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Table I: Results of the Parametric Simulations

| Building | Program | Results (GJ) Losses (A) | Gains (B) | Heating Load (C) | Utilized Gains (D) A - C | %'age of Gains Ut. | Time (s) |
|---|---|---|---|---|---|---|---|
| | SERI-RES | 18 | 0 | 18 | 0 | -- | 125 |
| 1 | MICROPAS | 20 | 0 | 22 | -2 | -- | 215 |
| | SUNCODE | 17 | 0 | 18 | -1 | -- | 1065 |
| | SERI-RES | 26 | 21 | 16 | 10 | 50 | 135 |
| 2 | MICROPAS | 30 | 24 | 19 | 11 | 45 | 305 |
| | SUNCODE | 25 | 26 | 15 | 11 | 41 | 1210 |
| | SERI-RES | 32 | 42 | 17 | 15 | 36 | 135 |
| 3 | MICROPAS | 37 | 47 | 14 | 23 | 49 | 305 |
| | SUNCODE | 32 | 52 | 16 | 15 | 30 | 1215 |
| | SERI-RES | 32 | 41 | 17 | 15 | 37 | 140 |
| 4 | MICROPAS | 38 | 44 | 14 | 23 | 53 | 305 |
| | SUNCODE | 32 | 51 | 16 | 16 | 30 | 1305 |
| | SERI-RES | 149 | 42 | 118 | 31 | 73 | 225 |
| 5 | MICROPAS | 308 | 47 | 73 | 234 | 500 | 685 |
| | SUNCODE | 141 | 52 | 112 | 29 | 56 | 2045 |
| | SERI-RES | 58 | 42 | 28 | 30 | 73 | 185 |
| 6 | MICROPAS | 101 | 47 | 56 | 45 | 96 | 380 |
| | SUNCODE | 59 | 52 | 25 | 33 | 64 | 1615 |



# A Standard for Computer-Aided Design/Drafting (Construction)

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KEYWORDS

Construction, Buildings, Computer Graphics, Computer-Aided Design, Computer-Aided Design Drafting, Drafting Standards, Drafting Symbology.

ABSTRACT

The recent move to automated technology by the construction industry has created a need for a consensus on symbology and presentation for computer-aided design/drafting before the majority of the community adopts the technology. A standard for computer-aided design/drafting would greatly assist the construction industry and the development of software in Canada and in the international community. Canadian Standards Association Committee B78.5 has developed a Canadian standard which applies to the computer-aided preparation and reproduction of construction drawings. In general context, it establishes the detailed recommendations on symbology and drafting techniques for computer-aided design/drafting in the construction industry. This paper introduces the standard, which will be published in summer 1986, and outlines the history of the standard, the requirement for standardization of computer-aided design/drafting, the goals of the standard, and the potential benefits for the construction industry.

Norme en matière de conception/dessin assisté par ordinateur (construction)

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MOTS CLEFS

Construction, bâtiments, infographie, conception assistée par ordinateur, conception/dessin assisté par ordinateur, normes de dessin, symbolique du dessin.

RÉSUMÉ

Par suite de la récente vague d'informatisation qu'a connue l'industrie de la construction, il est apparu nécessaire de s'entendre sur la symbolique et la présentation de la conception/dessin assisté par ordinateur avant que la plupart n'emboîtent le pas. L'existence d'une norme en cette matière serait très utile à l'industrie de la construction et favoriserait grandement le développement de logiciels au Canada et dans les autres pays. C'est pourquoi le comité B78.5 de l'Association canadienne de normalisation a élaboré une norme canadienne s'appliquant à la réalisation et à la reproduction de dessins de construction par ordinateur. Cette norme renferme des recommandations détaillées concernant la symbolique et les techniques en matière de conception/dessin assisté par ordinateur dans l'industrie de la construction. Ce document présente la norme, qui sera publiée à l'été 1986, puis il en trace un historique, indique pourquoi il importe de normaliser la conception/dessin assisté par ordinateur, énonce les objectifs de la norme et précise les avantages que pourrait en retirer l'industrie de la construction.



INTRODUCTION

This paper introduces a standard for computer-aided design drafting (construction) and provides an outline of its development, the requirement for standardization of computer-aided design/drafting, details of the proposed structure of Canadian Standards Association (CSA) Standard B78.5, and benefits of the standard. The standard applies to the computer-aided preparation of construction drawings and, in general context, it establishes detailed recommendations on implementation of drafting techniques and symbology for computer-aided design/drafting in the construction industry.

HISTORY OF CSA B78.5

The origins of CSA B78.5 are found in a sister document, CSA B78.3-Standard on Building Drawings [1]. The CSA was given the mandate by the Standards Council of Canada to prepare the Standard on Building Drawings as one of CSA's Technical Drawing Standards series. This was done primarily to assist the construction industry in the conversion to metric usage in design and on the building site. The committee was established in 1975 and this standard was released after nation-wide approval in 1977. It was later confirmed as a National Standard, CAN3-B78.3-M77-Building Drawings. Subsequent to this, a commentary on CSA B78.3 was published in 1983 by the Division of Building Research (DBR) [2].

In the early 1980's, it was realized by DBR and CSA that computer technology would play an important role in design/drafting in years to come and a standards group should develop a consensus on the basic issues before the majority of the community adopted the technology. A meeting of interested parties was held in October 1983 and this *ad hoc* group was officially recognized as a CSA Committee in January 1984. The standard was submitted for CSA approval in February 1986. On recommendation by the Canadian delegate to the International Standards Organization (ISO) Technical Committee (TC) 10, Subcommittee (SC) 8, a similar working group has been formed to develop a draft international standard. Delegates from the United Kingdom, Sweden, Norway, Canada, and Finland attended the first meeting in September 1985 and Working Group (WG) 12 is looking closely at the Canadian initiative for direction.

CADD PHILOSOPHY

Computer-Aided Design/Drafting

The Committee recognized that design/drafting had definite boundaries and the standardization of symbols and presentation would be extremely useful not only for the construction industry, but also for software manufacturers. To restrict the standard to production drafting would not include the designers in the industry: engineers, architects, and interior designers. The committee agreed that computer-aided design (CAD) was too large a technology for standardization. Computer-aided design/drafting (construction) was therefore selected as the mandate of the Committee and the standard addresses the requirements of both the drafter and the designer.

Adopt Existing Manual Practice

The final product - the construction drawing - must be readable not only by the technical personnel, but also by the site operator and the construction workers. This indicated to the committee that it would take some time for the entire construction industry to adopt CADD techniques or for the technology to reach the various construction disciplines: therefore conventional drafting symbols and methods had to be retained. This standard adopts conventions for symbology and presentation currently accepted in construction practice.

Standard for the Future

Many Committee discussions focused on the merits of automation systems for the construction industry; the majority of existing CADD systems provide only minimal production-time decreases and productivity increases and these systems relate more to the mechanical parts and printed circuit board design than to construction drafting practice. In addition, the low popularity of CADD within the construction fraternity in the early 80's indicated that the structure of the information was not suited for design/drafting in the building industry. Committee members decided that different directions had to be investigated to meet the requirements of the construction industry and still have the standard amenable to automation. The standard provides a structure reflecting current thinking for computer graphics that can be met by existing CADD systems.

Importance of Information Structure

The major difference between CADD and manual practice is the data handling capability of automated systems. All CADD systems employ an internal data structure, either sequential, hierarchic, or relational, to organize the graphical data. However, in most conventional CADD systems, many capabilities of the computer or data structures are not being optimized by practitioners, or worse, by the software developers. This standard is designed to encourage the use of a data structure relating to the structure of construction information and is written to optimize CADD systems without affecting the final drafting product. This data structure is described at length later in this document.

Optimize CADD Speed and Presentation Possibilities

The computer draws quickly and the information can be easily modified; these are saving graces of CADD technology. Its drawbacks are that some operations, such as toning, hatch, or *poché*, are more easily accomplished and more cost-effective using manually-placed tone sheets. In addition, data retrieval and search strategy using conventional sequential files greatly limits design alterations or "what if?" scenarios and therefore restricts designers. Alternate methods had to be investigated to find a solution that would use the speed and presentation possibilities of the CADD equipment and make it more cost-effective than manual practice. The solution was found in the structure of existing computer graphic standards in related fields. CSA B78.5 encourages a data structure closely resembling that of construction information.

Dissemination of Good Drafting Practice

The information explosion made possible by advanced computer technology has both helpful and debilitating effects. It disseminates information rapidly; the library symbols developed in one province or state are passed to other locations when CADD software is sold. Unfortunately, the symbol libraries may be of poor quality, inconsistent structure, or just plain wrong, because standards developed by CADD vendors are normally created by junior staff members with minimal construction experience. A well-organized approach would



see standards organizations developing the standard symbology, and making this available to CADD vendors: the standard is thus made available to a wide audience.

## EXISTING INTERNATIONAL STANDARDS AND PRACTICES IN COMPUTER GRAPHICS

CSA B78.5 was greatly influenced by existing standards in related fields and salient points from these standards are reflected in the structure of the standard for computer-aided design/drafting. These standards are Graphical Kernel System (GKS) [3] for computer graphic protocols and the Initial Graphics Exchange Specification (IGES) [4] for the exchange of CADD data.

GKS is a protocol for ensuring that graphics software running on one input or output device should run equally well on another. It was adopted as ISO 7942 and is supported by a large number of computer graphics firms. One important feature of GKS is the use of attribute data, i.e. additional information tagged to graphical data. This permits descriptive information, whether alphanumeric or graphical, to be added to specific graphical data. This concept is essential for CADD in the construction industry: the structure of building information has similar requirements and the ability to tag additional information to the graphical representation is imperative.

IGES is a protocol for transferring CADD data from one "turnkey" system to another. The general principle of the specification is for all CADD vendors to send their data to a well-defined file format. Once in this file format, the information can be transferred to any other CADD system. This saves CADD vendors from having to develop a translator to and from all of their competitors' systems. It is still in a developmental stage, is heavily graphics-based and numerous levels of compatability for data transfer already exist. In addition to being necessary in the CADD industry for data transfer, IGES structures reflect the requirements of the structure of construction industry information. This protocol therefore had significant impact on the development of the standard. The CSA B78.5 standard complements IGES and thereby facilitates the communication between different machines and systems.

In addition to the computer graphics standards, a number of manual practices influenced the CADD standard. These include CSA B78.2, Technical Drawings - General Principles [5], ISO documents relating to graphical presentation for construction drawings, the ASHRAE Handbook [6], and the Handbook of the Canadian Institute of Steel Construction [7].

## PROPOSED DATA STRUCTURE FOR CADD INFORMATION

The structure of CADD information encouraged in the standard can be implemented with all CADD systems. It provides the framework for CADD information and will assist in the data entry, data manipulation, and data storage and retrieval at different stages of design and building operation. This pertains to project-specific or library-specific information. Filing and drawing management in the drafting office are beyond the scope of the standard.

Data structure means the arrangement of information in a logical format so as to be easily accessed and modified by the computer. This can be the internal structure the computer uses to arrange the data or the external structure developed by the CADD user to arrange the building information. The standard encourages the use of an external data structure that reflects the function of the building component. For example, all the information for the electrical system should be structured to represent the electrical network design.

To date, the only CADD external data structure has been layering. Layering was essential in CADD systems of the 70's, but it reflects technology developed for mechanical parts and printed circuit board design and not the diverse needs of the construction industry. Although it paralleled pin-registered drafting techniques, it only optimized data input for CADD information handling. As with word-processing, the real value in automation is in modification and reuse of information, and this is essential in the building industry. Conventional layering uses only one level in the output presentation structure. The user can only turn on or turn off one layer of information on the screen or the output device at a time, thereby restricting the use of the information. Additional work is required by the drafter or designer if the information is required in a different form.

To augment layering, a multi-tiered tree structure is suggested in CSA B78.5. It mirrors the structure of construction information, follows the rationale of the design process, and can be easily understood by the majority of the personnel involved. An example of this form of data structure is seen in Fig. 1.

#### Primitives

Primitives are the lowest level of a graphic or an alphanumeric entity. They may be line, arc, spline, text, fill, polygon, or any object that cannot be further subdivided by the user. Every primitive can possess a number of attributes.

#### Pictograms

The use of pictorial representation is encouraged where no confusion arises with the selection of the pictogram. It must also be possible to break down these components to facilitate the modification of symbols and to increase the number of available symbols. To differentiate the various types of pictograms, two new terms have been developed: symbols and graphics.

##### Symbols

Symbols are pictograms not drawn to scale. They can possess a graphical reference which denotes the location of the symbol on the drawing or schematic, a graphical reference point which denotes the origin or "handle" for rotation, scale and translation (move), and a relationship to a higher functional grouping which denotes the symbol's "parent", and can consist of a number of primitives, graphics, or other symbols. Symbols can possess attributes and their components can also contain attributes (see Fig. 2).

##### Graphics

A graphic is a dimensionally-accurate pictogram. It may be a simplified representation of a building component, but it is accurate with respect to the principal dimensions. Graphics can possess a graphical location, a graphical reference point, and a relationship to a higher functional grouping, and can consist of a number of primitives, symbols, or other graphics. Graphics can possess attributes and their components can also contain attributes (see Fig. 3).



#### Groupings

The term grouping is used to denote a function-dependant collection of symbols, graphics, primitives or other groupings. A grouping may include attributes that are related to the entire group or may be specific to individual components of the grouping. Groupings can be as large as a drawing set or as small as a number of primitives.

#### Use of Attributes

Conventional CADD methods greatly increase the amount of data handled in the standard office owing to the facility of creating "variations on a theme". This, however, creates considerable redundant information. In the most simple case, there is no need to create 20 or 30 different symbols in a CADD library based on permutation of a standard I-Beam; one will suffice, but that symbol will possess graphical attributes of height, flange width, and thickness, and numeric attributes of weight per metre, supplier, etc. These may be alphanumerics (i.e. text, letters) that distinguish between types of nearly identical components, as in the case of Fig. 2, or graphical features indicating a different usage, as in the case of Fig. 3; even colours can be considered attributes. The use of attributes will assist in the production of bilingual drawings; French, English or both may be shown when required.

The attributes form part of the primitive, pictogram, or grouping and it should be possible to alter the attributes of any component either locally (for a specific component), globally (for a number of discrete components), or temporarily ("non-permanent"). In addition, attributes associated with lower level components (primitives, pictograms, etc.) must override attributes of higher level components (their parents, grouping, discipline drawings.).

#### World Coordinate Systems

CADD systems store information in "on-site" measurements and use the computer to calculate the representation at various scales. If a building is 50 metres long, it is entered on the CADD system as 50 metres. When plotted or viewed on the screen it can be shown in any scale required. This creates some problems with standard symbols because the drawing in computer storage is always full size, therefore the symbols must be able to display the proper information at all scales.

## ADDITIONAL BENEFITS OF A CADD STANDARD IN THE BUILDING INDUSTRY

There are numerous benefits for standardization in this rapidly-evolving technology. Some of the more obvious are listed below:

- The standard promotes the use of the speed and intelligence of the CADD systems in many areas, as they relate to building design/drafting, to obtain a long-term high productivity for CADD users.
- The standard reflects current thinking in computer graphics, implementing faster, more effective techniques for automated drafting and thereby extending the life of the standard.
- The standard acts as a teaching tool for novice designers and drafters by providing standard symbols, line thicknesses, lettering styles, presentation formats, etc. in one document.

- The standard assists the sale of CADD systems by providing a full set of drafting tools to the user: the vendor has a machine to draw lines, but CSA provides him (and thereby practitioners) with the templates, font styles, presentation formats, symbols, etc.

This paper is a contribution of the Division of Building Research, National Research Council of Canada.

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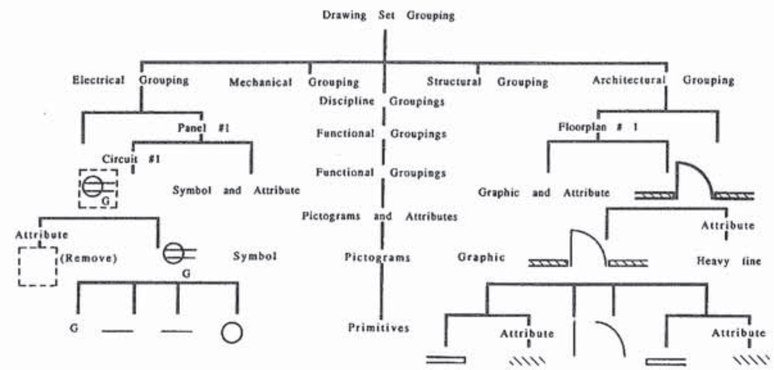


Fig. 1 Recommended Data Structure


| LEGEND | |
|---|---|
| Dashed Line - | Fixture to be removed |
| G - | Grounded Circuit |

Fig. 2 Symbol and Attribute


| LEGEND | |
|---|---|
| Heavy Line - | Install new fixtures |
| S - | Type S-100b Door |

Fig. 3 Graphic and Attribute