

Guide to

Hazards in the transport and storage of packages —

Part 1: Climatic hazards

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Foreword

This guide makes reference to the following British Standards:

BS 1133, *Packaging code*.

BS 4672, *Guide to hazards in the transport and storage of packages — Part 2: Climatic hazards (maps and diagrams)*.

The preparation of this guide was undertaken, under the authority of the Packaging Standards Committee, following requests to BSI to carry out work on package testing and the evaluation of package performance with the object of facilitating co-ordination of packaging requirements, statutory and otherwise, at national and international levels.

As a first step in the work, detailed information on the climatic hazards to which packages are exposed was collected, and the BSI technical committee responsible felt that the information gathered was of immediate value to those concerned with the transport and storage of goods, either from the point of view of package design or because they have responsibility for the care of cargoes in transit. Accordingly, Parts 1 and 2 of the guide, dealing with climatic hazards, are being published now, and it is anticipated that a Part 3, dealing with mechanical and other hazards, will be published in due course.

The work has now become closely associated with work now proceeding within Technical Committee ISO/TC 122, Packaging, of the International Organization for Standardization (ISO). A sub-committee of ISO/TC 122 is concerned with performance requirements and tests for transport packages, and is supported by two Working Groups, one of which is collecting and assessing the validity of existing information on hazards, while the other is considering the compilation of package performance test schedules appropriate to the various systems of distribution. Some of the work being undertaken is of a relatively long-term nature but the sub-committee is also working on a short-term rationalization of existing methods of test. It is the intention of the ISO sub-committee to take account of work going on at the United Nations Economic and Social Council's committee of experts on the transport of dangerous goods.

Much of the information in Part 1 was provided by the Meteorological Office, who also prepared the maps and diagrams in Part 2 and grateful acknowledgement is made to them.

NOTE Where values stated in metric units are followed by equivalents in imperial units, the conversions are sometimes approximate. More accurate conversions should be based on the tables in BS 350 "Conversion factors and tables".

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 26 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 General

1.1 Scope

This Part of this guide provides selected information about the climatic conditions likely to be encountered by packages in different areas of the world, and as modified aboard ship, in aircraft, in road or rail vehicles, and during storage. It describes the bearing which these conditions may have on the protection needed by goods in transit to or through these areas. Generalized advice is given about measures to be taken to control the insulation and ventilation in a ship's hold.

Appendix A gives some information on the ventilation of ships' cargoes. Appendix B gives a bibliography of some publications that may be of interest to those concerned with a more detailed study of climatic hazards in general or of the particular problems of certain special kinds of cargo.

All references to Figures in this Part of this guide relate to the maps and diagrams in Part 2¹⁾.

NOTE Guidance on packaging problems generally is given in BS 1133, "Packaging code". Section 5, "Protection against spoilage of packages and their contents by micro-organisms, insects, mites and rodents", and Section 6, "Temporary protection of metal surfaces against corrosion (during transport and storage)", are of special relevance to this Part of this guide.

1.2 Terminology

Although this Part of this guide has been written as far as possible in non-technical language the use of a limited number of technical terms used in meteorology, climatology and statistics is necessary. Formal rigorous definitions of the several terms used may be obtained from the scientific literature dealing with those subjects. For the purposes of this Part of this guide the following broad definitions may be regarded as applicable:

- 1) *Vapour pressure*. That part of the total atmospheric pressure which is exerted by water-vapour.
- 2) *Saturation vapour pressure*. The maximum possible pressure which can be exerted at a given temperature by water-vapour.
- 3) *Relative humidity (r.h.)*. The ratio (expressed as a percentage) of the actual vapour pressure to the saturation vapour pressure at the same temperature.

NOTE This can also be defined as the ratio (expressed as a percentage) of the amount of moisture in the air to that in saturated air at the same temperature.

4) *Dew point*. The temperature at which the actual pressure equals the saturation vapour pressure of the water-vapour in the air.

NOTE The dew point of the air can also be defined as the temperature of a glass or metal object just cold enough to cause dew to appear upon it when it is exposed to that air.

5) *Hygroscopic substance*. A substance which is capable, under the right conditions, of absorbing water-vapour from the surrounding atmosphere. Such a substance will continue to absorb moisture until the vapour pressure of the absorbed water is equal to that of the water-vapour in the air. It is then said to be in equilibrium. The equilibrium moisture content of the substance is dependent upon both its temperature and the relative humidity and temperature of the surrounding air. If the moisture content is above the equilibrium value the substance will give up water until equilibrium conditions are reached.

6) *Isopleth*. A line drawn on a map to display the geographical distribution of any element, each line being drawn through places at which the element has the same value; e.g. an isobar is the isopleth of equal pressure.

7) *Troposphere*. The lower layers of the atmosphere extending to about 16 km (52 500 ft) near the equator, 11 km (36 000 ft) in latitude 50°, 9 km (29 500 ft) near the poles, the upper limit being the tropopause.

8) *Tropopause*. The atmospheric boundary between the troposphere and the stratosphere.

9) *Stratosphere*. That region of the atmosphere lying above the troposphere in which temperature does not decrease with increasing height. The stratosphere extends from the tropopause to a height of about 50 km (164 000 ft), where the temperature reaches a maximum.

2 Climatic conditions

2.1 Effect of climatic conditions

Unless adequately protected, goods are likely to be affected to some extent by any or all of the climatic conditions which they encounter during transport and storage. Clauses 2.2 to 2.7 contain information on the principal types of climatic hazards and give examples of some of the kinds of damage which may arise from those hazards.

¹⁾ BS 4672, "Guide to hazards in the transport and storage of packages", Part 2, "Climatic hazards (maps and diagrams)".

The climatic conditions likely to be hazardous to goods during transport and storage rarely exist in isolation, but for convenience they are listed under the following main headings; some examples of the kind of damage likely to arise are also given:

1) *Extremes of temperature*. Very high temperatures may cause expansion of metals, blistering of paintwork, weakening of glued joints, cracking of rubber, softening of preservative coatings, melting of chocolate and fats, and deterioration of oils, fats and chemical products.

Very low temperatures may cause cracking of textile materials when frozen, embrittlement of certain materials, hardening of cushioning materials such as foamed rubber, separation of emulsions, solidification of edible oils carried in bulk, and damage to certain fruits and vegetables if accidentally frozen.

Consideration should be given to variations in temperature during transport when determining the degree of filling allowable in liquid containers. Differential expansion of container and contents may cause rupture or deformation of the container and leakage of contents.

2) *Relative humidities*. High relative humidities may result in moisture absorption which causes corrosion, deterioration of foodstuffs or deterioration of packaging materials such as gummed tape or fibreboard.

Low relative humidities may result in loss of moisture in horticultural produce, loss of resilience in certain cushioning materials within a pack, and shrinkage and cracking of timber.

3) *Association of high temperatures and high humidity* may result in acceleration of corrosion or oxidation of metals, growth of fungi and increased activity of insects and mites.

4) *Large changes of atmospheric temperature and humidity* may give rise to danger of condensation on exposed surfaces of cargoes, the walls of a confined space, or the internal surfaces of a sealed container; moisture in the contents may be lost to the package atmosphere and deposited on the walls of the package when the temperature falls.

5) *Wetness due to precipitation, fog, dew or melting of hoar frost* may cause loss of structural strength of paper and board, corrosion or oxidation of metals, blistering of paints and lacquers, or damage to soluble chemicals.

6) *Heavy snowfall* may cause difficulties and delays in transport by road or rail and possibly by air, and possible damage to goods when the snow melts.

These hazards are examined below in greater detail in relation to transport and storage.

In the clauses which follow some information is given regarding these different climatic conditions over much of the earth's surface. In most instances sets of maps²⁾ for four different months of the year give a pictorial representation of suitable parameters of these climatic conditions. The corresponding texts explain the use of the maps and describe the more important points of special interest.

The information on atmospheric conditions given in the maps refers only to the state of the external air. These conditions will be modified in buildings, vehicles and containers, as well as by any packaging materials and the commodities themselves. The degree of modification will be determined by the specific circumstances.

For instance, the variations in temperature within an unheated building will lag behind the external changes, and the diurnal variations will be reduced. A similar effect will occur within freight containers, railway vans, etc., provided that the skies are overcast. During periods with clear skies, solar radiation may raise the internal temperature significantly above the external temperature during the day, while at night radiation from the surface of the container may reduce the internal temperature to slightly below that of the external air (see Figure 21, Figure 23 and Figure 25), the overall effect being to increase the diurnal variation within the container.

The effects upon thermally insulated containers will depend upon the original temperatures of the contents, but the diurnal variation may be virtually damped out. Long-term (e.g. seasonal) changes in temperature will be followed nearly completely irrespective of the type of enclosure, as thermal insulation will only slow down and not prevent the transmission of heat. In a sealed container these temperature changes can give rise to changes in the internal relative humidity.

²⁾ See Part 2, "Climatic hazards (maps and diagrams)".

Owing to the heating of the upper surface of a container or vehicle by solar radiation, it is possible to get large temperature gradients within the interior. The steel deck of a ship may, for instance, reach temperatures up to 70 °C (158 °F) when exposed to tropical sunshine, but the temperature of the air in the upper hold will fall rapidly with increasing distance from the deck and might be up to 50 °C (122 °F) at 500 mm (20 in) below the deck (see 3.2.2, eighth paragraph).

In all instances the package, as well as the contents themselves, will further modify those internal temperatures.

Changes in the internal relative humidity inside a container in the absence of hygroscopic material are approximately in inverse relationship to changes in the temperature (see Figure 22, Figure 24 and Figure 26). If the contents are hygroscopic, however, the position is much more complex, as the relative humidity is a function of both the temperature and moisture content of the air (which will be governed by the moisture content of the external air), of the degree to which the contents are isolated from the exterior, and of the original moisture content and hygroscopic properties of the goods and packaging material.

Both temperatures and relative humidities internally will be further influenced by the quantity of goods, the way in which they are stacked and the size of the building or container. Matters are further complicated by variations in conditions within stacks of goods. The items on the outside of the stack will be affected by the surrounding conditions to a larger extent than those nearer the centre of the stack, the diurnal variations being reduced towards the centre.

Long-term changes in external temperature will be followed at all points in the stack, but the relative humidities will be more likely to be influenced by the original moisture content of the goods and packaging materials.

It should also be remembered that changes of conditions will occur within sealed packages containing hygroscopic materials, the relative humidities generally rising with increase in temperature, owing to moisture being given up by the contents. The actual relative humidity inside the package is dependent upon the original moisture content of the goods, their variation in hygroscopic properties with temperature, and the ratio of free space to volume of material within the package.

If there is sufficient moisture in the materials within the package, it is quite possible for temperature variations to give rise to condensation on the internal surfaces of the package when their temperatures fall below the dew point of the internal atmosphere.

This effect is especially liable to occur with supposedly sealed packages containing certain desiccants where the absorption of water is reversible, such as silica gel or activated clays, which have become exhausted owing to permeation of water-vapour through the barrier during prolonged storage or to diffusion through a fault in the barrier.

Such exhausted desiccants, because of their high moisture contents, will give off more water for a given rise in temperature than will the goods they are intended to protect, and will thus increase the probability of internal condensation.

2.2 Extremes of temperature

Useful indications of the distribution of extremes of temperature over the land surfaces of the earth can be obtained from maps of the average monthly maximum and minimum air temperatures.

(Average monthly maximum and minimum air temperatures are defined in Appendix C.) Data from the Meteorological Office publication Met.O.617³⁾ were used to compute average monthly maximum and minimum air temperatures. From plots of these computed values plus some additional data, the isotherms for January, April, July and October shown in Figure 1 to Figure 8 were drawn. From these isotherms an approximation to the average monthly maximum/minimum air temperatures may be obtained at any place. These average monthly maximum/minimum air temperatures will be surpassed for only a few hours during the period of the given month and, for practical purposes, may virtually be regarded as the upper/lower limits to the air temperature during that month.

Figure 1 to Figure 8 are in the main self-explanatory. Examination of Figure 1 to Figure 4, for example, shows that the maximum temperatures over the world occur in a belt which in January is centred about latitude 30 °S and which moves, following the march of the sun with a lag of between one and two months, to about latitude 35 °N in July. In this belt average monthly maximum air temperatures over land may exceed 40 °C (104 °F).

³⁾ See bibliography, Appendix B (B.1).

The isotherms of Figure 1 to Figure 4 are derived from temperatures measured in the shade at a height of 1.25 m to 2 m (4 ft to 6 ft approx.) above the ground, but the surface temperature of a body exposed to radiation from the sun is generally much higher and is a maximum for a dark nonconducting material. Some indication of the temperatures on the steel deck of a ship at sea and exposed to clear skies and strong sunshine by day may be obtained from 3.2.2. In some instances special consideration and care may need to be given to particular types of goods (e.g. gas cylinders when filled at high pressures) if they are likely to be transported or stored in the open. The excess temperature inside a container, for example, will depend on the specific heat and thermal conductivity of the container, its contents and the packaging materials. The excess temperature will be less if the external surfaces of the container are light in colour, or if light-coloured covers are used, the worst colour being black and the best white; a matt surface is worse than a polished one. In addition it should be noted that, in certain circumstances, the contents of containers or vehicles may generate heat and it may be necessary to ensure that some or all of the generated heat is adequately dissipated.

Figure 1 to Figure 4 may also be interpreted in the following way. On the “cold” side of any isotherm the temperature during the given month will be on average nearly always below the value of that isotherm; in particular, on the cold side of the 0 °C (32 °F) isotherm the air temperature will be almost continuously below 0 °C (32 °F) throughout the month.

From Figure 5 it can be seen that in January Canada, the northern half of the U.S.A. and most of the U.S.S.R. are extremely cold, with average monthly minimum temperatures below – 30 °C (– 22 °F). In April, as can be seen from Figure 6, these are still the coldest regions, but temperatures are now some 20 °C (36 °F) warmer than in January. From Figure 7 and Figure 8 it can be seen that the southern hemisphere patterns in July and October are similar to those of the northern hemisphere in January and April respectively, but the cold areas are less extensive and temperatures do not in general fall as low as those in the northern hemisphere. One exception to this, however, is Antarctica, where the world’s lowest temperature of – 97 °C (– 126.9 °F) has been recorded.

On clear nights, owing to the loss of heat by radiation, a body exposed to the sky may be several degrees colder than the shade temperature, but the difference is unlikely to exceed 10 °C (18 °F).

Similarly to Figure 1 to Figure 4, Figure 5 to Figure 8 may be interpreted to give an indication of a value below which the air temperature will almost never fall in the given month. For example, on the “warm” side of the 0 °C (32 °F) isotherm the risk of an air temperature below 0 °C (32 °F) is virtually negligible. Similarly on the warm side of the 20 °C (68 °C) isotherm the air temperature will almost never be below 20 °C (68 °F).

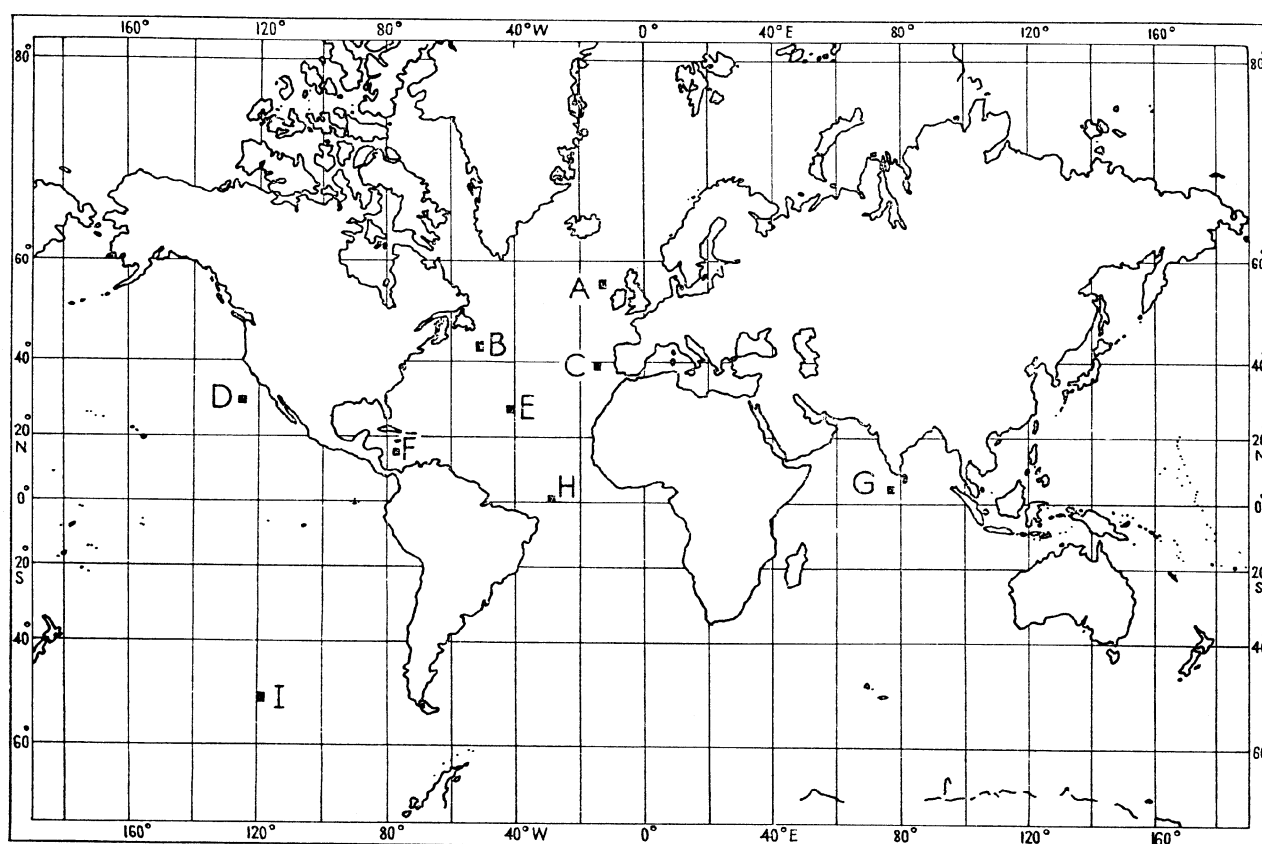
When using Figure 1 to Figure 8 it should be borne in mind that, on the scale of these figures, it is not practicable to indicate very detailed features. For example, where there is much variation in orography over short distances, details of variations in temperatures in valleys and on hills cannot possibly be adequately portrayed in these figures. If a packer needs more precise information on temperatures than is given in Figure 1 to Figure 8, reference should be made to the Meteorological Office publication Met.O.617⁴⁾ or to the relevant meteorological service.

2.3 Relative humidity

The water-vapour content of the air can vary within wide limits, ranging from almost none to an upper limit which depends only on the temperature. At low temperatures the amount is small, but as the temperature increases the maximum amount of moisture that the air can hold increases rapidly. Between – 7 °C and 38 °C (20 °F and 100 °F) the capacity of the air to hold water-vapour is approximately doubled with each 11 °C (20 °F) rise in temperature. When a mass of air contains the maximum amount of water-vapour for its temperature it is said to be saturated, and this condition is expressed by saying that the relative humidity is 100 %. Usually the air contains less water than is needed for saturation, but if air which is nearly saturated is cooled by coming into contact with objects which are at a lower temperature, moisture will be deposited. The temperature at which condensation first occurs and moisture is deposited is called the dew point, and it should be noted that the dew point can only be lower than or equal to the temperature of the ambient, or surrounding, air. The greater the difference between this temperature and the dew point, the drier is the air, the greater the amount of cooling necessary before condensation takes place and the greater the capacity of the air to take up additional moisture. By itself the dew point temperature is an accurate index of the amount of water-vapour in the air; an increase in dew point implies that moisture has been taken up and a decrease that moisture has been condensed.

⁴⁾ See bibliography, Appendix B (B.1).

Table 1 — Monthly mean relative humidities at certain areas at sea



Area code (see map above)	Latitude and longitude	Monthly mean relative humidities											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A	54–56 °N 12–14 °W	% 88	% 83	% 85	% 83	% 85	% 89	% 87	% 86	% 84	% 88	% 84	% 79
B	42–44 °N 50–52 °W	88	90	91	89	92	92	92	90	90	89	83	79
C	38–40 °N 14–16 °W	81	84	83	85	85	84	84	84	83	84	84	83
D	28–30 °N 124–126 °W	73	77	85	86	87	91	88	87	83	75	77	79
E	26–28 °N 40–42 °W	84	83	79	80	83	83	81	79	83	77	80	83
F	14–16 °N 76–78 °W	83	82	84	81	83	83	83	83	80	85	81	81
G	4–6 °N 76–78 °E	74	80	78	79	79	81	81	83	83	79	75	77
H	0–2 °N 28–30 °W	91	87	87	90	89	83	84	82	84	84	86	89
I	50–52 °S 118–120 °W	87	90	89	91	88	84	85	87	86	88	87	88

NOTE Saturation (100 % relative humidity) is relatively rare.

Over the oceans, where the diurnal variation of the relative humidity is small, an estimate of the mean relative humidity in February and August can readily be obtained by means of the charts of temperature (Figure 56 and Figure 57) and dew points (Figure 32 to Figure 53) over the oceans. Charts of mean dew points are not given, but at any point over the ocean the mean dew point is given with reasonable accuracy by the point lying half way between the minimum and maximum dew points. Given these values of the mean temperatures and dew points, values of the mean relative humidity can be obtained by the use of hygrometric tables⁵⁾. The mean relative humidities at certain representative areas of the oceans are given in Table 1.

In some instances it will be important to know the approximate extreme values of the relative humidity. These values can be determined by using the maps of maximum and minimum values of the dew point in conjunction with the map giving the mean air temperature over the ocean. For example, to determine the approximate lower limit of relative humidity at the position 40-N, 40-W during February, the mean air temperature read from Figure 56 is about 13.5 °C (56 °F), while the minimum dew point read from Figure 32 is about 2.5 °C (37 °F); for these values the Meteorological Office publication Met.O.265b⁵⁾ gives 47 % as the lower limit of relative humidity to which exposed cargoes may be subjected. In many areas over the oceans, the upper limit of relative humidity may be assumed to be about 100 %.

NOTE The maximum and minimum dew points in Figure 32 to Figure 53 are, in fact, 95 and 5 percentile values. These values have been used because they eliminate the very rare extreme values which may be erroneous. The 95 percentile of a series of values is that value which is exceeded by 5 out of every 100 observations, whereas the 5 percentile is that value which only 5 out of every 100 observations fail to reach. It follows that 90 % of the observations will normally lie between the values of the 5 and 95 percentiles.

The months selected for these dew point figures are February and August for the Atlantic and Pacific; February, May and September for the Indian Ocean. These months have been selected because they are the periods in which, over substantial areas of the oceans, dew points are likely, in general, to attain the highest and lowest values.

The months of February and August were chosen for Figure 54 to Figure 57 (mean sea surface temperatures and mean air temperatures over the oceans) because they can, in general, be considered the worst extreme temperature months.

For relative humidities in ports and other places on land, users can obtain details of the mean relative humidity from the Meteorological Office publication Met.O.617⁵⁾.

It will be found that these tables give, for most stations, two values of relative humidity, the first observation being made early in the morning and the second during the afternoon, approximating roughly to the maximum and minimum relative humidities respectively during the day. In the absence of more detailed information the user can make some rough assessment of the “average” relative humidity from these published values. Where the tables give only one observation for the day, however, it is very difficult or even impossible to make any estimate of the “average” relative humidity.

An alternative method of showing data on relative humidity is given in Figure 9, which illustrates the relative humidity throughout the year, at different times of the day, at four places of widely different climates. Similar information for other localities can be obtained from any meteorological service.

The physical properties of many packaging materials (such as paper, fibreboard, some cellulose films, woodwool) vary with changes in relative humidity; these variations may affect the protection which the pack will give to the contents. The physical condition of the goods themselves may also affect or be affected by these changes.

The shelf-life of a package during storage and the rate of transmission of water-vapour through moisture barrier materials will also depend upon the relative humidity. It is thus necessary when considering the behaviour of the pack over a period of time to arrive at some “average” value because of the normal marked diurnal variation in relative humidity.

It should be noted that whereas the relative humidity of the surrounding atmosphere will affect packs exposed to the atmosphere, the conditions of packages in the interior of a stack will be governed largely by the original moisture content of the hygroscopic materials in the stack, as well as by the temperatures within the stack at any given time.

2.4 Association of high temperature and high humidity

Generally, conditions of high humidity occurring in association with sustained high temperature favour the growth of mould and bacteria (which will attack organic materials, e.g. leather, paper and foodstuffs) and spoilage by insects (which, for example, will attack food and agricultural products). Insect pests, however, are generally more tolerant of lower relative humidities than are moulds. Some materials deteriorate substantially; for example, some metals corrode rapidly, and there may be complex effects on electrical and electronic apparatus.

⁵⁾ See bibliography, Appendix B (B.1).