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# Experimental Cool Stores at Scoresby, Victoria

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**The Horticultural Research Station at Scoresby, Victoria, was established in 1946 by the Victorian Department of Agriculture, which pioneered fruit cool storage research in Australia. This article outlines the history of the establishment and its research activities.**

THE Victorian Department of Agriculture was the pioneer in fruit cool storage research in Australia. The Department established its own cool stores in Flinders Street, Melbourne (the Government Cool Stores) in 1891. This store was used for the storage and cooling for export of all types of perishable foodstuffs, including fruit. In 1904 the Department established and operated at Doncaster the first of a number of cool stores built exclusively for fruit cool storage. Subsequently fruit cool stores were established in other fruit-growing districts.

## Early Research

Over those early years the Department conducted quite a number of simple storage trials of the "hit or miss" type and it soon became known which fruits could easily be stored and which could not. The limiting factor to successful fruit cool storage in those days was the onset of disorders concerning which virtually nothing was known.

It was realized by all concerned that progress in fruit cool storage depended on continuous research into the behaviour of fruit at low temperatures. With that in view the Department in 1923 set up at its Government Cool Stores (then greatly enlarged and transferred to its new site at Victoria Dock) a number of experimental chambers to be used exclusively for fruit cool storage research. The work has continued ever since.

The first experimental cool chambers were constructed merely by subdividing a large commercial chamber to form a central passage-way with four small chambers each about 10 ft by 10 ft on either side. Some of the chambers were cooled by air circulation over a grid of cold external pipes sprayed with brine, whilst in other chambers the direct expansion system of cooling was adopted, with cooling coils placed on walls and ceiling. In all cases temperature control was manual, adjustments to ventilators and expansion valves being made by the stores' engineers on their regular two-hour rounds. Even so, temperatures fluctuated several degrees and storage experiments involving precise temperature control were scarcely possible. Later, automatic temperature control was installed, the above systems being scrapped in favour of automatic brine circulation through overhead cooling coils.

## Collaboration with CSIR

It is of interest to record that over the years 1932–40 the tempo of the work was stepped up by CSIR (the forerunner of the present CSIRO), which joined forces with the Department on a cooperative basis. The first work by CSIR on fruit cool storage was conducted there, but laboratories and experimental cool chambers were later set up at Homebush, N.S.W., and CSIR transferred its officers to that centre.

The early work showed that the storage behaviour of fruit was determined by pre-storage factors, particularly maturity at picking time, just as much as by the actual storage conditions, and that progress depended largely on being able to control the orchard factors as well as the actual storage conditions.

## The Scoresby Research Station

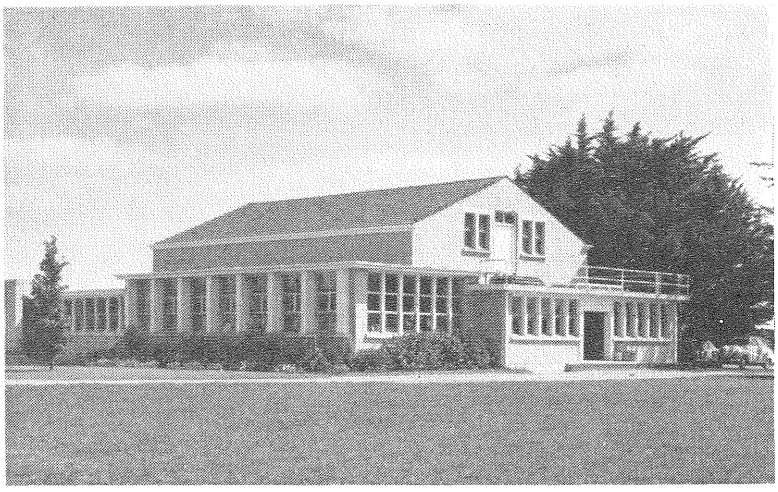
In 1946 the Department decided to set up at Lower Ferntree Gully the Scoresby Horticultural Research Station to study the production of the commercial fruits grown in southern Victoria, i.e. apples, pears, peaches, apricots, plums, cherries, and lemons. There, fruit of known cultural history gradually became available year after year, and it was logical that this should be followed up by storage trials with such fruit. Hence in 1956 the old experimental cool stores at the Government Cool Stores, Victoria Dock, were abandoned and new ones were constructed at the Scoresby Horticultural Research Station. The new stores are much larger and better equipped than the old.

At Scoresby there are now 11 experimental cool chambers. On one side of a wide air lock there are four chambers, each 20 ft by 15 ft, whilst on the other side of the air lock are seven smaller chambers of varying size, but mostly about half this size. One of the smaller chambers is specially equipped for deep-freeze studies, while another is used for controlled ripening at higher temperatures.

The chambers are constructed of brick and are insulated with 4-in. Onazote. Temperature control is automatic to within $\pm\frac{1}{2}^{\circ}$, while humidity is controlled fairly accurately by manual adjustment of back pressure valves.

Cooling is effected by forced-draught circulation over external, heavily finned, flooded ammonia cooling coils. The refrigeration is supplied by three Wildridge and Sinclair compressors of 8-, 4-, and 2-ton capacity, with the switchgear arranged so that the appropriate compressor can be brought in according to the refrigeration load. Also installed are two additional W. and S. compressors of 10- and 5-ton capacity to be used for the cooling of five additional chambers under construction. These are for the storage of the Station's bulk crops of apples and pears.

The engine room housing the refrigeration machinery is situated at the west end of the block of cool chambers, whilst a large room for receiving and examining fruit after storage is situated at the east end.



*Experimental cool stores and laboratories at Scoresby Horticultural Research Station.*

Attached to the block of experimental cool chambers are general offices, laboratories, and a library. These also temporarily serve the requirements of the staff of the research station.

## Research Activities

The staff engaged solely on cool storage research is small, consisting of two research officers and one field officer. On the other hand, we are fortunate in being able, at a moment's notice, to call upon quite a large labour force from the research station staff for the harvesting of fruit and for placing it in cool storage, if need be, within a few hours of harvest. Thus in determining the all-important influence of picking maturity on storage behaviour, it is relatively easy to arrange for a number of varieties of apples and pears each to be picked at, say, eight or nine stages of maturity.

*Apples and Pears.*—Investigations into the effects of picking maturity and storage temperature on fruit quality, storage life, and the development of storage disorders have been the principal lines of research conducted with apples and pears. A technique of reducing storage temperature was introduced in 1940 for the Jonathan variety, which is subject to the low-temperature disorders deep scald and breakdown. This technique is now successfully used in most Victorian cool stores. A similar technique has also been developed for the storage of Granny Smith apples to reduce the development of superficial scald.

Over a period of years the cool storage of apples and pears in controlled atmospheres has been investigated. This work has mainly been with atmospheres obtained by controlled ventilation, and has again been concerned with the study of the effects of maturity and storage temperature. Pear storage work has concentrated on the determination of calendar dates as a guide to the maturity of pears for long storage. The successful storage of pears in Victoria is based upon this information, combined with prompt storage at 29–30 °F.

*Fruit from these apple rootstock trials at Scoresby is used for experimental storage.*

*Stone Fruit.*—Attention has been given to the problems associated with the storage of the soft fruits—peaches, plums, and apricots. Artificial ripening methods have been developed and are being introduced. Considerable interest has been shown in a ripening technique developed for clingstone canning peaches. A "heat therapy" treatment at 104 °F to inhibit the growth of brown rot and transit rot is combined with subsequent ripening at 75 °F; this permits the ripening,

free of rots, of semi-ripe peaches. The treatment is now being used commercially by two of the major Goulburn Valley canneries.

*Grapes and Citrus.*—Experiments with grapes and oranges have mostly been concerned with the prevention of mould wastage, both by chemical treatments and by the use of various storage techniques. Over the past eight years the development and testing of sterilization treatments against fruit fly in oranges have been a major project, conducted under the direction of the Committee on Fruit Fly Sterilization Investigations in Citrus. In cooperation with other State Departments of Agriculture and CSIRO, a cold storage treatment was first developed and a fumigation treatment using ethylene dibromide has now been evolved.*

* See article on p. 15.

Other investigations are currently being made into the storage of berry fruits and vegetables.

With the ever-increasing number of fruit cool stores in Victoria, a considerable proportion of the staff's time is occupied in giving general advice on such matters as cool store construction and techniques to be applied for the successful storage of fruit.

Since 1923, when the work was begun, we have naturally gone a long way and, in general, growers in Victoria can now store their fruits with very little risk of loss. This is shown by the spectacular increase in the number of fruit cool stores in Victoria. Since that time it has increased from a couple of dozen to over 430, with a present capacity of nearly six million bushel cases. The number of fruit cool stores in Victoria and their total capacity now exceed those of all the other States of the Commonwealth combined.

# Temperature Measurement

**By J. Middlehurst**

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**In many industrial and experimental situations it is usually sufficient to know that the temperature at which a process is carried out is the same as it was on some previous occasion, whether a day before or a year before. In some instances, however — for example when starting up a copy of a process — it may be necessary to know the actual value of the temperature. It is then essential that the instruments used to measure the temperature of the original process and the copy be calibrated with reference to the same temperature scale.**

## TEMPERATURE SCALES

A temperature scale is rather different from the scale on a ruler. The latter can be produced by starting at one end (the zero point of the scale) and, after deciding on a standard unit of length, marking off these units with a simple ruling engine. The only theory involved in this is the theory of numbers, i.e. 2 in. is twice as long as 1 in., the interval from 3 in. to 4 in. is the same as that from 6 in. to 7 in., and so on.

A temperature scale cannot be devised in this simple manner without involving additional assumptions. Thus one cannot be sure that 60° on the scale is in fact twice as hot as 30°, or that a change in temperature from 1° to 2° is the same as a change from 61° to 62°. Temperature scales are set up by choosing a zero point and then *assuming* a particular relation between a measurable physical property of some substance and its temperature. The first relationship assumed was that the expansion of water was a linear function of temperature. A scale based on the assumption that the linear expansion of mercury (Hg) is directly proportional to temperature produces a different temperature scale.

## The International Practical Temperature Scale

Lord Kelvin was the first to realize, some 100 years ago, that a perfect gas engine using the expansion of a "perfect" gas could be used to establish a temperature scale that depended on *known*, not assumed, temperature relationships. The scale so produced is known as the thermodynamic or absolute scale. In practice, however, it is not possible to build a perfect gas engine, and other means must be devised to set up temperature scales of practical utility. A number of practical temperature scales do indeed attempt to approach the Kelvin absolute scale as closely as possible, and the best of these is the International Practical Temperature Scale, which has now been adopted by standards authorities all over the world.

The International Practical Temperature Scale (usually abbreviated to I.P.T.S.) is built up by allotting certain numbers to a few fixed points of the temperature scale. Thus the number 100 is allotted to the temperature of condensing steam at a pressure of 1 standard atmosphere (760 mmHg). There are several other fixed points of the I.P.T.S., and those lying within the range $-183°$ to $445°$ are shown in the following table.

**Primary Fixed Points of the I.P.T.S. between $-183°$ and $630{\cdot}5°$**

| | |
|---|---|
| Boiling point of oxygen at 760 mmHg | $-182{\cdot}97°$ |
| Triple point of water | $+0{\cdot}01°$ |
| Boiling point of water at 760 mmHg | $100°$ |
| *Freezing point of zinc | $419{\cdot}505°$ |
| *Boiling point of sulphur at 760 mmHg | $444{\cdot}6°$ |

* The last two points are alternatives.

According to the I.P.T.S. concept, if a sample of the purest zinc obtainable is melted and then allowed to start freezing, so that crystals of zinc and molten zinc are simultaneously present, the temperature of the mixture is *defined* as $419{\cdot}505°$. There is no such thing as absolutely pure zinc with a melting point of, say, $418°$ or, indeed, any value other than $419{\cdot}505°$.

## Subdivision of the Scale

It is easy enough to define fixed points, but the scale must also be arranged so that one can measure temperature anywhere along its range. For the I.P.T.S. this is done by defining standard measuring instruments to be applied over certain ranges of the scale, and in the range of temperature associated with foods the standard instrument is the pure platinum resistance thermometer.

The platinum resistance thermometer consists of a coil of fine platinum wire, constructed in a special way. The thermometer is first calibrated by measuring its resistance at four fixed points (see table). After that it can be placed in any other temperature from $-183°$ to $630{\cdot}5°$, and the temperature can be calculated from a measurement of its resistance.

Such resistance thermometers are normally only to be found in standards laboratories, where they are used as primary standards. These are used to calibrate secondary standards, which in turn are used to calibrate ordinary industrial equipment.

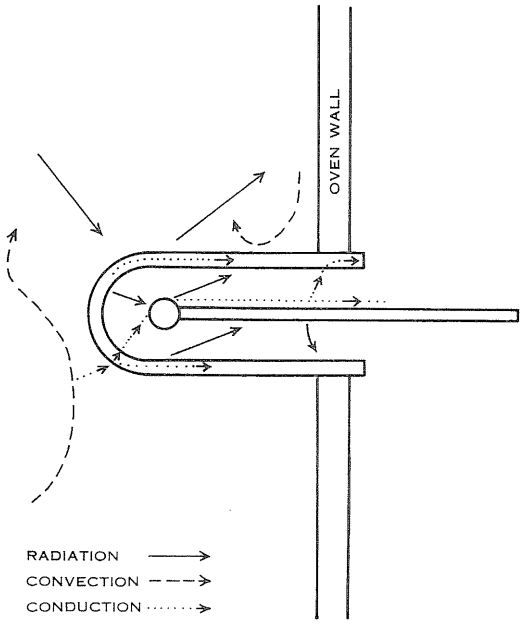
## Advantages of Calibration against I.P.T.S.

It is clear that if each standards laboratory has a reference sample of pure zinc and the other primary materials required for fixed points, the temperature scales used in various countries having such standards laboratories should be very nearly identical. As a consequence if, for example, the CSIRO National Standards Laboratory calibrates a mercury-in-glass thermometer and reports that it indicates $98° \pm 0{\cdot}2°$ when the true temperature is $100°$, one can expect the same thermometer calibration to be obtained elsewhere (e.g. in the U.S. National Bureau of Standards), within the limits of accuracy given by the authority. In this way the I.P.T.S. is truly an international scale.

It is comparatively easy to have all temperature-measuring instruments calibrated with respect to the I.P.T.S., and it is risky not to do so. If a new process is developed using a calibrated thermometer and the thermometer is accidentally broken, a new one, also calibrated, can be used immediately. If the broken thermometer were not calibrated, much time would be wasted finding out what the indication on the new one must be to bring the process to its former condition.

## INSTRUMENTS AND TEMPERATURE MEASUREMENT

All temperature measurement is a compromise. When a temperature-measuring device is placed in a system in order to measure its temperature, its indication will be steady when the heat flowing into it balances the heat flowing out of it. In general, for a given set of conditions this occurs only for a particular temperature of the device; and this temperature differs from that which would




*Heat flow pattern of a sheathed sensing element in an oven.*

have existed in the system if the device had not been placed in it. The only instance in which the correct temperature is indicated is that in which there is no heat flow from the system to the device.

The diagram above illustrates the heat balance at a temperature-measuring device enclosed in a sheath in an oven. The effects of conduction of heat from the device to its surroundings can be reduced by making it of material having a low thermal conductivity, by making it long and thin, and by placing it so that as much of it as possible is at the temperature being measured. The effects of thermal radiation to and from the device can be reduced by making it as small in diameter as possible and by making it a good reflector or surrounding it with one.

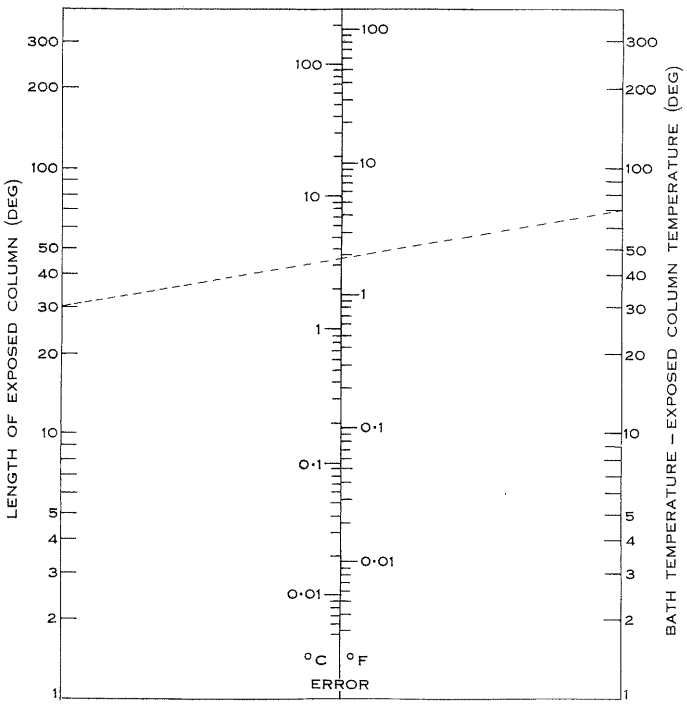
### Types of Error

In temperature measurement it is possible to distinguish between two basic types of error. The first of these, random error, is due to small fluctuations in the sensing device and the indicator, and also in the way the person takes the measurements. For example, an operator may decide to "round off" to 98° a particular temperature close to 97·5° which on a previous occasion he rounded off to 97°.

Systematic error, the second type, tends to be consistent, and accounts for the greater part of the difference between the mean observed temperature and the true temperature. In the above example, if the operator did not know that the thermometer used had a positive bias of 2° he would, in recording 97° or 98° as the mood took him, be making an average systematic error of 2°, the true temperature being somewhere close to 95·5°. Systematic errors may be thought of as "blunders" in temperature measurement, but such blunders do not matter provided one knows the size of the error and the necessary correction that must be applied in order to gain the true figure.

Random errors in temperature measurement are usually small and need only be considered in precise work. Systematic errors, on the other hand, can be very large, and it is necessary to know when they can exist and how to test for them.

All common temperature-measuring systems have at least two sources of systematic error. These are the heat balance at the sensing element, and the calibration correction of the system. The latter is the difference between the true temperature at the sensing element and the temperature indicated by the system under perfect conditions. Other errors may occur, depending on the particular type of temperature-measuring method used, and some of these are indicated in what follows.




*Immersion error of mercury-in-glass thermometers.*

## Mercury-in-glass Thermometers

There are two basic types of mercury-in-glass thermometer: those intended for total immersion and those designed for partial immersion. The total-immersion type is used with the whole of its mercury column at the temperature being measured. The partial-immersion type has a mark on it, usually about 4 in. from the bottom of the bulb, and is immersed only to that mark. Since the reading of a partially immersed thermometer depends not only on the temperature being measured but also on the temperature of the exposed mercury column, this column temperature itself must be measured before one can calculate the true temperature from the thermometer reading. For this reason, and also because the column temperature is affected by draughts, partial-immersion thermometers are used only where total immersion is not physically possible.

*Correction for Stem Immersion.*—A partial-immersion thermometer can be used as a total-immersion thermometer (and vice versa) provided that a correction is made to allow for the column not being at the correct temperature. This can be seen in the following example.

Suppose a total-immersion thermometer used fully immersed in a bath of liquid indicates the liquid temperature of 210 °F correctly (i.e., the thermometer has a calibration correction of 0 °F). Suppose that it is now withdrawn so that the 180 °F mark is level with the top of the liquid, across which air at 140 °F is blowing. The mercury column above the bath will now be cooler (i.e. at 140 °F) than it should be (210 °F), and so will contract: as a consequence the thermometer will indicate only 208·1 °F, even though the bath temperature is still 210 °F.

The diagram above may be used to estimate the error produced in any similar case. If from a point representing the length of the exposed part of the column on the left-hand scale a straight edge is placed so that it intercepts the right-hand scale at a point equal to (estimated bath temperature) minus (average temperature of exposed column), the straight edge will intercept the ERROR line at a point which indicates the correction to be applied. Obviously, if the exposed part of the column is at a lower temperature than

the remainder a positive correction has to be applied, whereas in the converse case the observed reading would be too high and the correction would have to be subtracted from the observed value.

In the particular example given, a straight line has been drawn from 30 on the left-hand scale (i.e. 210 − 180) to 70 on the right-hand scale (210 − 140) and the intercept on the ERROR line is 1·9 °F. This figure added to the observed value (208·1 °F) gives the correct figure of 210 °F.

Clearly, if a partial-immersion thermometer is used in a hot bath as a total-immersion thermometer it will indicate too high a temperature. Conversely, a total-immersion thermometer will give too low a reading.

*Bulb Changes.*—Even when used correctly, the mercury-in-glass thermometer may not indicate the correct temperature. When this type of thermometer is heated, the size of the bulb increases, and on subsequent cooling the bulb does not return immediately to its former size. This lowers the reading (at temperatures below the maximum to which the thermometer was taken) by about 1 degF per 220 degF rise. The effect can be avoided by cooling the thermometer slowly.

Bulb changes can also give rise to other systematic errors. Thus it is usually found that corrections applied to the scale of a thermometer vary along the stem, because of variations in diameter of the capillary; these variations do not change during the life of the thermometer, but because the size of the bulb changes with age all readings may be affected by an equal amount at any given time. The error can be allowed for by checking any one point on the scale. The usual check point is the "ice point" at 0 °C, since this is easily reproducible.

A break in the column of mercury or droplets distilled into the expansion chamber at the top of the stem also produce systematic errors that can be detected by checking at the ice point. Any such defects must, of course, be rectified before the thermometer is used.

## Mercury-in-Steel Thermometers

Mercury-in-steel thermometers are used industrially where remote indication of temperature is required and where thermal lag is not important. After removal of air the system is filled with mercury to a pressure of 600 lb/sq in or more. Better-class systems have compensated capillaries (between the bulb and the gauge) and compensated Bourdon tubes (pressure-sensitive device in the gauge) in order that changes in these caused by local changes in temperature will not affect the reading.

After calibration of this type of thermometer, the chief remaining systematic errors are due to heat balance effects and to the effect of level. The former can be minimized by ensuring that the length of capillary exposed to the temperature being measured is at least 20 times the capillary diameter. A level or "head" deviation occurs if the bulb is higher than the indicating dial and owing to the high density of mercury can be quite appreciable. If the system was calibrated with the bulb level with the Bourdon tube and the bulb is then elevated above it, the pressure at the Bourdon tube increases by about 7 lb/sq in per foot rise of the bulb. This excess pressure causes the instrument to indicate an apparently higher temperature, the magnitude of the deviation depending on the initial filling pressure and the characteristics of the Bourdon gauge and capillary system. Placing the bulb below the Bourdon gauge has a negligible effect for distances up to about 50 ft, again depending on filling pressure.

## Vapour-pressure Thermometers

In an effort to improve on the sensitivity of the mercury-in-steel thermometer while retaining its robustness, the vapour-pressure thermometer has been developed. It relies on the large change that occurs in the vapour pressure of a liquid near its boiling point as the temperature is changed. This gives a greatly expanded scale over much of the dial for the critical region of temperature, the remainder of the scale being somewhat cramped. By suitable choice of liquid the expanded portion of the scale may be arranged to fall within a convenient temperature range. The time constant (a measure of responsiveness) is similar to that of the mercury-in-steel thermometer, but there are certain disadvantages. Condensation of the vapour in the capillary can occur under certain conditions and leads to serious errors in the indicated temperature. This can be avoided only by ensuring that the bulb is always the coolest part of the whole system.

### Gas Thermometers

Originally developed for low-temperature systems, the gas thermometer has been slowly refined and is coming into prominence in commercial applications. Since the gas never condenses, the difficulties of the vapour-pressure instrument are avoided. One considerable advantage of the gas thermometer is that the scale can be calculated from known physical laws and can easily be arranged to be linear. The time constant is about the same as the mercury-in-steel thermometer, but recent models are somewhat faster.

### Bimetallic Thermometers

These instruments have the advantage of ruggedness and cheapness but are not suitable for remote indication. Apart from heat balance deficiencies, their main defect is hysteresis. The consequences of hysteresis may be illustrated by considering for example a thermometer indicating the temperature of a bath raised from 170°F to 190°F which is then allowed to cool to its original temperature. The thermometer might have shown an initial reading of 168°F and given a final reading of 172°F. The difference of 4 degF is called hysteresis, and is caused mainly by friction in the mechanism. It can sometimes be reduced by lightly tapping the indicator dial. To reduce conduction of heat to the surroundings and so minimize heat balance effects the stem of the bimetallic detector should be immersed to a depth at least 20 times its diameter.

### Thermocouples

A thermocouple measures the temperature difference between its "hot" and "cold" junctions, so any temperature indicated by a thermocouple instrument always contains an error associated with the measurement of the cold junction temperature. Incorrect location, inhomogeneity of the wires, and stray currents are the chief sources of additional errors.

Since thermocouples are more manoeuvrable than most temperature-sensing devices it is possible to put the hot junction actually at the position where the temperature is required. This makes the heat balance much easier to adjust towards the desirable condition where no heat flows to the sensing element.

Inhomogeneity of the wires is important only in those parts of the thermocouple that are in a temperature gradient, e.g. where it passes through an oven wall. It can be checked by changing the depth of immersion of the thermocouple, preferably without changing the position of its hot junction, and noting whether the temperature indication changes. Since it is very difficult to calculate the allowance to be made it is better to reject any thermocouple showing a significant effect.

Stray currents can be generated in the electrical connections to thermocouples by having dissimilar metals in temperature gradients, and also by chemical means. The former can be avoided by having each metal junction at a uniform temperature; this applies to the measuring junction, connections between the thermocouple and any compensating leads or switches, and between the thermocouple or the compensating leads and the measuring instrument.

Chemically induced currents can be generated in a thermocouple if any part of it becomes damp. This is usually caused by accidental wetting or by condensation of steam or water vapour. Large, often constant, error voltages can be generated in this way, and careful attention to the insulation of the wires is essential if such errors are to be avoided.

## CONCLUSION

The calibration of all temperature-measuring instruments with respect to the International Practical Temperature Scale makes possible the substitution of one temperature detector for another and facilitates the ready interchange of information without complications arising from the use of individual temperature scales. However, quite large differences can still occur unless there is constant vigilance against systematic errors. The fact that the scale of a thermometer is graduated to, say, 0·02 deg is no indication that this is the final accuracy that will be achieved during use. Indeed, even if the observed readings are reproducible to this degree of precision an overlooked systematic error may result in errors of perhaps several degrees.

# Discoloration in Processed Cauliflower

By B. V. Chandler
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**Non-enzymic discoloration in processed cauliflower is a frequent and widespread problem and has been the subject of recent investigations in the United States of America, Russia, and Germany.**

THIS discoloration in processed cauliflower is not directly related to the discolorations due to the effect of sunlight that appear on fresh cauliflower (de Brouwer and van Koot 1955, quoted from Donath 1962), and such discoloured fresh material can be processed into a satisfactory product, provided that conditions of processing are such that colour changes in normal fresh material are not produced. Also, variations in solar radiation have no significant effect on the degree of discoloration in the processed product obtained from undiscoloured fresh material (Strachan 1959; Donath 1962), as would be expected if exposure to sunlight was the cause.

## TYPES OF DISCOLORATION

Although known in cauliflower processed by other methods, discolorations are particularly important in canned cauliflower products, where two types of discoloration are recognized (Donath 1962).

The first, accompanied by changes in flavour and texture, is due to over-processing, believed to result in the formation of brown products from sugar–amino acid interaction. This discoloration, which can be reproduced in any cauliflower sample providing the conditions of processing are extreme enough, will not be further discussed here, since it can be avoided by using suitable processing times and temperatures. For example, German workers (Serger and Kirchhoff 1956, quoted from Donath 1962) recently recommended for a No. 1 tall can a bringing-up time of 6 minutes, a holding time of 14 minutes at 240 °F, and a 6-minute cooling time. (For comparison, the recommended N.C.A. process for such a can is 20 minutes at 240 °F from an initial temperature of 140 °F.)

The second type of discoloration is distinguished by the considerable variations which cauliflower samples can show in their susceptibility: while some products on processing develop colours ranging from pink to green-black, other samples retain satisfactory colour when processed under identical conditions. Varieties and variants, agricultural treatments, time of picking, and duration and temperature of storage before processing have all been shown to affect the degree of the discoloration (Széchényi 1956, quoted from Donath 1962; Donath 1962).

Many suggestions have been made for the mechanism behind the development of this second type of discoloration: reaction between soluble iron and hydrogen sulphide, alleged to be released in small quantities during processing (Serger and Kirchhoff 1956, quoted from Donath 1962); formation of metal oxides, either naturally occurring or introduced as contaminants (Rummel, private communication quoted by Donath 1962); intervention of polyphenolics (Kyzlink and Chytra 1959, quoted from Donath 1962), and particularly their oxidation to coloured polymers (Markh *et al.* 1959*a*). The same type of discoloration has been reported in canned cabbage (Anon. 1963), and similar suggestions have been made for its origin (Bose 1961), without any positive recommendations for its control.

## Ascorbic Acid

A recent paper (Strachan and Nonnecke 1961) has indicated that ascorbic acid, a recommended additive to processed cauliflower products at the level of 30 mg/100 g brine (cf. Hoogzand and Doesburg 1961), will cause the development within three days of a pink discoloration when used in levels above 50 mg/100 g brine. A process similar to the classic acid-catalysed browning reaction between sugars and amino acids was suggested as the basic mechanism for colour development, but no discoloration occurred when ascorbic acid was replaced by other organic acids or by carbohydrates. The amount of ascorbic acid naturally present (equivalent to 100 mg/100 g brine in the final product) was claimed to have no effect on the degree of discoloration, but a thorough investigation did not appear to have been made into the possibility that variations in discoloration between cauliflower samples could arise from differences in natural ascorbic acid contents. The pink colour was reported to be illusory, since extraction of the pink curd with water gave a colourless solid residue and a brown solution similar in colour to that obtained on treating aqueous extracts of fresh cauliflower with ascorbic acid.

## Polyphenols as a Contributory Cause

The cauliflower studied in the investigations of Strachan and Nonnecke mentioned above was packed in glass jars and, while an explanation based on the above observations may account for discoloration under other processing conditions, an alternative mechanism with particular application to canned cauliflower can be proposed, based on more extensive evidence. This explanation follows from the recent investigations of Donath (1962) on cauliflower discolorations. His results, which disproved earlier theories involving the intervention of oxygen or hydrogen sulphide, indicated formation of complexes between heavy metals and polyphenolics as the basic cause of the discoloration.

A similar explanation has since been offered to account for the post-cooking darkening of potatoes, a problem which Donath recognized as similar to that of cauliflower discoloration. Thus Hughes and Swain (1962) demonstrated that potato darkening was due to a reaction between soluble iron and a polyphenolic acid present in potatoes, namely, chlorogenic acid; though present in separate cells in the raw vegetable, these are able to diffuse together after blanching and cooking. The variable delay in the development of the discoloration was accounted for in terms of the oxidation of soluble iron in the ferrous form to the ferric condition by atmospheric oxygen. Also, while the degree of discoloration was not absolutely dependent on the amounts of iron and chlorogenic acid present, it was dependent on the ratio of chlorogenic acid to citric acid in the potato, since citric acid effectively prevented the iron–chlorogenic acid reaction by formation of stable iron–citric acid complexes. Thus variations in darkening within and between tubers and the effect of changes in pH and acidity levels could be explained satisfactorily in terms of complex formation.

Donath's investigations showed that cell wall destruction was necessary for the development of discoloration in cauliflower, and that the discoloration was more intense in those parts of the head containing the greatest amounts of polyphenolics. In this case the polyphenolics involved were glycosides of the flavonoids, quercitin and kaempferol, and the degree of discoloration in cauliflower heads was directly related to the yellowness of the raw material, which is due to the presence of these flavonoids. Discoloration could be produced, where it would not otherwise occur, by addition of heavy metals, particularly iron, and Donath believed that under normal conditions metal contaminants rather than naturally present metals were involved. However, the iron content of cauliflowers (*c.* 15 mg/kg) would indicate that metals present could be just as responsible for this discoloration as they are in the darkening of potatoes (*c.* 10 mg/kg), the problem being accentuated by metal pick-up during processing and by can corrosion.

## Complexes of Iron and Tin

The problem with cauliflowers differs from that with potatoes in that exposure to oxygen is not required for colour development. This difference can be explained on consideration of the reactants concerned.

The polyphenol in potatoes, chlorogenic acid, forms with ferrous ions weakly coloured complexes that are stable to hydrolysis only at pH levels above 5; these ferrous complexes are readily oxidized to strongly coloured ferric complexes, which are stable to hydrolysis above pH 4. However, the ferric complexes can comparatively readily be broken, or their formation prevented, by the addition of compounds that complex more strongly with ferric ions, such as citric acid, EDTA, and pyrophosphoric acid (Hunsader and Hanning 1958; Hughes and Swain 1962; Barackman and Klis 1962).

In contrast, the polyphenolics in cauliflower (glycosides of quercitin and kaempferol) form with ferrous ions coloured complexes that are stable to hydrolysis above pH 4, and their complexes with ferric ions are stable to hydrolysis at pH levels above 2·5. Both types of complex require the addition of comparatively large amounts of sequestering agents before their formation is inhibited (Heintze 1960).

It is thus evident that in canned cauliflower the state of oxidation of the soluble iron would make only a little difference to the colour of the product, and the addition of sequestering agents would not necessarily provide the same ready solution of the problem as it does for potatoes. Moreover, if the cauliflower were packed in plain cans the discoloration would almost certainly involve stannous ions, since with flavonoids these are capable of forming complexes that are much more stable than ferrous complexes and that resist hydrolysis at pH levels down to 2·5 (Heintze 1960). While these stannous complexes are not as highly coloured as those of iron, being yellow rather than green or black, they provide an explanation for the discoloration of cauliflower packed in plain cans under conditions where ferric ions may not be present, and under conditions of acidity where ferrous complexes would not be stable.

## PREVENTIVE MEASURES

Donath (1962) made a few suggestions for improving the colour of processed cauliflower: the water used in washing, blanching, and preparation of the curd should at all times be low in iron, and stainless steel equipment should be used throughout. He also reported that Markh *et al.* (1959*b*) had recommended steeping the cauliflower in 0·2% sulphur dioxide solution for 30 minutes or in 0·15% sulphur dioxide solution for 120 minutes before processing, longer times or higher sulphur dioxide levels intensifying the discoloration. However, the context of his reference would imply that the cauliflower was to be used for pickling, not canning (the original paper is not available to the present writer), and under these circumstances the function of the sulphur dioxide could be to inhibit the formation of ferric complexes, since the ferrous complexes then formed would be less coloured and, more important, less stable. Similarly, citric acid has been recommended for reducing the discoloration in pickled cauliflower and in the storage of cauliflowers before processing. As mentioned above, there are limitations to the effectiveness of this treatment for canned cauliflower.

In the light of the above discussion, the following recommendations may be made to obviate discoloration of the type being considered:

- Select raw material as close to white as possible.
- Eliminate all possibility of metal pick-up during preparation.
- Use ascorbic acid and sulphur dioxide only at the stipulated levels.
- Use lacquered cans.
- Avoid excessive heat treatment during sterilization.

## CONCLUSION

Finally, since it appears that the tendency of cauliflowers to discolour during processing depends on the variety and on conditions of growth and storage, it has been recommended (Donath 1962) that a thorough investigation of the influence of such variables could provide a satisfactory permanent solution to the problem. It may be noted that investigations into post-cooking darkening of potatoes now centre on breeding, fertilizer treatment, and pre-cooking storage. Although these variables mainly affect the citric acid content of the raw material, and hence may not be

important factors in cauliflower discoloration, it is quite possible that a solution to the problem may be found in investigations of this nature.

In addition, much remains unknown regarding the stability of polyphenolic–metal complexes and the effect thereon of sulphur dioxide and ascorbic acid, and fundamental studies on this aspect of the problem could provide practical suggestions for the elimination of cauliflower discoloration by variations in preparation and processing procedures.

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# New Processes and Product Development

The University of Florida and the Florida Section of the Institute of Food Technologists, U.S.A., are conducting a short course for the food industry at the University of Florida, Gainesville, Florida, from September 28 to October 1, 1964. The course, entitled "New Processes and Product Development", will review procedures for determining consumer demand, for collecting and screening new ideas, for developing new products in accordance with economic and quality specifications, and for gauging consumer acceptance. It will also outline recent advances in freeze drying, in aseptic processing, and in the use of ionizing radiation and sonic and ultrasonic devices.

The fee for the course is $30.00. Additional information may be obtained from Dr. G. D. Kuhn, 111 Dan McCarty Hall, University of Florida, Gainesville, Florida 32603, U.S,A.

# Post-harvest Sterilization of Oranges against Queensland Fruit Fly*

By D. Leggo,† J. G. Gellatley,† J. A. Seberry,† I. D. Peggie,‡ J. K. Long,† and E. G. Hall§

**For quarantine purposes, New Zealand has recently officially recognized ethylene dibromide (EDB) fumigation of packed oranges as an acceptable measure against Queensland fruit fly. This follows the successful completion of considerable research in Australia on post-harvest sterilization methods, research in which the Australian citrus industry and State and Federal authorities have collaborated closely since 1955.**

THE Queensland fruit fly, *Dacus* (*Strumeta*) *tryoni* (Frogg.), has in the past caused serious interference to trade between fly-affected citrus areas in Australia and places here and abroad where quarantine barriers against the fly exist. As a consequence, much work has been carried out on post-harvest commodity treatment techniques, chiefly in New South Wales and Victoria. What was required was a technique of post-harvest sterilization which would not only be effective against Queensland fruit fly but would be economically practicable and acceptable to the citrus industry.

In 1955 the problem was brought formally to the attention of State and Commonwealth authorities by the Federal Citrus Council of Australia, with a request that research in this field be intensified and coordinated. Subsequently, on the recommendation of the Australian Agricultural Council, the Technical Committee on Fruit Fly Sterilization Investigations in Citrus was established to initiate and direct investigations. This committee comprised representatives of the Department of Primary Industry, of CSIRO, and of the Departments of Agriculture of New South Wales, Victoria, and South Australia. Funds for the investigations were contributed on the basis of one-quarter each by the Commonwealth and the Federal Citrus Council of Australia, and one-sixth by each of the above three States.

Earlier cooperative investigations by the Division of Food Preservation of CSIRO and the Entomology Branch of the N.S.W. Department of Agriculture had shown that a vapour heat treatment developed by the U.S. Department of Agriculture (Baker *et al.* 1944) for sterilization of citrus caused injury to Australian fruit. The committee therefore directed investigations into sterilization by low-temperature storage and by fumigation with ethylene dibromide (EDB), since these treatments were in use in other parts of the world against other species of fruit fly. More recently work was commenced on gamma irradiation, these studies being undertaken by the CSIRO Division of Food Preservation in collaboration with the Australian Atomic Energy Commission.

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Artificial infestation of oranges with Queensland fruit fly proved to be necessary for the experimental work. Oranges are not a preferred host, and even from areas where fruit fly is abundant it was not possible to obtain naturally infested oranges in sufficient quantity. A method of artificial infestation of oranges by deep implantation of fruit fly eggs collected from laboratory-bred Queensland fruit flies was developed by Friend (1957). This enabled several hundred heavily infested oranges to be produced each week.

## LOW-TEMPERATURE STERILIZATION OF ORANGES

In 1955, New Zealand quarantine regulations already allowed the entry of South African oranges stored at 31 $\pm$ 1°F for 21 consecutive days as a sterilization treatment against fruit flies, but this treatment caused excessive injury to Australian oranges. Because injury after 14 days' cold storage was usually negligible, it was desirable to ascertain whether the shorter period of storage was equally effective for sterilization purposes.

Investigations were commenced on low-temperature sterilization in 1955 by the Entomology Branch of the N.S.W. Department of Agriculture, using cool storage facilities provided by the Division of Food Preservation, CSIRO. Fruit fly eggs for this work were provided by the CSIRO Division of Entomology and by the Department of Zoology of the University of Sydney. Thirteen trials of low-temperature treatment of 14 days at 31 $\pm$ 1°F were carried out between November 1955 and February 1956, using artificially infested Valencia oranges. Only two larvae out of 19,571 survived, and even these failed to develop into adult flies.

The results of these trials were presented to the New Zealand authorities, who indicated acceptance of the treatment in May 1956, and the 14-day cool storage treatment has since been used for Australian oranges exported to New Zealand from fruit fly areas. However, it is not favoured by the trade because of the space and time involved in storing the fruit and because of the cost of the treatment; there is also some risk of cold injury to the fruit.


*Commercial EDB fumigation chamber (Wyong Co-operative Citrus Packing House, Ltd.).*

## EDB FUMIGATION

### Sterilization of Oranges

Investigations in Hawaii and California showed that fumigation with EDB for two hours at 70°F or over was a satisfactory quarantine measure against Oriental and other fruit flies, and this treatment was subsequently approved as a condition for entry of Hawaiian fruits into the mainland of the U.S.A. (U.S. Bureau of Entomology and Plant Quarantine 1951). The EDB treatment has the practical advantage over low-temperature sterilization that it is of short duration and requires relatively inexpensive equipment.

After preliminary studies in Sydney and at Gosford, special laboratory and insectary

facilities were constructed at the Citrus Wastage Research Laboratory, Gosford, and investigations were commenced in 1956. These investigations were carried out mainly at Gosford by the Entomology Branch and the Division of Horticulture of the N.S.W. Department of Agriculture and by the CSIRO Division of Food Preservation. Associated investigations on non-infested fruit were carried out by the Division of Horticulture of the Victorian Department of Agriculture at Mildura and Melbourne and, in the early stages, by the Department of Agriculture of South Australia.

and the initial work was confined to unpacked fruit in field cases. For mortality studies the oranges were artificially infested with fruit fly eggs produced in the insectary.

Most of the fumigations at Gosford were carried out in experimental 10 cu ft galvanized-iron chambers containing two field cases, each case holding one bushel of oranges. This represented a 40% loading of the chamber. Liquid EDB was volatilized by heat and the vapour circulated constantly by an electric fan. Distribution of EDB was found to be uniform in fruit located in various positions within the 10 cu ft chambers and

*Citrus Wastage Research Laboratory, Gosford. Investigations on EDB fumigation of citrus fruit have been in progress at this centre since 1956.*

## Investigations at Gosford

The initial trials at Gosford indicated that the fumigation dosage rate recommended in Hawaii against Oriental and other fruit flies was not adequate against Queensland fruit fly in oranges. Consequently the use of higher initial dosages and the possibility of fruit injury at these levels were examined.

Another problem was to determine dosages, for various fruit temperatures, that would obviate the necessity of heating fruit to 70°F, as such heating would be both time-consuming and expensive. Valencia and Navel oranges were used in the investigations, within a larger 550 cu ft fumigation chamber.

As a first step, a series of exploratory fumigations was carried out at 50, 60, and 70°F, and the minimum dosages of EDB likely to give 100% larval mortality at each temperature were estimated. Subsequently a large number of experimental fumigations were carried out at these temperatures to accumulate the data necessary to establish that at the chosen dosages none of the treated fruit fly larvae would survive. In a separate series of experiments the movement of EDB into and out of the juice of fumigated oranges was studied.

### Tests on Fruit Injury

Since the early work showed that high concentrations of EDB can cause rind injury to oranges, the dosages proposed for the larval mortality studies were widely tested for fruit injury. Surveys carried out at Gosford with coastal oranges and in Victoria with oranges from the Lower Murray River citrus areas showed that injury was not likely to occur at the dosages required for satisfactory sterilization.

The effect of variation of chamber load on EDB absorption and rind injury was examined in a series of trials at Mildura. Reducing the loading rate from 30% to 15% increased EDB absorption considerably, but often caused development of severe rind injury. On the other hand, increasing the loading rate from 45% to 60% had little effect on absorption of EDB by the fruit.

### Tests on Toxicity

Tests were also carried out to ensure that oranges fumigated with EDB would not present a health risk to consumers. According to standards laid down by the United States Food and Drug Administration (1957), these tests showed that under the least favourable conditions the fruit would be acceptable five days after fumigation. Oranges exported to New Zealand would not arrive at the market less than a week after fumigation and would therefore meet this requirement.

### Acceptance of the Treatment

Studies of various problems associated with EDB fumigation continued until 1961. After 275 separate experimental fumigations in which larval mortality was studied at three temperatures, namely, 50, 60, and 70°F, the total kill was 175,669 larvae, with only four survivors (see table). There were no survivors at EDB dosages now recommended for commercial use, which, for the temperatures shown, are those given in the table.

In the light of these results New Zealand authorities accepted EDB fumigation of unpacked oranges as a quarantine treatment in August 1961.

It was still necessary, however, to test the treatment on commercially packed fruit. Trials at Gosford showed that washed, fungicidally treated, waxed and wrapped packed oranges can be fumigated in a similar manner to unpacked fruit, and in January 1964, New Zealand authorities accepted EDB fumigation as a quarantine treatment for such fruit also. This followed a series of trial shipments to New Zealand in 1963.

The culmination of this work in an effective and economically practicable method of treating oranges from fly-affected areas in Australia is expected to have far-reaching results. Besides having a beneficial effect on inter-State trade in oranges, the process is likely to open up new export possibilities for Australian citrus in the Philippines and elsewhere, as well as in New Zealand.

**Larval Mortalities after Fumigation with EDB for 2 Hours**

| Fruit Temperature | Dosage (oz/1000 cu ft) | No. of Fumigations | Larvae Killed | Larvae Surviving |
|---|---|---|---|---|
| 70°F or over | 18* | 38 | 24,506 | 0 |
| | 16 | 111 | 60,785 | 3 |
| 60 ± 3°F | 24* | 28 | 39,136 | 0 |
| 50 ± 3°F | 32* | 49 | 25,232 | 0 |
| | 24 | 49 | 26,010 | 1 |
| Total | | 275 | 175,669 | 4 |

* Dosage recommended.

For commercial application of the EDB treatment, the fumigation chambers must comply with certain specifications for design and performance, and each fumigation must be supervised by a Departmental inspector. A guide entitled "Instructions for the Design, Official Testing, and Routine Operation of Fumigation Chambers" has been issued by the Technical Committee for Fruit Fly Sterilization Investigations in Citrus.

## INVESTIGATIONS ON OTHER FRUIT

Following completion of the investigations with oranges, a new series of EDB fumigation trials on lemons, mandarins, and grapefruit has been commenced at the Gosford laboratory. A cold-storage sterilization treatment for pears is also being studied.

To deal adequately with these extended activities the Technical Committee has been reconstituted to include a representative from the Queensland Department of Primary In-

dustries. It is now known as the Fruit Fly Commodity Treatment Committee. Funds for the new citrus investigations are being provided by the Commonwealth, the citrus industry of New South Wales and Queensland, and the Departments of Agriculture in New South Wales, Victoria, South Australia, and Queensland. The pear work is being carried out with funds provided by the Northern Victoria Fruitgrowers' Association, the Victorian Department of Agriculture, and the Commonwealth.

## IRRADIATION STERILIZATION

Irradiation as a possible method of post-harvest sterilization of fruit against fruit fly is also being studied. In conjunction with the Australian Atomic Energy Commission the Division of Food Preservation of CSIRO is carrying out studies in this field. So far it has been found that Queensland fruit fly in oranges can be killed by low doses of gamma radiation, but it is not certain whether rind injury can be avoided. When suitable commercial irradiation facilities become available this may prove a useful method of quarantine treatment.

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# NEWS FROM THE DIVISION OF FOOD PRESERVATION

## SIR WILLIAM HARDY CENTENARY

Dr. J. R. Vickery, Chief of the Division, is delivering one of the three lectures being given at Cambridge, England, on June 16, 1964, to commemorate the centenary of the birth of Sir William Hardy, who is regarded as the founder of food science. Dr. Vickery will also be an official representative of CSIRO at the commemoration.

Dr. Vickery's subject is "Hardy's Contribution to the Application of Science in the Food and Refrigeration Industries". The other lecturers are Sir Eric K. Rideal, noted physical chemist who was formerly Professor of Chemistry at King's College, University of London, and Professor A. V. Hill, the distinguished physiologist who was Foulerton Research Professor of the Royal Society for many years.

Sir William Hardy, who died in 1934, was Director of the Food Investigation Board which was set up in England at the end of World War I, and the first superintendent of the Low Temperature Research Station for Biochemistry and Biophysics at Cambridge. Hardy possessed an unusual combination of talents, being equally at home in the physical and biological sciences, and it is to him that we owe the conception of food research as a field of applied biology.

## ASIAN VISITORS

Mr. Seung Yo Ahn, a senior research chemist from the National Research Institute, Ministry of Commerce and Industry, South Korea, who came to Australia in September 1963 as a Colombo Plan Fellow for a period of 18 months, is engaged on an investigation on the discoloration of processed vegetables, at

the Division's laboratories at North Ryde. Mr. Ahn is making a study of food research in CSIRO, and he is visiting a variety of food production areas and food processing plants in the eastern States of the Commonwealth.

Mr. Sher Ahmad Khan, a food technologist from the Agricultural Research Institute at Tarnab near Peshawar, West Pakistan, is spending about half of his six months' sojourn in Australia in the laboratories of the Division of Food Preservation. On this occasion, the second on which he has visited Australia, Mr. Khan is on a Fellowship granted by the Food and Agriculture Organization of the United Nations. He is studying many aspects of food technology and visiting commercial establishments, particularly in New South Wales and Victoria. Mr. Khan, who arrived in Sydney in January 1964, is returning to Pakistan in July.

## NEW APPOINTMENTS

Dr. F. B. Whitfield has joined the Frozen Foods Section of the Division as a Research Officer to undertake chemical and biochemical investigations into the nature and causes of deterioration in stored frozen fruits and vegetables. After a number of years' experience in the laboratories of Unilever Australia, Dr. Whitfield took a science course at the University of New South Wales, where he qualified for his Ph.D. degree in 1963, following a period of chemical research.

The group investigating cyclopropenoid compounds, which are of considerable importance to the poultry and cottonseed industries in the U.S.A. and elsewhere, has been strengthened by the recruitment of two Experimental Officers. Mr. A. C. Fogerty, an organic chemist who holds an M.Sc. degree from Sydney University, and who has had eight years' experience in chemical industry, is assisting with chemical aspects of the research. Mrs. J. A. Pearson, who also holds an M.Sc. degree from Sydney University, is working on the biochemical aspects of the synthesis and biological activity of cyclopropenoid compounds.

Mr. W. J. H. Jackson, who graduated in science at Sydney University at the end of 1963, has joined a team engaged on cattle and beef research. He is carrying out biophysical studies on muscle proteins in the Division's Physical Chemistry Unit.

Miss J. M. Hinchy, a Sydney University science graduate with experience in microbiological research, has accepted a temporary appointment to assist with research into the water relations of bacteria important in food spoilage and food poisoning.

## RECENT PUBLICATIONS OF THE DIVISION

Copies of most of these publications may be obtained from the Librarian, Division of Food Preservation, Box 43, P.O., Ryde, N.S.W. (Tel. 88 0233.)


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