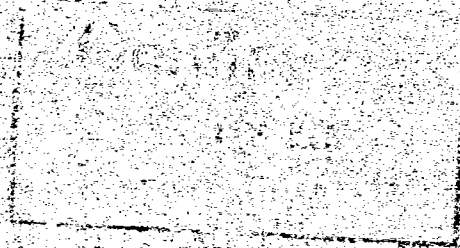




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UDC 620.1.05.001.4

**Recommendations on the
Design and testing of
enclosures for environmental
testing**



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FOREWORD

A wide variety of enclosures (climatic chambers, cabinets, humidity ovens, etc.) is used for the environmental testing of materials and equipment; the range is from small enclosures for, say, testing electronic components to 'walk-in' enclosures for testing large equipment. The atmospheric conditions of temperature, humidity and pressure in the enclosure may need to be maintained constant for periods of from hours to months or to be varied in a prescribed cyclic manner. The conditions required are often stated in the relevant testing specifications for the materials or equipment, but the user may sometimes specify other conditions in an enclosure to meet his own particular requirements.

These recommendations continue the series dealing with controlled-atmosphere enclosures suitable for work on atmosphere-sensitive materials or equipment. Previous standards in the series are:

BS 3718 Laboratory humidity ovens (non-injection type)

BS 3898 Laboratory humidity ovens (injection type)

BS 4194 Design requirements and testing of controlled-atmosphere laboratories.

BS 3898 specifies the performance and constructional requirements of humidity ovens operating at ambient atmospheric pressure and at temperatures within the range from about ambient temperature to 60 °C with humidities up to 95 % r.h. The present publication gives recommendations concerning enclosures that operate within a wider temperature range, with humidity control over part of this range, and where the air pressure in the enclosure may be ambient atmospheric pressure or may be varied, for example, to simulate conditions at high altitudes. It is not envisaged, however, that a particular enclosure will necessarily be able to operate over the whole range of temperature, humidity or pressure referred to in the scope of this standard; the actual operating ranges will depend upon the particular environmental testing to be carried out in the enclosure.

Owing to the wide variety of requirements for enclosures of this kind, it has not been found practicable to draw up a general specification on the lines of BS 3718 or BS 3898. The pattern of BS 4194 has therefore been followed, in that guidance is given on the factors that should be taken into account in the design of an enclosure for a specified performance, and methods of testing the performance are also described.

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Experience has shown that with some installations unsatisfactory performance can be attributed to inadequate specification or inadequate consideration of the relevant factors at the design stage. It is hoped, therefore, that these recommendations will help to minimize the risk of an installation failing to meet the requirements of the user.

A summary of items requiring specification or agreement between the supplier and the user is given in Appendix P.

BRITISH STANDARD RECOMMENDATIONS ON
THE DESIGN REQUIREMENTS AND TESTING OF
ENCLOSURES FOR ENVIRONMENTAL TESTING

1. GENERAL

1.1 SCOPE

1.1.1 These recommendations relate to the control of temperature, relative humidity (r.h.) and pressure in enclosures used to produce specified atmospheric environments for conditioning or testing purposes. They apply particularly to enclosures operating within the following ranges, which cover the requirements of most existing test specifications.

Temperature	:	-75 °C to +200 °C
Relative humidity	:	30 % r.h. to near saturation, controlled over the temperature range 15 °C to 65 °C (see also 2.2)
Pressure	:	Atmospheric (at sea level) to 1 kN/m ² (10 mbar)

NOTE. It is not envisaged that a particular environmental testing installation will necessarily be able to operate over the whole of these ranges (see 2.2).

1.1.2 Guidance is given on the information that is required for the design of an environmental test enclosure, and on the testing of performance with respect to temperature, relative humidity and pressure. For some applications it may be necessary to specify additional requirements. Methods of test are detailed in appendices. Certain recommendations concerning installation and maintenance are also included.

NOTE. The titles of the British Standards referred to in this standard are listed on the inside back cover.

1.2 DEFINITIONS

For the purposes of these recommendations, the following definitions apply:

- (1) *Working space*. That part of the enclosure in which the specified conditions are maintained within the specified limits.
- (2) *Enclosure temperature*. The temperature at the centre of the working space.
- (3) *Temperature variation*. The difference at any moment between the temperature at the centre of the working space and at any other point in the working space.
- (4) *Temperature fluctuation*. The difference between the maximum and minimum temperatures at any one point in the working space during a specified interval of time.
- (5) *Relative humidity variation*. The difference at any moment between the relative humidity at the centre of the working space and at any other point in the working space.
- (6) *Relative humidity fluctuation*. The difference between the maximum and minimum relative humidities at any one point in the working space during a specified interval of time.
- (7) *Pressure fluctuation*. The difference between the maximum and minimum pressures at any one point in the working space during a specified interval of time.

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(8) *Thermometer*. A temperature measuring device, e.g. a thermocouple, resistance thermometer.

(9) *Thermal time constant* (of a thermometer). The time taken for a thermometer to indicate 63.2 % of the total change in temperature which occurs when the thermometer at one temperature is suddenly immersed in air at a different temperature, for specified conditions of air velocity and pressure.

NOTE. The thermal time constant of a thermometer is often quoted in relation to flowing water, and it should be realized that the value in air will be much greater.

1.3 BASIS FOR DESIGN

The supply and installation of an environmental test enclosure will normally be the subject of a contract in which the requirements of the user, and the tests forming the basis of acceptance by the user, should be clearly specified. In order that no feature of the working conditions which might affect the operation of the enclosure may be overlooked, it is necessary for the user to make sure that the designer is informed, as fully as possible, about the uses for which the enclosure is required, including any special hazards that may be encountered. In particular, information should be given on any special test equipment to be used within the enclosure, e.g. for subjecting the test specimens to vibration.

If a load comprising equipment and personnel present during the operation of the enclosure will significantly affect the conditions by introducing gains or losses of heat, moisture, air or other factors, it will be necessary to specify the characteristics of this load.

If it is desired, for special purposes, to have the facility of replacing the normal temperature control system (based on the air temperature at the control point) by control based on the surface temperature either at or adjacent to the test specimen, full information should be given about the applications envisaged.

The performance may be specified for the enclosure either unloaded or with an agreed thermal load.

2. DESIGN DATA REQUIRED

2.1 WORKING SPACE

The working space will not normally extend to the boundaries of the enclosure. Its extent in a given installation will depend on the operating conditions, such as temperature, air speed and air distribution, and especially on the air pressure inside the enclosure. The manufacturer should state the boundaries of the working space at atmospheric pressure and should provide information on the changes caused by reduced pressures.

2.2 OPERATING RANGES OF TEMPERATURE, RELATIVE HUMIDITY AND PRESSURE

It is necessary to specify the ranges of enclosure temperature, relative humidity and pressure, within the working space, which the enclosure is required to provide, including any special requirements concerning relative humidity control outside the temperature and humidity ranges mentioned in 1.1.1.

2.3 CONTROL LIMITS OF TEMPERATURE, RELATIVE HUMIDITY AND PRESSURE

2.3.1 It is necessary to specify the limits within which the temperature, relative humidity and pressure in the working space should be maintained, when the enclosure is operating at nominally constant conditions within the designed ranges.

2.3.2 The limits of temperature and relative humidity that can be met at any point are determined by the spatial variation, which depends largely on the air circulation, and the fluctuation due to the operation of the control equipment. For many enclosures it is sufficient to specify the performance in terms of overall limits within which the temperature or relative humidity is required to remain at any point in the working space. It may sometimes be necessary, however, to specify limits for the variation also. For example, if the fluctuation is very small, the overall limits might permit an excessive variation from point to point.

It is necessary to take into consideration the fact that temperature variation will itself cause a change in relative humidity in an atmosphere of constant moisture content (see Appendix N).

According to the requirements of the user, the performance requirements for temperature and relative humidity may be specified by either of two methods.

(1) The limits may apply to readings taken at any time, i.e. no excursions outside the specified limits are permitted.

(2) The limits may apply to readings averaged over a stipulated period or number of control cycles. This system permits occasional excursions outside the specified limits, and may be acceptable if such occasional excursions are unimportant in relation to the use for which the enclosure is intended.

In the following clauses it is assumed that method (1) applies; the use of method (2) is described in Appendix M.

2.4 HEATING AND COOLING REQUIREMENTS

2.4.1 *Unloaded enclosure.* When the temperature is being changed from one specified value to another, the following criteria are relevant.

(1) The maximum allowable time to reach stability at the new temperature.

(2) The maximum allowable rate of temperature change (see also 2.8.11).

The rate of heating or rate of cooling requirements may be specified in terms of one or both of these criteria; the specified rates should be attainable after the enclosure has been operating at a steady temperature for a sufficient time for the relevant parts of the structure to have reached thermal equilibrium. Any further requirements, for example, concerning the temperature/time curve should be specified; these may materially increase the power requirements and cost of the enclosure.

2.4.2 *Loaded enclosure.* As an alternative to, or in addition to, requirements for the unloaded enclosure, heating and cooling requirements may be specified in the same way for the enclosure containing a thermal load agreed between the supplier and the user. Such a thermal load can consist, for example, of a block of steel of specified dimensions or mass, or of a heat-generating device such as an electric heater. In the latter case the load may be specified as the number of watts dissipated at particular temperatures within the designed range.

2.5 RELATIVE HUMIDITY DURING HEATING AND COOLING

If it is required that the relative humidity should be maintained within specified limits or if condensation is required during a temperature change, all necessary details should be given of the temperature range and rate of temperature change concerned.

The performance test may be carried out on an unloaded enclosure or with a load agreed between the user and the manufacturer.

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2.6 PRESSURE CHANGE REQUIREMENTS

2.6.1 *Rate of change of pressure.* When the pressure is being changed from one specified value to another, the following criteria are relevant:

- (1) the maximum allowable time to reach stability at the new pressure;
- (2) the maximum allowable rate of pressure change.

The rate of evacuation or rate of restoration of pressure requirements may be specified in terms of one or both of these criteria. Any further requirements concerning the pressure/time curve should be specified.

2.6.2 *Restoration of atmospheric pressure.* It may be required to provide for air admitted to the working space for restoring atmospheric pressure, after the enclosure has been evacuated, to be passed through a drier containing a clean, inert desiccant such as silica gel or activated alumina. Alternatively, if moist conditions are required, the drier may be replaced by a saturator. For a very dry atmosphere, means of admitting dry air or other gas should be provided.

2.7 GENERAL FEATURES AFFECTING DESIGN

The following list covers further features that should be taken into account in the design of an enclosure for environmental testing, but it may need to be supplemented by additional items for particular installations.

- (1) Dimensions of space available for enclosure and ancillary plant.
- (2) Particulars of doors, windows and other entries into enclosure. (At least one port should be provided for the entry of electrical connections and other services to equipment or specimens under test.)
- (3) Maximum and minimum values of temperature and relative humidity of air surrounding the enclosure (and of air surrounding ancillary plant if this is remote from the enclosure).
- (4) Acceptable air speed in working space.
- (5) Internal heat and moisture gains or losses, e.g. from occupants, lighting and electrical equipment, specimens or equipment under test.
- (6) If equipment under test introduces air or other gas into the enclosure, it will be necessary to ensure that the pumping capacity is sufficient to maintain the required low pressure.
- (7) Position and size of any equipment and structure likely to cause major interference with air flow through the enclosure.
- (8) Acceptable levels of noise and vibration.
- (9) Details of load-bearing capacity of enclosure floor.
- (10) Details of load-handling equipment.
- (11) Whether or not internal surface of enclosure should be of high thermal emissivity (see 2.8.12).
- (12) Details of electricity and water supplies and of any other services required for operation of the enclosure, including cooling air or cooling water for refrigeration plant and other ancillary plant.

(13) Purity of water required for humidification.

(14) Whether enclosure can be shut down at intervals or whether special measures are required to provide for continuous operation.

(15) Details of services into the enclosure itself.

Over-riding safety controls are required and should be fitted to protect the enclosure and be of a fail-safe type.

NOTE. Guidance on the design and safe operation of refrigeration plant is given in BS 4434.

2.8 PARTICULAR FEATURES OF DESIGN

In addition to the general features of design outlined in 2.7, mention may be made of various features that may call for particular attention.

2.8.1 Humidifying system. If the nature of the work for which the enclosure is intended is such that the presence of water droplets in the atmosphere is unacceptable, it is necessary for the humidifying system to be so designed that any droplets formed are removed before humidified air enters the working space.

2.8.2 Heating system. The surface temperature of heaters may need to be restricted, e.g. for hazardous materials. If heaters are to be used at low atmospheric pressures, they should be rated accordingly (see also 2.8.12 for other requirements).

2.8.3 Electrical systems. The electrical system should be so designed and installed that all wiring, fittings and electrical apparatus exposed to the wide range of environmental conditions within the enclosure (including high and low temperatures, high relative humidities and low air pressures) will withstand these conditions without deterioration. In particular, all parts of the system exposed to these environmental conditions should be adequately protected against the effects of low air pressure and high relative humidity.

2.8.4 Thermal insulation. If the enclosure is intended for operation at temperatures below ambient, it is important to ensure that the insulating material is protected from the ingress of moisture. If the insulating material is inside a pressure shell, arrangements should be made to avoid excessive differences in pressure between the insulating material and the working space, without direct interconnection. The release of moisture from the insulating material, on evacuation of the enclosure, can make it difficult to obtain and maintain the desired low pressure.

2.8.5 Vacuum systems. With many enclosures the vacuum system will be exhausting saturated air for most of its operating time, and the system should be suitably designed for this requirement. If it is necessary to evacuate air at a high temperature (e.g. 65 °C), a cooling system for the pump will be required.

2.8.6 Air distribution. With large enclosures in particular, it is desirable to provide deflectors or similar devices for adjusting the air distribution so that the desired distribution can be obtained under all conditions of operation.

2.8.7 Air flow. If the enclosure operates over a wide range of temperature and pressure, it may be necessary to provide means for adjusting the air speed (e.g. a variable speed fan) in order to obtain the specified mass air flow.

2.8.8 Air change. If a change of air within the enclosure is required details should be agreed between the supplier and the user.

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2.8.9 *Special hazards.* If the enclosure is intended for the testing of hazardous materials or equipment, all necessary precautions should be agreed between the supplier and the user (see 1.3).

2.8.10 *Protection of specimens.* If it is required to protect the specimens from damage owing to failure of the normal control system, the time constants of the protective devices should be related to those of the likely specimens, the enclosure and the normal control system. These protective devices should be of the fail-safe type.

2.8.11 *Safety measures.* Enclosures that are large enough to allow an individual to enter should incorporate the following features.

(1) A window or other means (e.g. closed circuit television camera) to enable the interior of the enclosure to be observed continuously.

(2) An alarm button that will call attention and simultaneously shut off the conditioning functions of the plant (heating, cooling, humidification, air-circulation, vacuum).

(3) If relevant, a device that can be operated from inside the enclosure, to enable air to enter at a suitable rate, so as to equalize the pressures inside and outside the enclosure.

(4) Emergency lighting.

(5) An internal release for the door, or other means of exit, which can be operated from inside the enclosure.

The following additional features are useful but less important.

(6) A separate alarm button that can call attention without necessarily switching off the conditioning plant.

(7) An indicator light, outside the door, which can be switched on when the enclosure is occupied.

2.8.12 *Enclosure walls.* Some test specifications include a requirement that the walls of the enclosure shall not differ from the test temperature by more than 3 % of the test temperature expressed in degrees Kelvin, and that the specimen shall be unable to 'see' any heating or cooling elements that do not comply with this requirement. It is also sometimes specified that the walls of the enclosure shall be as near as possible to thermal black (high emissivity).

2.8.13 *Tests with thermal shock.* Normally the maximum rate of temperature change is specified in order to avoid unacceptable thermal shock to the specimens under test. However, tests involving thermal shock are included in some test specifications and although separate facilities may be required for such tests, the possibility of designing the enclosure so that thermal shocks can be provided may need to be considered.

3. TESTING OF PERFORMANCE

3.1 CONDITIONS OF TEST

3.1.1 Agreement should be reached between the supplier and the user on the ambient conditions under which the acceptance tests are carried out and on the electricity and water supplies (within the ranges covered by 2.7 (3) and 2.7 (12)) used.