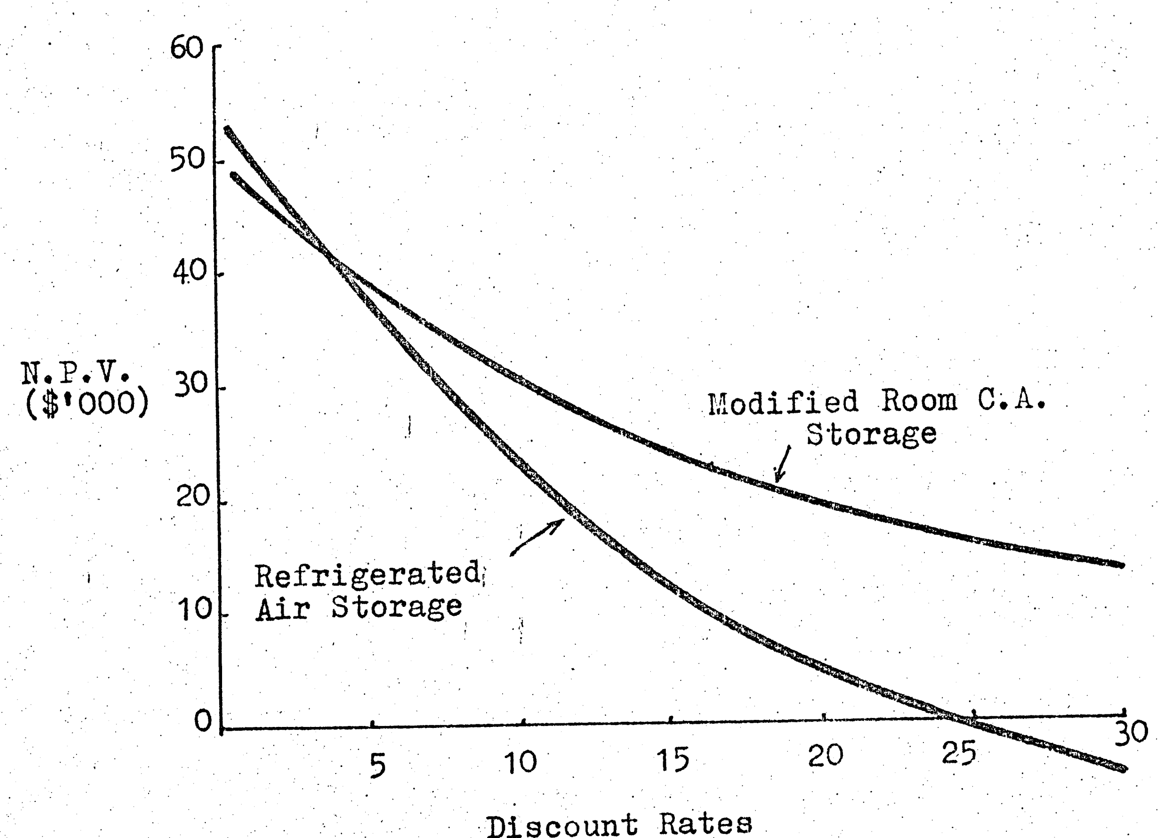
For refrigerated air storage the story was different. For the four smaller room sizes, the choice of discount rate affected whether the system was profitable or not. If proposing to invest in any of these systems, the decision maker will have to carefully select his discount rate so he can accurately decide on whether to invest or not.

Some interesting results occur when refrigerated air storage and modified room C.A. storage are compared. Since these two types of storage have in the past been competitors for the same storage space, this comparison is necessary. Taking a 10,000 bushel room, Figure 3 shows the two N.P.V. curves.

It can be seen that if the investor has a discount rate on his funds of greater than 3 per cent, it is more profitable for him to convert his existing refrigerated air storage to C.A. storage by using a plastic tent modification. For a 6,000 bushel room an almost identical discount rate divides the region where conversion to C.A. storage is profitable. The question does not arise in the smallest room size however as at all discount rates the profitability of modified C.A. storage is greater than that of refrigerated air storage.

FIGURE 3

N.P.V. Curves for Refrigerated Air Storage and Modified Room C.A. Storage; (Open Flame); 1 Per Cent - 30 Per Cent Discount Rates; 10,000 Bushel Room; 10 Year Planning Horizon




## 7.2 PROFITABILITY CRITERIA

Closely related to the practice of varying discount rates to check the sensitivity of profitability is the concept of internal rate of return (I.R.R.). This is the other profitability criterion normally used to examine cash flows over time, and is defined as the discount rate at which the N.P.V. equals zero. It has been used here to test the sensitivity of profitability to an alternate decision criterion.

Table 5 shows the I.R.R.'s for each of the storage systems analysed. Comparison with Table 4 indicates that much the same general relationships hold under the I.R.R. criterion as under N.P.V. with a 10 per cent discount rate, i.e., the profitability increases with room size increases; modified C.A. storage is more profitable than refrigerated air storage at each room size compared; gastight rigid C.A. rooms are only marginally more economic than leaky ones; and the ranking of generator systems in rigid room setups (Capco + lime, Capco + Capco, Tectrol) remains unaltered.

Overall then the profitability of the storage systems studied is not greatly affected by the choice of criteria. This was as expected, because the cash flows patterns produced very similarly shaped N.P.V. curves, so the relationship of N.P.V. to I.R.R. should have been fairly constant for all alternatives analysed.

TABLE 5

I.R.R. for Alternative Storage Systems Studied (%); 10 Year Planning Horizon

| Room Size (bushels) | Type of Storage System | | | | |
|---|---|---|---|---|---|
| | Refrigerated Air Storage | Controlled Atmosphere Storage | | | |
| | | Generator Type | Rigid Room C.A. | | Modified Room C.A. |
| | | | Gastight | Leaky | |
| 3,000 | 8.5 | Open flame | | | 31.2 |
| | | Capco + lime | | | 14.6 |
| 6,000 | 19.3 | Open flame | | | 82.4 |
| | | Capco + lime | | | 53.5 |
| 10,000 | 24.7 | Open flame | | | 138.0 |
| | | Tectrol | 44.3 | 44.0 | |
| | | Capco + Capco | 52.4 | 52.1 | |
| | | Capco + lime | 55.0 | 54.9 | 95.6 |
| 15,000 | 27.6 | Tectrol | 56.3 | 56.2 | |
| | | Capco + Capco | 62.4 | 62.4 | |
| | | Capco + lime | 66.3 | 66.2 | |
| 25,000 | 30.5 | Tectrol | 74.3 | 74.1 | |
| | | Capco + Capco | 81.4 | 81.2 | |
| | | Capco + lime | 83.3 | 83.1 | |

## 7.3 PLANNING HORIZON

One of the assumptions of the analysis was a 10 year planning horizon. To test for the sensitivity of storage systems to changes in this variable, the cash flows were analysed on 8 and 12 year bases.[30]

Still assuming an N.P.V. criterion and a 10 per cent discount rate, the findings of this test were, in general, that the longer planning horizon increased the N.P.V. of the investments and the shorter planning horizon decreased the N.P.V. All the relationships outlined in Table 4 still held except that on a 12 year base the 3,000 bushel refrigerated air store just gains profitable status. On an 8 year planning horizon this alternative is highly unprofitable, but all others are still profitable.

Using an I.R.R. criterion and varying the planning horizon, much the same relationships hold as under N.P.V. The point is however that I.R.R. varies directly with the length of the planning horizon. In the upper ranges of I.R.R. (say above 40 per cent) the difference is virtually non existent, but in the 3,000 bushel refrigerated air store for example the I.R.R. ranges from 4.5 per cent to 10.5 per cent as the planning horizon moves between 8 and 12 years.

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30 Changing the planning horizon really means altering the economic lives of the capital assets. Thus replacement of stores and equipment is assumed to be required at 8 and 12 years when the planning horizon is shortened and lengthened respectively.

# CHAPTER 8

## FUTURE PRICE CONSIDERATIONS

The previous chapter tests the sensitivity of the calculated profit criterion to changes in discount rate, decision criterion and length of planning horizon. It has been noted above that another factor which would certainly affect economic feasibility is the set of price assumptions used. Ideally then, a test of the sensitivity of profitability to changes in returns should also be done, especially the premium between C.A. stored apples and normally stored apples.

Problems exist however even in specifying the direction of movement of apple prices let alone the magnitude. A complex simulation model would probably be required to account for even a reasonable proportion of possible changes. Hence this chapter merely examines factors likely to affect the price of apples and as a result, assumes that there will be a slowly declining percentage premium between C.A. and normally stored fruit.[31]

Pasour and Oldenstadt[32] have listed the factors affecting annual supply and demand for apples, and these are discussed below in the Australian context.

### 8.1 FACTORS AFFECTING APPLE SUPPLY

#### (a) Total Apple Production

Table 6 indicates that N.S.W. apple production is increasing steadily.

This increase has been the result of the introduction of dwarf rootstocks and other technical improvements, giving a

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31 This is based on Thomas and Jensen, op.cit., p. 8, who showed that the C.A. premium in the U.S.A. decreased by about 20 per cent over a five year period, and data from Orange orchardists who felt that the present premium of $0.80 per bushel case would decline over the next 10 years as the quantity stored under C.A. rose.

32 Pasour, E.C. Jr. and D.L. Oldenstadt, Farm Prices of Apples for Canning and Freezing, U.S.A., 1951-61, (U.S.D.A: Agricultural Economic Report, No. 35, 1963).

higher density of trees per acre. Acreages have been fairly stable. Survey results indicated that more than 20 per cent of apple trees in the Orange district are non-bearing, so production will continue to increase. Present profitability levels will ensure that this tendency will remain for some years.

A general decline in apple prices would seem to be the logical outcome of this expected increase in total production, although the extent of this fall will also depend on other supply forces and demand parameters. The effect on C.A. prices will largely be determined by the proportion of apples stored under C.A. conditions.

TABLE 6

N.S.W. Apple Production (1965-73)[33]

| Year (To March) | Production ('000 bus.) | Annual % Change | Cumulative % Change |
|---|---|---|---|
| 1965 | 2988 | - | - |
| 1966 | 2924 | - 2.1 | - 2.1 |
| 1967 | 3324 | +13.7 | +11.2 |
| 1968 | 3287 | - 1.1 | +10.0 |
| 1969 | 3980 | +21.1 | +33.2 |
| 1970 | 3783 | - 4.9 | +26.6 |
| 1971 | 4016 | + 6.2 | +34.4 |
| 1972 | 3635 | - 9.5 | +21.7 |
| 1973 | 4131 | +13.6 | +38.3 |

(b) Quantities Stored in C.A.

U.S. studies[34] reported that the most likely proportion of apples stored there to be C.A. stored was likely to reach about 25 per cent while Carrol[35] felt that the proportion in Australia would reach about 40 per cent mainly because of more suitable varieties. The present N.S.W.

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[33] N.S.W. Department of Agriculture, Division of Marketing and Economics, Production and Marketing of Fruit, (Sydney: Jan 1974).

[34] French, B.C., The Long-Term Price and Production Outlook for Apples in U.S.A. and Michigan (Michigan State University, Department of Agricultural Economics: Technical Bulletin No. 225, 1956).

[35] Carrol, E.T., "Controlled Atmosphere Storage of Apples", Australian Journal of Refrigeration, Air Conditioning and Heating, 23 (11), (November 1969), pp. 20-22.

C.A. capacity of 894,000 bushel cases represents 26 per cent of the 3,454,700 bushel case total cool storage capacity, implying that about a quarter of apples stored are under C.A. Thus growth in the construction of C.A. facilities can be expected for some time, and C.A. prices should decline slightly as the quantity of C.A. stored apples increases.

A major limiting factor is to get enough fruit of high enough quality to warrant using C.A. storage. Higher quality apples should bring higher returns, but increased use of C.A. storage will alter the distribution of quantities of apples marketed through the year. This redistribution effect should act to decrease C.A. prices, so the overall effect should be fairly neutral.

(c) Legislative or Co-operative Marketing

Many growers interviewed saw the need for some form of marketing body to take charge of the whole apple marketing process. They saw this body not just as a marketing tool to organize selling of apples throughout the year, but also as the instigator and regulator of a hail insurance scheme, an information service, an advertising and promotional programme, and legislation setting C.A. fruit standards. Some states in the U.S.A. already have such laws.[36] Consumers would be protected and the reputation built for high quality in C.A. apples would tend to increase prices paid.

(d) Technological Advances

The development of gas-tight containers, and some method of maintaining a low $O_2$ atmosphere within the containers, could revolutionise exports of C.A. apples. Greater quantities diverted to the export market may tend to raise C.A. prices slightly on the domestic market.

Storage of apples for processing would ease some of the pressure on the fresh apple markets, although a recent feasibility study on this concluded that such a move would be uneconomic at present.[37]

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[36] To qualify for a "C.A." label, apples must be stored under a 5 per cent, $O_2$ level or less for at least 90 days, with the 5 per cent attained within 20 days of room sealing.

[37] Layton, R.A., An Economic and Marketing Feasibility Study of a Proposed Apple Processing Plant at Orange, (Unisearch, University of N.S.W.: Sydney, 1968).

(e) Overall Supply Effect

Generally, the dominance of increasing production and increasing construction of C.A. stores indicates a decline in apple prices together with a decrease in the C.A. margin.

## 8.2 FACTORS AFFECTING APPLE DEMAND

(a) Exports

The effect on Sydney wholesale apple prices of the recent curtailment of traditional European markets is expected to be minimal. Increasing exports to other markets, especially South-East Asian nations, does have a large impact on Sydney wholesale prices, as the major proportion of these exports come from N.S.W. Currently, exports are mainly refrigerated air stored, but C.A. stored apples are increasing in popularity as technical developments make containerised C.A. storage feasible.

N.S.W. exports will face heavy competition from other countries displaced from European markets and from countries which have devalued against Australia in recent years, but overall the expansion in exports plus an expected increase in price obtained for exported apples should relieve some of the downward pressure on apple prices noted in 8.1.

(b) Population Changes

Gruen[38] estimated that Australian population should increase at an annual average growth rate of between 1.8 - 2.3 per cent to 1980. Combined with a steady per capita consumption of fresh apples, we can expect marginal increases in C.A. apple consumption in line with population movements.

Many of the migrants coming to N.S.W. originate in European countries where C.A. apples have been commonplace for many years. Their influence could raise N.S.W. prices for C.A. apples to some small degree.

Another factor is the rapid increase which has taken place in processed apple products. Thus some supplies usually destined for the fresh fruit market will be channelled into processing with a consequent positive effect on the prices of C.A. apples.

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[38] Gruen, F. et.al., Long-Term Projections of Agricultural Supply and Demand - Australia 1965 to 1980 (Monash University, Department of Economics: October 1966).

(c) Quality of Fresh Apples

The N.S.W. Department of Agriculture regularly conducts field days to make growers aware of the disadvantages of poor quality fruit being stored and marketed as C.A., since only fruit which is initially sound will have an extended life under C.A. storage. Quality as well as price affects consumer demand. One U.S. study of demand factors for fruit and vegetables found... "that in fresh fruits and vegetables, quality is the first consideration and price is somewhat secondary".[39] Hence the combined effects of C.A. storage on better quality apples should tend to raise the price of this fruit.

(d) Promotion

The maintenance of a high C.A. premium in the U.S. "...was probably due to a higher demand curve being established for C.A. apples, reflecting their higher quality and also a vigorous advertising and promotion campaign...".[40] One conclusion of a recent study[41] was that N.S.W. apples were suitable for some form of promotional programme. As yet no co-ordinated promotion of C.A. apples has taken place, but the higher quality aspects of C.A. apples should make them more suitable for promotion. If adopted this would tend to stimulate demand and encourage higher prices.

(e) Overall Demand Effect

Combining the above factors, the most likely result is that the demand curve will be shifted upwards, negating most of the downward effect on prices of an outward movement of the supply curve.

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[39] Folz, W.E. and A.C. Manchester, The Changing Retail Market for Fresh Fruits and Vegetables (U.S.D.A.: Marketing Research Report No. 417, July 1960).

[40] Johnson, J.F., "The Significance of Controlled Atmosphere Storage to the Apple and Pear Industry", in Proceedings of an Extension School on C.A. Storage of Apples and Pears, (Sydney: N.S.W. Department of Agriculture, March 1969), p. 77.

[41] Boyer, R.A., Co-operative Advertising of Apples in a Competitive Environment - A Case Study of the Bilpin Area (University of New England, Armidale: unpublished dissertation, 1970).

## 8.3 CONCLUSIONS ON FUTURE PRICES

Any prediction about the future is fraught with danger, but weighing up the evidence given by an analysis of supply and demand factors however leaves us with the impression that the prices of C.A. apples will tend gradually downward over the period of the planning horizon. Short-term disturbances in output and in requirements will obviously produce variations around this trend. In line with this absolute price decline, the premium for C.A. fruit will also probably fall to some lower though still profitable level.

# CHAPTER 9

## CONCLUSIONS

The conclusions of this study of alternative storage possibilities for the Orange area are fairly straightforward, and can be segregated into three sections.

1. Selecting a discount rate of 10 per cent, a planning horizon of 10 years and a Net Present Value decision criterion, and using the assumptions of Appendices II-IV, we found:

   (a) refrigerated air storage is basically profitable for all but the smallest room size studied;

   (b) rigid room C.A. storage of apples is highly profitable and a better investment than refrigerated air storage for comparable room sizes. Choice of generator system and scrubbing apparatus, and whether the room is leaky or gas-tight, marginally affects profitability;

   (c) modified C.A. storage investments yield economic returns (higher than those of comparable refrigerated air storage rooms), and choice of generator system affects profitability slightly;

   (d) economies of size in storage rooms were not evident.

2. Net Present Value curves obtained by varying the discount rates (and holding the planning horizon constant) showed that in the range of 1-30 per cent, profitabilities of all stores varied inversely with the discount rate, but only the 3,000 bushel refrigerated air store fell to unprofitable levels. For a discount rate greater than 3 per cent for 6,000 and 10,000 bushel rooms, it is profitable to convert existing refrigerated air storage to plastic tent C.A. storage.

   The economic feasibility of the storage systems were also examined using an Internal Rate of Return criterion, and the results were unchanged.

   Shortening the planning horizon decreased the profitabilities of the storage systems analysed, and vice versa for lengthening the planning horizon, but the relationships between the systems remained unchanged.

3. A quick examination of factors affecting the future supply and demand for C.A. stored apples concluded that the price of these apples will trend gradually downward over the period of the planning horizon. Concurrently, the premium for C.A. fruit will also probably fall to some lower though still profitable level.

It should be stressed again that the above conclusions only relate to the specified assumptions and parameter values, hence any deviation from these will affect the results. Also the choice of storage systems, even though based on survey results, is obviously only one such combination, so again any deviation from these systems will alter the conclusions reached.

# APPENDIX I

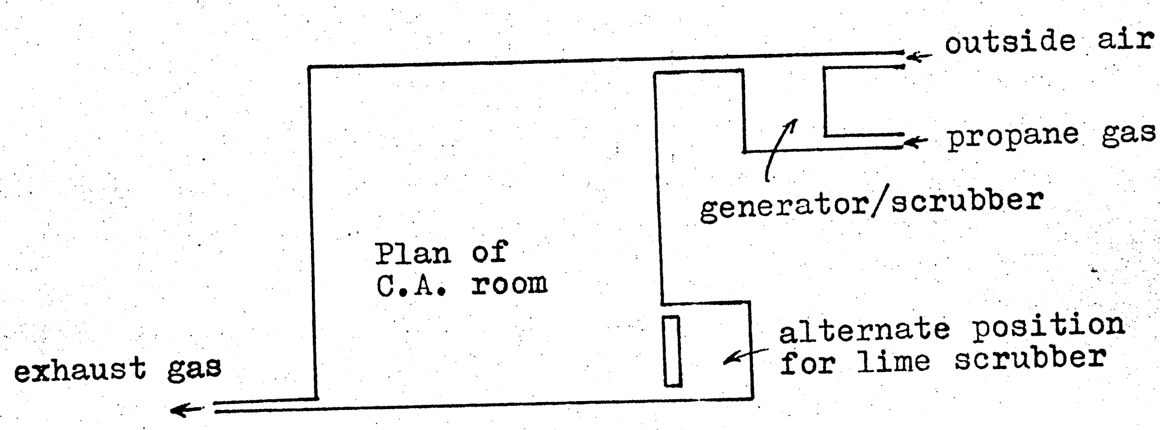
## GENERATOR SYSTEMS

### (i) Flushing Generators

With this system propane gas at pressure is combusted with normal air, removing all but 2 per cent-3 per cent $O_2$ and producing about 12 per cent $CO_2$. The excess $CO_2$ is scrubbed down to the required level and the resultant gas is flushed through the C.A. room by a small fan. Portion of the room atmosphere is exhausted by another fan and the process continues. Figure 4 gives details of this system.

FIGURE 4

Flushing Generator System




Two makes of flushing generators are used in the Orange district. The Tectrol unit, the first generator available in Australia, was the most expensive, and was generally regarded as economically inefficient operating on a room of less than 10,000 bushel capacity. An activated charcoal scrubber was incorporated in the generator. This type of generator is no longer on sale, but has been included in the analysis to give at least an *ex post* idea of its profitability.

A low cost "open flame" generator was developed by engineers of the Department of Agriculture to enable smaller orchardists to own and operate C.A. facilities. It is used primarily in conjunction with a dry slaked lime scrubber.

Full details of this generator have been described by Holligan.[42]

Historically orchardists in the Orange area have used the open flame generator for small rooms (in the 5,000 bushel range) and the Tectrol unit for larger installations. The bushel capacity which can be controlled by a generator does however depend on the gas-tightness of the room. Thus an open flame generator could probably handle, for example, five 5,000 bushel gas-tight tents just as effectively as a Tectrol could service one 10,000 leaky room, simply because a leaky room needs almost constant generation of the required atmosphere. Gas-tight rooms on the other hand only need atmosphere control after opening for filling or emptying.

(ii) Recirculating Generators

With this system air from the C.A. room is passed through the generator, where it is mixed with a flow of propane gas under pressure, and combusted over a catalytic burner. The resultant gas of 2 per cent-3 per cent $O_2$ and 12 per cent-13 per cent $CO_2$ then flows back into the C.A. room under a low pressure fan. Excess $CO_2$ is scrubbed out and the process continues. Figure 5 gives details of this system.

Recirculating generators are technically more efficient for achieving and maintaining C.A. conditions then flushing generators, chiefly because less propane gas is required. Details have been described by Holligan.[43] The recirculating generator used in the Orange area is the Capco, which historically has been used on medium to large stores. Again, however, controllable capacity is positively related to the gas-tightness of the room, so larger stores can be atmospherically controlled easily if the room is reasonably gas-tight.

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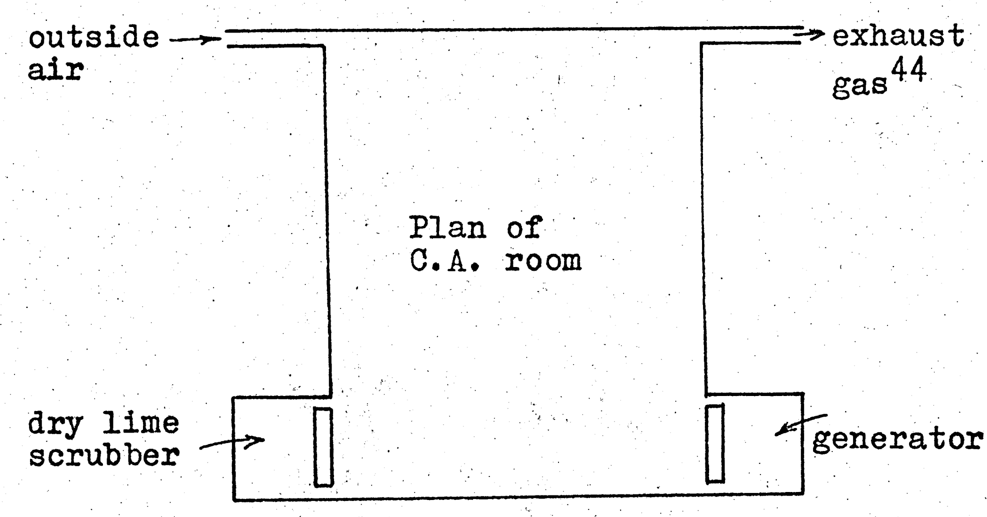
[42] Holligan, P.J., An Open Flame Controlled Atmosphere Generator op. cit., p. 1.

[43] Holligan, P.J., (personal communication), op.cit.

FIGURE 5

Recirculating Generator System

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[44] This outlet is used only for pressure equalisation and for flushing the room prior to marketing.

## APPENDIX II

### GENERAL ASSUMPTIONS

The following assumptions relate to all alternatives examined:

(1) The orchardist stores only Delicious, Jonathan and Granny Smith apples in his store, and in the ratio 2:1:1.

(2) The orchardist fully utilises his capacity with his own fruit (i.e. no allowance is made for rental of storage space to or from other store operators).[45]

(3) Constant real prices hold for the period of the planning horizon.

(4) Average size and quality of the stored fruit are constant for the period of the planning horizon.

(5) Agents commissions, transport costs and other marketing charges are assumed the same whether the fruit is stored or not.

(6) Losses due to breakdown while in storage are assumed negligible, as are the less tangible benefits of orderly year-round fruit marketing.

(7) A year is from March to February.

(8) Construction of new stores, modifications to existing space, and erection of plastic C.A. tents begin in year 0 and are completed within that year. All operations commence in year 1.

(9) Expended life of existing stores being converted to C.A. is assumed negligible.

(10) Stores are filled in March-May, and no stored fruit is sold before July.

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[45] Renting storage space to either orchardists is often a very profitable sideline.

## APPENDIX III

## COST ASSUMPTIONS

(i) Refrigerated Air Storage Costs ($)

| Items | Room Size (Bushels) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3,000 | | 6,000 | | 10,000 | | 15,000 | | 25,000 | |
| | Total | $/Bus. | Total | $/Bus. | Total | $/Bus. | Total | $/Bus. | Total | $/Bus. |
| A. Capital Costs | | | | | | | | | | |
| Store Erection | 4,800 | 1.60 | 9,600 | 1.60 | 16,000 | 1.60 | 24,000 | 1.60 | 40,000 | 1.60 |
| Refrigeration Equipment | 1,000 | .33 | 2,000 | .33 | 3,300 | .33 | 5,000 | .33 | 8,300 | .33 |
| Fork Lift | 6,000 | 2.00 | 6,000 | 1.00 | 6,000 | .60 | 6,000 | .40 | 6,000 | .24 |
| Fruit Bins | 1,800 | .60 | 3,600 | .60 | 6,000 | .60 | 9,000 | .60 | 15,000 | .60 |
| Additional Capital Expenditure | 300 | .10 | 600 | .10 | 1,000 | .10 | 1,500 | .10 | 2,500 | .10 |
| TOTAL | 13,900 | 4.63 | 21,800 | 3.63 | 32,300 | 3.83 | 45,500 | 3.03 | 71,800 | 2.87 |
| B. Annual Operating Costs | | | | | | | | | | |
| Coolant, Electricity for Refrigeration | 204 | .068 | 408 | .068 | 680 | .068 | 1,020 | .068 | 1,700 | .068 |
| Repairs and Maintenance | 417 | .139 | 654 | .109 | 969 | .097 | 1,365 | .091 | 2,154 | .086 |
| Labour | 225 | .075 | 225 | .038 | 225 | .023 | 225 | .015 | 225 | .009 |
| Insurance | 90 | .030 | 180 | .030 | 300 | .030 | 450 | .030 | 750 | .030 |
| 7 Per Cent[1] Interest on Capital Cost (a) | 973 | .324 | 1,526 | .254 | 2,261 | .226 | 3,185 | .212 | 5,026 | .201 |
| TOTAL | 1,909 | .636 | 2,993 | .449 | 4,435 | .444 | 6,245 | .416 | 9,855 | .394 |

1 Notes on Appendix III are on page 46.

APPENDIX III (CONT.)

(ii) Modified Room C.A. Storage Costs ($) (b)

| Items | Room Size (Bushels) | | | | | |
|---|---|---|---|---|---|---|
| | 3,000 | | 6,000 | | 10,000 | |
| | Total | /Bus. | Total | /Bus. | Total | /Bus. |
| **A. Capital Costs** | | | | | | |
| Room Modifications | 600 | .200 | 800 | .133 | 1,000 | .100 |
| Plastic Tents | 850 | .280 | 1,000 | .167 | 1,150 | .115 |
| Generators - Capco | 2,500 | .833 | 2,500 | .417 | 2,500 | .250 |
| - Open Flame | 950 | .320 | 950 | .160 | 950 | .095 |
| Lime Scrubber | 75 | .025 | 80 | .013 | 100 | .010 |
| Gas Analyser | 100 | .030 | 100 | .017 | 100 | .010 |
| Thermometers | 150 | .050 | 150 | .025 | 150 | .015 |
| LPG Cylinders (c) | 100 | .030 | 100 | .017 | 100 | .010 |
| DPA Dipping Equipment | 500 | .150 | 500 | .083 | 500 | .050 |
| Oxygen Apparatus | 100 | .030 | 100 | .017 | 100 | .010 |
| Water Tower (d) | 250 | .075 | 250 | .042 | 250 | .025 |
| TOTAL - Capco | 5,225 | 1.742 | 5,580 | .93 | 5,950 | .595 |
| - Open Flame | 3,425 | 1.142 | 3,780 | .63 | 4,150 | .415 |
| **B. Annual Operating Costs** | | | | | | |
| Coolant, Electricity for Refrigeration | 204 | .068 | 408 | .068 | 680 | .068 |
| Capco costs - LPG | 21 | .007 | 42 | .007 | 71 | .007 |
| - Electricity | 40 | .013 | 80 | .013 | 133 | .013 |
| Open Flame - LPG | 50 | .017 | 100 | .017 | 167 | .017 |
| - Electricity | 45 | .015 | 90 | .015 | 150 | .015 |
| Lime Scrubber | 50 | .017 | 100 | .017 | 167 | .017 |
| DPA dips or wraps | 30 | .010 | 60 | .010 | 100 | .010 |
| Gas analyser | 15 | .005 | 15 | .003 | 15 | .001 |
| Insurance | 150 | .050 | 300 | .050 | 500 | .050 |
| Labour | 450 | .150 | 450 | .075 | 450 | .045 |
| R & M - Capco (e) | 150 | .050 | 150 | .025 | 150 | .015 |
| - Open Flame | 100 | .033 | 100 | .017 | 100 | .010 |
| 7 Per Cent on Capital | | | | | | |
| - Capco | 366 | .122 | 391 | .065 | 417 | .042 |
| - Open Flame | 240 | .080 | 265 | .044 | 291 | .029 |
| TOTAL - Capco (f) | 1,476 | .492 | 1,996 | .333 | 2,683 | .268 |
| - Open Flame | 1,334 | .445 | 1,888 | .315 | 2,620 | .262 |

APPENDIX III (CONT.)

(iii) Rigid Room C.A. Storage Capital Costs ($)

| Items | Room Size (Bushel) | | | | | |
|---|---|---|---|---|---|---|
| | 10,000 | | 15,000 | | 25,000 | |
| | Total | /Bus. | Total | /Bus. | Total | /Bus. |
| Store Erection | 11,000 | 1.100 | 15,000 | 1.000 | 20,000 | .800 |
| Refrigeration Equipment | 3,300 | .333 | 5,000 | .333 | 8,300 | .333 |
| Tectrol Generator/Scrubber | 8,000 | .800 | 8,000 | .533 | 8,000 | .320 |
| Capco Generator | 2,500 | .250 | 2,500 | .167 | 2,500 | .100 |
| Capco Scrubber | 1,500 | .150 | 1,500 | .100 | 1,500 | .060 |
| Lime Scrubber | 100 | .010 | 130 | .009 | 200 | .008 |
| Gas Analyser | 100 | .010 | 100 | .007 | 100 | .004 |
| Thermometer | 150 | .015 | 150 | .010 | 150 | .006 |
| Water Tower - Capco | 250 | .025 | 250 | .017 | 250 | .010 |
| - Tectrol | 550 | .055 | 550 | .037 | 550 | .022 |
| LPG Cylinders | 100 | .010 | 100 | .007 | 100 | .004 |
| DPA Dipping Equipment | 500 | .050 | 500 | .033 | 500 | .020 |
| Oxygen Apparatus | 100 | .010 | 100 | .007 | 100 | .004 |
| Fork Lift | 6,000 | .600 | 6,000 | .400 | 6,000 | .240 |
| Fruit Bins | 6,000 | .600 | 9,000 | .600 | 15,000 | .600 |
| TOTAL - Tectrol | 35,800 | 3.580 | 44,500 | 2.970 | 58,800 | 2.350 |
| - Capco "with" Capco Scrubber | 31,500 | 3.150 | 40,200 | 2.680 | 54,500 | 2.180 |
| - Capco "without" Capco Scrubber | 30,100 | 3.010 | 38,830 | 2.590 | 53,200 | 2.130 |

APPENDIX III (CONT.)

(iv) Rigid Room C.A. Storage Annual Operating Costs for Gas-tight Room ($)

| | Room Size (Bushels) | | | | | |
|---|---|---|---|---|---|---|
| | 10,000 | | 15,000 | | 25,000 | |
| | Total | /Bus. | Total | /Bus. | Total | /Bus. |
| Coolant, Electricity for Refrigeration | 680 | .068 | 1,020 | .068 | 1,700 | .068 |
| Tectrol costs - LPG | 134 | .014 | 206 | .014 | 344 | .014 |
| - Elect. | 123 | .012 | 185 | .012 | 308 | .012 |
| Capco "with" - LPG | 49 | .005 | 73 | .005 | 122 | .005 |
| - Elect. | 110 | .011 | 163 | .011 | 273 | .011 |
| Capco "without" - LPG | 49 | .005 | 73 | .005 | 122 | .005 |
| -Elect | 20 | .002 | 30 | .002 | 50 | .002 |
| Lime Scrubber | 167 | .017 | 250 | .017 | 417 | .017 |
| DPA dips or wraps | 100 | .010 | 150 | .010 | 250 | .010 |
| Gas Analyser | 15 | .002 | 15 | .001 | 15 | .001 |
| Insurance | 500 | .050 | 750 | .050 | 1,250 | .050 |
| Labour | 450 | .045 | 450 | .030 | 450 | .018 |
| R & M - Tectrol | 1,074 | .107 | 1,333 | .089 | 1,764 | .071 |
| - Capco "with" | 945 | .095 | 1,206 | .080 | 1,635 | .065 |
| - Capco "without" | 903 | .090 | 1,164 | .078 | 1,596 | .064 |
| 7 Per Cent on Capital | | | | | | |
| - Tectrol | 2,506 | .251 | 3,115 | .208 | 4,116 | .165 |
| - Capco "with" | 2,205 | .221 | 2,814 | .188 | 3,815 | .153 |
| - Capco "without" | 2,107 | .211 | 2,718 | .181 | 3,724 | .149 |
| TOTAL - Tectrol | 5,582 | .558 | 7,224 | .482 | 10,197 | .408 |
| - Capco "with" | 5,054 | .505 | 6,641 | .443 | 9,510 | .380 |
| - Capco "without" | 4,991 | .499 | 6,620 | .441 | 9,574 | .383 |

APPENDIX III (CONT.)

(v) Rigid Room C.A. Storage Annual Operating Costs for Leaky Room ($)

| | Room Size (Bushels) | | | | | |
|---|---|---|---|---|---|---|
| | 10,000 | | 15,000 | | 25,000 | |
| | Total | /Bus. | Total | /Bus. | Total | /Bus. |
| Coolant, Electricity for Refrigeration | 680 | .068 | 1,020 | .068 | 1,700 | .068 |
| Tectrol costs - LPG | 167 | .017 | 250 | .017 | 417 | .017 |
| - Elect. | 150 | .015 | 225 | .015 | 375 | .015 |
| Capco "with" - LPG | 71 | .007 | 105 | .007 | 176 | .007 |
| - Elect. | 133 | .013 | 199 | .013 | 332 | .013 |
| Capco "without" - LPG | 71 | .007 | 105 | .007 | 176 | .007 |
| - Elect. | 25 | .003 | 38 | .003 | 63 | .003 |
| Lime Scrubber | 167 | .017 | 240 | .017 | 400 | .017 |
| DPA dips or wraps | 100 | .010 | 150 | .010 | 250 | .010 |
| Gas Analyser | 15 | .002 | 15 | .001 | 15 | .001 |
| Insurance | 500 | .050 | 750 | .050 | 1,250 | .050 |
| Labour | 450 | .045 | 450 | .030 | 450 | .018 |
| R&M - Tectrol | 1,074 | .107 | 1,333 | .089 | 1,764 | .071 |
| - Capco "with" | 945 | .095 | 1,206 | .080 | 1,635 | .065 |
| - Capco "without" | 903 | .090 | 1,164 | .078 | 1,596 | .064 |
| 7 Per Cent on Capital | | | | | | |
| - Tectrol | 2,506 | .251 | 3,115 | .208 | 4,116 | .165 |
| - Capco "with" | 2,205 | .221 | 2,814 | .188 | 3,815 | .153 |
| - Capco "without" | 2,107 | .211 | 2,718 | .181 | 3,724 | .149 |
| TOTAL - Tectrol | 5,642 | .564 | 7,308 | .487 | 10,337 | .413 |
| - Capco "with" | 5,099 | .510 | 6,709 | .447 | 9,623 | .385 |
| - Capco "without" | 5,018 | .502 | 6,660 | .444 | 9,641 | .386 |

APPENDIX III (CONT.)

(vi) Notes on some variables.

(a) A further operating cost of all types of storage, which should at least be recognised, is the interest on returns from fruit which is forgone by storing rather than marketing immediately after harvest. This cost however was ignored in the above analysis.

(b) Assumed gas-tight.

(c) Orchardists can either buy or rent these cylinders from the supplier. Size will obviously vary with gas requirements, so $100 can only be regarded as a rough approximation.

(d) Water towers are only necessary to maintain gas pressure in recirculating generators (Capco) and for flushing generators in leaky rooms. Thus they are not needed for gas-tight tents, run by open flame generators.

(e) Repairs and maintenance includes the testing of all C.A. rooms prior to harvesting the new season fruit, and totals 3 per cent of capital cost.

(f) This Capco system contains a lime scrubber, not a Capco scrubber.

# APPENDIX IV

## PRICE ASSUMPTIONS

(i) Average Monthly Wholesale Prices, 1967-71 ($/Bushel)

| | Delicious (125/180) | | Jonathan (138/180) | | Granny Smith (138/180) | |
|---|---|---|---|---|---|---|
| | No storage + Refrig. storage | C.A. | No storage + Refrig. storage | C.A. | No storage + Refrig. storage | C.A. |
| January | 1.65 | 5.90 | - | - | 3.70 | 5.17 |
| February | 3.28 | 5.29 | 2.98 | - | 2.80 | 3.57 |
| March | 3.32 | - | 2.80 | - | 2.55 | - |
| April | 3.36 | - | 2.67 | - | 2.29 | - |
| May | 3.57 | - | 2.90 | - | 2.40 | - |
| June | 3.59 | - | 3.13 | 4.01 | 2.61 | - |
| July | 3.59 | 4.93 | 3.34 | 3.98 | 2.75 | - |
| August | 3.70 | 5.26 | 3.33 | 3.70 | 2.86 | - |
| September | 3.98 | 4.76 | 3.38 | 4.08 | 3.16 | 4.34 |
| October | 4.37 | 5.29 | 3.30 | 4.57 | 3.33 | 4.77 |
| November | 4.52 | 6.10 | 4.00 | 4.96 | 3.75 | 4.55 |
| December | 5.69 | 6.33 | - | 3.30 | 3.80 | 4.73 |

(ii) Refrigerated Air Storage Marketing Plan

| Month | Delicious | Jonathan | Granny Smith |
|---|---|---|---|
| July | | $\frac{1}{4}$ of initial stock | |
| August | | $\frac{1}{2}$ of initial stock | |
| September | $\frac{1}{8}$ of initial stock | $\frac{1}{4}$ of initial stock | $\frac{1}{8}$ of initial stock |
| October | $\frac{1}{8}$ of initial stock | | $\frac{1}{8}$ of initial stock |
| November | $\frac{1}{4}$ of initial stock | | $\frac{1}{4}$ of initial stock |
| December | $\frac{1}{2}$ of initial stock | | $\frac{3}{8}$ of initial stock |
| January | | | $\frac{1}{8}$ of initial stock |

APPENDIX IV (CONT.)

(iii) C.A. Storage Marketing Plan

| Month | Delicious | Jonathan | Granny Smith |
|---|---|---|---|
| July | | ½ of initial stock | |
| August | | | |
| September | ¼ of initial stock | ½ of initial stock | |
| October | | | |
| November | ½ of initial stock | | ½ of initial stock |
| December | | | |
| January | ¼ of initial stock | | ½ of initial stock |

(iv) Refrigerated Air Storage Price Benefits ($/Year)

| Room Size (Bus.) | Returns if No Storage | Returns from Refrig. Air Storage | Net Returns from Refrig. Air Storage |
|---|---|---|---|
| 3,000 | 8,925 | 12,758 | 3,833 |
| 6,000 | 17,850 | 25,516 | 7,666 |
| 10,000 | 29,750 | 42,525 | 12,776 |
| 15,000 | 44,625 | 63,788 | 19,164 |
| 25,000 | 74,375 | 106,313 | 31,940 |

(v) Modified Room C.A. Storage Price Benefits ($/year)

| Room Size (Bus.) | Returns from Refrig. Air Storage | Returns from C.A. Storage | Net Returns from Modified Room C.A. Storage |
|---|---|---|---|
| 3,000 | 12,758 | 15,241 | 2,483 |
| 6,000 | 25,516 | 30,482 | 4,966 |
| 10,000 | 42,525 | 50,801 | 8,276 |

APPENDIX IV (CONT.)

(vi) Rigid Room C.A. Storage Price Benefits ($/Year)

| Room Size (Bus.) | Returns if No Storage | Returns from C.A. Storage | Net Returns from Rigid Room C.A. Storage |
|---|---|---|---|
| 10,000 | 29,750 | 50,801 | 21,051 |
| 15,000 | 44,625 | 76,202 | 31,577 |
| 25,000 | 74,375 | 127,003 | 52,628 |

# APPENDIX V

## CALCULATION OF N.P.V.

As an example of how N.P.V. is derived, calculation of the following cash flow budget for a 15,000 bushel leaky rigid room C.A. store with Capco generator and lime scrubber is described.

| Year (n) | Annual Costs | Annual Benefits | Net Benefits Annual | Net Benefits Discounted |
|---|---|---|---|---|
| | $ | $ | $ | $ |
| 0 | 38,830 | 0 | -38,830 | -38,830 |
| 1 | 5,496 | 31,577 | 26,081 | 23,710 |
| 2 | 5,496 | 31,577 | 26,081 | 21,554 |
| 3 | 5,496 | 31,577 | 26,081 | 19,595 |
| 4 | 6,660 | 31,577 | 24,917 | 17,018 |
| 5 | 6,660 | 31,577 | 24,917 | 15,471 |
| 6 | 6,660 | 31,577 | 24,917 | 14,066 |
| 7 | 6,660 | 31,577 | 24,917 | 12,786 |
| 8 | 6,660 | 31,577 | 24,917 | 11,624 |
| 9 | 6,660 | 31,577 | 24,917 | 10,567 |
| 10 | 6,660 | 35,460 | 28,800 | 11,104 |
| Total discounted net benefits (N.P.V.) | | | | 118,665 |

### Annual Costs

The details of the capital cost of equipment ($38,830) incurred in year 0 (that is, at the beginning of the 10 year period) are set out in Appendix III, (iii). The annual costs for the remaining years comprise only operating costs (see Appendix III, (v)). Repairs and maintenance charges are not included for years 1 - 3.

### Annual Benefits

The annual benefits listed above (from Appendix IV, (vi)) represent the <u>additional</u> annual gross returns from the sale of C.A. stored apples (in this case 15,000 bushels) over and above the gross returns from the same quantity of apples marketed without the benefit of refrigerated or C.A. storage (the latter are assumed to be sold at average March prices).

The relevant storage, marketing, and price assumptions are set out in Appendix II and Appendix IV, (i) and (iii).

The annual benefit for year 10 ($35,460) includes $3,883, the 10 per cent (of initial value) salvage value of the equipment assumed to be sold at the end of its useful life of 10 years (see chapter 4, pages 12 and 13).

The assumption of a 10 year useful life accounts for the adoption of the 10 year horizon, that is, the period adopted for N.P.V. calculations.

Net Benefits

Annual net benefits = annual benefits - annual costs.

Discounted Net Benefits

$P_n$, the discounted net benefit for year n is calculated as follows

$$P_n = B_n (1 + i)^n$$

Where $B_n$ is annual net benefit for year n, i is the discount rate (in this case 10 per cent), n is the year of the planning period in which the net benefit occurs.

Total N.P.V.

This figure is a means of comparing the different systems of storage on a standardised basis. The relative values of the respective N.P.V.'s are used to rank the economic worth of each of the systems. The actual dollar value of each N.P.V. is of little significance in itself.