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The feasibility of an enhancement of Geometric Design Processor (GDP) to include dimensioning /

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THE FEASIBILITY OF
AN ENHANCEMENT OF GEOMETRIC DESIGN PROCESSOR (GDP) TO
INCLUDE DIMENSIONING

by

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Certificate of Approval

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May 9, 1984
Date

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Chairman of Department

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I dedicate this thesis to my parents for their encouragement throughout my years at Lehigh University.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

The purpose of this thesis is to explore the feasibility of expanding the capabilities of Geometric Design Processor (GDP) to include dimensions on the solid model. The user defines views of the model and positions these views with respect to one another in a multiview display as on a drawing. Dimensions and leaders can then be placed and edited on drawing views. These dimensions and leaders are referenced directly to the 3-D model. To facilitate both design and documentation, the GDP user is able to observe dimensions and leaders directly on the model, as well as on the drawing display views.

GDP is an internal modeling software package consisting of a solid modeler and a graphics interface (abbreviated as GRIN) to this solid modeler. With GDP, a mechanical designer can easily create and manipulate models of complex 3-dimensional objects. These models can be created both by combining geometric volume primitives, such as cuboids and

hemispheres, and by sweeping polygons constructed in a 2-dimensional plane.[1] However, to associate design documentation, such as dimensions and leaders, with the model view, the user must download the 3-D model information to CADAM [2] ,a 2-D automated drafting package.

There are several benefits derived from referencing 3-D dimensions to solid models. An engineer can receive direct visual feedback on a part design from within the GDP environment. Stroked dimensions and leaders are correctly foreshortened in displays. GDP dimensions follow the model as the eyepoint changes. Dimensions are updated automatically, where possible, as the model is altered. Most importantly, since dimensioning is the mechanism through which designers can specify tolerances, this dimensional enhancement is the prerequisite for tolerance analyses in GDP.

This thesis encompasses the development of an interactive system to enter and edit dimensions and leaders on a

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1 W. Fitzgerald, F. Gracer, R. Wolfe, "GRIN: Interactive Graphics for Modeling Solids," IBM Journal of Research Development, Vol. 25, 1981, pp. 281-294.

2 CADAM is a registered trademark of CADAM, Inc.

multiview drawing display of a model. Of particular importance in design was user interface, especially in the development of menus and a single procedure for entering dimensions on both multiview and isometric projections. A detailed system design is included to serve as a user's guide to GDP Dimensioning.

BACKGROUND

Projections

A view of an object can be thought of as a projection of the model onto a plane. In perspective projection, visual rays (called projectors) converge to a single point (the eyepoint). In orthographic projections, parallel projectors extend from the model perpendicular to the viewing plane. The eyepoint is considered to be at an infinite distance away from the model. Perspective views do not reveal exact sizes and shapes, and therefore are not very useful for working engineering drawings. Orthographic views, however, do preserve the same size and shape of the object.[3]

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[3] Warren J. Luzadder, Basic Graphics for Design Analysis Communications and the Computer (Englewood Cliffs: Prentice-Hall, Inc., 1968), pp. 81-82.

Luzadder categorizes orthographic views into multiview and axonometric projections. A multiview (multiplanar) drawing is

> a method by means of which the exact shape of an object can be represented by two or more separate views produced upon projection planes that are usually at right angles to each other.[4]

Multiviews usually consist of principal views which are orthographic projections of object faces. These projections do not describe depth, so multiviews usually consist of two or more principal views positioned according to the generally accepted convention used in this country (See Figure 1). A simple object may be described in one view with a depth note, while a complicated design may need many views for complete multiview representation.[5]

Since multiview projections consist of 2-dimensional views arranged and described according to strict conventions, the model represented by these views may not be easily comprehended by an untrained eye. An axonometric projection describes the depth of an object by including

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[4] IBID. , p. 86.

[5] IBID. , pp. 82-83.

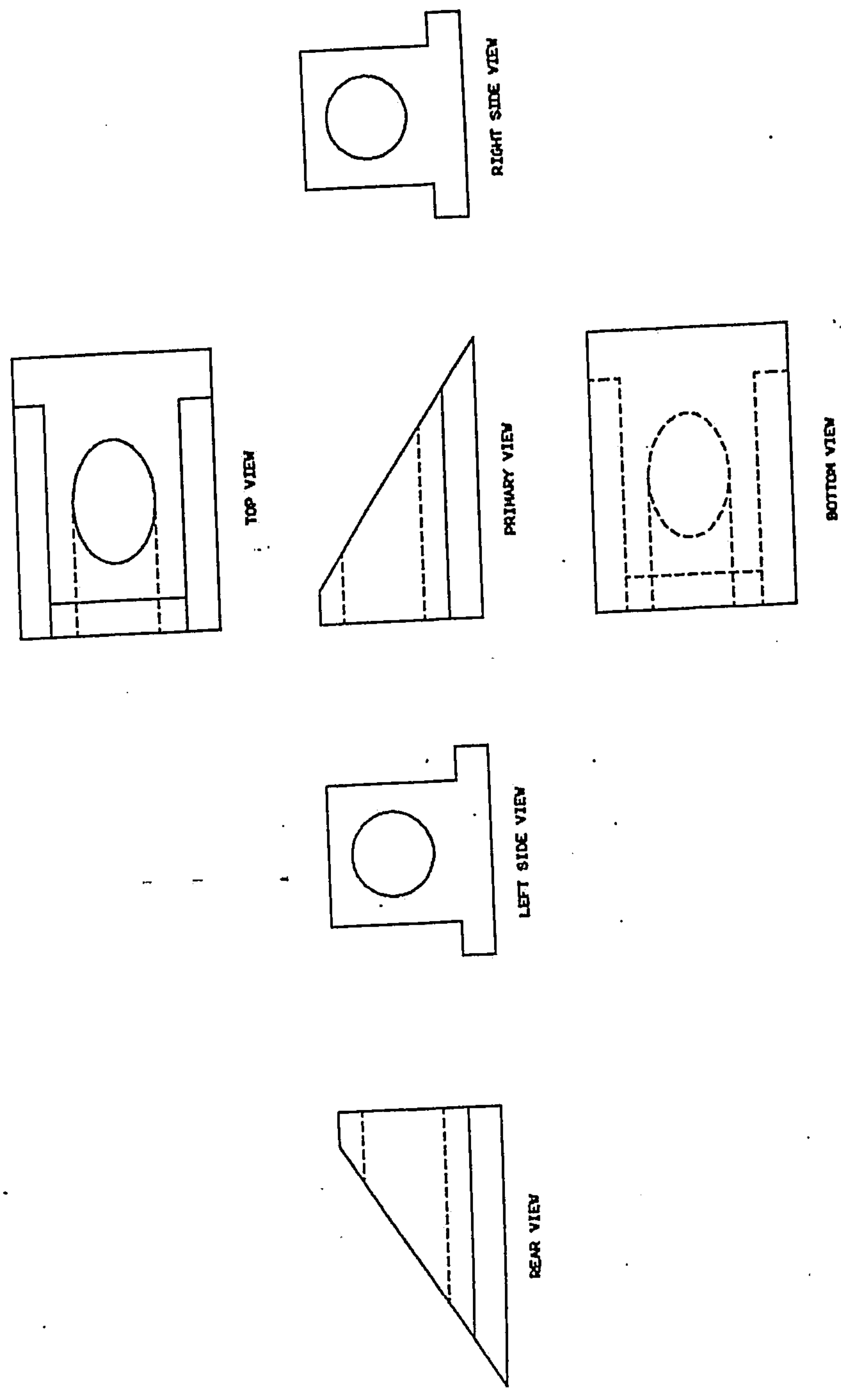

Figure 1. A MULTIVIEW DRAWING

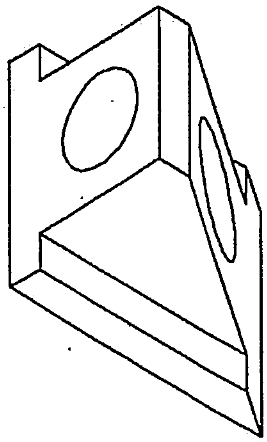

Figure 2. AN AXONOMETRIC PROJECTION

multiple faces (See Figure 2). Axonometric projections more readily convey information about the object to the casual observer. Therefore, one view of an axonometric projection is often sufficient to describe a part.

Axonometric projections, however, are more difficult to draw, since edges of a model must be foreshortened (reduced by depth direction). Of the three types of axonometric projections, isometric projections are the easiest to construct and the most popular in mechanical drafting. In isometric projections (literally meaning "one measure") axial lines are equally foreshortened. In dimetric projections two axes are equally foreshortened, while the third is foreshortened by a second measure. Trimetric projections are the most difficult to draw, since these require three measures for foreshortening axial edges.

Current GDP View Capabilities

In GDP, GRIN allows the user to manipulate the view of the model under the VIEW function.[6]

VIEW - Modify the Model View Parameters

Permits the user to change the position, elevation, and azimuth of the eyepoint, thereby enabling the user to translate and rotate the view. Any principal or axonometric view of a model can be obtained within VIEW by specifying the angles of rotation up or down and left or right.

RX A - Rotate to an Axis

Allows the user to quickly obtain a view parallel to any axis in the world coordinate system (WCS) or to any axis in the user-defined local coordinate system (LCS).

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6 Fitzgerald, William J., et. al., Op. Cit., p. 286.

RI - Rotate to an Isometric

Permits the user to easily create an isometric view of the model.

Drawings

A releasable drawing includes one or more views of a part or an assembly of parts, along with documentation necessary for the manufacture, assembly, and inspection of the design. A simple part drawing might be contained on a single sheet, whereas a complex design may span over a hundred sheets. Drawing documentation consists of dimensions, tolerances, explanatory leader notes, sheet title block information, and cross references to related views. This study focuses on multiview and isometric drawings.

A multiview drawing includes multiview projections (See Projections). Occasionally, an isometric projection is included on a multiview drawing to illustrate a design. Currently, most assembly drawings are multiview drawings.

Isometric drawings, like isometric projections, involve the proportioning of edges. Traditionally, dimensions have been placed on multiview drawings, because multiviews are easier to draw manually. Manufacturers, however, would like to have assembly drawings as isometrics. There is also pressure for dimensions on isometric drawings. It is harder to dimension isometric drawings, but these would be more valuable than dimensioned multiview drawings.

With a solids modeler, such as GDP, isometric views of a model are as easy to generate as orthographic views. Therefore, a facility to enter dimensions and tolerances to multiview and isometric drawings would be desirable.

Dimensions and Leaders

This thesis discusses the following types of dimensions:

1. Linear dimensions,

2. Angular dimensions,

3. Curve length dimensions,

4. Leader dimensions, and

5. Miscellaneous dimensions.

The formats of these dimensions is described below.

Linear Dimensions

Linear dimensions measure the straight-line distance between objects (See Figure 3). These dimensions are composed of:

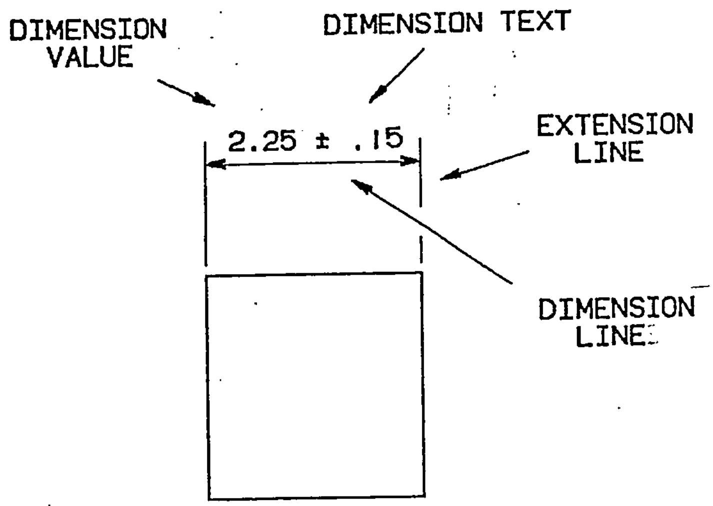


Figure 3. LINEAR DIMENSION COMPONENTS

1. A straight double-arrowed dimension line(s) representing the actual distance dimensioned,

2. Two extension lines referencing the dimension to the elements with a gap from the reference element and extending past the dimension line,

3. A dimension value signifying the nominal length of the dimension, and

4. (Optional) Text associated with the dimension, including tolerances.

Angular Dimensions

Angular dimensions are similar to linear dimensions except that they measure angles between edges (See Figure 4). Angular dimensions consist of:

1. A curved double-arrowed dimension line(s) representing the angle dimensioned,

2. Two extension lines referencing the dimension to the elements with a gap from the reference element and extending past the dimension line,

3. A dimension value signifying the nominal number of degrees of the dimension, and

4. (Optional) Text associated with the dimension, including tolerances.

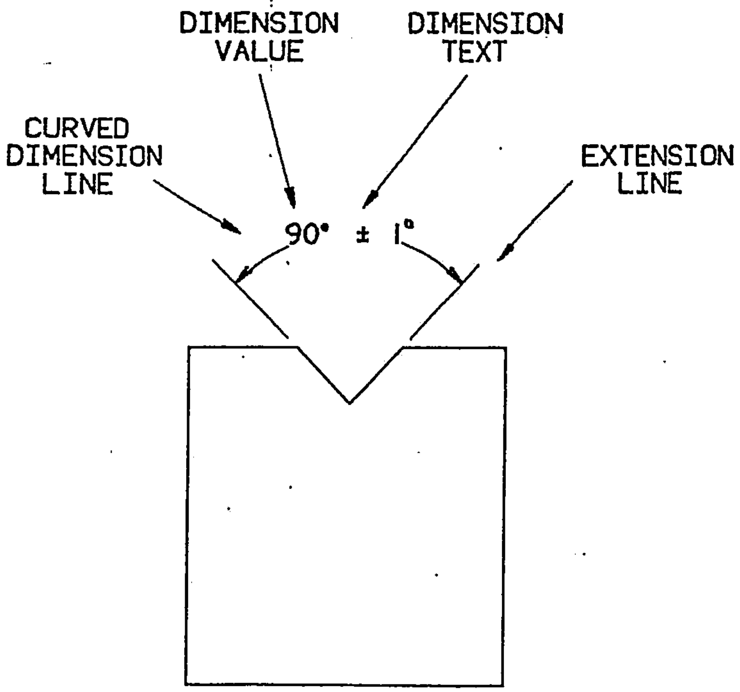


Figure 4. ANGULAR DIMENSION COMPONENTS

Curve Length Dimension

Curve length dimensions appear similiar to angular dimensions but they measure curve length instead of angles. Curve length dimensions are comprised of:

1. A curved double-arrowed dimension line(s) representing the length of the curve dimensioned,

2. Two extension lines referencing the dimension to the elements with a gap from the reference element and extending past the dimension line,

3. A dimension value signifying the nominal length of the dimension, and

4. (Optional) Text associated with the dimension, including tolerances.

Leader Dimension

The format of a leader dimension is different from that of linear and angular dimensions (See Figure 5). Leader

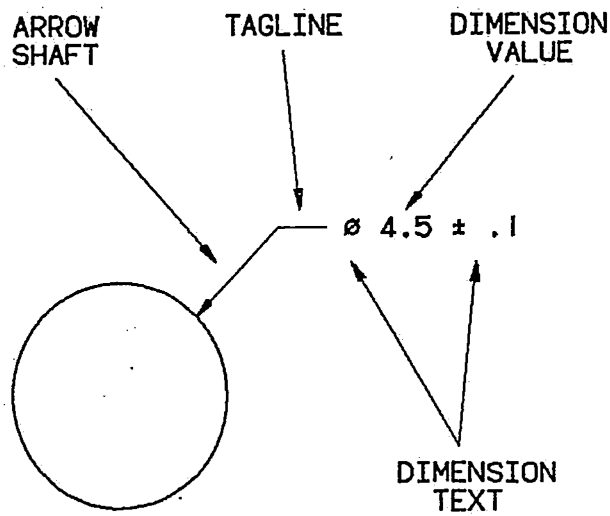


Figure 5. LEADER DIMENSION COMPONENTS

dimensions are defined in this system as radius and diameter dimensions. Leader dimensions are composed of the following:

1. An arrow shaft extending to the referenced element,

2. A horizontal tagline connecting the end of the arrow shaft to the dimension text,

3. A dimension value signifying the length of the radius or diameter,and

4. (Optional) Text associated with the dimension including tolerances.

Miscellaneous Dimension

Dimensions such as tapers and chamfers are examples of miscellaneous dimensions, which will be drawn as leaders in this study (See Leaders).

Leaders

Leaders have a display format similar to leader dimen-sions. A leader carries explanatory text attached to an object, which may or may not have a dimension value associ-ated with it. In this study, geometric tolerances also use the leader format. Specifically, a basic dimension will be used for the center point, and a leader will be used for true-position toleranciny. Leaders have the following com-ponents:

1. An arrow shaft extending to the referenced element,

2. A horizontal tagline connecting the end of the arrow shaft to the leader text,

3. Text associated with the leader.

Dimension Uses

Dimensions convey important design information about a part to people such as manufacturers, assemblers, and inspectors. A mechanical designer ensures part functionality and assemblability through dimension and tolerance specifications. Dimensions may be employed individually or grouped into a base line family. There are also basic and reference dimensions which do not include tolerances.

Base line dimensioning is a system of dimensioning whereby multiple dimensions share a common extension-line (called the base line). This system treats a group of dimensions which share a base line on the same side as a base line family, and orders these dimensions by increasing measure for the user. The advantages are that base line dimensioning limits tolerance accumulation, and aids part manufacture and inspection.

Basic dimensions are theoretically exact (untoleranced) descriptions of the size or location of a feature. They are used as a base from which permissible variations are established by notes or tolerances on other associated dimensions. This study uses the convention of enclosing basic dimensions in a rectangle. Basic dimensions are mainly used to initiate inspection set-ups.

Reference dimensions are untoleranced values recorded for the convenience of Engineering or Manufacturing personnel. The reference dimension is a mechanism for circumventing the conventional practice of placing a dimension only once on a group of drawings. This study uses the convention of labelling a reference dimension with the abbreviation REF following the dimension value.

PROBLEM DEFINITION

Presently, GDP does not contain a dimensioning function. Therefore, to add dimensions, a user must create views of the model in GDP, and then download these views to CADAM, a 2-D automated drafting software package. The user can then add dimensions to these views. When many changes are in progress, maintenance would be easier if dimensions were part of the solid model.

Designers tend to associate tight tolerances with dimensions of parts to ensure that these parts will both assemble correctly and meet functional specifications. In many instances, a close tolerance on a part strictly from a design functionality viewpoint may dictate the manufacturing process. For example, a tight tolerance on a hole may require additional machining operations. Tolerance analysis capabilities available to a designer on a solid modeler such as GDP would provide the user with valuable statistics concerning functional and assembly issues. Since a designer specifies most tolerances through dimensions, the need was demonstrated to develop a dimensioning enhancement to GDP as a prerequisite for tolerance analyses.

The availability of dimensions within GDP itself would aid design development. With a GDP dimensioning function the designer can easily document models in the early design stages, as well as throughout the entire development process. By facilitating early discussions among designers, manufacturers and management, a dimensioning and drawing display capability would be an excellent productivity enhancement to GDP.

Specifically, the tasks of this thesis involve the definition and design of the following capabilities for the GDP user to:

- create many views of a model and position them with respect to one another as on a drawing,
- easily enter dimensions and leaders to model views,
- enter dimensions on either multiview or axonometric views,
- associate dimensions with a view so that when the view is modified, the dimensions follow, and

- reference dimensions directly to the model so that when components are altered, dimensions follow, if possible.

A major design concern was user-friendliness. For the realization of productivity improvements, dimensioning and drawing displays must be easy for the mechanical designer to use.

METHODOLOGY

The GDP dimensioning system was developed in a top-down, modular fashion. This structured approach ensured that the design met the following criteria:

1. That the dimensioning function integrated well with current and proposed GDP code and practices,

2. That this dimensioning facility was useful to GDP designers, and

3. That the dimensioning package encouraged and supported promising GDP tolerance analysis alternatives.

The development of GDP dimensioning can be divided into three phases: System Definition, Structured Design, and Implementation.

System Definition

The specifications of the system were defined through interviews and discussions with GDP users and designers. These basic system requirements were directed by the early formalization of GDP tolerance analysis alternatives and expectations.

Other computer graphics systems were investigated as a measure of completeness. These included CADAM, the Applicon BRAVO editor, and DDS Release 15.

A user's guide was developed from these dimensioning and tolerancing discussions which documented the interactive procedures and system capabilities desired by the users. This user's guide directed the entire design.

Structured Design

The major modules of the system were defined. The interaction and arrangement of these areas followed the current and proposed GDP system. This top-level relationship served as the framework for the entire system development.

The model structure was designed to give dimensions compliancy. This structure was developed to be both efficient for the dimension function, while having the minimal effect on the current system.

The design of prompts, messages, and menus was based on the following considerations:

1. Consistency with current and proposed GDP prompt, message, and menu standards and formats,

2. Minimization of the number of interactions (e.g., selections indicates, keys, etc.),

3. Complete handling of error conditions, and

4. Extensive use of defaults for ease of use.

The top-level hierarchy was further designed into smaller modular components in a structured approach. State diagrams were used to document the detailed design, especially menus, prompts, and messages.

Implementation

System Development Methodology

A methodology was designed to facilitate and coordinate system development. This plan defined:

1. file arrangement,
2. access priveleges,
3. inline documentation standards,

4. external documentation standards,

5. regression testing, and

6. error documentation.

Coding

PL/I is the language used to implement this system. Code developed within GDP2D will be investigated for application within this system to achieve consistency and avoid redundancy.

The coding of this system is beyond the scope of this thesis. The programming task is not completed at this time.

User's Guide

A clear and concise user's guide for GDP Dimensioning was developed for documentation and training. The format and style of this guide follows that of the existing GDP manual. This user's guide is included in this thesis (See Detailed System Design).

CONSTRAINTS

The constraints on this system were specified. These factors are listed below.

Hardware

The hardware configuration consists of a standard IBM 3251 graphics terminal running on an IBM 4341 processor with 16 megabytes of virtual memory.

It is anticipated that this configuration will support an upgrade to an IBM 5080 color terminal.

Software

GDP2D is the most current version of GDP. GDP2D runs in a VM/CMS environment. PL/I is the language in which GDP source code is written. PL/I can call assembly routines.

Timetable

One of the tasks of a project at Lehigh University is to enhance the GDP solid modeler. These enhancements include planar constructions (working planes), dimensioning, and tolerancing. Working planes were completed in the GDP2D version. This design has addressed dimensioning with a parallel effort in the formalization of tolerance analysis problems.

SYSTEM DESIGN

This system defines a display mode consisting of multiple views of the model positioned with respect to one another as on a drawing. Once this drawing display has been established, the user can enter and edit dimensions and leaders in any established view of the multiview. These dimensions are directed by the orientation of the local coordinate system (LCS).

The system structure chart is divided into two main modules. The module "Enter Multiview Mode" controls the arrangement of views of the model on the drawing display (See Figure 6). It initializes or accesses the drawing display. The user can then establish new views or alter predefined views. The multiview function is described in the Detailed System Design chapter.

The second module is the "Enter Dimension Mode" which controls the dimensioning of the drawing display (See Figure 7). It initializes the orientation of the dimensions

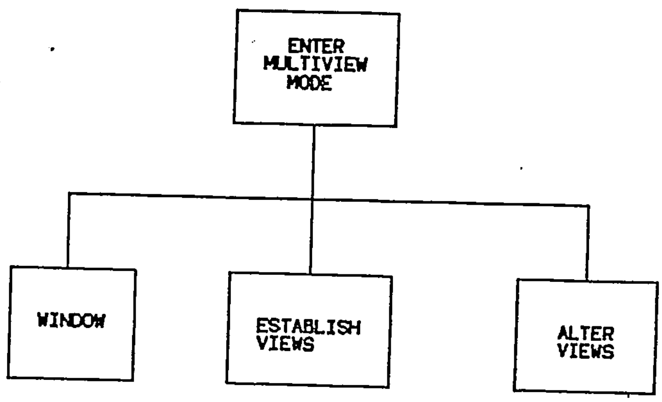


Figure 6. SYSTEM STRUCTURE CHART - MULTIVIEW

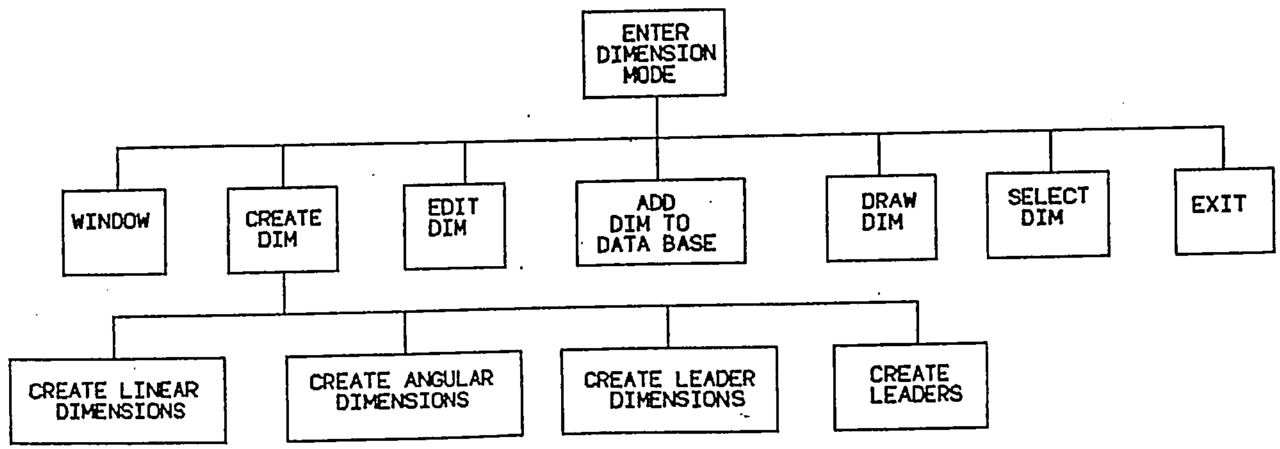


Figure 7. SYSTEM STRUCTURE CHART - DIMENSION

from the LCS, and then passes control to one of the submodules. The user can create and edit linear dimensions, angular dimensions, curve length dimensions, leader dimensions, and leaders in a view. These functions are also described in the Detailed System Design chapter. These modules call the remaining units when needed, including:

- Adding Dimensions and Leaders to the Data Base - This module adds dimensions and leaders to the data base by referencing them directly to the model. This storage also performs the housekeeping work for the maintenance of base line dimension families.

- Selecting Leaders and Dimensions - This module interacts with a graphics package to retrieve information about selected dimensions and leaders.

- Drawing Dimensions and Leaders - This function draws dimensions and leaders from the corresponding information already entered into the model data base.

DETAILED SYSTEM DESIGN

The details of this system are discussed in three sections:

- The multiview function key,
- The dimension function key, and
- The changes to existing GDP code to accomodate the multiview and dimension modules.

Multiview - (MV)

The GDP multiview function key permits multiple views to be positioned with respect to each other as on a drawing.

When multiview is selected and no drawing views have been previously established for the model, the primary view should be established through the view commands.

The main menu of multiview permits the following additional functions:

/ESTAB/CHOOSE/SCL/MOVE/ERS/SHO/NOSHO/

ESTAB - Establish a New View

Allows the user to establish a new view of the model by indicating any of the eight areas defined by the extremes of the primary view (See Figure 8). The view commands are available to establish any axonometric view of the model.

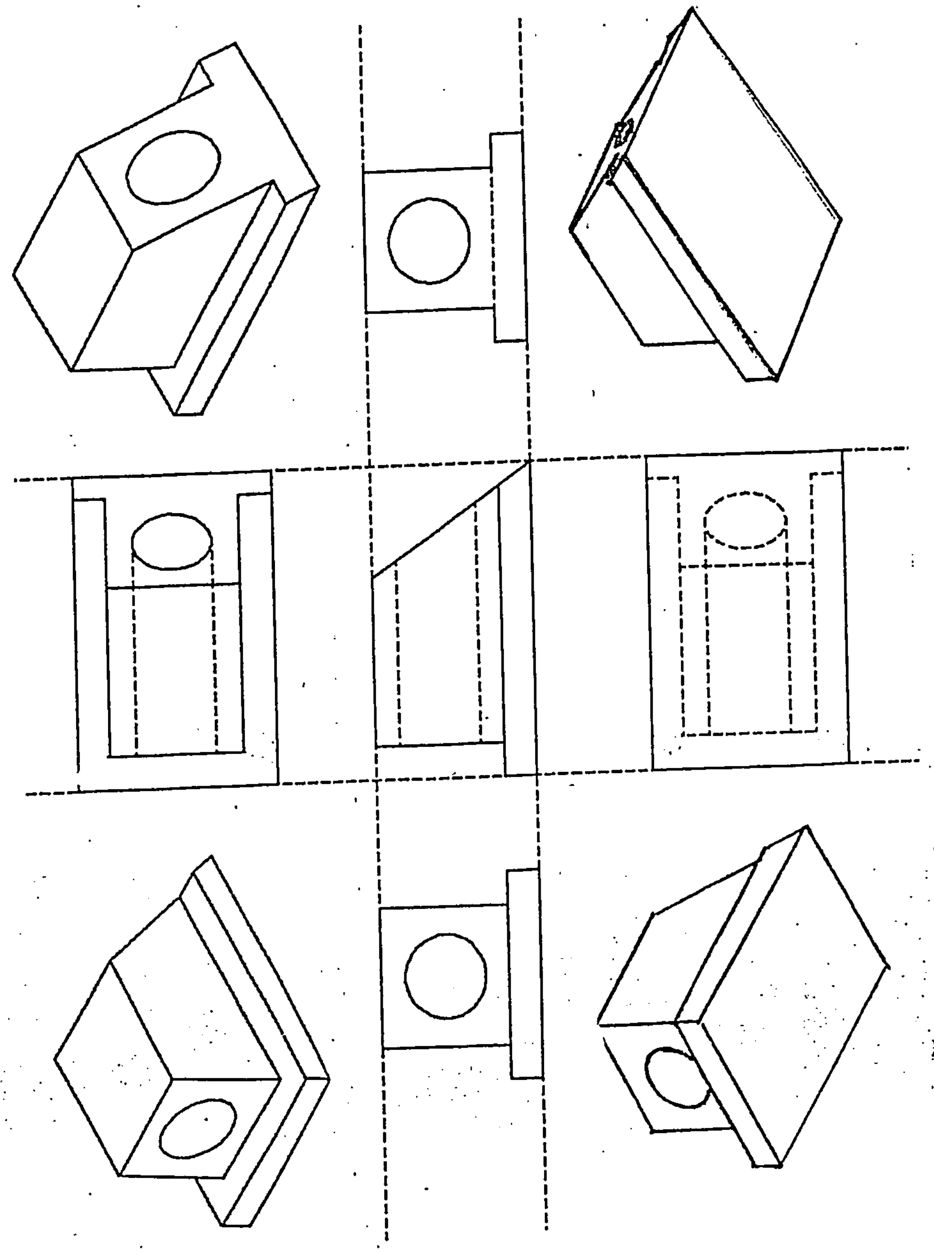


Figure 8. DEFAULT VIEWS IN MULTIVIEW

CHOOSE - Choose the Current View

Allows the user to make one of the shown views current.

SCL - Scale the Current View

Allows the user to increase or decrease the size of the current view.

MOVE - Move a View

Permits the user to move a view with respect to the other views.

ERS - Erase a View

Permits the user to erase any view.

SHO - Show a View

Allows the user to show (display) an entire view that has been previously no-shown.

NOSHO - No Show a View

Permits the user to no show (remove from the display) an entire view.

Dimension - (DIM)

Prior to selecting the dimension function key, the user should make the view to be dimensioned current through the multiview (MV) function key.

Axial dimensions will be entered in the UV direction indicated by the local coordinate system (LCS). The LCS subfunction is available if a change in the direction of the UV axes is desired.

Through the use of levels (standard offsets from elements), the system will automatically assure standard spacing between dimensions. A current level is maintained.

The display precision code consists of a digit. The digit describes the precision to the right of the decimal point, e.g., "2" signifies that the least significant digit is two places to the right of the decimal point. Trailing zeroes are not displayed. The current precision is maintained.

Dimensioned values and texts are centered between the extension lines, if they fit. Dimension arrowheads are automatically positioned between the extension lines if the value and text also fit.

Whenever elements, referenced by a dimension, are not in the same UV plane, they are projected upon a common UV plane before the value of the dimension is calculated.

The main menu of Dimension enables the user to enter and edit dimensions:

/U/V/AN/PR/NM/RD/DIA/CV/LDR/BASE/EDIT/SHO/NOSHO/

U - Enter a Linear Dimension in the U-Direction

Allows the user to enter a linear dimension in the u-direction of the LCS between any two elements, with the

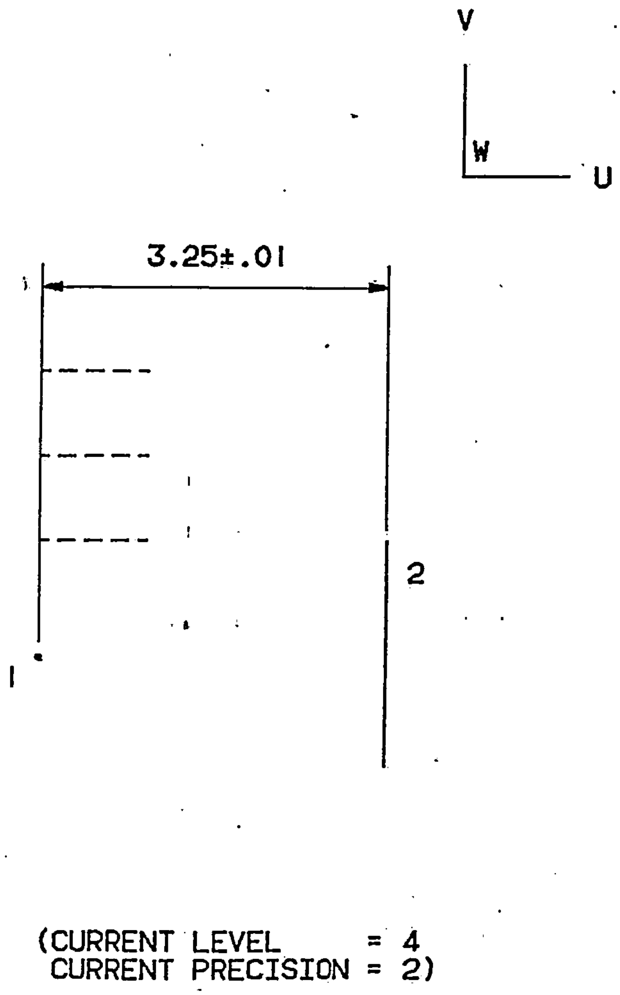


Figure 9. A LINEAR DIMENSION IN THE U-DIRECTION

value centered between the extension lines, if possible, and at the current level and precision (See Figure 9).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

/RELOC/INCR/DECR/EXT-LN/TEXT/ALIGN/NO LEV/

/ERS/OUT-OF-SCL/RET/

V - Enter a Linear Dimension in the V-Direction

Allows the user to enter a linear dimension in the v-direction of the LCS, between any two elements, with the value centered between the extension lines, if possible, and at the current level and precision (See Figure 10).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

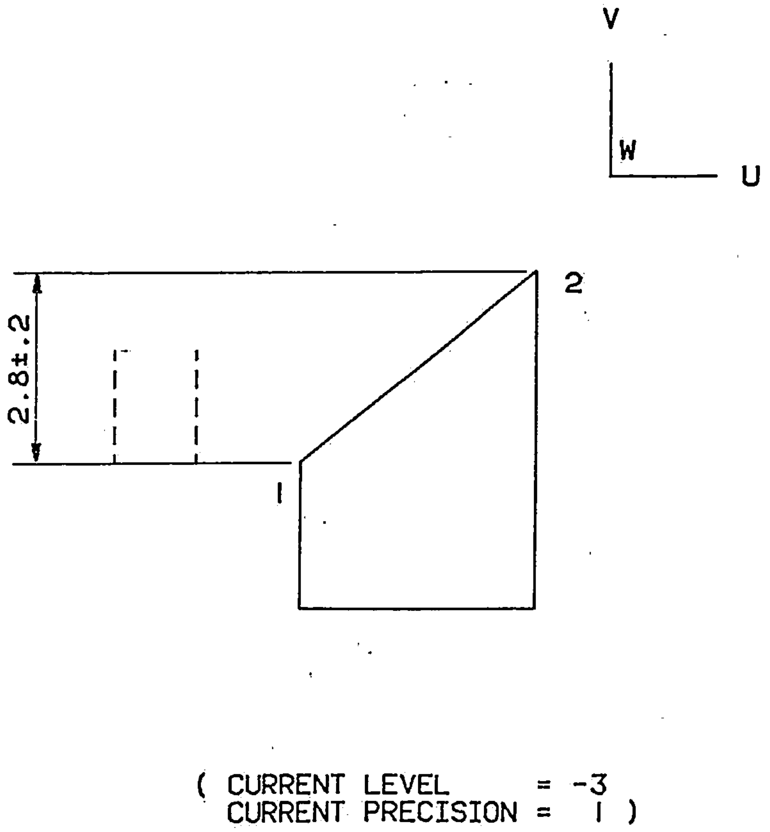


Figure 10. A LINEAR DIMENSION IN THE V-DIRECTION

/RELOC/INCR/DECR/EXT-LN/TEXT/ALIGN/NO LEV/

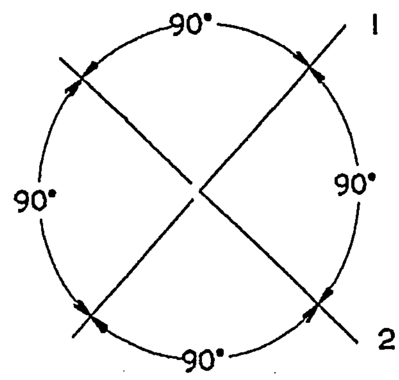
/ERS/OUT-OF-SCL/RET/

AN - Enter an Angular Dimension

Allows the user to place an angular dimension at the position indicated between two nonparallel edges. With a third indication, the user determines the level at which the angular dimension is to be placed with the dimension value centered between the extension lines, if possible, and with the current precision and angle format (See Figure 11).

The angle format is described by a single letter code as follows:

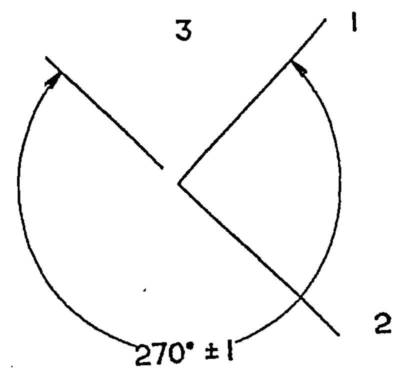
- D - degrees only
- M - degrees and minutes
- S - degrees, minutes, and seconds



(A)

METHOD:

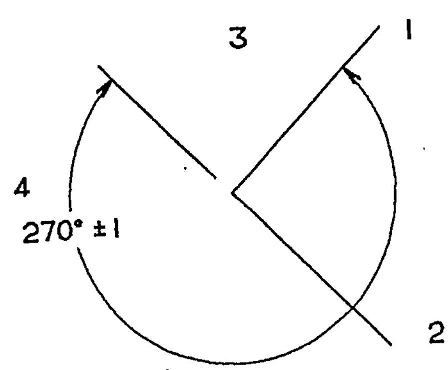
1. SEL LINE1 AND LINE2
2. IND A QUADRANT



(B)

METHOD:

1. SEL LINE1 AND LINE2
2. IND QUADRANT LABELLED 3
3. SEL /OPP/



(C)

METHOD:

1. SEL LINE1 & LINE2
2. IND QUADRANT LABELLED 3
3. SEL /OPP/
4. SEL /RELOC/
5. IND NEW POSN (4)

Figure 11. ANGULAR DIMENSIONS

- F - degrees, minutes, seconds, and fractions of a second.

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

/RELOC/INCR/DECR/OPP/EXT-LN/TEXT/ALIGN/NO LEV/

/ERS/OUT-OF-SCL/RET/

PR — Enter a Parallel Dimension

Permits the user to place a linear dimension between two vertices and parallel to an edge, with the dimension value centered between the extension lines, if possible, and at the current level and precision (See Figure 12).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

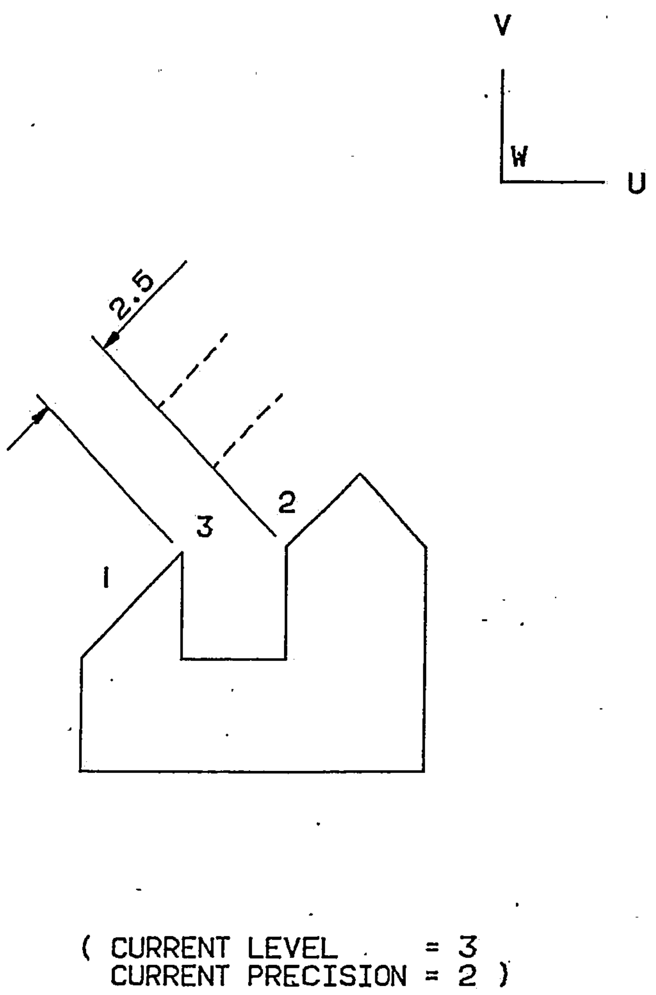


Figure 12. PARALLEL DIMENSIONS: Trailing zeroes suppressed

/RELOC/INCR/DECR/EXT-LN/TEXT/ALIGN/NO LEV/

/ERS/OUT-OF-SCL/RET/

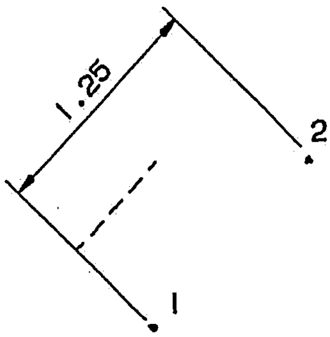
NM - Enter a Normal Dimension

Allows the user to enter a normal dimension between any two elements, with the value centered between the extension lines, if possible, and at the current level and precision (See Figure 13).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

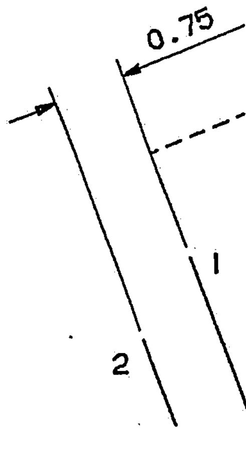
/RELOC/INCR/DECR/EXT-LN/TEXT/ALIGN/NO LEV/

/ERS/OUT-OF-SCL/RET/



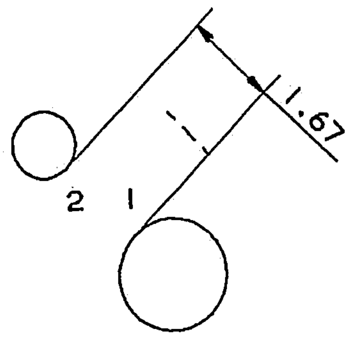
BETWEEN 2 VERTICES

(A)



BETWEEN 2 LINES

(B)



BETWEEN 2 CIRCLES

(CURRENT LEVEL = 2
CURRENT PRECISION = 2)

(C)

Figure 13. NORMAL DIMENSIONS

RD - Enter a Radius Dimension

Allows the user to enter a radius dimension to an arc or circle with the current precision, tag line direction, and arrow convention. With a second indication, the user determines both the dimension level and beginning of the dimension text (See Figure 14).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

/RELOC/INCR/DECR/TEXT/FLIP/ALIGN/ARREV/NO LEV
/ERS/OUT-OF-SCL/RET/

DIA - Enter a Diameter Dimension

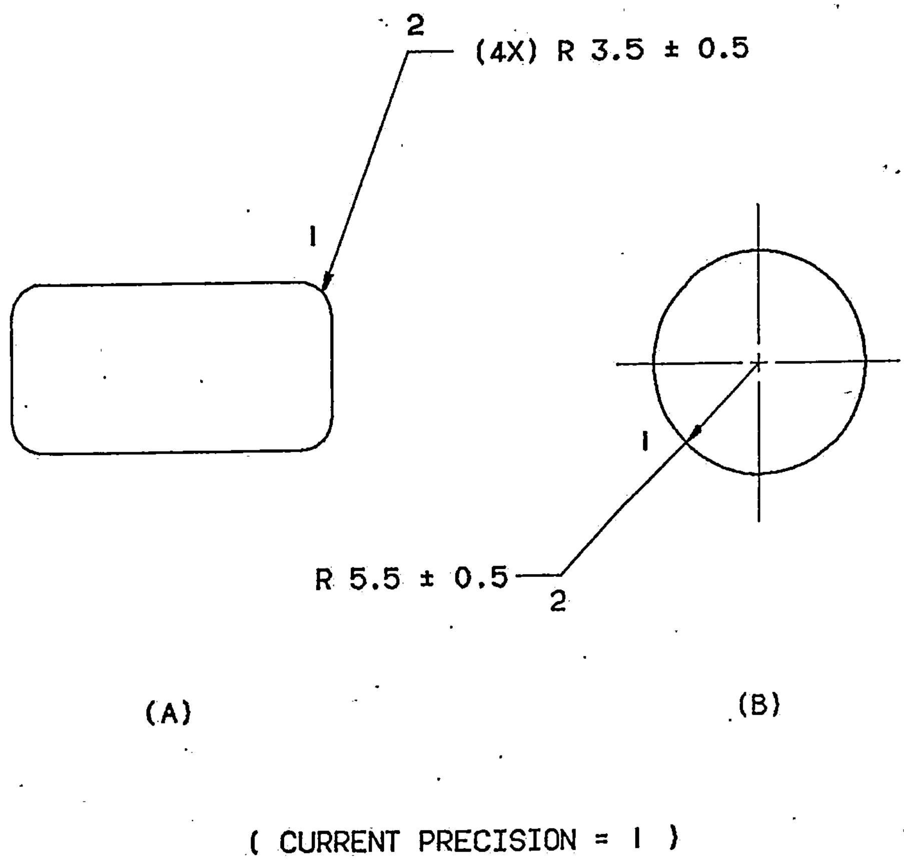


Figure 14. RADIUS DIMENSIONS

Permits the user to enter a diameter dimension to a circle or an arc, with the current precision, tag line direction, and arrow convention. With a second indication, the user determines both the dimension level and beginning of the dimension text (See Figure 15).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

/RELOC/INCR/DECR/TEXT/FLIP/ALIGN/ARREV/NO LEV/
/ERS/OUT-OF-SCL/RET/

CV - **Enter a Curve Length Dimension**

Allows the user to enter a dimension of the indicated length of an arc of a circle, with the current precision. Vertices used to indicate the limits of the curve length and which do not lie on the curve are projected onto the curve. Another indication by the user determines the level at which the dimension value is to be placed (See Figure 16).

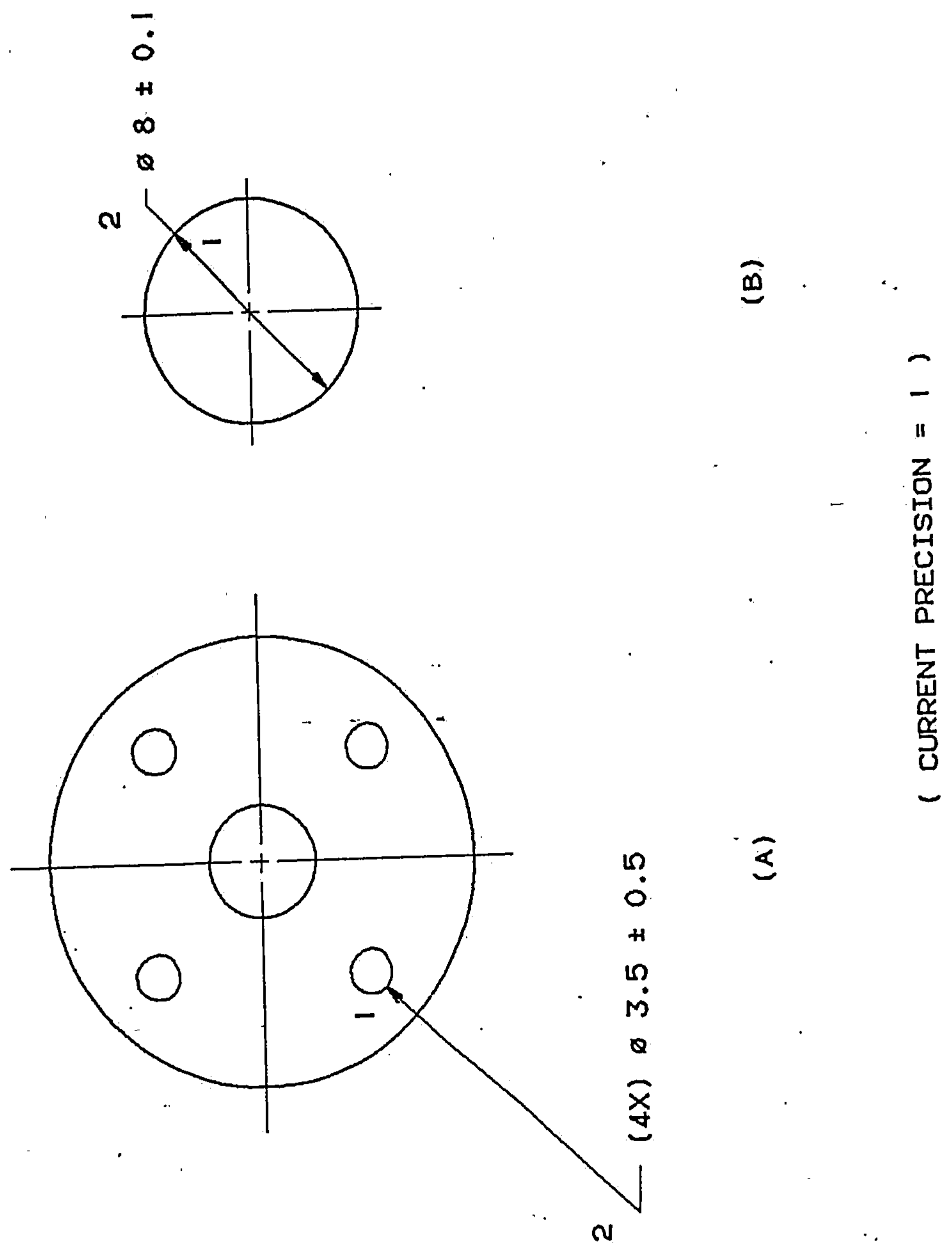


Figure 15. DIAMETER DIMENSIONS

1.0

MICRODEX CORRECTION GUIDE (M-9)

CORRECTION

The preceding document has been re-photographed to assure legibility and its image appears immediately here-after.

REMINGTON RAND

(B)

(CURRENT PRECISION = 1)

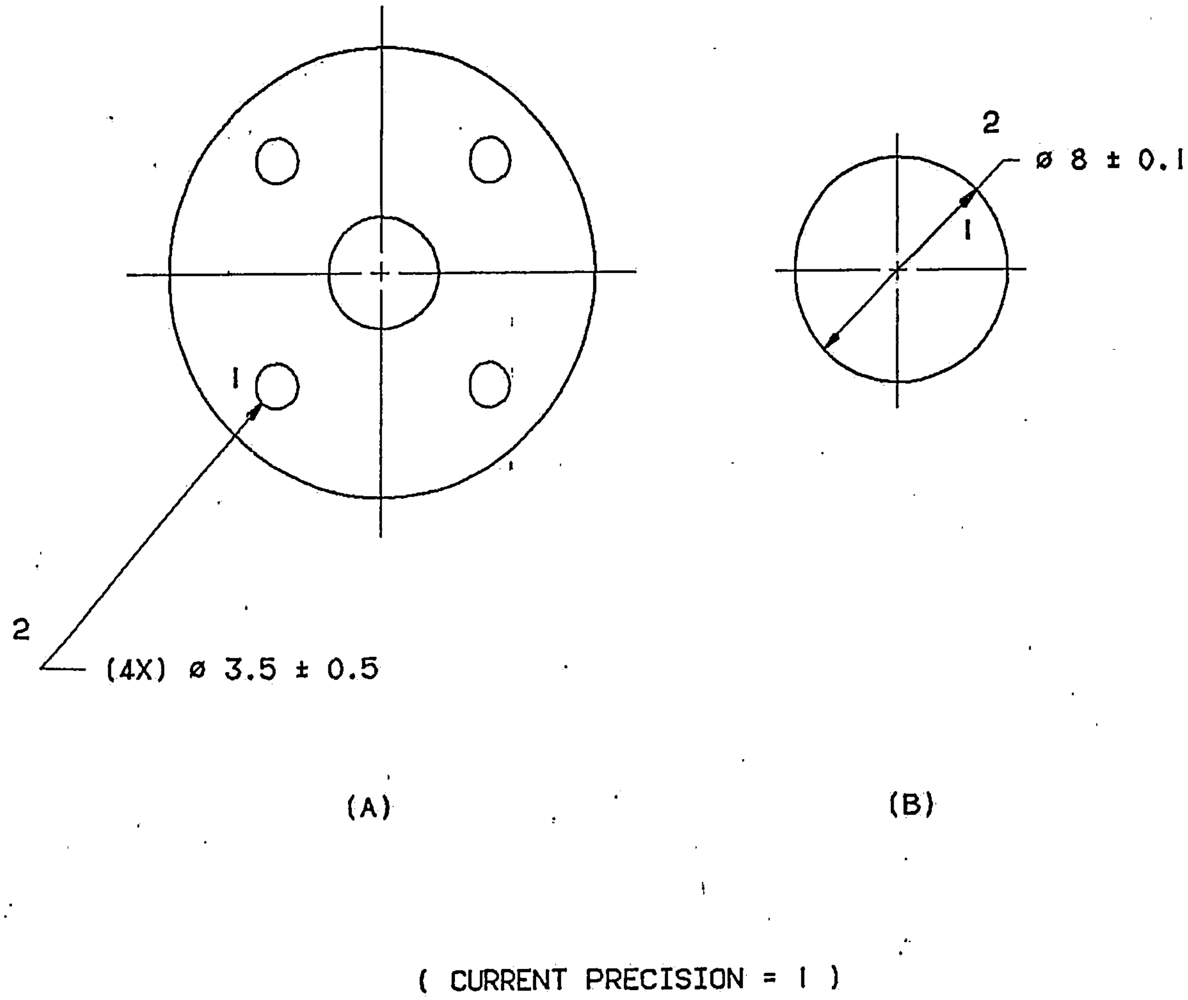
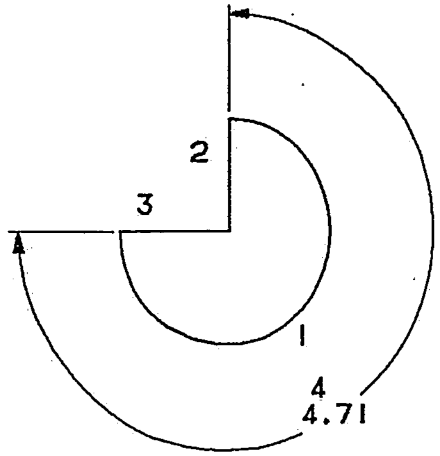


Figure 15. DIAMETER DIMENSIONS



(CURRENT PRECISION = 2)

Figure 16. A CURVE LENGTH DIMENSION

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

/RELOC/INCR/DECR/OPP/EXT-LN/TEXT/ALIGN/NO LEV/

/ERS/OUT-OF-SCL/RET/

LDR - Enter a Leader

Allows the user to enter leader text referenced to a vertex or an edge with the current tag-line direction. With a second indication, the user determines the leader level and beginning of leader text (See Figure 17).

The following menu (discussed in detail under EDIT) allows the user to edit the new dimension:

/RELOC/INCR/DECR/TEXT/FLIP/ALIGN/NO LEV/
/ERS/OUT-OF-SCL/RET/

BASE - Enter Base-Line Dimensions

Base line dimensions share an extension line on the same side. Dimensions to a base line are automatically

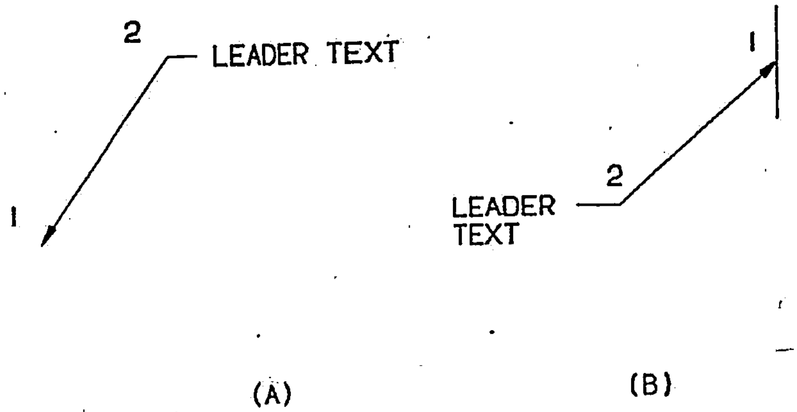


Figure 17. LEADERS

maintained with dimension values in increasing order, and with the current precision. Erasure of a base line dimension results in compaction.

BASE allows the user to enter base line dimensions:

/U/V/AN/PR/RET/

U - U-Direction Base line Dimension

Allows the user to enter linear dimensions in the u-direction of the LCS with respect to a base line vertex (See Figure 18).

V - V-Direction Base line Dimension

Permits the user to enter linear dimensions in the v-direction of the LCS with respect to a base line vertex (See Figure 19).

AN - Angle Base line Dimension

Allows the user to enter angular dimensions in the current angle format with respect to a base line and a base line vertex. The base line vertex is at the intersection of the base line and the first edge dimensioned as an angle base line dimension (See Figure 20).

PR - Parallel Base line Dimension

Permits the user to enter linear dimensions in a direction parallel to an selected edge with respect to a base line vertex (See Figure 21).

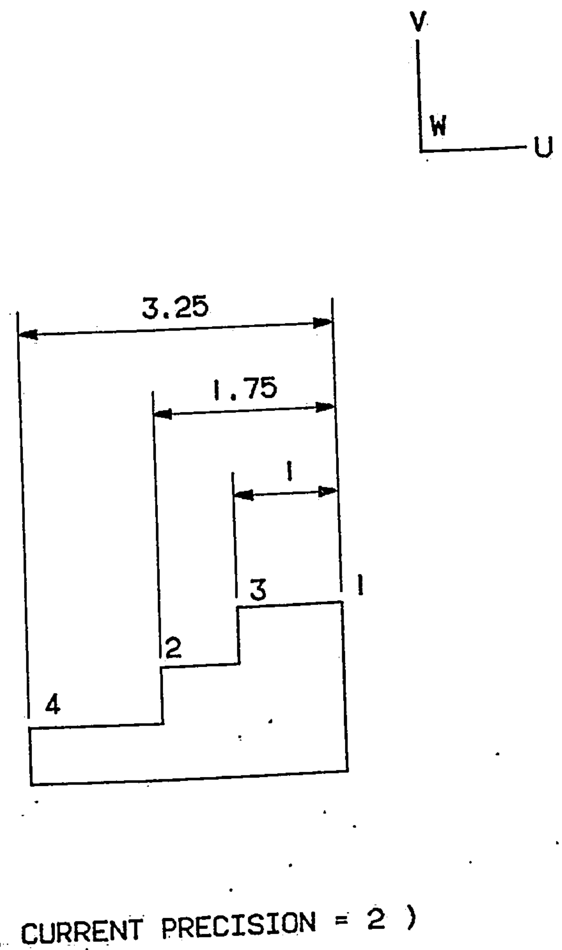
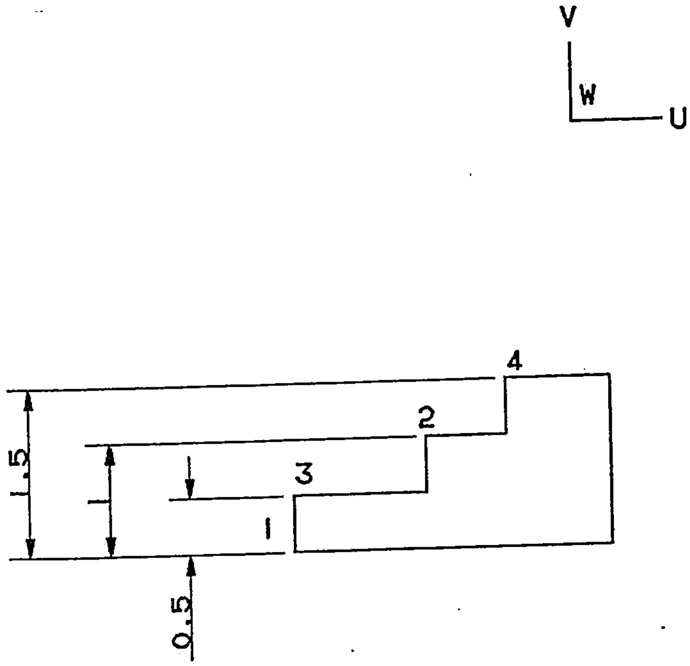
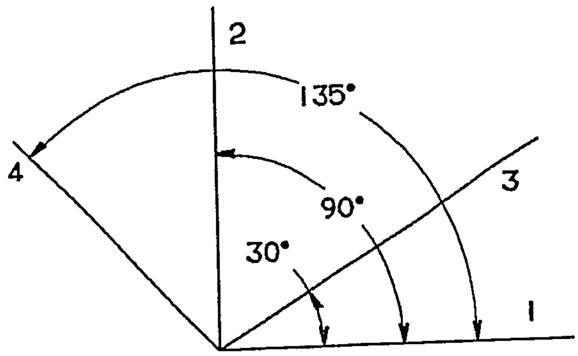


Figure 18. BASE LINE DIMENSIONS IN THE U-DIRECTION



(CURRENT PRECISION = 1)

Figure 19. BASE LINE DIMENSIONS IN THE V-DIRECTION

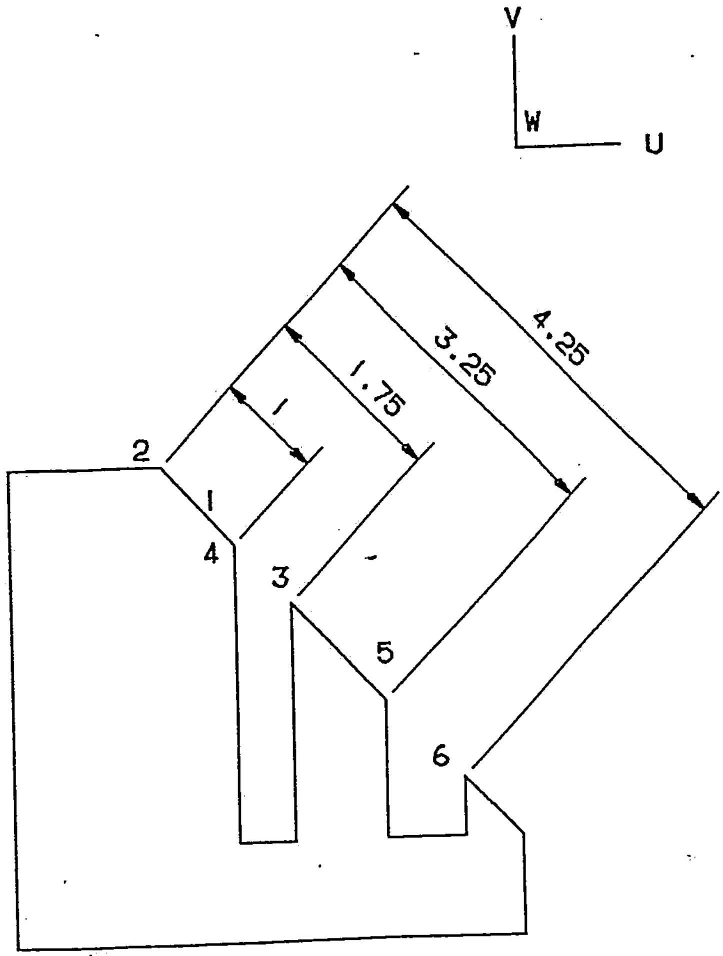


(CURRENT ANGLE FORMAT = D)

Figure 20. ANGULAR BASE LINE DIMENSIONS

RET - Return

The system returns to the main menu of DIM.



(CURRENT PRECISION = 2)

Figure 21. PARALLEL BASE LINE DIMENSIONS

EDIT - Edit a Dimension

Allows the user to edit a dimension through a subset of the following functions, depending on the type of dimension indicated:

/RELOC/INCR/DECR/EXT-LN/OPP/TEXT/FLIP/ALIGN/ARREV/
/NO LEV/ERS/OUT-OF-SCL/RET/

RELOC - Relocate the Beginning of a Dimension

Allow the user to relocate both a dimension and its text (See Figure 22).

INCR - Increment Dimension Level

Permits the user to increment a dimension's level. Incrementation is in the +V direction of the LCS, unless the dimension itself is in the V direction, in which case incrementation is in the +U direction. The maximum level is +20.

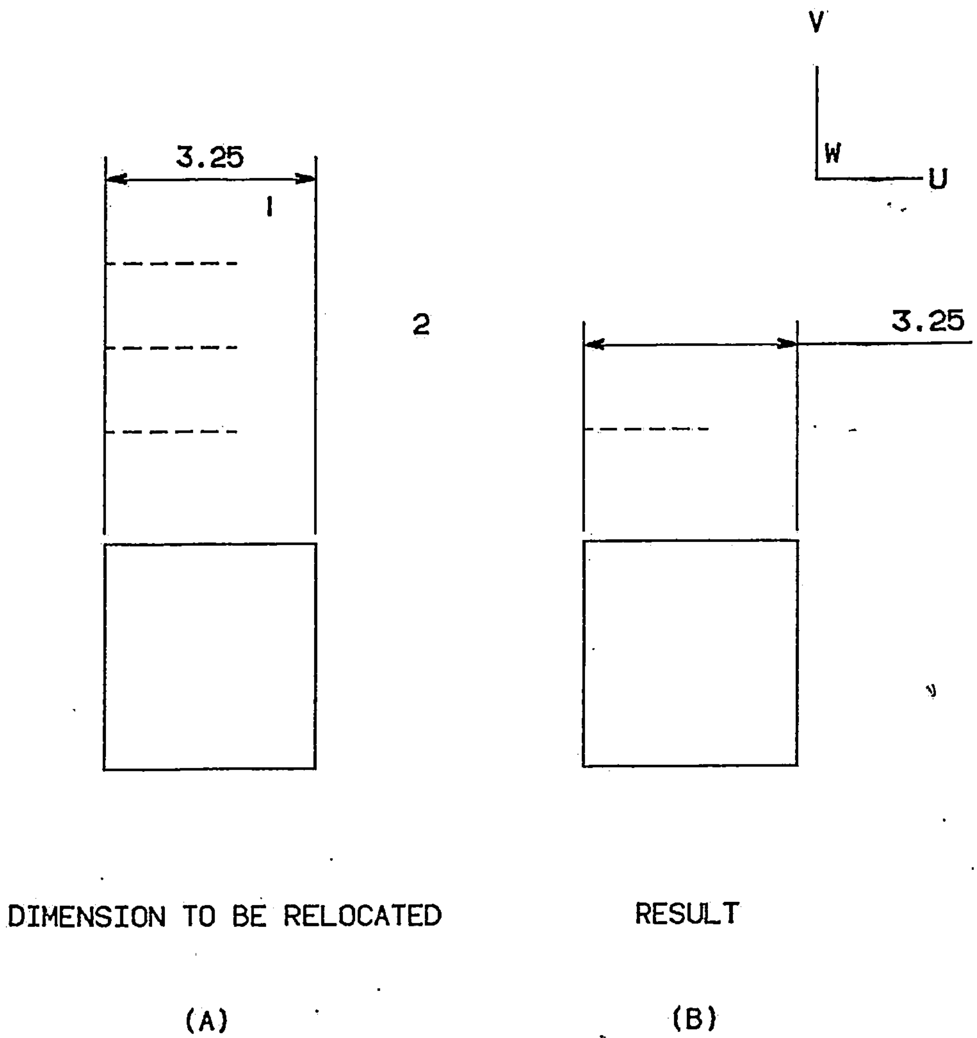


Figure 22. RELOCATING A DIMENSION WITHIN EDIT

DECR - Decrement Dimension Level

Allows the user to decrement a dimension's level. Decrementation is in the opposite direction of incrementation (See incrementation for definition of incrementation). The minimum level is -20.

EXT-LN - Display Dimension Extension Line

Permits the user to show (or no-show) an extension line of a dimension.

OPP - Opposite Angle Dimension

Allows the user to change an angle dimension to 360 degrees minus the angle (See Figure 11 on page 49).

TEXT - Dimension Text

Permits the user to add or alter text associated with a dimension value.

FLIP - Flip the Text (and value if any) of a Dimension

Allows the user to switch the text (and value, if any) between the sides of the arrow in a radius dimension, diameter dimension, or leader (See Figure 23).

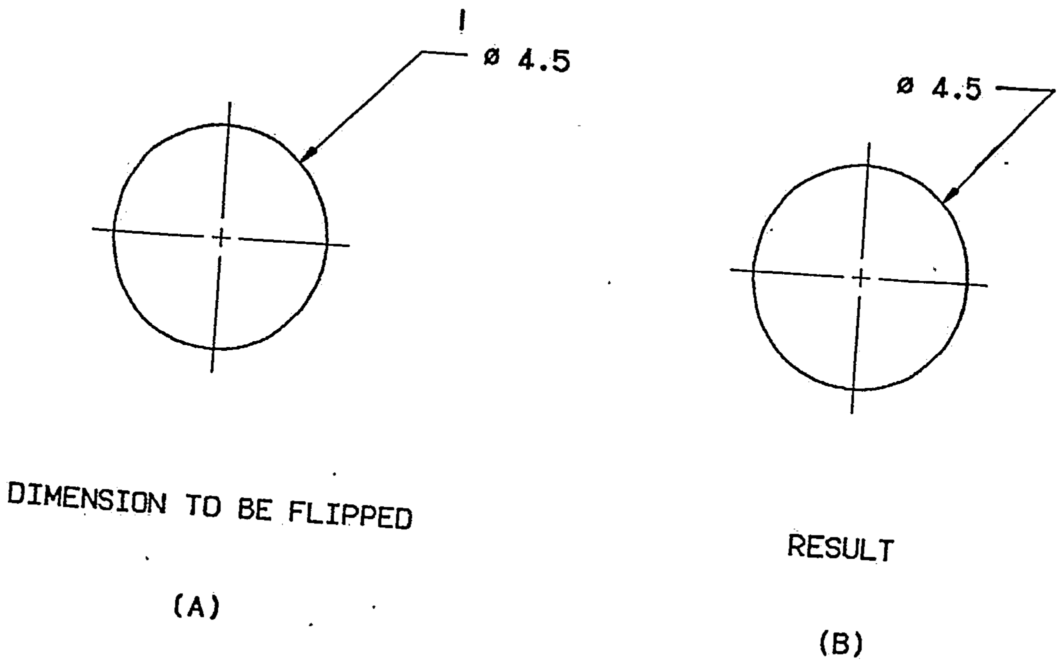


Figure 23. A DIMENSION FLIP WITHIN EDIT

ALIGN - Dimension Align Mode

Permits the user to select a dimension or vertex and then to continue selecting dimensions to be placed on the same level as the initial dimension or vertex.

ARREV - Reverse Arrow Direction

Allows the user to reverse the direction of the arrow component of a leader dimension.

LEVEL - Enable Dimension Level Mode

Automatically places dimensions on levels to assure standard spacings.

NO LEV - Disable Dimension Level Mode

Dimensions will not be placed on levels automatically.

ERS - Erase Dimension Mode

Permits the user to erase dimensions.

OUT-OF-SCL - Out-of-Scale Dimension

Allows the user to change the value of a dimension. The out-of-scale dimension value is underlined.

RET - Return

Returns the user to the main menu of DIM.

SHO - Show Dimensions

Permits the user to display no-shown dimensions.

NO SHO - No Show Dimensions

Allows the user to no show (remove from the display) dimensions.

Changes to Existing GDP Code

In this study dimensions and leaders are referenced directly to the model. Dimensions and leaders, therefore, hang together with the model when the view of the model is changed. When the model is altered, the system automatically updates dimension values and references where possible. The expansions of the functions, which change the model and the view of the model, to handle dimensions are discussed.

DOBJ - Select the Object to be Displayed

DOBJ is the object to which dimensions will be referenced.

TURN (N) - Turn the Current View

Turn the current view about the center of the screen N degrees relative to its present position. A subcommand ABS (N) permits turning to an absolute angle of N degrees.

UNMERGE - Unmerge an Object (Clear a Polyhedron)

If there are dimensions to the object to be unmerged, the system will move the dimension references to sons of the polyhedron where possible. If a dimensioned vertex or edge does not exist in the sons, the user can:

1. Abort the unmerge,

2. Reference the dimension to another vertex or edge, or

3. Erase the dimension.

EO - Erase Object

If there are dimensions which reference the polyhedron to be ERASED, the user can:

1. Abort the erase,

2. Reference the dimension to another vertex or edge, or

3. Erase the dimension.

EDIT - Editing Objects

When the user MOves, ROXs, ROPs, FLIPS, or ROSs an object, any dimension referencing that object will have its extension line(s) repositioned automatically. When the user REPs or REFs an object, the dimensions will also be replicated.

After any of the above seven operations the system will check all linear and angle dimensions. If either end of a dimension references the edited object, the system will analyze the distance or angle to see if it agrees with the value in the dimension. If there is no agreement, the user can:

1. Accept the new value,

2. Delete the dimension, or

3. Rereference the dimension (and the system checks the dimension in its new position).

DATA STRUCTURES

In GDP, models are represented as nodes in a hierarchical data structure. Nodes which are combined to form a more complex node are called "sons" of the resultant node. These constituent nodes are referred to as "brothers," and the composite node is called their "dad" (See Figure 24). The node which describes the entire model is called the model node. The highest level node in the GDP hierarchy is the top node. Its son is the model node.

In addition to pointers, the nodes in the model also contain information about the 3-D orientation of the object, the type of the object (e.g., cuboid, non-primitive), and another pointer to a polyhedron list. The polyhedron list contains the faces, edges, and vertices of the model. [7]

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7 Carol Riggin, "The Enhancement of IBM Solid to Include Geometric Constructions in a Plane," (Lehigh University: Masters Thesis, 1983), p. 69.

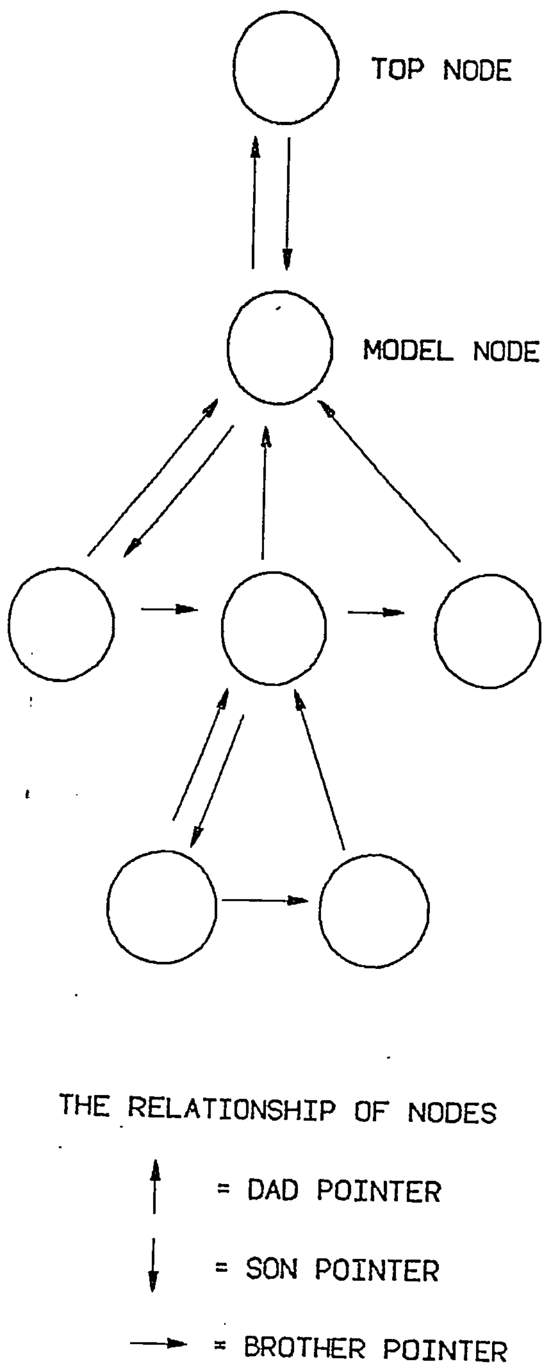

Figure 24. GDP'S HIERARCHICAL MODEL STRUCTURE

Conversely, a primitive is the lowest level node in that it does not point to a son. A solid primitive, such as a cylinder, can merge with other nodes to form a composite node. A collection or bunch of dimensions forms a different type of object primitive. The dimension node contains information about dimensions and their 3-D orientation. Unlike solid primitives, dimension bunches are not merged with other nodes.

Dimension bunches are sons of the model node. (See Figure 25). In this configuration, any reorientation of the model also affect its dimensions. Also, reorientation of subnodes will not affect dimensions. This helps keep dimensions in the same relative position when the entire model is reoriented.

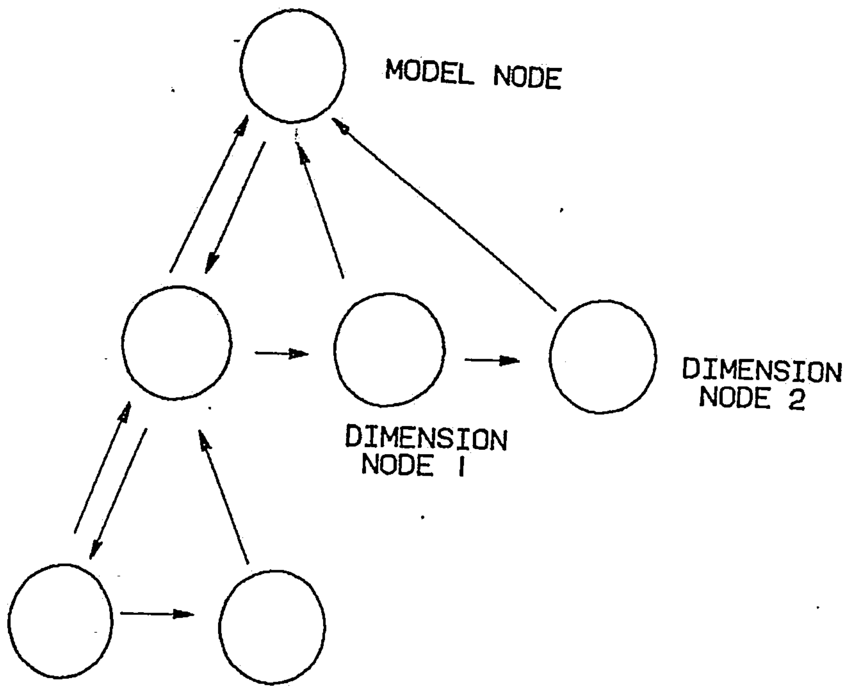

Figure 25. HIERARCHICAL LOCATION OF DIMENSIONS

SUMMARY AND CONCLUSIONS

This thesis demonstrated the feasibility of a facility in GDP to:

1. define multiple views as on a drawing,

2. enter dimensions and tolerances, and

3. edit all of these elements.

The benefits of dimensioning in GDP include:

Increased Productivity

- A quick facility to document designs to facilitate discussions between GDP users and managers and manufacturers.

- An easy method for establishing common drawing views of a model.

- Easier to enter dimensions on axonometric views than on other systems.

- Automatic determination of levels.

- Easier to enter base line dimensions than on other systems.

Increased Flexibility

- The user can document a GDP model and view these dimensions and leaders in a multiview drawing display or directly on the model.

- Dimensions will follow model view changes and model alterations, where possible.

Simplicity

- A consistent procedure for entering dimensions on mutliview and isometric projections.

- The system attempts to place a dimension in one plane oriented by the w-axis of the LCS.

Increased Acceptance

- This system connects 2D drawings with solid modelers. In the drawing display mode, mechanical designers are able to interact with a model as a familiar drawing.

As noted in the Background, designers usually dimension principle views of a design, because these were the easiest to draw manually. In this system's drawing display mode, any axonometric view of a model can easily be established.

Since the same procedure is used to place dimensions on both multiview and isometric views, an increase in the use of dimensions on isometric views might be envisioned.

AREAS OF FUTURE STUDY

The addition of a dimensioning capability was the second phase of enhancements to GDP. The third phase encompasses the application of tolerances to the solid modeler.

The planar representations employed in GDP support mass property calculations and fixed length analysis, such as nominal interference checking. Many interesting issues arise in the interpretation of toleranced models, representing an acceptable family of designs.

From toleranced representations, results of testing, such as worst-case and statistical tolerance analyses, should provide the designer with the necessary feedback to either loosen or redistribute tolerances to reduce the number of rejected parts.

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VITA

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Mr. Glemser was awarded a Distinguished Computer-Aided Manufacturing (CAM) Fellowship to pursue a Masters of Science degree in Industrial Engineering at Lehigh University.