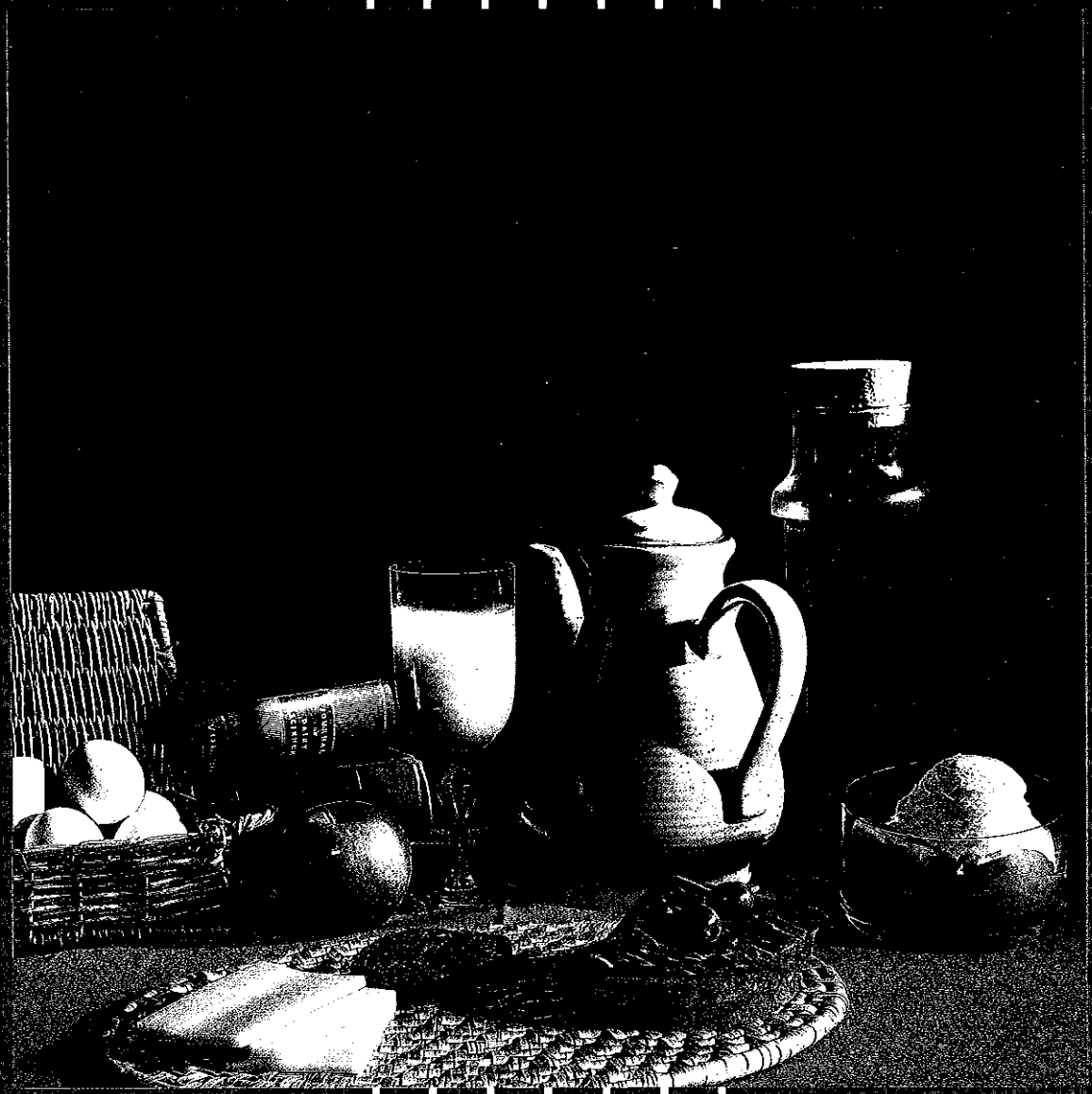
CSIRO Food Research Quarterly

VOLUME 49
NOS. 1 + 2 1989



CSIRO

Food Research Quarterly

Volume 49

Numbers 1 & 2, 1989

P.O. Box 52
North Ryde, NSW 2113

TELEPHONE: (02) 887 8333
TELEX: AA23407
TELEFAX: (02) 887 3107

Located at: Gate 1
51 Delhi Road, NORTH RYDE

Editor: Keith Richardson, Food Technology Liaison Officer
Division of Food Processing, CSIRO

Editorial
Committee: K.C. Richardson (Chairman)
J.H.B. Christian
D. Graham
I. Mathieson
J. Prentice
C. Chandler
S. Zadow

Design &
typesetting: Eames Communications Pty Ltd

Printing: All Graphics Printing Pty Ltd

ISSN 0310-9070

Contents

FROM THE EDITOR

Volume 49 of the CSIRO Food Research Quarterly introduces a change in style and format of our journal. Regular readers will be aware that the publication of the journal has been erratic in recent times. In an attempt to restore our publication schedule, volume 49 will comprise two double issues. We will then revert to four single issues per year.

The Quarterly will continue to publish papers from the CSIRO Division of Food Processing, other relevant CSIRO Divisions and selected papers from other sources. The Editorial Committee trusts that the new format will be well received by our readers and welcomes constructive criticism or comment.

K.C. Richardson

Chief's Message

CSIRO Division of Food Processing has always pursued an active policy of balancing strategic and tactical research.

Changes in organisation and funding of CSIRO have resulted in a shift of emphasis of our research program and the acceptance of a good deal of contract work. Much of this is confidential and the results of such work will not be published except with the express permission of the original contracting party.

However, it remains the primary aim of the Division to carry out high quality strategic research for the benefit of the food industry as a whole and for the consumer. The Food Research Quarterly has served both the Division and its readers well as a vehicle to communicate research results and general information, and it is my intention that it will continue to do so.

Funding constraints have not diminished the creativity and farsightedness of the Division's scientists. New elements of the research program include studies on plant cell culture, biosensors, processed meat products, food composition and nutritional quality, and packaging film innovations. New directions are being taken in food flavour research, sensory analysis, technologies for the processing of plant and animal foods. Readers may look forward to reports on such work in future issues of the Quarterly.

Des Walker

Chief of Division

Impact on Food Refrigeration of Ozone Protection Legislation

N.L. Wade

Senior Research Scientist, NSW Department of Agriculture & Fisheries, Located at CSIRO Division of Food Processing, North Ryde, NSW 2113

Supplies of the refrigerants R11, R12, R113, R114, R115, R500 and R502 will be reduced by the Ozone Protection Act 1988. Owners and operators of coolstores and freezing plants that use any of these refrigerants will have to continue their usage, since no refrigerants are currently available that can be used as direct substitutes in the same machinery and pipework. Although not prescribed by the Act, it will now be good practice to avoid the release of these refrigerants, so as to prevent atmospheric contamination and to conserve supplies by recycling.

No new plant should be commissioned that uses a refrigerant scheduled under the Act. Food refrigeration will rely heavily in future on R717 (ammonia) and R22, because these are not affected by the legislation. Some important technical differences distinguish R22 from the more common R12 plants. These include the higher discharge temperature of R22 and the poor miscibility (mixing) of R22 with lubricating oils. Methods for design of R22 plant are described which prevent over-heating of compressors, seizure of compressor bearings, and loss of cooling efficiency in evaporators.

Introduction

Legislation controlling the supply and certain applications of some commonly used refrigerants has been passed by the Commonwealth Parliament. This new law is called the Ozone Protection Act 1989.

The purpose of this Act is to give effect to the obligations assumed by Australia under the Montreal Protocol on Substances that Deplete the Ozone Layer. This Protocol is designed to limit the worldwide consumption of certain scheduled substances that destroy ozone in the earth's atmosphere.

The manufacture of scheduled substances is to be progressively reduced, so that by mid-1998 production will be 50% of 1986 production.

Scheduled substances under the Act include the chlorofluorocarbon (CFC) refrigerants R11, R12, R113, R114 and R115. The supply of R500 and R502 is also affected, since these refrigerants are mixtures which include scheduled substances. Other scheduled substances are the halons. These are used mainly in fire-fighting. The refrigerants used most widely by the horticultural, dairy, meat and food processing industries are R12, R22, R502 and R717 (ammonia). The refrigerant R12 is also used very extensively in domestic refrigeration and air conditioning. Although R22 is a chlorofluorocarbon, it has only a slight ozone depleting potential, and is not included in the list of scheduled substances. This refrigerant is currently considered a technically acceptable and environmentally safe alternative for applications where R12 plant has until now been used.

Refrigeration applications where R502 is now used might be satisfied in future with either R22 or R717. Ammonia (R717) refrigeration is unaffected by these developments, and an increase in its use can be anticipated. There are, however, many refrigeration contractors who have no

experience with ammonia systems.

This article describes some of the requirements of the Ozone Protection Act, and discusses some of the probable consequences which will be experienced by users of refrigeration in the food and allied industries. It is not the purpose of this article to interpret the Act, and the comments made are not an interpretation.

MAIN REQUIREMENTS OF THE ACT

The Ozone Protection Act 1988 introduces a system of licences and tradeable quotas for the production, import and export of scheduled substances. The recycling of scheduled substances is encouraged by exclusion of recycled product from the manufacturing quota. These provisions (Parts III, IV, VI and VII of the Act) apply to those who manufacture or trade in scheduled substances, and will have the effect of reducing the total supply of scheduled refrigerants in accordance with the Montreal Protocol.

The other principal element of the Act (Part V) concerns the manufacture, import, export, distribution or use of products that contain scheduled substances or depend on such substances for their operation. The provisions of this Part are outside the Montreal Protocol, and for constitutional reasons apply only to specified persons (mainly corporations) and activities (such as international or interstate trade or commerce) that come under the legislative powers of the Commonwealth.

Schedule 4 of Part V sets out specific controls on manufacture or import (after various specified dates, the latest being 31 December 1989) of the following products if they contain, are produced by the use of, or are capable of being operated with a scheduled substance:

1. Dry cleaning machinery
2. Certain automotive air conditioning maintenance kits
3. Non-refillable containers under 5kg in weight for the maintenance of refrigerative units, including air conditioners
4. Polystyrene packaging or insulation
5. Aerosol products.

The provisions of Schedule 4 should benefit the refrigeration industry, by reducing the amounts of refrigerant consumed for other purposes, such as the manufacture of polystyrene foam and aerosol products.

Part V also provides for the future introduction of regulations similar to those in Schedule 4. Comprehensive provisions are made for enforcement of the Act, and heavy penalties are provided for offences (Part VIII).

In summary, the Act regulates the manufacture, export and import of scheduled substances by any person. It does not appear to regulate the distribution or use of these substances, or of products that contain or require these substances, by most people, unless the type of business or activity is subject to Commonwealth law. In other words, many (but not all) contractors and coolroom owners and operators are not regulated by this Act. The activities of these excluded people in relation to their uses of refrigeration fall within State jurisdiction. The Act specifically provides for the States to make their own ozone protection laws (Clause 4). Regardless of whether or not particular users of refrigeration have obligations under the law, the fact that most CFC refrigerants are harmful atmospheric pollutants which will become more difficult to procure imposes an obligation on all users to handle these substances carefully and prevent their waste.

EXISTING PLANT WHICH USES A SCHEDULED REFRIGERANT

Owners and operators of coolstores and freezing plants should ascertain the refrigerant type or types used in their equipment. This information should be found both on a plate fixed to the compressor body, and on a plate fixed near or on the machines (Rules 15.14.1 and 15.14.2 of the SAA Refrigeration Code, AS 1677- 1974). If these plates cannot be found, a refrigeration technician familiar with the plant should be consulted.

Refrigeration plants charged with a scheduled refrigerant must continue to use that refrigerant. Restrictions on manufacture of the refrigerant may, therefore, cause supply problems.

Both the federal government and the refrigerant industry have said that supplies of scheduled refrigerants will continue to be available for purposes where no alternative is available. Presumably, this means existing refrigeration plant.

When plant is opened to atmosphere for maintenance purposes, it will be good practice to transfer the charge of scheduled refrigerant to a collection vessel. It may then be purified and recycled. The plant will be re-charged from the restricted supply of refrigerant.

It is most important to be aware that refrigeration plant must NEVER be charged with any refrigerant other than that specified on the compressor and the identification plate for the complete plant (where affixed), or other than that for which the plant was designed. Such action will cause serious mechanical damage or even an explosion. An attempt is being made to develop a new refrigerant which may be used in equipment designed for R12.

The present such candidate refrigerant is called R134b. Should R134b be released (and this is by no means assured), it would not be until about 1998. There are significant technical and toxicological reasons why R134b might never be released.

It is sometimes possible to convert R12 plant to run on R22, but the cost is substantial. Compressors, condensers and evaporators rated for R12 are usually also rated for service with R22. The minimum high side refrigerant design pressures for air-cooled plant are, however, 1400 kPa for R12 and 2,300 kPa for R22 (Rule 10.2 of SAA Refrigeration Code). The refrigerant charge of R22 for equivalent duty is also less than for R12. Thus pipework designed for R12 cannot be used with R22. The discharge temperature of R22 is much higher than R12, so a substantially larger condenser is required for service with R22.

While there may be special circumstances where conversion would be justified, conversion cannot in general be recommended as an appropriate reaction.

NEW INSTALLATIONS

Any person installing or contemplating the installation of new refrigeration plant would be well advised to ensure that a scheduled refrigerant is NOT used. New plant will not only be subject to the same restraints foreshadowed for existing plant, but it is quite likely that additional restrictions will apply. It may well be that plant commissioned after some future date will not be assured further supplies of a scheduled refrigerant.

The use of R717 (ammonia) should now be routinely evaluated in any proposed new plant. Ammonia used to be the mainstay of commercial refrigeration, and is still used in many cool stores and freezers. Ammonia plant can be very cost-effective and economical to run. The principal disadvantage of ammonia is its high toxicity. Ammonia is also explosive under certain rather unusual conditions. The displacement of ammonia by chlorinated fluorocarbons in commercial refrigeration was perhaps the result of persuasive selling techniques rather than sound technical reasons. Extreme carelessness is possible in the handling of chlorinated fluorocarbons because of their low toxicity. Ammonia will probably become the preferred choice for larger installations. There is, however, a shortage of contractors who are qualified to build and maintain ammonia plant.

Where ammonia is not a practicable option, as in most smaller installations at present, R22 will be the refrigerant of choice for coolstorage applications at about 0°C and some freezer applications. Concern has been expressed that R22 may eventually be restricted in the same way as R12. This is not the situation at present, and such a restriction would be inconsistent with the present international Protocol, which excludes R22 from the list of scheduled substances.

Some important technical differences distinguish R22 from R12 plants. Coolstore operators should at least be aware that these differences exist, and ensure that refrigeration contractors whom they engage are thoroughly familiar with good engineering practice for R22 usage.

IMPORTANT CHARACTERISTICS OF R22 PLANT

Important differences between R12 and R22 are: a) the higher discharge temperature of R22 and b) the poor miscibility (mixing) of R22 with lubricating oils, especially at the temperature and pressure of the evaporator. These differences are unfortunately all too commonly manifested as frequent overheating of the compressor with subsequent shutdown by the high-pressure safety switch, and lubrication failure of the compressor. Seizure of the main bearing is a common result of lubrication

failure. A less obvious consequence is loss of cooling efficiency as the tubes on the evaporator become coated with oil.

Overheating related to high discharge and hence high condensing pressures is primarily a fault of the heat rejection equipment. Condensers must be adequately sized. Substantially larger condensers should be used when R22 is the refrigerant, relative to R12 plant performing the same duty.

Lubrication failures occur when the cyclical flow of refrigerant and oil around the refrigeration system is interrupted by separation of oil and refrigerant. The separated oil settles out and may not be able to find its way back to the compressor. The oil level in the compressor sump falls. In a splash-fed oil system the compressor seizes up. In a pumped oil system there may be sufficient loss of oil pressure to activate a safety-switch shutdown before damage occurs.

When the evaporator is located above the compressor and the suction line can be installed without risers or traps, oil that has separated will drain by gravity from the evaporator to the compressor crankcase, provided that all nominally horizontal piping is pitched downwards towards the compressor.

If, however, the compressor is above the evaporator, as in the very common situation where the compressor is housed on the roof of the coolroom, gravity return of oil is impossible. The suction riser must be sized small enough so that the resulting vapour velocity in the riser will be, even under minimum load (i.e. minimum vapour quantity) conditions, sufficiently high to entrain the oil and carry it up the riser and back to the compressor. Methods for sizing suction risers correctly are set out in various refrigeration manuals available to contractors. Where there is any doubt about the correct sizing, advice should be sought from major equipment suppliers.

Discharge risers should also be sized so that the vapour velocity is sufficient to entrain oil, unless an oil-separator is installed in the discharge line. As a general rule, discharge line oil separators should be installed in all systems employing non-miscible refrigerants, including those such as R22 which may only be non-miscible in the evaporator. A separator removes much of the oil from the refrigerant vapour, and returns the oil to the compressor.

Lubrication failure may also result from the accumulation of liquid refrigerant in the compressor crankcase. This circumstance probably causes more problems when the refrigerant is R22 rather than R12, because of the resultant complications common with R22. Liquid refrigerant may enter the compressor through the suction line because of liquid overfeed of the evaporator by a wrongly adjusted expansion valve, drainage of liquid by gravity from the evaporator during the off-cycle, or condensation of refrigerant during the off-cycle if the compressor is colder than the evaporator. Upon start-up of the compressor, the mixture of oil and refrigerant in the crankcase will foam excessively as the refrigerant vaporises, sweeping a substantial quantity of oil out of the compressor. In an R22 system, return of this oil may be insufficient to prevent a lubrication failure, even if an oil separator is fitted and pipes are sized correctly.

One method of reducing oil-foaming at start-up is to install electric heating elements in the crankcase. This heater switches on when the compressor cycles off. Another method, which may be used by itself or in conjunction with sump heaters, is the automatic pumpdown cycle.

A solenoid valve is installed in the liquid line before the expansion valve. When the room thermostat signals that the refrigeration duty has been satisfied the valve closes, but the compressor continues to run until the low side has been pumped free of refrigerant and the low-pressure safety switch is triggered. The compressor cycles on each time the low-side pressure climbs above the lower set limit, but refrigeration is prevented until the room thermostat calls for cooling and the liquid line solenoid valve opens.

Fruit and vegetable coolstores very often run on a seasonal basis, with long shutdowns in between. Sump heaters and automatic pumpdown systems cease to work when plant is shut-down completely. Special precautions should be taken when plant is to be put back into service. Liquid refrigerant may have gathered in the crankcase during the idle period. Sump heaters should be activated on the day before the plant is to be run, so as to drive refrigerant from the oil. An open compressor should be turned over by hand several

times to ensure that there is free movement of rotating parts. Only when the sump has been heated and freedom of movement verified should the compressor be started. The oil level should be watched carefully. The normal working oil level in compressors fitted with sight glasses is halfway up the glass, unless the manufacturer indicates otherwise. The level will fluctuate as the compressor cycles, but at all times the level MUST REMAIN WITHIN THE GLASS.

If there is refrigerant in the oil, then the level will be misleadingly high. A white, foaming emulsion will be visible in the sight glass, and the level will probably rise above the top of the glass and stay there. If any of these effects are seen, the compressor should be turned off immediately and a serviceman called. It is in any case wise to have a pre-season service carried out after a long shutdown, and to entrust the initial start-up to a service engineer.

CONCLUSION

Users of existing plant that is charged with a scheduled refrigerant will have to adapt to the impact which the Ozone Protection Act will have upon refrigeration practice.

Regulation of the supply of any substance must make its procurement more difficult. Because stocks of refrigerant will be smaller and presumably subject to closer supervision, problems in supply seem inevitable, especially in country areas. Any factor which increases plant down-time is potentially costly, especially when highly perishable foodstuffs are being handled. It must be clearly understood that there are no substitute, replacement or alternative refrigerants which can be used in existing plant.

New installations should not use a scheduled refrigerant. The horticultural, dairy, meat and food processing industries will have the choice of refrigerant for most applications reduced to R22 or R717 (ammonia). Whichever of these substances is chosen, difficulties will be encountered in finding contractors experienced in their use. The simplest transistion is from R12 to R22, but even here important differences between the two refrigerants must be accommodated in the design of plant. Inadequate heat rejection systems and oil distribution problems are important concerns with R22 plant.

This report gives an overview of the probable practical consequences of the new legislation concerning chlorofluorocarbon refrigerants and the options which users of refrigeration will have available. It seems inevitable that users of refrigeration will face a difficult period of adjustment and change until at least the end of the century.

FURTHER READING

Anon (1984). System practices for halocarbon refrigerants. In *'ASHRAE Handbook - 1984 Systems'* (American Society of Heating, Refrigerating and Air Conditioning Engineers: New York).

Commonwealth of Australia (1989). *Ozone Protection Act 1988.* (Commonwealth Government Printer: Canberra).

Dossat, R.J. (1981). 'Principles of Refrigeration', 2nd Ed., pp. 410, 471-74 (John Wiley & Sons: New York).

Fairclough, A.E. (1978). The design and installation of quality refrigeration systems. *Australian Refrigeration, Air Conditioning and Heating.* **32** (10), 14-26.

Gianni, S.J. (1962). Refrigerant piping for single compressor systems. *ASHRAE Journal.* **4**, 46-8.

Newton, A.B. (1981). The refrigeration compressor - the steps to maturity. *International Journal of Refrigeration.* **4**, 246-54.

Stolk, A.L. (1987). The need to curb CFC emissions. International Journal of Refrigeration **10**, 271-75.

Standards Association of Australia (1974). Rules for the design, installation testing and operation of refrigerating systems. SAA Refrigeration Code, AS 1677-1974.

The Use of Thermocouples to Monitor Cargo Temperatures in Refrigerated Freight Containers and Vehicles

A.K.Sharp

CSIRO Division of Food Processing, North Ryde, NSW 2113

The storage life of perishable foods such as chilled meat, fruits and vegetables depends primarily on their temperature. During transport in refrigerated containers or vehicles produce is kept cool by a stream of temperature-controlled air, that is circulated by the container's refrigeration unit. An air temperature is displayed on the container's temperature recorder, but produce temperatures usually differ from this value, especially during the first few days of the journey. Produce temperatures can be monitored from outside the container, using thermocouples installed while produce is being stowed into the container. This paper gives details of how thermocouples should be prepared, installed and monitored, and how errors in temperature readings may occur.

Produce temperature

To maximise storage life, perishable produce should be kept at the lowest temperature that will not cause injury. Chilled meat, temperate fruits such as stone fruit, pome fruit and berries, and many vegetables, can be cooled to just above their freezing points, which range from -1.5 to 0°C. Tropical and subtropical fruits, however, suffer chilling injury, and should be stored at higher temperatures (Table 1).

Container Operation

In a refrigerated freight container operating in warm surroundings, the loadspace is kept cool by a stream of refrigerated air, circulated around and through the cargo. Many types of refrigerated container are in use. Porthole containers are supplied with air from a clip-on refrigeration unit, or from a central refrigeration plant, whereas integral containers have their own refrigeration unit. In 'bottom-delivery' containers, the air is supplied at floor level, and returns from the top of the loadspace. All porthole, and many 20ft integral containers, have bottom-delivery air circulation.

Most 40ft, and some 20ft, integral containers have top-delivery air circulation, in which the air flows in the opposite direction. The modes of operation of the various types

Table 1
Optimal storage temperatures of some non-frozen produce
(Sharp, Irving and Beattie 1985).

Temperature (°C)					
-1.5	1	5	7	13	20
meat	apple	rockmelon	avocado	grapefruit	pineapple
-	apricot	mandarin	passionfruit	lemon	-
-	peach	-	cucumber	banana	-
-	kiwifruit	-	capsicum	mango	-
-	nectarine	-	eggplant	pawpaw	-
-	pear	-	bean	tomato	-
-	plum	-	orange	-	-
-	berries	-	watermelon	-	-

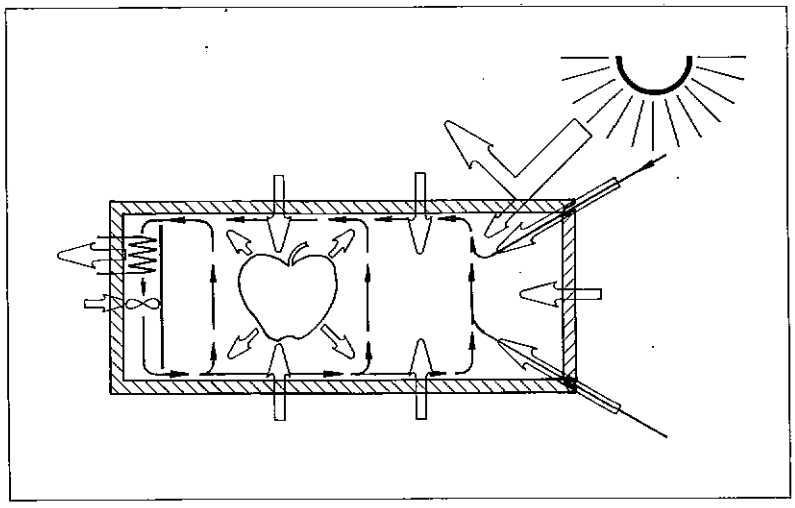


Figure 1. The container's refrigeration unit must remove heat from many sources, including the sensible heat of a stow that has not been pre-cooled, heat conducted from the walls, heat entering as air leakage and (with fruit and vegetables) the heat of respiration.

are described by Irving (1988).

The temperature of produce within a container depends on the balance of heat flows, as shown in Fig. 1. Heat enters the loadspace from the surroundings, by conduction through the walls, and in association with air leakage. Additional heat comes from produce that is loaded warm, from the heat of respiration of live produce such as fruit and vegetables, and from the electrical energy input to the fan. The air stream collects this heat and delivers it to the evaporator. As this air moves through the loadspace, absorbing heat, it becomes warmer. Produce in contact with air leaving the load-space, therefore, must be warmer than produce in contact with air delivered by the refrigeration unit. To maximise the storage life, the temperature of the delivery air stream should be controlled at the minimum value for the particular produce; the storage life of items stowed elsewhere will be slightly less, because they will be warmer. The temperature difference between the warmest and the coolest items within the container (the 'temperature spread') depends on many factors, including the type of container, the stowage pattern, and the ambient temperature. In an integral container, or a porthole container operated with a clip-on refrigeration unit, the temperature rise of the circulating air is typically 1 or 2 degrees C but can be as high as 3 or 4 degrees C. The temperature spread can be several times as great. The temperature normally recorded by the recorder incorporated in the refrigeration unit, however, is that of the return air stream.

Location of Temperature Sensor

Selection of the location within a refrigerated container at which the temperature should be monitored depends on the reason for measuring it. Produce is sometimes loaded warmer than the carriage temperature. To check whether the container is cooling this produce effectively, a temperature sensor should be placed in the slowest-cooling part of the stow. To carry produce as close as possible to its freezing point, a sensor should be placed in the coolest part of the stow. If the maximum temperature is also of concern, as when performing a cold disinfestation quarantine treatment against fruit fly, a sensor is also required in the warmest part of the stow. Where these places are located depends on the construction of the container and its refrigeration unit, and on the operating conditions.

The coolest part of the stow is always located close to the delivery air stream, and approaches the temperature of this air. In bottom-delivery containers, therefore, the coolest part is situated at floor level (location A in Fig. 2). The refrigeration unit always incorporates a sensor located in the delivery air stream. In containers that control the temperature of the delivery air stream this is the control sensor, and in containers that control the return air temperature it is the 'safety' thermostat. If the heat of respiration is very large relative to heat leakage through the walls of the container, the warmest part of the stow will be expected to be the centre (location C in Fig. 2). This is also the part of the stow that cools most slowly. For exports from Australia, however, the heat of respiration is usually relatively small compared to the wall heat

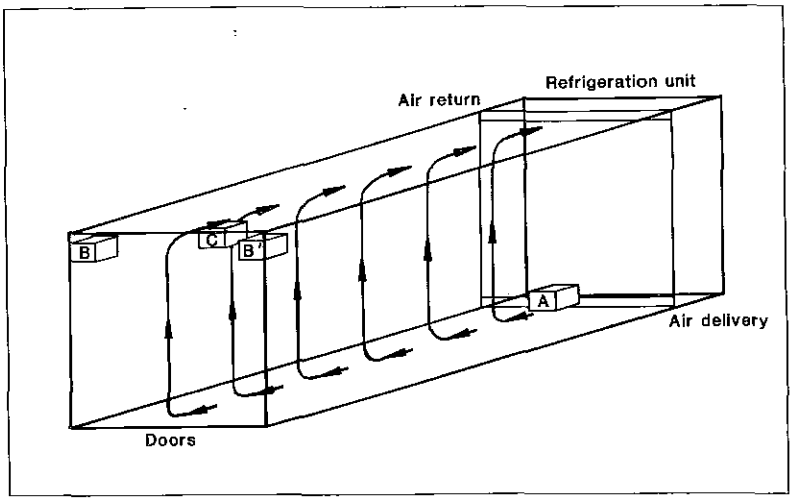


Figure 2. Locations of the coolest and the warmest parts of the stow in a bottom-delivery integral container. A: the coolest carton; B or B': the warmest carton when the wall heat load is high and C: the warmest carton when the wall heat load is low and/or the heat of respiration is high

leakage, and the warmest part of the stow is near the doors (location B or B' in Fig. 2. for a bottom-delivery container). In top-delivery containers the direction of air flow is reversed: the coolest carton is at the top of the stow at the refrigeration end of the container, and the warmest carton is near the doors, at floor level.

In fitting a sensor to monitor produce temperature, common practice is to place it in the second carton from the top, at the centre of the second tier from the door end of the container. This practice, intended to locate the slowest-cooling carton, originated with in-transit cold-disinfestation of fruit shipped to the US in porthole containers (all of which are bottomdelivery), and is inappropriate to top-delivery containers. In many containers the direction of air circulation is not obvious during loading. To avoid confusion, therefore, it is suggested that a sensor intended to monitor the slowest-cooling part of the stow should be placed at half height in the centre of the second tier from the doors. In all containers, top- and bottom delivery, a thermocouple at this location will indicate a value within 0.5 degrees C of the slowest-cooling part of the stow.

The temperature sensor need not be actually inserted into the produce; this is unnecessary, and may introduce moulds and other spoilage organisms. During transport (but not necessarily during rapid cooling) the temperature is almost uniform within each carton, and it is sufficient to place the sensor in contact with a piece of fruit near the centre.

The cable by which the sensor is connected to the measuring instrument should be lead out past the door seal, and must be long enough to reach the other end of the container; when stacked at the terminal, the container may be accessible only from the equipment end.

A total cable length of 10 metres usually is sufficient. The surplus length can then be coiled and taped to the doors until required.

Thermocouples

The thermocouple is most suitable for sensing temperatures remotely, as required in containers. Cheap enough to be discarded after use, it does not require individual calibration.

It consists of a pair of dissimilar metallic wires, insulated from each other and joined at one end. When the circuit is completed with a second, reference junction held at a known temperature, the thermocouple generates a small voltage which depends only on the types of metals chosen and the temperature of the measuring junction.

Traditionally the reference junction was immersed in wet ice to maintain it at 0°C, but this is often inconvenient, and instead the reference junction is usually allowed to remain at ambient temperature, and is monitored by another type temperature sensor.

Of the many types of thermocouple, Type K and Type T are most commonly used for measuring temperatures near ambient (see British Standard BS4937). Type K thermocouples consist of wires of Chromel (a nickel-chromium alloy) and Alumel (a nickel-aluminium alloy). Type T thermocouples consist of wires of copper and Constantan (a copper-nickel alloy), and are most common for transport applications. Plugs and sockets

Table 2. Colours used to identify Types K and T thermocouple wire in various countries.

Country	Type K Chromel (+)	Type K Alumel (-)	Type T Copper (+)	Type T Constantan (-)
US	Yellow	Red	Blue	Red
UK	Brown	Blue	White	Blue
Germany	Red	Green	Red	Brown
France	Yellow	Purple	Yellow	Blue
Japan	Red	White	Red	White

Table 3. Allowable tolerance of thermocouples (degrees C) in the temperature range -20 to +120°C). (National Bureau of Standards 1979).

Thermocouple type	Grade Standard	Special
K	+/- 2.2	+/- 1.1
T	+/- 0.8	+/- 0.4

used with thermocouples must be made from the same alloys, and in the US are coded yellow for Type K, and blue for Type T. The colours used to identify thermocouple wire, unfortunately, are not standardised internationally, as shown in Table 2. Wire bought locally could come from any one of these countries, so care must be taken to connect the wires correctly.

Type T thermocouple wire is produced to closer tolerances than Type K, as illustrated by the values allowed by the US National Bureau of Standards (see Table 3). Usually, however, each batch of thermocouple wire deviates much less than this from the standard tables, and thermocouples made from a single batch of cable are very similar to each other. Good practice, therefore, is to purchase sufficient thermocouple cable from a single batch to make all thermocouples for, say, one season. Samples should be calibrated over the temperature range of interest and kept for re-checking.

Type T thermocouples are generally preferred for use at low temperatures in preference to Type K because, in addition to being made to closer tolerances, they have several advantages associated with one of the conductors being of pure copper:

(i) Type T cable is cheaper than comparable Type K cable;

(ii) errors due to temperature gradients in the measuring instrument are reduced, because the conductors in electronic circuits are also made of copper;

(iii) the conductors of Type T cable are of different colours, which reduces the risk of connecting the wires with reversed polarity.

Thermocouples suitable for use in containers can be made from twin-core PVC-insulated Type T thermocouple cable. To make the measuring junction, one end of the cable is stripped, the wires are twisted, soldered, and trimmed, and the junction is protected and electrically insulated with a coat of lacquer (e.g. nail varnish) or epoxy resin (e.g. 'Araldite'). It is not sufficient simply to twist the wires together, because of the possibilities of poor electrical contact and corrosion. Soldered junctions are quite adequate for measuring low temperatures, and the junction need be welded only if it is to be used at temperatures that would melt the solder.

The other ends of the thermocouple are connected to the measuring instrument (usually a digital thermometer) via a miniature thermocouple plug, or by direct connection of the bare wires.

Thermocouple Thermometers

Temperatures in containers usually are required to be measured with an accuracy of better than one Celsius degree. Many makes and models of digital thermometer are now available, using a variety of sensors, including one made for Type T thermocouples (see Drewitt Smith and Sharp 1982).

A sensitive voltmeter is required to measure accurately the small voltages produced by thermocouples (a temperature change of 0.1 degrees C produces a voltage change of only 4 microvolts in Type K and Type T thermocouples). In addition to the measured voltage, to obtain the temperature of the measuring junction, the temperature of the reference junction must be measured, and the temperature-voltage relationship of the thermocouple must be known accurately. In electronic thermometers the temperature of the reference junction (where the thermocouple wires join the brass or copper conductors of the electronic measuring circuit) is monitored by a separate temperature sensor. In some instruments the reference junction is located at the input socket, but more usually the thermocouple materials are carried through a thermocouple input socket to the circuit board itself (see Fig. 3).

Most digital thermometers using thermocouples as sensors are fitted with standard miniature thermocouple sock-ets, and the thermocouple cable should be fitted with an equivalent plug. Bare wires can also be inserted directly into the socket if care is taken to obtain a good electrical connection. Alternatively bare-wire thermocouples can be connected to screw terminals made of appropriate thermocouple alloys, or to a spring-terminal adaptor make of thermocouple alloys. Some manufacturers of digital thermometers offer a bare-wire adaptor as an accessory, or an adaptor can be made relatively simply, provided that care is taken to ensure a continuous electrical path in thermocouple alloys, as shown in the Appendix.

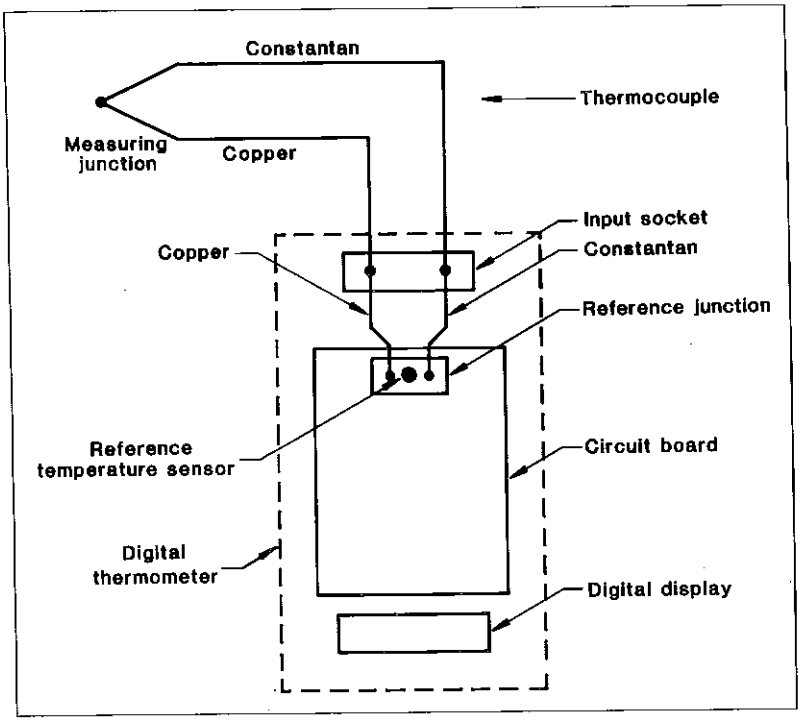


Figure 3. A Type T Thermocouple connected to the input of a digital thermometer, showing the input connector and reference junction.

Ice-point check

The temperature of wet ice made from pure water is 0.0°C, and the levels of contamination in normal drinking water lower the freezing point by less than 0.1 degrees C (see footnote). Careful calibration at the temperature of wet ice made from good drinking water, therefore, is a good way to check the accuracy of a thermometer or, indeed, the complete measurement system. Clean, shaved or crushed ice (pieces smaller than 5mm X 5mm X 5mm) should be packed tightly into a wide-necked vacuum flask (e.g. a 'Thermos') and wetted with ice-water. If crushed ice is not available, block ice can be wrapped in a clean towel and smashed with a hammer.

A thermocouple made from the same batch of cable as the thermocouples to be monitored, and reserved for checking, is then inserted into the the centre of the ice-pot, and the thermometer reading taken when it is steady.

An ice-point check should be performed each day as a matter of routine, and the readings recorded in a logbook. If the ice-point reading is not within 1.0° of 0.0°C, the thermometer should be rechecked using another thermocouple; if still not within 1.0°, the thermometer should be sent to the distributor for adjustment or repair. The ice-point reading enables the operator to detect any drift in or damage to the thermometer. A sudden change in ice-point reading may simply be caused by dirty input connectors or a flat battery, but if attention to these measures does not produce a reading close to zero, the thermometer should be sent for adjustment and recalibration.

The ice-point reading can be used to correct other measurements, but to avoid confusion, the actual temperature reading should always be recorded in the field note book, and then any correction applied later.

NOTE: The main contaminant affecting the freezing point of drinking water is salt. The maximum allowable level of sodium chloride in town water is 0.1% (WHO 1971), which lowers the freezing point to -0.06°C. Sodium chloride in water has a detectable taste at levels above 0.06%, and at 0.2% tastes recognisably salty (Amerine et al 1965) (and depresses the freezing point by -0.12 degrees C). Wet ice made from water which is acceptable for drinking, therefore, will have a temperature between -0.1 and 0.0°C.

Sources of Error

An electronic thermometer converts the electrical input signal to a temperature, regardless of the origin of the signal. Temperature differences in other parts on the circuit, or voltages produced by other means, therefore, produce errors in the indicated temperature. The factors known to cause errors in thermocouple-type thermometers include the following:

(i) The accuracy of the thermocouple wire and voltage-to-temperature conversion. To some extent these errors can be compensated for by calibration of the cable and the thermometer. Calibration is more feasible if all thermocouples used together are made from the one batch of cable.

(ii) Poor electrical contact at the thermocouple junction. Thermocouple junctions should be twisted and soldered.

(iii) Poor electrical contact at the input socket. A firm dry mechanical connection is required, preferably using a thermocouple plug.

(iv) Moisture. The alloys from which Types K and T thermocouples are made are corroded by water, especially by seawater, producing voltages which alter the signal generated by the thermocouple. Before each reading inspect the pins of the thermo-couple plug (or the ends of the thermocouple wires), and clean them if necessary, using a fine abrasive such as a pencil eraser or metal polish (e.g. 'Brasso'). The input socket of the therm-ometer should also be inspected from time to time, and cleaned or replaced if found to be corroded.

(v) Induced voltages. Devices such as electric motors and radio transmitters generate electro-magnetic fields that induce voltages in all conductors, including thermocouple wires. Because thermocouple voltages are so small, induced voltages can cause large errors. An on-site ice-point check is the best way to check whether induced voltages are causing errors.

(vi) Thermal gradients in the thermocouple circuit. Temperature differences at junctions between a thermocouple wire and other metals may cause errors in the indicated temperature if any part of the external circuit is not made from thermocouple cable. Most such problems are caused by terminals and switches. Even some switches supplied for use with thermocouples incorporate conductors made of other metal. Protect such components from excessive temperature gradients, make an ice-point check of the complete measurement system, including any switches or terminals, under the conditions that are encountered in use.

(vii) Transient errors. Thermocouple-type thermometers are more liable to transient errors than those using other types of temperature sensor. They arise from the use of non-thermocouple metals in the circuit. The transient error can be measured by observing the indicated temperature of a thermometer that is monitoring the temperature of wet ice (i.e. 0°C) as the whole assembly is moved from one ambient temperature

to another. For example, the responses of one thermometer, reading a thermocouple immersed in wet ice, are given in Fig. 4. The thermometer, and ice-pot, were transferred quickly from a room at 22°C to a room at 38°C. (This is similar to the temperature change that occurs during the summer when the thermometer is taken from an airconditioned office for use outdoors.) Using a thermocouple input plug the transient error was minimal because the thermocouple conductors continue in the same thermocouple metals all the way to the measuring circuits. Replacing the input socket with non-thermocouple materials (speaker terminals), however, caused a large transient error, which persisted for 50 minutes. To minimise such problems the entire circuit should be made in thermocouple materials. A spring-terminal adaptor, suitable for reading bare-wire thermocouples, is described in the Appendix.

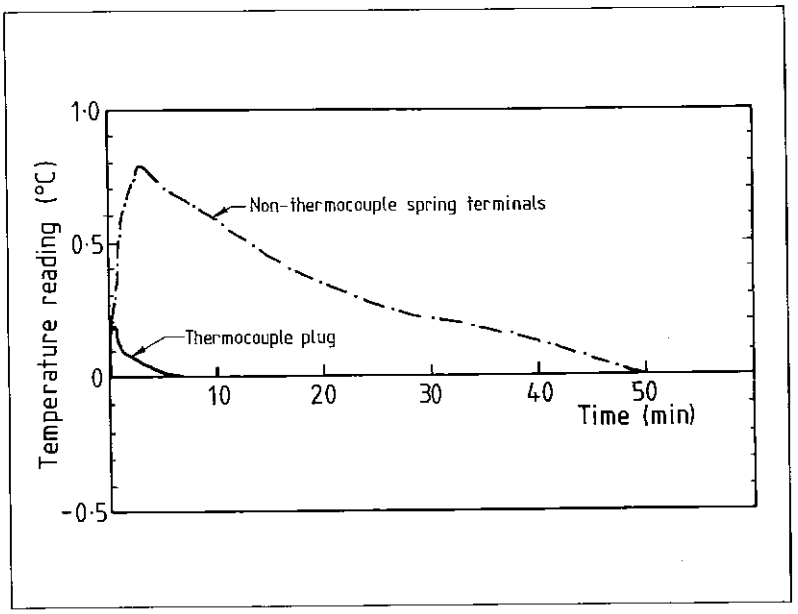


Figure 4. Transient responses of a Type K digital thermometer after transfer from a room at 22 °C to a room at 38 °C, while measuring the temperature of wet ice (0.0 °C).

(viii) Reversed polarity of the thermocouple leads. Connecting the thermocouple wires in reverse polarity will cause errors. If large, this error will be obvious, but if the temperature of the thermometer is similar to that of the object being measured (e.g. when monitoring a container of fruit during the winter) the temperature error may pass unnoticed. To help avoid this type of measurement error, all thermocouple connections should be made and checked by responsible personnel.

(ix) Instrument drift. Since the temperatures of most food products are close to 0°C, an ice-point check is an excellent way to confirm the reliability of the measuring system.

(x) Mis-match between thermocouple and thermometer. Use only digital thermometers that are intended for the type of thermocouple in use.

Recommendations

1. Maximum product temperatures in a freight container can be monitored using a temperature sensor placed at half-height in the centre of the second tier of cartons from the door end. The sensor cable should be taped to the ceiling and led out of the container via the door seals. The total length of the cable should be at least 10 meters, to ensure that it is accessible from either end of the container.

2. Thermocouples are the best type of temperature sensors for use in monitoring cargo within freight containers or other transport equipment. Thermocouple junctions are easily made from thermocouple cable, by joining the wires at one end, and fitting a thermocouple plug to the other. For convenience in calibration, all thermocouples used together (and preferably all thermocouples used for one season) should be made from a single batch of cable; a reference thermocouple made from this batch can then be calibrated, and this calibration applied to all thermocouples made from that batch of cable.

3. Thermocouple junctions should be soldered, and insulated with lacquer epoxy resin.

4. Suitable thermocouple-type thermometers, having a resol-

ution of a tenth of a degree, are available. They should only be used with thermocouples of the same type.

5. To read thermocouples not fitted with an appropriate thermocouple plug, the bare wires can be pushed into the socket of the digital thermometer. More conveniently, bare-wire thermocouples can be connected via a suitable terminal adaptor. The entire electrical circuit of such an adaptor must be made of the appropriate thermocouple alloys; large unpredictable errors can occur if normal spring terminals are used.

6. Electronic thermometers should be checked against wet ice before each day's measurements. Wet ice has a temperature of 0°C. The temperature indicated for ice can be used to correct the day's readings. If the correction required exceeds 1 degree C, the thermometer should be checked.

7. When making critical measurements, further ice-point checks should be made during the day's readings to check the equipment and the operator's technique.

References

Amerine, M.A., Pangborn, R.M., and Roessler, E.B. (1965). *Principles of Sensory Evaluation of Food'* . p. 65. (Academic Press: New York).

British Standards Institution. (1974). *International thermocouple reference tables.* BS 4937.

Drewitt Smith, D.B. and Sharp, A.K. (1982). Hand-held digital thermometers for the measurement of fruit and vegetable temperatures: an evaluation. *CSIRO Food Research Report* 160 and supplements 160/1-4 (1984), 160/5 (1987), and 160/6-7 (1989).

Irving, A.R. (1988). Refrigeratedcontainers: understanding their operation and using them effectively. *CSIRO Food Research Quarterly*, 48, 1-18.

National Bureau of Standards, Washington, D.C. (1979). Temperature reference tables. *NBSMonograph* 125.

Sharp, A.K., Irving, A.R. and Beattie, B.B. (1985). Transporting fresh produce in refrigerated trucks. N.S.W. Department of Agriculture *Agfact* Hl.4.3.

WHO (1971). *International Standards for Drinking Water.* 3rd ed. p.39. (WHO: Geneva).

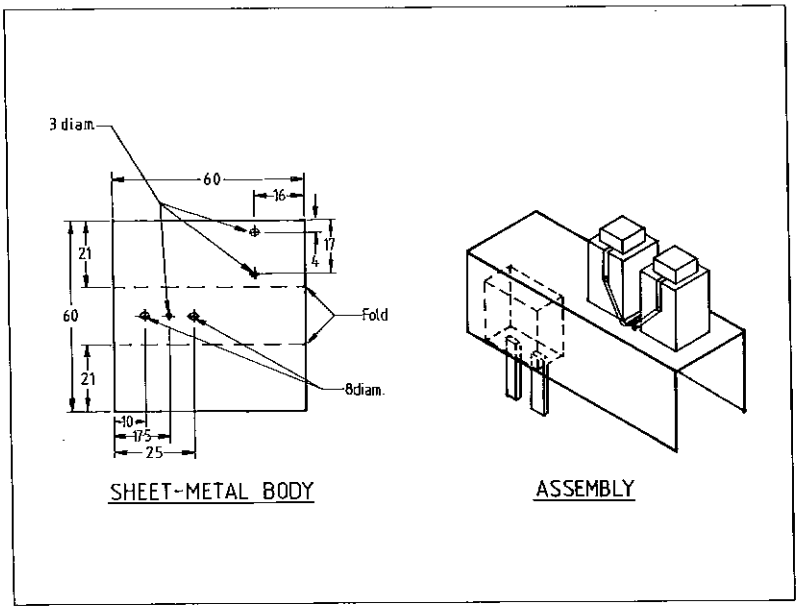
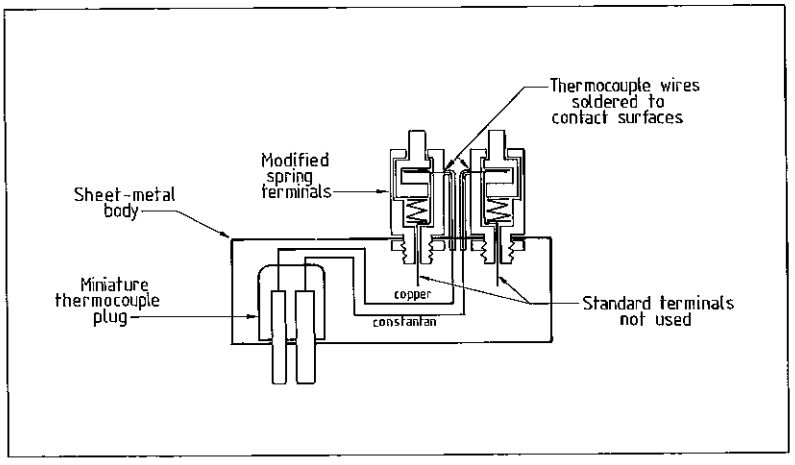


Fig. A1. Spring terminal thermocouple adaptor: construction details. Fig. A2. Spring terminal thermocouple adaptor: section.



APPENDIX: Spring Terminal Thermo-couple Adaptor

The essential property of a thermocouple adaptor, in order to avoid thermal errors, is that it must provide a continuous circuit in thermocouple alloys, from the contact face of the spring terminal to the conductors of the thermocouple plug. This need not require the manufacture of custom-made spring terminals, however. High-quality, mass-produced, brass spring terminals can be used by soldering thermocouple wire directly to the contact face, bypassing the brass circuit.

By this means, the brass spring terminal provides the mechanical connection, but the electrical circuit is completed in thermocouple alloys.

A spring terminal thermocouple adaptor can be made as described below and in Figs A1 and A2. The completed adaptor is shown in Fig. A3.

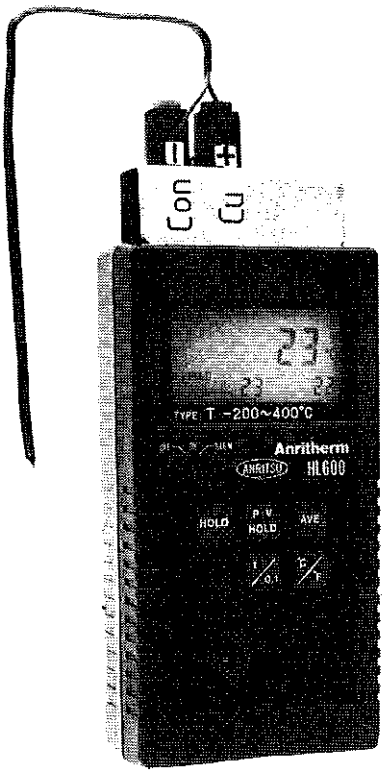


Fig. A3. Spring terminal thermo-couple adaptor fitted to digital thermometer.

Parts List:

Aluminium sheet: approx 1.5mm thick, 60mm X 60mm, drilled and folded.

Miniature Thermocouple plug: Part no. 1260-T, Marlin Manufacturing Corp. from Electro Chemical Engineering Pty Ltd, 7 Mobbs Lane, Carlingford, NSW.

Spring terminals: Part 434-374 (black) and Part 434-368 (red), from Radiospares Components Pty Ltd, 6 Durdans Avenue, Roseberry, NSW).

Terminals and plugs from other suppliers may also be used, provided that they permit a continuous circuit of thermocouple alloys.

Modification to thermocouple plug (Marlin) Drill through the blind hole, and tap to suit a 3mm fixing screw.

Modifications to spring terminals (Radiospares Components)

1. Twist solder tail straight.
2. Dissemble by pushing in tail.
3. Remove spring and long plated brass contact insert.
4. Drill small (e.g. 0.6mm diam.) hole through insert for thermocouple wire.
5. Bare end of thermocouple wire, insert through hole, and solder against contact face.
6. Slit rear of plastic body with a hacksaw.
7. Reassemble, leading wire out through slit.
8. Cut off end of solder tail, and insulate with heat-shrink tube.

Assembly

Assemble terminals to body as shown, connect wires to thermo-couple plug, and secure plug to inside of body with screw.

The Impact of Microbiological Advances & Problems on Australian Food Exports — An Historical Perspective*

J.H.B. CHRISTIAN

CSIRO Division of Food Processing,
NORTH RYDE, NSW 2113

Microorganisms have played important roles in the development, and the frustration, of Australia's food export trade. This has been particularly evident with meat. Examples of developments and problems are given for meat and dairy products and of difficulties encountered with some other exports. A miscellany of quality defects has affected exports but the paramount safety defect has been contamination with salmonellae.

INTRODUCTION

Over the last 150 years, Australia has exported a wide range of foods which, because of the distances from main markets, have been troubled by microbiological problems and have frequently depended on microbiological innovation for success.

The problems have been of three broad types. First, there were those which afflicted foods processed empirically, before the microbiological principles were understood. Here we have no scientific data, but can surmise in the light of later knowledge what the problems were. Second, there have been quality (spoilage) problems for which the microbiological cause has been identified. Third, there have been important instances where the acceptability of Australian food exports has been compromised by the presence of unacceptable numbers of pathogenic microorganisms.

It is rarely possible to quantify the extent or cost of microbiological problems in Australia's food exports. Rather than attempt a complete and chronological list of microbiological disasters, examples will be given of the wide range of microbiologically related problems that have arisen, with some comment on the technical developments that were necessary if particular foods were to be exported successfully. In respect of trade in Australia's early days, I have drawn extensively on Dr K.T.H. Farrer's (1980) publication 'A Settlement Amply Supplied' which is acknowledged with gratitude.

**Based on a paper presented at the 22nd Annual Convention of AIFST, Perth, WA, May 1989.*

MEAT

Salting The earliest food export of any significance from Australia was probably beef that was salted in New South Wales from 1830 specifically for export. Substantial quantities of salt beef and pork were subsequently exported from the 1840's to the 1880's. The meat was salted, pressed, brined, pressed again and layered with salt in barrels.

It is now known that the organisms that spoil proteinaceous substrates in saturated salt solutions, the extreme halophiles, are strict aerobes.

Thus when spoilage of this export product occurred it is likely to have resulted from failure to maintain anaerobic conditions at the meat surfaces.

Canning

Experiments in meat canning began in Australia about 1843. By 1850 there was a developing

export trade in canned meats to England. It withered away by 1855 but restarted in the late 1860's.

Processing in steam under pressure was little used in the Australian canning industry in the 19th century. Calcium chloride was normally the heating medium, achieving temperatures of 250-260°F. Meat was packed into handmade cans, which were closed with a lid containing a pin hole that allowed steam to escape. This was sealed with solder towards the end of the process.

Spoilage was not uncommon and, as it was recognised that the larger (greater than six pound) sized cans were more likely to spoil, under processing was clearly a problem.

The perceived object of the heat process was to drive out air which supported putrefaction. That the heat destroyed contaminating bacteria was not appreciated, although Pasteur had already demonstrated the true purpose of heat processing.

Contamination through the pin-hole would not have been common, as the hole was usually sealed towards the end of the processes in the face of issuing steam. However, post-processing contamination of leakers may have been a major problem as the handmade cans might not have stood up well to the rough treatment they probably experienced.

Post-processing incubation of cans at 100° to 130°F was common, and apparently effective, for detecting and discarding cans with contents not commercially sterile.

Alternatively, the sea voyage through the tropics to England provided a similar test. Failures there must have been, but, given the slight economic margin that maintained the export industry against competition from other exporters, they must have been relatively few.

The trade continues - in 1987 Australia exported over 10,000 tonnes of canned meat, mainly to the UK.

As Farrer (1980) summarises it: 'Reduced to its essentials, Australian canning in the nineteenth century was a hand operation relying on high temperature heating for times empirically determined and based on the erroneous assumption that the critical parameter for successful food preservation was the removal of air.'

Even so, the microbiological problems that must have plagued the early canners are not unknown to their modern counterparts.

In 1964, an outbreak of typhoid fever in Aberdeen, Scotland, was traced to canned corned beef from the Argentine. The cause of the problem was post-processing contaminations by unchlorinated cooling water from the River Plate. Although the 400 cases of typhoid were not caused by Australian product, the effect on exports of corned beef from all sources, including Australia, was substantial.

More recently, in 1973 a major Australian export meat cannery was deregistered by the UK Department of Health & Social Security - the company could no longer export to that market. The rate of spoilage of canned meat from the plant was up to five per cent. Clostridia and faecal streptococci were found in many cases. Under processing was indicated. When time/temperature processes were corrected, it was found in later batches that leakage occurred through seams, a defect compounded by overfilling.

Freezing and Chilling

The successful shipment of 34 tons of frozen meat to London on the s.s. Strathleven in 1879-80 marked the beginning of an Australian export trade that continues to be of major importance.

Given fresh meat of good quality, efficient refrigeration equipment and reasonably controlled thawing, there have been no major microbiological problems. However, 'drip' and 'freezer burn' were aesthetic problems and Australian frozen meat competed poorly in Britain with meat imported chilled, not frozen, over much shorter distances from the Americas.

The discovery that elevated levels of carbon dioxide in the atmosphere would greatly extend the storage life of chilled meat made it possible to contemplate commercial shipment of unfrozen Australian meat across the world.

In fact, the requirements included minimising the initial microbial load on carcasses, appropriate reduction in surface water activity as a result of drying during chilling, accurate maintenance of meat temperature close to freezing, and provision of a storage atmosphere containing 10 percent carbon dioxide. Failure to meet any of these requirements could result in spoilage.

The first experimental shipment of Australian chilled beef arrived in London in ex-

cellent condition in 1934, and by 1939 one third of Australia's beef exports were chilled. However, it was World War II, not microbes, that put an end to this brief export episode.

Post-war, the export trade in frozen beef expanded. The problem of 'drip' had been reduced somewhat through a better understanding of the properties of muscle and the major trade was in boneless manufacturing meat for the U.S. market. The microbiological problems here were related not to spoilage but to *Salmonella*.

For a period in the 1960's and 1970's, there was great concern in the U.S. about the incidence of *Salmonella* in many foods, not least frozen raw meats. Although much is now known about the cycle of contamination and growth of *Salmonella* through the ruminant animal and its environment, little of this knowledge seems yet to have been applied to control the incidence of this bacterium in meat.

It is now accepted by most food microbiologists that the absolute exclusion of *Salmonella* from most raw meats is currently impracticable, but two decades ago standards demanding absence of *Salmonella* from meat were not uncommon.

However, the cost of adequately sampling and examining Australia's frozen meat exports to the U.S. - over 360,000 tons in 1987 - was prohibitive and, for whatever reason, testing has been erratic. In 1965-75, an average of 2.4 percent of beef sampled in boning rooms was positive for *Salmonella* - the figure is now around one percent.

The testing of imported meat is anything but erratic in Sweden. Following a major outbreak of salmonellosis in the 1950's, traced to imported veal, Sweden introduced a stringent sampling plan. Meat is allowed into Sweden if not more than five percent of samples are positive for *Salmonella*, provided that neither *S. typhimurium* nor *S. newport* are identified in the product.

Above five percent positive, the shipment is rejected and re-exported. Below five percent (provided again that neither of the specified serotypes is present) only those cartons found to be positive are destroyed and the remainder are accepted.

The five percent reject level may be varied and with meat from some works a shipment may be re-tested if it is found to be three to five percent positive.

Application of this standard resulted in rejection rates for Australian beef of around 10 percent in 1980-85, but it has been reduced significantly since. In 1985, insurance against *Salmonella* rejection of meat in Sweden cost about four percent of the value of the meat compared with about 0.5 percent for meat to America. Note that the total volume of exports of frozen and chilled meats to Sweden is only about one per cent of that to the U.S.A.

About 10 years ago, an outbreak of salmonellosis in north-eastern U.S.A. was traced to roast beef. The organism was *S. bovis-morbificans*, a serotype rare in the U.S. but relatively common in Australian beef.

This happened at a time when there was concern about the undercooking of roasts (which are, in fact, often 'boil in the bag' beef) and U.S. Meat Inspection Regulations now quote a minimum internal temperature (63°C) for cooking beef and a range of time/temperature combinations that will destroy *Salmonella* and give the required degree of 'doneness'.

The export of chilled, vacuum packed primal cuts of beef has been a microbiological success. Careful hygiene, suitable packaging films and adequate temperature control give a storage life in excess of 12 weeks. The anaerobic conditions with carbon dioxide generated by the muscle tissue inhibits pseudomonads which spoil chilled meat quite rapidly under aerobic, low carbon dioxide conditions. The selected lactobacilli grow more slowly and the products of their metabolism are much less objectionable than the products of proteolysis by the gram-negative bacteria.

Problems arise with beef of pH > 5.9 which permits growth of *Brochothrix thermosphacta* with much greater spoilage potential than the lactobacilli. A more recently discovered problem relates to the presence of strains of lactobacilli containing a plasmid carrying genetic information for the production of hydrogen sulphide from cysteine. This organism will cause meat to spoil more rapidly than will other lactic acid bacteria.

Another process for increasing the storage life (and hence export possibilities) of vacuum packaged meat is the acetic acid treatment of lamb and mutton. Treatment with

1.5 percent acetic acid at 55°C or 3.0 percent at 25°C as a spray or a dip will reduce surface bacterial counts by c. 99.5 percent and extend storage life by 50 percent.

Butter & Cheese

An important trial shipment of butter was sent to the UK in 1865. However, it was not until cream separators were introduced in the 1880's, giving much better and more consistent quality of butter and the almost concomitant availability of shipboard refrigeration, that significant export of butter became practicable. By 1926 butter exports to Britain were valued at 6 million pounds per annum. Even so, the quality of butter still deteriorated during shipment.

Well into the 20th century, Australian exports of butter and cheese drew heavy criticism, the butter for chemical and microbiological taints, the cheese for moulding and the failure of starter cultures. A problem in butter not solved until 1940 was the bacterial defect 'rabbito' taint.

Some quality problems that arose in wartime due to lack of refrigeration in the tropics were overcome by development of a hardened butter concentrate prepared from butterfats, skim milk powder and salt.

Postwar, a major problem in cheese related to moulds on the traditional export cheddar. Large, round, bandage-wrapped cheeses were often blemished by surface cracks and mould. The introduction of rindless cheeses wrapped in polyethylene solved this. A much greater problem involved slowness or failure of cheese starter cultures due to bacteriophage attack which on occasion became so serious as to cause factories to close. A series of developments which essentially overcame this problem began with the distribution of pure, phage-free starter cultures from a central point, then rotation of cultures, through freeze dried to frozen starters and more recently to the use of factory-derived strains resistant to phages endemic in the particular factory.

Milk Powders

Most of the microbiological criteria in place throughout the world relate to dairy products, and some of these have affected Australian exports adversely. Some Japanese criteria are in this category, but the most important have been US requirements for dried milks and milk-derived powders.

The development of Australian microbiological controls on export dried milk products took place in three periods, beginning about 1968. Over 1968-76, there was routine microbiological monitoring, on a survey basis, with no specific standards being applied. In the eight years and over 5,000 samples, no *Salmonella* isolations were reported.

By mid-1976, the US was increasing pressure on Australia to enter into a Memorandum of Understanding (MOU) on dried milks and threatened to step up testing for *Salmonella*. These organisms were being isolated from Australian caseins in the USA.

The second period, the 1976/77 season, saw the Australian outbreak of salmonellosis caused by *S. bredeney* in infant formula, and another outbreak in which the vehicle was calcium caseinate. The *S. bredeney* outbreak had a major impact on export of powdered infant formulas, at that time running at over 10,000 tonnes per annum.

The Department of Primary Industry (DPI) imposed an embargo on export in July, 1977, and there were recalls in importing countries. Extensive work was undertaken to bring the factory concerned up to standard. Salmonellae had passed through cracks in the cone of a drier, multiplied in the insulation and recontaminated subsequent batches of powder.

In the third period, from 1977 onwards, the DPI introduced a *Microbiological Testing* Regime for all dried milk products and Australia was able to sign an MOU with the USA to cover all dried milk products for edible use. Under this MOU, results of tests carried out in Australia on export products were accepted, with occasional check analyses, by the US Department of Agriculture.

One difference between the most severe DPI export specifications and the MOU requirements was absence of *Salmonella* in 15 x 25 g samples in the former and absence in 30 x 25 g samples in the latter.

Shellfish

Oysters are not a major export item from this country but the trade, worth $250,000 per year in 1978, collapsed when over 2,000 people in five Australian states suffered food poisoning attributed to these molluscs.

The DPI suspended the issue of export licences as a precautionary measure but exporters had suspended exports voluntarily before this. It was concluded that the causal agent was Norwalk virus. Several years previously, Sydney rock oysters had come under suspicion in the UK as vectors of food poisoning. Here also the Norwalk virus appears the likely agent but this was not confirmed.

Fruit

Australia is a long standing exporter of fresh pome and citrus fruits, and substantial losses had occurred from time to time. With apples and pears, the problems have been predominantly physiological disorders rather than microbial wastage. The more common problems with citrus, however, have been attack by fungi.

The dried fruit industry has a much longer export history. It emerged in Australia in the 1890's, based on the sun-drying of grapes. Mechanical dehydration of apples commenced in Tasmania at about the same time. The sun-drying of fruits encountered many difficulties, even after pre-drying dips and sulphuring were introduced.

Fungal attack was a problem that had to be addressed by proper moisture control before a flourishing export trade could be established. But established it was, and some 60,000 tonnes of raisins, sultanas and currants are now exported annually, the largest markets being the Federal Republic of Germany and Canada.

In recent years there have been major rejections of dried vine fruits in Europe because of mouldy and musty off-flavours which are accentuated when the fruit is used in bakery products.

These taints can be derived from chlorophenols used as preservatives of the adhesives employed in constructing cardboard boxes and used as preservatives of timber in containers. The problem is indeed a microbiological one, because moulds that grow on boxes when moistened by condensation methylate the chlorophenols to chloroanisoles, which were the tainting chemicals in many cases.

Bean Sprouts

Salmonellae are commonly transmitted to humans via foods of animal origin. On occasions, however, plant materials are the vectors. Outbreaks of salmonellosis in both the UK and Sweden in 1988 were traced to bean sprouts produced from Australian mung beans - now a significant export item.

As with dried food such as milk powder, *Salmonella* can survive for long periods in or on the dry seed and can multiply rapidly on hydration which is necessary to promote germination and production of the bean sprout. *Salmonella saint-paul* and *S. virchow* were isolated from patients and sprouts in the UK, and *S. saint-paul*, *S. havanna* and *S. meunchen* in Sweden. At the height of the outbreak the main British importer held stock, presumed to be contaminated, worth $300,000.

Salmonellae are difficult to isolate from mung beans prior to germination. Then the conditions become favourable for multiplication to large, and apparently infective, numbers. A code of practice to control contamination of beans with *Salmonella*, which apparently comes from the harvesting and handling environment, has been developed by the Department of Primary Industry and Energy in Australia.

Political Microbiology

This example of a microbiological problem on the food export market is a little bizarre. In 1983, three members of a family in Griffith, NSW, were hospitalised with botulism after a meal that included Taiwanese canned mushrooms.

The mushrooms were suspected as the vehicle, and Taiwanese mushrooms were withdrawn from the Australian market and health departments in Germany, USA and Japan were informed.

No scientific evidence linking botulism with these mushrooms was found, but it was claimed that Taiwan's $60 million canned mushroom export trade was wiped out.

What has this to do with Australian food exports? In reprisal, Taiwan banned imports of Australian meat and dairy products worth $100 million a year (and threatened to extend the ban to coal and iron ore - worth $120 million a year).

Our annual imports of mushrooms from Taiwan were valued at $4 million. The ban was lifted after a month.

Conclusion

The events reported here are not meant to be comprehensive but to show the types of problems with a microbiological basis that have affected our food exports.

They range from the mysterious, in the days before microbial activities were understood, to the complex, where microorganisms not necessarily in contact with foods have caused taints. In between there are situations which, by hindsight, should have been predicted. They weren't, any more than the problems of Listeria in soft cheeses and *Clostridium botulinum* in garlic preparations have been more recently. Microbiologically, there is always something new around the corner.

Reference

FARRER, K.T.H. (1980). *'A Settlement Amply Supplied'*. (Melbourne University Press: Clayton).

News From The Division

Retirement of Dr J.N. Olley

CSIRO's distinguished biochemist and fish technologist, Dr June Olley, has retired from the organisation.

After completing her PhD in 1950 and working with Medical Research Council, Dr Olley spent 18 years at Torry Research Station at Aberdeen, the UK laboratory devoted to seafood technology.

Her work at Torry mainly involved fish lipid biochemistry and her applied work concerned the processing and nutritional properties of fishmeal.

She decided to move to Tasmania, and in 1968 she joined the CSIRO Division of Food Preservation at the Tasmanian Regional Laboratory.

In Hobart, she quickly established herself as an authority on the canning, drying and general processing of abalone, an industry then in its infancy and in need of scientific help. This was followed by investigations into heavy metal pollution in the Derwent Estuary and its effects on the fledgling oyster growing industry and the inshore fisheries.

Many other general fish technology problems were tackled under her guidance, including mechanical separation of fish flesh, electrophoretic identification and sensory evaluation.

Dr Olley has always maintained a high level of industry liaison, believing it essential for the effectiveness of a fish technology group. She has worked on problems of practical significance in the belief that underlying patterns will emerge and that a broad brush approach is the best way of seeing the patterns in the data. Furthermore, she has inspired others to follow the same path.

This is particularly evident in her most important work temperature function integration, bacterial growth rates and rates of deteriorative change in stored foods.

Much of this work has been done in collaboration with the University of Tasmania, but it has been Dr Olley's enthusiasm, drive and good spirits that have kept the momentum.

This highlights a most important part of Dr Olley's scientific approach in that she is always willing to listen and to share: 'why compete when you can have more minds working on the problems, since there are more than enough [problems] to go round'.

Many students have benefited from her wisdom, advice and help, given unstintingly. Similarly, many young scientists (and some not so young) have much to thank her for in helping their careers.

This is evident in her Fellowship of Christ College of the University of Tasmania, where she is regarded as something of a 'fairy godmother'. In more recent times, she has taken an interest in the development of research centres in South East Asia, particularly Indonesia, Thailand, Malaysia and the Philippines.

Among her many achievements and awards are: a DSc from the University of London in 1968; Membership of the Order of Australia in 1987; Fellow of the Institute of Food Science and Technology (UK); Foundation Fellow of the Academy of Technological Sciences; Member of the Faculty of Agricultural Science at the University of Tasmania; Senior Vice President of the Tasmanian Royal Society; Member of the National Research Fellowships Advisory Committee and Award of Merit from the Australian Institute of Food Science and Technology.

In addition to this recognition, she also received an honorary Doctorate in Science from the University of Tasmania in April, 1989.

Dr Olley is now in residence at the Department of Agricultural Science, at the University of Tasmania where she is writing a book with two of her co-workers, Drs Tom McMeekin and David Ratowsky.

Retirement of Mr K.J. Scott

Mr Kevin Joseph Scott, a Senior Research Scientist with the Department of Agriculture, NSW, took early retirement in January, 1989, so closing his official career of 32 years during most of which he was located in the CSIRO Division of Food Processing and its predecessors.

In 1952 he received his B.Sc.Agric. degree at Sydney University which he followed with a Teaching Diploma and Certificate in Education. After school teaching for a few years he jomed the Department of Agriculture, NSW as a Fruit Research officer in 1956. Kevin was assigned to work with Mr Eric Hall's group in the then Division of Food Preservation at Homebush in Sydney, NSW.

This continued the long collaboration in fruit storage research between the Department and the Division which began in 1938.

His scientific achievement is recorded in over 90 published papers covering his work on most of the major and minor fruits grown in Australia. Kevin's work resulted in major recommendations to the industry for the storage of apples and pears. He made a speciality of storage disorders which afflicted fruit as improvements in storage techniques gradually extended their storage life, especially under controlled atmosphere conditions. His work on the post-harvest application of calcium salts to prevent the physiological disorder of apples known as bitter pit was at the forefront of worldwide efforts to overcome this commercially important disorder.

Collaboration over a some years with the New Zealand Apple and Pear Board permitted rapid commercial implementation of his findings, leading to the control of this disorder in certain varieties both in New Zealand and Australia. Kevin has strongly advocated commercial application of research findings but only after thorough verification.

He has always been conscious of the costs involved in the commercial implementation of research findings and has often developed his research projects with this in mind so that the smaller growers would be able to up-grade their facilities in line with economic benefits to them.

Kevin's career has been notable for the extent of his collaboration with colleagues in CSIRO, other State Departments of Agriculture, Universities, particularly the University of NSW, and more recently in overseas countries.

This has enabled him to take a leading role in initiating research not only in the major crops such as apples, pears and bananas but also in a range of the 'new' tropical and subtropical fruit crops such as mango, avocado, litchi, guava, custard apple and kiwifruit. A long series of papers with R.B.H. Wills has substantially advanced our knowledge of the causes and means to ameliorate the storage disorders of apples. Some of the principles established in this work are being applied in other fruit. It is sad to see that, despite the research efforts of Kevin Scott and other colleagues in Australia, the industry has been unable to maintain its overseas export markets for apples and pears in competition with other S. Hemisphere producers.

Kevin in recent years has been able to apply his wide experience in fruit handling and storage to a number of overseas situations in South East Asia and China. Support from the Australian Centre for Intemational Agricultural Research allowed three years work on the handling and transport of fruits and vegetables in Papua New Guinea.

This has resulted in replacement of the highly expensive air transportation system by more cost effective land and sea transport by container with attendant improvements in quality.

Consultancies in the Philippines and Indonesia have permitted, for example, application of the polyethylene bag method for storage and transport of bananas which was developed by Kevin in collaboration with CSIRO colleagues at the Food Research Laboratory. His work in the People's Republic in China, has begun the process of improving banana handling there.

Kevin was always ready to help colleagues, particularly younger scientists starting their careers. His wise counsel, skills and experience will be missed in the public sector research. However, he is continuing his work through private consultancies. His sailing boat will doubtlessly prove an even greater temptation in retirement.

D. Graham

Retirement of Dr W. B. McGlasson

Dr Barry McGlasson, Senior Principal Research Scientist, took early retirement on 8th December, 1988, following his transfer to the Division of Horticulture. He had served CSIRO for over 24 years, joining the Division of Food Preservation as a Senior Research Scientist in June 1964.

Barry was born in South Australia and took his B. Agric. Science degree at Adelaide University in 1951. He was the first Horticultural Research Officer with the South Australian Department of Agriculture from 1951 to 1964, taking leave during 1959-62 to obtain his Ph.D. at the Department of Vegetable Crops, University of California, Davis, USA, studying under Professor H.K. Pratt. He has maintained strong connections with the United States in his field since then.

He joined the Fruit Storage Section of the Division of Food Preservation 'to take a leading part in the research on the physiology of fruits after harvesting, especially in relation to disorders occurring during ripening and storage'.

From these beginnings Barry has developed a national and international reputation not only in fundamental postharvest physiology of fruits but also in the applied aspects of storage, handling and marketing of fruits and vegetable. In Australia, he is known as 'Mr Tomato' to the industry and the consumer for his expertise in the fruit which has become his major speciality. He has published over 80 papers, including a number of seminal reviews on the role of ethylene and other hormones in the ripening of fruit. He is a co-author of the introductory text 'Post-harvest: An Introduction to the Physiology and Handling of Fruit and Vegetables'.

After joining the Division of Food Preservation, Barry quickly built up a laboratory for research on postharvest physiology. He has attracted many overseas workers to it.

His early research concentrated on apple disorders, chilling injury of bananas and the role of ethylene and other hormones in fruit ripening. He was co-author in 1971 of a key paper with K.J. Scott, J.R. Blake, G. Strachan & B.L. Tugwell on polyethylene bag storage of bananas which has opened the way to the increasing use of modified atmosphere packaging for transport of bananas at ambient temperatures.

This work has now been applied by others to many other fruit at a range of temperatures, with varying success.

Study leave in 1973 to Purdue University resulted in his recognising the value of the physiological-genetics approach to ripening. He pursuaded his colleagues that this was the way to go and it has resulted in physiological and biochemical studies on tomato ripening which have gained him, and his colleagues C.J. Brady and J. Spiers, international recognition.

Since the mid 70's Barry increasingly sought to apply his fundamental knowledge to the handling, transport and storage of fruits and vegetables. He is well known throughout the industry, particularly at the marketing end. His advice is frequently sought by the industry and the media.

He has also applied his expertise to overseas situations through a series of aid projects, including the ASEAN Postharvest Horticulture Project in which he helped in designing and commissioning the ASEAN Postharvest Horticulture Training and Research Centre at Los Banos in the University of the Philippines. He contributed to aid projects in Pakistan, Bhutan, Papua New Guinea and China.

Barry always strongly advocated the need for Government supported scientists to carry out public service. Apart from industry extension activities and the many media presentations, he helped organise the highly successful XX International Horticultural Congress held in Sydney in 1978. He was Chairman of the Technical Program Subcommittee and his professionalism ensured the highest standards were maintained.

Following his retirment from CSIRO Barry has been invited to be a Fellow of the Faculty of Horticulture at the newly-formed University of Western Sydney to lead the development of postharvest horticulture teaching and research at the University's Hawkesbury campus.

CSIRO's loss is certainly the University's gain since his experience and expertise are ideally suited to the task. We all wish Barry well in his future career, knowing that his talents will be applied to the benefit of the students and faculty of the University and the postharvest horticulture industry at large.

Death of M. Henri Cheftel

The following notice was provided to the Division by M. Claude Cheftel. The Division regrets the passing of M. Henri Cheftel and is pleased to acknowledge his outstanding contribution to food science.

Born in Milan in 1902, Henri Cheftel graduated in chemical engineering at the Federal Polytechnic School in Zurich. After additional training in microbiology and biological chemistry at the Pasteur Institute, Henri Cheftel started the Research Laboratory of Carnaud et Forges de Basse-Indre (Paris), the major French tin plate and can manufacturer.

As head of this research laboratory from 1930 to 1969, then as scientific consultant till 1976, Henri Cheftel devoted all his professional activities to the scientific and technical study of food canning.

Henri Cheftel was the first in France to study and verify the recently proposed laws of food sterilization, and was responsible for their correct application throughout the French food industry. Studies carried out with his collaborators concerned the nutritional value, microbiology, statistical sampling and quality assurance of canned foods; can corrosion, various biochemical and technical aspects of canned fish, fruits and vegetables, the invention of the flame sterilizer and the contamination of certain foods by trace metals.

These studies were reported in about one hundred scientific publications, fourteen printed monographs (including one on sterilization process times, translated into several languages), and four books. Henri Cheftel was also the organiser of the first six International Congresses on Canning (starting in 1937); one of the founders, teachers and advisors of the School of Canning and Appert Institute (Paris); one of the experts of the joint FAO/WHO Committees on Food Additives; a member of the French Academy of Agriculture, of the French Public Hygiene Advisory Board, and of several other scientific societies, including the Institute of Food Technologists (designated as Fellow in 1983).

Several prizes were awarded to Henri Cheftel, among which were the International Award of the American Institute of Food Technologists (1958), the Underwood-Prescott award from the Massachusetts Institute of Technology (1965) and seven French awards of distinctions.

New Publication

'Food Science and Technology in Australia'

By Dr J.R. Vickery

The main purpose of this book is to give food technologists in industry and students in training a comprehensive review of research findings by Australian workers in government, university and industrial laboratories.

To further its aims as a reference book, detailed bibliographies of some 1,400 research papers have been compiled—particularly for the period prior to access to references through computer data banks.

Another aim has been to draw attention to the many contributions which brought international recognition to their authors; Australia should be proud of them, particularly those who, in the earlier years, did not have the advantages of modern separation, analytical and computational techniques.

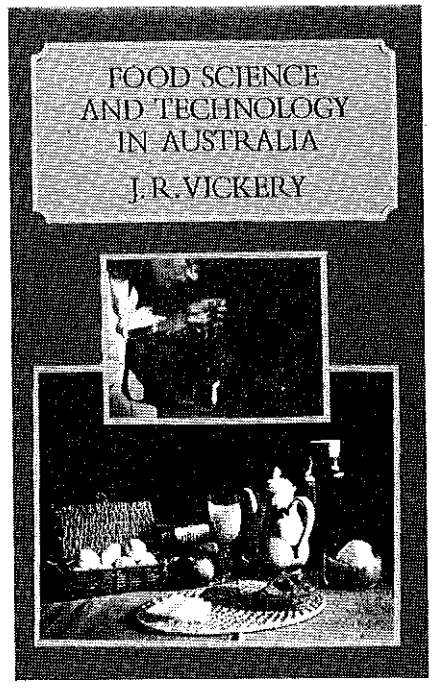
THE AUTHOR

Dr J.R. Vickery, OBE, MSc, PhD, FAIFST, FRACI, FIFST (Hon), Fellow IFT (USA), FTS was appointed Officer-in-Charge of the CSIR Section of Food Preservation in 1932, and Chief of its successor, the Division of Food Preservation, in 1940. He retired in 1967 and, until 1985, held a Senior Research Fellowship in CSIRO.

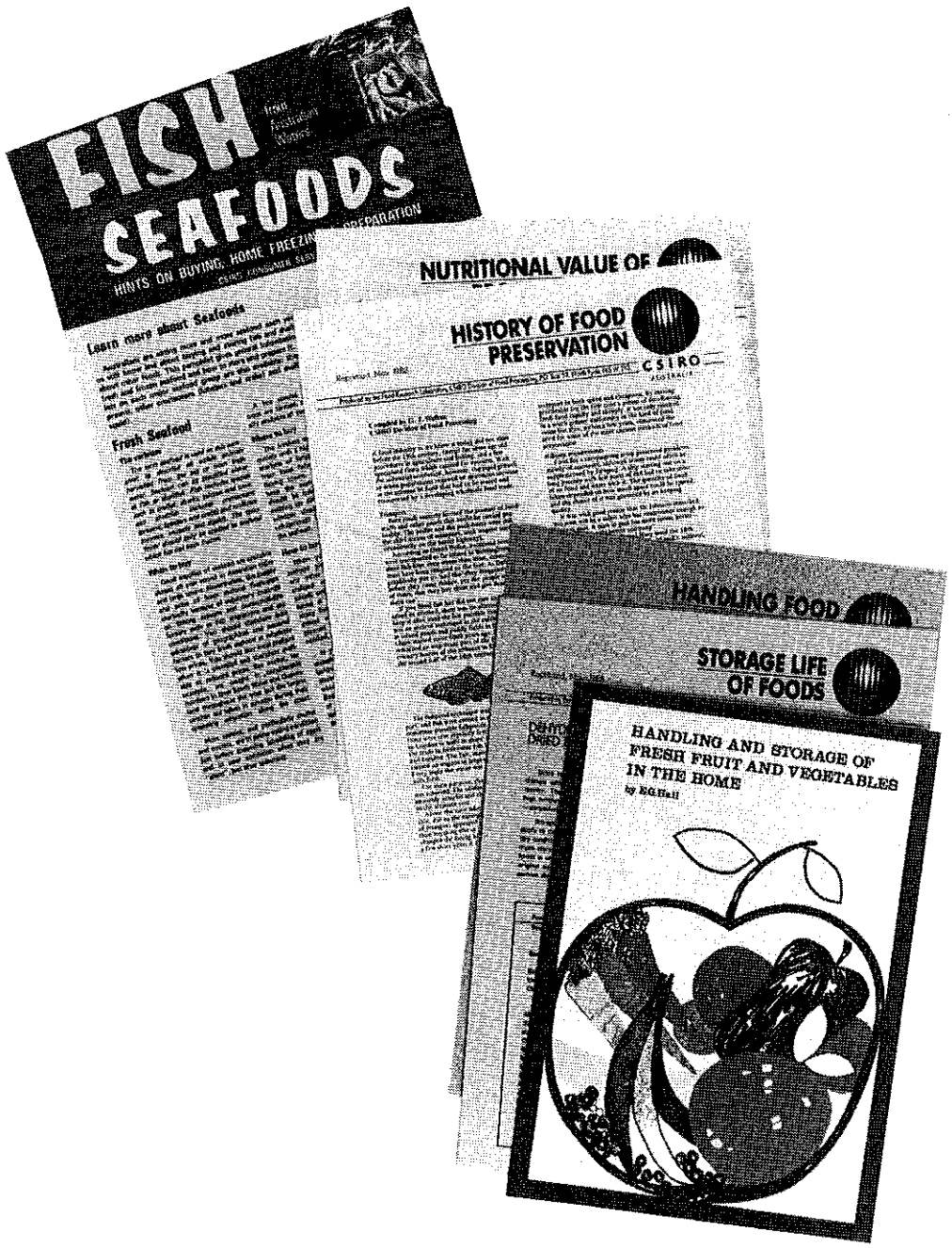
In 1958 he was seconded to the British Ministery of Agriculture, Fisheries and Food to advise the Government concerning the establishment of a meat research institute in the United Kingdom. He has received the International and Australian Awards of the Institute of Food Technologists (USA), 1960 and 1966, and was the Fred W. Tanner lecturer of the Institute in 1971. He was the first recipient of the James Harrison Medal of the Australian Institute of Refrigeration, Airconditioning and Heating, 1973. The 'James Vickery Medal' and the 'James Vickery Lecture' were created by the Australian National Committee of the International Institute of Refrigeration (1987) and by the Australian Institute of Food Science and Technology (1988) respectively.

His personal research interests have been mainly in the chemistry and processing of meat and eggs and in the chemistry of lipids. He has been the author of some 50 research papers.

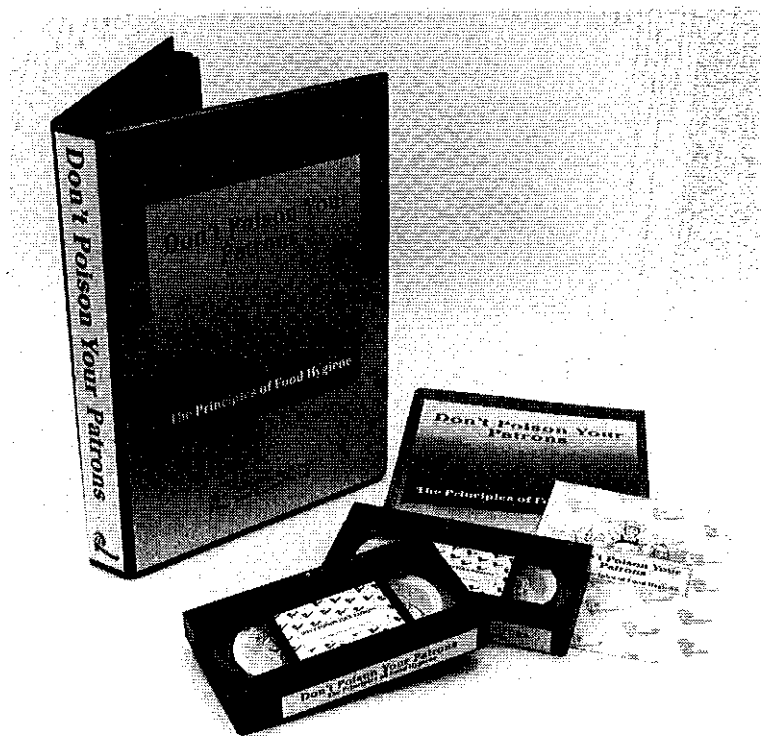
February, 1989, 200 pages hardcover. $30.00 rrp.
ISBN 0 643 050507



Division of Food Processing Selected Publications



Selected publications available on application to Food Research Laboratory
PO Box 52, North Ryde, NSW 2113 Ph: (02) 887 8333



Selected publications available on application to Food Research Laboratory
PO Box 52, North Ryde, NSW 2113 Ph: (02) 887 8333