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The Structure of Building Specifications

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The Structure of Building Specifications

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ABSTRACT

This paper provides a scientific basis for the formulation and expression of performance standards and specifications and for explicit attention to performance in procedural and prescriptive standards and specifications.

The provisions of the NBS-developed Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, a performance specification, are classified in terms of the physical entities addressed, the attributes of the built environment, and the properties which group together particular physical entities which may be subject to similar dysfunctions. These provisions are also subjected to a linguistic analysis which examines in detail the wording used and formalizes certain key concepts which are realized in the wording.

The provisions of the Uniform Plumbing Code, a prescriptive code, are classified in terms of the physical entities addressed and the performance attributes which can be inferred (though they are not explicitly addressed).

Guidelines for the expression of provisions in performance codes and specifications are presented. These guidelines are based on the classification studies and the linguistic analysis mentioned above.

Key words: Building code provisions; building codes; building component classification; building specifications; building standards; performance concept.

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1. INTRODUCTION

1.1 Objectives

This study is a pilot investigation for the establishment of a rational framework for specifications, dealing with both the detailed organization of individual provisions and the overall organization and classification of provisions.

The study includes the detailed analysis and classification of two documents:

- the Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, National Bureau of Standards, January 1975 [12]*;

- the Uniform Plumbing Code, International Association of Plumbing and Mechanical Officials, 1973 Edition [21].

These two documents were chosen because they represent as closely as possible the extreme points on the performance-prescriptive specification continuum.

The objectives of the study are:

- to investigate the vocabulary of specifications; that is, the terms used to describe the objects dealt with and the performance expected;

- to identify the manner in which the terms mentioned above are used to form specification provisions;

- to investigate classification schemes for the terms used, so as to derive organizational bases for specifications; and

- to develop rules for the use of terms, specification provisions, and classification schemes.

1.2 Background

Building codes, design specifications and standards referenced by building regulatory documentation constitute one of the major communication and control mechanisms for the building industry. The development of new codes and standards and the maintenance of existing ones involves a substantial effort on the part of researchers, product developers, building officials and professionals in many disciplines. The enactment and enforcement of building codes requires a large building regulatory system. The codes, specifications and standards control the professional output of designers and the products of builders and building manufacturers. The quality and coverage of these codes and standards has a major effect on both the quality and cost of buildings.

There is, therefore, a critical need to improve our understanding of the organization and structure of codes and specifications and to develop basic principles from this understanding. These principles are expected to serve specification writers to develop better processes and improve their product. This report is a pilot study in this direction.

The need for this study is manifested in two ways. First, new codes and specifications are being developed by many sources, either to reflect changing requirements in areas traditionally subject to code control such as health, safety and welfare or to introduce new requirements reflecting national needs, such as energy conservation. Developers of such new codes and specifications would be well served by a more rigorous framework within which their efforts could be organized and evaluated Because of the importance of specifications, the entire building community can benefit from more rational control.

Moreover, existing codes and specifications are undergoing a constant process of maintenance, updating and adoption. A mechanism is needed whereby the changes and amendments thus introduced can be readily related to the existing body of codes. Closely related to this is the need for comparison of existing codes. A major

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*Bracketed numbers refer to references listed on pages 76 and 77.

problem experienced by design and construction firms operating in multiple jurisdictions is that of identifying and dealing with the dissimilarities and local deviations among codes. An organized framework for representing codes and specifications would not only assist these firms, but also those agencies responsible for the promulgation and adoption of codes and standards, in identifying and evaluating differences.

1.3 Nomenclature

In this study, the term "specification" is used to refer to all formal documents for the evaluation of engineering or architectural designs. These include:

- legislated building codes, such as the New York City Building Code [3];
- model building codes, such as the Basic Building Code of the Building Officials and Code Administrators International, Inc. [4];
- consensus standards, such as the American Concrete Institute (ACI) Building Code Requirements for Reinforced Concrete [1];
- proprietary or trade association specifications, such as the American Institute of Steel Construction (AISC) Specification for the Design, Fabrication and Erection of Structural Steel for Buildings [2]; and
- specifications of agencies or owners, such as the Minimum Property Standards of the U.S. Department of Housing and Urban Development [11].

Specifically excluded from this discussion are building specifications made a part of the contract documents for a building project and product specifications describing proprietary products or systems.

The study deals with three types of specifications*, which differ in their level of abstraction, namely:

- performance specifications, which state required attributes in an implementation-independent manner, such as the "Guide Criteria for the Design and Evaluation of Operation BREAKTHROUGH Housing Systems" [10].
- procedural specifications, consisting of calculation and evaluation procedures, which state required attributes and procedures for their evaluation in an implementation-dependent manner such as the ACI and AISC specifications [1,2]; and
- prescriptive specifications, which state required dimensions or properties in a manner completely defining the acceptable configurations or procedures in an implementation-dependent manner, such as the One and Two Family Dwelling Code [17].

In this study, the term provision will be used to refer to any normative statement in a specification; that is, requirements or criteria in performance specifications or paragraphs in prescriptive and procedural specifications.

1.4 Previous Work

Essentially all previous studies on the organization and structure of specifications were motivated initially by the prospect of computer processing of specification provisions for design or code conformance checking. While the formalism and rigor required for computer processing is a very useful intellectual framework for developing an understanding and principles, the concepts which thus emerge need not necessarily be implemented in computer programs. The concepts can also be used for manual, or non-computerized, codes.

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*It deals with all three types with the following qualifications. It offers no detailed study of any procedural specifications and it has more material on performance specifications than prescriptive specifications.

An elementary notation, or "language" and data structure for representing building problems for computer applications was described in 1967 by Clark [5]. It included rules for organization of code-like provisions. Kapsch's review of existing architectural information indexing systems [13] found all such systems lacking in precision and coverage. A report to the Center for Building Technology of the National Bureau of Standards (CBT) by Eberhard, et al [7] postulated a number of potential computer applications for building regulation use, but did not present a formal structure for them.

The senior co-author, in collaboration with R. N. Wright, has dealt extensively with the representation of procedural specifications and the application of this representation to computer-aided design, and developed improved formats and organization for procedural specifications [9,15,16]. The status of that work as of early 1975 is summarized in [8]. Refinements of this work were carried out at the University of Illinois in a project initiated by R. N. Wright and then continued under J. W. Melin (see [22]). Other extensions of the work are underway at Carnegie-Mellon University under the direction of the senior co-author. The work at Carnegie-Mellon University and the University of Illinois to date has not dealt with performance specifications <u>per se</u>, nor did it produce any of the formal structures and concepts introduced in this report. The computer aids developed as part of the University of Illinois project are, however, well suited for operating on the classification structures presented here.

1.5 Scope of Report

Chapter 2 develops a model of specifications and examines the overall organization of provisions as well as the detailed organization. Special emphasis is given to performance specifications, because of their need to specify objectives in general terms, and because of the special character of the requirement-criterion-test-commentary hierarchy.

Chapter 3 presents the analysis of the Solar Heating Performance Criteria; Chapter 4 presents the analysis of the Uniform Plumbing Code.

Chapter 5 presents rules of style in specification writing. Chapter 6 sketches out potential applications of the study for the analysis of existing specifications and for the synthesis of new ones. Chapter 7 contains conclusions and recommendations for further work.

2. MODEL FOR PROVISIONS AND THEIR ORGANIZATION

In this chapter, a model for the classification of provisions and their organization is presented, and some of the problem areas which constrain further formalization at this time are discussed. The discussion covers all three types of specifications mentioned earlier, but Section 2.4 deals with the specific considerations related to performance specifications.

2.1 General

The basic concept in this study is that each provision of a specification, whether performance, procedural or prescriptive, addresses a performance attribute of a physical entity.

In performance specifications, provisions are customarily organized into requirements, (usually qualitative statements of required attributes) and criteria, (usually quantitative statements giving levels of performance necessary to meet the requirements). Also, in performance specifications an attempt is made to address the physical entity involved in terms of the attribute being considered (or to omit any mention of the physical entity), so as not to overspecify and thus inhibit innovation.

Prescriptive and procedural specifications differ from performance types in two aspects. First, the attributes addressed, and even the requirements, are not always spelled out, but frequently have to be inferred. Second, the physical entities to which the provisions apply tend to be identified in detail.

It is recognized that the above comments pertain directly only to wholly performance and prescriptive specifications, and that most specifications actually contain a mixture of the two types. Section MP 3F of [18] discusses this point; a table on page 6 of that section describes nine levels of performance/prescriptive mixture, and gives sample provisions from each level. A review of the table shows that the basic concept is maintained throughout; that is, each sample provision addresses a physical entity and (implicitly or explicitly) a desired attribute.

The model for organization is formulated at two levels:

- the way single provisions are composed; and
- the manner in which related provisions are organized.

These two levels form the subject of the next two sections.

2.2 Detailed Organization: Provision Structure

The contents of provisions in all types of specifications contain the same type of information, namely:

- a subject, which refers to or makes some mention of a physical entity; and
- a predicate, which relates to the attribute to be satisfied.

There are only small variations in the formats of specification provisions in performance and prescriptive specifications. A classification scheme for the formats of provisions will be presented in Section 3.3.

By contrast, many provisions in procedural specifications describe calculation and evaluation procedures to be executed. The representation of the organization of such provisions has been presented elsewhere [15,16] and will not be dealt with further in this study.

2.3 Overall Organization: Classification Schemes

As regards the overall organization of specifications - be they performance, procedural or prescriptive - provisions in them are related to one another either through the physical entity addressed or the attribute to be satisfied.* In order to reflect this relationship, classification schemes are employed.

The objective of a classification scheme is to:

- provide hierarchical groupings of related provisions; and
- provide a basis for textual organization, notably outlining and indexing, of the specification.

By the nature of the subject matter, two independent major classification schemes are needed, namely:

- by physical entity; and
- by attribute.

Performance specifications developed in CBT customarily use these two classifications as row and column indexes of two-dimensional matrices and record the applicable provisions (requirements and criteria) at the intersections. While this representation has proved workable in CBT, it has shortcomings, primarily because it does not display the internal structure, or "texture", of the classification, such as the finer subdivision of entities or attribute parts within a box of the matrix; because it is not well suited for outlining and indexing; and because it promotes unnecessary redundancy in the repetition of nearly identical provisions.

In this study, the two classifications will be dealt with separately, and no attempt will be made to develop a single representation for the two. The classifications will be discussed in turn.

2.3.1 Physical Entity Classification

In developing a classification scheme for the physical entities addressed by a specification, a major problem is that of identifying the various functions of a physical entity and then distinguishing this from the specific place of the physical entity among other physical entities. A given physical entity may be referred to in several contexts, and in each such context it may be associated with different sets of other physical entities. For example, a piece of pipe may be referred to:

- by its material and its intrinsic properties,
- as a fluid container, subject to pressure changes, vacuum, etc.
- as a mechanical element, subject to noise, vibration, fatigue, thermal stresses, etc.
- as a chemical reagent, subject to corrosion, contamination, etc.
- as a load-carrying element, subject to external imposed loads, earthquake effects, etc.
- as a potential projectile in an explosion, a thermal source in a fire, etc.
- etc.

In each of these contexts, the pipe can be associated with different sets of physical entities which are related to it in the specific context being considered.

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*In addition, though of little interest here, provisions in procedural specifications which deal with one evaluation procedure are arranged in a hierarchically related sequence.

The problems of developing an appropriate classification scheme for physical entities are different in different types of specifications:

- in performance specifications, it is important to avoid a purely hierarchical classification by part name, such as one based on "system-subsystem-component-material" subdivisions, because such a classification would unduly over-specify the physical realizations possible and thus inhibit innovation in design;

- in prescriptive and procedural specifications, part names dominate; function and context often have to be inferred, thus making difficult the task of generating higher-level classifications and groupings.

Two applications of generating physical classifications are given in the two following chapters.

2.3.2 Attribute Classification

The development of an appropriate classification scheme for the attributes of the provisions of a specification is more difficult than the development of the physical classification, for the following reasons:

- there is a general lack of suitable definitions of attributes; while the highest-level terms, such as "health and safety", are freely used in prescriptive as well as performance specifications, there are no established subdivisions; e.g., subdivisions of health into biological, physiological or psychological health;

- in performance specifications, there is a large jump from general statements of "user needs" to the more detailed prescribable attributes that can be addressed directly by the provisions;

- in prescriptive specifications, usually resulting from a long, historical process of accretion, the original attributes may be lost, blurred or combined with others, as in the ubiquitous "health and safety".

This problem is further complicated by the frequent referencing of external standards in both types of specifications. These references typically describe "what to do" or "how to do it," rather than "why", that is, the attribute to be satisfied.

Two approaches to generating attribute classifications are discussed in the following two chapters.

2.4 Organization of Performance Specifications

Performance specifications introduce two additional considerations bearing on the organizational model of specifications, as described in the following sections.

2.4.1 Property Classification

As described in Section 2.3.1, one crucial objective of performance specifications is to avoid overspecification of the physical entities involved, so as to allow for innovation in design. In other words, the specification writer must avoid any mention of specific physical entities or else address them in an implementation/independent fashion.

The current study has revealed a mechanism (not previously identified) which has been used by performance specification writers to overcome this double constraint. The mechanism involves addressing a number of physical entities by common <u>properties</u>, rather than through extensive enumeration. These properties occur in provisions as modifiers of nouns which refer to physical entities. Thus, in statements such as:

- "system assemblies <u>containing heat transfer fluids</u>"

- "components <u>involving moving parts</u>"

- "subassemblies . . . <u>that are accessible</u>"

each underlined portion, which modifies the noun preceding it, calls attention to a specific property, while avoiding a detailed enumeration of all possible physical entities possessing this property. The concept of property is thus used in performance specifications to achieve economy of terms and precision without over-specification.

The concept of property acts as an indirect coupler or selector between the physical entities and the attributes. Specifically, a property calls attention to a performance characteristic, common to some group of physical entities, which may be susceptible to a dysfunction associated with a particular attribute. In the three examples above, "system assemblies containing heat transfer fluids" are subject to mechanical and chemical forces which may affect durability, "components involving moving parts" are subject to wear and deterioration, and "subassemblies that are accessible" may cause hazards to occupants from exposure to high temperature.

The development of a classification scheme for properties must therefore parallel that for physical entities and attributes. One scheme developed is given in the next chapter.

2.4.2 RCTC Format

The format of performance specifications, as used in CBT, introduces an intermediate level of organization between that of the individual provisions and the overall classification. This level is implicit in the "Requirement-Criterion-Test-Commentary" (RCTC) statement, namely:

- there are one or more requirements associated with each attribute class;
- a requirement is a qualitative statement regarding some physical entity and some attribute class;
- there are one or more criteria associated with each requirement;
- a criterion is a quantitative statement which gives a measurable level of performance necessary to meet the requirement with which it is associated;
- there is a test associated with each criterion;
- the test, or evaluation, sets forth the methods whereby a judgment can be made that the criterion has been complied within the design or construction of a building system;
- there is (usually) a commentary associated with each criterion; and
- the commentary provides background information.

The RCTC format imposes two organizational conditions;

- a criterion is related to its requirement by addressing: (1) a subset of the physical entity; (2) a specific property grouping a number of physical entities; and/or (3) a subset of the attribute class addressed by the requirement.
- the test, or evaluation, needs to be related to the type of measure given in the criterion it accompanies.

Examples of these hierarchical interrelations are given in Section 3.4.

3. APPLICATION TO SOLAR HEATING CRITERIA

This chapter presents an analysis of a performance specification according to the general model described in Chapter 2.

3.1 General

The analysis is performed on the first six chapters of the NBS performance specification entitled Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, 1975 [12] referred to hereafter as the "Solar Criteria." Although a formal physical entity-attribute matrix is not used in the specification, it is organized by chapters on the basis of the following attribute classes:

Chapter 1. Function

Chapter 2. Mechanical

Chapter 3. Structural

Chapter 4. Safety

Chapter 5. Durability/Reliability

Chapter 6. Maintainability

In terms of the physical entities, the specification treats the following systems and subsystems:

- the heating (H) system
- the combined heating and cooling (HC) systems
- the domestic hot water (DHW) system/subsystem
- the energy transport subsystem
- the control subsystem
- the auxiliary energy subsystem
- the collector subsystem
- the storage subsystem

3.2 Classifications

Using the above specification as a source, classification schemes for physical entities, attributes and properties were developed. These schemes and their derivations are discussed in the next three sections. In developing these categories and the entries within them an effort has been made to inject a minimum of external information and rely as much as possible on the terms actually used in the document. Section 3.2.4 presents the actual classification of the provisions (requirements and criteria). It should be understood that these classifications were derived from the Solar Criteria and are not to be construed as final or definite.

3.2.1 Physical Classification

As described above, the beginning of a hierarchical classification of the physical entities involved is given in the specification itself through the identification of three system types (H, HC and DHW) and five subsystems (energy transport, control, auxiliary energy, collector and storage).

In the current study, this classification was extended in two ways, as follows. At the topmost level, it became necessary to distinguish between the system itself, encompassing all three types, and elements external to it, such as drains, supporting structure, (service) manuals, and the like. At the lower levels, it became necessary to introduce an analytical framework to encompass the specific terms for the entities appearing in the specification. The final classification scheme developed in the current study is summarized in Table 3.1; it consists of the following hierarchical levels:

Level I. Global: System or External.

Level II. System type: H, HC, or DHW (as in the Solar Criteria).

Level III. Subsystem: Collector, Storage, Energy Transport, Control or Auxiliary Energy (as in the Solar Criteria).

Level IV through VII. Assembly/Component/Element. This is a hierarchical classification scheme with multiple subdivisions, encompassing the elements specifically cited in the Solar Criteria.

For Levels IV through VII, the terms used and their hierarchy are shown in Table 3.2. It can be seen that some sub-hierarchies are based on a part-to-whole relation (e.g., "manifold" is an element of the "piping" component of the "conveying" assembly of the "mechanical" subsystem), while other sub-hierarchies are classifications by type (e.g., "hazardous or toxic" is one type of "liquid" which in turn is one type of "fluid").

It can also be seen from Table 3.2 that the entries "Collector" and "Control" duplicate entries under Level III: "Subsystems". These redundant entries were introduced in the current study to ensure that the physical entities listed under each are restricted in application; that, e.g., "glazing" applies only to "collector" and "instrumentation" applies only to "control."

The classification of external elements is given in Table 3.3.

3.2.2 Attribute Classification

Even though the Solar Criteria specification was written in performance terminology and therefore highlighted attributes, still it was necessary in this study to experiment with several alternatives in order to develop an acceptable classification for these attributes. This testifies to the lack of understanding of and consequent need for research into the nature of attributes. Two of the chapter headings in the Solar Criteria, "Mechanical" and "Structural," were rejected as not being proper attributes in the sense that qualitative or quantitative performance statements can be assigned to them. As in the case of the physical classification, an attempt was made to use the classification and terms appearing in the Solar Criteria to the maximum extent possible.

The following classification scheme was selected:

1. Functionality: ability of system to provide its rated output This category can be further subdivided into:

    1.1 Rating: establishment of basic rating of system.

    1.2 Efficiency: establishment of criteria whereby the demonstration project can be evaluated, namely, reduction in use of conventional energy sources.

2. Operability: requirements for satisfying performance for the design life of the system under actual use conditions. A subdivision into the two subcategories of Reliability and Durability used in the document proper was considered, but finally, a subdivision was established essentially on a stylistic basis, namely:

    2.1 Requisites: performance requirements which need to be satisfied.

    2.2 Dysfunctions: performance impediments which need to be avoided.

3. Habitability: requirements dealing with the health and comfort of occupants, further subdivided into:

   3.1 Health.

   3.2 Comfort.

4. Maintainability: provisions for maintaining the system in good operating conditions.

5. Safety: provisions for mitigation of hazards, further subdivided, where applicable, into:

   5.1 Safety with respect to intrinsic effects, such as explosion of a system component.

   5.2 Safety with respect to extrinsic effects, such as earthquakes or fires from external causes.

The attribute classification is reproduced for reference in Table 3.4.

It is to be noted that four of these five attribute classes (Functionality, Operability, Maintainability, Safety) correspond to the chapter headings of the Solar Criteria (Function, Durability/Reliability, Maintainability, Safety), and that a new one, namely Habitability, has been introduced. As stated before, the two chapter headings dealing with Structural and Mechanical aspects have been omitted.

3.2.3 Property Classification

As discussed in Section 2.4.1, the identification of common properties both significantly reduces the length of the physical classification and acts as a filter or selector to focus specific attributes onto groups of physical entities, independently of their location in the building component hierarchy in a particular implementation. Let it be emphasized that property is a phenomenon discovered in the current study and that anything said about property is based only on the analysis of the Solar Criteria. The current study proposes the following major categories of properties in the Solar Criteria: (1) external exposure, (2) internal exposure or contact, (3) exposure to or contact with fluids, (4) location, (5) access, (6) mechanical, (7) structural, and (8) serving multiple housing units. As an example of how a property focuses specific attributes onto groups of physical entities, a specific type (3) property is "containing heat transfer fluids," which focuses certain durability - related attributes onto those groups of physical entities which do in fact contain heat transfer fluids.

Considering that the notion of property has never been formally identified, it is quite surprising that it occurs in a very large number of the provisions in the document (see the "property" columns in Table A.1). Furthermore, it is worth noting that the properties identified are also well-structured hierarchically, as shown in Table 3.5.

3.2.4 Classification of Provision

The three classifications - physical entity, attribute and property - described in the preceding sections were applied to the 141 requirements and criteria contained in Chapters 1 through 6 of the Solar Criteria. Table A.1 presents the classification of these provisions based on the information given in Tables 3.1 through 3.5. In the table, an entry is made only when the requirement specifically applies to an element of the classification scheme; thus, blank entries mean both not applicable and applicable to all subdivisions of a given level.

The table is not claimed to be completely correct, nor the classification schemes optimal. In particular, as mentioned earlier, the physical classification is somewhat redundant, inasmuch as "collector" and "control" appear in both the subsystem (Level III) and assembly (Level IV) classifications. Also, the provisions dealing with the heat transfer fluid are classified both under the "energy transfer" subsystem (Level III) and under "fluid" classification (Level IV).

Second, the interaction between the assembly category of the physical classification and the property category needs to be further investigated; at present, the assignment of a provision to entries in one or both categories is occasionally arbitrary, reflecting, in some cases, the ambiguity of the text. For example, Criterion 2.6.2* is entitled "Air quality" and thus suggests a provision whose subject is the component "air"; the text of the criterion, however, deals with "duct and fan systems", i.e., physical entities having a property "exposed to air."

Finally, on the attribute side, the creation of the new attribute subcategory "health" appears to be somewhat premature, as in many cases dealing with mechanical subsystems the provisions are simply identified with the general attribute "health and safety." Similarly, the recurring statement "safe and efficient operation" defies precise classification by attribute at the present state of knowledge.

Notwithstanding the above inconsistencies, Table A.1 could be used to review the Solar Criteria and suggest changes in the organization of that specification based on the following observations:

- the physical classification is occasionally too detailed, and an attempt should be made to express the scope of a provision differently than by extensive enumeration of components.

- the treatment of the property classification deserves considerable further study.

- the attribute categories should be more carefully defined and an attempt should be made to split the major categories into more meaningful subcategories.

Additional rules of usage are given in Chapter 5.

The tabulation given also lends itself to the generation of summary statistics which could be used to improve and "even out" the coverage of the document. As a simple illustration, a frequency count of the attributes occurring in the provisions is given in Table 3.6. Such a table could be used to ascertain whether the number of provisions is commensurate with the importance and complexity of the various attribute classes.

3.3 Structure of Provisions

In this section attention is turned to the manner in which provisions are put together out of constituent parts. Structures are introduced which allow one to "talk about" important concepts which are realized in the wording of provisions (as is done in Chapter 5). Section 3.3.1 deals with the structure of the provisions as they actually occur in the Solar Criteria; Table 3.7 summarizes this structural classification as it applies to requirements. Section 3.3.2 proposes standard forms for requirements and criteria which would explicitly incorporate certain concepts into the actual sentence structure. These proposed structures are based on wording observed in the Solar Criteria; they form the basis of the rules of usage elaborated in Chapter 5.

3.3.1 The Solar Criteria Provisions

For the most part, the provisions in the Solar Criteria contain a subject followed by a predicate. This observation on structure can be depicted as follows:

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*Hereafter in the text and in the tables, C is often used for Criterion (e.g., C 2.6.2) and R is often used for Requirement (e.g., R 2.6).

PROVISION

SUBJECT PREDICATE

Examples from the Solar Criteria are:

C 4.6.4 PROVISION

SUBJECT	PREDICATE
Components and materials used in the H, HC and DHW systems	shall not promote the growth of fungi, mold or mildew

R 2.7 PROVISION

SUBJECT	PREDICATE
Pipe hangers, pipe trenches and other supports	shall carry the static and operational loads normally imposed without impairing system function.

Note that in both cases the SUBJECT refers to or makes some mention of a physical entity and the PREDICATE relates to one (or very rarely, two) of the performance attributes.

So much for the simplest structure for provisions. Many provisions in the Solar Criteria are more complex. One additional complexity is the condition, a group of words appended in front of the basic structure introduced above for the purpose of postulating a certain implementation. The structure accommodating this complexity is:

PROVISION

CONDITION PROVISION

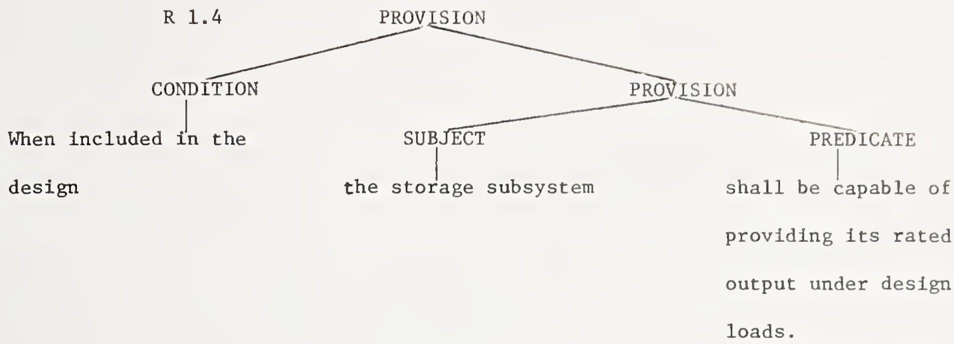
SUBJECT PREDICATE

Examples from the Solar Criteria are:

C 2.2.3 PROVISION

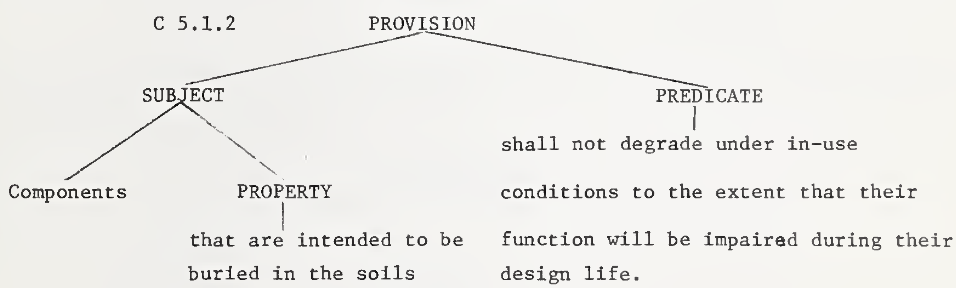
CONDITION PROVISION

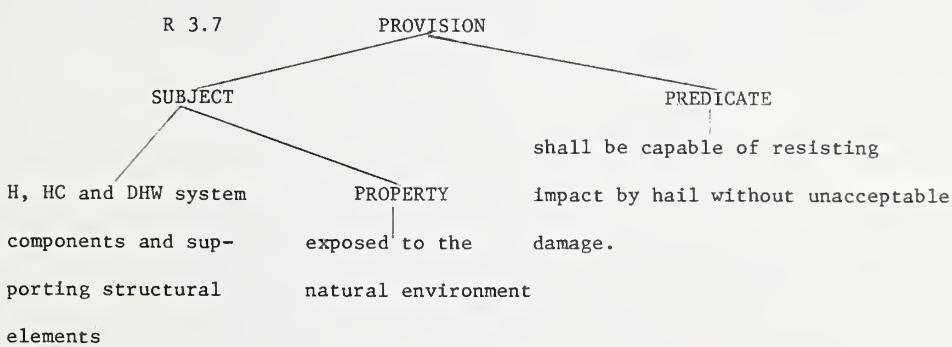
CONDITION	SUBJECT	PREDICATE
When a liquid is used as the transfer fluid and quick-closing valves are employed in the design	the piping system	shall be capable of providing its rated output under design loads.



C 2.2.3 uses a condition to postulate an implementation using a liquid transfer fluid in conjunction with quick-closing valves in order to call attention to the problem of "water hammer." R 1.4 postulates an implementation using a storage subsystem to call attention to the necessity of providing rated output under design loads. Note that these provisions postulate the incorporation of certain physical entities in acceptable designs without specifying the incorporation of those physical entities.

Another complexity in some provisions is the presence of a property (see Section 2.4.1 for an introduction to the notion of property). Properties usually take the form of groups of words in the subject position which modify (and come after) words which refer to some group of physical entities. They are used in provisions to group together a number of physical entities in a possible implementation which are subject to the same dysfunction. The following examples clarify these points:





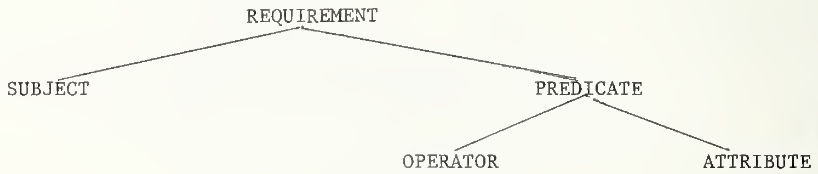
First, note that in the subject position in both these provisions, a word or group of words referring to a set of physical entities comes first, followed by a property which modifies the preceding word or group of words. Note also that the predicate in each case mentions a dysfunction (degradation in C 5.1.2 and impact by hail in R 3.7) that applies to the physical entities grouped together by the property (components buried in soil in C 5.1.2 and components exposed to the natural environment in R 3.7).

Table 3.7 gives a representation of every requirement in the Solar Criteria in terms of the concepts just discussed. A few observations concerning these representations are in order. First, there are two requirements (R 1.1 and R 4.5) which contain two sentences; in both cases the table gives a representation of the first sentence only since it was felt that only the first sentence could stand alone as a requirement. Second, two requirements (R 2.6 and R 4.5) were re-worded in order to better fit the representation scheme; the re-wording does not change the meaning of either of the requirements as they occur in the Solar Criteria. Third, the consistency of this table with the classification of requirements given in Table A.1 is not guaranteed in every case. This is because extensive re-wording of the provisions would be necessary, and re-wording from the original text has been kept to an absolute minimum; e.g., Table A.1 splits requirements that address two attributes whereas Table 3.7 leaves the original wording intact. Finally, as discussed below, criteria could be subject to the same sort of representation scheme above equally successfully, though this has not been done. The only obvious problem in the way would seem to be that the complexity of the wording of some of the criteria in Chapter 3 of the Solar Criteria exceeds that of the structures introduced.

3.3.2 Proposed Structures for Provisions

The provision structures introduced in the previous section are applicable equally to requirements and criteria. This section introduces tentatively proposed structures which distinguish between requirements and criteria. These structures are based on the wording found in some of the provisions in the Solar Criteria. They are not as generally applicable to the actually-occurring provisions as the structures introduced in Section 3.3.1. The structures in this section can be thought of as proposed models for rewriting currently existing provisions or for composing new ones. As such, they form the basis of the rules of usage in Chapter 5.

The tentatively proposed structures for requirements are now introduced. First, the basic structure:



The only structural innovation here is that the predicate is composed of two parts: an operator and an attribute. The operator always consists of "shall" possibly followed by "be," "not," or "not be." The attribute is a sequence of words relating to one of the attribute classes.

Examples from the <u>Solar Criteria</u> now follow:

R 1.1

- REQUIREMENT
  - SUBJECT
    - The H and HC systems
  - PREDICATE
    - OPERATOR
      - shall be
    - ATTRIBUTE
      - capable of collecting and converting solar energy into thermal energy.

R 4.2

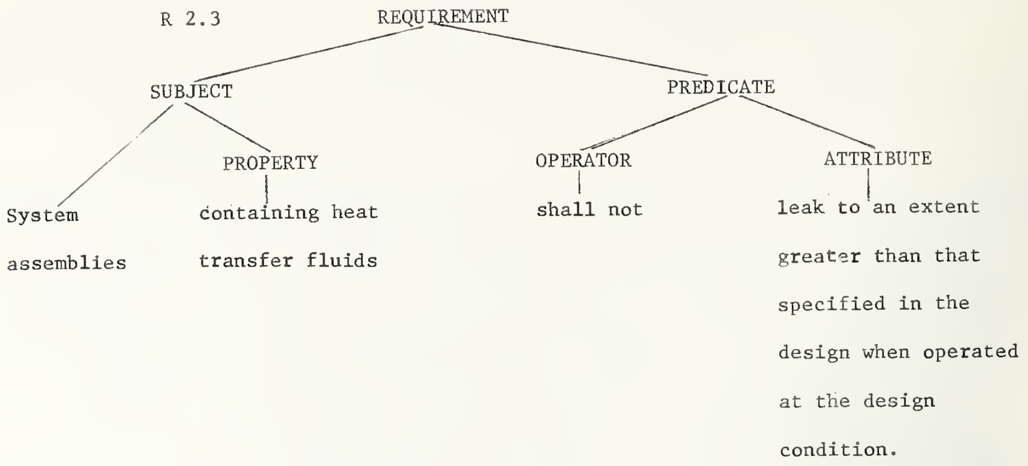
- REQUIREMENT
  - SUBJECT
    - The H, HC and DHW systems
  - PREDICATE
    - OPERATOR
      - shall be
    - ATTRIBUTE
      - fail-safe in the event of damage to system components or a power failure.

Note that in both cases the operator is "shall be" and that the attribute in R 1.1 is a sequence of words relating to the rating attribute class, while the attribute in R 4.2 relates to intrinsic safety.

The proposed structures accommodate conditions and properties discussed in the preceding section, as the following examples show:

R 1.4

- REQUIREMENT
  - CONDITION
    - When included in the design
  - REQUIREMENT
    - SUBJECT
      - the storage
    - PREDICATE
      - OPERATOR
        - shall be
      - ATTRIBUTE
        - capable of providing its rated output under design loads.



Attention is now turned to tentatively proposed structures for criteria. Everything just said about parts of requirements applies to parts of criteria with the exception of the attribute. That is, criteria and requirements are similar in that both can contain conditions and properties, and in that both can contain the same types of subjects and operators. They differ in that where requirements have attributes, criteria have measures. A measure states the level of performance that the physical entity must achieve in support of the requirement associated with the criterion. A measure is composed of two parts*: a phenomenon, which identifies a dysfunction to be avoided, or a requisite to be assured; and a quantifier, which states a method for avoiding the dysfunction or assuring the requisite.

Criteria can be classified according to the ways in which they specify methods for assuring performance. A classification based on the analysis of the Solar Criteria is now presented. First, there are those criteria which refer to other codes or standards for complete conformance-checking procedures; these criteria are called implicit criteria (see Example 1 below). All other criteria are explicit criteria, of which there are two sub-types: complete and incomplete. Incomplete criteria are those in which no quantifier is stated; only such words as "is avoided" or "is assured" are used (see Example 2 below). The two sub-types of complete criteria are existence criteria - those in which the existence of a device or concept is specified in the quantifier (see Example 3) and value criteria - those in which a value is specified in the quantifier.

There are three sub-types of value criteria: value from document - those in which the value which assures performance is given in the solar criteria document - either in the criterion under observation or elsewhere in the document (see Example 4); value from design - those in which the value is stated to be governed by the design of the system (see Example 5); and value from other source - those in which the value is said to be obtained from some other code or standard (see Example 6). This classification scheme is summarized by the following table:

Criterion

- 1 Implicit
- 2 Explicit
  - 2.1 Incomplete
  - 2.2 Complete
    - 2.2.1 Existence
    - 2.2.2 Value
      - 2.2.2.1 Document
      - 2.2.2.2 Design
      - 2.2.2.3 Other Source

---

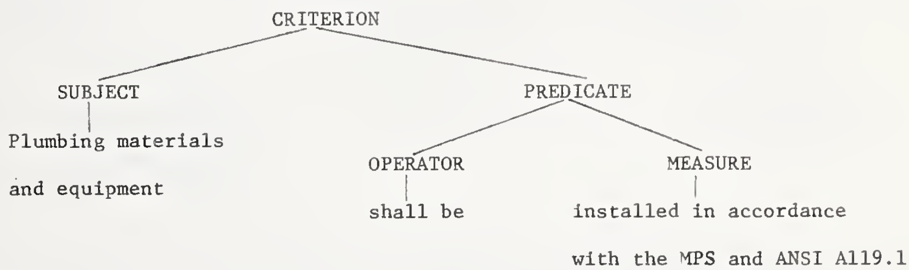
*Except for measures in implicit criteria (see below); these are not subdivided.

Measure in implicit criteria is not subdivided into phenomenon and quantifier.

The following trees are displayed in order to better explain the quantifier constituent. The wording of the criteria in these trees is not always the same as the wording in the document; rewording is intended to be without change in meaning.

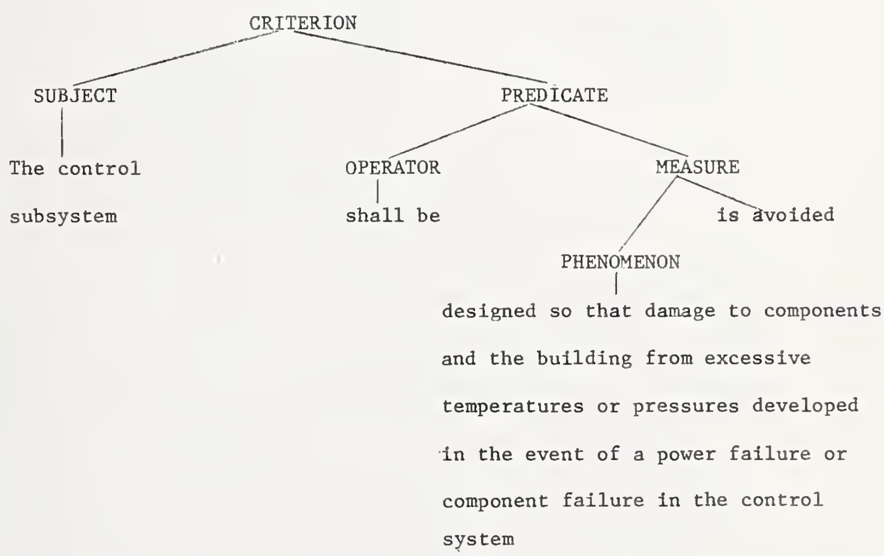
Example 1 - Implicit Criteria - C 4.1.1

Note that the measure here refers to another source for the whole conformance-checking procedure.



Example 2 - Incomplete Criterion - C 4.2.1

The first sentence of this criterion contains two phenomena - damage to components and danger to occupants. The following example is an analysis of the part dealing with damage to components. Note that the criterion is incomplete in that it does not introduce a quantitative measure.



Example 3 - Existence Criterion - C 1.7.4

The first sentence of this criterion is reworded and analyzed as follows:

- CRITERION
  - SUBJECT
    - The DHW system/ subsystem
  - PREDICATE
    - OPERATOR
      - shall be
    - MEASURE
      - PHENOMENON
        - designed so that the regulation of domestic water output temperature
      - QUANTIFIER
        - is assured by providing a manually set, automatic control.

Example 4 - Value-From-Document Criterion - C 1.7.4

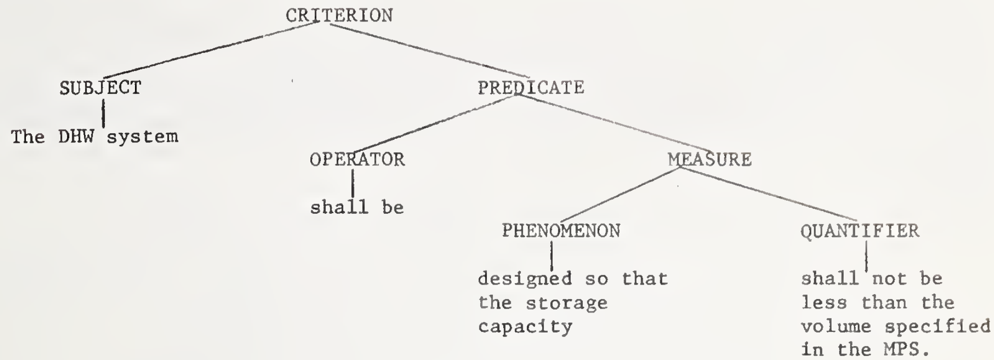
The second sentence of this criterion is reworded and analyzed as follows:

- CRITERION
  - SUBJECT
    - The DHW system/ subsystem
  - PREDICATE
    - OPERATOR
      - shall be
    - MEASURE
      - PHENOMENON
        - designed so that water temperature at the DHW storage tank
      - QUANTIFIER
        - shall be capable being controlled within the range of 105° to 160° F.

Example 5 - Value-From-Design Criterion - C 1.6.1

- CRITERION
  - SUBJECT
    - The energy transport subsystem
  - PREDICATE
    - OPERATOR
      - shall be
    - MEASURE
      - PHENOMENON
        - designed so that thermal losses and use of electrical power
      - QUANTIFIER
        - shall not exceed the operating design values.

Example 6 - Value-From-Other-Source Criterion - C 1.2.2



3.3.3 Test

Following each criterion in the Solar Criteria there is a test or evaluation which sets forth the methods upon which an objective judgment can be made that the criterion has been complied with. Two general types of test methods, each with three subtypes, have been identified in the document:

Test Methods

A. Analytical

   1. modeling

   2. calculations

   3. inspection of plans and specifications

B. Physical

   1. testing

   2. documentation of historical performance

   3. testing in lieu of calculations and performance

Examples of each of the above are:

A1. E 1.1.4, ". . .An analytical model . . . shall be utilized. . ."

A2. E 1.1.1, ". . .calculations based upon ASHRAE analytical methods."

A3. E 1.7.3, "Review of drawings and specifications."

B1. E 3.4.1, "Physical simulation and testing. . ."

B2. E 5.1.2, "Documentation of satisfactory long term performance under in-use conditions. . ."

B3. E 5.3.4, "Where adequate existing information is unavailable, testing. . .will be used."

There seems to be no reason at this time in the development of this classification system to analyze the structure of evaluation statements in the way that requirements and criteria have been analyzed. This is because such statements are of little interest in and of themselves; they acquire interest and importance only as they are associated with their related criteria. This one of the hierarchical relationships discussed in the next section.

3.4 RCTC Format

In this section, the two organizational requirements introduced in Section 2.4.2 are explored in light of the proposed structures discussed in Section 3.3.

First, a criterion should be related to its requirement by the fact that it addresses: (1) a subset of the physical entity; (2) a specific property associated with the physical entity; and/or (3) a subset of the attribute class addressed by the requirement.

Examples of these three relations are now presented in turn:

1) R 4.1 addresses plumbing and electrical materials and equipment

   C 4.1.1 addresses plumbing materials and equipment

   C 4.1.2 addresses electrical materials and equipment

2) R 4.6 addresses all material and equipment

   C 4.6.1 addresses materials in contact with potable water

   C 4.6.2 addresses subsystems utilizing nonpotable heat transfer fluids

3) R 1.2 deals with the amount and temperature of the potable hot water to be supplied.

   C 1.2.1 deals with the acceptable temperature of potable hot water

   C 1.2.2 deals with the amount of potable hot water.

Second, the evaluation needs to be directly related to the type of measure given in the criterion it accompanies. Using the classification of measures presented in Section 3.2.2, the following observations can be made:

- The existence measure seems to be the most general and any one of the six evaluation types may be associated with it;

- The value measures seem to call for a restricted set of evaluation types, presumably on the basis that if a value or range of values can be established in the document, there probably is not enough uncertainty to warrant the use of all six evaluation methods;

- The implicit measures also seem to be paired with a restricted subset, presumably because these criteria usually reference prescriptive codes and such codes do not generally allow for conformance checking at all six of the evaluation levels; for example, testing is not allowed.

Examples of criterion - evaluation pairs follow, one for each of the three measure types.

- Existence measure

  C 1.7.3: The DHW system/subsystem shall be provided with a manually set, automatic control that provides effective regulation of the domestic water output temperature.

  E 1.7.3: Review of drawings and specifications.

- Value measure

  C 1.6.1: Thermal losses and use of electrical power in the energy transport subsystem shall not exceed the operating design values.

  E 1.6.1: Engineering review of drawings, specifications, calculations and test data.

- Implicit measure

C 2.7.1: Piping shall be installed in accordance with Section 615 of the MPS (4900.1 and 4910.1) and Part C of the ANSI A119.1, where applicable.

E 2.7.1: Review of drawings, calculations, and specifications.

Table 3.1

Physical Classification

Level: I Global	II System	III Subsystem	IV-VII Assembly
A. System	A. H, HC B. HC only C. DHW	A. Collector B. Storage C. Transport D. Control E. Aux. Energy	(See Table 3.2)
B. External			(See Table 3.3)

Table 3.2

Classification by Assembly
(System Components)

Level	IV	V	VI	VII
	1. Mechanical			
		1.1 Motive		
			1.1.1 Pump	
			1.1.2 Fan	
		1.2 Heat Exchanger		
			1.2.1 Heater	
			1.2.2 Condenser	
		1.3 Conveying		
			1.3.1 Piping	
				1.3.1.1 Manifolds
				1.3.1.2 Circulation Loops
				1.3.1.3 Catch Basins
				1.3.1.4 Drain/Fill Attachments
			1.3.2 Ducts	
		1.4 Hangers		
	2. Electrical			
	3. Structural			
		3.1 Conventional		
			3.1.1 Ultimate strength	
			3.1.2 Working stress	
		3.2 Non-conventional		
	4. Collector			
		4.1 Mounting		
		4.2 Glazing		
		4.3 Cover Plate		
	5. Control			
		5.1 Regulators		
		5.2 Instrumentation		
		5.3 Controllers		
		5.4 Shutoff Valves		
	6. Fluids			
		6.1 Liquids		
			6.1.1 Hazardous or Toxic	
	7. Filters			
	8. Gaskets and Sealants			

Table 3.3

Classification of External Elements

Level: IV

1. Drains
2. Supporting Structure
3. Fire Resistant Assemblies
4. Manual

Table 3.4

Classification of Attributes

Level: I	II	
1.	Functionality	
	1.1	Rating
	1.2	Efficiency
2.	Operability	
	2.1	Requisites
	2.2	Dysfunctions
3.	Habitability	
	3.1	Comfort
	3.2	Health
4.	Maintainability	
5.	Safety	
	5.1	Intrinsic
	5.2	Extrinsic

Table 3.5

Classification of Properties

Level: I	II
1.	External Exposure
	1.1 Rain, Hail, and Ice
	1.2 Pollutants, Solar Degradation
	1.3 Freezing
	1.4 Wind
2.	Internal Exposure or Contact (other than fluids)
	2.1 Elevated Temperature and Pressure
	2.2 Dissimilar Materials
	2.3 Leachates and Decomposition Products
3.	Exposure to or Contact with Fluids
	3.1 Potable Liquids
	3.2 Non-Potable Liquids
	3.3 Corrosive Liquids
	3.4 Pressurized Liquids
	3.5 Liquids Requiring Special Handling
	3.6 Air
4.	Location
	4.1 Elevated
	4.2 Buried
5.	Access
	5.1 Requiring Access
	5.2 Accessible to Occupant
6.	Mechanical
	6.1 Subject to Vibration
	6.2 Involving Moving Parts
7.	Structural
	7.1 Requiring Cutting
8.	Serving Multiple Housing Units

Table 3.6

Frequency of Attributes

	Attribute	Number of References
1.1	Rating	15
1.2	Efficiency	2
2.1	Requisites	40
2.2	Dysfunctions	61
3.1	Comfort	7
3.2	Health	9
4	Maintainability	18
5	Safety	9
5.1	Intrinsic Safety	8

Table 3.7

Analysis of Requirements

		SUBJECT		
	CONDITION		PROPERTY	PREDICATE
R 1.1		The heating (H) and combined heating and cooling (HC) system		shall be capable of collecting and converting solar energy into thermal energy.
R 1.2		The domestic hot water (DHW) system/subsystem		shall be capable of collecting and converting radiant solar energy into thermal energy which shall be used in combination with storage, where provided, and auxiliary energy to supply an adequate amount of potable hot water at an acceptable temperature to meet the needs of the user.
R 1.3		The solar collector		shall absorb and convert incident solar energy into useful thermal energy.
R 1.4	When included in the design,	the storage subsystem		shall be capable of providing its rated output under design loads.
R 1.5		The presence of the system components		shall not significantly affect the efficient operation of the H, HC or DHW system or the habitability of the dwelling.
R 1.6		The energy transport subsystem		shall transfer the required thermal energy between the operating subsystems at or above the design efficiency under design full load conditions.
R 1.7		The control subsystem		shall provide for the safe and efficient operation of the H, HC and DHW systems.
R 1.8		The auxiliary energy subsystem		shall be integrated into the H, HC and DHW systems to the extent necessary to automatically provide the designed heating, cooling and domestic hot water.
R 2.1		The systems for heating (H) and combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem		shall be capable of functioning at their designed flow rates, pressures and temperatures.
R 2.2		Mechanical stresses that arise within the system		shall not cause damage or malfunction of the system or its components.

Table 3.7 (Continued)

	CONDITION	SUBJECT	PROPERTY	PREDICATE
R 2.3		System assemblies	containing heat transfer fluids	shall not leak to an extent greater than that specified in the design when operated at the design conditions.
R 2.4		The collector subsystem		shall be capable of being located, oriented, and tilted as required by the design to capture sufficient solar energy to meet functional requirements.
R 2.5		Shutdown of the sub-systems in one dwelling unit		shall not impair the distribution of energy to other dwelling units of the building.
R 2.6		The heat transfer fluid		shall be maintained at a level of quality that does not impair its heat transfer function.
R 2.7		Pipe hangers, pipe trenches, and other supports		shall carry the static and operational loads normally imposed without impairing system function.
R 2.8		The piping system and associated equipment		shall be protected against rupture or leakage from excessive pressures and temperatures.
R 3.1		The structural design of the heating (H), combined heating and cooling (HC) and the domestic hot water (DHW) systems including con-nections and supporting structural elements		shall be in accordance with nationally recognized codes and standards and shall be based on loads anticipated during the service life of the systems.
R 3.2		The structural elements and connections of the H, HC and DHW systems		shall not fail under ultimate loads expected during the service life of the system.
R 3.3		The structural elements and connections of H, HC and DHW systems.		shall be designed to withstand service loads without damage of unacceptable magnitude.
R 3.4		The structural elements and connections of H, HC and DHW systems		shall not fail under the application of cyclic loads expected during the service life.
R 3.5		Cutting of structural elements for the install-ation of H, HC and DHW systems		shall not reduce the required load capacity of structural elements.

Table 3.7 (Continued)

	CONDITION	SUBJECT		PREDICATE
			PROPERTY	
R 3.6		The load capacity of structural connections and elements supporting the H, HC and DHW system components		shall not be impaired by the effect of creep and residual deflections.
R 3.7		H, HC and DHW system components and supporting structural elements	exposed to the natural environment	shall be capable of resisting impact by hail without unacceptable damage.
R 3.8		The structural elements and connections of H, HC and DHW systems		shall comply with Criterion 3.2.1 while simultaneously subjected to constraint loads expected during the service life.
R 3.9		Horizontal surfaces of the H, HC and DHW systems		shall be designed in a manner that will assure stability in service under ponding conditions.
R 4.1		The design and installation of the systems for heating (H), combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem and their components		shall be in accordance with nationally recognized plumbing and electrical codes and standards for health and safety, where applicable.
R 4.2		The H, HC and DHW systems		shall be fail-safe in the event of damage to system components or a power failure.
R 4.3		The design and installation of the H, HC and DHW systems and their components		shall provide a minimum level of fire safety consistent with applicable codes and standards.
R 4.4		Heat transfer fluids	which require special handling because of toxicity and/or flammability	shall not be used unless the systems in which they are used are designed to avoid exposing the occupants of dwellings to unreasonable hazards.

Table 3.7 (Continued)

	CONDITION	SUBJECT	PROPERTY	PREDICATE
R 4.5		The H, HC and DHW systems		shall not unduly hinder the movement of occupants of the building or emergency personnel.
R 4.6		No material, form of construction, fixture, appurtenance or item of equipment		shall be employed that will support the growth of micro-organisms or introduce toxic substances, impurities, bacteria or chemicals into potable water or air circulation systems in quantities sufficient to cause disease or harmful physiological effects.
R 4.7		Temperatures of exterior surfaces of the H, HC and DHW systems		shall not create a hazard.
R 5.1		The systems for heating (H) and combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem and their various subassemblies		shall not be affected by external environmental factors to an extent that will significantly impair their function during their design life.
R 5.2		Components		shall be capable of performing their intended function for their design life when exposed to the temperatures and pressures that can be developed in the system.
R 5.3		Materials used in the systems and their various subassemblies		shall have sufficient chemical compatibility to prevent corrosive wear and deterioration that would significantly shorten the intended service life of components under in-use conditions.
R 5.4		Components	that involve moving parts	shall, with normal maintenance, be capable of performing their intended function without excessive wear or deterioration for their service lives.
R 6.1		The systems for heating (H), combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem		shall be designed, constructed, and installed to provide sufficient access for general maintenance, convenient servicing and monitoring of system performance.
R 6.2		A manual		shall be provided for the installation, operation and maintenance of the H, HC and DHW systems.
R 6.3		The H, HC and DHW systems		shall be designed in such a manner that they can be conveniently repaired by qualified service personnel.

4. APPLICATION TO PLUMBING CODE

This chapter provides an analysis of an existing prescriptive specification to determine how its information is classified and organized. This, when added to the performance document dealt with in Chapter 3, provides a broader spectrum for the analysis of specification provisions.

4.1 General

The provisions of the Uniform Plumbing Code (often referred to hereafter as the "Plumbing Code") [21] are analysed by: 1) Physical Classification and 2) Attribute Classification. This analysis differs from the previous example of classification of the Solar Criteria (see Chapter 3) where provisions are analyzed by: Physical Classification, 2) Attribute Classification and 3) Property. In a performance document, the classification of provisions by "property" encourages the use of innovative materials and methods of construction. An example of the use of a property is "assemblies carrying heat transfer fluids." This wording in a provision allows the use of any assembly which satisfies the property. On the other hand in a prescriptive document such as the Plumbing Code, the assemblies or components which should satisfy a particular attribute are enumerated. Hence, the concept of property has no place in a prescriptive document.

4.2 Classification

Classification schemes for organizing the provisions of the Plumbing Code are developed and presented in this chapter. These include classification schemes for physical entities and for attributes. The classification of provisions of the Plumbing Code is presented in Table B.1, Appendix B. These classifications were derived from the Plumbing Code, and, as was the case for those derived from the Solar Criteria, these are not to be construed as final or definite.

4.2.1 Physical Classification

Table 4.1 presents the overall physical classification scheme developed in this study. Through an iterative process an acceptable framework was developed for encompassing specific terms for physical entities appearing in the Plumbing Code. The top level (Level I) of the physical classification scheme is labeled as Global. It addresses the entire plumbing system and may be identified with any of the subgroups of the physical classification schemes. Level II of the physical classification scheme is labeled as System. It includes the entries: Drainage, Venting and Water Distribution Systems. Each of the above systems are separately subdivided into Subsystems (Level III) and Components (Level IV). The entries identified at this level appear in Table 4.2. Level V of the physical classification scheme is labeled Assembly (Global); it includes only the entry Fixtures and Equipment in general. Fixtures and Equipment is further subdivided into Assembly (Level VI) and Elements (Level VII). The entries in these two levels are given in Table 4.3. Level VIII of the physical classification scheme is labeled Appurtenances (Table 4.4). This includes elements, subelements or components applicable to any of the subgroupings of the physical classification scheme and is therefore an independent grouping. Level IX of the physical classification scheme is labeled Materials (Table 4.5). This is also an independent grouping and is applicable to any of the other subgroupings of the physical classification scheme.

4.2.2 Attribute Classification

The Plumbing Code does not specify performance attributes. However, other model plumbing codes do include specific performance rules or principles which are intended to cover situations not specified in the body of the codes. The first code to include specific performance rules was the National Plumbing Code [14]. These rules are reproduced in Table 4.6. Another document identified was the HUD Operation Breakthrough Guide Criteria [10], which includes a performance attribute classification scheme for plumbing. This classification scheme is reproduced in Table 4.7. Initial attempts were made to classify the provisions of the Plumbing Code using the above two attribute schemes. The groupings under the two schemes did not appear to be unique and seemed to be incomplete in the classification of some of the provisions of the Plumbing Code. Therefore, it was necessary to develop an alternative attribute classification scheme. Level I of the scheme corresponds to a large extent to the scheme developed in the previous chapter for the Solar Criteria. The definition of headings in the classification scheme is as follows:

1. Function: ability of system to perform its intended function.

1.1 Water supply

Water should be supplied in sufficient volume so that plumbing fixtures can perform their essential function under normal conditions of use.

1.2 Water supply and drainage flow

Water supply and drainage systems should provide adequate minimum flow rates in accordance with design conditions.

1.3 Pipe sizes

Water supply piping should be sized so that it can perform its essential function without excessive wear and noise. Drainage piping should be sized so that sewage can be transported to an acceptable point of disposal without overflowing or accumulating within the premises.

1.4 Sewer and drain connections

Plumbing fixtures and equipment which discharge liquid waste or sewage should be directly connected to the sanitary drainage system, except where indirect connections are required. The waste should be transported to an acceptable point where proper connections should be made for further transport to the main sewer.

1.5 Air Flow

Proper venting should be provided to limit pneumatic pressures within the system and adequately protect trap seals. Vent terminals should not return foul air to the building.

1.6 Location for function

Fixtures and equipment should be located so that the plumbing system functions satisfactorily.

1.7 Non-interference with other facilities

The installation of the plumbing system should not interfere with the operation of non-plumbing systems and facilities (i.e., structural members should not be weakened by cutting, notching, etc., and proper clearances should be provided for operation).

2. Health and Safety: requirements dealing with health and safety of occupants.

2.1 Potable water

Premises intended for human habitation should be provided with a supply of pure wholesome water.

2.2 Contamination

Proper protection should be provided to prevent contamination of foods and water by backflow of sewage.

2.3 Backflow, overflow, siphonage

Suitable provisions should be made to prevent backflow and overflow of sewage in the system.

2.4 Hot water equipment

Devices for heating and storing water should be designed and installed so as to prevent danger from explosion through overheating.

2.5 Number of fixtures

The minimum number of plumbing fixtures considered essential for good health and sanitation should be provided.

3. Operability, Durability, Reliability: requirements for satisfying performance for the design life of the system under actual use conditions.

3.1 Damage

The plumbing system (fixtures, joints and connections) should be protected from physical damage that would impair essential function.

3.2 Corrosion

The dangers of premature failure or excessive maintenance relating to corrosion should be minimized by taking into account the character of the water supply, the soil, properties of materials and other environmental factors.

3.3 Deterioration

Plumbing fixtures should be constructed of smooth and non-absorbent material without any concealed fouling surfaces. They should be located in ventilated enclosures. Appropriate consideration should be given to treatment of hazardous wastes and environmental factors.

3.4 Material durability

The plumbing system (piping, fixtures, connections) should be of durable material and capable of giving satisfactory service for its expected life.

3.5 Deflection, misalignment and sagging

Proper supports should be provided, spaced at appropriate intervals, to prevent deflection, misalignment and sagging.

3.6 Structural strength

The proper functioning of plumbing fixtures and the integrity of their supports should not be impaired when subjected to structural loads.

4. Maintainability: provisions for maintaining the system in good operating conditions.

4.1 Fouling, deposits and clogging

To guard against fouling, deposit of solids and clogging cleanouts should be provided. These cleanouts should be arranged in a way so that the pipes can be readily cleaned.

4.2 Fixture accessibility

All plumbing fixtures should be installed and spaced so as to be reasonably accessible for maintenance.

4.3 Maintenance procedure

Proper maintenance procedures should be followed so that the plumbing system is in a sanitary and serviceable condition at all times.

4.4 Location for maintenance

The plumbing systems and equipment should be such as to assure practical maintainability. They should be so located to be convenient for cleaning, servicing, adjusting or replacing various elements or components.

5. Standards: conformance to external standards referenced in the code or procedure outlined in the code.

5.1 External product standards

This pertains to external product standards referenced in the code.

5.2 External installation standards

This pertains to external installation standards referenced in the code.

5.3 Accepted engineering practice

This provides for the judgment of the code official as to the soundness of the design.

5.4 Code procedures

This pertains to appropriate procedures outlined in the code and provided as part of the code requirement.

The attribute classification has been reproduced for reference in Table 4.8.

4.2.3 Classification of Provisions

Table B.1 provides the results of the exercise of classifying the provisions of the Uniform Plumbing Code by applying the physical and attribute classification schemes discussed above to the provisions. The chapters covered are:

a) Chapter 2 - Materials and Alternates

b) Chapter 3 - General Regulations

c) Chapter 4 - Drainage Systems

d) Chapter 5 - Vents and Venting

e) Chapter 6 - Indirect and Special Wastes

f) Chapter 7 - Traps and Interceptors

g) Chapter 9 - Plumbing Fixtures

h) Chapter 10 - Water Distribution

Chapter 8 - Joints and Connections, Chapter 11 - Building Services and Private Systems, Chapter 12 - Fuel Gas Piping and Chapter 13 - Water Heaters and Vents were considered to be outside the scope of this study and were therefore omitted.

The Uniform Plumbing Code contains both direct and indirect references to materials. Provisions such as "fittings shall be made of brass" were classified by using hierarchical identifiers from the physical classification scheme which address "fittings" and the identifier from the attribute classification scheme which addresses "prevention of corrosion," on the assumption that the primary concern is with the satisfaction of that attribute, and not with material selection; therefore, the identifier from the material grouping was not used. On the other hand, provisions such as "fittings shall be made of brass or other approved material" were classified by using the physical entity identifier for "material-general" and the identifier from the attribute classification scheme addressing "approved standards." Furthermore, in provisions specifying "brass fittings should be. . .," the identifier for "material-brass" was used along with the identifiers for the appropriate attribute.

For some provisions it was difficult to ascertain the intention of the code writers. Therefore it was difficult to identify a specific attribute addressed by these provisions. These provisions were therefore classified under attribute classification "code procedures" along with other provisions which were directly addressed by that attribute.

4.3 Analysis

It can be seen from the comparison of attribute classifications shown in Table 4.9 that single attributes are often addressed by more than one rule of plumbing or Guide Criteria attribute; conversely, a single rule of plumbing or Guide Criteria attribute often addresses more than one attribute. In order to make the rules of plumbing and Guide Criteria requirements applicable for classifying plumbing provisions they should be unique and complete and therefore consistent with Table 4.8.

Table B.1 can be subjected to different analyses; one such analysis is given in Table 4.10; the table shows the frequency distribution of attributes covered by the provisions of the Uniform Plumbing Code. It provides the reader with a picture of the content of the code and a record of emphasis.

Table 4.1

Physical Classification

Level	I	II	III	IV	V	VI	VII	VIII	IX
	Global	System	Subsystem	Component	Assembly (Global)	Assembly	Elements	Appurtenances	Material
	A. System	D. Drainage System V. Venting System W. Water Distribution System	Table B.1 Table B.1 Table B.1		F. Fixtures and Equipment	Table B.2		Table B.3	Table B.4

Table 4.2

Physical Classification: Drainage Systems

Level III Subsystems	Level IV Components
a. General	a. General
b. Drainage piping	b. Interceptors
c. Building sewer	c. Grease interceptors
d. Building drain	d. Garage interceptors
e. Storm drain	e. Building traps
f. Storm sewer	f. Sand interceptors
g. Area drain	g. Traps
h. Subsoil drain	h. Direct waste connections
i. Hoistway drain	i. Indirect waste connections
j. Catch basin	j. Interior leaders or downspouts
k. Gutters	k. Cleanouts
l. Condensate drain	l. Backwater valves
m. Indirect waste piping	m. Indirect connections
n. Pressure drainage	
o. Utility drain	
p. Industrial waste piping	
q. Commercial waste piping	

Physical Classification: Venting Systems

Level III Subsystems	Level IV Components
a. General	a. General
b. Vent piping	b. Vent header
c. Stack vent	c. Vent terminal
d. Common vent	d. Vent extension
e. Wet vent	e. Vent fittings
f. Relief vent	f. Vent opening
g. Combination waste and vent	g. Vent connection
h. Circuit and loop vent	h. Waste pipe
	i. Trap
	j. Cleanouts

Physical Classification: Water Distribution Systems

Level III Subsystems	Level IV Components
a. General	a. General
b. Water piping and fitting	b. Ballcock
c. Standpipe	c. Direct connections
d. Hot Water piping	d. Indirect connections
e. Water Storage tank	e. Water Storage Control valves
f. Hot Water Storage tank	f. Gate valve
g. Hot Water heater	g. Meters
h. Water pump	h. Vacuum breakers
	i. Pressure relief valves
	j. Temperature relief valve
	k. Emergency shut-off devices
	l. Valves
	m. Covers
	n. Pressure regulators
	o. Pressure--temperature relief valve

Table 4.3

Physical Classification: Fixtures and Equipment

Level VI Assembly

a. General
b. Bathtub
c. Lavatory
d. Shower
e. Kitchen sink
e1. Garbage disposal
f. Water closet
f1. Flushometer valve
f2. Flush tank
g. Urinal
g1. Flushometer valve
g2. Flush tank
h. Floor drain
i. Laundry tray
j. Dishwasher
k. Clothes washer
l. Drinking fountain
m. Swimming pool
n. Hot Water heater
o. Sumps
p. Ejectors, pumps
q. Lawn sprinklers
r. Interceptors, intercepting tanks
s. Evaporative cooler, air washer, refrigerator and cooling counters
t. Walk-in refrigerator
u. Receptors
v. Stills, sterilizers
w. Condensor
x. Plumbing fixtures (unclassified)
y. Commercial sinks
z. Island sinks

Level VII Elements

a. General
b. Piping (discharge)
c. Piping (supply)
d. Drainage fittings
e. Shower receptors
f. Faucet
g. Shower head
h. Drains
i. Traps
j. Vents
k. Valves
l. Mixing valves
m. Gate valves
n. Vacuum breakers
o. Washdown pipe
p. Cleanouts
q. Hose bib outlet
r. Outlets
s. Inlets
t. Strainers
u. Flashings
w. Backflow preventing devices
x. Motors, compressors, and air tanks
y. Trap arm
z. Overflows
0̸. Ballcock
1̸. Bends

Table 4.4

Physical Classification: Level VIII (Appurtenances)

Level VIII

a. General
b. Threads
c. Connections (direct)
d. Joints
e. Flanges
f. Plugs
g. Locks
h. Bushings
i. Hangers
j. Supports
k. Slip joints
l. Expansion joints
m. Hose clamps
n. Unions
o. Ferrules
p. Screws
q. Bolts
r. Washers
s. Access covers
t. Outlets
u. Joining material
v. Fittings
w. Connections (indirect)
x. Cleanouts
y. Seals
z. Flashings

Table 4.5

Physical Classification: Level IX (Material)

Level IX

a. General
b. Wrought iron
c. Steel
d. Brass
e. Copper
f. Galvanized Iron
g. Cast Iron
h. Bronze
i. Lead
j. PVC (plastic)
k. ABC (plastic)
l. Malleable Iron
m. Concrete
n. Metal

Table 4.6

Rules of Plumbing
(from the National Plumbing Code) [14]

P 1 - All premises intended for human habitation, occupancy, or use shall be provided with a supply of pure and wholesome water, neither connected with unsafe water supplies nor subject to the hazards of backflow or backsiphonage.

P 2 - Plumbing fixtures, devices, and appurtenances shall be supplied with water in sufficient volume and at pressures adequate to enable them to function satisfactorily and without undue noise under all normal conditions of use.

P 3 - Plumbing shall be designed and adjusted to use the minimum quantity of water consistent with proper performance and cleaning.

P 4 - Devices for heating and storing water shall be so designed and installed as to prevent dangers from explosion through overheating.

P 5 - Every building having plumbing fixtures installed and intended for human habitation, occupancy, or use on premises abutting on a street, alley, or easement in which there is a public sewer shall have a connection with the sewer.

P 6 - Each family dwelling unit on premises abutting on a sewer or with a private sewage-disposal system shall have, at least, one water closet and one kitchen-type sink. It is further recommended that a lavatory and bathtub or shower shall be installed to meet the basic requirements of sanitation and personal hygiene.

All other structures for human occupancy or use on premises abutting on a sewer or with a private sewage-disposal system shall have adequate sanitary facilities but in no case less than one water closet and one other fixture for cleansing purposes.

P 7 - Plumbing fixtures shall be made of smooth nonabsorbent material, shall be free from concealed fouling surfaces, and shall be located in ventilated enclosures.

P 8 - The drainage system shall be designed, constructed, and maintained so as to guard against fouling, deposit of solids, and clogging, and with adequate cleanouts so arranged that the pipes may be readily cleaned.

P 9 - The piping of the plumbing system shall be of durable material, free from defective workmanship and so designed and constructed as to give satisfactory service for its reasonable expected life.

P10 - Each fixture directly connected to the drainage system shall be equipped with water-seal trap.

P11 - The drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use.

Table 4.6 (Continued)
Rules of Plumbing

P12 - Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building.

P13 - The plumbing system shall be subjected to such tests as will effectively disclose all leaks and defects in the work.

P14 - No substance which will clog the pipes, produce explosive mixtures, destroy the pipes or their joints, or interfere unduly with the sewage-disposal process shall be allowed to enter the building drainage system.

P15 - Proper protection shall be provided to prevent contamination of food, water, sterile goods, and similar materials by backflow of sewage. When necessary, the fixture, device, or appliance shall be connected indirectly with the building drainage system.

P16 - No water closet shall be located in a room or compartment which is not properly lighted and ventilated.

P17 - If water closets or other plumbing fixtures are installed in buildings where there is no sewer within a reasonable distance, suitable provision shall be made for disposing of the building sewage by some accepted method of sewage treatment and disposal.

P18 - Where a plumbing drainage system may be subject to backflow of sewage, suitable provision shall be made to prevent its overflow in the building.

P19 - Plumbing systems shall be maintained in a sanitary and serviceable condition.

P20 - All plumbing fixtures shall be so installed with regard to spacing as to be reasonably accessible for their intended use.

P21 - Plumbing shall be installed with due regard to preservation of the strength of structural members and prevention of damage to walls and other surfaces through fixture usage.

P22 - Sewage or other waste, from a plumbing system which may be deleterious to surface or sub-surface waters shall not be discharged into the ground or into any waterway unless it has first been rendered innocuous through subjection to some acceptable form of treatment.

Table 4.7

Operation Breakthrough Guide Criteria Plumbing Requirements [10]

1 Structural Serviceability

H.1.1 Deflection
H.1.2 Vibration
H.1.3 Structural loads

2 Structural Safety

H.2.1 Inserts and hangers
H.2.2 Installation

3 Health and Safety

H.3.1 Number of fixtures
H.3.2 Leakage
H.3.3 Hot water supply
H.3.4 Protection of water-heating equipment
H.3.5 Water quantity: user needs
H.3.6 Water potability
H.3.7 Resistance to entry of vermin
H.3.8 Improper emission of gases or liquids
H.3.9 Overflow or back-up
H.3.10 Water pipe sizing
H.3.11 Storm water disposal

4 Fire Safety

H.4.1 Fire endurance
H.4.2 Sprinkler systems
H.4.3 Hazardous areas
H.4.4 Water for fire fighting

5 Acoustic Environment

H.5.1 Noise

6 Illuminated Environment

H.6.1 Artificial light

7 Atmospheric Environment

H.7.1 Condensation

8 Durability/Time Reliability (Function)

H.8.1 System life expectancy
H.8.2 Fixtures and appliances
H.8.3 Installation
H.8.4 Access
H.8.5 Freezing
H.8.6 Corrosion

9 Spatial Characteristics and Arrangement

H.9.1 Size and location

Table 4.8

Classification of Attributes

Level I	Level II
1. (F)*Function	
	1.1 (a.) Water supply
	1.2 (b.) Water supply and drainage flow
	1.3 (c.) Pipe sizes
	1.4 (d.) Sewer and drain connections
	1.5 (e.) Air flow
	1.6 (f.) Location for function
	1.7 (g.) Non-interference with other facilities
2. (H) Health and Safety	
	2.1 (a.) Potable water
	2.2 (b.) Contamination
	2.3 (c.) Backflow, overflow, siphonage
	2.4 (d.) Hot water equipment
	2.5 (e.) Number of fixtures
3. (O) Operability, Durability, Reliability	
	3.1 (a.) Damage
	3.2 (b.) Corrosion
	3.3 (c.) Deterioration
	3.4 (d.) Material durability
	3.5 (e.) Deflection, misalignment and sagging
	3.6 (f.) Structural strength
4. (M) Maintainability	
	4.1 (a.) Fouling, deposits and clogging
	4.2 (b.) Fixture accessibility
	4.3 (c.) Maintenance procedure
	4.4 (d.) Location for maintenance
5. (C) Standards	
	5.1 (a.) External product standards
	5.2 (b.) External installation standards
	5.3 (c.) Accepted engineering practice
	5.4 (d.) Code procedures

*The letter codes shown in parentheses are used in the detailed classification of provisions in Table B.1.

Table 4.9

Comparison of Attribute Classifications

	Attribute	Applicable Plumbing Rules	Applicable Guide Criteria Requirements
1.1	Water supply	P 2, P 3	H.3.10
1.2	Water supply and drainage flow	P 2	H.3.10, H.8.4
1.3	Pipe sizes	P 3	H.3.9, H.3.10
1.4	Sewer and drain connections	P 5, P 17	H.3.9
1.5	Air flow	P 11, P 12	H.3.8, H.3.9
1.6	Location for function	P 7, P 16	L.9.7
1.7	Non-interference with other facilities	P 21	H.1.3, H.2.1
2.1	Potable water	P 1	
2.2	Contamination	P 15, P 22	H.3.6
2.3	Backflow, overflow, siphonage	P 1, P 10, P 15, P 18	H.3.6, H.3.8, H.3.9, H.3.11
2.4	Hot water equipment	P 4	H.3.4
2.5	Number of fixtures	P 6	H.3.1
3.1	Damage	P 14	H.1.2, H.1.3
3.2	Corrosion		H.8.2, H.8.6
3.3	Deterioration	P 7	H.1.3
3.4	Material durability	P 9	H.8.2
3.5	Deflection, misalignment and sagging		H.1.3
3.6	Structural strength	P 21	H.1.3
4.1	Fouling, deposits and clogging	P 8	H.8.4
4.2	Fixture accessibility	P 20	H.8.4
4.3	Maintenance procedure	P 19	H.8.4
4.4	Location for maintenance	P 8	H.8.4
5.1	External product standards		H.8.2
5.2	External installation standards		H.8.3
5.3	Accepted engineering practice		H.8.3
5.4	Code procedures	P 13	H.8.3

Table 4.10

Frequency of Attributes

	Attributes	Number of References
1.1	Water supply	1
1.2	Water supply and drainage flow	19
1.3	Pipe sizes	24
1.4	Sewer and drain connections	8
1.5	Air flow	10
1.6	Location for function	25
1.7	Non-interference with other facilities	9
2.1	Potable water	1
2.2	Contamination	3
2.3	Backflow, overflow, siphonage	33
2.4	Hot water equipment	1
2.5	Number of fixtures	3
3.1	Damage	8
3.2	Corrosion	13
3.3	Deterioration	3
3.4	Material durability	3
3.5	Deflection, misalignment and sagging	5
3.6	Structural strength	4
4.1	Fouling, deposits and clogging	3
4.2	Fixture accessibility	19
4.3	Maintenance procedure	12
4.4	Location for maintenance	14
5.1	External product standards	69
5.2	External installation standards	4
5.3	Accepted engineering practice	3
5.4	Code procedures	78

5. ELEMENTS OF SPECIFICATION WRITING STYLE

In this chapter, the analyses and observations of the study are summarized as an informal guide to specification writers. The "don't use" and "use" style is patterned after the Elements of Style by Strunk and White [20]. Only performance specifications are covered here, but similar guidelines could be developed for prescriptive specifications. The examples used are from solar heating and cooling technology, though not all are from the Solar Criteria, the basis for the study. In particular, not all of the "don't use" examples are from that specification. The guidelines are in two groups: Section 5.1 lists those which pertain to the composition of individual provisions; Section 5.2 lists those which pertain to relations among two or more provisions.

5.1 Composition of Provisions

1. Avoid overspecifying physical entities. In defining the physical entity addressed, use the most general term that applies. Avoid naming specific physical entities, which amounts to overspecifying.

Don't use:	Use:
• "pumps, fans, compressors or similar equipment"	• "rotating machinery"
• "duct and fan systems"	• "air-handling systems"
• "pipe hangers and other supports"	• "supports"
• "pipes, joints, fittings, etc."	• "piping"

2. Group physical entities by common properties. Combine physical entities addressed by referring to the common properties affected by the attribute in question (common properties underlined).

   - "assemblies containing heat transfer fluids"
   - "components exposed to the natural environment"
   - "subassemblies that are accessible"

   The specification writer can use common property grouping in order to consider dysfunctions which pertain to classes of physical entities. In the example above, "assemblies containing heat transfer fluids" are those that are subject to mechanical and chemical forces affecting durability, "components that are exposed to the natural environment" are those that are subject to ice and hail loads, and "subassemblies that are accessible" are those that are potentially unsafe to occupants because of high temperatures. Note that any attempt to enumerate physical entities in any of the three examples would constitute over-specification by the writer.

3. Use conditions to postulate implementations. When a requirement or criterion applies only to specific implementations, single this fact out by preceding the entity description by a condition:

   - "when quick-closing valves are used, . . . "
   - "when the storage subsystem is included in the design. . . "
   - "when a liquid is used as the heat transfer fluid. . . "

   This allows the writer the option of considering such an implementation (without specifying it), as in:

   - "When liquid heat transfer fluids are used, the system shall provide suitable means for air removal."

4. Define attribute of requirement. In every requirement, define specifically the attribute to be satisfied. It may help the writer to think of an attribute as being a general, qualitative statement in support of one of the attribute classes. Thus, the attribute "prevention of corrosive wear" is in support of the attribute class "operability." On the other hand, the attribute of a requirement is usually more general than the phenomena of the criteria associated with the requirement. Thus, the attribute "prevention of corrosive wear" is more general than the phenomena "corrosion by leachable substances" and "corrosion of dissimilar materials," which are relatively specific.

   If the attribute can't be specified, the provision is probably not a requirement.

5. Define phenomenon of criterion. Include in each criterion the specific phenomenon for which a level of performance is to be achieved. (Recall that a phenomenon identifies a possible dysfunction to be avoided or a requisite to be assured.) Examples of dysfunctions to be avoided are:

   - "excessive noise arising from vibration of equipment"
   - "danger to occupants arising from excessive temperatures or pressure in the event of a power failure"

   Examples of requisites to be assured are:

   - "regulation of domestic water output temperature"
   - "means for the detection of leaks"

6. Use an active operator. In both requirements and criteria, use positive, active terms to describe the result expected.

   Don't always rely on the catch phrase:

   - ". . .shall be designed and installed so that. . ."

   In many cases, more specific wording can be used:

   - "(the collector subsystem) shall be located, oriented, and tilted so that. . . . ."
   - "(piping) shall be sized to. . . ."

   Also don't be unnecessarily wordy:

Don't use:	Use:
• ". . .shall be designed to provide. . . ."	• ". . .shall provide. . ."
• ". . .shall be designed to be capable of accommodating. . . ."	• ". . .shall accommodate. . ."

7. Use quantitative measures in criteria. Ensure that criteria are quantitative by specifying the level of performance expected, or, at least, by specifying precisely the device or process that is to be provided to ensure performance.

   Under a requirement dealing with the efficient operation of the DHW system,

Don't use:	Use:
• "The water temperature shall be regulated." or • "Regulation of the water temperature shall be assured."	• "The water temperature shall be regulated within the range of 105° to 160°F."

   The underlined material shows how the efficient operation mentioned in the requirement is ensured.

If a quantitative measure can't be defined, the provision is probably not a criterion.

8. Make evaluation correspond to quantifier. Give a clear, precise statement as to how the criterion measure is to be evaluated. Certain things cannot be evaluated by a mere review of plans and specifications! For example, in

- "Systems. . .shall accommodate flexing. . .,"

an examination of design criteria is more appropriate than a review of drawings and specifications; and in

- "systems. . .shall not leak when tested. . .,"

a review of test results is more appropriate.

9. Avoid blanket references to specifications and standards. The entire purpose of performance specifications is defeated by excessive references to external specifications and standards. Do not say:

- ". . .shall be designed and installed in accordance with (name of specification)."

At least, specify the attribute that is to be achieved.

- ". . .shall provide a minimum level of fire safety consistent with (name of specification)."

Better yet, define the phenomenon to be quantified and depend on the specifications and standards only for establishing the quantitative measure:

- ". . .shall meet the requirements for draw and recovery specified in (name of specification)."

10. Choose title based on attribute or phenomenon. Make the title of the requirement or criterion descriptive of the attribute or phenomenon, rather than of the physical entity covered.

- (under a requirement dealing with Leakage prevention)

Don't use:	Use:
"Air transport systems"	"Air leakage"

- (under a requirement for Excessive pressure and temperature protection)

Don't use:	Use:
"Relief valves and vents"	"Pressure and temperature relief"

- (under a requirement for Effects of external environment)

Don't use:	Use:
"Components or materials exposed to sunlight"	"Solar degradation"
"Components buried in soil"	"Soil corrosion"

11. Do not deliberately vary wording to avoid monotony. Note the underlined words in the following:

- ". . .collecting and converting solar energy into thermal energy."
- ". . .collecting and converting radiant solar energy into thermal energy. . ."
- ". . .convert incident solar energy into useful thermal energy. . ."

Such "stylistic" variation is confusing to the reader, who may try to find some technical reason behind the different choices of words.

12. Avoid using subjective wording in requirements and criteria. Even requirements, which are qualitative statements, should be as free as possible of words which are subject to interpretation by guesswork on the part of the reader. Certainly criteria, which are quantitative statements, should not use such words. Consider the following:

- ". . .suitable means for air removal. . ."
- ". . .adequate provisions for thermal expansion. . ."
- ". . .damage of unacceptable magnitude. . ."

How is the reader to interpret "suitable," "adequate," and "of unacceptable magnitude"?

Other subjective words and phrases to be avoided are "significant(ly)," "excessive(ly)," "below acceptable levels," "unduly," "normal(ly)," "beyond acceptable limits," etc.

5.2 Organization of Provisions

1. Use only one attribute per provision. A provision (requirement or criterion) addressing more than one attribute is improperly written and should be split. Each of the following examples can be split into two criteria:

• ". . .shall be sized to carry the heat transfer fluid at design flow rates without excessive noise	Criterion a
or erosion-corrosion"	Criterion b

• ". . .shall not significantly affect the efficient operation of the H, HC, or DHW systems	Criterion a
or the habitability of the building."	Criterion b

The use of catch words "health and safety" and "safe and efficient operation" as attributes will automatically result in the violation of this rule.

2. Do not misplace criteria. A criterion is misplaced if:

a. the physical entity addressed is not a subset of the entity addressed by the requirement under which the criterion appears, or

b. the physical entity addressed is not a common property grouping within the entity addressed by the requirement under which the criterion appears, or

c. the phenomenon addressed is not a subset of the attribute of the requirement.

Examples of misplaced criteria:

a. Requirement addresses collector.
Criterion addresses whole system.

b. Requirement addresses collector.
Criterion addresses components buried in soil.

c. Requirement addresses failure loads and load capacity.
Criterion addresses glazing design.

3. Order criteria by related phenomena. In ordering the criteria associated with a requirement, sequence them by the phenomena they address. In the sequence below, the second criterion, dealing with air, is out of place between criteria dealing with liquids, and should be moved to the end.

Requirement: Heat transfer fluid quality.

Criteria:
1. Liquid quality
2. Air quality
3. Liquid treatment
4. Freezing protection (applies to liquids only)

4. Use single-criterion requirements sparingly. The specification writer will find that usually it will be necessary to associate two or more criteria with a requirement in order to completely address the level of performance stated in the requirement. It is appropriate sometimes, however, to use single-criterion requirements.

The rule to follow is that the criterion must address a subset of the requirement (either physical entity, common property grouping, or attribute) or else must introduce a quantifier. If none of the above applies then it is questionable whether the "requirement" is in fact a proper requirement. In the following sequence, the rule is not followed; the criterion is merely a rough rewording of the requirement:

R: Shutdown of subsystems in one dwelling unit shall not impair the distribution of energy to other dwelling units of the building.

C: Shutdown of the H, HC or DHW subsystems in one dwelling unit of a multifamily housing complex shall not interfere with the operation of the subsystems in other dwelling units.

5. Avoid unnecessary cross-referencing. With proper assignment of criteria to requirements and proper ordering of requirements, it should not be necessary within a criterion or requirement to cross-reference other criteria and requirements. The situation is analagous to the one noted in rule 9 in group 5.1 on referencing other specifications and standards. Blanket cross-references are to be avoided:

- ". . .shall be designed to meet the requirements specified in. . ."

More specific cross-references may be used where necessary duplication of the same material would result:

- ". . .shall be designed to meet the requirements for load combination specified in. . ."

6. POTENTIAL APPLICATIONS

In this chapter, the potential applications of the model and methodology developed in this study are discussed, with emphases on the analysis of existing codes and standards and the synthesis of new ones.

6.1 Analysis

As discussed in the Introduction, there is a need for the classification, maintenance, and comparison of existing codes and standards.

Every specification has to be continually maintained to keep up with social and technological changes. This on-going maintenance would be aided by a standardized organized framework, both for initial provisions and for later modifications, additions and deletions.

There is an equally strong need for a mechanism whereby the coverage of different codes and standards could be systematically compared by the following types of organizations:

- design and construction organizations operating under multiple jurisdictions need ready access to information on similarities and differences among codes, so as to adjust their work accordingly;

- building regulatory agencies adopting model codes need a mechanism for locating and identifying those provisions which warrant local changes or exceptions;

- model code authorities and other bodies responsible for the promulgation of codes and standards need a similar mechanism for representing changes and exceptions introduced in the adoption process to guide them in their maintenance activities;

  and

- groups and organizations interested in broadening the coverage of existing codes and working towards broader national consensus need a representational tool to display the coverage of codes, so as to be able to systematically review, and hopefully eliminate, the existing differences or discrepancies.

The methodology presented in this study could be developed and extended to produce a classification scheme and representational method to satisfy the above needs. In such a classification scheme each provision would be classified as to:

- the physical entity addressed;

- the property of that entity (where applicable);

- the attribute to be achieved (for requirements);

- the measure of satisfaction required (for criteria).

Initial approaches for the physical entity and attribute classifications have been presented in Chapters 3 and 4. Further work will be required in order to extend these to practical and generally applicable classifications. In particular, the terms for physical entities should be standardized. Also, the concept of common property developed in Chapter 3 should be extended so as to serve its intended purpose; as a "shortcut" to eliminate or reduce extensive enumeration of components. Similarly, the classification of attributes should be extended to cover the entire range of codes and design specifications. For prescriptive specifications, standard interpretations of implied attributes must be agreed upon, as they could then form a solid basis on which the intent and adequacy of provisions could be evaluated. Finally, it will be necessary to extend considerably the list of possible measures discussed in Chapter 3 to encompass all cases that may occur; such measures are essential to define the levels of performance specified.

With a classification scheme of the type discussed, any specification could be concisely represented by a table such as Tables A.1 and B.1, or by the implementation of such tables in a computer-based information system. Local exceptions, modifications, updates, etc. could be rapidly and conveniently located by reference to the classifiers describing the provisions.

An illustration of the potential advantage of using a standardized classification scheme of the type discussed in this report for representing existing specification provisions can be taken from Reference [6].

The 1969 Edition of ANSI Standard A119.1, Standard for Mobile Homes [19], contained the following provision in Section 7.3 (page 15):

> ". . . All wall and partition surfaces shall be capable of resisting a horizontal load of not less than five pounds per square foot."

The provision did not appear in the editions of 1972 through 1974. In the process of adopting the Standard in state regulatory programs, the provision of the 1969 Edition was included in two states codes:

- in North Carolina, as an amendment of Section 7.3;
- in Oregon, as an amendment of Section 6.2: Design Live Loads.

The provision was re-introduced in the 1975 Edition, but his time under Section 6.7: Interior Walls. Thus, in a period of six years, the same provision has cropped up in three different sections of the Standard or State code based on the standard. If the provision had been classified not by arbitrary section numbers, but as a provision accessible by the classifiers:

physical entity = interior wall
attribute = structural strength

the provision could have been readily located, regardless of section number, and the various editions of the standard, as well as the State codes adopting them, could have been directly compared.

6.2 Synthesis

It is expected that the major use of the concepts of this study will be in the synthesis or development of new specifications, especially of performance specifications. Before such work can be undertaken, however, some of the preliminary steps discussed in the preceding section will have to be accomplished, albeit for a different purpose:

- in developing a practical physical classification, effort must be made to generate classifications of entities which are implementation - independent, separate from traditional building part names; the extension and systematic exploitation of appropriate "property" categories may be one way to achieve this objective;
- the list of specific entity names needs to be formalized and coordinated with the general functional classifications and properties, to serve as the basis for implementation - dependent evaluation procedures for performance specifications as well as for procedural or prescriptive specifications;
- the list of required attributes and their underlying phenomena to be controlled needs to be considerably extended, subdivided and properly defined, so as to clearly identify the user needs addressed by each; and
- the list of available measurements, and the appropriate evaluation methods for each, needs to be formalized to a much greater extent than the present, so as to provide a clear basis for choosing appropriate measures for each criterion.

The availability of such classification schemes could formalize and considerably improve the process of synthesizing new specifications.

At the conceptual or planning level, the synthesis process could begin with the clear identification of applicable attributes and the phenomena to be controlled. Through appropriate properties, the general functional classes of physical components susceptible to dysfunction could be next identified, and thus a general framework of requirements and criteria sketched. This framework could then be systematically "fleshed out" through technical and economic analyses to determine the appropriate type and level of measures for each criterion.

In practice, of course, the development of new performance criteria will seldom, if ever, be the direct, linear sequence of activities described above. Rather the process will tend to be iterative, where new considerations, even the need for new research, will emerge as portions of the document are developed. A computer-based interactive information management system based on the classifications presented could serve as an effective management and control mechanism for the operational phase of synthesis.

At the operational or developmental level, the framework of general requirements and criteria would be entered into the information management system when the detailed development begins. Tentative elaborations of proposed requirements and criteria would be entered as they are developed, together with appropriate classifiers. Periodically, the provisions could be sorted and listed, and the output examined to ascertain progress, to review and modify as necessary the proposed classifications, and to identify "holes" or other indications of uneven coverage. On the detailed level, provisions could be examined for conformance with accepted structures and for the proper maintenance of the RCTC hierarchy. At the same time, as provisions accumulate and are "firmed up," tentative groupings and chapter layouts may be developed. Through appropriate identifiers related to the classification schemes, alternate organizations may be explored and evaluated, thereby reducing the dependence of the organization on a sometimes arbitrary two-dimensional matrix. From previous studies [15,16], it appears that theoretically inclined readers would prefer an organization where the major groupings are based on attributes, with further subdivisions based on physical components, whereas practically-oriented people would be more comfortable with the opposite ordering. Tentative outlines for these two schemes, or combinations thereof, could be readily generated and compared. The final organization and assignment of chapter, requirement and criterion sequence could thus be delayed until the project is essentially complete, resulting in more readable, easier-to-follow documents. The development of extensive indexes structured according to alternate ordering of classifiers would be an automatic byproduct of the classification scheme maintained by the information management system.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This study is a pilot project for identifying concepts and methods for the establishment of a rational framework of specifications, dealing with both the detailed organization of individual provisions and the overall classification of provisions in the document.

It has been shown that all specification provisions have a simple basic structure, consisting of two basic elements:

(1) a subject, which makes some mention of a physical entity, and

(2) a predicate, which relates to one of the attribute classes.

This simple structure permits the study of organization at two levels: (1) the way the elements are composed in a single provision; and (2) the manner provisions are related through the subjects they address and the attributes they seek to achieve.

Detailed study of the first aspect, that is the composition of provisions, was only carried out for a performance document. Studies of the second aspect were performed on a performance document and a prescriptive document. Studies at both levels require a carefully structured classification of the physical components forming the subjects of provisions, and of the attributes to be satisfied. Classifications have been developed for these two domains for two documents, representing extreme points on the performance-prescriptive continuum.

Physical classifications could be developed with reasonable ease from both documents. In both documents, there appears to be too much reliance on naming specific building parts. As a result, it is sometimes difficult to group the entities into larger units in a hierarchical fashion. Nevertheless, it appears entirely feasible to extend the classification to other documents, and eventually to standardize both the terminology for building elements and hierarchical groupings for the terms.

The development of attribute classifications was hampered by the occasional lack of clarity and definitions of attributes in the performance document and their complete absence in the prescriptive document. The classification reported here should be considered highly tentative.

In the performance document, an important mechanism was identified for achieving conciseness in addressing physical components without over-specification. The mechanism consists of referring to a common property such as "exposed to solar degradation," which singles out entities susceptible to dysfunction under a particular attribute in a completely implementation-independent fashion. A classification of properties contained in the document was developed; significantly, the properties identified are well structured hierarchically.

Also, in the performance document, the "traditional" RCTC hierarchy could be given more precise meaning by associating criteria with properties or with subsets of the entities and/or attributes of the corresponding requirement, and by associating the form of the evaluation with the type of measure specified in the criterion. However, because of the wide range of measures contained in the criteria, the latter association could not be demonstrated to the same degree of concreteness as the former.

This study of the composition of provisions in the performance specification produced a formal representation of the syntactic structure of requirements and criteria.

The classification systems and the analyses in Section 3.3 produced concepts and terminology which were used in giving guidance for future efforts in performance specification writing.

On the basis of the studies reported, two potential applications were presented. First, it was shown that a classification scheme of provisions according to physical entities, attributes (explicit or implicit) and measures specified can serve as a concise representation which may be used to represent and compare the coverage of specifications and the extent of local exceptions, modifications, and proposed and actual changes.

Second, it was shown that the classification scheme could serve in the development or synthesis of new specifications in two significant ways: at the initial planning or conceptual level, by permitting the development of groupings of requirements before any detailed work is undertaken, and at the operational and developmental level by "tracking" progress and by allowing tentative groupings and chapter layouts to be developed and evaluated.

7.2 Recommendations for Further Study

There are a number of directions for future work which are continuations of some of the research activities reported on in this study.

- The classifications of physical entities and attributes exhibited in this study are illustrative rather than recommended. Clearly there is a need for research on more general classifications.
- The analysis reported on in Section 3.3 of this study is tentative in nature. Further research into the nature of attributes of requirements and measures of criteria is called for. This work is expected to relate closely to the research on attribute classification called for just above.
- The notion of "property" needs further research. The role of properties as selectors of physical entities for attributes needs to be investigated further.
- The classification work for evaluations in this paper is tentative rather than recommended. Further research is necessary in that area as well as in the larger area of the RCTC hierarchy.

In addition, there are a number of proposed areas for study which are not simple continuations of research in this paper but which are logical next steps for that research to take.

- There is a need for the analysis of the language of provisions in prescriptive specifications. It is of interest to determine to what extent the structures and concepts developed for performance provisions are applicable to prescriptive provisions.
- The research reported on in this paper is related to the research recently conducted at the University of Illinois under contract to the National Bureau of Standards (see [22]). The relationship needs to be investigated further, especially the language analysis in this paper with the decision table analysis in the Illinois study and the classification studies in this paper with the outlining algorithms in the Illinois study.
- The implementation of a pilot information retrieval system along the lines developed in Chapter 6 is a possible next step to take. It could be based on classification schemes such as those developed in Chapters 3 and 4. It would allow for the orderly development of such classification schemes and would provide a prototype context for developing some of the ideas advanced in Chapter 6.
- The automatic generation of the text of provisions could be explored. Given as input the physical, property and attribute classification schemes along with the structures introduced in Section 3.3, it would be possible to generate provision-like word sequences which could be examined for acceptability. The style guidelines from Chapter 5 possibly could be used as constraints in the generation process.

- Another potential research task is the exploration of converting specifications which are in prescriptive form into performance form. Classification schemes such as those developed in Section 3.2 and Section 4.2, structures such as those developed in Section 3.3, and rules governing the expression of provisions such as those developed in Chapter 5 would all be desirable components in such a conversion scheme.

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APPENDIX A. Classification of Provisions of Solar Criteria

Table A.1

Provision	Physical							Property		Attribute	
	I	II	III	IV	V	VI	VII	I	II	I	II
R.1.1	A	A								1	1
C.1.1.1	A	A								1	1
C.1.1.2	A	B								1	1
C.1.1.3	A	A								3	1
C.1.1.4	A	A								1	2
C.1.1.5	A	A								2	2
R.1.2	A	C								1	1
C.1.2.1	A	C								1	1
C.1.2.2	A	C	B							1	1
C.1.2.3	A	C								1	2
C.1.2.4	A	C								2	1
R.1.3	A		A							1	1
C.1.3.1	A		A							1	1
R.1.4	A		B							1	1
C.1.4.1	A		B							1	1
R.1.5	A									2	2
	A									3	1
C.1.5.1	A									2	2
	A									3	1
R.1.6	A		C							1	1
C.1.6.1	A		C							1	1
R.1.7	A		D							1	1
C.1.7.1	A		D							4	
C.1.7.2(a)	A		D							2	2
	A		D							5	1
(b)	A		D							3	1
C.1.7.3	A	A	D	5	3					3	1
C.1.7.4	A	C	D	5	3					3	1
R.1.8	A		E							1	1
C.1.8.1	A		E							1	1

2 Table A.1

Provision	Physical							Property		Attribute	
	I	II	III	IV	V	VI	VII	I	II	I	II
R.2.1	A									2	1
C.2.1.1	A			1	1					2	1
C.2.1.2	A			1	3					2	1
	A			1	3					2	1
C.2.1.3	A			1	1			2	1	2	2
	A			1	2			2	1	2	2
	A		D	5	1			2	1	2	2
	A		A	4				2	1	2	2
C.2.1.4	A		A	1	3	1	1			2	1
C.2.1.5	A		C	1				3		2	1
C.2.1.6	A		C	1				3		2	1
C.2.1.7	A			1	3	1				2	2
C.2.1.8	A			1	3	1	4			2	1
	B			1						2	1
R.2.2	A			1						2	2
C.2.2.1	A			1	3	1		6	1	2	2
	A			1	3	2		6	1	2	2
	A			5	2			6	1	2	2
	A			5	3			6	1	2	2
C.2.2.2	A			1	1			6	1	2	2
	A			1	1			6	1	3	1
C.2.2.3	A			1				3		2	1
C.2.2.4	A			1	3	1		4	1	2	2
	A		B					4	1	2	2
C.2.2.5	A			1						2	1
C.2.2.6	A			1				3		2	1
R.2.3	A		C	1				3		2	2
C.2.3.1	A		C	1				3	2	2	2
	A		C	1				3	2	3	2
C.2.3.2	A		C	1				3	1	2	2
	A		C	1				3	1	3	2
C.2.3.3	A		C	1	3	2				2	1
R.2.4	A		A							2	1
C.2.4.1	A		A	4	1					2	1
C.2.4.2	A		A							2	1
R.2.5	A							8		4	
C.2.5.1	A							8		[illegible]	
R.2.6	A		C	6						2	2
C.2.6.1	A		C	6	1					2	2
C.2.6.2	A			1	1	2		3	6	2	2
	A			1	3	2		3	6	2	2
C.2.6.3	A		C	6	1					2	2
C.2.6.4	A		C	6	1			1	3	2	2
R.2.7	A			1	4					2	1
	A							4	2	2	1
C.2.7.1	A			1	3					2	1
R.2.8	A			1				2	1	2	2
C.2.8.1	A			5	1					2	1

3 Table A.1

Provision	Physical							Property		Attribute	
	I	II	III	IV	V	VI	VII	I	II	I	II
R.3.1	A			3						2	1
	B			2						2	1
C.3.1.1	A			3						2	1
	B			2						2	1
C.3.1.2	A			3						2	1
R.3.2	A			3						2	2
C.3.2.1	A			3	2					2	1
C.3.2.2(a)	A			3	1	1		1	1	2	1
	A			3	2			1	1	2	1
C.3.2.2(b)	A			3	1	2		1	1	2	1
C.3.2.3(a)	A			3	1	1		4	2	2	1
	A			3	2			4	2	2	1
C.3.2.3(b)	A			3	1	2		4	2	2	1
C.3.2.4	A			3	2					2	1
R.3.3	A			3						2	2
C.3.3.1	A			3	2					2	2
C.3.3.2	A		A	4	2					2	1
R.3.4	A			3				6	1	2	2
C.3.4.1	A			3	2			6	1	2	2
R.3.5	B			2				7	1	2	2
C.3.5.1	B			2				7	1	2	2
R.3.6	A			3						2	2
C.3.6.1	A			3	2					2	2
R.3.7	A			3				1	1	2	2
C.3.7.1	A			3						2	2
R.3.8	A			3						2	1
C.3.8.1	A			3						2	1
R.3.9	A			3				1	1	2	1
C.3.9.1	A			3				1	1	2	2

4 Table A.1

Provision	Physical							Property		Attribute	
	I	II	III	IV	V	VI	VII	I	II	I	II
R.4.1	A									3	2
	A									5	1
C.4.1.1	A			1	3					3	2
	A			1	3					5	1
C.4.1.2	A			2						5	1
R.4.2	A									5	1
C.4.2.1	A		D							5	1
	A		D							2	2
C.4.2.2	A		D	5	1			3	4	5	1
R.4.3	A									5	
C.4.3.1	A									5	
C.4.3.2	B			3						5	
R.4.4	A		C	6	1	1				5	1
C.4.4.1	A		C	1	3	1	3	3	5	5	
	A		C	1	3	1	3	3	5	3	2
C.4.4.2	A		C	6	1	1		3	5	5	
R.4.5	A									5	
C.4.5.1	A									5	
C.4.5.2	A		C	2				5	1	5	
	A		C	5	4			5	1	5	
R.4.6	A							3		3	2
C.4.6.1	A							3	1	3	2
C.4.6.2	A		C	1	3	1	2	3	2	3	2
C.4.6.3	A		C	1	3			3	2	3	2
C.4.6.4	A							3	6	3	2
R.4.7	A							5	2	5	1
C.4.7.1	A							5	2	5	1

5 Table A.1

Provision	Physical							Property		Attribute	
	I	II	III	IV	V	VI	VII	I	II	I	II
R.5.1	A							1		2	2
C.5.1.1	A		A					1	2	2	2
C.5.1.2	A							4	2	2	2
C.5.1.3	A							1	2	2	2
C.5.1.4	A		A	4	3					2	2
C.5.1.5	A		A							2	2
C.5.1.6	A							1	4	2	2
R.5.2	A							2	1	2	1
C.5.2.1	A							2	1	2	2
C.5.2.2	A		C	6						2	2
C.5.2.3	A			1				2	1	2	1
C.5.2.4	A		C	1				3		2	2
C.5.2.5	A			8				3		2	2
C.5.2.6	A		A	4						2	2
R.5.3	A							2	2	2	2
C.5.3.1	A			1				3		2	2
C.5.3.2	A							2	2	2	2
C.5.3.3	A							2	3	2	2
C.5.3.4	A							2	3	2	2
R.5.4	A							6	2	2	2
C.5.4.1	A			1	1	1		6	2	2	2
	A			2				6	2	2	2
	A			5	1			6	2	2	2

6 Table A.1

Provision	Physical							Property		Attribute	
	I	II	III	IV	V	VI	VII	I	II	I	II
R.6.1	A									4	
C.6.1.1	A							5	1	4	
C.6.1.2	A			4	2			5	1	4	
C.6.1.3	A							3		4	
C.6.1.4	A			1	3	1	4	3		4	
C.6.1.5	A			7						4	
C.6.1.6	A	C	D	4	4					4	
R.6.2	B			4	4					4	
C.6.2.1	B			4						4	
C.6.2.2	B			4						4	
C.6.2.3	B			4						4	
C.6.2.4	B			4						4	
R.6.3	A									4	
C.6.3.1	A									4	
C.6.3.2	A									4	

APPENDIX B. Classification of Provisions of Plumbing Code

Table B.1

Provisions	Physical									Attribute	
	I	II	III	IV	V	VI	VII	VIII	IX	I	II
201 (a)					F					C	a
									a	C	a
(b)					F					C	a
									a	C	a
202		W,D	b						b,c,d,e	C	a
		W,D	b					b	b,c,d,e	C	a
203 (a)		V,D	b						e	C	a
(b)		V,D	b						e	C	a
(c)		D	b						e	O	c
(d)		W	b						e	C	a
204					F	x			i	C	d
		V	x	c				z	i	C	d
					F		i,ψ		i	C	d
205 (a)&(b)								h,o		O	d
								h,o		C	d
206 (a)					F	f		e	a	C	a
					F	f		e		C	d
(b)					F			e		C	d
(c)					F			e		C	b
(d)					F			e		O	f
(e)					-			p,g,r		O	b
					F			p,g,r		O	f
207 (a)					F		p	v		C	d
					F		p	f		C	a
(b)					F		p	f,v		C	a
					-		p		a	C	a
(c)					F		p			M	c
208 (a)								v	a	C	d
(b)					F		d			C	d
					F		d	b		C	d
					F		d		e,h	F	f
(c)		W						v	g	O	b
(d)		W,V						v	b	O	b
209		D		1						H	c
		D		τ						C	d
		D		τ				s		C	d
210 (a)					F		m			C	d
(b)					F		k		a	C	a
		W						v		C	d
		W						v	g	C	d

2 Table B.1

Provision		Physical									Attribute	
		I	II	III	IV	V	VI	VII	VIII	IX	I	II
302						F	a	a	a		F	d
303	(a)					F	a				F	d
	(b)		D	b							F	b
304	(a)		D	a							O	a
	(b)		D	e,g,k							F	d
305	(a)		D								O	a
	(b)		D								H	b
308		A									O	g
309	(a)	A									C	c
	(b)	A								a	C	c
310	(a)					F	a	d			C	c
	(b)		D,V	b							C	d
			D	b						g	C	d
	(c)					F	f	ψ	c		C	d
	(d)		V	b					c		F	e
	(e)	A									F	b
						F	f	ψ			C	d
	(f)	A							c		M	b
	(g)	A									F	b
313			D	d							F	d
314	(c)		D,V						t		M	c
315	(a)		D,W,V	b							O	a,b,e
			D,W,V	b							C	d
	(b)		D,W,V	b							O	e,f,g
			D,W,V	b							C	d
	(d)		D	b						a	C	a
	(e)		D,W,V	b							O	a,b,c
316			D,W,V	b							O	a,e
401	(a)		D	b							C	a
			D	b						b,c	F	f
			D	b						j,k	C	d
	(b)					F		d			O	c
						F		d		a	C	d
						F		d	b	a	C	d
402		A									F	c
403	(a)		D	b							F	c
	(b)		D	a							F	c
404	(a)					F	a	d			C	a
						F	a	d			F	f
	(b)					F	a				F	b
						F	a	d			C	a

3 Table B.1

Provision	Physical									Attribute	
	I	II	III	IV	V	VI	VII	VIII	IX	I	II
405 (a)					F	a	d			F	b
					F	a	d			C	a
(b)					F	a	d			C	a
					F	a	d			F	b
(c)					F	a	d			C	a
(d)					F	a	d			F	b
406 (a)		D	b	k						M	a
		D	b	k						M	d
(b)		D	b	k						M	a
(c)		D	b	k						M	d
(d)		D	b	k						C	d
(e)		D	b	b				x		M	d
(f)		D	b	k						M	b
(g)		D	b	k						M	b
		D	b	k						M	d
		D	b	k						M	d
		D	b	k						M	d
(h)					F	a	d			F	c
407		D	b							F	b
408					F	a				F	b
					F	a				F	f
409 (a)		D	a							F	d
		D	a							F	b
		D	a	l						C	a
		D	a	l						F	f
(b)		D	b							F	d
		D	b							F	b
					F	o				F	b
					F	o				C	a
					F	p				C	a
					F	p				C	d
(c)		D	b							F	c
					F	o				F	c
(d)					F	p	b			H	c
		D	o	l						M	b
		D	o	l						C	d
(e)		D	c							F	c
		D	d							F	c
(f)					F		k,m,x			M	b
					F		k,m,x			M	c
					F		k,m,x			M	d

4 Table B.1

Provision	Physical									Attribute	
	I	II	III	IV	V	VI	VII	VIII	IX	I	II
409 (h)					F	o,p			a	C	a
					F	o,p			m	C	a
					F	o,p				C	c
					F	o,p				O	b
(i)					F	o,p				C	d
(j)					F	o,p				M	c
					F	o,p				F	e
					F	o,p	j			F	e
					F	o,p	j			M	b
					F	o	j			F	c
(k)					F		x			F	b
					F	p				O	g
501					F	a	i			H	c
		D								F	e
502 (a)					F	v				F	e
					F	v				H	c
(b) (b)					F	y	i			F	e
					F	y		w		H	c
503 (a)		V	b						a	C	a
		V							b,c	F	f
(b)		V		e					a	C	a
		V		e					b,c	F	f
(c)		V		e						C	a
		V	b							C	d
504 (a)		V	b							F	c
		D	b							F	e
		V	b							F	c
		D	b							F	b
505		D	b							F	d
(a)		V	a	a						O	e
		V	a	a						F	f
(b)		V	b							F	f
(c)		V	b							C	d
(d)		V	b							C	d
		V	b							F	e
(e)		V		f						F	f
(f)		V	c							F	b
506 (a)		V	b							C	d
		V	b							F	f
(b)		V	b							C	d
(c)		V	b							F	f
		V	b							C	d
(d)		V	b							F	f
		V	b							C	d

5 Table B.1

Provision	Physical I	II	III	IV	V	VI	VII	VIII	IX	Attribute I	II
506 (e)		V	b							M	c
		V						z		C	a
507 (a)		V		g						F	f
		V	f							F	e
		V	f							F	c
(b)		V	f	g						F	f
		V	f	g						C	d
601					F	s				H	c
					F	t				H	c
603		D	m							F	c
		D	m							F	e
		D	m							M	d
		D	m							M	a
604				F	u					C	a
(a)				F	u					M	b
				F	u					F	c
				F	u	i				M	d
				F	k	h				F	f
(b)				F	k	h				C	b
605				F	m	h,j,z				H	c
				F		h,j,z				H	c
		D		n						F	c
606				F	l					C	a
607				F	r					H	c
608				F	x					H	c
				F	j					H	c
				F	j	d				C	a
609		D	o							H	c
		D	o							C	d
610				F	l					H	c
611 (a)		D	o							H	c
				F	o					H	c
				F	o	j				F	e
				F	o	i				H	c
				F	o	j,r,s				F	c
		D	o							H	c
(b)				F	o,r,w				m	C	d
				F	w				n	C	d
				F	w				n	O	b
(c)				F	o,w					M	b
				F	o,w					M	c

6 Table B.1

Provision		Physical									Attribute	
		I	II	III	IV	V	VI	VII	VIII	IX	I	II
612	(a)		D	p							O	a
			D	m							C	c
			D	m							C	b
	(b)		D	p						a	O	b
			V	b						a	O	b
	(c)		D	p					u		C	a
	(d)		D	p							M	b
	(f)		V	b							O	g
	(g)		D								O	g
613	(a)		V	e							H	e
			V	e							C	d
	(b)		V	e							F	c
	(c)		V	c							F	c
614						F	u	i			C	d
						F	u	j			C	d
615	(a)		V	g							O	g
	(c)		V	g							F	e
			V	g							C	d
			V	g							F	c
	(d)		V	g	h,i						F	c
	(e)		V	g	h						C	d
	(f)		V	e							M	c
			V	g							C	d
701	(a)					F	a	i			C	a
	(b)					F	c,i,p	i			C	d
	(c)					F	e,el	i			C	d
						F	i,k	i			C	d
	(d)										F	f
702	(a)					F	a	i			H	c
						F	a	i			F	e
	(b)					F		j			F	f
	(c)					F		y	d		C	d
	(d)		V		f						F	f
						F	f	j			F	f
703	(a)					F	a	i			C	d
						F	a	i		a	C	a
	(b)					F	a	i	v		H	e
	(c)					F	a	i			F	c
704						F	a	i			C	d
						F	a	i			F	e
705						F	a	i			C	d
706						F	h	i			M	b
						F	h	i			F	c

7 Table B.1

Provision	Physical									Attribute	
	I	II	III	IV	V	VI	VII	VIII	IX	I	II
706					F	h	i			M	d
					F	h	i			H	c
707					F	h	i			C	a
708 (a)		D		b						F	b
(b)		D		b						C	d
		D		b						C	a
		D		b						F	f
(c)		D		f						M	b
		D		f						C	d
(d)		D		b						F	e
		D		b						C	d
(e)		D		b						M	b
709		D	b							F	b
		D		c						C	a
710		D		f						C	a
		D		f						M	c
711 (a)		D	q							F	b
		D		c						C	a
(c)		D		c						C	d
(d)		D		c						C	d
(e)		D		c						C	d
		D		c						H	e
(f)		D		c						F	e
		D		c						H	c
		D		c						C	d
(g)		D		c						M	b
(h)		D		c						M	c
(i)		D		c						O	d
		D		c				s		M	b
(j)		D		c						C	d
(k)		D		c				y		C	a
		D		c						C	b
712		D	el							F	d
901					F	a				O	d
					F	a				C	a
					F	a				C	d
					F	f				C	d
902					F	x			a	C	a
					F	y			c	C	d
					F	a			n	C	c
903					F	a	z			F	f
					F	a	z			C	d
					F	f2,g2	z			C	d

8 Table B.1

Provision		Physical I	Physical II	Physical III	Physical IV	Physical V	Physical VI	Physical VII	Physical VIII	Physical IX	Attribute I	Attribute II
904	(a)					F		t			C	a
	(b)					F	a		c		M	b
	(c)					F			c		C	d
						F			c		F	c
	(d)					F	el,j,k	d			C	a
						F	j	h			F	d
905	(a)					F	f				C	d
						F	f				H	c
						F	l				F	f
	(b)					F	b,c,f			a	C	d
906	(a)					F	x				H	c
	(b)					F	el				F	d
907	(a)					F	a				M	b
						F	a	b,c			M	d
	(b)					F	a				C	d
	(c)					F	a				C	c
						F	a				F	d
						F	a		p,q		O	b
	(d)					F	a		c		O	f
						F	f2,g2		p,q		O	b
	(e)					F	a				C	d
						F	f				O	g
						F	g				O	g
	(f)					F		a			H	c
908						F	g	c	w		H	c
	(a)					F	f2;g2				C	d
	(b)					F	fl,gl				C	d
	(c)					F	g	t	t		F	c
						F	g	t	t		C	d
						F	g	t	t	d	C	a
						F	F2,g2				C	d
	(d)					F	g				C	a
909	(a)					F	h	t			C	a
						F	h	t			F	c
						F	h,u				C	d
	(b)					F		e			C	d
	(c)					F		e			C	d
	(d)					F	d				C	d
	(e)					F	d				C	d
						F		e			C	d
						F		e		a	C	a
	(f)					F	d				M	c

9 Table B.1

Provision	Physical									Attribute	
	I	II	III	IV	V	VI	VII	VIII	IX	I	II
1001					F	a				F	a
					F	a				H	c
					F	f2,g2				C	a
					F	f1,g1				C	a
1002 (a)		W	a							H	c
(b)		W	a							H	a
		W	a							H	c
(c)					F	a				H	b
					F	a				H	c
1003					F	a	w			H	b
					F	a	w			C	a
					F	a	w			M	c
(a)					F	f1	n			C	a
					F	f1	n			F	f
(b)					F	f2	ϕ			C	a
					F	g2	ϕ			C	a
					F	f2	ϕ			F	f
					F	g2	ϕ			F	f
(c)					F	g1	n			C	a
					F	g1	n			F	f
(d)					F	a	c			F	f
(e)		W	a	c						C	d
		W	a	d						C	d
		W	a	h						C	a
		W	a	h						H	c
(f)		W	b							F	f
		W	b							M	c
(g)					F	o,u	n			F	f
					F	o,u	s			C	d
(h)					F	q	n			C	a
					F	q	n			F	f
(i)					F	a	r,s			H	c
					F	a	n			C	a
					F	a	n			F	f
(j)					F	x	r			H	c
					F	x	n			C	a
					F	x	n			F	f
(k)					F	s	n			F	f
					F	s	n			C	a
(m)		W	d	h						C	a
		W	d							H	c
(n)		W	g	h						C	a
		W	g							H	c

10 Table B.1

Provision	Physical									Attribute	
	I	II	III	IV	V	VI	VII	VIII	IX	I	II
1003 (o)		W	a							H	c
					F	a	n			H	c
					F	a	n			C	a
1004 (a)		W	a						a	C	a
(b)		W	a						g	O	b
(c)		W	a						l	O	b
(d)		W	a							H	b
1005 (a)		W	a	l					a	C	a
		W	a	l						C	d
		W	a	f						C	d
(b)		W	a	f						F	b
		W	a	f						M	d
		W	a	f						M	b
(c)		W	a							C	a
(d)		W	a	e						M	d
(e)		W	a	e						M	b
(f)		W	a	e						M	d
1006		W	e							H	b
		W	e	m						C	d
1007 (a)		W	h							F	b
(b)		W	a	n						F	c
		W	a	n						M	d
		W	a	n						M	b
(c),(d)		W	g	i						C	a
(e)		W	a	i						F	d
		W	a	i						C	d
		W	g	i						C	d
					F	n	h			C	d
					F	n	k			F	f
(f)		W	g	i						H	d
		W	g	i						C	a
(g)		W	a	o						C	a
1008 (a & b)		W	a							C	d
(c)		W	a						a	O	g
		W	a							O	a
		W	a							O	e
		W	a							C	c
		W	a							O	b
1009 (a - g)		W	a							C	b
(h)		W	a	p						F	c
(j)					F	fl,gl				F	c
(k)		W	d							F	c

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This paper provides a scientific basis for the formulation and expression of performance standards and specifications and for explicit attention to performance in procedural and prescriptive standards and specifications.

The provisions of the NBS-developed Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, a performance specification, are classified in terms of the physical entities addressed, the attributes of the built environment, and the properties which group together particular physical entities which may be subject to similar dysfunctions. These provisions are also subjected to a linguistic analysis which examines in detail the wording used and formalizes certain key concepts which are realized in the wording.

The provisions of the Uniform Plumbing Code, a prescriptive code, are classified in terms of the physical entities addressed and the performance attributes which can be inferred (though they are not explicitly addressed).

Guidelines for the expression of provisions in performance codes and specifications are presented. These guidelines are based on the classification studies and the linguistic analysis mentioned above.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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