

Australian/New Zealand Standard™

Lighting system performance— Accuracies and tolerances

Part 1: Overview and general recommendations

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee LG/12, Specification and Assessment of Lighting Performance. It was approved on behalf of the Council of Standards Australia on 15 May 1998 and on behalf of the Council of Standards New Zealand on 16 August 1998. It was published on 5 October 1998.

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Part 1: Overview and general recommendations

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee LG/12, Specification and Assessment of Lighting Performance, in response to a request by the Illuminating Engineering Society of Australia and New Zealand.

The objective of this Standard is to provide advice on the factors that influence variability in lighting performance and to recommend how such variability may be contained within tolerable limits in calculations and measurements of lighting parameters.

Attention is drawn to AS/NZS 3827.2*, which sets out the minimum requirements that should be complied with, in order for a design or verification to be considered of an acceptable accuracy with respect to the achievement of specified values of lighting parameters.

The term ‘informative’ has been used in this Standard to define the application of the appendix to which it applies. An ‘informative’ appendix is only for information and guidance.

* AS/NZS 3827 Lighting system performance—Accuracies and tolerances
AS/NZS 3827.2 Part 2: Compliance requirements

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Australian/New Zealand Standard

Lighting system performance—Accuracies and tolerances

Part 1: Overview and general recommendations

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard identifies the factors that influence variability in lighting performance and gives recommendations on how such variability may be contained within tolerable limits in the specification, calculation and measurement of interior and exterior lighting systems. It applies particularly where quantitative values of lighting parameters are specified, but does not cover qualitative or aesthetic attributes of lighting systems except where these involve specific lighting performance parameters.

The Standard sets out typical accuracies that might be expected for various elements of the calculation/measurement process, as well as the range of accuracies that can be expected for the overall design. These can be taken to apply unless otherwise specified, e.g. in a Standard covering the application, or by the client.

NOTE: Attention is drawn to AS/NZS 3827.2, which sets out the minimum requirements that should be complied with in order for a design or verification to be considered of an acceptable accuracy with respect to the achievement of specified values of light technical parameters.

1.2 APPLICATION This Standard is intended for use by persons who are involved in any aspect of the design, installation and assessment of interior and exterior lighting systems. This includes the client, lighting designer, installer, equipment supplier and photometric laboratory.

The Standard is also intended for use in the development of other Standards covering particular interior or exterior lighting applications.

1.3 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

- | | |
|--------|---|
| 1158 | The lighting of roads and other public thoroughfares |
| 1158.2 | Part 2: Computer procedures for the calculation of light technical parameters for Category A lighting |
| 1680 | Interior lighting |
| 1680.1 | Part 1: General principles and recommendations |
| 1680.3 | Part 3: Measurement, calculation and presentation of photometric data |

SAA

- | | |
|---------|--|
| HB18 | Guidelines for third-party certification and accreditation |
| HB18.25 | Guide 15—General requirements for the competence of calibration and testing laboratories |

AS/NZS

- | | |
|----------|--|
| 1158 | Road lighting |
| 1158.1.1 | Part 1.1: Vehicular traffic (Category V) lighting—Performance and installation design requirements |

AS/NZS	
3827	Lighting system performance—Accuracies and tolerances
3827.2	Compliance requirements
4293	International lamp coding system (ILCOS)
CIE*	
27	Photometry of luminaires for street lighting
43	Photometry of flood lights
69	Methods of characterizing illuminance meters and luminance meters
102	Recommended file format for electronic transfer of luminaire photometric data
BS	
667	Specification for illuminance meters
CIBSE†	
TM14	Standard file format for the electronic transfer of luminaire photometric data
IESNA‡	
LM63	Recommended standard file format for electronic transfer of photometric data

NOTE: A bibliography of additional documents relevant to the subject of this Standard is provided in Appendix A.

1.4 DEFINITIONS For the purpose of this Standard, the definitions below apply.

NOTES:

- 1 Some of the defined terms are illustrated in Appendix B. That Appendix also describes the use of these terms in lighting calculations/measurements.
- 2 In everyday speech, many terms are used that have a similar connotation, e.g. accuracy, precision, preciseness, tolerance, error, confidence, dispersion. In the statistical treatment of the subject, some of these terms may have a very specific meaning (see Refs 1, 2 and 7). However, in this Standard, only the terms defined in this Clause are given specific meanings; other terms are either avoided or have only the connotation of everyday speech.

1.4.1 Accuracy of calculation/measurement—the closeness of the agreement between the result of a calculation/measurement and a true value of the parameter being calculated/measured.

NOTE: ‘Accuracy’ is a qualitative concept which generally refers to the collective effects of a number of sources of error. Where a numerical value is assigned, the term ‘uncertainty’ is preferred.

1.4.2 Component uncertainty—the uncertainty of an individual element/component of a lighting calculation/measurement.

1.4.3 Level of confidence—a specification of uncertainty which gives the probability of finding the true value of a quantity within the range of uncertainty. For the purpose of this Standard, all uncertainties have been quoted at the 95% level of confidence, which means that the probability of a value lying outside the range of uncertainty is 5%.

1.4.4 Limiting tolerance—the tolerance that is applicable to the specified acceptance criteria. For example, for illuminance, the limiting tolerance would normally be the lower limit; for glare or luminous intensity, the limiting tolerance would normally be the upper limit.

* International Commission on Illumination, Vienna.

† Chartered Institution of Building Services Engineers, London.

‡ Illuminating Engineering Society of North America, New York.

1.4.5 Residual total uncertainty (of measurement)—total uncertainty remaining after the application of any photometer calibration and relevant adjustment to a measurement.

NOTES:

- 1 The residual total uncertainty will generally comprise the inherent uncertainty of calibration and that associated with the repeatability of measurement.
- 2 A stated value of uncertainty will have an associated level of confidence (see Clause 1.4.3).

1.4.6 Specified value—the value of a lighting parameter specified in a Standard or in the design brief.

1.4.7 Target value—the value of a lighting parameter on which a lighting design is predicated.

NOTE: The target value may differ from the specified value to allow for—

- (a) the expected uncertainty in the design process; and
- (b) subsequent light losses through the maintenance cycle, from the time that the lighting system is installed to the time that maintenance is required.

1.4.8 Tolerance—an allowance made in the specification of a lighting performance parameter, relative to a nominated value of that parameter, to take account of uncertainties in the various elements of the lighting design, e.g. uncertainties in the photometric performance of lighting equipment, uncertainties inherent in calculation methods, uncertainties in on-site measurements.

1.4.9 Total uncertainty—the total of all component uncertainties involved in a lighting calculation/measurement, summed in a specified way.

NOTES:

- 1 The method of deriving the total uncertainty is described in Appendix B.
- 2 A stated value of uncertainty will have an associated level of confidence (see Clause 1.4.3).

1.4.10 Uncertainty of calculation/measurement—parameter, associated with the result of a calculation/measurement, that characterizes the dispersion of the values that could reasonably be attributed to the calculated/measured quantity.

NOTES:

- 1 A value of uncertainty may be stated for a particular element of a lighting calculating/measurement (i.e. component uncertainty), or for the uncertainty of all elements of a lighting calculation/measurement (i.e. total uncertainty).
- 2 A stated value of uncertainty will have an associated level of confidence (see Clause 1.4.3).
- 3 See Appendix B for information on the derivation of the uncertainty of a lighting calculation/measurement.

SECTION 2 UNCERTAINTY IN LIGHTING DESIGN AND MEASUREMENT

2.1 UNCERTAINTY IN DESIGN Most lighting Standards specify minimum values only. For example, if the lighting level is below the specified value, the lighting does not comply with the requirements of the Standard, but if it is above by any amount, it does comply.

It is tacitly accepted, by reason of common sense, that a designer cannot guarantee to provide exactly a given lighting level; there are factors that produce a degree of uncertainty. However, the corollary is that uncertainty is not easily quantified (and is therefore likely to be ignored) by reason of the complexity of the elements, participants and phases associated with a lighting system. This state of affairs is illustrated in Figure 2.1. However, problems do arise from apparent discrepancies between predicted lighting values for, ostensibly, the same lighting design but using different procedures, and also between predicted and installed lighting values. In resolving such discrepancies the associated uncertainties should be addressed in accordance with this Standard.

2.2 ACCURACY Accuracy is the preciseness with which the calculated (or measured) value can be determined. If the degree of accuracy is to be quantified then the sources of uncertainty need to be assessed.

If the uncertainty inherent in the design is small, the possible deviation of the calculated value from the true value will be small and accuracy good; if uncertainty is large then accuracy will be poor.

A prudent designer can, from an assessment of the uncertainty and from experience, compensate by a degree of overdesign, for example, by adoption of a maintained illuminance of 350 lx rather than 320 lx for an office.

The implication of taking into account all possible uncertainty is that, to be reasonably certain that a design complies, a large safety margin might need to be applied if no action is taken to reduce the level of uncertainty, for example, by designing to 400 lx to be assured of obtaining the specified value of 320 lx.

2.3 TOLERANCES To help evaluate whether a design or the calculated/measured value is indeed acceptable, a tolerance can be stated for application to the specified value. A tolerance is an allowable variation of a lighting parameter about the desirable or specified value and might be based on a number of considerations, such as the following:

- (a) To take into account the expected accuracy of calculation or measurement.
- (b) To contain variations about the design value to tolerable limits within which there will be no adverse effect on, say, visual performance.

To take into account all possible uncertainties, the tolerances would probably need to be large, for example, $\pm 25\%$, which could lead to their misuse. A prudent designer and client would only accept a design that has a value close to the specified value, that is, at the middle of the tolerance range.

Most lighting Standards specify minimum values and until formal tolerances are introduced, the only way of avoiding the possibility of a discrepancy arising is to compensate by a degree of overdesign, as referred to in Clause 2.2. However, unsubstantiated overdesign might not be acceptable to the client for economic reasons and because of a lack of appreciation of the uncertainty in design.

2.4 CENTRALITY OF THE DESIGNER In Figure 2.1 the designer has a central position. This is by virtue of the fact that the designer is responsible for the production of the documentation of the lighting system and its integrity. It is the designer who makes judgements about balancing the requirements of a design that will meet the specification and will be economically viable, whilst making appropriate allowance for the uncertainties inherent in the design process.

Designers cannot wholly rely on their own expertise and experience. Other participants will influence the outcome; the designer is reliant on and has expectations as to information, for example, from the client for the site details, from manufacturers and suppliers for documentation of hardware and credibility of computer software, and from the applicable Standards (see Figure 2.1).

At the installation stage, the designer is reliant on the installer and the client to ensure that the design, as documented, is put in place. At the operation stage, the continuing integrity of the installed lighting is reliant on adherence to the set down maintenance procedures.

2.5 STANDARDS AND LIGHT TECHNICAL PARAMETERS The desirable attributes of a lighting design might be a mixture of utilitarian and aesthetic ones. In general, lighting Standards give numerical specifications for relevant lighting parameters of utilitarian attributes, for example, maintained illuminance, threshold increment and glare index. These attributes can be subject to a quantitative design process, documentation and checking. Whilst aesthetic attributes are important and, in some installations, are the dominant consideration, they are a matter of creativity and subjective judgement. As such, quantitative assessment of uncertainty and the probability of the design being without serious discrepancy with respect to the design objectives, is irrelevant.

2.6 COMPLIANCE To ensure and predict that a design will be accurate, that is, with only a low probability that it will deviate by a small amount from the specified (or target) value, is problematic. This arises from the complexity of the design process and the uncertainties involved.

However, uncertainty can be minimized and the best accuracy possible in the circumstances assured by considering the lighting process, which leads to requirements for procedures to be followed, including a simple quantitative assessment of the uncertainty.

This enables the present structure of Standards to be maintained, that is, the specification of minimum values without the introduction of formal tolerances.

Precedents exist for compliance with a Standard to be deemed if laid down procedures are followed; for example, AS 1158.1 calls up a specific design procedure including the use of specific software, and AS 1680.1 calls up specific design methods for the evaluation of glare control. However, this approach can only be taken with respect to attributes for which there are relevant light technical parameters and quantitative values, as set out in Clause 2.5.

2.7 ROUNDING OF CALCULATION RESULTS AND LIGHT MEASUREMENTS Where a specified or target value for a lighting parameter is given in a Standard or in other documentation, e.g. a contract specification, the number of significant figures should be stated to facilitate the verification of compliance with the given value.

Where this information is not provided, numbers resulting from calculations or obtained from measuring instruments, that are required to be compared with a specified or target value, should be rounded to one digit lower than the lowest significant digit in the other number before comparison. For this purpose, the lowest significant digit should be taken as the lowest non-zero digit in the number.

Example

- (a) 314.956 would round to 315 before comparison with 320.
- (b) 123 432.789 would round to 120 000 before comparison with 100 000.
- (c) 0.3061 would round to 0.306 before comparison with 0.31.

Any number that is generated by calculation or produced by a measuring instrument will have a certain number of digits, the number of digits being dependent on the method by which that number was determined and in some cases on the means of displaying the number. This can result in slight rounding errors, which, although not significant in themselves, can result in inconsistencies when compared to another number. For example, the result of a calculation within a computer program of 9.995 655 55 would fail to meet a minimum value of 10 if the comparison was made within the program using the number as calculated, yet the same result could be displayed by the program as 10.00 (due to the display format), from which the user of the displayed data would conclude that the value complied with the limit.

By applying the above rule, the internal result in the example would round to 10. The displayed result would also round to 10.

By the same rule, an internal result of 9.443 21 would round to 9. The displayed result of 9.44 would also round to 9.

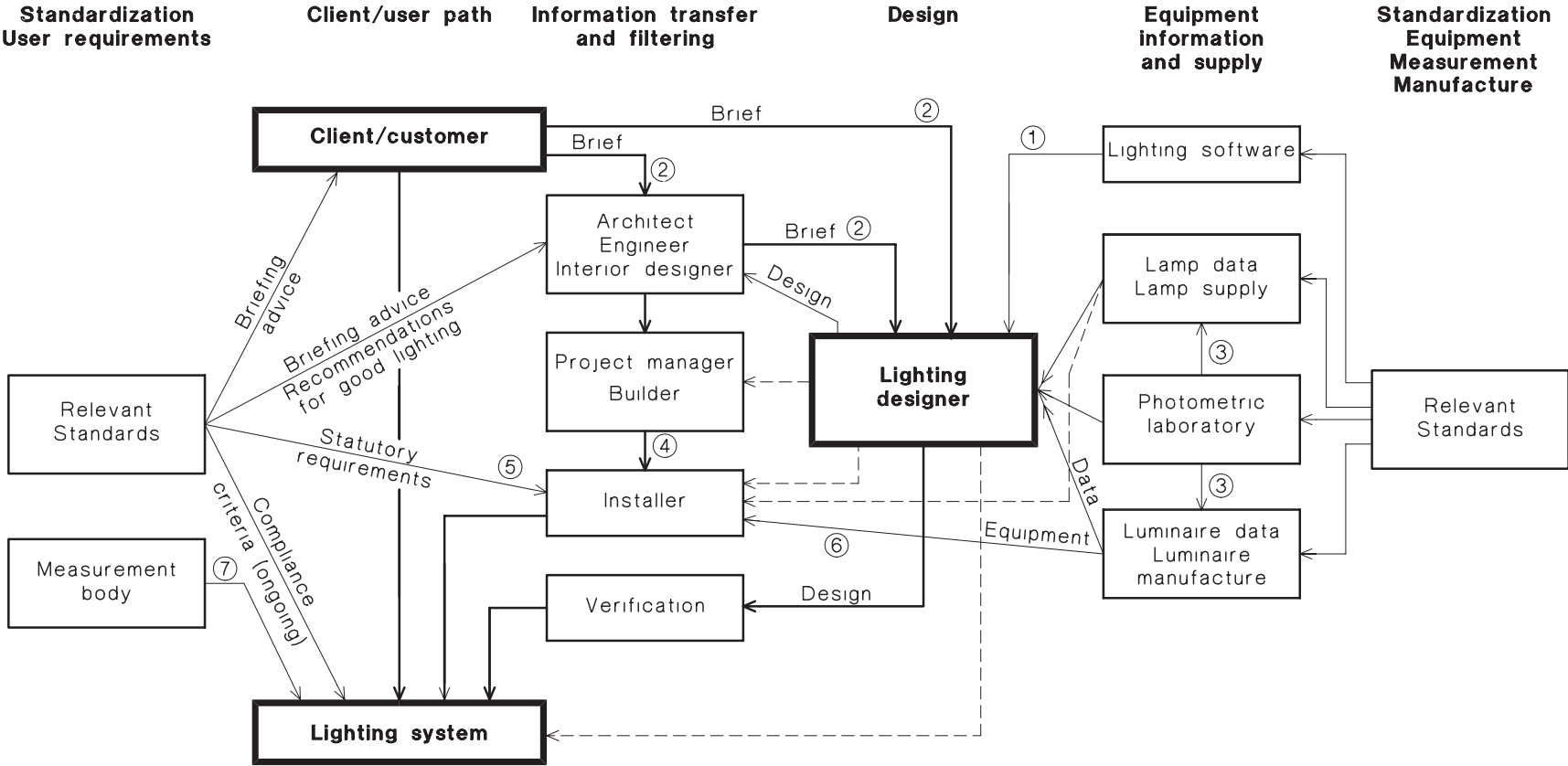
It is necessary to round to a significant digit rather than by a number of decimal places due to the range of numbers that can occur. For example, a minimum illuminance of 0.1 lx, or a maximum intensity of 100 000 cd.

2.8 THE FORMAT OF THE STANDARD Following the consideration of the aspects discussed in Clauses 2.1 to 2.7, this Standard has the following purposes:

- (a) To document the sources of uncertainties through the various phases of the lighting process, that is, design, documentation, installation, verification and management.
- (b) To identify the various participants at each phase and to set out for each participant their responsibility for minimizing uncertainties.
- (c) To document the design process at each phase and set out aspects of the process, attention to which will minimize uncertainties.
- (d) To give indicative uncertainties, methods of their quantitative assessment, the indicative accuracy of design and the method of resolution of discrepancies in design and verification.

NOTES:

- 1 Attention is drawn to AS/NZS 3827.2, which sets out the minimum requirements that should be complied with in order for a design or verification to be considered of an acceptable accuracy with respect to the achievement of specified values of light technical parameters.
- 2 Figure 2.2 identifies the development phases that are typically involved in the provision of a lighting system, and lists the type of information which the various participants in the process are likely to require at each phase.



LEGEND

- Thick border box** = Major interest/activity
- Thin border box** = Indicates the interest/activity may be omitted in some projects
- Solid arrow** = Formal transfer of information (bold lines show primary information flows)
- Dashed arrow** = Less formal transfer of information
- ①** = Possible source of error/tolerance (see separate list)

Points at which errors/tolerances introduce uncertainties into the process

- ① = Errors in the modelling algorithms for the specific lighting system
- ② = Inaccurate information on room reflectances, usage, furnishings
- ③ = Tolerances in photometry Difference between photometered luminaire and production average
- ④ = Design/budget compromise Substitution of luminaire Inaccurate communication of design intent
- ⑤ = Misinterpretation of documentation/design Ambiguity of design Lack of information
- ⑥ = Manufacturing tolerance Variation from photometered luminaire
- ⑦ = Error of measuring instrument

FIGURE 2.1 TYPICAL INTERACTIONS IN THE PROCESS OF A LIGHTING SYSTEM

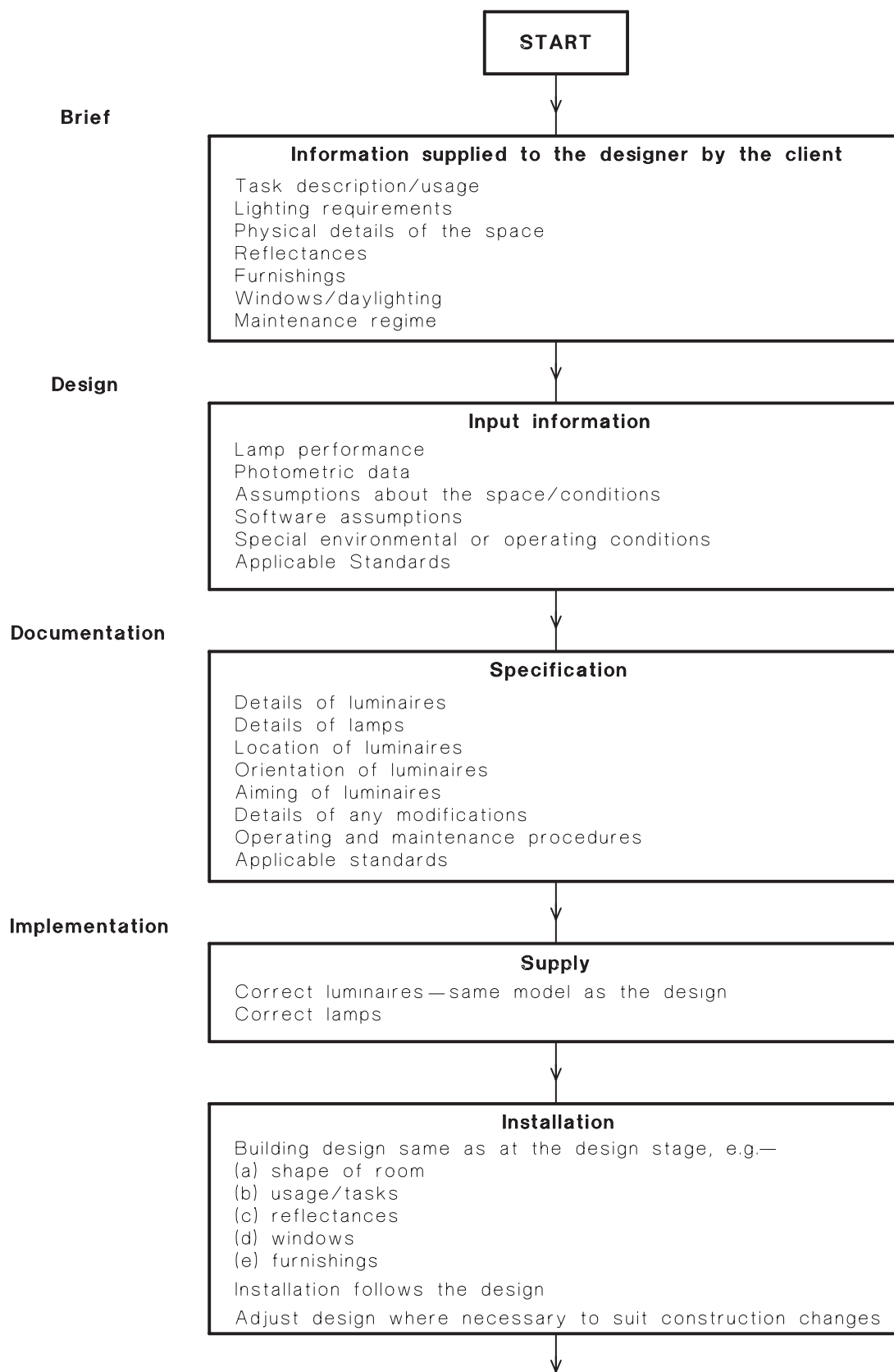
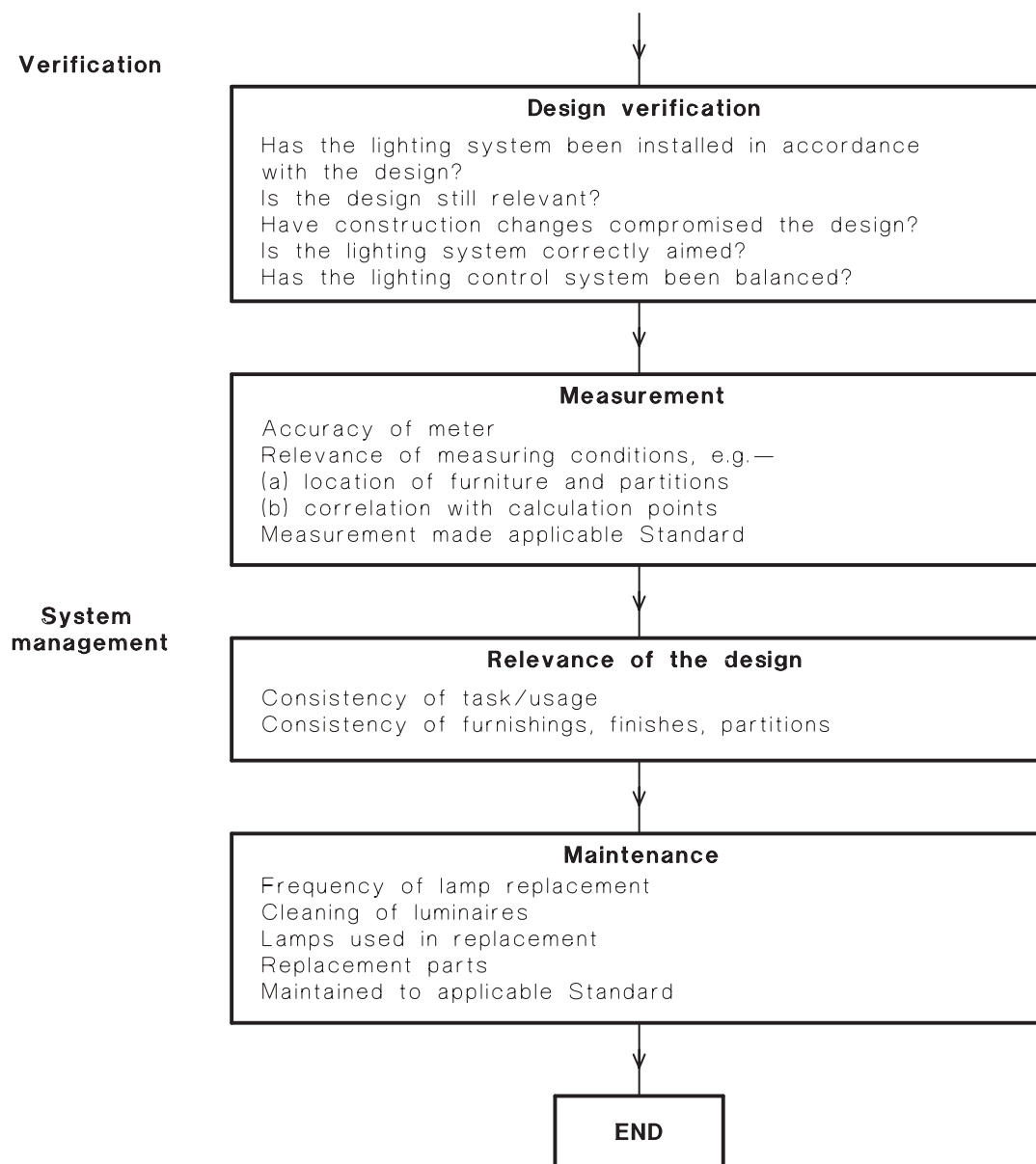


FIGURE 2.2 (in part) TYPICAL LIGHTING SYSTEM DEVELOPMENT PHASES



NOTE: The entries listed in each box are not exhaustive. Each design will have its own specific requirements/conditions. See further information provided in this Standard.

FIGURE 2.2 (in part) TYPICAL LIGHTING SYSTEM DEVELOPMENT PHASES

SECTION 3 INPUT INFORMATION

3.1 GENERAL Input data is information used in the design process for predicting lighting parameters. Data used in design should represent site conditions as closely as possible. This Section, therefore, recommends certain practices, procedures and methods to minimize variations to input data. It should be noted, however, that there are many variables beyond the control of the designer, which will result in variations between predicted and actual lighting parameters. These variables exist due to practical limitations on design techniques, manufacturing tolerances on equipment and installation conditions which are at variance with the conditions assumed at the time of design. The variations that can reasonably be expected to occur have been considered in this Standard. Thus, designs carried out in accordance with this Standard can be considered 'accurate' by the standards of current best practice.

Input data requirements are described in Clauses 3.2 and 3.3.

3.2 EQUIPMENT

3.2.1 Manufacture of lighting equipment The manufacturer should have a quality management system in place, which ensures that lighting equipment is manufactured to the same specifications as that of the sample used for testing and generating the input data. The quality management system should address all elements/attributes of the equipment, the variability of which influences lighting performance, e.g. lampholder position, reflector material or shape, ballast type. Where design changes are made to the lighting equipment, which affect these elements/attributes, the lighting performance should be reassessed by photometric testing.

Tolerances on the performance of equipment components (e.g. ballasts, lamps) should be in accordance with those specified in the applicable Standards.

NOTE: The specified tolerances may still result in considerable performance variations. For example, Standards for certain lamp types can permit variations in light output of up to 10%.

Each design/type of luminaire should bear a unique identification number or designation to relate the luminaire to the associated photometric performance data.

3.2.2 Lamp photometric performance data

3.2.2.1 Derivation of data Lamp performance data should be derived in accordance with relevant local or international Standards. While data are normally supplied by the lamp manufacturer in the manufacturer's own format, the traceability of this data back to the test of the lamp, in accordance with the relevant Standard, should be supplied on request.

Standards on lamps are not usually developed until the lamp has become an established type. Data on lamps that are not covered by a Standard should be regarded as provisional.

3.2.2.2 Types of data The following types of data may be required:

- (a) *Luminous flux* For calculation for lighting parameters, the initial luminous flux of a lamp is required together with information showing how this varies as the lamp ages. Initial luminous flux is that provided when the lamp is new but has had sufficient usage to stabilize the light output. The relevant Standards define sufficient usage (typically 100 hours for discharge lamps).

Depreciation of luminous flux over the life of the lamp is usually shown in graphical form. These 'depreciation curves' show how the flux output of the lamp varies with the number of burning hours. The curves may show an upper and a lower curve to denote the typical variation that can be expected.

For the purposes of consistent interpretation, the median value should be used in designs carried out in accordance with this Standard.

- (b) *Colour* Requirements for the colour characteristics of a design may vary. For example, security lighting may have no specific requirements while lighting for colour matching will have stringent requirements for the various parameters associated with colour.

Colour attributes for lamps, initial and over time, should be verified according to their significance to the application.

- (c) *Mechanical* The size, shape and position of the light centre of a lamp are critical to the photometric performance of a luminaire. Lamps to be used in a particular luminaire should have the same physical characteristics (e.g. form and dimensions) as those used when the luminaire was photometered. Specifying the lamp wattage and type, e.g. 150 W metal halide, will not necessarily ensure that lamps from different suppliers will have the same characteristics.

NOTE: Attention is drawn to AS/NZS 4293, which sets out details of an international lamp coding system for the designation of different lamp categories and their physical and electrical attributes.

3.2.3 Luminaire photometric data

3.2.3.1 Derivation of data Photometric performance data should identify the source of the data, i.e. laboratory name and test report number. The laboratory should be independently accredited as having competence to carry out the measurements involved, by NATA* or IANZ†, or be a laboratory of another country that is accredited under a mutual recognition agreement with NATA or IANZ.

NOTE: See HB18.25 for general requirements for the competence of calibration and testing laboratories.

Photometric data should be prepared in accordance with recognized procedures and in accordance with the recommendations of this Standard. Such procedures, as applicable, include—

- (a) for luminaires for interior lighting, those set out in AS 1680.3;
- (b) for road lighting luminaires, those set out in CIE Publication No. 27; and
- (c) for floodlights, those set out in CIE Publication No. 43.

Data for use in computer programs should be transferred from the test house to the program only by digital means.

NOTE: The practice of converting data from printed matter, such as facsimile or printed test reports, into machine-readable form is liable to introduce human error or machine error where optical character recognition systems are used.

3.2.3.2 Uncertainties of photometric data Uncertainties of various photometric parameters, as specified by the accrediting body, should not exceed the following:

- (a) Luminous intensity $\pm 7\%$.
- (b) Angle ± 0.5 degrees.
- (c) Light output ratio $\pm 5\%$.
- (d) Luminous dimensions $\pm 5\%$.
- (e) Lamp luminous flux $\pm 5\%$.

* National Association of Testing Authorities, Australia.

† International Accreditation New Zealand.