Best Practice Guide - Part 2

Best Practice Guide on the efficient harvesting, storage, packaging and marketing of UK-produced apples

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Introduction

It is increasingly difficult for UK growers to make a profit from their apple crop. Many factors contribute to this situation. It is clear that the future of the UK apple industry is dependent on the production of fruit with the quality characteristics demanded by the consumer. Moreover, in the future, the industry will need to respond to inevitable changes in consumer requirements. The information provided in this part of the Guide would help growers to provide UK consumers with fruit of the highest possible quality over the longest period possible.

This part of the Guide is divided in to 15 sections each concerned with a key area in the attainment of quality fruit to the consumer. The order of the sections reflects the biology of the apple through its phases of development from cell division through to maturity on the tree and finally to ripening and senescence changes that take place during and after storage. The factors that effect storage potential and eating quality are indicated for each phase of development. At any point, failure to adopt best practice can compromise the quality of fruit from store.

Sections 1-4 are concerned with the management of orchards in a manner that achieves high yields of large fruit without compromising eating quality or storage potential. It is particularly important to achieve the correct mineral balance in the fruit especially in Cox and Bramley and an accurate prediction of storage quality that helps implement a storage and marketing strategy. Picking at the correct stage of maturity for the intended market is probably the single most critical factor affecting quality to the consumer.

Sections 5-7 are concerned with the physical harvesting of fruits and their handling prior to placement in the cold stores. Fruit quality can be lost through bad picking and handling practice and the wastage in stored fruit may be unacceptable where post-harvest chemical treatments are not applied correctly.

Sections 7 and 8 deal with the critical requirement to maintain storage conditions that are most appropriate for each cultivar and for the duration of storage required. Stores must be capable of achieving the holding temperature and controlled atmosphere conditions within the limits prescribed.

Strategies for improving quality of stored apples by reducing ethylene production and improving flavour are outlined in Sections 9 and 10.

Careful monitoring of the quality of each consignment of fruit in each store needs to be carried out regularly. This will ensure that fruit is removed from store before it declines to the minimum quality required and before any development of disorders or diseases reaches a commercially significant level. Monitoring of fruit condition and identification of the major storage disorders affecting UK apples are described in sections 11 and 12 respectively.

The final sections (13-15) of this part of the Guide cover post-storage grading, packing and distribution of fruit to the wholesaler or retailer.

Storage facilities and operation

The engineering aspects of storage are not covered in this Guide. The decision to exclude engineering was based mainly on the variability in store construction and in ancillary and control equipment that exists in the UK. It would be impossible to suggest best practice for the maintenance and operation of stores that vary so much in age, construction, refrigeration plant, coolers, scrubbers, instruments and atmosphere control systems. Moreover modern storage and ancillary equipment has become more complicated and generally requires appropriately trained service engineers to carry out maintenance and rectify problems. For the purposes of this Guide it is assumed that the stores being used meet the requirements to cool fruit promptly (see section 7) and to maintain temperature and CA conditions accurately (see section 8). Where these requirements cannot be fulfilled the duration of storage must be adjusted accordingly or the storage facilities must be improved. In recognition of the range in capabilities within the UK industry, particularly as regards the level of gas-tightness of stores for CA, a range of possible CA conditions are provided wherever possible (section 8).

Those stores in the UK that are used for the storage of apple range in capability from very poor to good. Taken as a whole, for the national stock of apple stores, the average age is high and the average condition is mediocre. Additionally, the operation of many of the stores is less than ideal, particularly around loading time, with the result that fruit quality is compromised. In many instances, often through lack of appropriate training, the operators and often their managers, do not appreciate the significance to ultimate fruit quality of such matters as pre-cooling of stores, slow loading, slow cooling, or deviation from the recommended storage conditions for the specific cultivars. Also, many of the rooms are used for CA storage when they are not sufficiently gas-tight.

To compound further the difficulties of efficient store operation, the cost of energy was increased from 1 April 2001, by the introduction of the Climate Change Levy, specifically designed to promote moves towards more energy efficient practices and equipment and thus offset the impact of global warming. In round figures this can be expected to increase the energy bill for most commercial and industrial businesses by about 15%, with some sectors, including certain aspects of horticultural production not finalised at the time of writing, being granted a reduced rate of levy for perhaps five years. It has been estimated that for most refrigeration installations of more than a few years old - which will include most apple stores - electricity consumption is significantly higher than is strictly necessary. Often, reductions in energy costs of five to ten percent may be achieved with little or no capital outlay, rising to perhaps 20% or more for only modest investment. Professional advice is virtually essential to determine how best to achieve these savings for each particular installation; it should be expected that the electricity savings resulting from making the changes that are suggested will very quickly recoup the cost of the professional services as well as any capital expenditure.

In order that the best practice contained in the following 15 sections is put to maximum effect in providing consistently high quality fruit from store the stores must operate efficiently. Growers must record diligently the performance of the store as regards temperature pull-down, temperature variation within the store, control of carbon dioxide and oxygen concentrations and weight (water) loss in the fruit. Where a store under-performs this should be discussed with an appropriate technical expert to resolve the problem. This should be done as soon as the problems / shortcomings are recognised and remedial action taken prior to the next season. Likewise at this time preventative maintenance schedules must be in place. It is particularly important that the question of gas-tightness of CA stores is not overlooked. Growers often have maintenance contracts for their refrigeration plant, ancillary equipment and instruments but may overlook the vital need to check gas-tightness. It is important to test stores scheduled for CA operation for gas-tightness every season.

It is particularly important that operators of fruit stores receive adequate training in the following aspects:

- Store construction
- Monitoring and controlling store conditions
- Refrigeration
- Scrubbing systems and gas generators
- Pre-season checking and maintenance
- Store loading and routine operation

It is also helpful for fruit store operators to have some knowledge of fruit behaviour so that they can associate store performance with the quality of fruit.

Contents

Section 1. Optimising the pre-harvest management of orchards to maximise the storage and eating quality of fruits.

As a priority orchard management practice should be geared towards maximum yields of class 1 fruit. The influences of such practices on storage quality need to be considered in order that appropriate marketing strategies can be put into place. Where such practices adversely effect storage or eating quality remedial measures need to be taken where these are available.

The influence of pre-harvest factors on storage quality operate primarily through effects on yield, fruit size and vegetative growth.

Large fruit from lightly cropping trees do not generally store well due to mineral imbalance in the fruit and to a low calcium concentration in particular.

Overcropping trees produce small fruit that lack red colour and have insufficient dry matter for adequate texture although the fruit is unlikely to develop physiological disorders associated with low calcium.

Vigorous growth competes with the developing fruit for available nutrients and water and can often exacerbate problems due to low calcium.

Judgement of the correct level of cropping to achieve sufficient yield, fruit size and visual quality without unduly compromising storage potential is paramount in achieving profitable production and commercial success.

Hand thinning Cox trees to one fruit per cluster at 35-40 days after full bloom has improved the texture and eating quality of CA-stored fruit.

Chemical thinning (see Part 1 of the Guide) at the appropriate stage followed by hand thinning as necessary is the best practice to achieve the desired level of crop.

Adequate thinning will help to ensure that harvest isn't delayed beyond the optimum period for storage in an attempt to improve size and red colour.

The lighter the crop the greater the requirement for supplementing calcium nutrition of the fruit by the use of calcium sprays (see section 2), post-harvest calcium treatments (see section 7) and of pre-harvest mineral analysis to predict storage potential (see section 3).

Avoid hard pruning in the winter and use 'Cultar' as a means of controlling shoot growth in the spring and summer months. Effects of 'Cultar' on the storage quality of Cox and Bramley apples have generally been positive.

Late summer pruning reduces susceptibility of stored fruit to bitter pit and other calcium deficiency disorders and improves red colour and the efficacy of calcium spraying in the orchard.

Herbicide-based soil management may reduce phosphorus uptake into leaves and fruits and increase susceptibility of fruit to low temperature breakdown during

storage. Apply phosphorus sprays (see section 2) in Cox and Bramley orchards where phosphorus levels in the fruit are consistently low.

Ensure sufficient weed-free areas in Bramley orchards to reduce the competitive effects of grass on nitrogen uptake. Intense competition will reduce yield and fruit size and will promote red colour and reduce the intensity of greenness in the background colour. Reductions in fruit phosphorus and calcium due to increased area of bare soil and nitrogen application should be countered by the use of orchard sprays containing phosphorus and calcium respectively.

Growth regulators applied to reduce shoot growth ('Cultar') or improve skin finish ('Regulex') do not appear to cause adverse effects on storage quality. In many cases single or multiple applications of 'Cultar' have improved the storage quality of Cox and Bramley apples.

Thinning sprays may indirectly increase susceptibility of apples to calcium deficiency disorders such as bitter pit and senescent breakdown by increasing fruit size and the leaf to fruit ratio. The priority should be the achievement of the correct level of crop for profitable production but awareness of the effects of thinning on the mineral status of the fruit is essential for planning storage and marketing (see section 3). Safeguard storage potential by routine application of calcium sprays and correct harvest date. Fruit on lightly cropping trees tend to be ready to harvest earlier than those on carrying heavier crops.

Currently no growth regulators are available in the UK to specifically improve storage quality of apples. This situation may change in the future with the use of products such as 'ReTain^{R}' that is applied as an orchard spray to retard fruit maturity, extend picking period for storage and delay the rate of ripening and senescence of fruit in store. Early results on Cox apples have been particularly encouraging.

Section 2. Modifying tree nutrition for optimal storage quality.

Lime and fertilizer recommendations for apples are intended to ensure that availability and uptake of mineral nutrients do not limit growth and cropping. Soil and leaf analyses are used to determine general fertilizer requirements and to identify mineral deficiencies. However, it cannot be assumed that a nutrient supply that is satisfactory for tree growth and cropping necessarily produces fruit with a satisfactory storage potential and eating quality. In many cases the availability of specific minerals needs to be restricted or supplemented in order to improve storage and eating quality. Growers are advised to analyse soils, leaves and fruits on a regular basis in order to understand the full effect of their use of lime and fertilizers in specific orchards. These different types of analyses are necessary, as often there is a lack of association between fertilizer application and nutrient uptake or a poor correlation between nutrient levels in leaves and fruits. There are many factors other than fertilizer application that affects the levels of nutrients in the leaves and fruits. Soil type, water availability, rootstock, pruning and cropping are some of the more important factors that influence uptake and partitioning of mineral nutrients within the tree.

Practices that combine adequate cropping with good storage potential:

- In Cox orchards apply sufficient nitrogen fertiliser to achieve a maximum nitrogen concentration of 2.6% (dry weight) in leaves and 70 mg $100g^{-1}$ (fresh weight) in fruit at harvest.

- In Bramley orchards apply sufficient nitrogen fertiliser to achieve a minimum nitrogen concentration of 2.6% (dry weight) in leaves and a maximum nitrogen concentration 60 mg $100g^{-1}$ (fresh weight) in fruit at harvest.

- Economise on the use of nitrogen fertilizer by minimising grass / weed competition for water and nitrogen.

- Supplement phosphorus nutrition in orchards where there is a history of flesh breakdown in stored fruit and where low phosphorus is implicated in the problem. Proprietary products are available for this purpose. These include 'Seniphos' that has proved particularly effective in raising phosphorus levels and reducing low temperature breakdown in Cox and Bramley apples.

- In Cox orchards achieve a minimum phosphorus concentration of 0.24% (dry weight) in leaves and raise leaf phosphorus concentrations in Bramley to the higher end of the suggested range (0.18-0.23%).

- Apply phosphorus sprays in mid-June to mid-July to reduce susceptibility of fruits to breakdown in store. This is particularly important for Bramley where a third of orchards achieve fruit phosphorus levels below the recommended threshold of 9 mg $100g^{-1}$ (fresh weight).

- Potassium supply in orchards should be sufficient for adequate growth and cropping but major adverse effects occur during storage in fruit with excessive potassium.

- Potassium deficiency may be corrected by applying 3 sprays of potassium sulphate at 14-day intervals from petal fall. In Gala and Jonagold it may be appropriate to apply potassium nitrate if nitrogen levels are low.

- The application of calcium sprays should be regarded as routine on Cox, Bramley, Egremont Russet and Spartan. The effectiveness of the programme should be judged against mineral composition standards for good storage quality.

- Calcium chloride is the preferred salt for most cultivars for the control of bitter pit and related disorders. A minimum programme would apply 72 kg hectare^{-1} of 78% flaked grade calcium chloride per season.

- In Egremont Russet 110 kg hectare^{-1} of calcium nitrate prills (79% calcium nitrate) is preferred in order to avoid leaf scorch associated with the use of the chloride form.

- In Cox the nitrate form of calcium is preferred as fruit firmness is likely to be retained more effectively than with the use of the chloride form. Care is required in its application to avoid any lenticel injury to the fruit.

- To derive maximum effect from calcium sprays apply the full amount of material per season regardless of water volume and apply from June to as near harvest as is practicable. Minimise leaf scorch from calcium chloride by spraying in cool temperatures (<21^{o}C) or by reduced spray concentration. Where spray rates are reduced increase the frequency of spraying. It may not be necessary to be as cautious about spraying in high temperatures when applying calcium chloride in water volumes of 100 litres per hectare or less.

- Proprietary products such as 'wuxal type 2' and 'calcium metalosate' have given improved results over standard flake calcium chloride when applied at equivalent rates of calcium per hectare. Other proprietary calcium products may provide similar improvements in efficacy but evidence should be provided to this effect before these are used in preference to calcium chloride (or calcium nitrate) and particularly where lower rates of calcium per hectare are advised.

- Supplement magnesium nutrition where leaf analysis indicates sub-optimal levels or where there are visible symptoms of deficiency. Low magnesium in fruits may induce flesh breakdown in stored fruit whilst excessive levels increase susceptibility to bitter pit and related disorders.

- Two to five applications of magnesium sulphate (20 kg 1000 l^{-1} ha^{-1}) applied at 14 day intervals provides a more rapid control of magnesium deficiency than soil applied forms of magnesium. It is important to offset any increased bitter pit potential from the magnesium sprays by subsequently applying a full calcium spray programme. Other proprietary products are available to rectify deficiencies of magnesium. Growers should consider the most appropriate material and method of application for their particular orchards in consultation with their advisers and spray representatives.

- Although boron deficiency can cause serious corking problems in apples this is rare in the UK. There are adverse effects on storage quality that result from an over supply of boron. Analysis of soils, leaves and fruits should be carried out when boron deficiency is suspected.

- Boron deficiency can be rectified by soil application of materials such as borax (20 kg ha^{-1}) or Solubor (10 kg ha^{-1}) in the spring or by 3 sprays of Solubor (2 kg 1000 l^{-1} ha^{-1}), with an appropriate wetter, starting at petal fall and repeated at 2-3 week intervals. Other proprietary products are available to rectify deficiencies of boron. Growers should consider the most appropriate material and method of application for their particular orchards in consultation with their advisers and spray representatives.

Section 3. Predicting storage potential of apples using fruit mineral analysis.

- Make an assessment of the storage potential of Cox and Bramley apples from all orchards intended for storage by the use of mineral analysis.

- Sample fruit from Cox and Bramley orchards at harvest or up to 2 weeks prior to harvest and compare results with recommended standards (see Tables 1 and 2).

- Samples taken at random in the orchard from at least 20 trees usually by following a zig-zag path and taking one apple at random from alternate sides of successive trees. Place the 20 apples in a clean polythene bag and label clearly to indicate cultivar, orchard, farm and sampling date. If areas of the orchard have been managed differently, for example as regards soil or tree management or there are areas differing in terms of growth and cropping then these should be sampled separately. It may be necessary to segregate sections of the orchard at picking time and to allocate the fruit to different stores based on the indicated storage potential.

- Samples (20-fruit per orchard) at harvest can be taken directly from the bins prior to loading into store. The sampling method should be similar to that described for taking samples for monitoring quality during the storage period (see section 11).

- Additionally samples of fruit should be taken early in the season e.g. early-mid July to predict the likely achievement of the desired mineral composition at harvest and the need for the application of nutrient sprays to increase the concentration of important elements such as phosphorus and calcium.

- It is also possible to make a preliminary prediction of storage disorders based on fruitlet analysis and on the fruit size that is predicted at harvest. Further sampling for analysis is required at or just prior to harvest to check fruit size (mean fruit weight) and any categorisation of storage potential made earlier in the season. Advice is normally available from those providing the analytical service for fruitlets. It is not possible to draw up definitive analysis standards for fruitlets similar to those provided for fruit sampled at or just prior to harvest (Tables 1 and 2).

Table 1. Harvest mineral composition standards for Cox's Orange Pippin apples grown in the UK.

N	P	K	Ca	Mg	K/Ca
mg per 100 g fresh weight					
50-70	11 min	130-160[a]	5[c], 4.5[b]	5	30[d], 35[e] max

[a] - maximum of 150 mg per 100 g for storage in 1-1.2% oxygen later than January
[b] - minimum for storage in 2% oxygen (<1% carbon dioxide)
[c] - minimum for storage in air until the middle of October and 1-1.2% oxygen later than January
[d, e] - maximum for storage in air and CA respectively. Commercially significant losses from bitter pit and late storage corking are likely at larger K/Ca ratios

Table 2. Harvest mineral composition standards for Bramley's Seedling apples grown in the UK.

N	P	K	Ca	Mg
mg per 100 g fresh weight				
60 max	9 min	105-115	5[b], 4.5[a]	5

[a] - minimum for storage in ventilated CA conditions of 8-10% CO_2. Calcium requirement is likely to be lower for fruit stored in scrubbed low oxygen conditions of 6% CO_2 + 2%O_2, and particularly in 5% CO_2 + 1%O_2, although no definitive level has been set. In the interim a minimum level of 4 mg of calcium per 100 g is suggested.

[b] - minimum for storage in air until November.

Section 4. Predicting and choosing optimal harvesting dates for fresh consumption, short and long term storage of commercial apple cultivars and their clones

Correct harvest date is crucial in ensuring that the quality of apples reaching the consumers is optimal and that consignments meet the quality criteria that are set by multiple retailers and the wholesale market. For each cultivar the time of fruit maturation on the tree varies from orchard to orchard and from season to season. Consequently decisions on harvesting cannot be made based on an arbitrary calendar date.

Growers need to equip themselves with a penetrometer to test the firmness of the fruit and a quantity of a solution containing 1% iodine and 4% potassium iodide in order to perform starch tests (see below for advice on preparation). Testing for firmness and presence of starch in the weeks prior to the expected harvest date is essential in allowing the grower to draw up a harvesting schedule and make full use of harvesting 'window'. This will help to ensure that the fruit from each orchard is at the correct stage of maturity to enable the grower to implement his or her marketing plans.

Growers will need to be aware of information received from the Quality Fruit Group maturity programme and of long-range predictions issued earlier in the growing season. But, the final decision on when to harvest must be based on maturity measurements made on fruit from each orchard prior to picking. It is important that all quality characteristics of the fruit in each orchard are considered in order to achieve maximum profitability. The fruit must be sufficiently large and well coloured to satisfy market demands. However the consequences of delayed harvest to achieve higher grade-out of class 1 fruit must be realised fully and the fruit stored for an appropriate period under suitable storage conditions (see section 8).

Picking date criteria

Cox's Orange Pippin and clones for medium (December/January) to long-term (February/March) storage

- Picking dates of Cox for storage should be guided mainly by firmness of the fruit at the point of harvest. To achieve 6 kg firmness in fruit stored in CA (1.2% O_2 (<1% CO_2) at 3.5^{o}C until January or March the minimum firmness at harvest should be 8.2 and 8.7 respectively.

- Growers should not rely entirely on fruit firmness especially in years when the change in firmness is too gradual to provide a clear indication of when to pick. In this situation the change in starch pattern should also be used. Cox for long-term storage should be picked when the percentage of the cut surface stained blue/black is between 80-90% and no lower than 70%.

- When starch levels remain high then firmness can be used to decide when to harvest. However, where firmness remains high but starch declines to 90-80% then picking should commence and be completed by the time that starch declines to 70%.

Cox's Orange Pippin and clones for immediate sale or short-term (October/November) storage

- Cox apples with an average starch iodine staining pattern of less than 70% (black) have a higher potential eating quality but are only suitable for short to medium term CA storage (Table 3). They should remain in an acceptable condition for up to 3 months in CA (1.2% O_2 (<1% CO_2) storage at 3.5^{o}C.

- In many cases particular producer or marketing groups have developed there own maturity 'standards' in order to supply their retail customers with fruit of a higher sensory quality for a limited period.

Table 3. Harvest maturity parameters issued by the Quality Fruit Group for Cox apples intended for immediate sale and for CA storage for different periods. (N.B. Air storage of Cox apples should be terminated by mid-October (see section 8)).

Marketing periods	Minimum values at harvest	
	Firmness (kg) Penetrometer fitted with an 11 mm probe	Starch (% cut surface stained black)
Feb/March	8.6	75
Jan/Feb	8.2	70
December	8.0	60
Mid November	7.7	60
Mid October	7.5	50
Immediate	6.5	<50

Bramley's Seedling for long-term storage

- No harvest maturity standards are available.

- Earlier harvesting of Bramley is encouraged to avoid fruit becoming too large if left on the tree. However, there is an increased risk of scald and the development of bitter pit will be increased in low-calcium fruit. Late picking increases fruit softening and yellowing and the development of greasiness and flesh breakdown in stored fruit. Bruise susceptibility increases as picking is delayed.

- From general experience fruits picked after the middle of September are less likely to provide premium quality after prolonged CA storage.

Gala and clones for air and CA storage

- Fruit should be picked when the starch coverage is 50-90% (% black) and firmness is in excess of 7 kg

- Termination dates for storage in air and different CA conditions should be adhered to strictly

Meridian for CA storage

- Preliminary advice is to harvest fruit for storage when the firmness of the fruit is 7.1-7.6 kg

Details on the Starch-Iodine staining test

A solution comprising 1% iodine and 4% potassium iodide is required. Local chemist's shops should be able to prepare this. Alternatively growers can prepare their own solution by weighing out 1g of iodine and 4g of potassium iodide and adding to 1 litre of water. For smaller or larger quantities of solution adjust the proportions of the chemicals and water proportionately. The potassium iodide should be added to the water first followed by the iodine (iodine is insoluble in water) and the mixture should be agitated thoroughly before use. Precautions are necessary when handling these chemicals. Iodine is harmful by inhalation and in contact with skin and potassium iodide may cause sensitization by inhalation and skin contact and is irritating to eyes and skin and may cause harm to the unborn child. It is advisable to wear suitable protective clothing, gloves and eye/face protection. In the case of an accident or if you feel unwell, seek medical advice immediately and in the case of contact with eyes, rinse immediately with plenty of water and seek medical advice. The solution should be applied to a freshly cut surface. Although the pattern of staining may be apparent soon after application it is preferable to leave the stained sections for up to an hour in order to obtain a more reliable assessment.

Section 5. Optimising the harvesting and handling of fruits in the orchard

Only select and place in the bin Class 1 fruits, picked in such a way as to avoid damage. “Apples bruise more easily than eggs break”

Specification requirement.

In order to maximise the financial return it is important that pickers pick fruit that has the potential to meet the final pack specification. Even if 100% of the fruit selected by the picker meets this specification, the handling of the fruit from tree to final packed unit can reduce that percentage dramatically. Therefore it is vital that selection by the picker equals as near as possible the customer specification requirement**.**

To meet this objective it is important to:

(1) Identify the potential customer, be it multiple retailer, wholesaler or processor.
(2) Identify the criteria within each customer specification.
(3) Assess the potential grade-out of the crop within an orchard against planned customer specification.
(4) Evaluate the potential financial return, taking into consideration the handling, storage, packing and marketing costs.
(5) Decide which customer the fruit is targeted at.

Fruit that has no chance of achieving a positive financial return should be removed in advance of harvest. To achieve the optimum quality and volume performance from each picker, the picker should only have two decisions to make i.e. (A) Is it the correct size (B) Has it got the right colour.

Planning.

Identify factors that will enable efficient harvesting and handling to take place.

(1) Estimate the yield within the orchard.
(2) Calculate the number of bins required
(3) Ensure all bins have been checked and are fit for purpose.
(4) Ensure there is as near as possible a smooth surface, free of potholes and ruts for pickers bulk bins and tractors.
(5) Ensure all equipment such as tractors, pallet loaders, trailers/transporters have been serviced prior to harvest.
(6) Check picking buckets are in good order and free of dust, dirt and rough surfaces.
(7) Estimate the potential of each picker and ensure enough resources have been allocated for the job.

Training of Pickers and Supervisors.

Ensure pickers and supervisors have been trained. Where possible this should be done in advance of the first day of picking.

(1) Organise training courses for supervisors with a qualified instructor. The greatest influence on reduction of bruising will be gained by effective supervision.
(2) Organise where possible training courses for pickers in advance of the day of picking. Ideally gather the pickers together for a 2-hour training session. It is important that pickers understand where the apples they are picking will end up and a simple process flow example of the passage of fruit from the orchard to the supermarket shelf will help to indicate the importance of their actions.

Key factors in the training course are:

1. Health and safety.
2. Hygiene.
3. Proper use of the picking bucket.
4. What to pick.
5. Simple instruction on size evaluation.
6. Correct methods of picking - how to handle fruit without bruising it.
7. Correct approach to picking branches and trees.
8. Correct procedure for emptying the bucket into the bin without causing damage to the fruit.
9. Correct use of ladders or steps (where necessary).

Bin Placement.

During harvesting bins should be placed in a way that ensures that their subsequent movement is minimised and allows them to be picked up by the tractor/pallet loader without damage to the bin or fruit, while allowing the pickers easy access, without unnecessary walking with a full picking bucket. FAST surveys have linked the extent of bruising to the number of bin movements. The following points should be considered:

(1) Use the knowledge gained from crop estimates to ensure the correct number of bins is available.
(2) When placing the bins in the orchard ensure the position of each bin is optimised, in particular that the runners do not drop into any ruts making removal by pallet transporter difficult.
(3) Where growers have large enough orchards with intensive single row systems, it can be more cost and quality efficient to use bins mounted on low specially designed trailers, drawn between the rows by mini tractors and with small groups of pickers picking directly into the bins.
(4) Very large orchards with bed systems can be more efficiently picked using a self-propelled picking truck with transfer belts positioned within close reach of each picker.

Equipment.

Choose suitable equipment that matches the scale of the operation.

(1) Picking buckets should be selected and adjusted to meet the capability of pickers.
(2) Tractors should be able to access the rows without causing damage to the trees or fruit.
(3) Pallet forks should be of the type that allows easy access and removal from beneath the bulk bin.

Supervision of pickers.

Supervision of pickers is critical if damage to fruit during picking is to be minimised.

(1) Pickers should be organised into groups of 10 to ensure pickers are properly supervised. It is important that pickers should not be left without supervision for long periods.
(2) Supervisors should be capable of controlling the pickers with authority, but should be accessible and able to give advice while maintaining respect from the pickers.
(3) Supervisors should brief their group at the start of each day, or as soon as practicable to remind them of any key points found during the previous day's picking.
(4) To control pickers efficiently supervisors should have access to quality control (QC) assessments carried out at the packhouse / storage centre on each pickers fruit.

Safety, health and hygiene.

Before starting work all pickers should as part of their induction, be made fully aware of safety, health and hygiene requirements necessary to meet HSE and Food Safety Regulations.

(1) Any features of the site operation that could affect the picker or any other person present should be made known to the picker as part of the induction.
(2) The location of toilets and hand washing facilities must be clearly indicated to the picker.
(3) The location and name of the first aid person must be clearly available to the picker.
(4) A hygiene notice embodying all the key legal health, hygiene and safety requirements must be handed to each picker, this should be read, understood (translation provided where required) signed by the picker and returned to the management and filed against a register of pickers names.
(5) Signs indicating the site safety, health and hygiene requirements should be clearly displayed where pickers will be aware of the requirements.

Quality control in the Orchard.

A systematic approach to quality control (QC) in the orchard should be exercised, monitoring the performance of each picker against the required standard.

(1) Periodic assessment of fruit picked by each picker should take place during the working day. Samples should be taken directly from the bins for this purpose.
(2) An independent QC check on each picker's fruit should be made the following morning when any bruising not evident on the day of picking will be identifiable. Some bruises may not appear until 12 hours after picking. If fruit (as is likely) leaves the site for a central storage site, supervisors should remove a minimum of 50 apples from each picker's bins and carry out an assessment the following morning.
(3) Information from the next day QC check should be recorded and passed back to the orchard supervisor, where an independent QC carries this out.

Bin labelling for traceability.

Traceability is critical, and it starts in the orchard. Clear identification of critical information must be secured to the bin before it leaves the orchard.

(1) Critical identification information, which must be traceable from when the bin leaves the orchard, is **grower, orchard, cultivar, pick date, and picker**.
(2) There are various systems used by growers to identify bins:
    - A label containing the above information. This is ideally a 3 part system, allowing one part to be affixed to the bin, one part to be handed to the picker (which acts as a receipt to guarantee payment) and the third part to be handed to the office for accounting and payment purposes.
    - An identity label with a unique lot reference number that is supported by a reference document containing the essential information.
    - The FAST 'Applause' system that generates a label and bar code for the bin and holds all critical information in a hand-held PC.
    - A bar code system holding the critical information, e.g. the 'Pickwise' system that allows the details to be read at any time during the storage and packing process.

The future will almost certainly involve tag systems that will not only hold the critical information, but will allow easy access to this information when lorries, or fork trucks transfer bins within the transport and storage process.

6. Transport of fruit from the orchard to the pack-house / storage complex

Once harvested place fruit in the shade as soon as possible before transporting to the storage complex in a manner that avoids deterioration or damage to the fruit and is cost effective.

Planning

Identify the key factors that will influence the efficient movement of bins from orchard to the storage complex.

- Assess the potential number of bins that will be picked in each working day.
- Identify the distance from orchard to storage complex.
- It is important that fruit is moved from the orchard without delay to avoid detrimental effect on storage/shelf life.
- Identify equipment that is available to make this process more efficient.

Distances and location

Identify the distances from each orchard to the storage complex.

- Categorise the orchards into distance groups.
- Up to ¼ mile (400 metres)
- Between ¼ mile and ½ mile (400-800 metres)
- Greater than ½ mile (800 metres)

Roads and access

Assess the suitability of roads and access to orchards.

- Can hard roadways, either concrete or tarmac be utilised?
- What is the surface of internal pathways around orchards on which fruit will be transported?
- Is there suitable access for bin transporters or lorries?
- Is there hard standing for a collection point for loading lorries?
- Lorries need an area of at least 48 feet x 60 feet (16m x 20m)

Equipment

Identify the right equipment for your situation. It will differ from farm to farm.

- If all the orchards (or over 80%) on the farm are within ¼ mile of the pack-house / storage complex, the suggested system is a tractor-mounted rear end forklift capable of carrying two bins of fruit (approx. 1500 lbs or 680 kg).
- Where at least half the orchards are between ¼ and ½ mile (400-800 metres) from the pack-house / storage complex, a front end carrier and a rear end forklift fitted to the tractor may be used. This would enable three bins of fruit to be carried (2 at the rear and 1 in the front with a load of approx. 2250 lbs or 975 kg). However, this system can create excessive wear on axles and tyres, so very few growers use

it. An alternative is to use a system that involves a tractor-mounted forklift and a trailer capable of carrying up to eight bins.
- Where the system described above is used, the fruit will be carried to the headland by a tractor with pallet / bin carrier and placed in lines. A tractor with forklift attachment then stacks the bins into two's or three's ready for loading onto trailers or lorries.
- If all the orchards are greater than ½ mile (800 metres) from the pack-house / storage complex transport systems become more complex. In such situations, it is more convenient to transport the fruit on purpose built bin / pallet transporters or lorries.

Increase in fruit temperature once picked

It is important to avoid the build up of temperature in the bins once fruit has been picked.

- Ensure fruit does not stay in the orchard for longer than absolutely necessary.
- Covering bins with insulated and / or reflective white bin covers will give measurable benefits on early varieties, particularly Discovery.

Shaded area for holding fruit once picked.

Placing bins in a shaded area will alleviate temperature build up.

- Placing bins in the shade will help to reduce temperature build-up in the bins.
- Temperatures can rise by several degrees in the centre of the bin.
- The adverse effects of the temperature increase on storage life can be significant.

Fruit transferred to store within two hours of picking

The affect on storage life is dramatic if field heat is not removed quickly.

- Temperature build up will effect storage duration.
- Effects of temperature on quality changes in apples are described in section 15 of the Guide.

Loading tractor / lorry

Safety measures must be observed during loading to avoid risks to operators.

- When transporting fruit by tractor-mounted carriers, forklifts, trailers or transporters safe working rules and practices must be observed.
- Ignoring these rules could lead to injury or death to the operator or other people working nearby.
- Always make sure that tractors and other equipment is in safe working order before use (forks, chains, hydraulic hoses and couplings etc.).
- Operators should fully understand what each control is for.
- Controls should be clearly marked to avoid misunderstanding or misuse.

- All safety equipment required for legal compliance should be in place and fit for purpose e.g. guards etc.
- Maximum carrying capacity should not be exceeded.
- Always drive carefully, bearing in mind the load being carried, ground conditions and the state of any roads.
- Do not stop or start suddenly or corner at speed.
- When carrying bins or pallets of boxes ensure vision is not impaired.
- When reversing with loaded trailers or transporters, ensure there are no obstacles or people in the way before moving off.
- Take extra care in orchards where fruit is being picked.
- Slow down when leaving orchards or when joining roadways, your vision may be restricted.
- Look out for overhead obstructions.
- When the tractor is travelling unloaded, ensure forks are in the safe "transport" position or kept at 8 inches (20cms) above the ground.
- Carry bins/pallets as near to the ground as possible on tractor carriers. Forks should be tilted slightly so that bins or boxes are carried against the lift frame. Do not move a load that is higher than the backrest of the forklift.
- Do not carry extra people on tractors or trailers.

Shared transport to storage facility

Considerable benefits, in quality and cost efficiency can be gained from cooperation with others in transportation to a central storage facility.

- Sharing transport with a neighbour may enable fruit to be moved quickly, reducing unnecessary delays in the transfer from orchard to store.
- Savings in cost as well as quality benefits can be gained.

Correct lorries with air cushion suspension

To avoid unnecessary bruising in transit lorries with air cushion suspension should be used wherever possible.

- When fruit is transferred by any system, it is at risk from bruise/damage.
- Transferring fruit on a lorry can contribute towards unnecessary bruising if best practice is not observed.
- Whenever possible use lorries with air cushion suspension, particularly for longer distances. Generally today most haulage firms will operate lorries with air cushion suspension. But some smaller operators may still have lorries with conventional spring suspension. This may be perfectly satisfactory for short distances, if driven carefully, but should not be used for longer journeys.

Production areas and dedicated storage facilities

The location of storage facilities in relation to the production area can have a significant influence on long-term potential.

- The optimum location for a store would be close enough to the orchards to allow all fruit to be inside within 2 hours of being harvested.
- In most cases this may not be practical, and in order to utilise high specification storage longer distances may be required to access optimum storage.
- In order to ensure fruit has sufficient shelf life when the store is opened, it will be necessary to balance the factors involved.
- If high specification storage is available, with rapid temperature pull down capabilities, and the facility to achieve CA conditions with flushing, but 4 hours distant, it will still be better than storage close at hand with poor pull down and slow establishment of CA conditions.

Transport to central storage facility

A co-ordinated approach to transport arrangements to central storage facilities is vital if the benefits in fruit quality from the correct growing and harvesting of fruits are to be maintained.

- Where fruit is destined for a central storage complex, co-ordination of transport is vital.
- Transport arrangements should be part of central site planning, ensuring pickups are planned and at regular intervals to avoid unnecessary bottle-necks occurring.
- The optimum should be to remove fruit from the orchard and deliver to the storage complex within 2 hours i.e. three pick-ups a day.

Section 7. Post-harvest chemical treatment and cooling of apples

Only treat fruit post harvest with a chemical where a significant risk of fruit losses has been identified. Place in a store where the fabric, including the floor has been cooled down to below the final holding temperature. The following advice should be adhered in order to restrict the use of chemicals where possible and to ensure the most efficacious treatment of consignments of fruit where this is deemed to be necessary.

- Avoid the unnecessary application of post harvest chemical treatments by estimating the risk of diseases or disorders developing in the fruit during storage. This is particularly important where application of fungicides is being contemplated.

- Assess risk of storage rots (see Guide 3) and decide on the most appropriate treatment. When drenching or dipping Cox apples in carbendazim use half the label rate.

- To prevent scald development in Bramley apples apply full strength (2000 ppm) diphenylamine (DPA) where fruit is to be stored in ventilated CA conditions (8-10% CO_2) beyond November. Fruit stored in scrubbed, low-oxygen stores at 5% CO_2 + 1%O_2 (5/1) need not be treated where fruit is to be marketed by the end of March. Fruit stored in 5/1 for longer periods should be treated with half strength DPA solution. For untreated fruit stored in 5/1 it is important to establish CA conditions slowly to avoid CO_2 injury (see section 8).

- Assess the requirement for post harvest calcium application by taking samples of fruit for mineral analysis 2 weeks prior to harvest (see section 3). Where calcium levels are lower than those recommended calcium treatment is advisable. Do not exceed the suggested dose for any calcium product as damage to the skin may result. Only treat cultivars that are listed on the product labels.

- Growers should be aware of the legal requirements regarding operatives involved in the drenching or dipping of fruit with chemicals.

- All contractors or staff who were born after 31.12.1964 who apply pesticides must have attended and passed a National Proficiency Test Council (NPTC) recognised course in The Safe Use and Handling of Pesticides PA1, together with courses for the relevant piece of machinery, PA10 for drenchers.

- Those who are operating under the so-called ‘grandfather rights’ will need to produce a certificate of attendance at a recognised i.e. NPTC training course both in the Safe Use of Pesticides and The Post-Harvest application of pesticides.

The following procedures should be adopted for calibration:

- Measure volume of tank.
- For square tanks calculate volume = height x length x width
- For round tanks calculate volume = radius x radius x height x 3.142

- For measurements in metres multiply volume (cubic metres) by 1000 to provide volume in litres
- For measurements in feet multiply volume (cubic feet) by 6.24 to provide volume in gallons
- Measuring jugs and scales should be specific for the job and not used for any other purpose

The following procedures should be adopted for operation:

- Mark the tank to show the operating level (full).
- Add clean water until the tank is approximately three-quarters full
- Use a clear area to weigh or dispense chemicals
- List chemicals and quantities used in each tank mix
- Dilute the concentrate in the ratio of 1 part chemical to 9 parts water. Always cream wettable powders in water before adding to the tank
- Add to the tank and fill to the mark. Mix for at least 10 minutes
- Label tank clearly with contents
- Treat fruit for 60 seconds maximum
- Fruit should not be treated above 21^0C or below 10^0C (optimum 16^0C)
- Top up using solution diluted to the correct concentration
- Change solution every 2 or 3 days or when excessively dirty
- Record clearly details of any post harvest treatments. This should clearly identify each consignment of fruit, the date it was treated, the product and rate used and the justification for treatment and the first permissible sale date.

- Dispose of the used (dilute) solution on an area of land authorised for the purpose by the Environment Agency, via a licensed waste disposal company or by the use of equipment designed specifically to treat waste pesticides.

- After chemical treatment allow the fruit to drain before stacking into a store that has been cooled thoroughly prior to loading. Stores with insulated floors should be pre-cooled for 5 days and those with un-insulated floors for 10 days. Ensure that the refrigeration plant is switched off during loading. Use other available stores for pre-cooling fruit prior to loading. Ensure that fruit reaches the final holding temperature within 5 days of the start of loading.

Section 8. Optimal storage conditions

Ensure that the most appropriate conditions are used for the period of storage that is anticipated. Termination dates that are recommended should be a guide only since the quality of consignments in store is likely to vary from orchard to orchard and from season to season. Optimal quality can only be achieved by ensuring that consignments have adequate storage potential with respect to mineral composition and maturity at harvest (see sections 3 and 4). Careful monitoring of fruit condition throughout the storage period is required to ensure that quality retention is in line with expectations (see section 11). Those responsible for the storage of fruit should be fully aware of the notes that are included in the recommendations issued by HRI since these may be vital in achieving a successful outcome.

It is difficult to set precise termination dates for the storage of any cultivar, as there are so many variables involved. Provided the fruit has adequate storage potential, the termination dates that are advised should result in quality product. It is essential that:

- Stores are loaded in 2-3 days and the operating temperatures are achieved within 5 days of the start of loading
- The delay between picking and the start of cooling does not exceed 24 hours
- Final CA conditions are achieved within 14 days of the start of loading unless indicated otherwise
- Independent checks of store CO_2 and O_2 levels should be made regularly using portable analysers and drawing atmosphere sample direct from the store

Table 4. Cox's Orange Pippin and clones

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
3.5-4.0	38-39	5	Early Dec	5	3	Late Jan	1, 2
				<1	2	Late Feb	3
				<1	1.2	Late March	4, 5, 6, 7
				<1	1	Early April	5, 6, 7, 8, 9, 10

Air storage of Cox at 3-3.5^oC (37-38^oF) should be terminated by the middle of October

Notes:

1. Ensure that the recommended CO_2 level is not exceeded by more than 0.5%
2. There is a risk of core flush in 5% CO_2 regimes, particularly after cool growing seasons
3. Ensure that O_2 level does not fall below 1.7% when controlling manually at 2% O_2, aim to keep a mean of 2%
4. For operation at 1.2% O_2 use automatic equipment to control O_2 within the range 1.1-1.3%
5. Operate store at 2% O_2 for at least one week before lowering to 1.2% O_2 or below

6. Restrict storage in 1-1.2% O_2 to Cox of good storage potential (see section 3). In particular store only those fruit with calcium levels above 5 mg $100g^{-1}$ and potassium levels below 150 mg $100g^{-1}$. Avoid late picking (see section 4).
7. After cool summers maintain minimum fruit temperature of 4°C (39°F) to reduce risk of low temperature breakdown
8. For operation at 1% O_2 use automatic equipment to control O_2 within the range 0.9-1.1%
9. Use 1% O_2 for Cox stored beyond March in years when texture is suspect
10. Make regular weekly checks for traces of alcohol for first 4 weeks and thereafter at monthly intervals

Table 5. Bramley's Seedling

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
°C	°F						
4.0-4.5	39-40	8-10	June	6 5	2 1	June July	1, 2, 3, 4, 5 2, 4, 6, 7

Air storage of Bramley at 3-3.5°C (37-38°F) should be terminated by November

Notes:

1. Use post-harvest chemical treatment to control superficial scald. Where fruit is to be stored short-term without DPA treatment then establishment of CA conditions should be delayed (see 7 below) in order to avoid possible CO_2 injury
2. Slight risk of low temperature breakdown in fruit stored beyond May, especially if late-picked or fruit phosphorus is below 9 mg $100g^{-1}$ (see section 3)
3. Use scrubbed storage for Bramley to improve control of bitter pit
4. Ensure that the recommended CO_2 level is not exceeded by more than 0.5%
5. Ensure that O_2 level does not fall below 1.7% when controlling manually at 2% O_2, aim to keep a mean of 2%
6. Use diphenylamine (DPA) post-harvest to prevent possible injurious effects of this CA regime. Alternatively, for fruit not treated with DPA, delay the sealing of the store by 10 days from the completion of loading. Where nitrogen flushing is used to achieve low oxygen conditions extend the delay to 15 days. Where fruit is to be stored beyond March use half the recommended rate (1000 ppm) of DPA to control superficial scald
7. For operation at 1% O_2 use automatic equipment to control O_2 within the range 0.9-1.1%

Table 6. Gala and clones

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
1.5-2.0	35-36	8	Early Nov	<1	2	Early Jan	[1]
				<1	1	Mid Feb	[2]
				5	1	Early April	[2, 3]

Air storage of Gala at 0-0.5^{o}C (32-33^{o}F) should be terminated by the middle of December

Notes:

1. Ensure that O_2 level does not fall below 1.7% when controlling manually at 2% O_2, aim to keep a mean of 2%
2. For operation at 1% O_2 use automatic equipment to control O_2 within the range 0.9-1.1%
3. Ensure that the recommended CO_2 level is not exceeded by more than 0.5%

Table 12. Jonagold and clones

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
1.5-2.0	35-36	8	April	4	1.2	July	[1, 2]

Air storage of Jonagold at 0-0.5^{o}C (32-33^{o}F) should be terminated by January

Notes:

1. Ensure that the recommended CO_2 level is not exceeded by more than 0.5%
2. For operation at 1.2% O_2 use automatic equipment to control O_2 within the range 1.1-1.3%

Table 7. Red Pippin

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
3.5-4.0	38-39	-	-	3 <1	2 1.2	March April	1, 2, 3 3, 4, 5

Air storage of Red Pippin at 1-1.5^oC (34-35^oF) should be terminated by January. - No recommendations for storage in elevated CO_2 (un-scrubbed) only.

Notes:

1. Ensure that the recommended CO_2 level is not exceeded by more than 0.5%
2. Ensure that O_2 level does not fall below 1.7% when controlling manually at 2% O_2, aim to keep a mean of 2%
3. To achieve the green background ex-store required for Red Pippin avoid late picking
4. For operation at 1.2% O_2 use automatic equipment to control O_2 within the range 1.1-1.3%
5. There is a risk of scald during marketing

Table 8. Egremont Russet

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
3-3.5	37-38	6-8	January	5 5	3 1.2	Early March April*	1, 2 1, 2, 3

Air storage of Egremont Russet at 3-3.5^oC (37-38^oF) should be terminated by December. *The authors are grateful to World Wide Fruits for generously agreeing to the release of results of trials with the 5% CO_2 + 1.2% O_2 regime conducted by Home Grown Fruits.

Notes:

1. Risk of shrivel; reduce by loosely covering the top layer of fruit in each bin with polythene liners
2. Fruit may soften rapidly after storage and prompt marketing is advised. Use cool temperatures during holding and distribution of graded fruit (see section 15)
3. Where fruit in store is sufficiently firm raise the O_2 level to 2-3% a month before opening the store in order to improve flavour (see section 10)

Table 9. Meridian (interim recommendations)

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
3.5-4	38-39	-	-	<1	1.2	March	[1, 2]

Air storage of Meridian at 3^{o}C (37^{o}F) should be terminated by October. - No recommendations for storage in elevated CO_2 (un-scrubbed) only.

Notes:

1. For operation at 1.2% O_2 use automatic equipment to control O_2 within the range 1.1-1.3%
2. Avoid late harvesting. Pick when fruit firmness is between 7-7.5 kg and monitor the condition of fruit in store at regular intervals (see section 11)

Table 10. Braeburn and clones (Belgian recommendations)

N.B. There have been no storage trials done on Braeburn in the UK. Commercial experience indicates that CO_2 concentrations above ambient can cause injury to the fruit.

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^oC	^oF						
1	34	-	-	1	2-3	March	[1, 2]

A temperature of 1^{o}C (34^{o}F) is suggested for air storage. Termination dates for air storage have not been set. - No recommendations for storage in elevated CO_2 (un-scrubbed) only.

Notes:

1. Risk of scald and bitter pit
2. It is advised (Washington State, USA) to delay the sealing of CA stores for 3 weeks from the completion of loading to avoid Braeburn browning disorder (BBD). A CO_2 concentration of <1% may also be beneficial in reducing risk of BBD.

Table 11. Cameo (Experience in Washington State, USA)

NB There have been no storage trials on Cameo conducted in the UK

Controlled atmosphere (CA)							
No scrubber				Using a scrubber			
Temperature		% CO_2	Terminate	% CO_2	% O_2	Terminate	Notes
^{o}C	^{o}F						
0.5-1	33-34	-	-	1-3	1	June	[1]

A temperature of 0.5-1^{o}C (33-34^{o}F) is suggested for air storage. Termination dates for air storage have not been set. - No recommendations for storage in elevated CO_2 (un-scrubbed) only.

Notes:

1. For operation at 1% O_2 use automatic equipment to control O_2 within the range 0.9-1.1%

Section 9. Strategies for reducing ethylene in stored fruits

Ethylene gas is produced by apples during the process of ripening either on the tree or during storage. Ethylene, the 'ripening' hormone, triggers and coordinates many of the ripening changes that occur in stored apples such as softening and aroma development. Storage under refrigeration and in controlled atmospheres reduces the rate at which these ripening changes take place. More effective control of ripening and a consequent improvement in fruit quality may be expected by further suppression of ethylene production by the fruit.

Bramley's Seedling

- The removal of ethylene from the storage atmosphere using heated catalyst scrubbers is a proven alternative to the use of diphenylamine (DPA) for delaying scald development
- Growers can achieve control of scald for 6 months by attaching an ethylene scrubber to storage chambers where the carbon dioxide level is maintained at 8-10% by ventilation with outside air
- Longer storage without scald development is possible where ethylene scrubbing is combined with low oxygen storage (5% CO_2, 1%O_2)
- In commercial trials no scald was evident in fruit stored in 5% CO_2 + 1%O_2 with continuous removal of ethylene when the trials were concluded after 10 months
- DPA treatment is substantially more cost effective in controlling scald than ethylene removal
- If the use of DPA comes under threat in the future then ethylene removal is a viable alternative strategy for scald control

Despite the effectiveness of ethylene scrubbing in controlling scald this method is not currently justified due to the higher capital and running costs.

Cox's Orange Pippin

- Although there are major quality benefits that can be achieved in Cox apples by removing the ethylene for CA stores the effects are inconsistent from year to year and between consignments.
- Ethylene production in Cox apples is higher than in Bramleys due to the fact that they are harvested closer to the point of ripening (initiation of rapid ethylene production) on the tree.
- For Cox stores the size of scrubber that is required and consequently the investment and running costs are increased by a factor of about 4 when compared to Bramley stores.
- Additional 'conditioning' techniques are required to reduce ethylene production in order to make ethylene removal effective which adds to the complexity of managing the crop during the early period of storage.
- Some 'conditioning' treatments such as pre-treatment with high levels of carbon dioxide may have deleterious effects on the fruit late in the storage period.

Future developments may improve the efficacy or cost-effectiveness of ethylene removal for Cox but at the present time this is not viable commercially.

Section 10. Strategies of maintaining flavour in stored fruits

Controlled atmosphere (CA) storage delays ripening and senescence changes in apples and preserves many important quality attributes such as firmness, acidity and soluble solids (sugar) concentration. However one negative consequence of the use of CA storage for prolonged periods is the reduced production of compounds that contribute to aroma and flavour.

In order to increase the flavour of Cox apples:

- Harvesting should not be earlier than is necessary to achieve the period of storage that is required (see section 4). Delay in harvesting maximises flavour potential, but harvesting too late reduces storage life and has adverse effects on fruit texture

- Reserve the use of ultra-low oxygen or ULO (1-1.2% O_2) for medium or long-term storage (see section 8) provided that the firmness of fruit stored short-term is adequate for the requirements of the market

- Raise the oxygen concentration in ULO stores to 2% O_2 4-5 weeks prior to opening the store provided that firmness is adequate for the requirements of the market

- Practices to maximise flavour in stored Cox apples should only be implemented when there is unlikely to be any detrimental effects on other quality parameters. Full knowledge of the condition of the fruit in store is essential in the decision making process which can be achieved by regular store monitoring (see section 11)

- The advice provided above is likely to be appropriate to all dessert cultivars stored in ULO conditions

Section 11. Monitoring the condition of fruit in store.

At least once a month assess the eating quality and internal condition of samples of fruit that represent the major orchards within a store. Once a store is opened continue monitoring samples of fruit from all the major orchards regularly and check fruit quality remains above the customer's specification.

Sampling

All apples destined for marketing after the middle of October should be stored under CA conditions (see section 8). It is essential to examine fruit at regular intervals to check quality and internal condition. Representative samples need to be taken at harvest and placed in a bin under the store hatch. As fruit from each orchard is loaded into the store one sample should be taken for every proposed month of storage after October. It is important to ensure that samples are representative of the whole orchard and that there are sufficient samples to provide monthly monitoring of every orchard. Twenty apples are required per orchard per month. To obtain the samples for monitoring one apple should be taken from every tenth bin from that orchard as it is being loaded into the store. If less than 200 bins from an orchard are going into the store then fruit should be taken more frequently e.g. sample every bin from a 20-bin consignment. The 20 fruits should be placed in a string net and labelled with orchard name, picking date and store number. This procedure should be repeated for each proposed month of storage after October, by taking apples from the same bins. The samples should be placed in a bin under the hatch and covered with a layer of fruit. If a second orchard is to be loaded into the store, or that orchard is to be included in a second store, then another set of samples should be taken.

Fruit Assessment

Each month from October a sample of each store/orchard combination is taken out and assessed. **It should be remembered that the atmosphere is lethal, and under no circumstances should anybody enter the store. The safety of the operator must be stressed. At no time should the operator place any part of his or her body in the store. People should always work in pairs, and use a 'boat hook' or similar extended hook to remove the netted samples.**

Each apple in the sample should be carefully examined externally for any signs of blemish or storage disorder developing (see section 12). Such disorders include lenticel blotch pit, carbon dioxide injury, superficial scald or damage due to calcium sprays or the use of a post harvest drenching solution. Colour is very difficult to quantify without the aid of sophisticated instruments. The skin of an apple is variable with patches of different shades of green and bleached areas where leaves have shaded fruit. With dessert apples the stripes of red colour within the background colour makes it very difficult to assess. A subjective method has been adopted in which the 20 fruits are laid out and the overall background colour described as dark green, green, light green, light yellow or yellow. The percentage of the surface area of the fruit coloured red is estimated for each fruit and expressed as a range. To ensure consistency the light condition used should be good and the same for each assessment.

Ten fruits from the sample are taken for firmness measurements, the five largest and five smallest apples having been excluded. Average values taken from month to

month can be used to provide general guidance on the softening rate of stored apples and pears. The most widely used instrument for measuring firmness is the hand-held Effigi penetrometer. For more consistent results this should be mounted in a drill stand and supported on a firm base. An 11mm diameter probe should be used for apples and an 8 mm probe for pears. The instrument should be calibrated against an accurate balance at least once a year. Fruit juice is very corrosive and thus the instrument should be washed, dried and coated in a thin mineral oil after use.
The following procedure should be adopted when carrying out the test:

1. Remove a thin slice of peel from opposite sides of each of 10 apples
2. Lower plunger into the flesh at a steady rate
3. Take 2 seconds to travel 8 mm into the fruit
4. Record value and reset
5. Repeat on the opposite side of the fruit

Where this procedure has been adopted little difference has been found in the readings obtained by different operators. However, to guard against any possible 'operator error' the same person should carry out the test whenever possible. It is recommended that individuals using penetrometers should compare their results occasionally to safeguard against any operating errors.
The ten apples used for measurement of firmness are then examined internally for the presence of disorders (see section 12). A transverse cut is made close to the calyx end of the apple and the presence or absence of bitter pit or browning recorded. A second cut is made across the equator of the fruit through the core area and the cut surface assessed for core flush, low temperature breakdown and senescent breakdown. The extent of the disorder is quantified by assessing the area of the cut surface affected. Slight is up to one third, moderate is between one and two thirds and severe above two thirds. During the examination fruits are tasted for eating quality and the presence of any taints or 'off-flavours' are noted. The remaining ten apples are placed in a room at 18^0C and the external and internal condition assessed after seven days.
The mean fruit firmness together with the percentage of fruit with various disorders should be calculated and recorded on a purpose designed form. By using one form for each store/orchard combination the change in fruit quality or the development of storage disorders with time can be followed clearly.

Monitoring of Storage Conditions

Successful storage is a combination of the right fruit stored under the right conditions. If the temperature or oxygen is too high fruit will mature quicker and, if too low there is a risk of damaging the flesh or fruit developing alcoholic taints. If the carbon dioxide is too high there is a risk of damaging the fruit if too low the rate of decline in background colour from green to yellow will increase. It is therefore very important not only to check the fruit condition regularly but also the storage conditions. Computer based systems provide automatic control of storage conditions and are essential where low oxygen levels are being used (see section 8). However the printed output generated from such systems is often difficult to interpret. It is important that store operators maintain a manual record of store conditions. At least once a day the temperature, CO_2 and O_2 levels should be entered in a logbook using a separate page for each store. This provides evidence that the storage conditions for each store has been checked each day and makes it easy to see overall changes in storage conditions

during each month. During the monthly inspection of fruit samples the store logbook should be examined.

Fruit Quality Standards

All fruit in store should remain above the minimum quality standards required by the customer and have sufficient quality to allow for a seven day shelf life. WWF-Qualytech minimum standards are given in Table 12.

Table 12. WWF-Qualytech minimum fruit quality standards. Firmness is defined in terms of an average for 10 apples and the minimum recorded for any of the individual apples within a 10-fruit sample.

Cultivar	Pool	Background Colour Card 1, green - 4, yellow	Firmness (kg) Penetrometer	Soluble Solids (%) Refractometer
Cox	A	Green – Light Green (1-2)	Mean 6.5 Min. 5.8	>12
Cox	B	Green – Light Yellow (1-3)	Mean 5.8 Min 4.8	>10
Jonagold	A	Green – Light Green (1-2)	Mean 6.5 Min. 6.0	>12
Jonagold	B	Green – Light Green (1-2)	Mean 5.5 Min. 4.8	>10
Bramley	A	Green – Light Green (1-2)	Mean 6.5 Min. 5.5	>12
Bramley	B	Light Green – Light Yellow (2-3)	Mean 5.5 Min. 4.8	>10

During the establishment of storage conditions Cox fruits may loose 0.5 to 1.0 kg in firmness. The rate of softening in store depends on the oxygen levels, the lower the level below 3% the slower the rate. Generally the following rates of softening have been found for Cox:

5%CO_2 + 3%O_2:	0.3 – 0.4 kg a month.
<1%CO_2 + 2%O_2:	0.2 – 0.3 kg a month.
<1%CO_2 + 1.2%O_2:	0.1 – 0.2 kg a month.

Post-Storage Management

All CA stores should be opened before the fruit quality falls below the recommended standards and has sufficient reserve quality to ensure all product reaches the consumer in prime condition. Provided there is not a seasonal high risk of low temperature breakdown, the temperature of fruit in Cox stores should be lowered to 1^0C once opened. The rate fruit softens is significantly reduced as the temperature is lowered (see section 15).

Historically fruit store monitoring has been confined to netted samples placed under the hatch. However, once the store is opened the full extent of any bin to bin variation can be determined by sampling directly from a number of bins from each orchard. The samples should be assessed as previously described and the results compared to the last netted samples. Samples should be taken from the bins at regular intervals until all the fruits from that store have been graded and delivered to the customer.

Section 12. The identification of storage disorders, causes and varietal susceptibility (including illustrations)

Apples supplied to the market need to be free from internal or external disorders and should have limited potential to develop disorders during the period from retailing to consumption. Growers need to recognise early symptoms of disorders during the monitoring of their stores (see section 11) and to determine the likely progression by examining after a simulated marketing period. Proper diagnosis of disorders is important in order to take remedial action in the future thereby preventing a recurrence of the problem.

Classification of disorders.

Symptom expression varies according to variety and storage conditions but in most cases it is possible to make an accurate diagnosis on the basis of the photographs provided. The disorders have been grouped arbitrarily into those that are visible externally and those that are visible on cutting the fruit. It is accepted that some disorders could be placed in either category e.g. water core develops internally but in some cases, particularly in Bramley apples, the disorder is visible externally. Within each of the two main categories three further categories of disorders are recognised. Firstly those that occur as a normal consequence of storage. Secondly those induced by the storage conditions and usually due to incorrect concentrations of carbon dioxide or oxygen. Thirdly, disorders associated with the application of post-harvest chemical treatments (external disorders only) or by mineral deficiencies in the fruit at harvest (internal only). It is recognised that some disorders could be placed in more than one category e.g. bitter pit and related disorders occur naturally during storage but are induced by mineral deficiencies in the fruit at harvest. Despite this the classification below should be helpful to growers to recognise the disorders and determine the likely cause. The list is not fully comprehensive. Disorders that do not generally affect the more important commercial cultivars in the UK have been omitted.

A. Disorders of the skin.

<u>Occurring naturally during storage:</u>

Superficial scald

Patches of skin turn bronze or brown and become slightly sunken. In the early stages of development undegraded green skin is interspersed with affected skin. The incidence and severity of the disorder increases with duration of storage and may develop rapidly when fruit is brought to ambient temperatures. Of the apple cultivars currently grown in the UK Bramley's Seedling is the most scald susceptible. Post-harvest application of chemical antioxidants such as diphenylamine (DPA) provides effective control of superficial scald (see Section 7). Alternative methods of control include scrubbed low oxygen or low ethylene storage (see sections 8 and 9 respectively). Where scald is detected during store monitoring the affected consignments should be marketed immediately. Scald susceptibility is influenced markedly by climatic conditions during fruit development and is aggravated by early harvesting (see section 4).

Senescent scald

As the name implies there are certain cultivars of apple that develop a browning of the skin when the fruit is over-stored. Generally this type of scald should not be a problem where storage recommendations are adhered to (see section 8). Gala is susceptible to senescent scald late in the storage period. The problem is aggravated by late harvesting, poor control of storage conditions, over-storage and delayed marketing. DPA is unlikely to provide control of the problem. Susceptible cultivars (Fiesta (Red Pippin), Gala and Jonagold) required for long storage should be stored in CA conditions with a relatively high carbon dioxide content (see section 8).

Lenticel blotch pit

Lenticel blotch pit is a disorder that is related closely to bitter pit. Brown lesions form in each 'pit' beginning at a lenticel (fig.). Bramley's and Cox apples are particularly prone to the disorder. The disorder occurs in fruit with abnormally low levels of calcium. Consignments of Cox apples containing more than 3.8 mg $100g^{-1}$ fresh weight of calcium are unlikely to develop lenticel blotch pit. Fruit analysis should be used to determine risk (see section 3). Control measures are the same as those described for bitter pit (see section 2).

Skin necrosis in Gala apples

A skin disorder has been observed on Gala apples stored under commercial conditions in the UK. The problem occurs rarely and has only been observed on fruit that has been harvested very late and kept in air storage. The problem has not been apparent on CA-stored fruit or in air-stored fruit picked at the correct stage of maturity (see section 4) and held at the recommended storage temperature for the prescribed period (see section 8). Mineral composition of affected and non-affected apples was similar. Provided growers adhere to guidelines provided on harvest dates and storage recommendations this disorder should not be a problem in commercial consignments of Gala.

<u>Induced by CA conditions:</u>

External carbon dioxide injury

This form of damage never occurs in air-stored apples and is not common in apples stored under CA conditions in the UK (Wilkinson and Fidler, 1973). Generally carbon dioxide injury occurs where fruit is kept in atmospheres containing carbon dioxide at higher than recommended concentrations. In the early stages of development damage symptoms may be confused with those of superficial scald. However, lesions caused by excessive carbon dioxide are more sharply defined than those described for scald. Moreover, external carbon dioxide injury occurs within the first few weeks of storage and does not progress thereafter. In contrast, superficial scald usually develops after several months and becomes progressively worse with time in store. Bramley's Seedling apples are susceptible to external carbon dioxide injury under recommended CA conditions. Fortunately DPA applied for scald control also prevents carbon dioxide injury (Johnson, et al., 1998). Where DPA treatment is omitted it is important

that the establishment of CA conditions is delayed in order to prevent injury to the fruit (see section 8).

Low oxygen injury.

Injuries to the skin of apples due to low-oxygen storage are generally not recognised on apples grown in the UK. In other growing regions low-oxygen injury is expressed in the form of darkening of the red and green regions of the skin. Ribbon scald may also be induced in some varieties by low-oxygen atmospheres. McIntosh is considered the most sensitive to this type of injury (Lidster, et al., 1990). The risk of low-oxygen injury is minimised by picking at the correct stage of maturity, establishing storage conditions promptly and maintaining CA conditions within prescribed limits (see section 8).

Induced by chemicals:

Post-harvest DPA application

In the UK diphenylamine (DPA) applied as a dip or drench treatment is used to control superficial scald on Bramley's Seedling apples. In other apple growing regions of the world DPA is used widely on a number of dessert cultivars for scald prevention. Damaging concentrations of DPA occur where liquid is allowed to accumulate or where there are slow drying conditions in bulk containers. Symptoms may appear as small black spots or as a grey / black stain of the skin. In the most severe cases of injury extensive areas of the skin become blackened and sunken. The latter symptoms are likely to occur on fruit at the base of treated bins that remain in contact with the solution. DPA can cause injury to the core area in Bramley apples that have an open calyx tube. In wet harvests internal damage caused by DPA may provide a site for infection by fungal pathogens such as Mucor (Johnson et al., 1986b). In such years it is particularly important to maintain hygienic conditions by changing the solution in accordance with manufactures instructions. This practice also ensures the most efficacious treatment for scald control.

Post-harvest calcium application

The concentration of calcium in apple fruits can be increased by post-harvest application of calcium chloride and proprietary formulations containing calcium. Such treatment reduces susceptibility of apples to calcium-dependent disorders such as bitter pit and senescent breakdown. Higher application rates result in greater uptake of calcium but there is a corresponding increase in the risk of injury to the fruit. The injury is usually centred on lenticels although in severe cases entire areas of skin may be affected. The areas around the lenticels become brown or black and may become sunken. There may be localised greening of the skin related to the localised uptake of calcium. There is marked varietal variation in susceptibility to calcium injury. It is important therefore to treat only those cultivars advised by the manufacturers and to apply materials in strict accordance with label instructions. Pre-harvest sprays containing calcium may also cause lenticel injury to the fruit. Damage symptoms from calcium sprays are generally similar to those described for post-harvest treatments although early sprays can result in distortion of the fruit of sensitive cultivars.

B. Disorders of the flesh of the fruit

Occurring naturally during storage:

Senescent breakdown

This disorder is usually associated with over-maturity or over-storage and is accentuated by mineral imbalance in the fruit at harvest and particularly with inadequate calcium. Compliance with suggested mineral standards (see section 3), harvesting at the correct stage of maturity (see section 4), maintaining the correct storage conditions for the periods advised (see section 8) and prompt marketing of fruit after storage should avoid the problem. It is particularly difficult to distinguish different forms of breakdown on the basis of visual symptoms. The appearance varies between cultivars and storage conditions have a major influence on expression of symptoms. Typically in air-stored Cox and Bramley apples (and sometimes in CA-stored fruit) senescent breakdown appears on the outside as a dull darkening of the skin that progresses inwards. However, in CA-stored fruit there may be a gradual discoloration of the flesh that can be confused with low temperature breakdown. In Gala apples senescent breakdown generally effects the layers of tissue immediately below the skin and spreads around the fruit before progressing inwards.

Low temperature breakdown

As with senescent breakdown the symptoms of low temperature breakdown (LTB) vary according to storage conditions and it is often difficult to be certain about the type of breakdown where the apple flesh is affected by a general browning. In air-stored Cox and Bramley apples areas of the cortical tissue affected by LTB appear similar to senescent breakdown. However, in LTB affected apples there is normally a zone of healthy tissue immediately below the skin and the cut surface of affected tissue is usually moist when compared with senescent breakdown. LTB normally develops before fruits become overripe. Fruit kept in CA are more susceptible LTB than those kept in air storage. Recommended storage temperatures reflect this fact (see section 8). LTB symptoms in CA-stored fruit are different to those in air-stored fruit and take the form of a general browning of the cortical tissue and often there is a wedge-shaped pattern in the apple cortex. This is apparent particularly in Bramley but less so in Cox. LTB is a product of two factors namely temperature and time of exposure. Short periods of exposure to low temperatures will not cause LTB. The disorder can occur at recommended storage temperatures. Cool growing seasons and late picking increase the susceptibility of Cox and Bramley apples to LTB (Sharples, 1975). Prediction of LTB risk is possible based on climatic conditions during the growing season and mineral composition of the fruit at harvest (Johnson, et al., 1989; Johnson and Ridout, 1998). The disorder is progressive in store and may progress significantly in apples removed to ambient conditions. Immediate marketing is recommended when LTB is present in samples removed during store monitoring (see section 11).

Water core breakdown

As the name implies water core breakdown is a flesh breakdown that develops in fruit affected by water core at harvest. The disorder is not common in apple cultivars grown in the UK since water core is not usually problematic (see water core below).

Diffuse browning disorder

Referred to colloquially as 'boggy bank disorder' after the first reported occurrence in a Cox orchard of that name. In appearance the disorder resembles a physiological disorder that affected stored Cox in the 1972/73 storage season (Johnson, 1975). Prior to 2000 there were few cases of diffuse browning disorder causing significant problems in commercial fruit. However, the disorder caused severe problems in some consignments of Cox apples from the 2000 crop. The disorder first appears as a localised browning of the flesh predominantly towards the calyx end of the fruit. The disorder progresses around the fruit and may progress to the inner cortex. The cause of the disorder is unknown but does not seem to be attributable to poor mineral composition of the fruit and has been found in fruit harvested at the correct stage of maturity and stored under the most appropriate conditions. After the outbreak of a similar problem in 1972 there were no reported cases in the following year. It is therefore possible that unusual weather conditions in 1972 and 2000 may have been a causal factor in the development of these unusual disorders.

Induced by CA conditions:

Internal carbon dioxide injury ('brownheart')

As the name implies internal carbon dioxide injury is normally associated with abnormally high concentrations of carbon dioxide in the storage atmosphere. Adherence to storage recommendations that are provided for different cultivars of apple should avoid the problem. However, in the absence of DPA treatment, Bramley's Seedling apples stored in 5% CO_2 + 1% O_2 are susceptible to brownheart and it is necessary to delay establishment of CA conditions until 10 days after loading is complete (Johnson, 1998a). Similarly it is important to ensure that carbon dioxide concentrations are 1% or less when low oxygen conditions (1.2% O_2) are first established in Cox stores. It is important to operate Cox stores at 2% O_2 for at least a week prior to lowering to 1 or 1.2% O_2 in order to reduce respiration rate (and CO_2 concentration inside the fruit). Carbon dioxide injury often begins in the vascular tissue and then extends to include large areas of the cortical tissue. Injured areas have a moist, rubbery texture at first but eventually the injured tissue dries out and 'cork-like' cavities appear.

Core flush

Core flush is a pink or brown discoloration of the core of apples. It occurs late in the storage period and is aggravated by increased carbon dioxide in the storage atmosphere and by lower storage temperatures. Cultivars vary in their susceptibility to the disorder. In the UK Cox's Orange Pippin and Bramley's Seedling are regarded as highly susceptible although application of best practice as regards the use of appropriate storage conditions, avoidance of over-storage and prompt marketing of fruit after storage generally ensure that core flush is not a commercial problem.

Storage of Cox apples in the virtual absence of carbon dioxide, and in low oxygen conditions provides good control of the disorder. Generally core flush is aggravated by early harvesting, unduly high water loss in store and cool summer temperatures (Wilkinson and Fidler, 1973; Sharples, 1975).

Induced by mineral deficiencies pre-harvest

Bitter pit

Bitter pit is probably the disorder that is most familiar to apple growers, both in the UK and abroad, and is of major economic importance. Symptoms appear as roughly spherical brown lesions in the flesh of the fruit. The 'pits' are dry in appearance and occur mostly just below the skin but in severe cases may affect the entire cortex. Bitter pit susceptibility is linked with critical levels of calcium in the tissue and the more frequent occurrence at the calyx end of the fruit relates to the low calcium status of this region. Although symptoms of bitter pit may be seen on the tree generally the disorder develops progressively in store. Consignments of fruit with inadequate calcium as evidenced by fruit analysis should be sold immediately or stored for short periods (see section 3). Orchards should be managed in a way that ensures adequate calcium uptake and retention by the developing fruit. It is important to avoid irregular and excessive vegetative growth. Heavy use of potassium and nitrogen fertilizer should be avoided and a comprehensive programme of calcium sprays is recommended for susceptible cultivars (see section 2). Under UK conditions Bramley's Seedling, Cox's Orange Pippin and Egremont Russet are particularly susceptible to bitter pit. Meridian and Red Pippin are also susceptible whereas the disorder is rarely seen in Jonagold and has not been reported in Gala. Although bitter pit is essentially an orchard condition the development of symptoms after harvest is influenced markedly by the conditions under which the fruit is stored. Prompt cooling, lower storage temperatures and more stringent CA conditions retard bitter pit development and may be partly curative. These effects are taken into account when setting mineral analysis standards (see section 3).

Late storage corking

This disorder of Cox apples is usually apparent only after 6 months storage in 1-2% oxygen (Johnson, 1990). The lesions are 'corky' in appearance and have similarities with bitter pit. However late storage corking is more extensive and, unlike bitter pit, occurs predominantly in the region between the stem-end and the equator of the fruit. The disorder is progressive in storage and may increase significantly during distribution and marketing particularly at ambient temperatures. Emphasis for prevention of the disorder is placed on pre-harvest factors. An imbalance of potassium to calcium in the fruit at harvest has proved to be of major importance. Consequently, fruit for long-term storage in 1.2 % oxygen should contain more than 5 mg $100g^{-1}$ of calcium and less than 150 mg $100g^{-1}$ of potassium (Johnson, 1989).

Water core

Water core occurs in fruit on the tree and therefore is not strictly a storage disorder. It usually becomes less severe during storage and symptoms may disappear entirely. However, water core symptoms may be present in fruit removed from store at which time water core breakdown may also be present (see above - water core breakdown). Water core is described as a 'glassy' appearance of the apple flesh caused by the presence of sap in the intercellular spaces. Analysis of apples affected by water core showed that concentrations of calcium were very low (< 4mg $100g^{-1}$) and therefore incidences of these disorders in the orchard indicate that other calcium-dependent disorders, such as bitter pit and senescent breakdown, are likely to develop during storage (Perring, 1984a). Control measures for watercore are similar to those described for bitter pit (see above).

Internal corking

Internal corking disorders of apple may have some similarities with bitter pit but are associated with boron deficiency. However internal cork always affects the core area. In seriously affected fruit part or most of the flesh will be affected. When the flesh is affected brown, corky, diffuse streaks or wedge-like areas extend from the core into the flesh. Although it has been stated that boron deficiency symptoms are unknown in apples grown in the UK (Wilkinson and Fidler, 1973) it is probably more accurate to state that problems associated with boron deficiency are rare under UK conditions. The internal corking symptoms shown were found in a 'Malling' Kent apple with a low boron concentration (<0.1 mg $100g^{-1}$ fresh weight) (Perring et al., 1985).

Section 13. Post storage grading of fruits

Once a store is opened fruit should be assessed against customer specification requirement and graded to deliver optimum return to the grower.

Planning.

- Before a store is opened, all available information should be assessed.
- Pre-storage assessment and store monitoring data (section 11) will be vital in determining the potential marketing outlet.
- Only fruit with the potential for a good grade-out will be worth packing for a multiple (supermarket) outlet.
- Poor raw material may end up producing a negative return if allowed to enter the higher cost operation required for multiple use.

Customer specification

- Depending on which outlet the fruit is intended for i.e. multiple, wholesale, or processing, assessment will need to reflect customer specification.
- All standards will involve visual, textural, internal and organoleptic characteristics.
- Multiple standards will be the highest for all quality characteristics, but processing will still require fruit of good shape and freedom from internal problems including underskin bruising.
- The minimum standard for any product sold into the wholesale or multiple sector must meet EC (MAFF) standards.
- Visual standards cover shape, colour, and the amount of bruising and blemish, freedom from pests, diseases and foreign matter.
- Textural standards recognize that good textured fruit are generally firm. Penetrometer measurements are a standard requirement for all multiple customers. Good textural quality will also be associated with fruit tissue in which cells break under pressure from the teeth thus releasing juice and flavour. In contrast in fruits that are described as 'mealy' or 'floury' the cells will separate under pressure from teeth and will fail to liberate juice. Currently there is no instrument that is equivalent to the penetrometer that can be used to indicate an acceptable texture in soft fruit.
- Internal standards require freedom from disorders such as bitter pit, low temperature and senescent breakdown, carbon-dioxide injury, etc. These are described in section 12.
- Organoleptic standards are concerned with freedom from any taints and levels of sugar (^{o}Brix) and acidity. Overall acceptance by taste panels will be part of some customer specifications.
- All consignments of fruit supplied to multiple retailers must be traceable. They should be from an approved source and an Assured Produce number is required where the red tractor logo is used.

Pre-grading assessment

- As soon as the store is opened an assessment of each orchard should take place. In practical terms this may have to be an ongoing process due to access to fruit from particular orchards.
- Ideally 100 apples taken from a minimum of 20 bins from each orchard should be assessed.
- Assessment should be made against the intended customer specification.
- Assessment will take into account all the visual, textural, internal and organoleptic criteria indicated above.
- Once an assessment report has been made, and customer target confirmed, levels of staff on the inspection tables can be decided and any instructions given regarding particular defects.
- Ongoing assessment of raw material from each orchard should continue to take place on a daily basis to confirm the status of the fruit prior, to grading. This would be at a reduced level with a minimum of 15-20 fruits assessed. The results should be recorded and entered in to a raw material assessment report.

Temperature of fruit during packing

- Ideally pack-houses should be air-conditioned with a working temperature around $10^{o}C$.
- The temperature of fruit at packing may influence the level of grader damage as fruit passes along the line.
- Some varieties such as Discovery are more susceptible than others to grader damage.

Time between harvest and packing

- An interval between picking and packing will be required to reduce grader damage and will be influenced by variety and weather at picking time. Heavy rain prior to harvest will result in turgid fruit, which will bruise easily if graded too quickly.
- Depending on the grading equipment, it may require up to a week for fruit to reach a condition allowing satisfactory handling, without drastically reducing grade-out.
- If uncertainty about a batch exists, it would be good practice to either grade a small batch, or simulate if possible fruit grader movement to evaluate the probability of damage occurring.

Equipment

- Selection of equipment equal to the task should be part of any assessment before committing apples to a packing line.
- The scale of operation will influence the equipment decision.
- Large packing operations depend on large volume throughput for cost efficient operation.
- Small / medium sites will generally grade and pack as part of one operation.
- Large operations will generally carry out the grading and packing in two parts.

- Raw material should be off-loaded by water flotation into water flumes, passing onto the "grader" where size, colour and defects are sorted either with human selection or by high specification camera.
- Fruit is then returned to designated water flumes before, collection and return to bins.
- Bins are then returned to cold store, before returning to the packing line. (See section 14)
- The intended customer outlet ie multiple, wholesaler or Processor may also influence the decision on grading.
- Lower value outlets may not justify the use of expensive high technology operations.

Dry tip or water flotation

- Dry tip operations will only be justified in a small operation. Where dry tipping is used the tipper should always be of the type unloading from the top of the inverted bin, reducing movement of fruits within the bin. Other types of tipper where fruit is down loaded from the bottom cause fruit to be bruised, blemished or punctured by stalks. In addition, any rots within the bin will break up causing rot residue to infiltrate the packed product.
- Dry tipping should make use of a water cleansing system (spray bars fitted in line using potable water) to remove where possible any undesirable foreign matter (rot residue, dust etc.)
- Ideally water flotation systems will start with automated bin down loading, allowing fork truck loading of the equipment and automatic selection (usually from stacks of three, on a roller feed entry system) of fresh bins into the water flotation system, reducing unnecessary labour input. Empty bins will be collected and removed in the same manner.
- Modern systems will carry bins through a pre-wash of chlorine solution to reduce any damaging pathogens on the fruit.
- Once empty, bins will go through a second chlorine wash, aimed at leaving the bins clean and free of any unwanted foreign matter and pathogens, which could affect the next crop.
- Fruit once down-loaded will travel in water flumes to the grader.

Optical sizing and colour selection

- Sizing has moved on from historic rising bar systems and weight graders that can be difficult to calibrate accurately when fruit density and shape varies. Both historic systems fail to deliver size grading which is accurate enough for today's customer requirements.
- Even sizing within a container is vital.
- Optical sizing by camera is the current best practice.
- In many pack-houses colour selection is carried out subjectively by staff on the grading line. However cameras are being used increasingly to select apples for colour. The latest technology will allow colour streaming which enables a more uniform colour presentation within the final pack. This in turn allows efficient pack-houses the opportunity to deliver to the retail customer a top quality pack, and the grower the maximum possible colour grade-out within the specification.

Quality selection by camera technology

- Quality selection in most packing operations is currently still achieved by human selection.
- This operation depends on the physical removal of fruit by grading staff on the packing line onto a moving belt. The use of electronic wands also requires human selection, but allows automatic transfer of below specification fruit out of the line into a designated area.
- Quality selection cameras allow computer aided recognition of defects, reducing the need for large numbers of personnel on the grading tables.
- Currently this technology works well on the continent with their varieties, but has limited use in the UK.
- There are systems operating and these will continue to be improved.
- Current systems working in the UK have reduced the need for personnel on the grading line to a minimum. At times human involvement is required for the removal of rots but generally any human quality selection can be confined to the final packing stage, where any minor defects which have passed the camera can be removed.

Non-destructive (infra-red) texture selection

- One of the most difficult problems to deal with in any raw material is the uncertainty of variable textured fruit. This often can result in fruit being assessed as unsuitable for multiple use due to that uncertainty.
- Non-destructive texture selection is currently only at the developmental stage for apples but inevitably will play a part in the future, making selection from variable raw material possible.
- Recognition of underskin bruising and internal disorders may also be possible in the near future.

Gentle and efficient movement of fruit through the grading and packing system

- The Loughborough University study for ADAS (1986) demonstrated that packing line grading damage could reduce marketable fruit by 38% - 49%.
- Most packing lines have improved considerably since the 1986 study, but even on the smoothest system damage can occur if people and equipment do not handle fruit with care.
- Packers should carry out regular 'step testing' to ensure equipment is calibrated to give the best possible performance.
- To step test, a sample should be gathered and assessed for bruise/blemish and introduced to the grading line. A proportion of fruit is removed at each step and left for 24 hours before being assessed. Results are compared with those from the original sample. This should identify where poor performance areas exist on the grading line.
- There is an electronic apple now available which can be used to identify 'hot spots' in a more scientific albeit more costly way.

Relationship between size and weight

- Depending on the density of the apple, and this will vary within, as well as between varieties, size / weight relationships can vary considerably.
- This can cause considerable problems with accurate size and targeted weights in final packs.
- There are always 'difficult sizes' within any range of sizes. For example where the standard size has been 65-70mm in Cox, a reduction in size range to 63-68mm will often make achieving the target weight impractical where fruit density varies on a regional basis.
- The lower density of Discovery will dictate lower pack “target weights” than, for example Cox.
- This will impact on increased haulage charges per lb/kg of fruit.
- Delivering accurate size and consistent pack weights will depend on optimising performance where a weight grader is used.
- Optical cameras for sizing will improve sizing accuracy, but fruit density will still influence pack weights particularly where packs are by 'count' but a minimum pack weight is still required.

Calibration of equipment

- Delivering accurate size and consistent pack weights will depend on regular calibration of any grader, but particularly where a weight grader, is used.
- Fruit should be monitored regularly to assess accuracy, and the grader re-calibrated where necessary.

Accurate grading/assessment

- Delivering accurate grading performance is vital for any pack-house intending to stay competitive.
- Under grading will put customer service levels at risk resulting in possible de-listing.
- Over-grading will result in reduced financial returns to the grower and loss of potential business for the packer.
- It is therefore vital that quality controllers assess the performance of the grading line on a regular basis. This should be done at each step of the production line.
- It is vital that all product is assessed i.e. class 1, class 2 and any out-grade fruit. This is particularly important, as it is very easy to over-grade when attempting to satisfy a demanding retail customer.
- All pack-houses must recognise the customer base is grower and retailer together if they are to succeed.
- Best practice should deliver accurate grading acceptable to the grower and retail customer.

Staff training

- Staff training is a critical part of pack-house performance.
- Training should always be targeted at the level required. For example all staff must have induction training to take account of site health and safety issues.

- General training should be given to ensure each worker has the level of skill required for his or her tasks. For example grading staff need to be fully conversant with customer specification requirements. This may be achieved by training in the aspects of the specification which are key to the task involved.
- All pack-house staff should be aware of grading standards and should be prepared to remove defective fruit at any stage of grading rather than rely on others to do so.
- Supervisors will need to be conversant with all aspects under their control.

Motivation

- Motivation is an important factor.
- Personnel will respond to various motivation factors.
- Performance pay may be considered to aid motivation.
- An understanding of the product and its destination is also a key factor in improving performance.
- Involving personnel at all levels, keeping them informed of overall performance and critically sharing any success with them will vastly improve the overall performance.
- Communication is the key factor involved in any performance motivation.

On-line process controls

- These are dealt with in detail in the next section (14).

Section 14. Post storage packing and distribution of fruit

Once graded place fruit in a suitable container to avoid damage. All product should be "cool chained" up to and including the point of sale.

Planning

- Identify the intended customer.
- Plan packing against a known customer programme.
- Ensure all personnel involved in the packing operation are fully conversant with the customer specification requirements, including all aspects of packaging.
- Most multiple customers require dedicated crates, customised packaging and labelling.
- Ensure sufficient stock of correct packaging is available to meet the programme.
- Ensure all operatives have had induction training on site health and safety issues.
- Ensure all on-line operatives have been trained for their specific tasks.
- Ensure all equipment is in good working order, fit for purpose and calibrated where applicable.
- Calibration records should be kept, with clear reference to identified equipment. This is particularly relevant to scales for weighing product on-line and for QC equipment.
- It is a legal requirement that all product sold by minimum weight must be weighed on scales that have been DTI stamped (approved by the Department of Trade and Industry). Any calibration by a certified engineer must have been carried out with weights traceable to national standards and identified as such on any calibration certificate.
- A certified engineer should calibrate equipment at least once a year and more frequently on a busy site.
- Calibration checks on scales should take place at least once a day before starting a production run and ideally at the end of the batch. Calibration weights should take account of the intended range in weights i.e. check using weights that represent the bottom and top end of the range.
- Penetrometers, refractometers, thermometers, QC sizing rings and all scales should be calibrated regularly.
- Identify labelling requirements and ensure equipment and associated software will produce labels compliant with customer specification.
- Identify and install QC procedures required to meet customer requirements.

Customer programme

- Fruit should always be sold as part of an agreed customer programme, if optimum returns are to be realised.
- Programmes will allow controlled marketing, this will in turn allow packers to pack and distribute fruit in the optimum condition, with sufficient stock to be flexible on a day to day basis, but without unnecessary build up and deterioration of stock.
- In practice the pack-house will receive a weekly programme, with order confirmation on a daily basis received from the sales office.

- The packer should ideally pack sufficient stock for the orders anticipated for the next day. On this basis fruit would not have been packed more than 36 hours before despatch. There will be exceptions to this rule, for example the build-up prior to Christmas. However, this must be an exception rather than the rule.

Packaging materials

- Packaging materials should be appropriate for the customer, destination, and mode of transport.
- Best practice for multiple outlets will utilise plastic RDT's (retail display trays) as the outer packaging unit. RDT's also come in cardboard as the second favoured option.
- Wholesale markets often prefer a 30 lb or 40 lb sealed box, rather than RDT's.
- RDT's can be placed directly on to the retail shelf thus avoiding the unnecessary decanting of fruit. Decanting will inevitably increase the risk of in-store damage to the product and cost to the producer.
- Plastic crates offer the best protection for fruit in transit and are more cost efficient than cardboard equivalents. Generally the turnaround cost comparison indicates plastic as half the cost of cardboard. In addition, regulations for the disposal of waste materials increase the hidden costs for cardboard.
- Internal packaging i.e. fibre-moulded trays offer the best protection for loose product and allow maximum presentation of loose product at the retail level.
- If product is well presented, it will reduce the level of consumer selection and handling in the store that so often spoils otherwise acceptable fruit. This spoiling of product and eye appeal detracts from sales.
- Pre-packed fruit in the form of polybags or overwraps offer two distinct advantages. Polybag fruit allows easy selection by the consumer and introduction of promotions of smaller sizes (25% extra for example). However, fruit must be of consistent quality within the pack or loss of consumer confidence will result in fewer repeat purchases. Overwrapping i.e. 4 or 6 apples in moulded trays sealed with pre-formed tops, offers the opportunity to add value to fruit with enhanced attributes. For example for ready-to-eat (pre-ripened) fruit.
- MAP (modified atmosphere packing) which is commonplace in other product areas, usually by positive MAP (injected gasses in the case of meat) will soon be standard in the apple supply chain as well (Section 15). This technology has been tried in the past, but now improved permeable films offer an opportunity for MAP to become a standard procedure. This type of MAP will rely on a product-generated atmosphere using permeable films to establish and control the atmosphere inside the pack. Product will be packed into polybags and punnets. The benefit of this technology is a greatly enhanced shelf life, delivering enhanced texture to the consumer. The same technology will become commonplace in stone fruit and soft fruit as well.

Packing product into the final container (RDT or Pre-Pack unit)

- Assuming that grading has been carried out as described in section 13 fruit will arrive at the final packing point for selection and packing into the RDT either as loose or pre-packed product.

- Before fruit is accepted onto the line, it should be assessed as suitable for the intended customer. This should be done by reference to QC reports carried out at the grading point and from a further assessment to confirm status before use.
- This assessment must involve confirmation of penetrometer readings (firmness), Brix levels (sugar) and taste acceptance (free of any taints etc.) as well as general quality criteria.
- Information on raw material quality on to the grading line will allow supervisors to ensure correct placement of packing line operatives and provide any relevant instructions. For example a higher than normal proportion of apples that are marginal for shape or russetting requires extra vigilance on-line.
- Correct packaging and any associated labels should be confirmed and signed off by management in advance of the packing operation.
- All aspects of handling should be taken with extreme care. An apple can bruise as easily as an egg can break. All packing operatives should be made aware of the care needed.
- All staff should be clean and tidy, with short fingernails. If gloves are worn they must be of a suitable material and non-allergenic.
- Hygiene training has been dealt with in section 5. Additionally, as a minimum, pack-house supervisors should have a certificate for Basic Food Hygiene Training.
- Induction training on health and safety issues should be a standard.
- An experienced trainer who, ideally, will have qualifications for training should give training in quality requirements.
- At the final packing stage operatives should be ensuring that fruit not only meets the customer specification but is also presented to maximum effect. As the market place becomes increasingly competitive it is essential that presentation is maximised. This also applies to labels, whether individual apple labels, or labels on pre-packed product. Both should be positioned consistently and in compliance with customer requirements.
- Labels for pre-packed fruit must carry the information required by law and customer specification.
- Placement of pre-pack and overwrap packs into the 'outer container' is important on two counts. Firstly, to ensure that the product is packed in a manner that provides minimum risk from pressure marking (bruising against other packs or against the crate etc.). Secondly, to comply with customer requirements for presentation at the retail level. Most customer specifications require a particular arrangement of the packs within the crates and these should be tested in-house. Any detrimental effects on the fruit should be discussed with the customer via marketing / technical personnel.
- Where product is sold by minimum weight, all packed units must be weighed on DTI approved scales. Trading Standards Officers will check these if they confirm any reported 'underweights' at the retail display level.
- The ability to demonstrate compliance with legal requirements will be a due-diligence defence if prosecution for underweights takes place.
- Sufficient 'tare' for any packaging materials used must be allowed for and added into the final pack weight, where minimum weights apply.
- The affect of moisture loss will result in reduction of packed unit weight from point of packing until its final acceptance point. This must be anticipated by adding sufficient tare to compensate for moisture loss. Most customer

specifications indicate the required tare to accommodate moisture loss. This will vary between 10-30 g per kg. This is sufficient for pre-packs but for loose product in a 12kg RDT (approximately 26lb) a 100 g allowance may be required.

NOTE. UK Apples are generally sold by weight, using the 'minimum weight regulations'

Where automated polybagging machines are used that optimise weight and minimise 'giveaway' weight, it is a legal requirement for machines that are not DTI approved (stamped) that packs are check weighed on a separate DTI approved scale before release for sale to the consumer.

In pre-packs sale by count is becoming popular. For trading standards purposes a consumer must be given a consistent offer. It is not permissible to offer 10 apples of 60-65 mm one week, and then offer on "promotion" (indicating an increased value offer) 10 x 55-60mm apples (less weight) at a lower price the next week. The offer must be comparable.

Average weight regulations are commonly used for products such as flour and sugar (fine grained) where an average weight (label depicts an 'e' mark) can be offered. For example a nominal 1 kg pack can legally fluctuate between 985 g and 1015 g, but must average 1000 g).

This is probably impractical for apples with average individual weights of 100+ g and would give no benefit to the grower / packer / supplier over minimum weight regulations.

Stacking fruit for optimum air flow and security.

- When stacking boxes on pallets always try to optimise the flow of air between the boxes.
- In practice plastic crates, or any other RDT (cardboard) packed for a multiple customer will not allow any deviation from the basic 3 x 2 per layer and will need to be tight to each other for efficient transportation.
- Where an impact can be made is on early season fruit such as Discovery that is targeted for the wholesale market. Fruit quality will benefit from spacers between the boxes to allow air movement. Benefit would be gained also where fruit in market boxes moves quickly from the orchard into a cold store and then on to the marketplace in the same boxes.

Optimum pallet loading (full pallets)

- Optimising pallet loading will benefit quality and cost efficiency.
- Where part loaded pallets travel long distances, transit damage will occur. On occasions this can result in fruit arriving below the customer specification and will result in rejection.
- Part pallets will often end up stacked on top of other pallets in transit. This increases the risk of damage.
- The optimum loading per pallet will depend on various factors:

- Height of the pallet in relation to lorry height space. The longer the journey the greater the gain in quality and cost efficiency from maximum pallet height.
- Health and safety regulations. Acceptable pallet heights must be determined by risk assessment.
- Multiple customers will often operate different height restrictions. This is because risk assessment will take into account the circumstances in operating areas, which may be different. Receiving high load pallets may be possible if a system of de-stacking can be employed without risk of injury to operatives. Some companies may err on the side of caution when setting height limits.

Securing fruit on pallets

- Securing individual pallets will depend on the type of box used.
- Whichever type of box is used, careful alignment is paramount. Boxes overlapping the pallet, however slight this may be, or not tight to one another, will result in damage to the product and / or packaging at the destination. Even an untidy appearance will impact on the saleability of the product.
- Cardboard RDT's require cornerboards and strapping. A minimum of 3 straps should be used at the top, middle and bottom of the pallet.
- It is important to maintain this format. If the bottom strap is too far up, it will result in the bottom boxes bowing and compressing. This will be exacerbated by damp air conditions.
- Corner boards as a 'belt and braces' approach may secure plastic RDT's. Generally they will be secured adequately by 2-3 plastic straps. Standard practice would be for the top strap to be on the penultimate layer and the lower strap on the 4th layer from the bottom.
- All plastic straps should be tight. This can only be achieved effectively with a strap tightener.
- Where pallets with fruit exposed (cardboard RDT's) are intended for wholesale market best practice should include the use of pallet covers. This will reduce the potential for soiling and in particular the risk of birds attacking the exposed fruit. Where fruit is intended for a multiple outlet and is conveyed through a closed system the use of pallet covers may not be necessary. This implies that fruit is loaded directly from the despatch store onto a lorry through closed system (docking bay) and unloaded again at a docking bay.
- If pallets with fruit exposed are not transferred by closed system best practice should include pallet covers. The cost of pallet covers is approx. 75p each.

Labelling boxes and pallets

- Labels should be printed and utilised in the pack-house in a tightly controlled manner.
- Before use, all new labels should be approved. This will involve the printer operator receiving a specification from the commercial manager. A specimen label should be printed and passed back to the commercial manager for checking and finally sending to the customer for approval.

- On a daily basis, the printer will check labels against the specification / specimen and print only sufficient for the intended order with 2 extra for label print records. The print number should be recorded in the label print records.
- Labels should be checked at the start of the print run and at the end of the run.
- Where bar codes are an integral part of the label, they should also be scanned with a suitable approved scanner to ensure that the bar codes are readable and are carrying the correct information.
- Printed labels will then be passed to the supervisor, who will check the labels and sign for acceptance.
- Any unused labels must be returned, destroyed, and recorded in label print records.
- The same procedures are applicable for box end and product (polybag) labels.
- Labels applied to RDT's should be securely placed in the designated position. If labels become dislodged, valuable information on traceability will be lost, in addition to the risk of rejection by the customer depot QC.
- Some of the multiple sorting systems depend on label presence and accuracy, therefore label compliance will become ever more critical in the future.
- In addition to box end labelling, pallets should also have a large clear destination label placed in a prominent position.
- Some multiples require a standard bar coded pallet label usually colour coded as well. This will soon become the standard for all.
- All pallets should be checked for correct labels as part of final inspection, before despatch.

Traceability

- As part of label information, full traceability must be maintained.
- Each label must have the supplier identity, either by name or by accepted code or both.
- In addition the grower identity should be shown as a code on the label.
- 'Display until' information will normally be included.
- All information aids traceability. Consumer complaints advised to suppliers will always refer to 'display until' dates as well as supply codes etc.
- Traceability is important for all involved in the supply chain. Any question against the safety of product will result in its withdrawal. If clear traceability cannot be confirmed, safe product may also be withdrawn i.e. guilty by association.
- Traceability back to the orchard may be difficult to record on the box end label. However it is critical that records are held to demonstrate which orchards were used against each batch despatched.

Cool chain effect on fruit firmness

- The benefits of maintaining a cool chain are described in section 15 of the guide.
- The maximum benefit will be gained where a cool chain is maintained up to and including the retail display.
- This benefit is recognised by the retailer but the cost of conversion means implementation will take time in the larger retail operations.

- Cool chain at the retail level allows more 'ready-to-eat' fruit to be displayed without loss of quality.
- This in turn increases customer satisfaction and generates increased sales of higher value products.

Quality Control Operation

There are 4 distinct areas of QC within the grading and packing operation namely raw material assessment, on-line QC inspection, and final QC inspection and shelf life assessment.

Raw material assessment.

- This is dealt with in section 13.

On-Line QC Inspection.

- This is designed to ensure packed product is within the specification. It is the responsibility of supervisors to maintain the required standard but QC's should monitor the situation by sampling fruit at various stages of each production run. Product should be inspected and the results recorded at the beginning, during and at the end of the production run. Times of inspection should be recorded. Assessment should be made for visual quality, firmness, edibility, label compliance and pack weight conformance. As a guide 3% of product should be inspected on line. The QC should inform the supervisor of any quality issues and appropriate action must be taken. This may result in stopping the line, withdrawing product and rectifying the problem. For example product that is underweight will require re-weighing.

Final QC Inspection.

- Final QC Inspection should only be a confirmation of the status of the packed fruit. If product at this stage of production is found to be below grade, clearly other QC inspections have failed. This is a serious issue and investigations should take place to identify where systems have failed. Final QC inspection should take account of visual quality, fruit firmness, weights, label compliance including traceable information, pallet stacking and security. Some multiples require final inspection to be a positive release formally signed off and shown on a positive release pallet label. This is taking the place of depot inspection and passing the responsibility to the supplier to ensure product fully complies with customer specification.

Shelf Life Assessment.

- Shelf Life procedures allow the supplier to monitor a sample of despatched product. This enables a pre-warning of any issues of product deterioration, which may indicate a serious problem requiring withdrawal of product or possibly a reduced 'display until' period. For example where a product loses its condition before the 'display until' date, it will be beneficial to the supplier, retailer and consumer to reduce the period on display.

FOOTNOTE. BRC STANDARDS. The procedures of best practice indicated in sections 13 and 14 deal with in house grading and packing activities. However, the packing, environment and general procedures for all multiple customers and many higher profile wholesale customers require compliance with the British Retail Consortium (BRC) standard. This code of practice covers all aspects of recognised

best practice in product management systems. The BRC standard has three levels of certification:

1. Fit to Supply (the lowest).
2. Foundation Level.
3. Higher Level (the highest)

Accredited auditors carry out audits of suppliers seeking to achieve the BRC standard. The supplier may choose the auditor from a list of accredited auditors. The supplier bears the cost of audit expenses and the audit results are the supplier's property. The supplier will authorise release of the audit reports to potential customers in support of any business agreement.

Section 15. Maintaining quality during marketing

Early season apples intended for direct marketing begin to lose quality immediately after harvest. Likewise apples from CA storage lose quality as soon as the 'gas' seal is broken. In both cases without sufficient control of produce respiration the quality of product reaching the consumer may be inadequate to provide satisfaction. This can have an immediate and long-term adverse reaction to the sales of UK fruit.

Much can be done to ensure higher quality product in the market place through an awareness of the benefits of temperature control after harvest (early apples) or after grading (storage cultivars). Following best practice will help to ensure that all the efforts to achieve high quality through application of good husbandry and storage practice are not wasted after fruit leaves the packing-house.

Where cool temperatures cannot be maintained and the period between packing and consumption exceeds 10 days the use of modified atmosphere (MA) packaging provides useful improvements in product quality. However, it is important that growers discuss the use of MA packaging with their marketing agents and their customers (retailers and wholesalers) to ensure their acceptance in the market place. It is particularly important that supply of product in retail MA packs is acceptable to retailers that are accustomed to selling the bulk of their product 'free-flow'. In this regard it may be that the bulk packs (18-kg cardboard cases lined with a suitable polymeric film) that preserve quality to the retail shelf are the most appropriate application of MA technology for UK retailers. It is also important for producers to be able to achieve higher prices for their higher quality product in order to meet the additional costs of packaging.

Although the quality benefits of MA packaging are proven for a number of cultivars these are achieved generally at ambient temperatures and over periods in excess of 2 weeks. Where prompt distribution of product occurs at cool temperatures the use of MA techniques may not be justified. Consequently, at the present time the use of MA packaging is not included in best practice.

Early season apples:

- Keep fruit shaded after picking and during transport from the orchard
- Ensure fast removal of field heat by loading fruit into store that has been pre-cooled to 0^{o}C. Load no more than 10% of the total capacity of the store e.g. a maximum of 10 tonnes of fruit into a 100 tonne store.
- After pre-cooling grade and pack quickly, return packed fruit to a pre-cooled holding store
- Short journeys in non-insulated transport should be made during the hours of darkness
- Insulated or refrigerated transport should be used for long or daytime journeys
- All transfers on and off vehicles should be done rapidly
- Encourage the use of cool displays at the retail level

Storage cultivars:

- Terminate storage while there is sufficient quality to allow for packing and distribution
- Keep packed fruit cool, ideally 3.5^{o}C but at below 10^{o}C at least
- Use chilled distribution where possible
- Encourage cool display in retail outlets
- Avoid 'back-storage'

Growers can use Table 13 below to convince marketers and distributors of the need for prompt delivery of their product to the retail shelf and of the importance of maintaining cool temperatures during distribution. These results apply to Cox apples removed from CA storage where the intention is to achieve 6kg firmness on the retail shelf.

Table 13. Effect of temperature on firmness decline in Cox apples.

	Days to reach 6 kg firmness (projected)			
Firmness ex-store (kg)	1.5^{o}C	3.5^{o}C	10^{o}C	18^{o}C
6.6	30	20	12	9
6.4	20	13	8	6
6.2	10	7	4	3