Physical Properties
User Guide and Menu Reference

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Preface

The *Physical Properties User Guide and Menu Reference* provides information and instruction for engineers who need to calculate physical properties of CADDS 5 explicit and/or parametric geometry within either an active part or assembly. This book assumes that you are familiar with physical properties calculations and have a working knowledge of CADDS 5 Explicit and Parametric modeling and assembly design.

Related Documents

The following documents may be helpful as you use *Physical Properties User Guide and Menu Reference*:

*   *Introduction to CADDS 5*
*   *Explicit Modeling User Guide and Menu Reference*
*   *Parametric Modeling User Guide and Menu Reference*
*   *Concurrent Assembly Mock-Up User Guide and Menu Reference*

Book Conventions

The following table illustrates and explains conventions used in writing about CADDS applications.

Convention	Example	Explanation
Menu selections and options	List Section option, Specify Layer field	Indicates a selection you must make from a menu or property sheet or a text field that you must fill in.
User-selected graphic location	X, d_1 or P1	Marks a location or entity selection in graphic examples.

Convention	Example	Explanation

User input in CADDS text fields and on any command line	`cvaec.hd.data.param`
	
	`tar -xvf /dev/rst0`
		Enter the text in a CADDS text field or on any command line.

System output	`Binary transfer complete.`	Indicates system responses in the CADDS text window or on any command line.
Variable in user input	`tar -cvf /dev/rst0` filename	Replace the variable with an appropriate substitute; for example, replace filename with an actual file name.
Variable in text	tagname	Indicates a variable that requires an appropriate substitute when used in a real operation; for example, replace tagname with an actual tag name.
CADDS commands and modifiers	INSERT LINE TANTO	Shows CADDS commands and modifiers as they appear in the command line interface.
Text string	`"SRFGROUPA"` or `'SRFGROUPA'`	Shows text strings. You must enclose text string with single or double quotation marks.
Integer	n	Supply an integer for the *n.*
Real number	x	Supply a real number for the *x.*
#	`# mkdir /cdrom`	Indicates the root (superuser) prompt on command lines.
%	`% rlogin` remote_system_name `-l root`	Indicates the C shell prompt on command lines.
$	`$ rlogin` remote_system_name `-l root`	Indicates the Bourne shell prompt on command lines.

Window Managers and the User Interface

According to the window manager that you use, the look and feel of the user interface in CADDS can change. Refer to the following table:

Look and Feel of User Interface Elements

User Interface Element	Common Desktop Environment (CDE) on Solaris and HP	Window Manager Other Than CDE on Solaris, HP, and Windows
Option button	ON — Round, filled in the center OFF — Round, empty	ON — Diamond, filled OFF — Diamond, empty
Toggle key	ON — Square with a check mark OFF — Square, empty	ON — Square, filled OFF — Square, empty

Online User Documentation

Online documentation for each book is provided in HTML if the documentation CD-ROM is installed. You can view the online documentation in the following ways:

- From an HTML browser

- From the Information Access button on the CADDS desktop or the Local Data Manager (LDM)

Please note: The LDM is valid only for standalone CADDS.

You can also view the online documentation directly from the CD-ROM without installing it.

From an HTML Browser:

1. Navigate to the directory where the documents are installed. For example,

   `/usr/apl/cadds/data/html/htmldoc/` (UNIX)

   Drive:`\usr\apl\cadds\data\html\htmldoc\` (Windows)

2. Click `mainmenu.html`. A list of available CADDS documentation appears.

3. Click the book title you want to view.

From the Information Access Button on the CADDS Desktop or LDM:

1. Start CADDS.

2. Choose Information Access, the i button, in the top-left corner of the CADDS desktop or the LDM.

3. Choose DOCUMENTATION. A list of available CADDS documentation appears.

4. Click the book title you want to view.

From the Documentation CD-ROM:

1. Mount the documentation CD-ROM.

2. Point your browser to:

   CDROM_mount_point`/htmldoc/mainmenu.html` (UNIX)

   CDROM_Drive:`\htmldoc\mainmenu.html` (Windows)

Online Command Help

You can view the online command help directly from the CADDS desktop in the following ways:

- From the Information Access button on the CADDS desktop or the LDM

- From the command line

From the Information Access Button on the CADDS Desktop or LDM:

1. Start CADDS.

2. Choose Information Access, the i button, in the top-left corner of the CADDS desktop or the LDM.

3. Choose COMMAND HELP. The Command Help property sheet opens displaying a list of verb-noun combinations of commands.

From the Command Line: Type the exclamation mark (!) to display online documentation before typing the verb-noun combination as follows:

```
#01#!INSERT LINE
```

Printing Documentation

A PDF (Portable Document Format) file is included on the CD-ROM for each online book. See the first page of each online book for the document number referenced in the PDF file name. Check with your system administrator if you need more information.

You must have Acrobat Reader installed to view and print PDF files.

The default documentation directories are:

- `/usr/apl/cadds/data/html/pdf/`doc_number`.pdf` (UNIX)

- `CDROM_Drive:\usr\apl\cadds\data\html\pdf\`doc_number`.pdf` (Windows)

Resources and Services

For resources and services to help you with PTC (Parametric Technology Corporation) software products, see the *PTC Customer Service Guide*. It includes instructions for using the World Wide Web or fax transmissions for customer support.

Documentation Comments

PTC welcomes your suggestions and comments. You can send feedback electronically to `doc-webhelp@ptc.com`.

Chapter 1 # Getting Started

This chapter describes the Physical Properties software and explains how to use it.

- Overview of Physical Properties Functions
- Using Physical Properties
- Extracting Parametric Mass Properties Data

Overview of Physical Properties Functions

You can calculate various physical properties of the CADDS models.

Explicit Environment

Within the Explicit environment, CADDS 5 Physical Properties software allows you to calculate the following properties of bounded planar regions and volumes enclosed by surfaces:

- Volume

- Area

- Mass

- First moments

- Center of mass

- Moments and products of inertia with respect to the model space x-, y-, and z-axis

- Moments and products of inertia with respect to an arbitrary coordinate system

- Polar moment of inertia about a point

- Radius of gyration

- Principal axes

- External surface area

- Center of gravity

Numeric Accuracy

The CADDS numeric representation extends to 7+ significant digits. However, the iterations and complex computations used limit the actual precision to approximately five significant digits for direct analytic techniques, such as projection and rotation. Additionally, these numeric precision limitations affect the number of accurate decimal places. For example, the use of three-digit numbers results in answers accurate to two decimal places.

As the accuracy of a calculation is influenced by numerical and methodological effects, we recommend that you test the routine for each class of parts. Compare the software answer to known answers and derive an accuracy estimate from the comparisons. The comparisons provide reasonable guidelines for the accuracy of the *total* procedure for each class of measurement.

The Mass Point

Mass points provide a way to store physical properties data in the Explicit environment. Each time you perform a calculation, you can create a mass point. CADDS uses the standard center of mass symbol to identify the location of the object's centroid (center of mass). You can change this location with the Move icon.

Mass point symbol
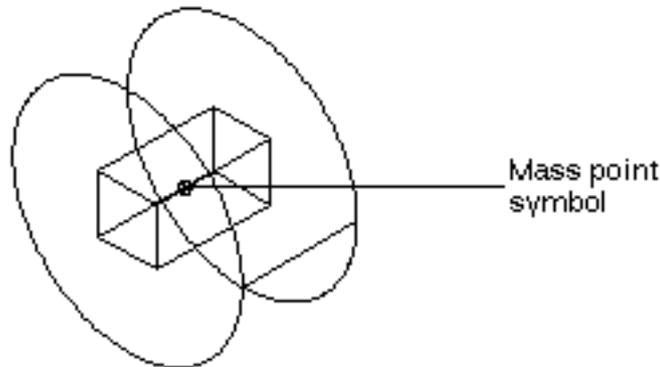
You can also store physical properties data outside the part database in a standard text file, allowing you to quickly transfer physical property data to and from mass points.

Please note: To store physical properties data in a text file, use the List Mass Point property sheet with the Save Data to File option enabled. See Chapter 5, "Reporting Mass Point Data," to learn more about this feature.

In addition to creating mass points to store the results of area, volume and mass properties calculations, you can also create a mass point to store other aspects of an object. These include:

• Density

• Part Unit

• Part Identifier - full name of active CADDS part

• Date of calculation

• MIP, TAG, and Layer of solid (Tsurf) used in calculation

• Description - as defined by the DESCR property value in CADDS (often used for material identifier)

These other aspects can be listed using the List Mass Point property sheet by enabling the Generate Detailed Reports option. See Chapter 5, "Reporting Mass Point Data" to learn more about this feature.

During the calculation of mass properties, you can create mass points on multiple solids. CADDS assigns mass properties of each solid you select to the respective mass point. CADDS allows you to select a maximum of 600 objects at a time.

Mass points can be associative or nonassociative. Mass points can optionally be merged to created composite mass points to determine weight, center of gravity, and other properties of multiple objects.

Please note: Associative mass points can be created only if the solid or Tsurf to which they pertain is physically located within the active part.

Parametric Environment

Within the Parametric environment, you can use the Calculate Properties option to report the following properties of the surfaces or solid you select:

- Volume
- Surface area
- Mass
- Centroid/Center of Mass
- First mass moment
- Moments of inertia
- Principal moments of inertia
- Principal axes

Please note: Except for information on extracting data "Extracting Parametric Mass Properties Data" , the remainder of this book explains procedures for calculating and displaying physical properties data within the Explicit environment.

Object Types

Physical properties can be calculated for four types of objects: two-dimensional, implied surface of revolution, implied tabulated cylinders, and objects defined by cross sections.

You can calculate physical properties for the following types of objects:

- Two-dimensional planar region bounded by a series of curves
- Implied surface of revolution consisting of one or more bounded regions within a plane and an axis of revolution

- Implied tabulated cylinder consisting of one or more bounded regions within a plane and an axis of projection

Additionally, you can represent the object as a series of cross sections, which are calculated separately and then summed to approximate the physical properties of the object.

The boundary of each bounded region consists of one or more of the following entities:

- Lines
- Arcs
- Conics
- B-splines
- Strings
- Curve poles
- Nodal lines

An object's boundary can enclose either a positive (solid) or a negative (hole) region.

Requirements for Two-Dimensional Objects

To calculate physical properties for two-dimensional objects,

1. All boundary curves must lie in the same plane.
2. The number of closed boundaries (solid and holes) is not limited, but the number of entities in each boundary must be fewer than 300.

Please note: An example.
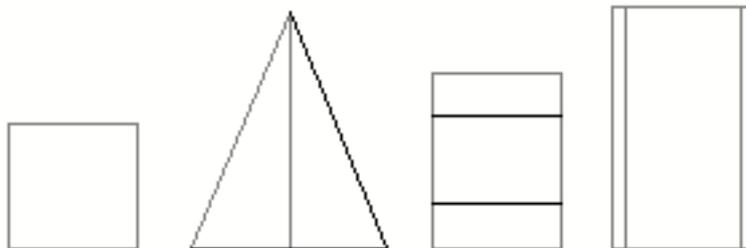
Requirements for an Implied Surface of Revolution

To calculate physical properties for an implied surface of revolution,

1. All boundary curves must lie in the same plane.

2. The axis of revolution also must lie in the same plane as the boundary curves and cannot intersect the curves, although the axis can touch (be tangent to) the curves.

3. The number of closed boundaries (solid and holes) is not limited, but the number of entities in each boundary must be fewer than 300.

Please note: Because all physical properties calculations are based on the defining curves, it is not necessary to create any surfaces or solids.

Cone generated by a triangle

Sphere generated by a closed half-circle

Torus generated by a circle
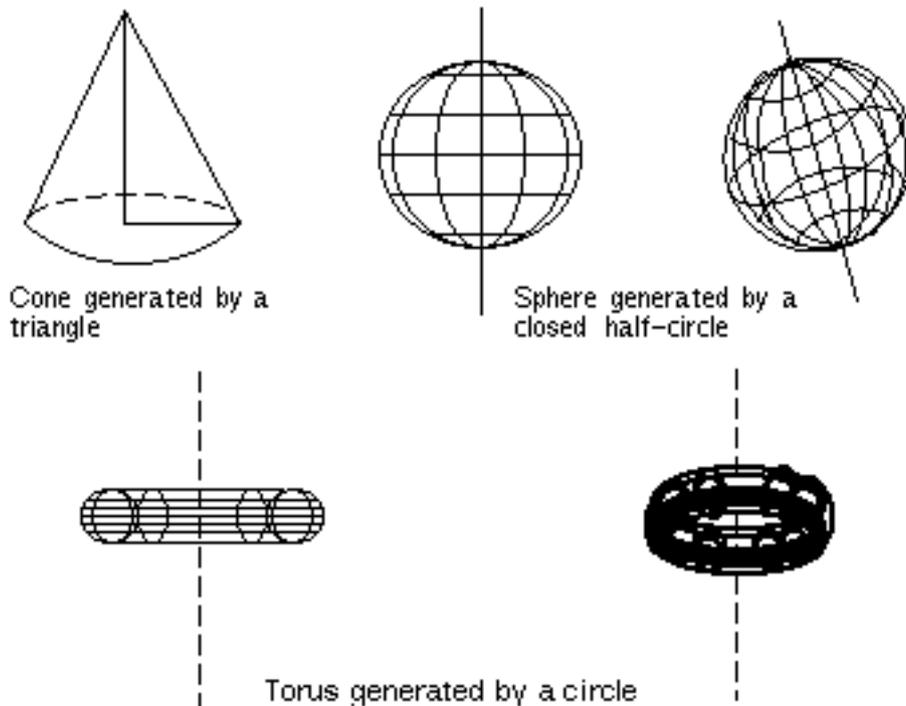
Physical properties are calculated based on the closed boundary from which the 3-D object is generated.

Requirements for an Implied Tabulated Cylinder

To calculate physical properties for an implied tabulated cylinder:

1. All boundary curves must lie in the same plane.

2. The axis of projection must *not* lie in the same plane as the boundary curves.

3. The number of closed boundaries (solid and holes) is not limited, but the number of entities in each boundary must be fewer than 300.

Please note: Because all physical properties calculations are based on the defining curves, it is not necessary to create any surfaces or solids.

Please note: An example.
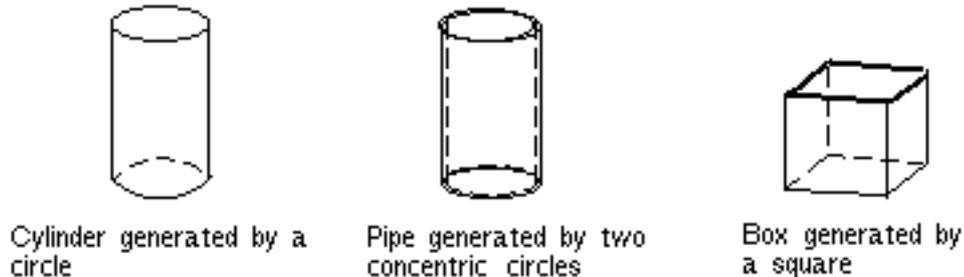
Cylinder generated by a
circle

Pipe generated by two
concentric circles

Box generated by
a square

Physical properties are calculated based on the closed boundary from which the 3-D object is generated.

Object Defined by Cross Sections

To calculate the properties of an object that cannot be defined by the rotation or projection of a bounded region, represent the object as a series of cross sections. In this method, physical properties are calculated for each cross section and then summed to approximate the physical properties of the object.

Each cross section consists of a curve or series of curves that enclose one or more regions within a plane. A cross section also can consist of a single point.

Accuracy of the Cut and Sum Method

The number of cross sections used in the calculation determines the accuracy in the cut and sum method. Errors due to interpolating between the given cross sections could result in large deviations form the theoretical physical properties.

Exercise care to interpret the results obtained by the cut and sum method. Appendix B describes techniques helpful when determining which object and appropriate calculation method you should use.

Requirements:

1. The planes of all cross sections must be parallel.

2. Boundary curves in each cross section must lie in the same plane.

3. The distance between cross sections need not be fixed (that is, variable thickness is allowed between cross sections).

Please note: An example.

Top view   Front view   Isometric view
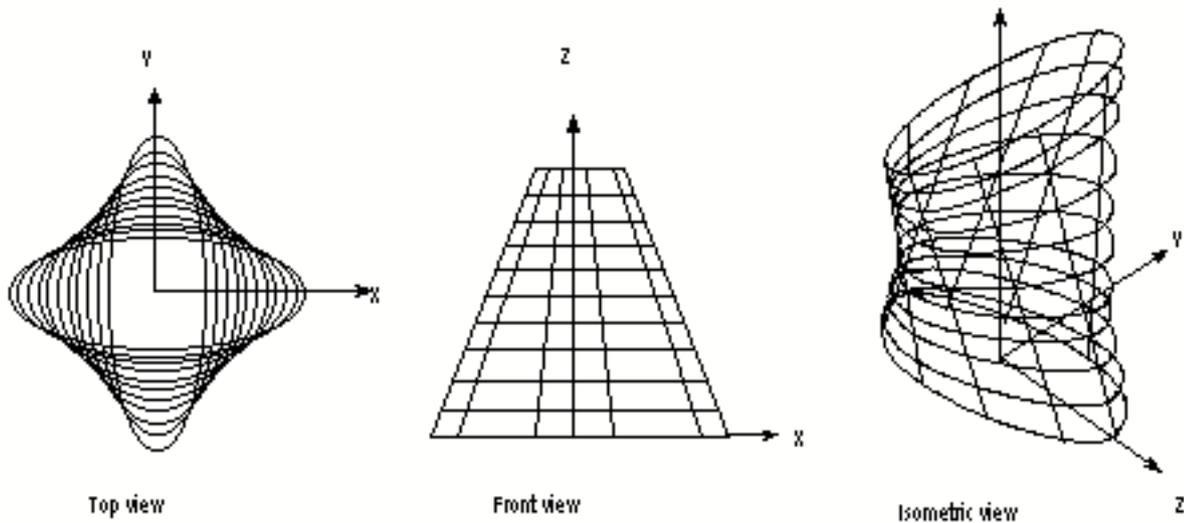
Using Physical Properties

This section explains how to calculate area, volume, and mass properties, how to work with mass points, and how to report mass point data in the Explicit environment.

Preliminary Procedures

To work with Physical Properties within the CADDS 5 Explicit environment, activate a part that has entities in it. For information on how to use the CADDS interface, see the *Explicit Solid Modeling User Guide and Menu Reference*.)

Physical Properties Options
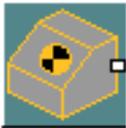
When you select the Physical Properties icon from the Model task set, the following menu appears:

The icons are labeled from left to right below:

- Calculate Area
- Calculate Volume
- Calculate Mass Properties
- Mass Points (Insert, Merge, Change)
- Calculate Center of Gravity
- Update Select Associations
- Update All Associations
- Highlight Associations
- Move Highlit Associations to Layer n
- Break Association

Please note: Mass points created by calculating mass properties or merging mass points can be associative or non-associative.

Calculating Area

Selecting the Calculate Area icon displays the following property sheet.
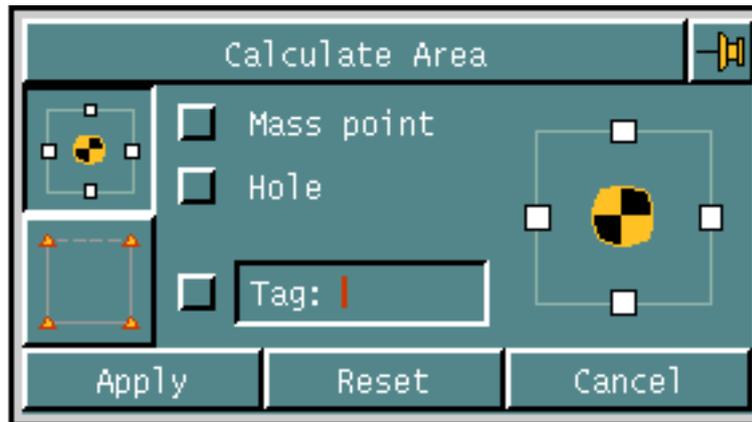
The options on this property sheet allow you to

- Calculate the area within an enclosed boundary.
- Calculate the area within a defined polygon window.
- Create a mass point to store the calculations.

Directions for calculating areas are in Chapter 2, "Calculating Areas".

Calculating Volume

Selecting the Calculate Volume icon displays the following property sheet.
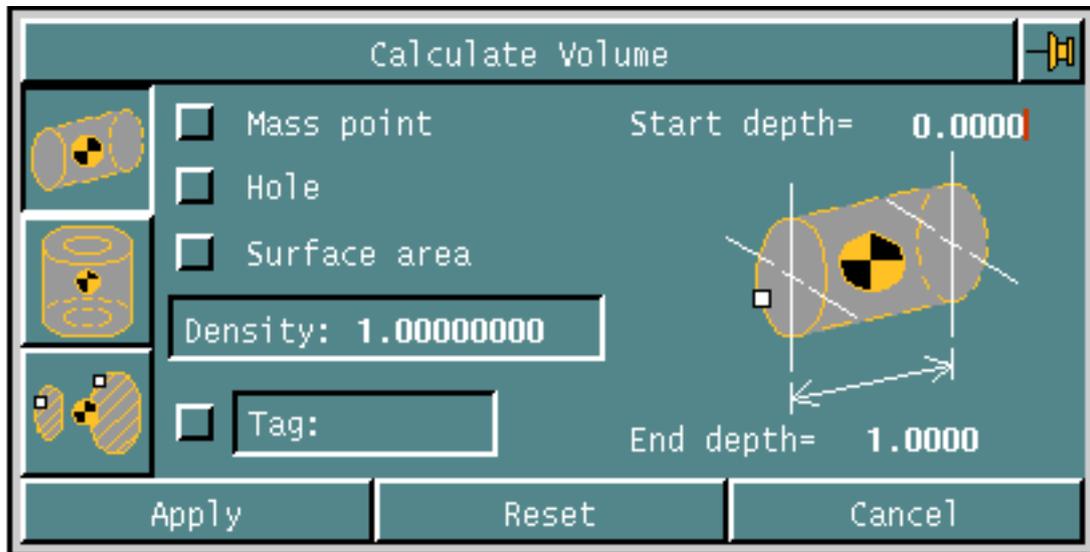
The options on this property sheet allow you to calculate the volume of an object using the

- Projection method
- Rotation method
- Cross sections method
- Create a mass point to store the calculations.

Directions for calculating volumes are in Chapter 3, "Calculating Volumes".

Calculating Mass Properties

Selecting the Calculate Mass Properties icon displays the following property sheet.
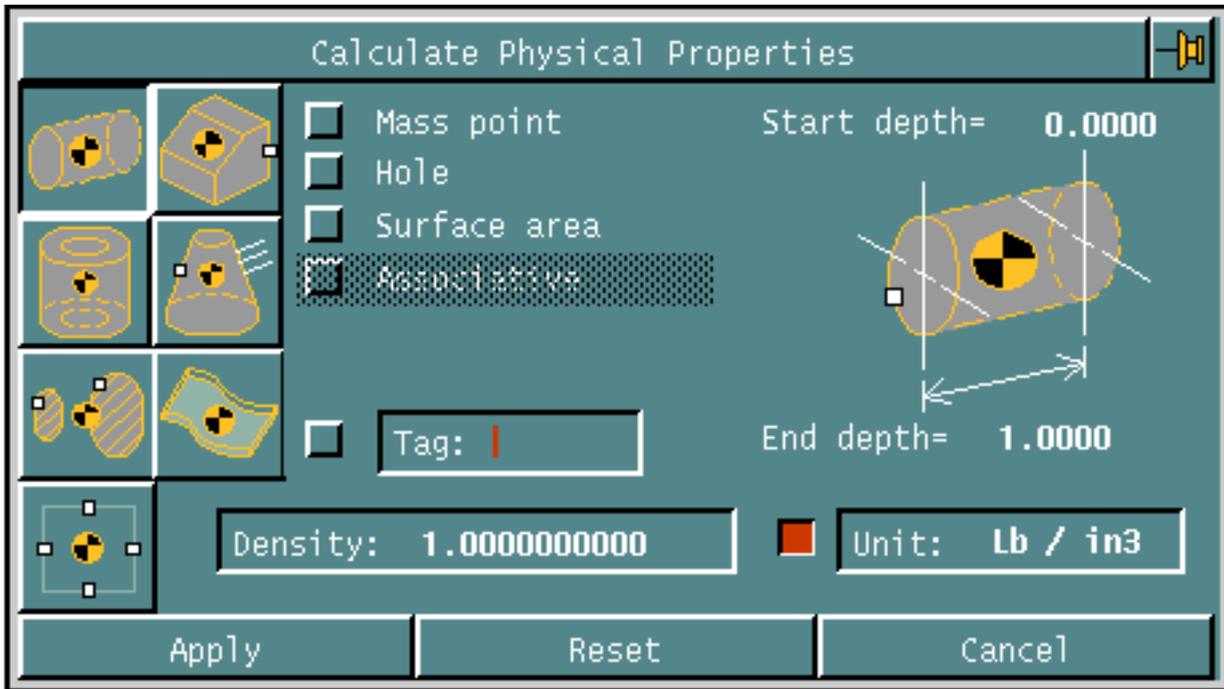
The options on this property sheet allow you to calculate the mass properties of an object using the

- Projection method
- Rotation method
- Cross sections method
- Create a mass point to store the calculations.

Additionally, you can calculate the mass properties of a solid object and an object defined as a volume enclosed by one or more surfaces.

Directions for calculating mass properties are in Chapter 4, "Calculating Mass Properties".

Working with Mass Points

Selecting the Mass Points icon from the Physical Properties property sheet displays the following property sheet.
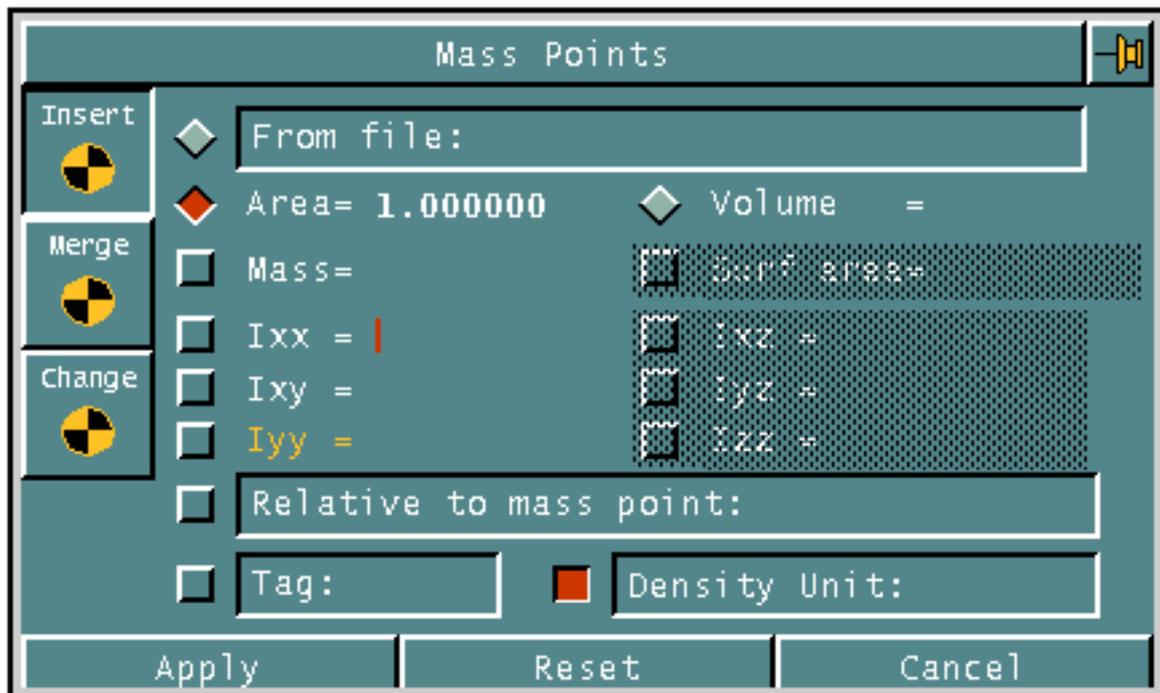
The options on this property sheet allow you to

- Insert mass point data by creating a mass point containing physical property values which you supply.

- Merge mass point data by adding or subtracting the values stored in two or more mass points.

- Change mass point data by modifying existing mass point data values.

Directions for inserting, merging, and changing mass point data are in Chapter 5, "Working with Mass Points".

Calculating Center of Gravity

Selecting the Calculate Center of Gravity icon displays the following property sheet.

If you select Include Property Value in Report, you can specify a property.

If you select Create Mass Point For Each Object, you can specify a layer.

If you select Create Composite Mass Point, you can specify a layer.

The default is to send error messages to the screen.

Information about the data you can enter in this property sheet is in Chapter 6, "Calculating Center of Gravity".

Listing Mass Points

To report mass point data, select the Query icon from the top bar. Selecting the Mass Properties option from the resultant menu displays the following property sheet.

```
┌─────────────────────────────────────────┐
│         List Mass Point            ─┤I│  │
│                                          │
│  ◆  Polar                                │
│  ◇  Axis                                 │
│  ◇  Principal axes     [Length=  2.0000] │
│                                          │
│  ■ [ Save data to file:   |           ]  │
│                                          │
│  □ [ Relative to mass point:          ]  │
│                                          │
│  □  Save data in fixed format            │
│                                          │
│  □  Generate detailed reports            │
│                                          │
│  ■  Report Units  [ Density Unit:  Lb / in3 ] │
│  ┌──────────┬──────────┬──────────┐      │
│  │  Apply   │  Reset   │  Cancel  │      │
│  └──────────┴──────────┴──────────┘      │
└─────────────────────────────────────────┘
```

Use this property sheet to list information stored in a mass point. In addition to the data computed by mass properties calculations, you can report the

• Polar moment of inertia about any point

• Moment of inertia about any axis

• Principal axes and principal moments of inertia at any point

Directions for reporting data stored in mass points are in Chapter 5, "Working with Mass Points".

Extracting Parametric Mass Properties Data

While you are within the Parametric environment, use the Calculate Properties option to report on various physical properties.

You can request a report on the following *current* physical properties of a solid or selected surfaces:

- Volume

- Surface area

- Mass

- Centroid/center of mass

- First mass moment

- Moments of inertia

- Principal moments of inertia

- Principal axes

When requesting the report, you have the following options:

- Type of units for calculation output. Choose among the following unit types:
  - Current model display units (the default)
  - Centimeter/gram/second (CGS)
  - Inch/lb-mass/second (ENG)
  - Meter/kilogram/second (MKS)
- Density for the solid or surface. A density value is needed to calculate the properties (the default is 1.0000).
- Thickness of the surface. A thickness value is needed to calculate the properties of a surface. If you do not specify a thickness, the default value used is 0.0; therefore only surface properties are calculated.

You can select more than one surface or solid, in which case a single report is displayed with the total mass properties of all your selections.

Please note: Mass property calculations are only valid for the *current state* of the model. Therefore, recalculate the mass properties for any model you regenerate.

Restrictions

Note the following restrictions:

- Mass property calculations have a *tolerance* of 1/10 of 1 percent.

- Mass property calculations in the Parametric environment do not retain the calculation data in the model database or create a mass point, as is the case in the Explicit environment.

Calculating Mass Properties

To calculate mass properties,

1. Select the Query icon from the top bar.

2. Select the Mass Properties option from the Query menu.

3. When the property sheet appears, select the options and enter any necessary information.

```
┌──────────────────────────────────────────┐
│      Calculate Mass Properties        ┤┣  │
│                                           │
│  Units:   ◆  Current model units          │
│           ◇  Centimeter/gram/second       │
│           ◇  Inch/lb-mass/second          │
│           ◇  Meter/kilogram/second        │
│  ┌──────────────────────────────────────┐ │
│  │ Density  :    1.00000000000000       │ │
│  └──────────────────────────────────────┘ │
│  ┌──────────────────────────────────────┐ │
│  │ Thickness:    0.00000000000000       │ │
│  └──────────────────────────────────────┘ │
│  ┌──────────┐  ┌──────────┐  ┌──────────┐ │
│  │  Apply   │  │  Reset   │  │  Cancel  │ │
│  └──────────┘  └──────────┘  └──────────┘ │
└──────────────────────────────────────────┘
```

The options are

Option	Description
Units	Specifies the type of units to calculate the mass properties. The default option is to perform the calculations using the current model units.
Density	Specifies the density of the surface or solid you select (default = 1.00000000000000). Enter a density value from the calculator.
Thickness	Specifies the thickness of the surface you select (the default is 0.00000000000000). Enter a thickness value from the calculator.

4. Select Apply. The following menu appears on the property sheet:
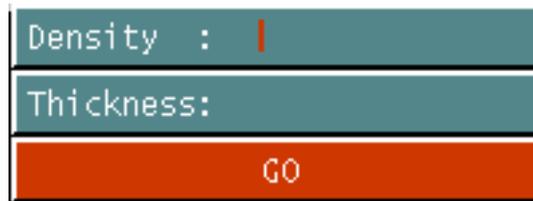
If you select more than one object, you can optionally specify the density and thickness separately for each from the property sheet menu.

5. In the graphics window, select one or more solids and/or surfaces.
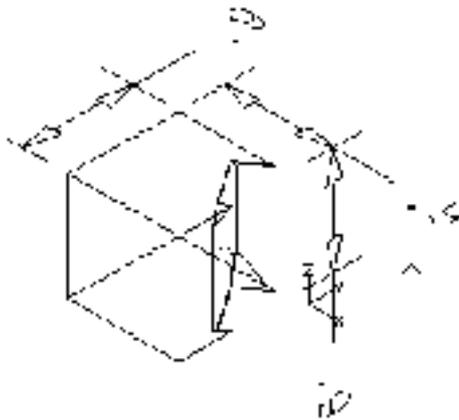
6. Select GO.

7. The results of the calculations are displayed in the Report window.

```
----------------  Physical Properties Report  -----------------
 #   Type     Entity Name      Density   Thickness
---  ----     -----------      -------   ---------
 1   Solid   (No entity name)    1.00000
Volume                  =  0.614275  in3
Surface Area            =  4.485941  in2
Mass                    =  9.828397 oz-mass
Centroid (x,Y,Z)        = -1.077685   -0.095642   -0.000009 inch
Center of Mass (x,y,z)  = -1.077685   -0.095642   -0.000009 inch
1st Mass Moment (x,y,z) = -0.055166   -0.004896   -0.000000 ft-lbm
Moments of Inertia
  Moments (xx,yy,zz)    =  1.375566   12.642074   12.683438 ozm-in2
  Products (xy,yz,zx)   = -0.859250    0.000035   -0.000064 ozm-in2
  Radii of Gyr (x,y,z)  =  0.374110    1.134143    1.135997 inch
Principal Moments of Inertia
  Moments (x,y,z)       =  1.310411   12.707229  12.683438 ozm-in2
  Radii of Gyr (x,y,z)  =  0.379169    0.334542   0.346320 inch
Principal Axes (Normalized)
  Principal Axis 1    :   0.99714     0.07561    5.3475e-06
  Principal Axis 2    :  -0.07561     0.99714     0.001667
  Principal Axis 3    :   0.00012071 -0.0016626         1
```

Calculating Areas

This chapter provides instructions for calculating the areas of bounded regions, combined regions, regions containing holes, and unbounded regions defined by polygon windows.

- General Area Calculation Procedures
- Calculating Combined Areas
- Calculating an Area with Holes
- Calculating an Area Defined by a Polygon Window

General Area Calculation Procedures

You can compute the area inside one or more closed boundaries for a two- or three-dimensional object, optionally subtracting the area of one or more holes if any exist.

You can calculate areas for models or drawings whose solid and hole boundaries consist of

- Lines
- Arcs
- Conics
- B-splines
- Strings
- Nodal lines (Nlines)

To calculate the area,

1. Select the Physical Properties icon from the Model Taskset on the side bar to display the Physical Properties palette as shown below.
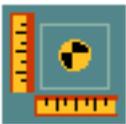
2. Select the Calculate Area icon from this palette.

The following property sheet appears.
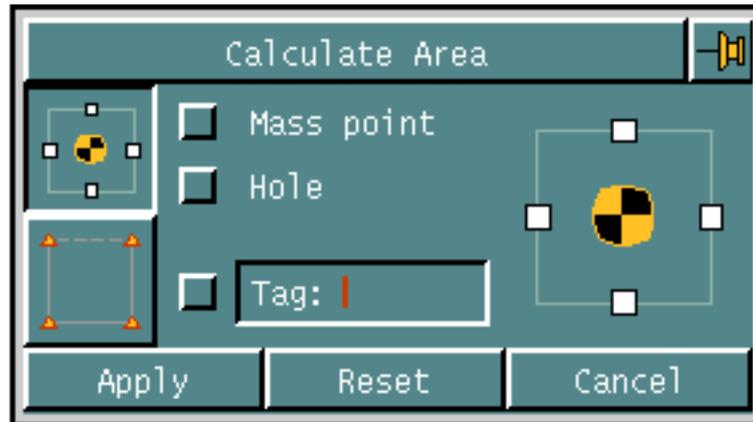
The following options are available for calculating area:

Option	Description
	Calculates the area of any closed boundary (default option).
	Calculates the area of region not bounded by existing entities by defining a polygon window whose corner locations (vertices) create the boundary. The system closes the polygon, automatically connecting the first and last selected locations. At least three locations are required to define a polygon window's boundary.
Mass point	Creates (in Model mode only) a mass point symbol at the centroid (center of mass) of the given boundaries to store the results of the calculations.
Hole	Specifies one or more hole boundaries (the negative area) to subtract from the defined bounded area (the positive area). The total negative (hole) area is subtracted from the total positive area to calculate the resulting area.
Tag	Assigns a tag to the mass point. Tag names are limited to six alphanumeric (A-Z, 0-9) characters.
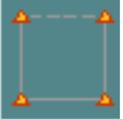
3. When finished choosing the options you want, select Apply.

The menu appears on the property sheet with options related to those chosen on the property sheet.

4. In response to prompts appearing in the command line, enter the information as directed, using the menu options.

   To ensure that the calculated results are correct, make sure that all boundaries selected lie on a single plane and that no boundary intersects itself.

5. When finished, select Done from the property sheet menu.

The system performs the calculations and reports the results in the text window.

Calculating Combined Areas

The following example calculates the combined area of a square and a circle.
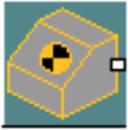
1. Select the Physical Properties icon from the Model Taskset on the side bar.

2. Select the Calculate Area icon from the menu.

3. When the property sheet appears, select the Calculate Bounded Area icon.
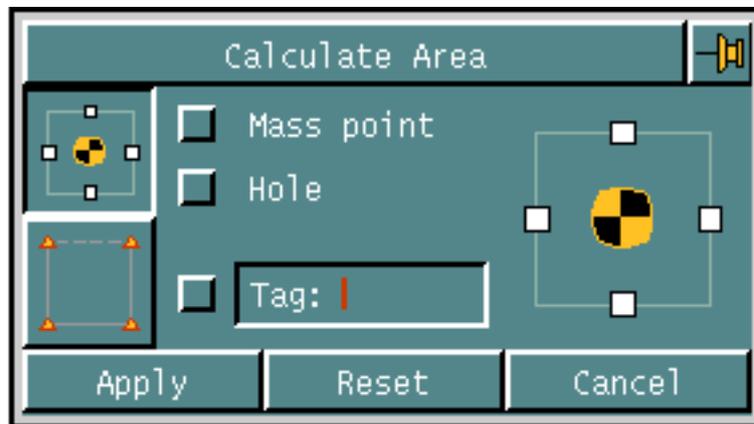
4. Select Apply. The following menu appears on the property sheet.

5. In the graphics window, select the square's four line boundaries in order.

6. Select More boundaries from the property sheet menu.

7. Select the circle.
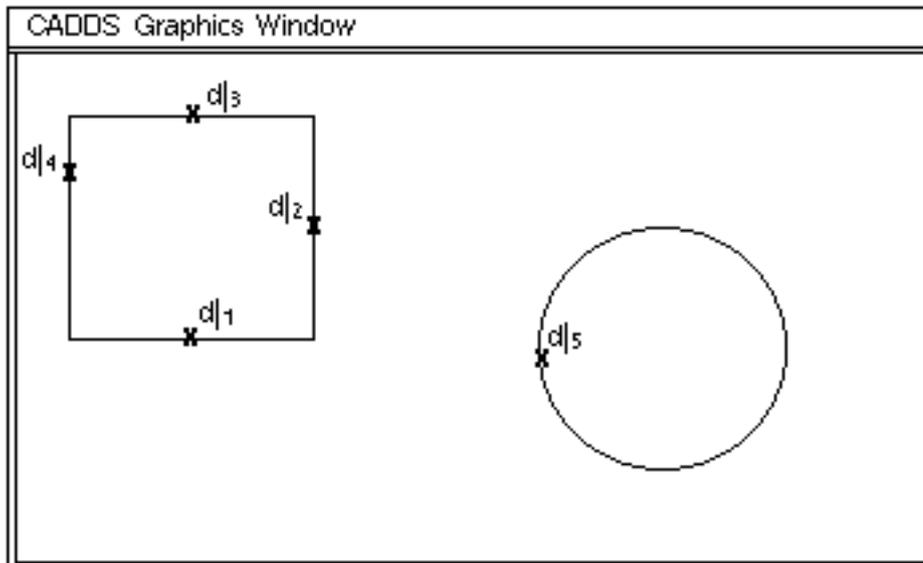
8. Select Done from the property sheet menu.

The system reports the results in the text window.

```
AREA      = 53.2743339
```

Calculating an Area with Holes

The following example calculates the area of a square with two holes.
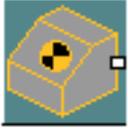
1. Select the Physical Properties icon from the Model Taskset on the side bar.

2. Select the Calculate Area icon from the menu.

3. When the property sheet appears, select the Calculate Bounded Area icon.

4. Select the options you want and enter the necessary information. In the example the chosen option is to subtract the area of hole(s).
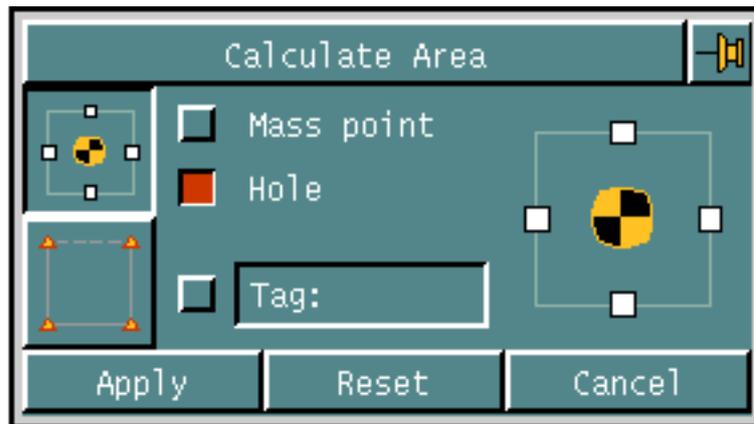
5. Select Apply. The following menu appears on the property sheet.

6. In the graphics window, select the square's four line boundaries in order. The example uses the Chain selection aid from the top bar and selects one of the lines.

7. Select hole from the property sheet menu.

8. Identify one of the holes.

9. Select More holes from the property sheet menu.

10. Identify the other hole.
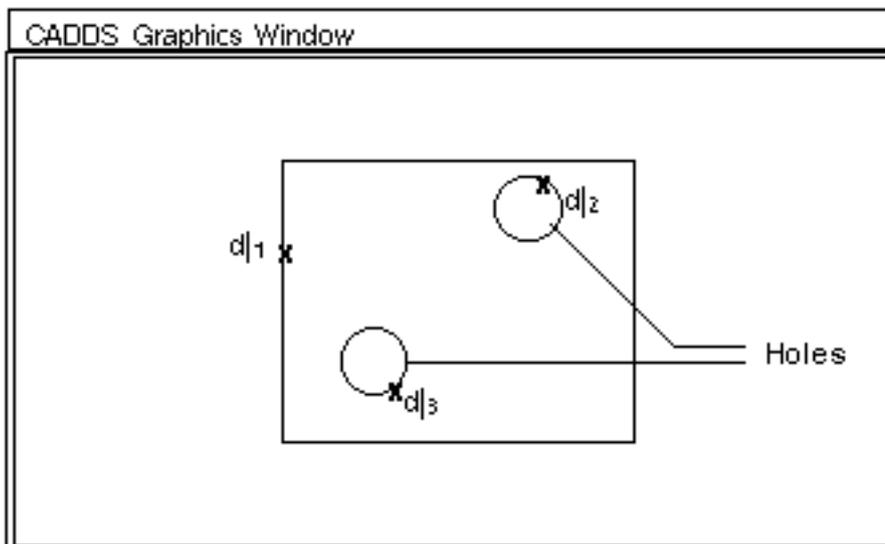
11. Select Done from the property sheet menu.

The system performs the calculations, subtracting the area of the holes from the area of the square, and reports the results in the text window.

```
AREA      = 78.064227282735

CENTROID:

   X = 0.02759424437445   Y = 0.01876422252637   Z = 0.0
```

Calculating an Area Defined by a Polygon Window

The following example calculates the area bounded by a polygon window and stores the results in a mass point.
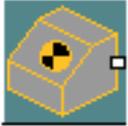
1. Select the Physical Properties icon from the Model Taskset on the side bar.
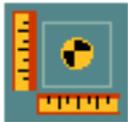
2. Select the Calculate Area icon from the menu.

3. When the property sheet appears, select the Calculate Polygon Window Area icon.

4. Select the options you want and enter necessary information. In the example the chosen option is to create a mass point.
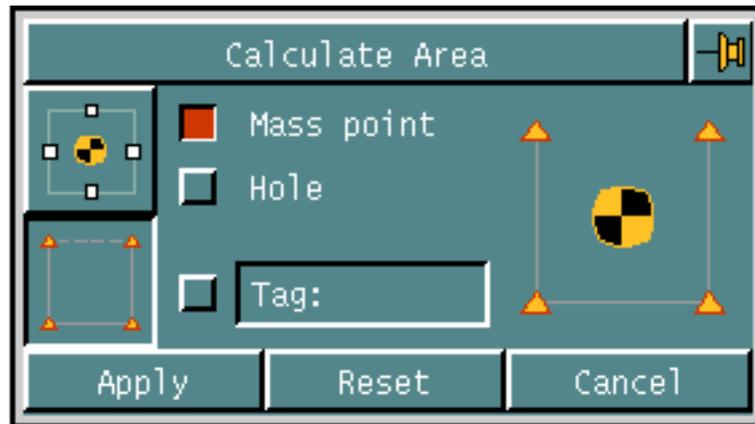
5. Select Apply. The following menu appears on the property sheet.

6. In the graphics window, define a polygon window by selecting locations to enclose the area you want to calculate. The system connects the first and last locations to create a bounded area. You must select a minimum of three locations.

7. Select Done from the property sheet menu.
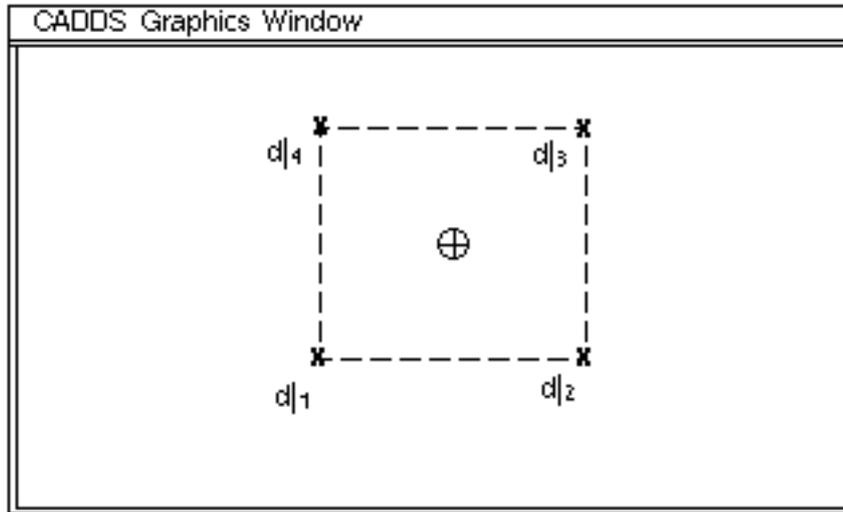
The system calculates the area enclosed by the polygon window and its center of mass. Then it creates a mass point symbol at the calculated centroid position to store the results, and reports the results in the text window.

```
AREA           = 84.696614718486
CENTROID:
   X = 0.01835714617692   Y = 0.03176306845243   Z = 0.0
```

Chapter 3

Calculating Volumes

This chapter provides instructions for calculating the volumes of objects using the projection, rotation, and cross sections methods.

- General Volume Calculation Procedures
- Calculating the Volume of a Projected Object
- Calculating the Volume of a Rotated Object
- Calculating a Volume Using Cross Sections

General Volume Calculation Procedures

You can compute the volume of an object defined by one of the following methods:

- The projection of planar boundaries along an axis

- The rotation of planar boundaries about an axis

- A series of planar cross sections

Optionally, you can also compute an object's surface area.

You can calculate volumes for models whose boundaries consist of

- Lines

- Arcs

- Conics

- B-splines

- Strings

- Nodal lines (Nlines)

To calculate the volume,
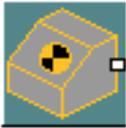
1. Select the Physical Properties icon from the Model Taskset on the side bar.

2. Select the Calculate Volume icon from the Physical Properties command palette to display the following property sheet.
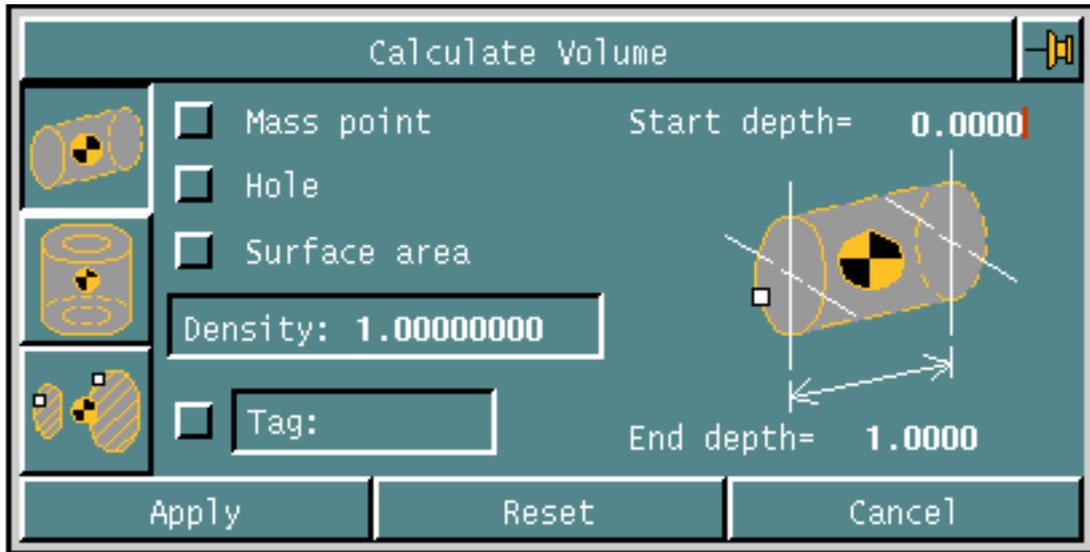
The following options are available for calculating volume:
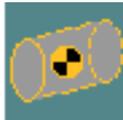
Option	Description
	Calculates the volume defined by the projection of an object's boundaries along an axis. The axis for projection *must not* lie in the plane of the boundaries. All of the boundaries must be on the same plane and no boundary can intersect itself.

If you select the projection method to calculate volume, the following options are available:

Option	Description
Start depth = 0.0000	Specifies the distance from the plane of the boundaries to the bottom (low boundary) of the projected object (default is 0.0), measured along the axis from the plane of the boundaries.
End dept = 1.0000	Specifies the distance from the plane of the boundaries to the top (high boundary) of the projected object (default is 1.0), measured along the axis from the plane of the boundaries.

Option	Description
	Calculates the volume defined by the rotation of an object's boundaries about an axis.
	The axis for rotation *must* lie in the plane of the boundaries. All of the boundaries must be on the same plane and no boundary can intersect itself.

If you select the rotation method to calculate volume, the following options are available:

Option	Description
Start Angle	Specifies the minimum extent of the angle of rotation (default = 0°), which is measured from the plane of the boundaries according to the right-hand rule.
End Angle	Specifies the maximum extent of the angle of rotation (default = 360°), which is measured from the plane of the boundaries according to the right-hand rule.
	Calculates the volume defined by a series of cross sections.

If you select the cross sections method to calculate volume, the following options are available:

Option	Description
Sections	Specifies the number of cross sections defining the object (default = 2).
Start layer	Specifies the layer on which the first cross section is identified (default = layer 1).
Increment layer by	Specifies the increment in the layer number of successive cross sections (default = 1).

Please note: The cross sections method for calculating volumes is approximate because the variation of the shape of the part between cross sections is not known. Therefore, use either the projection or rotation methods whenever possible. If the cross sections method must be used, specify as many cuts as possible near the region of the part where extreme changes of geometry take place. (See Appendix B, "Improving Mass Properties and Volume Calculations" for further detail on the cross sections method.)

The following options are available with any method:

Option	Description
Mass point	Creates (in Model mode only) a mass point symbol at the centroid (center of mass) of the given boundaries to store the results of the calculations.
Hole	Specifies one or more hole boundaries (the negative area) to subtract from the defined bounded area (the positive area). The total negative (hole) area is subtracted from the total positive area to calculate the resulting area.
Surface area	Calculates the outermost surface area of the object.When using the rotation or projection method, it is the surface area generated by the first boundary selected; for the cross sections method, it is the area of a surface interpolated between the first boundaries of each section.
Density = 1.000000	Specifies the density of the object (default is 1.00000000).
Tag	Assigns a tag to the mass point. Tag names are limited to six alphanumeric (A-Z, 0-9) characters.

3. When finished choosing the options you want, select Apply.

   A menu appears on the property sheet with options related to those chosen on the property sheet.

4. In response to prompts appearing in the command line, enter the information as directed, using the menu options.

5. When finished, select Done from the property sheet menu.

The system performs the calculations and reports the results in the text window.

Calculating the Volume of a Projected Object

The following example calculates the volume and surface area of a cylinder with a square hole using the projection method.
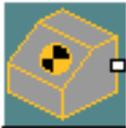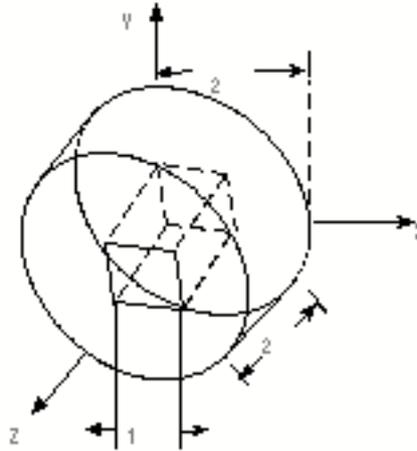

1. Select the Physical Properties icon from the Model Taskset on the side bar.

2. Select the Calculate Volume icon from the menu.

3. When the property sheet appears, select the Projection Method icon. That is, the top most icon.

4. Select the options you want and enter the necessary information.
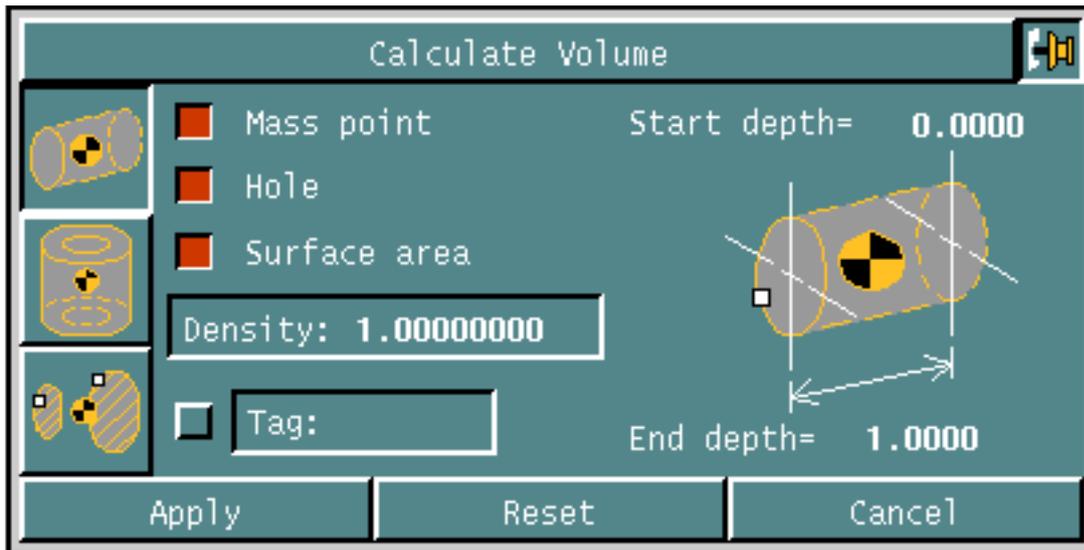
In the example, the chosen options are to

- Calculate the surface area
- Subtract hole(s)
- Project the end depth to 2 inches

5. Select Apply. The following menu appears on the property sheet:

6. In response to the MODEL loc prompt in the command line, select two locations to define the projection axis.

7. In response to the following prompt in the command line, select the cylinder.

```
Please Enter Solid Boundary # 1
```

8. Select hole from the property sheet menu.

9. In the graphics window, select the square's four lines in order.

10. Select Done from the property sheet menu.

The system reports the results in the text window.

```
VOLUME                  =   23.1327419
SURFACE AREA            =   48.26548
```

Calculating the Volume of a Rotated Object

The following example calculates the volume of a hemisphere with a cylindrical hole in the base using the rotation method.
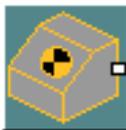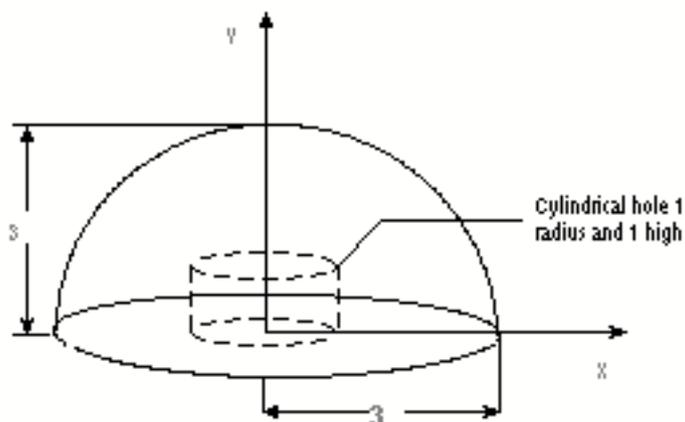
1. Select the Physical Properties icon from the Model Taskset on the side bar.

2. Select the Calculate Volume icon from the menu.

3. When the property sheet appears, select the middle icon, the Rotation Method icon.

4. Select the options you want and enter the necessary information. In the example the chosen options are to create a mass point and calculate the surface area.
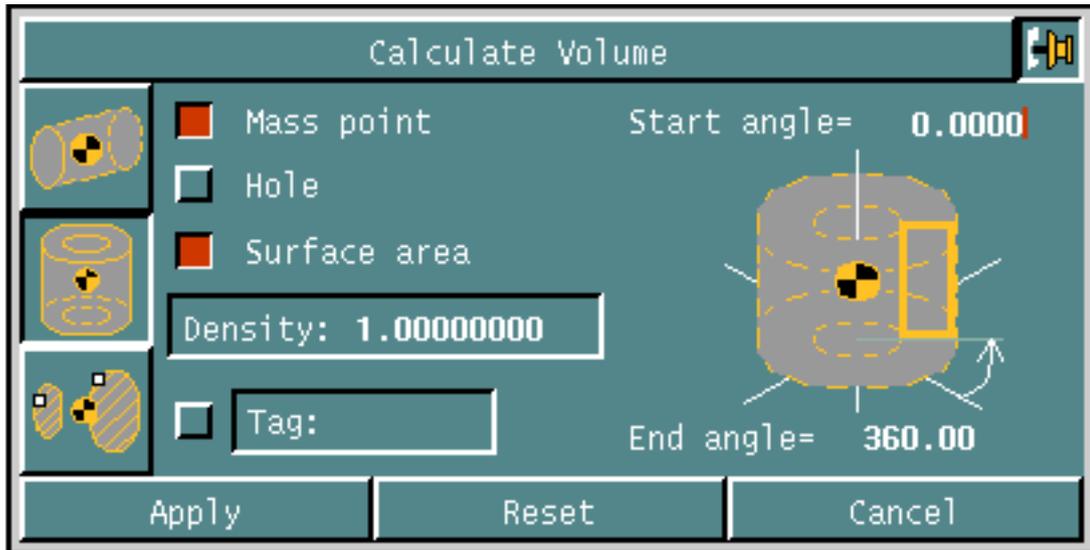
5. Select Apply. The following menu appears on the property sheet.

6. In response to the MODEL loc prompt in the command line, select two locations to define the rotation axis.

7. In response to the following prompt in the command line, select the lines, in order, to identify the boundary.

```
Please Enter Solid Boundary # 1
```
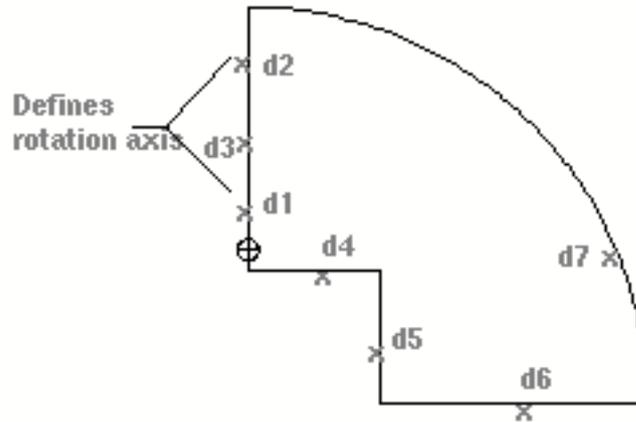

8. Select Done from the property sheet menu.

The system calculates the volume and center of mass. Then it creates a mass point symbol at the calculated centroid position and reports the results in the text window.

```
VOLUME              = 53.4070701
MASS                = 53.407067
SURFACE AREA        = 91.1061782
```

Calculating a Volume Using Cross Sections

The following example calculates the volume of a pyramid section containing an interior cylindrical hole using the cross sections method.

In the example the object has been sectioned by planes perpendicular to the z-axis, at a distance of one inch between each cross section.

Please note: Select an empty layer (by selecting Layer from the Status area of the top bar and SELECT from the Layer menu) when using the cross sections method with layer echoing; otherwise, undesired graphics may remain on the screen.

1. Select the Physical Properties icon from the Model Taskset on the side bar

2. Select the Calculate Volume icon from the menu.

3. When the property sheet appears, select the Cross Sections Method icon.

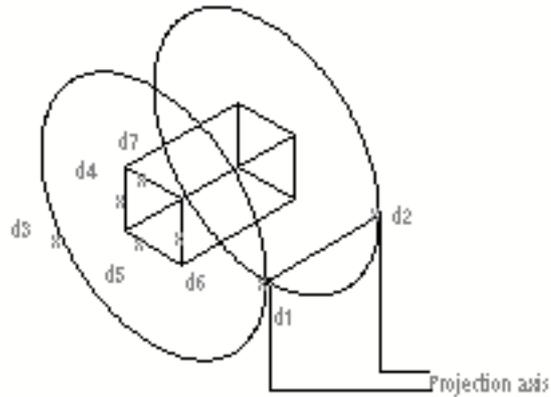**4.** Select the options you want and enter the necessary information.

In the example the chosen options are:

- Subtract hole(s)
- Calculate surface area
- Calculate 6 cross sections
- Starting layer is 4
- Increment the layer by 2

5. Select Apply. The following menu appears on the property sheet.

6. In the graphics window, select the boundaries of the first cross section.

7. Select the Select_hole option from the property sheet menu.

8. In the graphics window, select the boundaries of the hole in the first cross section.

Cross Section 1
(Bottom of cylinder)

9. For each successive cross section, repeat the following steps:

a. Select Next cross section on the property sheet menu.

b. In the graphics window, select the boundaries of the next cross section.

c. Select hole on the property sheet menu.

d. In the graphics window, select the boundaries of the hole in the identified cross section.

Cross Section 2

The steps are repeated for the third cross section.

Cross Section 3

The steps are repeated for the fourth cross section.

Cross Section 4

The steps are repeated for the fifth cross section.

Cross Section 5

The steps are repeated for the last cross section.

10. When finished, select Done from the property sheet menu.

The system calculates the volume and surface area and reports the results in the text window.

```
VOLUME              =   45.9467239
SURFACE AREA        =   89.0659561
```

Calculating Mass Properties

Chapter 4

This chapter provides instructions for calculating the mass properties of objects using the projection, rotation, and cross sections methods.

- General Mass Properties Calculation Procedures
- Calculating the Mass Properties of a Projected Object
- Calculating the Mass Properties of a Rotated Object
- Calculating Mass Properties Using Cross Sections
- Calculating Mass Properties Using a Solid and Associativity

General Mass Properties Calculation Procedures

You can compute the following mass properties of an object:

- Volume or area

- Mass

- Centroid

- First moments

- Moments of inertia

- Products of inertia

- Surface area

- Center of gravity

The selected object or objects can be either explicit or parametric entities that are either viewed in (that is, CAMU) or physically located in the active CADDS part.

The mass properties information is stored in a mass point which is automatically created at the centroid of the selected entity. The mass point is inserted into the physically active part. You can select one or more mass points to display the mass properties either in the text window or the Report Window.

You can create a mass point that is associative to the solid (Tsurf) geometry or is nonassociative. To be associative, the selected object must be physically located within the active part.

Boundaries can consist of:

- Lines

- Arcs

- Conics

- B-splines

- Strings

- Nodal lines (Nlines)

These boundaries can represent solid regions or holes. Boundary values are assigned relative to model space coordinates.

To calculate mass properties,
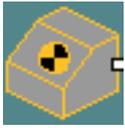
1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Calculate Physical Properties icon from the Physical Properties menu.

The following property sheet appears:
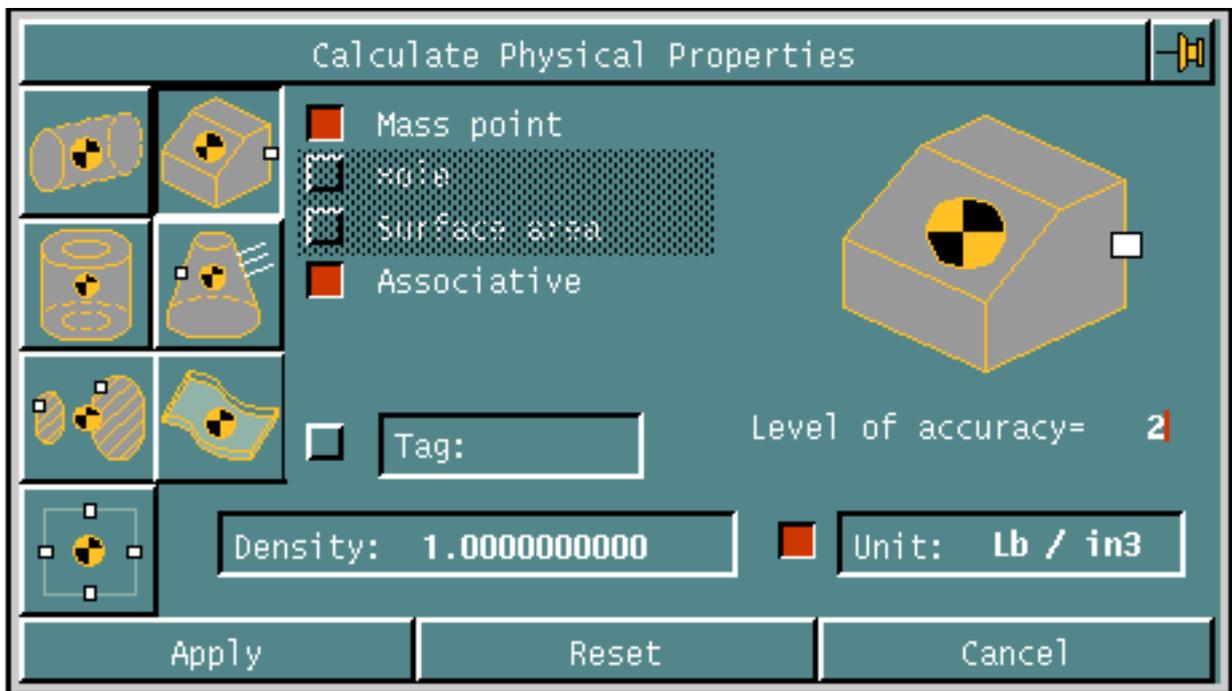
The following options are available for calculating mass properties:

Projection Along an Axis
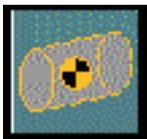
This option enables you to calculate physical properties by projecting the boundaries of an object along an axis. This axis must not lie in the plane of the boundaries. All boundaries must be coplanar and cannot be self-intersecting.

If you select the projection method to calculate mass properties, the following options are available:

Option	Description
Start depth = 0.0000	Specifies the distance from the plane of the boundaries to the bottom (low boundary) of the projected object (default is 0.0), measured along the axis from the plane of the boundaries.
End depth = 1.0000	Specifies the distance from the plane of the boundaries to the top (high boundary) of the projected object (default is 1.0), measured along the axis from the plane of the boundaries.

The terms related to projection methods for calculating mass properties are illustrated in the following figure:

Figure 4-1   Projection Methods for Calculating Mass Properties
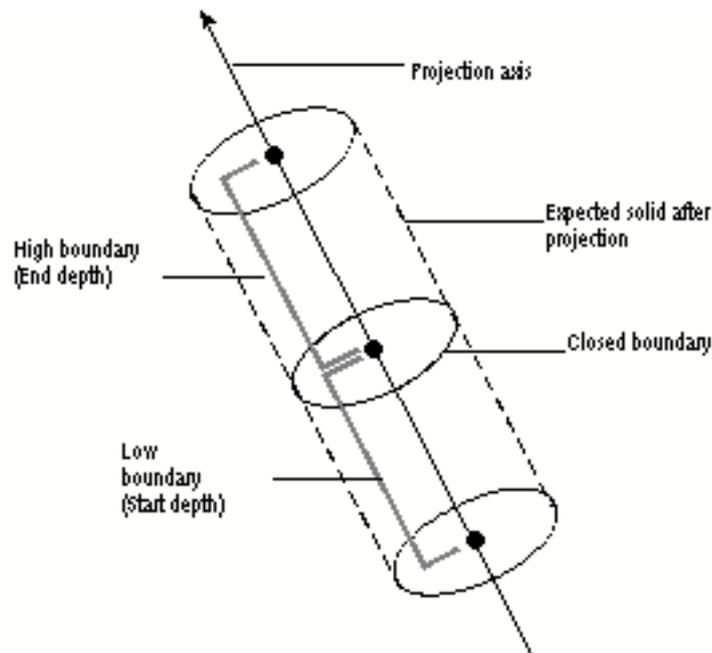
Rotating a Boundary About an Axis

This option enables you to calculate mass properties by rotating the boundaries of an object about a specified axis. This axis must lie in the plane of the boundaries. All boundaries must be coplanar and cannot be self-intersecting.

If you select the rotation method to calculate mass properties, the following options are available:

Option	Description
Start angle	Specifies the minimum extent of the angle of rotation (default = 0°), which is measured from the plane of the boundaries according to the right-hand rule.
End angle	Specifies the maximum extent of the angle of rotation (default = 360°), which is measured from the plane of the boundaries according to the right-hand rule.

Using a Series of Cross Sections

This option enables you to calculate mass properties using a series of cross sections.

If you select the cross sections method to calculate mass properties, the following options are available:

Option	Description
Sections	Specifies the number of cross sections defining the object (default = 2).
Start layer	Specifies the layer on which the first cross section is identified (default = layer 1).
Increment layer by	Specifies the increment in the layer number for successive cross sections (default = 1).

Please note: The cross sections method may not accurately calculate mass properties because the variation of the shape of the part between cross sections is not known. Therefore, use either the projection or rotation methods whenever possible. Specify as many cuts as possible near the region of the part where extreme changes of geometry take place if the cross sections method must be used. See Appendix B for more details on the cross sections method.

Using a Solid
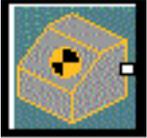
This option enables you to calculate the mass properties of a solid. See "Using a Trimmed Surface" to learn about the available options.

Using a Volume Enclosed By One or More Surface

This option enables you to calculate the mass properties of a volume enclosed by one or more surfaces.

You can apply a scale factor to the display of the object's surface normals. The default normal length is 3.0000.

If surfaces overlap or intersect one another, CADDS does not check the object's validity and results of the calculations may be incorrect.

Using a Trimmed Surface
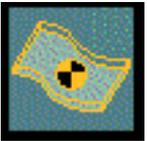
This option enables you to calculate the mass properties of a trimmed surface (Tsurf).

Selecting the Trimmed Surface option allows you to select a trimmed surface or solid. If a solid is selected, the mass properties are calculated as if the surface of the solid is a thin shell.

This option also allows you to specify thickness and accuracy.

- Thickness—When you specify thickness, the density is the mass per unit of volume. The thickness you specify must be small compared to the curvature of the surface.

  When you do not specify a thickness, the thickness is assumed to be infinitesimally thin. The default is a thickness of zero. When you specify a default thickness of 0, the density is defined as mass per unit of area.

  The more the thickness of the surface, the less the accuracy of the results. CADDS warns you when the thickness has become too large.

Please note: When you use this option, apply the property sheet, and select the object, you are prompted as shown below:

```
CALCULATE MPROPERTIES TSURF THICKNESS 2 ASSOCIATIVE: <dig>
Type ok to thicken surface on this side:
```

- Accuracy—When specifying accuracy, start with a small number, increment it, and perform the calculation again. If the two results are similar, the accuracy is high. Otherwise, increment the accuracy and perform the calculation again. To achieve a high level of accuracy, continue this sequence until the results are similar for two consecutive accuracy numbers.

    Quantities, except for the surface areas, are truncated to a number of significant digits consistent with the accuracy of the approximation.

Using Other Options

The Solid, One or More Surfaces, and Trimmed Surface options enable you to specify a level of accuracy. The higher the number, the more accurate the results. The default is 2.

The following options are available with any method, except as noted:

General Option	Description
Mass point	Creates (in Model mode only) a mass point symbol at the centroid (center of mass) of the given boundaries to store the results of the calculations. See "Calculating Mass Properties Using a Solid and Associativity" for an example.
Holes	Specifies one or more hole boundaries (the negative area) to subtract from the defined bounded area (the positive area). The total negative (hole) area is subtracted from the total positive area to calculate the resulting area.
	This option is not available with solids or volume enclosed by surfaces.
Surface area	Calculates the outermost surface area of the object. When using the rotation or projection method, it is the surface area generated by the first boundary selected; for the cross sections method, it is the area of a surface interpolated between the first boundaries of each section.
	This option is not available with solids.

Associative | This option creates an associative relationship between the selected Solid or Tsurface and the resultant mass point entity.
Note: The solid or Tsurf must be physically located within the active part for the association to be created.

This option is only available for a solid or Tsurf. See Chapter 4, "Calculating Mass Properties Using a Solid and Associativity" for an example.

The following options are available:

Option	Description
Density = n	Specifies the density of the object (default is 1.0000000000).
Tag	Assigns a tag to the mass point. Tag names are limited to six alphanumeric (A-Z, 0-9) characters.
Unit	Specifies the weight and length units used for the density measurement. You can specify either Centimeter/Gram/Second, Inch/LB-mass/second, Meter/Kilogram/Second, or specify other combinations of metric and English weight and length units. If no unit is specified, no unit is used.

3. When finished choosing the options you want, select Apply.

A menu appears on the property sheet with options related to those chosen on the property sheet.

4. In response to prompts appearing at the command line, enter the information as directed, using the menu options.

5. When finished, select Done from the property sheet menu.

CADDS performs the calculations and reports the results. In the Parametric environment, the description appears automatically in the Report Window but does not appear in the text window. In the Explicit environment, the description of the component or components is by default displayed only in the text window. To view the description of the object or objects in the Report Window in Explicit environment, set the environment variable in the .caddsrc-local file as follows:

```
setenv USE_EXP_REP_WINDOW 'yes'
```

The default setting for this environment variable is no.

The Report Window appears as follows when accessed from the UTILITY pull down menu:

```
                          Report Window
------------------------------------------------------------------------

Warning : no accuracy value retrieved from Mass Point MIP 73.

DATE: Thu Jul 19 16:04:52 2007

PART NAME: =USERS.CGHANTA.PARTS.ASDFSA.DEFAULT

PART UNIT: IN


VALUES ARE GIVEN WITH RESPECT TO MODEL SPACE COORDINATES.

   ORIGIN IN MODEL SPACE= 0.0 ,0.0, 0.0
   XAXIS VECTOR IN MODEL SPACE= 1.0 ,0.0, 0.0
   YAXIS VECTOR IN MODEL SPACE= 0.0 ,1.0, 0.0
   ZAXIS VECTOR IN MODEL SPACE= 0.0 ,0.0, 1.0

Tag:  (no tag selected)

DENSITY = 55.0

 AREA        = 1.0
MASS         = 55.0

 CENTROID:
   X=-4.873709   Y=2.758997   Z=0.0

 FIRST MOMENTS:
  Myz=-268.05397  Mxz=151.744823  Mxy=0.0
      Can't find desktop configuration E.gen_report_win Y7 .
------------------------------------------------------------------------
      Can't find desktop configuration E.gen_report_win # 0.
------------------------------------------------------------------------

VOLUME       = 0.523598 In3
MASS         = 0.523598 Lb
SURFACE AREA = 3.141588 In2

 CENTROID:
   X = -4.521739  Y = 2.608696  Z = -0.0 In

 FIRST MOMENTS:
   MYZ = -2.367574  MXZ = 1.365908  MXY = -0.0 Lb*In

 MOMENTS OF INERTIA:
   IXX = 3.615605  IYY = 10.757915  IZZ = 14.321156 Lb*In2

 PRODUCTS OF INERTIA:
   IXY = -6.17628  IXZ = 0.0  IYZ = -0.0 Lb*In2
```

| Clear | Cancel |

If you select the mass point option, CADDS also creates it. The mass point is created in the active part on the active layer.

Calculating the Mass Properties of a Projected Object

The following example uses the projection method to calculate the mass properties of a cylinder with a square hole.

Figure 4-2   Example for Projection Method to Calculate Mass Properites
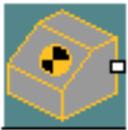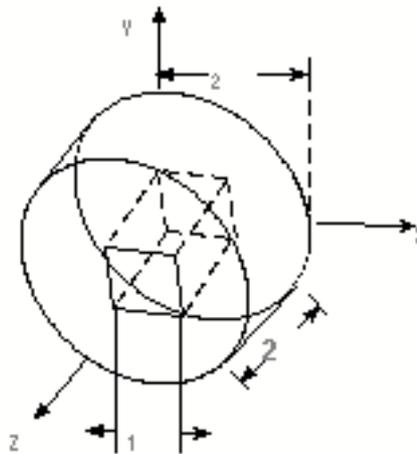
1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Calculate Mass Properties icon from the menu.
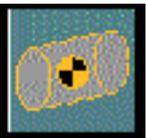
3. When the property sheet appears, select the Projection Method icon.

4. Select the options you want and enter the necessary information.
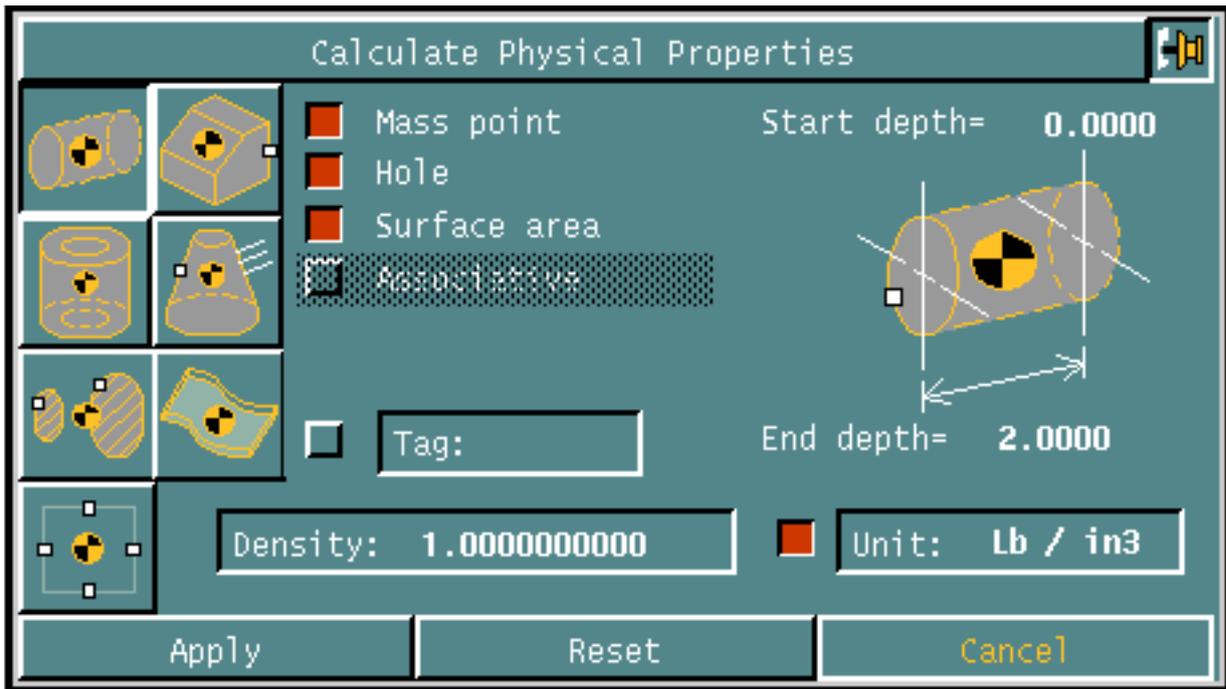
In the example, the chosen options are to

- Calculate the surface area

- Subtract one or more holes

- Project the end depth to 2 inches

- Create a mass point

5. Select Apply. The following menu appears on the property sheet:

6. In response to the `MODEL loc` prompt in the command line, select two locations to define the projection axis.

7. In response to the following prompt in the command line, select the cylinder.

`Please Enter Solid Boundary # 1`

8. Select hole from the property sheet menu.

9. In the graphics window, select the square's four lines in order.
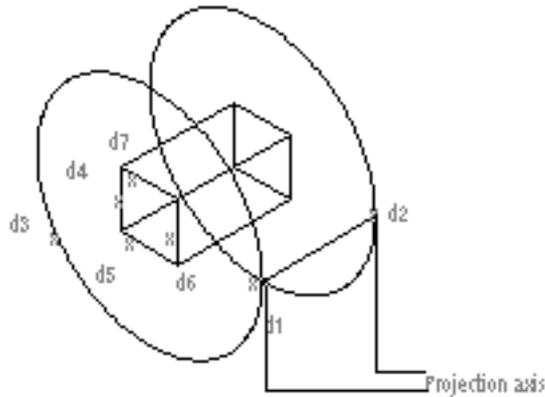
10. Select Done from the property sheet menu.

The system calculates the mass properties, surface area, and center or mass position (centroid). It creates a mass point and reports the results in the text window.
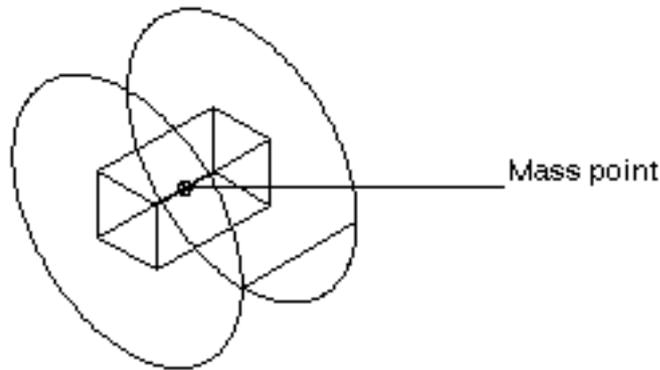

```
VOLUME          = 23.132741
MASS            = 23.132741
 CENTROID:
   X = 0.0   Y = -1.0   Z = -0.0
 FIRST MOMENTS:
   MYZ = 0.0   MXZ = -23.132741   MXY = -0.0
 MOMENTS OF INERTIA:
   IXX = 55.80973   IYY = 49.932149   IZZ = 55.80973
 PRODUCTS OF INERTIA:
   IXY = 0.0   IXZ = -0.0   IYZ = 0.0
```

Calculating the Mass Properties of a Rotated Object

To calculate the mass properties of a hemisphere with a cylindrical hole in the base using the rotation calculation method:
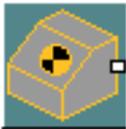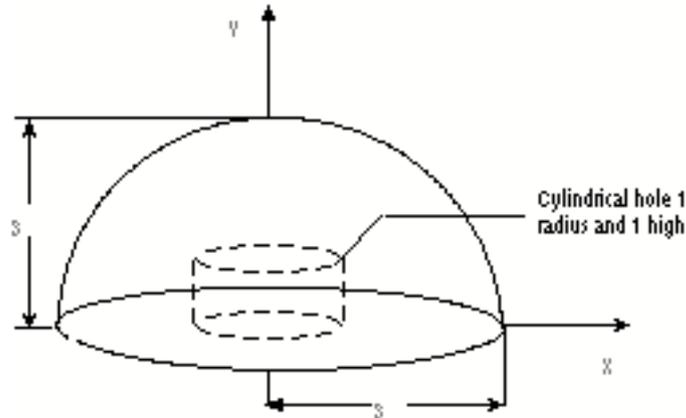
1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Calculate Mass Properties icon from the menu.

3. When the property sheet appears, select the Rotation Method icon.

4. Select the options you want and enter the necessary information.

In the example, the chosen options are to calculate the surface area and create a mass point.
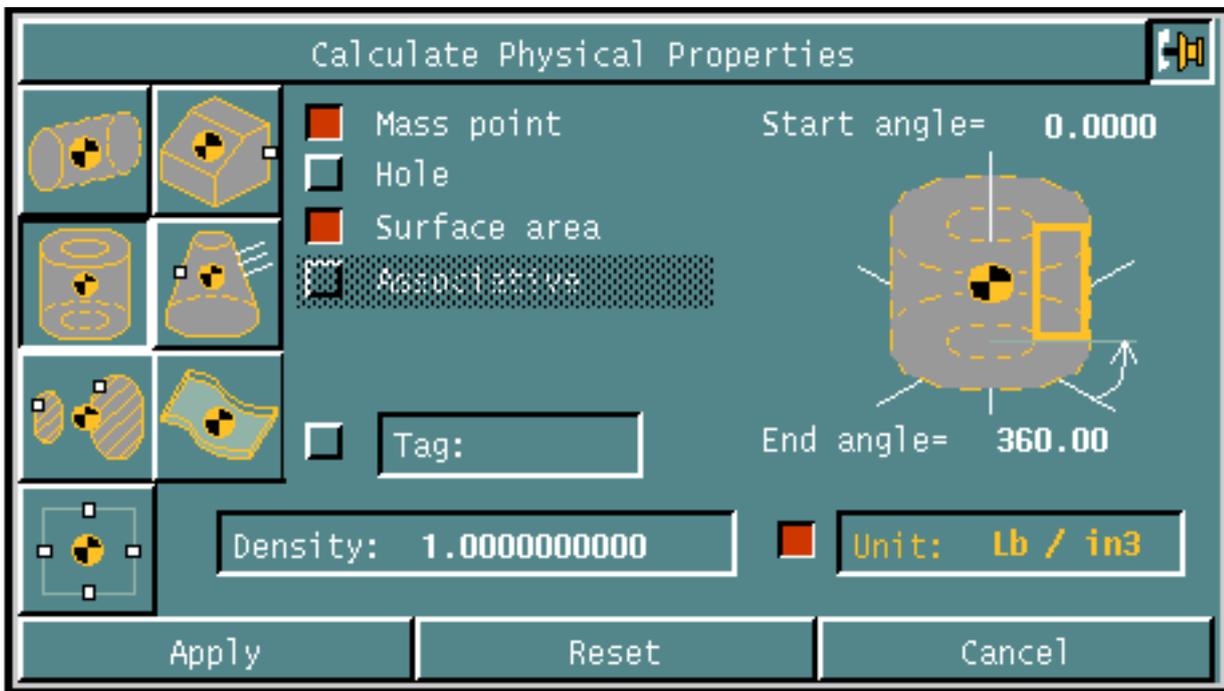
5. Select Apply. The following menu appears on the property sheet:

6. In response to the `MODEL loc` prompt in the command line, select two locations to define the rotation axis.

7. In response to the following prompt in the command line, select the lines, in order, to identify the boundary.

```
Please Enter Solid Boundary # 1
```
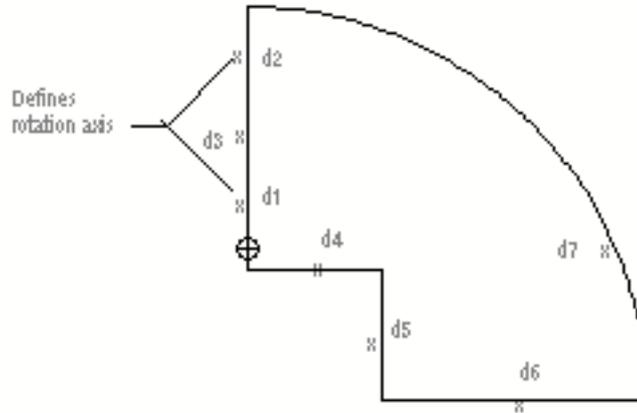

8. Select Done from the property sheet menu.

The system calculates the mass properties and center of mass. Then it creates a mass point symbol at the calculated centroid position and reports the results in the text window.
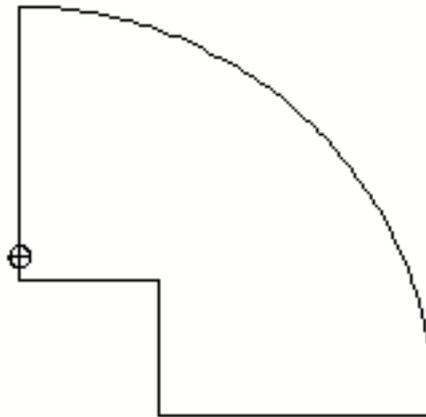

```
VOLUME            =   53.4070701
MASS              =   53.4070701
SURFACE AREA      =   91.1061782
CENTROID
  X   = 0.0000002    Y   = 1.1617647    Z   = 0.0
  Ixy = 0.0000125    Ixz = 0.0          Iyz = 0.0
FIRST MOMENTS:
  Myz = 0.0000121    Mxz = 62.0464515   Mxy = 0.0
MOMENTS OF INERTIA:
```

```
        Ixx = 201.7425994  Iyy = 202.0043945  Izz = 201.7425842
    PRODUCTS OF INERTIA:
      Ixy = 0.0000125    Ixz = 0.0         Iyz = 0.0
```

Calculating Mass Properties Using Cross Sections

The following example calculates the mass properties of a pyramid section containing an interior cylindrical hole using the cross sections method.

In the example the object has been sectioned by planes perpendicular to the z-axis, at a distance of one inch between each cross section.

Please note: Select an empty layer (by selecting Layer from the Status area of the top bar and SELECT from the Layer menu) when using the cross sections method with layer echoing; otherwise, undesired graphics may remain on the screen.

1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Calculate Mass Properties icon from the menu.

3. When the property sheet appears, select the Cross Sections Method icon.

4. Select the options you want and enter the necessary information.

In the example the chosen options are:

- Subtract hole(s)

- Calculate surface area

- Calculate 6 cross sections

- Starting layer is 4

- Increment the layer by 2

5. Select Apply. The following menu appears on the property sheet.

6. In the graphics window, select the boundaries of the first cross section.

7. Select the Select hole option from the property sheet menu.

8. In the graphics window, select the boundaries of the hole in the first cross section.

Cross Section 1
(Bottom of cylinder)

9. For each successive cross section, repeat the following steps:

   e. Select Next cross section on the property sheet menu.

   f. In the graphics window, select the boundaries of the next cross section.

   g. Select Hole on the property sheet menu.

   h. In the graphics window, select the boundaries of the hole in the identified cross section.
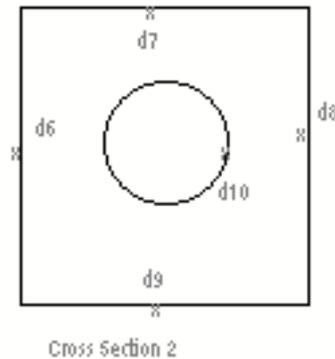
Cross Section 2

The steps are repeated for the third cross section.
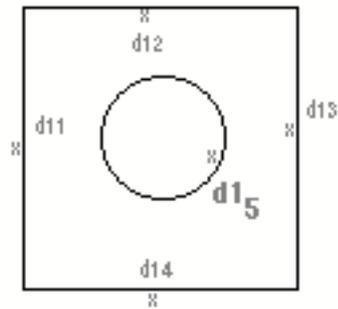
Cross Section 3

The steps are repeated for the fourth cross section.
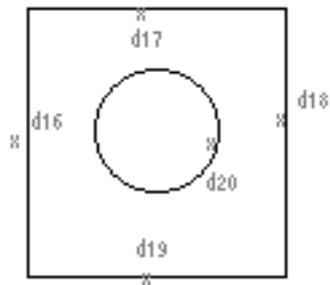
Cross Section 4

The steps are repeated for the fifth cross section.
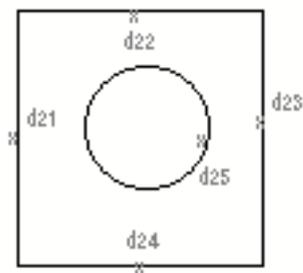
Cross Section 5

The steps are repeated for the last cross section.
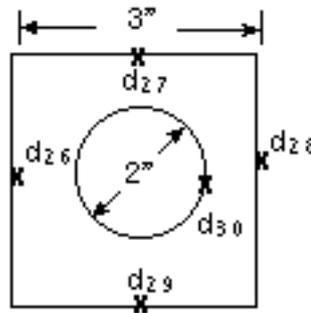
Cross Section 6
(Top of cylinder)

10. When finished, select Done from the property sheet menu.

The system calculates the volume and surface area and reports the results in the text window.

```
VOLUME            = 45.9467239
MASS              = 45.9467239
SURFACE AREA      = 89.0659561
CENTROID:
  X   = 0.0          Y   = 0.0          Z   = 2.1825222
FIRST MOMENTS:
  Myz = 0.0000014    Mxz = 0.0000007    Mxy = 100.279747
MOMENTS OF INERTIA:
  Ixx = 375.1889038  Iyy = 375.1889038  Izz = 122.7237625
PRODUCTS OF INERTIA:
  Ixy = 0.0000002    Ixz = 0.0000014    Iyz = 0.0000012
```

Calculating Mass Properties Using a Solid and Associativity
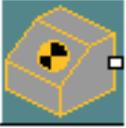
1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Calculate Mass Properties icon from the Physical Properties menu.

3. When the property sheet appears, select the Solid icon.

4. Enable the Mass Point option.

5. Enable the Associative option.
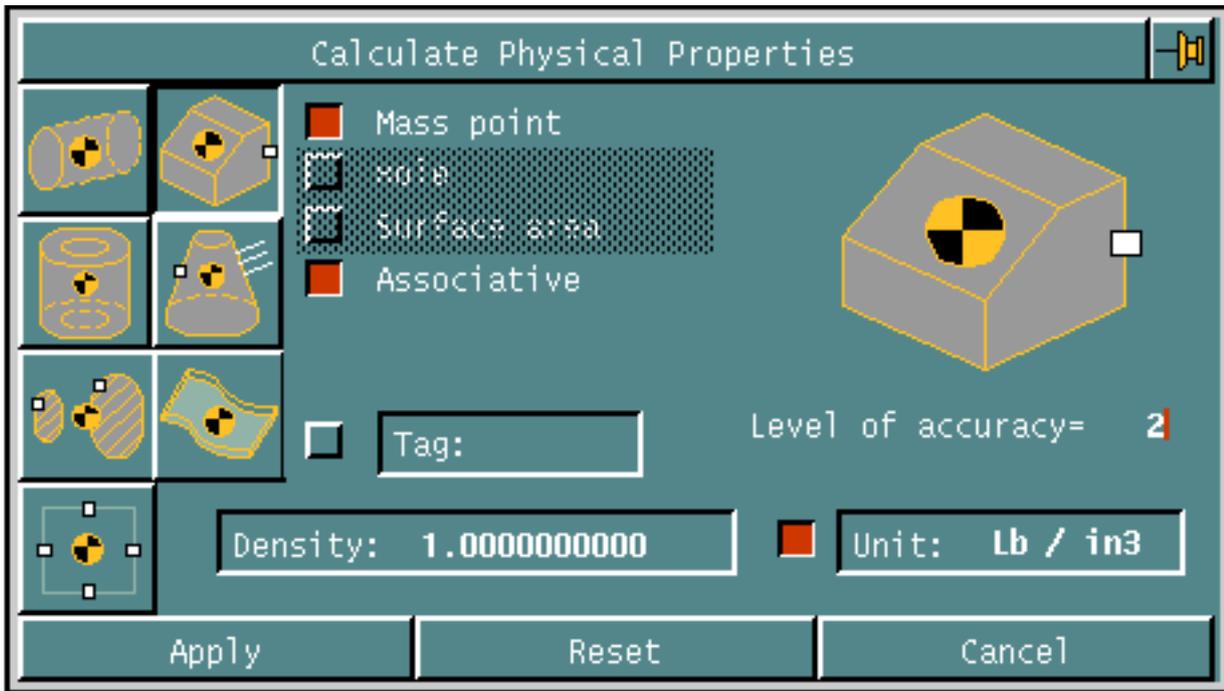
6. Apply the property sheet.

7. Select a solid.

8. Select the Done option on the Utilities menu or press the Return key on the keyboard.

The associative mass point is created at the centroid of the solid and placed on the active layer. Additionally, output is sent to the CADDS dialog window.

If the association fails for any reason the mass point will be created without any association relationship and the following message will appear:

```
Error in associating Solid (Tsurf) to Mass Point: creating a non
associated Mass Point.
```

Replacing an Existing Associated Mass Point

If the selected Solid (or Tsurf) already has an associated mass point, it will be deleted and a new one will be recomputed and associated to the selected Solid (or Tsurf). All the data stored into the old associated mass point will be removed along with the old associated mass point.

If the existing associated mass point is itself related to another existing merged mass point (i.e. it is a source mass point used in a previous MERGE MPOINT operation) the merged association (not the mass properties) are also updated by replacing the old MIPTR with the MIPTR of the new created mass point. This is repeated until all associations are updated.

Updating Associated Mass Points

See "Updating Associative Mass Point" Chapter 5 to learn about updating he physical properties information within an associative mass point.

Merging Mass Points

See "Merging Mass Point Data" Chapter 5 to learn about merging mass points to determine composite values of multiple objects.

Chapter 5

Working with Mass Points

This chapter provides instructions for reporting, inserting, merging, and changing mass point data.

- Reporting Mass Point Data

- Inserting Mass Point Data

- Merging Mass Point Data

- Changing Mass Point Data

- Updating Associative Mass Point

- Highlighting Mass Point Associations

- Breaking Mass Point Associativity

- Deleting Mass Points and Associated Entities

Reporting Mass Point Data

You can report the data contained in a mass point, including

- Volume or area

- Mass

- Surface area

- Centroid

- First moments

- Moments of inertia

- Products of inertia

Please note: Density is not currently stored in mass point data base but can be computed as Mass/Volume.

- Polar moment of inertia

- Radius of gyration

- Principal axes (axes of symmetry)

- Principal moments of inertia

Additionally, you can report the following information using the Generate Detailed Reports property sheet option:

- Part unit

- Part identifier (full name of CADDS part)

- Date of calculation

- MIP, tag, and layer of Solid(Tsurf) used in computation (if mass point associativity is used)

- CPL transformation data (with respect to Top Cplane) of the user entered CPL (CPLANE modifier) in the following format:
  CPL ORIGIN IN MODEL SPACE (X, Y, Z)
  Unitized Vectors for X, Y, Z axes.

Besides reporting the data in the text window, you can optionally save the data in a text file.

Options related to reporting mass point data are available from the Query icon on the top bar.

When you select the MASS PROPERTIES option from the Query menu, the following property sheet appears.
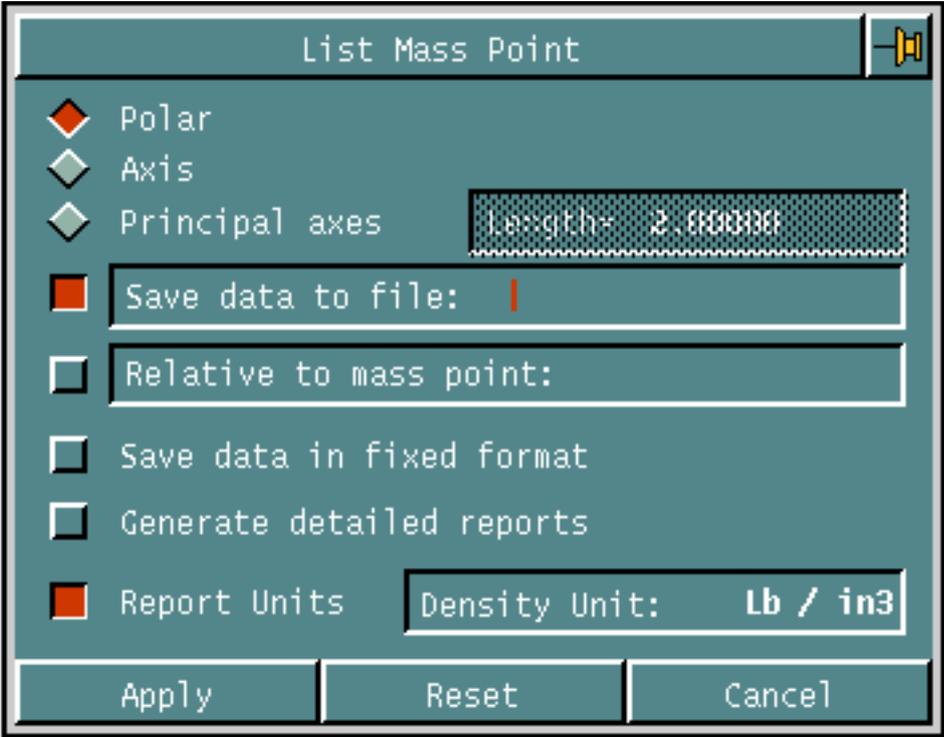
Here are the options you can select on this property sheet:

Table 5-1   Options on the List Mass Point Property Sheet

Option	Description
Polar	Lists the polar moment of inertia about a selected location (default).
Axis	Lists the moment of inertia and radius of gyration about a selected axis.
Principal axes	Lists the principal axes (axes of symmetry), as well as the moments of inertia about those axes, at selected locations.
Length = 2.00000	Specifies the length of the principal axes display.
Save data to file	Save the mass properties data in the file named. By default, the file is stored in the active parts storage directory. You can view the information in the file you have created at the operating system level. Change to the parts storage **_bcd** directory and display the file contents. The file is created using scientific notation with 7 significant digits.

Table 5-1   Options on the List Mass Point Property Sheet

Option	Description
Relative to mass points	Indicates that the mass property values are to be listed with respect to the coordinate system of the named Cplane. You can use this option in conjunction with the Polar option (default), implying a translation of the Cplane origin to the centroid. You select the Cplane from the list of existing Cplane names that appear. Command output states the named Cplane and it's transformation data relative to the Top Cplane
Save Data in Decimal Format	Saves the data to the external file using fixed format with 15 figures and 6 decimal places. If 15 figures is not sufficient, the output is automatically switched to scientific notation with 7 significant digits.
Generate Detailed Reports	Lists the following additional information - density, part unit, part identifier (full name of active CADDS part), date of calculation, MIP tag, and layer of solid/tsurface used in the calculation, and CPL transformation data.
Report Units	Specifies the weight and length units used in the report. You can specify either Centimeter/Gram/Second, Inch/LB-mass/second, Meter/Kilogram/Second, or specify other combinations of metric and English weight and length units. If no unit is specified, no unit is used in the report.

Please note: Since all values are with respect to model space coordinates (Top Cplane), use the Relative to mass point (Cplane) option if the coordinate system in which you want to determine the mass properties of the object is different from the Top Cplane of the part.

Select the Apply menu panel to process property sheet selections. A menu replaces Apply on the property sheet. In response to prompts appearing in the command line, enter the information, using the property sheet menu options. When finished, select Done from the property sheet menu.

Reporting Detailed Information

The following are three examples of output using the Generate Detailed Reports property sheet option:

1. Save Data to Filename option not specified (output appears in text window):

```
DATE: Fri Jul 26 10:10:10 1996
PART NAME: =users.mvalenti.parts.testpart
PART UNIT: mm
VALUES ARE GIVEN WITH RESPECT TO COORDINATE SYSTEM OF CPLANE
USER1:
ORIGIN IN MODEL SPACE= -250.0, 150.0, 100.0
                  XAXIS VECTOR IN MODEL SPACE= 0.0 ,0.0, 1.0
                  YAXIS VECTOR IN MODEL SPACE= 0.0 ,1.0, 0.0
                  ZAXIS VECTOR IN MODEL SPACE= -1.0 ,0.0, 0.0
```

```
Mass Point Description:
    "IRON_16500.HARD ITALY"
Tag:  MP1
ASSOCIATED SOLID:
MIP = 4
TAG: SOL1
LAYER = 10
DENSITY = 1.000000 Kg/mm3
VOLUME      = 255999999.999938 mm3
MASS        = 255999999.999938 Kg
SURFACE AREA = 11999999.999995 mm2
CENTROID:
    X = 1809.063665  Y = 1385.514831  Z = -44.375 mm
FIRST MOMENTS:
    MYZ = 4.63120e+11  MXZ = 3.54692e+11  MXY = -1.136000e+10 Kg*mm
MOMENTS OF INERTIA:
    IXX = 2.2e+15  IYY = 1.3e+15  IZZ = 3.5e+15 Kg*mm2
PRODUCTS OF INERTIA:
    IXY = -2.32e+14  IXZ = -2.055e+13  IYZ = -1.57e+13Kg*mm2
```

2. Save Data to Filename option specified (scientific format):

```
DATE: Fri Jul 26 10:10:10 1996
PART NAME: /users/mvalenti/parts/testpart
ULEN: mm
UWGT: Kg
DESCR: IRON_16500.HARD ITALY
TAG: MP1
ASSMIP = 4
ASSTAG: SOL1
ASSLAY = 10
CPL:USER1
CPLOX= -.2500000E+03
CPLOY= .1500000E+03
CPLOZ= .1000000E+03
CPLXX= .0000000E+00
CPLXY= .0000000E+00
CPLXZ= .1000000E+01
CPLYX=          .000000
CPLYY=         1.000000
CPLYZ=          .000000
CPLZX=        -1.000000
CPLZY=          .000000
CPLZZ=          .000000
DENS = .1000000E+01
VOL:  .2560000E+09
SAREA:  .1200000E+08
MASS:  .2560000E+09
CMX:  .1809064E+04
CMY:  .1385515E+04
CMZ: -.4437500E+02
FMX:  .4631203E+12
FMY:  .3546918E+12
FMZ: -.1136000E+11
IXX:  .2172464E+16
```

```
IYY:  .1297764E+16
IZZ:  .3468752E+16
IXY: -.2315693E+15
IXZ: -.2055096E+14
IYZ: -.1573945E+14
```

3. Save Data to Filename option specified with Save Data in Decimal Format also specified (decimal format):

```
DATE: 22-07-96
PART NAME: /users/mvalenti/parts/testpart
ULEN: mm
UWGT: Kg
DESCR: IRON_16500.HARD ITALY
TAG: MP1
ASSMIP = 4
ASSTAG: SOL1
ASSLAY = 10
CPL:USER1
CPLOX=      -250.000000
CPLOY=       150.000000
CPLOZ=       100.000000
CPLXX=          .000000
CPLXY=          .000000
CPLXZ=         1.000000
CPLYX=          .000000
CPLYY=         1.000000
CPLYZ=          .000000
CPLZX=         -1.000000
CPLZY=          .000000
CPLZZ=          .000000
DENS = 0.00000276
VOL: 255999999.999938
SAREA: 11999999.999995
MASS: 1413.787654
CMX: 1809.064134
CMY: 1385.515143
CMZ: -44.375000
FMX: 463120300000.000
FMY: 354691800000.000
FMZ: -11360000000.0000
IXX: .2172464E+16
IYY: .1297764E+16
IZZ: .3468752E+16
IXY: -.2315693E+15
IXZ: -.2055096E+14
IYZ: -.1573945E+14
```

Reporting a Polar Moment of Inertia

The following example reports the data stored in a mass point and the polar moment of inertia for a specified location.

1. Select the Verify icon from the top bar.

2. Select the Mass Properties option from the menu.

3. When the property sheet appears, select the Polar option (default).
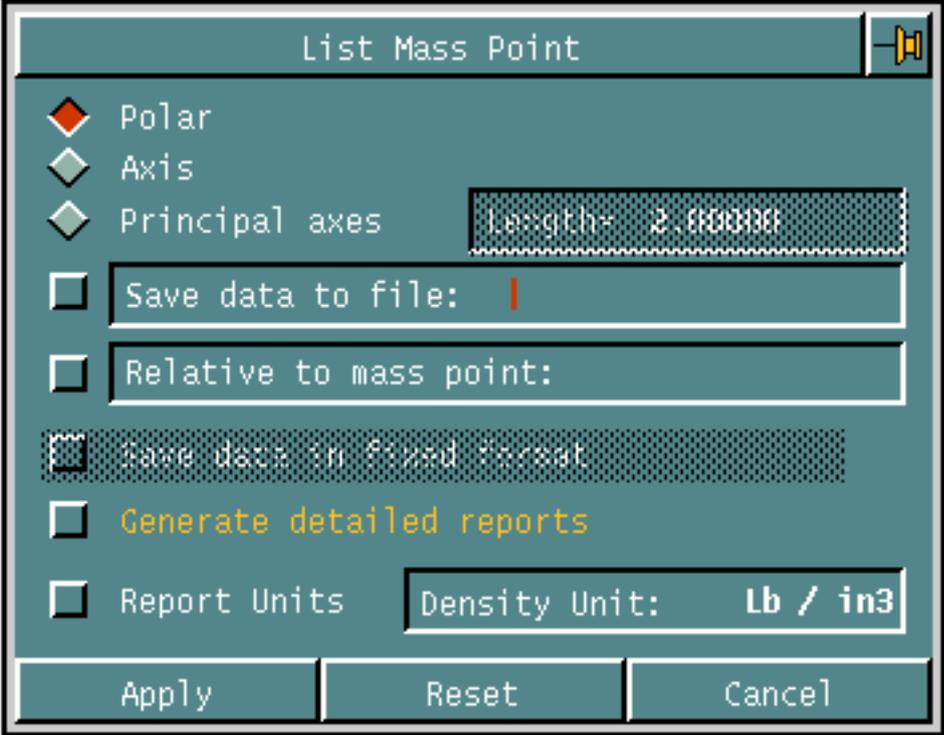
4. Select Apply. The following menu appears under the property sheet.
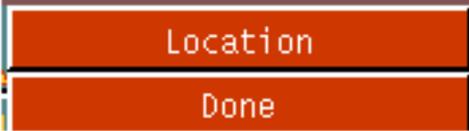
5. In response to the MODEL ent prompt in the command line, select the mass point.

6. Select Location from the property sheet menu.

7. In response to the MODEL org prompt in the command line, select the location about which the system will output the polar moment of inertia.

In the example, the origin of the cylinder is selected.
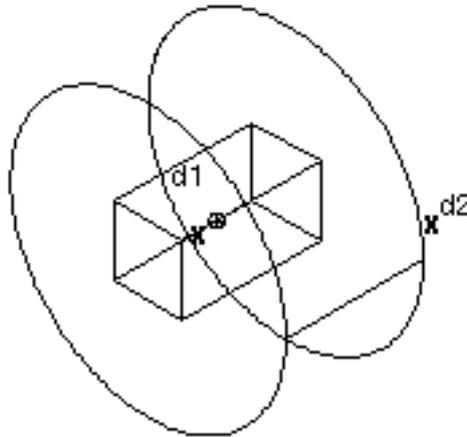
8. Select Done from the property sheet menu.

The system reports the mass point data in the text window.

```
 VALUES ARE GIVEN WITH RESPECT TO MODEL SPACE COORDINATES.
 Tag: (no tag selected)
VOLUME         = 23.132741
MASS           = 23.132741
 CENTROID:
   X = 0.0   Y = -1.0   Z = -0.0
 FIRST MOMENTS:
   MYZ = 0.0   MXZ = -23.132741   MXY = -0.0
 MOMENTS OF INERTIA:
   IXX = 55.80973   IYY = 49.932149   IZZ = 55.80973
 PRODUCTS OF INERTIA:
   IXY = 0.0   IXZ = 0.0   IYZ = 0.0
 POLAR MOMENT OF INERTIA = 80.775804
```

Reporting a Moment of Inertia about an Axis

The following example reports mass point data and the moment of inertia and radius of gyration about a specified axis.

1. Select the Verify icon from the top bar.

2. Select the MASS PROPERTIES option from the menu.

3. When the property sheet appears, select the Axis option.
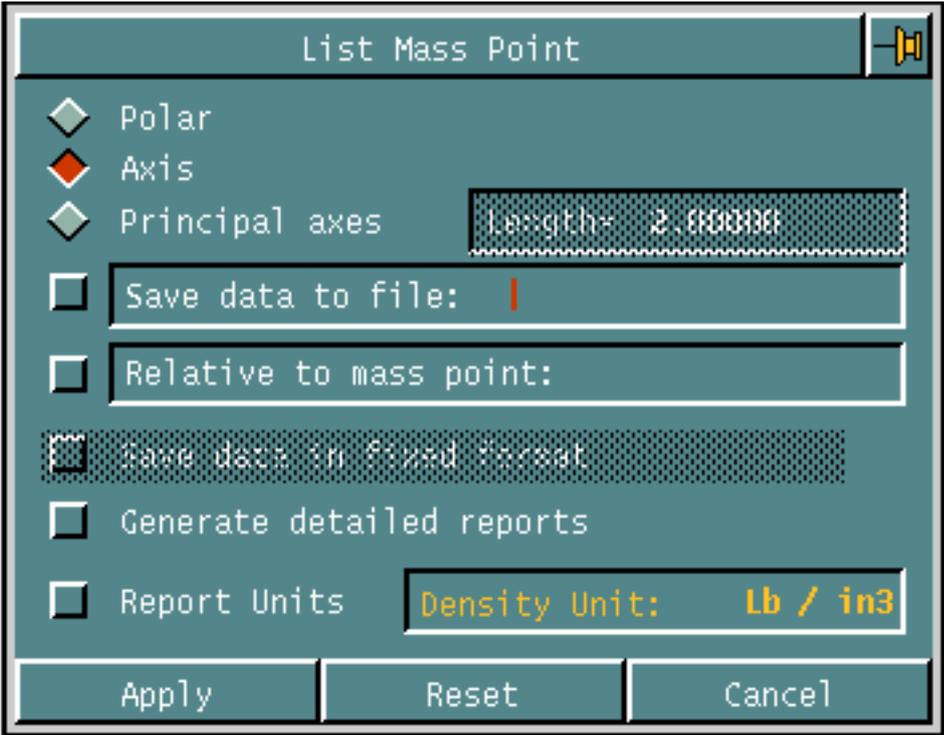
4. Select Apply. The following menu appears under the property sheet.

5. In response to the MODEL ent prompt in the command line, select the mass point.

6. Select Define axis from the property sheet menu.

7. In response to the MODEL loc prompt in the command line, select two locations to define an axis about which the system will output the moment of inertia and radius of gyration.

In the example, the End constraint is used to select the two end points of the line to define the axis.
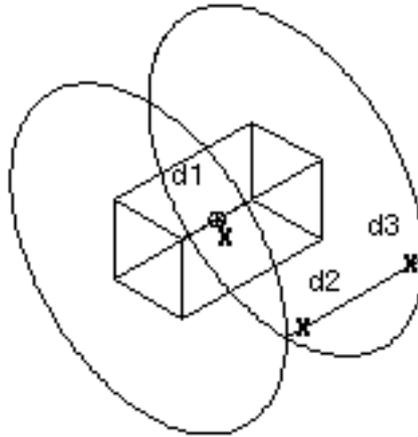
8. Select Done from the Property sheet menu.

The system displays the mass point information in the text window.

```
 VALUES ARE GIVEN WITH RESPECT TO MODEL SPACE COORDINATES.
 Tag:  (no tag selected)
VOLUME        = 23.132741
MASS          = 23.132741
 CENTROID:
   X = 0.0  Y = -1.0  Z = -0.0
 FIRST MOMENTS:
   MYZ = 0.0  MXZ = -23.132741  MXY = -0.0
 MOMENTS OF INERTIA:
   IXX = 55.80973  IYY = 49.932149  IZZ = 55.80973
 PRODUCTS OF INERTIA:
   IXY = 0.0  IXZ = 0.0  IYZ = 0.0
 MOMENT OF INERTIA ABOUT SELECTED AXIS = 142.463114
RADIUS OF GYRATION = 2.481634
```

Reporting Moments of Inertia about Principal Axes

The following example reports mass point data and the principal axes for a specified location.

1. Select the Verify icon from the top bar.

2. Select the MASS PROPERTIES option from the menu.

3. When the property sheet appears, select the Principal axes option.

In the example, the axes display length is 2 units (default).
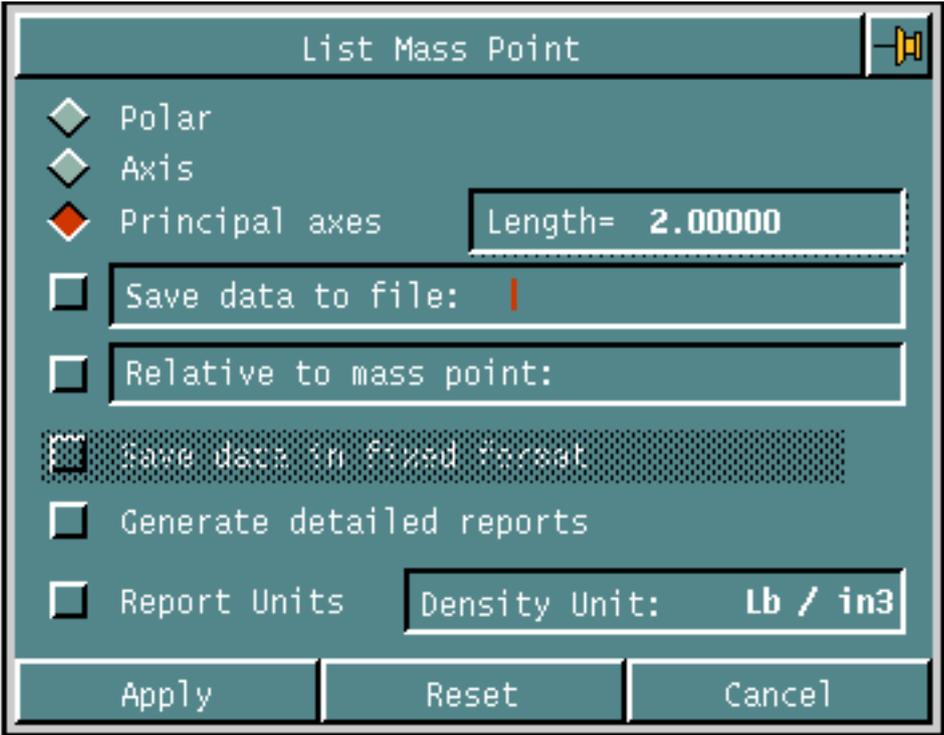
4. Select Apply. The following menu appears under the property sheet.

5. In response to the MODEL ent prompt in the command line, select the mass point.

6. Select Location from the property sheet menu.

7. In response to the MODEL org prompt in the command line, select the location at which the system will output the principal axes.

In the example, the origin of the cylinder is selected.
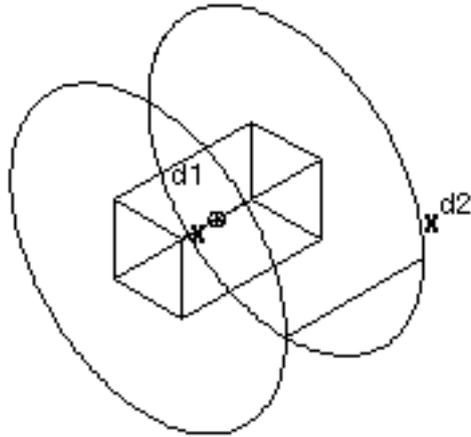
8. Select Done from the property sheet menu.

The system displays the principal axes as temporary graphics and reports the mass point information in the text window.

```
 VALUES ARE GIVEN WITH RESPECT TO MODEL SPACE COORDINATES.
 Tag:  (no tag selected)
VOLUME        = 23.132741
MASS          = 23.132741
 CENTROID:
   X = 0.0  Y = -1.0  Z = -0.0
 PRINCIPAL AXES:
1   X = 1.0  Y = 0.0  Z = -0.0
2   X = 0.0  Y = 1.0  Z = 0.0
3   X = 0.0  Y = 0.0  Z = 1.0
 PRINCIPAL AXES ANGLES OF ROTATION (RADIANS):
1 : 0.0
2 : 0.0
3 : 0.0
MOMENTS OF INERTIA ABOUT PRINCIPAL AXES:
   1: 55.80973  2: 49.932149  3: 55.80973
```

Inserting Mass Point Data

You can manually create a mass point entity with known values supplied by you or read from a text file. The system checks the values for consistency before inserting the mass point.

Please note: You can also automatically calculate these values based on the selected solid, surface, etc. using the Calculate Physical Properties menu. The Calculate Physical Properties menu also enables you to create an associative relationship between the mass point and the source geometry.

1. Select the Physical Properties icon from the Model task set to display the Physical Properties menu.

2. Select the Mass Point icon from the Physical Properties palette to display the following property sheet:
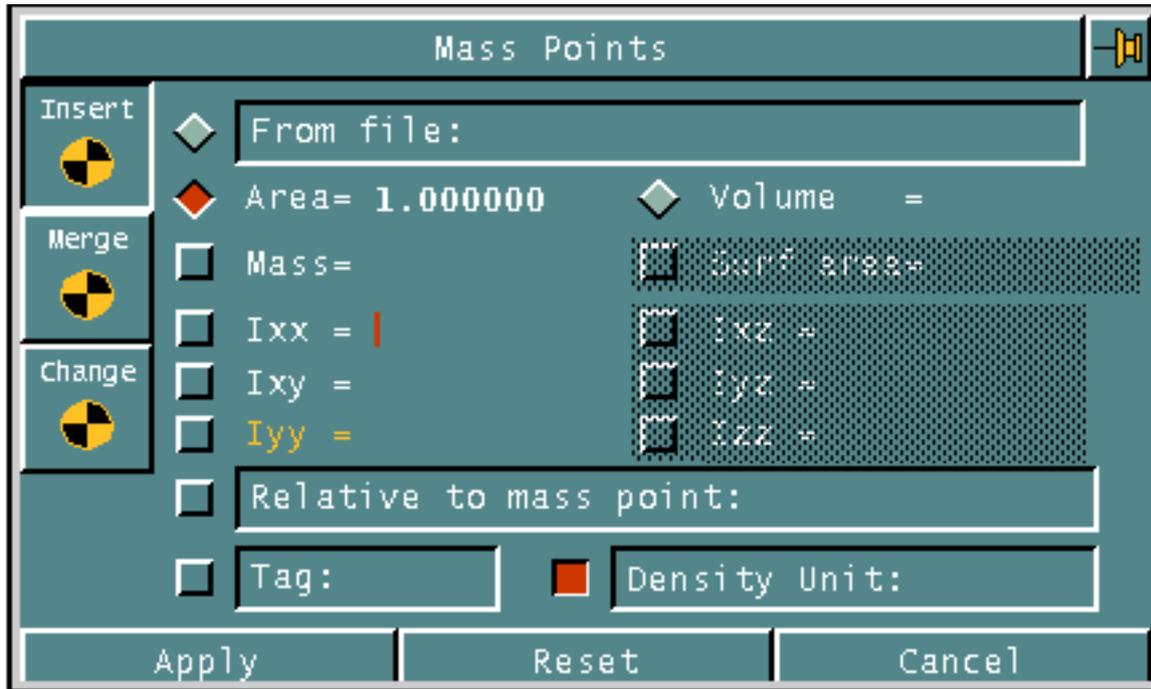
You can select one of the following options when creating a mass point and inserting known mass properties data:

Table 5-2   Options on the Insert Mass Point Property Sheet

Option	Description
From file	Specifies the file from which mass point data is taken.
Area = n	Specifies the area value.
Volume =	Specifies the volume value.

If you select Area or Volume options, you can enter values for any of the following options:

- Mass

- Ixx (x moment of inertia)

- Ixy (xy product of inertia)

- Iyy (y moment of inertia)

- Density (specify measurement units)

You can also designate the coordinate system that the mass property values reference by selecting a Cplane from the list of existing Cplanes.

If you select the Volume option, you can also enter values for any of the following options:

- Surface area

- Ixz (xz product of inertia)

- Iyz (yz product of inertia)

- Izz (z moment of inertia)

You can assign a tag to the system-created mass point. Tag names are limited to six alphanumeric (A-Z, 0-9) characters.

Inserting Mass Points Sample Session

The following example creates two mass points containing arbitrary data from the property sheet.
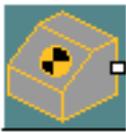
1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Mass Point icon from the menu.

3. When the property sheet appears, select the Insert option.

4. Select the options you want and enter the necessary information.

In the example, the chosen options are:

- Area of 10

- Mass of 20

- X moment of inertia (Ixx) of 21

- XY production of inertia (Ixy) of 22

• Y moment of inertia (Iyy) of 23
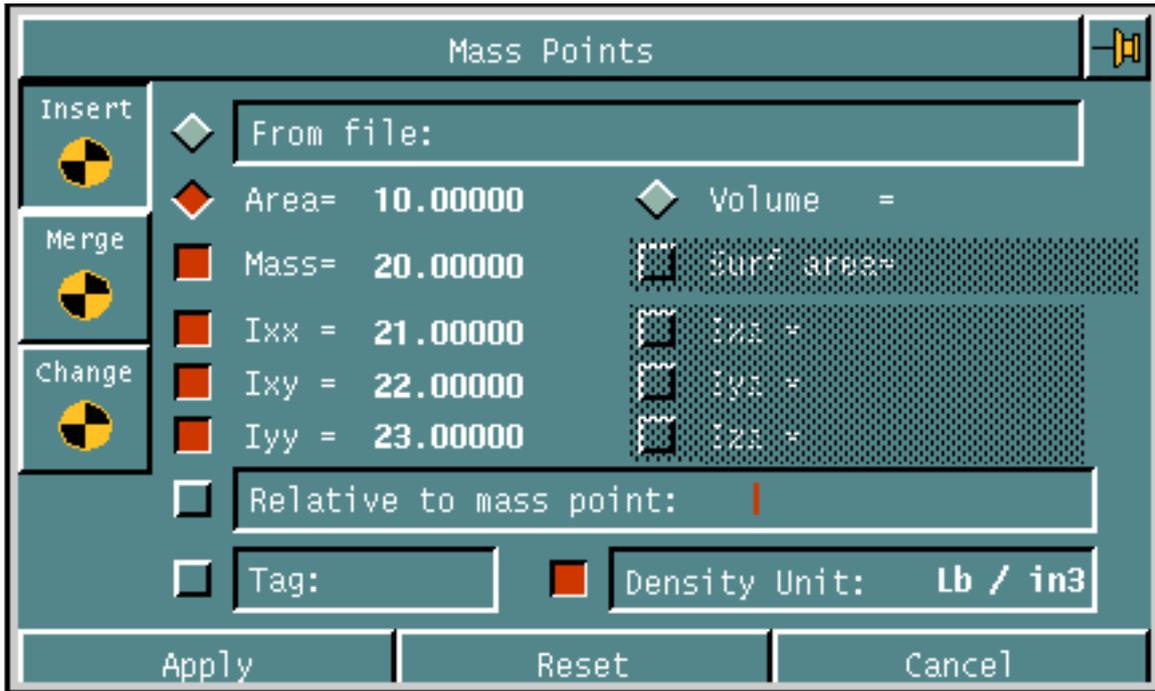
5. Select Apply.

6. In the graphics window, select mass point locations.

7. Select Done from the Utilities menu.

The system creates mass point symbols at the selected locations.
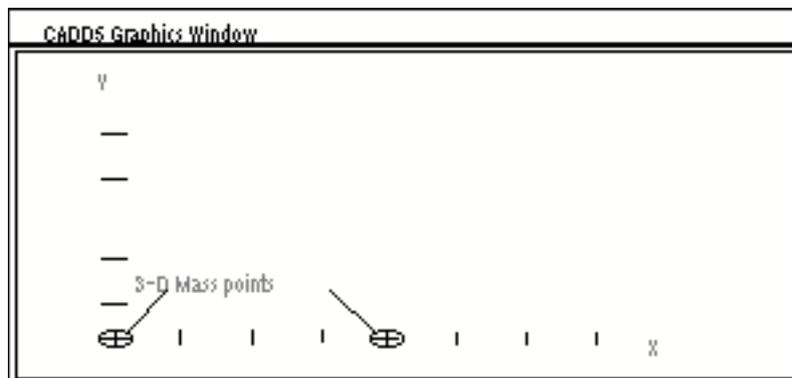
Merging Mass Point Data

You can create a mass point whose values represent the sum or difference of two or more existing mass points. You can optionally specify that the merged mass point be associative to the selected source mass points.

Use the Merge option to calculate the mass properties of an object that is the sum or difference of two or more other objects. For example, to calculate total weight, merge the masspoints of all models within an assembly.

Source mass points can be optionally deleted.

Any mass points can be a source mass point of one or several merge operations However, you can only merge mass points of the same type (those containing two-dimensional data or those containing three-dimensional data). You can merge both associative and non-associative mass points. You can also merge previously merged masspoints with other mass points.

If some mass points contain second moment data while others do not, the new mass point will not contain second moments.

If some mass points contain surface area data while others do not, the missing values are assumed to be zero.

Please note: If a merge would result in meaningless values (such as negative volume), the system does not perform the operation.

Conditions of Associative Merging

If you use the Associative option while merging the mass points of solids/Tsurfs, an association is created between the merged mass point and its source mass points. A mass point can be a source mass point of one or several merged associations; each association is maintained.

If the existing associated merged mass point is already related to another merged mass point (i.e. it is a source mass point used in a previous MERGE MPOINT operation) the merged association (not the Mass Properties) are also updated by replacing the old MIPTR with the MIPTR of the new created merged mass point. This is repeated until all associations are updated.

If you use the Replace original mass points option (for deleting the selected source mass points) the merged mass point is created without any association relationship.

If the association fails for any reason the merged mass point is created without any association relationship and the following message appears:

```
Error in associating Mass Points: creating a non associated Merged
Mass Point.
```

Please note: It is currently not possible to create associations to mass points that are not physically resident in the active part.

Merge Options

**1.** Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Mass Point icon from the Physical Properties menu to display the Mass Points property sheet.

When you select the Merge option, the following options appear.
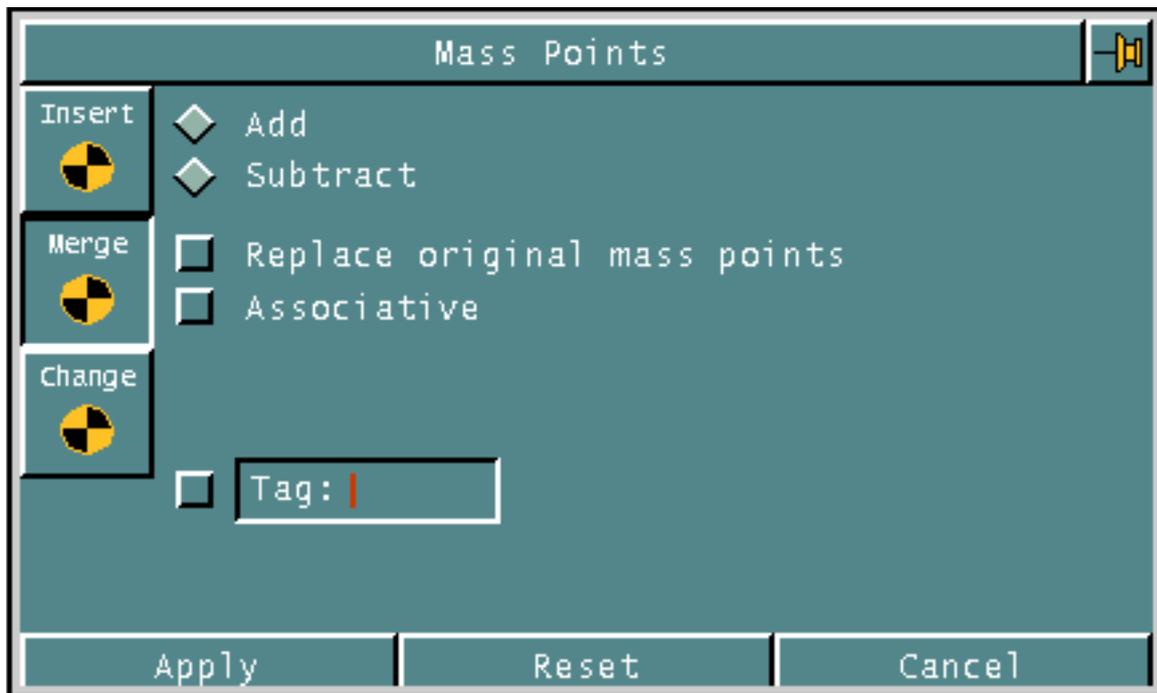
You can select one of the following options when merging mass points.

Table 5-3   Options on the Merge Mass Point Property Sheet

Option	Description
Add	Adds the indicated mass points.
Subtract	Subtracts the second and subsequent mass points from the first one.

You can select the following options with either the Add or Subtract options:

Table 5-4   Add/Subtract Options

Option	Description
Replace original	Deletes the original (source) mass points of the merged mass point.
Associative	Creates an association between the new merged mass point and all selected source mass points. See "Merging Mass Point Data" for more information.
Tag	Assigns a tag to the mass point. Tag names are limited to six alphanumeric (A-Z, 0-9) characters.

Merging Mass Points Sample Session

The following example creates a mass point whose values represent the sum of two merged mass points.
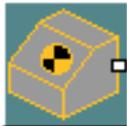
1. Select the Physical Properties icon from the Model task set on the side bar.

2. Select the Mass Point icon from the menu.

3. When the property sheet appears, select the Merge option.

4. Select the Add option.

5. Select the Associative option.

6. Select Apply.

7. In the graphics window, select the mass points that you want to merge.

8. Select Done from the Utilities menu.

Listing Mass Point Data

Create a file to list the values stored in the two source mass points and the resultant merged mass point used in the previous example.

1. Select the Verify icon from the top bar.

2. Select the MASS PROPERTIES option from the menu.

```
┌──────────────────────────────────────────────────┐
│            List Mass Point                   ─|○| │
│  ◆ Polar                                           │
│  ◇ Axis                                            │
│  ◇ Principal axes      ▓Length= 2.0000▓           │
│  ■ Save data to file:  |                          │
│  □ Relative to mass point:                        │
│  □ Save data in fixed format                      │
│  □ Generate detailed reports                      │
│  ■ Report Units    Density Unit:    Lb / in3      │
│  ┌─────────┬──────────┬──────────┐                │
│  │  Apply  │  Reset   │  Cancel  │                │
│  └─────────┴──────────┴──────────┘                │
└──────────────────────────────────────────────────┘
```
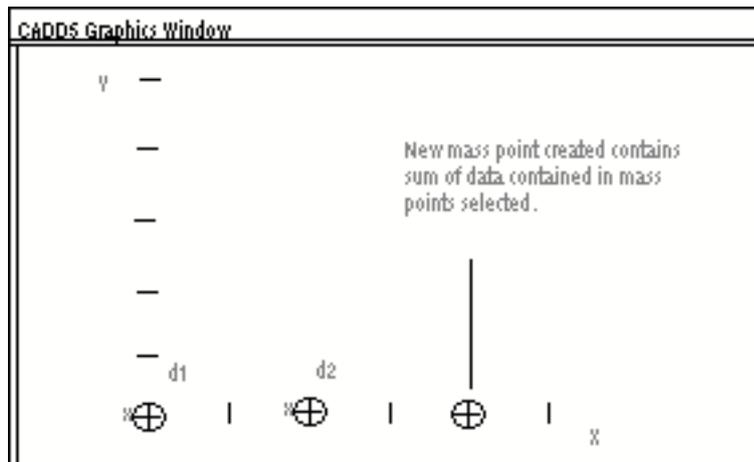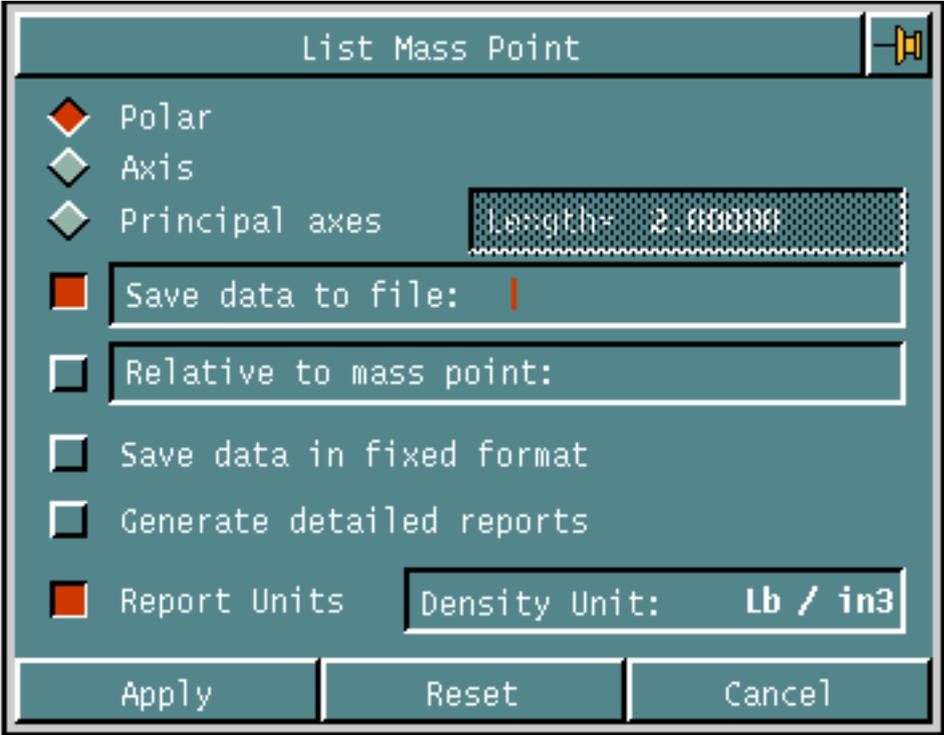
3. When the property sheet appears, select the Save data to file option and enter a name for the file.

4. Select any other desired options.

5. Select Apply.

6. In the graphics window, select the three mass points.

7. Select Done from the Utilities menu.

You can view the information in the file created at the operating system level. The file is stored under the _bcd subdirectory of the active part.

See "Highlighting Mass Point Associations" to learn about highlighting mass point associations. See "Updating Associative Mass Point" to learn about updating mass point associations.

Changing Mass Point Data

You can change the mass properties data contained in a mass point. The new data are checked for consistency before the change is made.

When you specify second moment data for a mass point that did not previously contain second moments, specify all of the appropriate moments (Ixx, Ixy, and Iyy for 2-D mass points and Ixx, Ixy, Ixz, Iyy, Iyz, and Izz for 3-D mass points).

Because changing the first moments also changes the location of the centroid, use the Translate Entity icon for this purpose. The second moments will be changed accordingly.

Selecting the Mass Point icon from the Physical Properties menu displays the Mass Points property sheet. When you select the Change option, the following options appear.
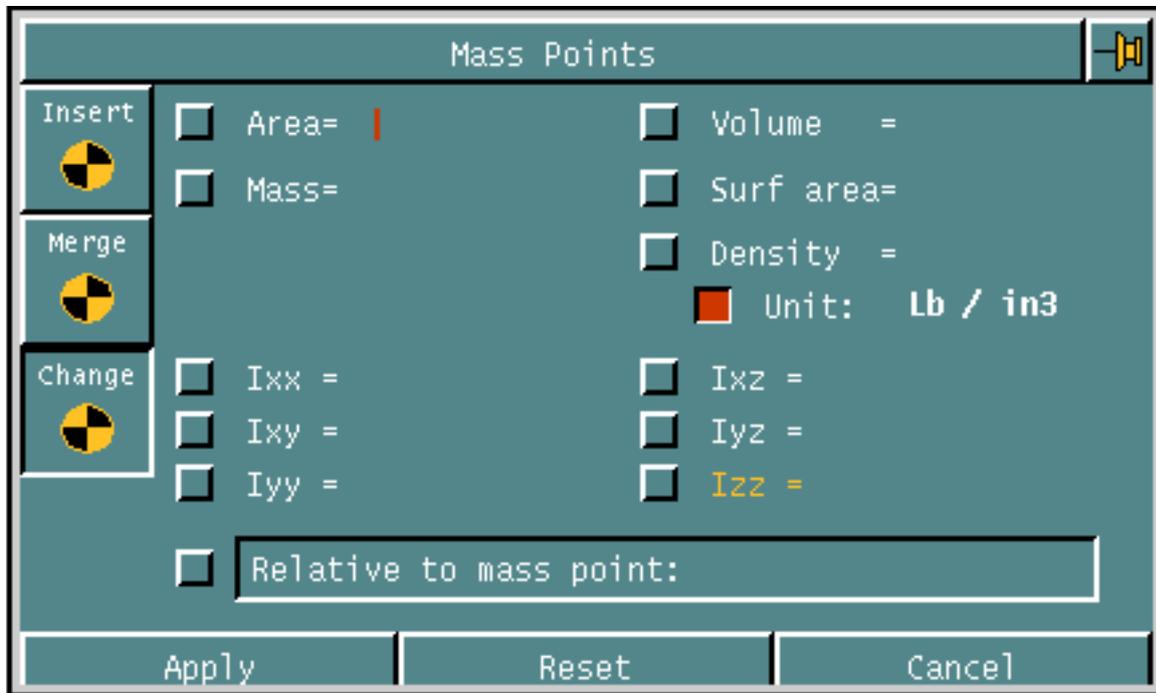
You can change the values for any of the following options:

- Area

- Mass

- Ixx (x moment of inertia)

- Ixy (xy product of inertia)

- Iyy (y moment of inertia)

- Volume

- Surf area

- Ixz (xz moment of inertia)

- Iyz (yz product of inertia)

- Izz (z moment of inertia)

You can also change the coordinate system that the mass property values reference by selecting a Cplane from the list of existing Cplanes that appears.

You can use the Description option to access the DESCR property attached to the mass point. You can use this property to store material identifiers and other user-specified data within the mass point. For more information about creating CADDS properties (attributes attached to entities) see the INSERT PROPERTY command in online command help.

After selecting the mass properties you want to change and entering the new values, select Apply. Then identify the mass point whose properties you want changed.

Changing Associative Mass Points

The only aspects of an associative mass point that can be changed (by the CHANGE MPOINT command) are density and description.

When you attempt to change any other aspect of the associative mass point, the following message appears:

```
Mass Point MIP # is associative, its properties cannot be changed.
```

Manipulating Associative Mass Points

You cannot translate, rotate, mirror, or revise an associative mass point without using the Copy option. If you attempt to, the following message appears:

```
Mass Point MIP # is associative, its properties cannot be changed.
```

Updating Associative Mass Point

To update an associative mass point when either its source geometry or source mass points have changed, you must use the Update Mpoint function. You can select a solid(tsurf) to update it's associated mass point or you can select the geometrically associated mass point itself. You can also select a merged mass point to update it based on the most current state of its associated source mass points. Lastly, you can request that all associative mass points be updated.

The two Update menu options obtained from the Physical Properties submenu are shown below. The first enables you to select specific associative mass point or solids (tsurfs) within the active part. The second acts on all associative mass points within the active part.

Each selected associative mass point is deleted, and a new one created, based on the following:

- The Layer, Color, Tag, Properties, Thickness, Thicken direction, and Density are retrieved from old mass point and stored in the new.

- For geometric mass point - the mass properties of the associated explicit or parametric Solid (Tsurf) are recomputed and stored in the new geometric mass point

- For merged mass point - a new merge operation between the associated source mass points is performed and the computed mass properties are stored in the new merged mass point

- For source mass points - if the selected mass point is related to other merged mass points then all the merged associations are also updated.

As each mass point is updated, the following message appears:

```
The Mass Point MIP # has been updated.
```

All association relationships are regenerated.

The following conditions exist:

- The update function does not check whether the solid (Tsurf) or source mass point associated to the selected mass point has been changed. The mass point update is always performed.

- The associative mass point is not duplicated when you duplicated an existing solid or Tsurface. To create an associative mass point for the new solid (Tsurf) you must use the Calculate Physical Properties property sheet.

- The Update function is not performed automatically when an associated solid (Tsurf) or associated source mass point is changed. You must request the function using one of the Update Associative Mass Point icons.

Highlighting Mass Point Associations

The Highlight function enables you to highlight the mass points and/or solid (Tsurf) associated to the selected mass point.

The highlight colors are listed below:

- Red for solid (Tsurf) and source mass point

- Green for merged mass points

- Blue for the first source mass point of the MERGE MPOINT SUBTRACT operations.

You can optionally move the marked entities onto a specified layer.

The two Highlight menu options obtained from the Physical Properties submenu are shown below. The first enables you to simply highlight the entities associated to the selected entity. The second moves the highlit entities to a specifies layer.

When you use either option, you are prompted to select one mass point or one parametric or explicit solid(Tsurf) or mass point.

A report is issued to the CADDS dialog window indicating pertinent information based on the selected entity. See online command help for the MARK MPOINT command for more detail.

Breaking Mass Point Associativity

The Dissociate function enables you to break an associative mass point relationship. You can break an association by either selecting a solid(Tsurf), it's associated mass point, or a merged mass point. You can not break a merged mass point association by selecting one of it's source mass point. To break a merged mass point association, you must select the merged mass point itself.

When you select this icon from the Physical Properties submenu, you are prompted to select one or more entities to dissociate. Select the Done option on the Utilities menu or press the Return key to process the command.

You are prompted to confirm the dissociation. Respond as prompted to break the selected associations.

The following conditions exist:

• When a geometric or merged mass point is deleted, one of the following message appears:

```
The Mass Point MIP # is now non associated to solid or tsurface MIP
#.
The Merged Mass Point MIP # is now non associated.
```

• When a geometric mass point is dissociated, the following message appears:

```
"The Mass Point MIP # is now non associated to solid or tsurface
MIP #."
```

• When you select a non associated mass point, solid or tsurface, the following message appears:

```
"No Mass Point, Solid or Tsurface is associated with entity MIP #:
nothing to dissociate."
```

• When you select a source mass point, the following message appears:

```
"The Mass Point MIP # is a source Mass Point. It will not be
dissociated.
```

Deleting Mass Points and Associated Entities

You can delete associated mass points and/or the solid (Tsurf) to which a mass point is associated. The selected entities are deleted and the remaining relationships are updated. If all associations to the mass point are deleted, the isolated mass point is also deleted.

The following conditions exist:

- When you delete a solid (Tsurf) that contains an associated mass point, the associated mass point is deleted automatically.

    - If the associated mass point is also a source mass point of a merged mass point, it is removed from the list of source mass points that comprise the merged mass point. This is also true if you delete the source mass point itself.

- When you delete a merged mass point, the association between the merged mass point and it's source mass points is automatically deleted. The source mass points are left intact.

    - If the merged mass point deleted is also a source mass point of another merged mass point, it is removed from the list of source mass points that comprise the next level merged mass point.

Chapter 6   # Calculating Center of Gravity

This chapter provides information about calculating center of gravity

- Overview of Calculating Center of Gravity
- Calculating Center of Gravity

Overview of Calculating Center of Gravity

Selecting the Calculate Center of Gravity icon calculates the center of gravity for the following kinds of components.

- Piping

- Steel

- Heating, Ventilating, and Air Conditioning

- User-defined

These components must have been created with packages in the Engineering Products set.

Calculations Performed

For each component, the system calculates the center of gravity with respect to a user-defined reference location, as well as the composite center of gravity for all entities selected. You can also select mass points and factor these into the composite center of gravity.

Calculation Output

Given a reference point, Calculate Center of Gravity provides offsets from each center of gravity to the reference location. These offsets are directed to a text file and listed in an output table containing

- Component identifiers such as STOCKNO, STEELID, or other user-selected property values

- Weight of the component

- Offset of its center of gravity from the reference point

Mass Points

You can also insert mass points in the database for each component's center of gravity, including the accumulated center of gravity. If you choose to use a mass point to represent a component, you must ensure that no property lookup occurs for that component; otherwise, it is included twice in all calculations--once using the information from the mass point, and again from the lookup.

## Calculations for Steel Inserted with Various Packages

When calculating center of gravity, the software interprets in different ways steel that has been inserted with the various Engineering Products steel packages. The interpretation used is based on the following.

- Structural Steel Modeling (SSM) members are Nfigures with the STEELIDENT property of 1. Their weight is determined from the WEIGHT/LENGTH column in the mass table and the length is specified by the CLINEDISP or BEAMLENGTH property. The center of gravity is calculated.

- Structural Modeling System (SMS) members are identified by the BDELNAME property on the Nfigure. Their weight is read from the WEIGHT column and the center of gravity is located from the center of gravity columns.

- Inner Hull Design (IHD) steel is identified by the ENTTYPE property. Its weight is read from the WEIGHT column and the center of gravity is located from the local center of gravity columns.

- Plant Design steel is identified by the FITTYPE property with a value of 100, 101, 110, or 300. Its weight is read from the WEIGHT column and the center of gravity is located from the local center of gravity columns.

When steel members are handled as point masses you must insert a property that is unique for each cross section and length combination onto the member. For example, for all members of cross section type A with a length of 12 feet, you can insert the property MTYPE (or any other text valued property) with a value of A-12.

In the mass table for this example, specify A-12 in the IDENTIFIER column, a weight value in the WEIGHT column, and the local center of gravity of the member in the XOFFSET, YOFFSET, and ZOFFSET columns. Then specify the MTYPE property value.

Calculating Center of Gravity
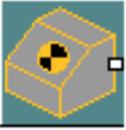
1. Select the Physical Properties icon from the Model Taskset.

2. Select the Calculate Center of Gravity icon from the Physical Properties menu.

   The property sheet for Calculate Center of Gravity appears as shown below.

Input Weight Filename

This is the name of the text file that contains a table that cross-references property values to weights, or weight/length for pipes, ducts, and entities with length. The mass table contains the information from which all weight and center of gravity calculations are performed.

The default name is MASS.TABLE.

Mass Table Format

The mass table must have a keyword header line and a row of values for each entity for which you want to calculate center of gravity. In addition, the mass table can have an optional units line and any number of comment lines. Comment lines are identified by an asterisk (*) in the first column of the line.

The units line specifies the weight units type in the mass table. It is written as UNITS=*wunits*. This line must be the first uncommented line, if it exists. Possible units below.

Abbreviation	Unit
LB	Pounds
KG	Kilograms
LTONS	Long tons (2240 pounds)
STONS	Short tons (2000 pounds)
MTONS	Metric tons
OZ	Ounces
GM	Grams

Header Line Keywords

The header line contains the following keywords in any order:

- IDENTIFIER This is the value of the property used to identify the entity such as STOCKNO for piping.
- XOFFSET Along with YOFFSET and ZOFFSET, these values specify an offset from the origin of the entity to be used as the center of gravity.
- YOFFSET
- ZOFFSET
- WEIGHT The weight of the entity.
- WEIGHT/LENGTH The weight per unit length of the entity. You can specify either WEIGHT or WEIGHT/LENGTH for a given identifier. You should specify WEIGHT/LENGTH for pipe, duct, and steel weights.

If the units line exists, the header line must be the second uncommented line. If the units line does not exist, the header line must be the first uncommented line.

Values for each entity must be lined up and left-justified under the corresponding keyword. Do not use tabs.

The table must be sorted alphabetically by IDENTIFIER.

Output Report Filename

This is the name of the text file that receives the report produced by Calculate Center of Gravity. The default name is CG.OUTPUT.

Output Report Weight Units

This specifies the type of weight units used in reporting results. Calculate Center of Gravity converts the units in the mass table to the units you specify here. The default is the unit specified in the mass table. Possible units are listed below.

Abbreviation	Unit
LB	Pounds
KG	Kilograms
LTONS	Long tons (2240 pounds)
STONS	Short tons (2000 pounds)
MTONS	Metric tons
OZ	Ounces
GM	Grams

Properties

Selecting Include Property Value in Output Report allows you to specify properties whose values are used as identifiers in the mass table. You can specify up to ten property names. The system looks for the specified property on all entities selected. It obtains the value of the property and uses that value as an identifier to match against identifiers in the mass table.

When specifying properties, follow the rules below.

• Real-valued identifiers must contain a period.

• Negative numeric values are not allowed.

Mass Points

Selecting Create Mass Point for Each Object requests the creation of a mass point entity for each entity whose center of gravity is calculated. You can specify the layer number for all new mass points created. The default is the currently selected layer.

Selecting Create Composite Mass Point requests the creation of a mass point entity for the accumulated center of gravity. You can specify the layer number for the net mass point created. The default is the currently selected layer.

Error Messages

Select Send Error Messages to Screen to display messages. Deselect it to turn off messages. The default is to printer error messages.

Appendix A # System Messages

This appendix is a reference guide for standard system messages. Each message listed in this appendix is followed by the input command string to which the system is responding. A short, descriptive paragraph is also provided to further explain certain entries.

- Nonalphabetical Messages
- Alphabetical Messages

Nonalphabetical Messages

2-D AND 3-D MASS POINTS INCOMPATIBLE - COMMAND ABORTED.

MERGE MPOINT

Alphabetical Messages

A

AREA AND SURFACE AREA ARE INCOMPATIBLE MODIFIERS - TRY AGAIN

CHANGE MPOINT

AREA OF NEW MASS POINT NOT GREATER THAN ZERO.

INSERT MPOINT

AT LEAST THREE DIGITIZES ARE NEEDED FOR CLOSED BOUNDARY, PLEASE TRY AGAIN

CALCULATE AREA
CALCULATE MPROPERTIES
CALCULATE VOLUME

C

COMPONENT ID # NOT LOADED INTO ASSEMBLY: CANNOT RETRIEVE SOURCE MASS POINT UID#.

UPDATE   MPOINT

The component containing a viewed-in source mass point used in MERGE MPOINT ADD ASSOCIATIVE is no longer present in the current assembly.

CROSS-SECTION # <N> HAS BEEN DELETED - PLEASE RE-ENTER IT

CALCULATE MPROPERTIES
CALCULATE VOLUME

D

DENSITY MAY NOT BE COMBINED WITH OTHER MODIFIERS - TRY AGAIN

CHANGE MPOINT

E

`ERROR CONDITION ENCOUNTERED. COMMAND ABORTED.`

CHANGE MPOINT
MERGE MPOINT

`ERROR CONDITION ENCOUNTERED IN "MPTDATA". PROGRAM TERMINATES.`

MERGE MPOINT

`ERROR IN UPDATING MASS POINT MIP #: MAINTAINING PREVIOUS DATA.`

`UPDATE MPOINT`

`ERROR OCCURRED DURING CREATION OF MASS POINT ENTITY`

CALCULATE AREA
CALCULATE MPROPERTIES
CALCULATE VOLUME

I

`ILLEGAL AXIS - PLEASE TRY AGAIN`

The axis must be in the same plane as the curves, but must not intersect.

CALCULATE MPROPERTIES
CALCULATE VOLUME

`ILLEGAL DATA.`

INSERT MPOINT

L

`LAST BOUNDARY IS NOT CONNECTED, PLEASE TRY AGAIN`

CALCULATE AREA
CALCULATE MPROPERTIES
CALCULATE VOLUME

`LAST LOCATION ENTERED IS IGNORED.`

You have tried to enter more than the maximum number of mass points that may be inserted.

INSERT MPOINT

M

MASS OF NEW POINT FOUND TO BE NEGATIVE. NO POINT CREATED.

MERGE MPOINT

MASS OF NEW POINT FOUND TO BE ZERO. NO POINT CREATED.

MERGE MPOINT

MASS OF NEW POINT NOT GREATER THAN ZERO.

INSERT MPOINT

MASS POINT MIP # HAS BEEN UPDATED.

UPDATE MPOINT

MASS POINT NO. <N> HAS BAD SECOND MOMENT DATA. DATABASE FOR THIS MASS POINT IS NOT CHANGED.

CHANGE MPOINT

MASS POINT NO. <N> IS INCOMPATIBLE WITH SELECTED MODIFIERS. DATABASE FOR THIS MASS POINT IS NOT CHANGED.

You may be trying to change a 3-D property on a 2-D mass point.

CHANGE MPOINT

N

NEW MASS POINT HAS BAD SECOND MOMENT DATA.

INSERT MPOINT

NO UNIT CONVERSION CAN BE PERFORMED, THERE IS NO UNIT ASSOCIATED TO THE SELECTED MASS POINT MIP #.

LIST MPOINT

```
LUNIT and/or WUNIT modifiers have been entered, but a Mass Point
with no unit has been selected.
```

```
NO ROOM FOR MORE INPUT-COMMAND CONTINUES WITH DATA INPUT SO FAR.
```

You may have been trying to merge too many mass points.

MERGE MPOINT

```
NOT ALL MASS POINTS SELECTED HAVE SECOND MOMENTS DATA.
NEW MASS POINT CREATED WILL NOT HAVE SECOND MOMENTS DATA.
```

You may be merging incompatible mass points.

MERGE MPOINT

```
NOT ALL MASS POINTS SELECTED HAVE SURFACE AREA DATA.MISSING
SURFACE AREA ASSUMED TO BE ZERO.
```

MERGE MPOINT

```
NOT ENOUGH MASS POINTS SPECIFIED (MINIMUM IS TWO)
```

MERGE MPOINT

```
NOT ENOUGH ROOM IN THE SCRATCH DATA BASE.
```

INSERT MPOINT
LIST MPOINT

S

SOURCE MASS POINT UID# BELONGING TO COMPONENT ID # NOT FOUND.

UPDATE MPOINT

The viewed-in source mass point used in the MERGE MPOINT ADD ASSOCIATIVE operation is no longer present in the component.

```
SPECIFIED CPLANE HAS YET TO BE DEFINED.
```

CHANGE MPOINT
INSERT MPOINT
LIST MPOINT

`SPECIFIED TAG NAME ALREADY EXISTS`

MERGE MPOINT

T

`THE LAST BOUNDARY HAS BEEN DELETED, <N> BOUNDARIES REMAIN`

CALCULATE AREA
CALCULATE MPROPERTIES
CALCULATE VOLUME

`THE SELECTED MASS POINT WAS GENERATED BY MERGE MPOINT ADD FROM N MASS POINTS.`

`MARK MPOINT`

`TWO POINTS NEEDED - PLEASE TRY AGAIN`

CALCULATE MPROPERTIES
CALCULATE VOLUME

U

`UNABLE TO BACKSPACE ONE BOUNDARY`

Abort and start again.

CALCULATE AREA
CALCULATE MPROPERTIES
CALCULATE VOLUME

`UNABLE TO BACKSPACE ONE SECTION`

Abort.

CALCULATE MPROPERTIES

UNABLE TO RETRIEVE N1 OF N VIEWED-IN SOURCE MASS POINTS MERGED INTO MASS POINT MIP#.

UPDATE MPOINT

The viewed-in source mass point used in the MERGE MPOINT ADD
ASSOCIATIVE operation is no longer present in the component.

V

VIEWED-IN MASS POINT CANNOT BE MOVED TO LAYER #.

MARK MPOINT

VIEWED-IN SOLID OR TSURF CANNOT BE MOVED TO LAYER #.

MARK MPOINT

VOLUME OF NEW MASS POINT NOT GREATER THAN ZERO.

INSERT MPOINT

W

WARNING: NO ACCURACY VALUE RETRIEVED FROM MASS POINT MIP #.
SETTING ACCURACY VALUE TO DEFAULT 2.

UPDATE MPOINT

Y

YOU MUST SELECT EITHER PROJ, ROT, XSECT OR PLANE;
PLEASE RE-ENTER MODIFIERS:

CALCULATE MPROPERTIES
CALCULATE VOLUME

Appendix B

Improving Mass Properties and Volume Calculations

This appendix contains some suggestions for obtaining the greatest possible accuracy from mass properties and volume calculations.

The two methods for obtaining the greatest possible accuracy from mass properties and volume calculations are: The projection and rotation method and The cross section method.

The projection and rotation methods for calculating mass properties and volume information provide exact answers (within the numerical accuracy of the system), while the cross sections method involves an approximation (described in detail in Appendix C, "Cross Sections Method Calculations").

- The Projection and Rotation Method
- The Cross Sections Method

The Projection and Rotation Method

You can frequently recognize portions of an object for which the projection and rotation methods are applicable.

For example, the object shown in the Figure B-1, consists of a 4-inch cube with a 1-inch radius spherical hole in the center. Boundaries that can be projected and rotated to generate a cube with a spherical hole in the center are shown on the left. The geometry after projection and rotation of the boundaries is shown on the right.

Figure B-1   Cube with a Spherical Center
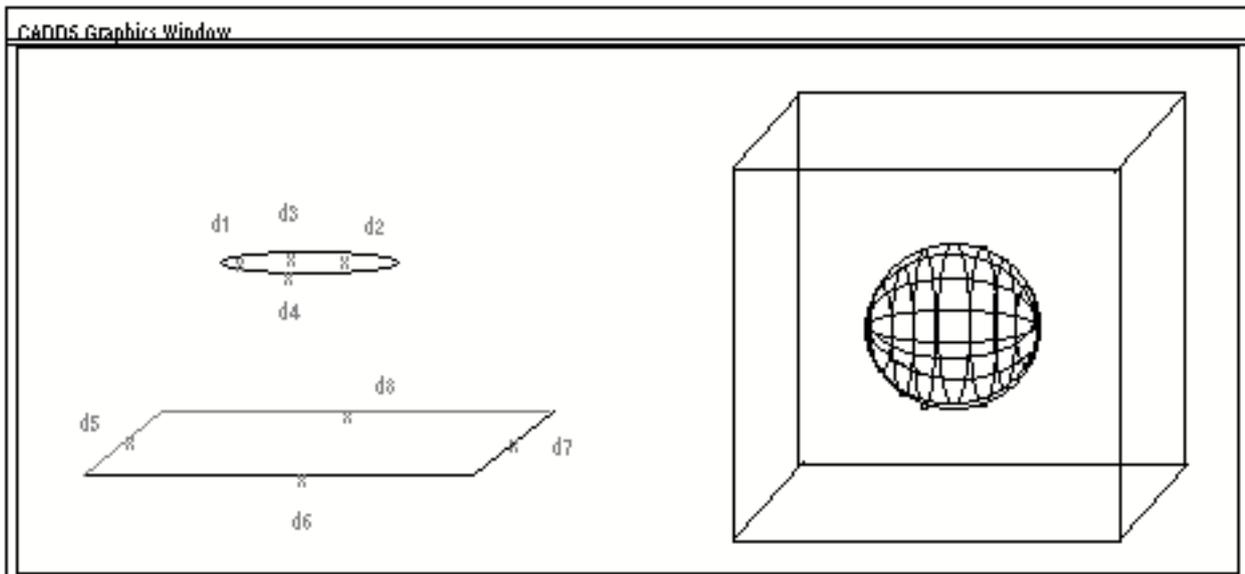
While this object may appear to be a candidate for the cross sections method because it is neither a solid of projection nor a solid of rotation, notice that the cube is a solid of projection and the sphere is a solid of rotation.

In the following example, the mass properties of each are calculated using the projection and rotation methods, then the mass point of the sphere is subtracted (using the Merge Mass Point option) from that of the cube.

```
t#n# CALCULATE MPROPERTIES ROTATE TAG M1:
PLEASE DIGITIZE TWO POINTS TO DEFINE ROTATION AXIS
MODEL loc END dd
PLEASE ENTER SOLID BOUNDARY # 1: dd
PLEASE ENTER SOLID BOUNDARY # 2:
VOLUME= 4.1887903
MASS= 4.1887903
```

```
CENTROID:
 X = 2.0Y = 2.0Z = 2.0
FIRST MOMENTS:
 Myz = 8.3775806      Mxz = 8.3775806      Mxy = 8.3775806
MOMENTS OF INERTIA:
 Ixx = 35.1858367     Iyy = 35.1858367     Izz = 35.1858367
PRODUCTS OF INERTIA:
 Ixy = 16.7551612     Ixz = 16.7551612     Iyz = 16.7551612
#n# CALCULATE MPROPERTIES PROJECT HIBND 4 TAG M2 :
PLEASE DIGITIZE TWO POINTS TO DEFINE PROJECTION AXIS
MODEL loc X0Y0Z0, X0Y0Z1
PLEASE ENTER SOLID BOUNDARY # 1: dddd
PLEASE ENTER SOLID BOUNDARY # 2:
VOLUME= 64.0
MASS= 64.0
CENTROID:
 X = 2.0Y = 2.0Z = 2.0
FIRST MOMENTS:
 Myz = 128.0          Mxz = 128.0          Mxy = 128.0
MOMENTS OF INERTIA:
 Ixx = 682.6666869    Iyy = 682.6666869    Izz = 682.6666869
PRODUCTS OF INERTIA:
 Ixy = 256.0          Ixz = 256.0          Iyz = 256.0
#n# MERGE MPOINT SUBTRACT TAG M3 : MODEL ent TAG M2;  MODEL ent TAG
M1
#n# LIST MPOINT : MODEL ent TAG M3
VALUES ARE GIVEN WITH RESPECT TO MODEL SPACE COORDINATES.
Tag: M3
VOLUME= 59.8112106
MASS= 59.8112106
CENTROID:
 X =  2.0Y = 2.0Z = 2.0
FIRST MOMENTS:
 Myz = 119.6224212    Mxz = 119.6224212    Mxy = 119.6224212
MOMENTS OF INERTIA:
 Ixx = 647.4808349    Iyy = 647.4808349    Izz = 647.4808349
PRODUCTS OF INERTIA:
 Ixy = 239.2448425    Ixz = 239.2448425    Iyz = 239.2448425
```

The Cross Sections Method

If you decide that the cross sections method is the best alternative, there are several things to keep in mind for best results.

First, this method is designed to approximate the mass properties of an object whose cross sections do not change much from one to the next. If the geometry changes quickly over some region of the object, include many cross sections from that region.

And, if the object has a sudden jump in the area or shape of the cross sections at some point (see Figure B-2), you will obtain better results by doing the calculation in two steps:

1. Calculate up to the jump.

2. Calculate from there onward.

Then you can merge the mass points to find the mass properties of the whole object.

Figure B-2   Object with a Step Change in Geometry
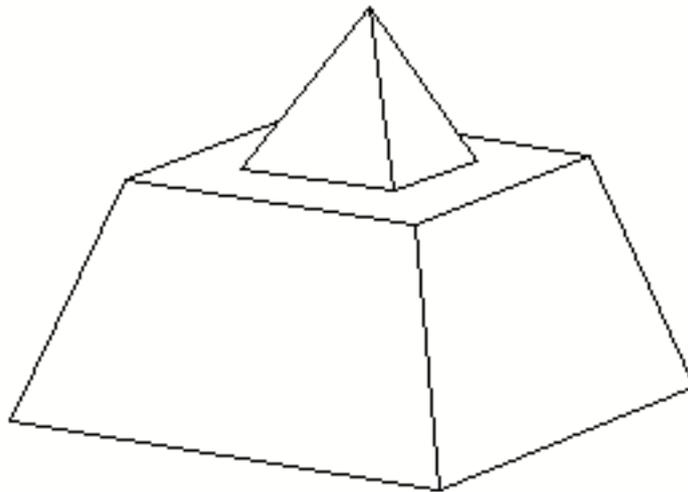
Second, the accuracy of results obtained with the cross sections method depends on the number of cuts (cross sections) used.

To illustrate this effect, mass properties are calculated on the object shown in the Figure B-3. The object is defined by a ruled surface between two ellipses on parallel planes 10 units apart, with their major axes perpendicular to each other.

The ellipse with its center at X0Y0Z0 has a half major axis of 5 and a half minor axis of 2. The ellipse with its center at X0Y0Z10 has a half major axis of 5 and a half minor axis of 1.5.

The object is cut with a plane perpendicular to the z-axis into different numbers of sections. Mass property calculations are performed on the cuts.

Figure B-3   A Ruled Surface between Two Ellipses

Top view   Front view   Isometric view
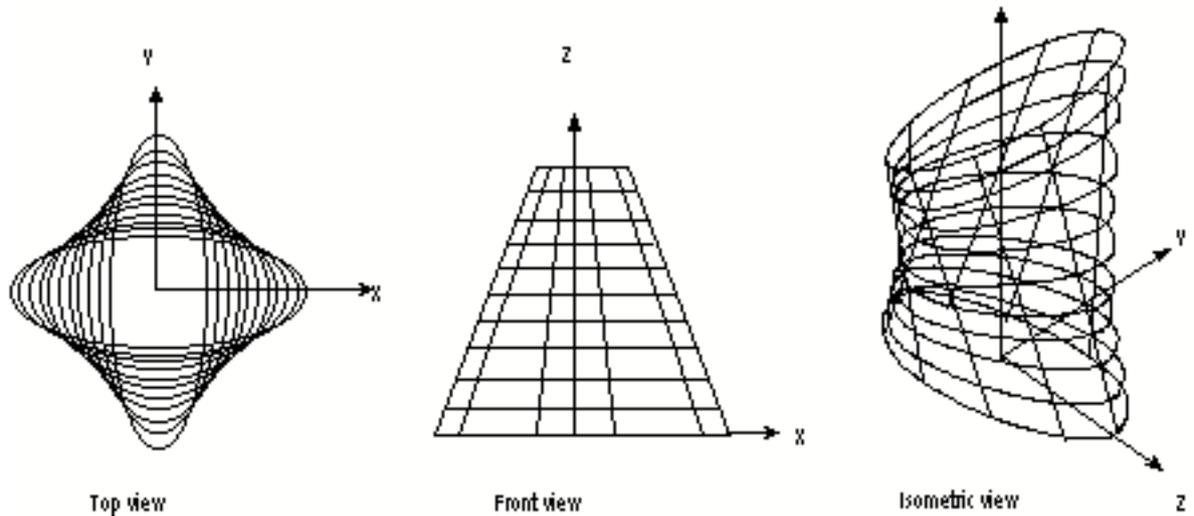
The Figure B-4 is a graph of the calculated volume versus the number of cuts used. It shows that for this geometry, increased accuracy is achieved as the number of cuts is increased to about 20, beyond which more cuts do not improve the answer significantly.

Figure B-4   Calculated Volume Plotted Against the Number of Cuts
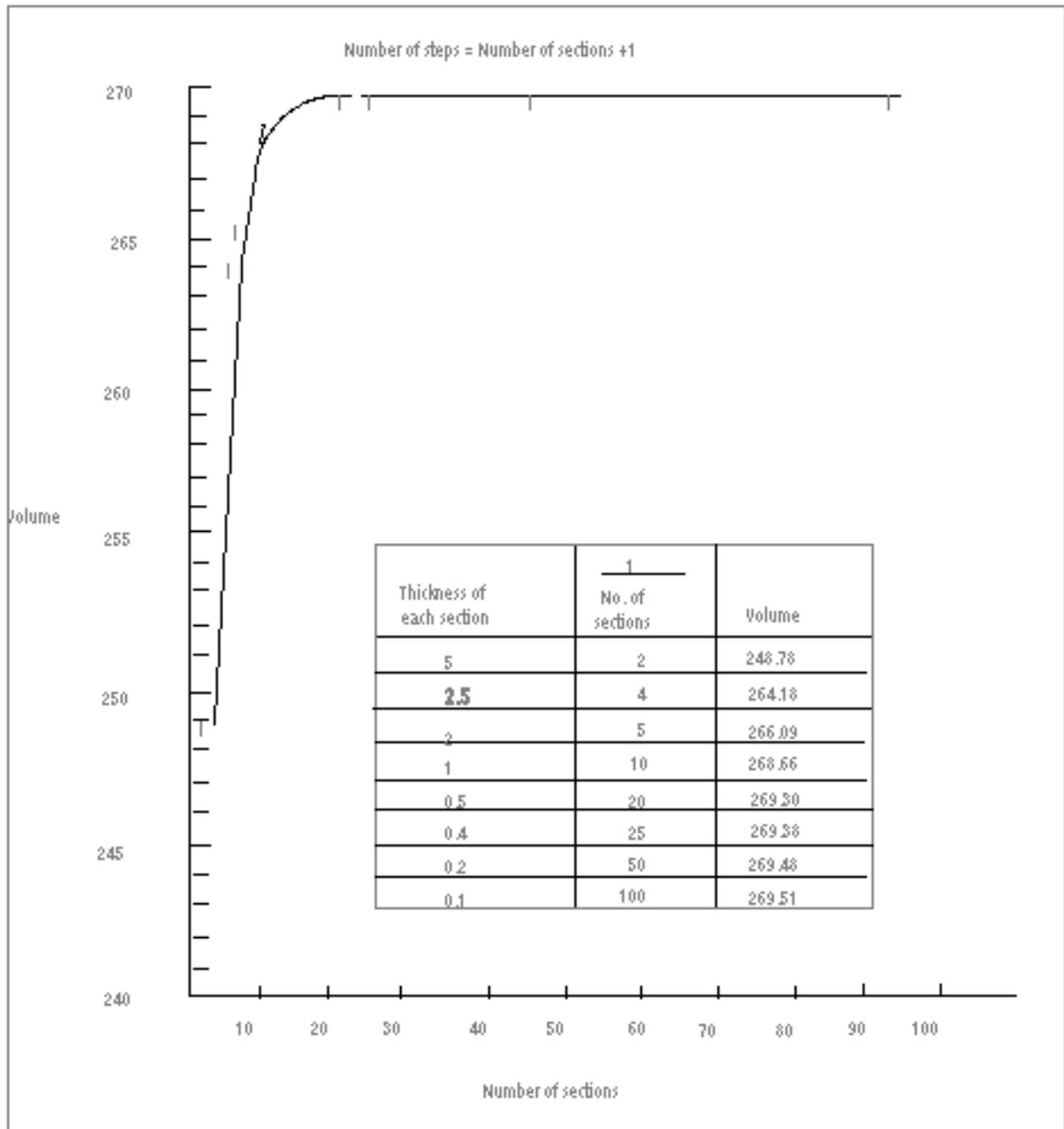
A useful technique for extrapolating the correct answer is to plot this data versus the reciprocal of the number of cuts, as shown in the Figure B-5. You can see that the volume of the object is between 269 and 270.

Figure B-5   The Calculated Volume Plotted Against the Inverse of the Number of Cuts
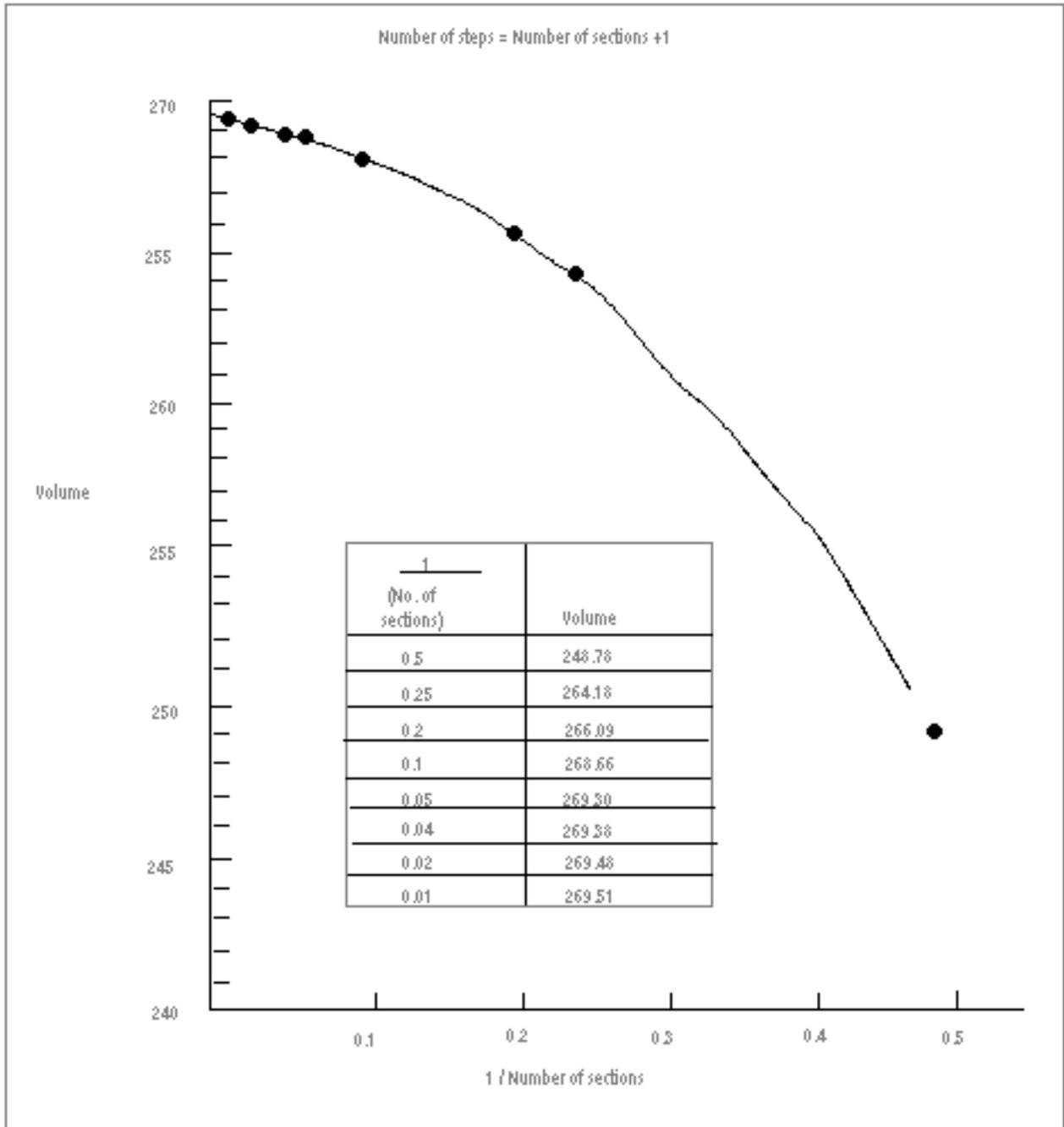
As a further illustration, the graphical technique shown earlier in "Calculated Volume Plotted Against the Number of Cuts" is repeated for the geometry in the following figure. The volumes are plotted and listed in "Calculated Volume Plotted Against the Number of Cuts" later in this appendix. The convergence of the volume to the true answer (45.9587) is seen as more cuts are used.

Figure B-6   A Pyramid Section with a Center Hole
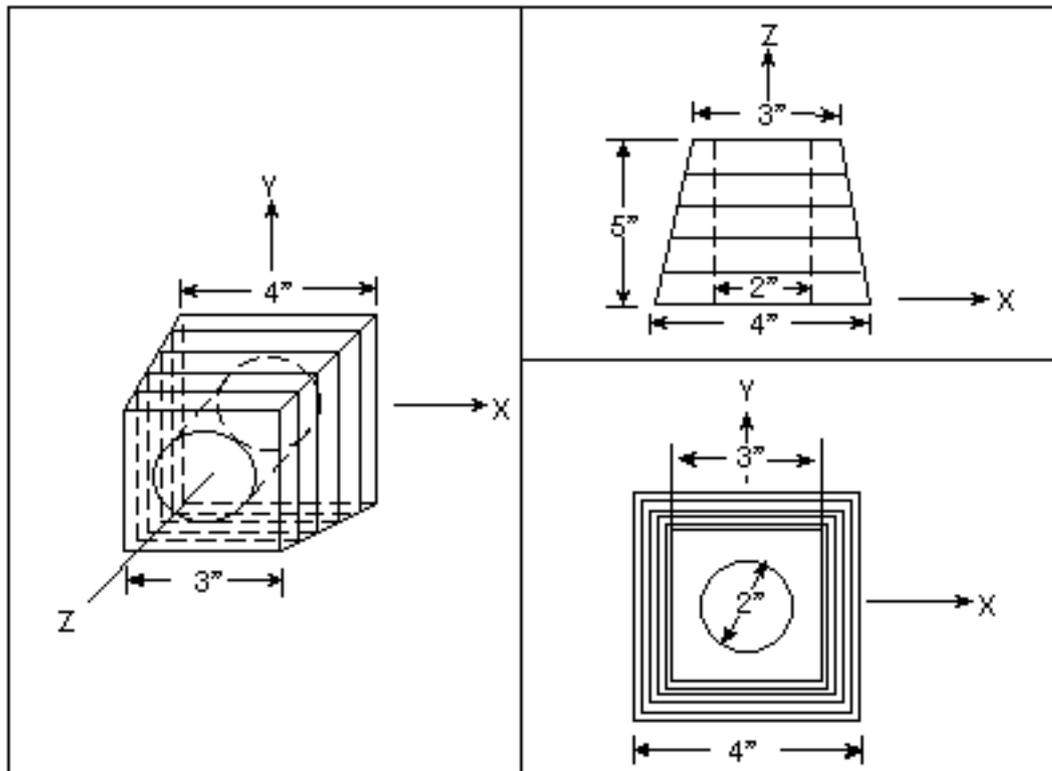
Actually, this geometry is an example of the situation discussed at the beginning of this appendix, where the cross sections method alone is not the best technique to use.

Because the cylindrical hole in the center of the frustum of the pyramid is a tabulated cylinder, you can obtain more accurate results by using the cross sections method on the frustum of the pyramid and the projection method on the cylindrical hole.

Afterward, you can find the mass properties of the complete object by merging (subtracting) the mass point of the cylinder and the mass point of the frustum of the pyramid.

With 10 sections (11 cuts) of the frustum of the pyramid and use of the projection method on the cylindrical hole, the volume is calculated as equal to the true answer (45.9897).

However, the true volume is found in this example because the formulas employed in finding the volume in the cross sections method are geared toward a more exact solution for geometries that are similar to the frustum of a pyramid (see Appendix C, "Cross Sections Method Calculations" for a discussion of the formulas used).

Figure B-7   Calculated Volume Plotted Against the Number of Cuts

Thickness of each section	No. of sections	Volume
5"	1	45.6601
2-1/2"	2	45.8839
1"	5	45.9467
1/2"	10	45.9557
1/4"	20	45.9580

Appendix C
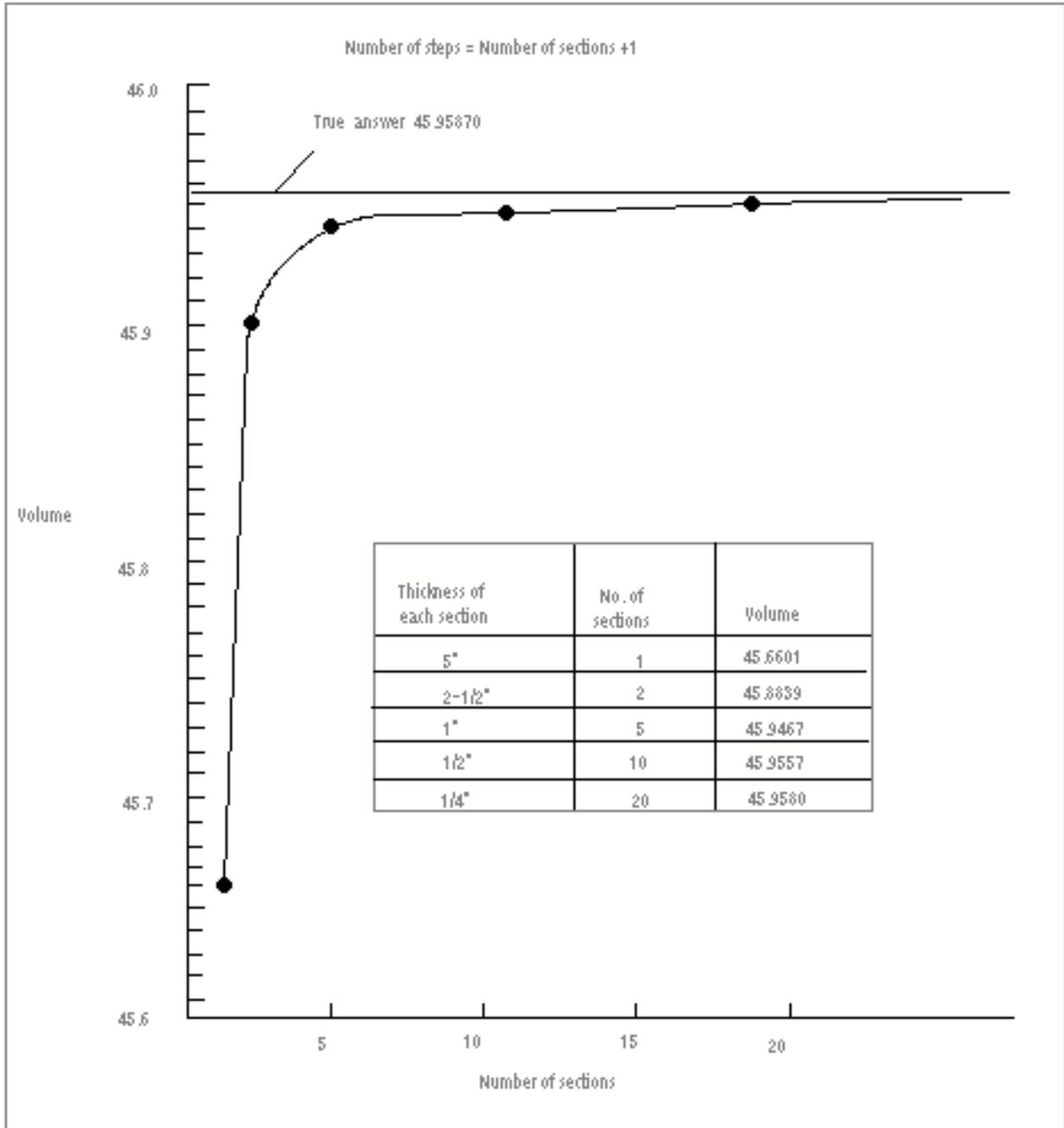
Cross Sections Method Calculations

The cross sections method for calculating physical properties first calculates the moments of each cross section. Then the moments of the entire object are found by summing the moments of the cross sections.

Two cross sections for an arbitrary object are shown below.
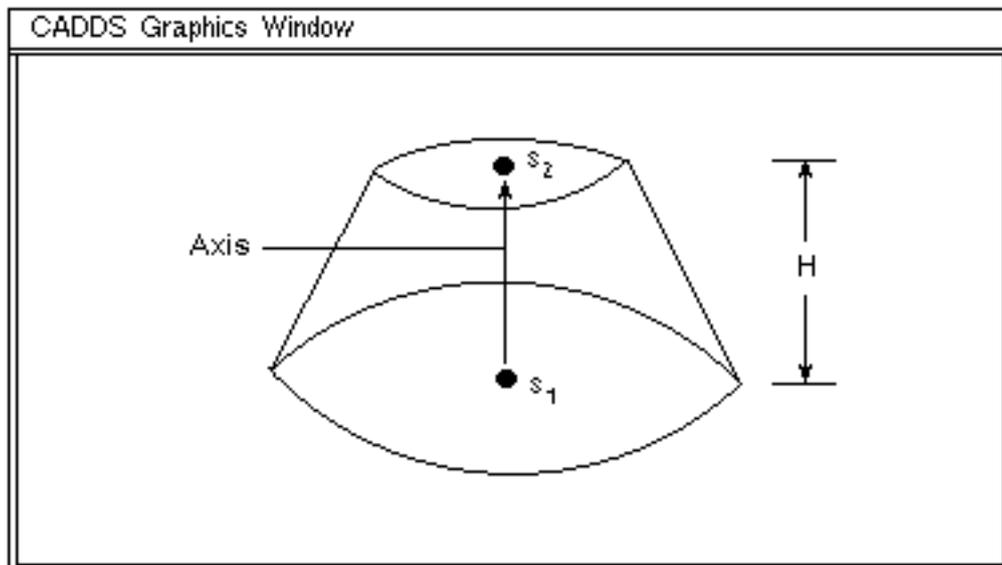
Suppose these two cross sections (S1 and S2) are the top and bottom cross sections of an arbitrary object.

Knowing the moments of S1 and S2 and the height of the object does not give you enough information to find the moments of the object, because the shape of the object between S1 and S2 is not defined.

Therefore, you must use an appropriate formula to find the moments of the object from the available information. In finding the volume and first moments of the object, you can assume that the area between S1 and S2 changes with the height like a cone, as follows:

$$r = k_1 + k_2 H$$

$$Area = k_3 r^2$$

In this formula, r is a fictitious radius and the ks are arbitrary constants. The above assumptions are exact for cones, pyramids, and other objects for which the square root of the cross-sectional area is proportional to the height (*H*).

From these assumptions, the volume enclosed by two cross sections is calculated as follows:

$$Vol = (H/3)(A1 + A1A2 + A2)$$

The first moments are given by:

$$F = VolCM1 + (H/12)(A1 + 3A2 + 2A1A2)(CM2CM1)$$

where *A*1, *A*2 are the areas of S1 and S2 and *CM*1, *CM*2 are the locations of the centroids of S1 and S2.

No similar formula exists for the second moments, which are therefore found by averaging the second moments of the projections of S1 and S2 along the vector joining *CM*1 and *CM*2, as follows:

$$Ixx = (H/2) \left[X^2 (A1 + A2)/3 + (F1x - F2x)X + I1xx + I2xx \right]$$

$$Iyy = (H/2) \left[Y^2 (A1 + A2)/3 + (F1y - F2y)Y + I1yy + I2yy \right]$$

$$Izz = (H/2) \left[(A1 + A2)/3 + (F1z - F2z)Z + I1zz + I2zz \right]$$

$$Ixy = (H/2[XY(A1 + A2)/3 + (F1y - F2y)(X/2) + (F1x - F2x)(Y/2) + I1xy + I2xy]$$

$$Ixz = (H/2)(XZ(A1 + A2)/3 + (F1z - F2z)(X/2) + (F1x - F2x)(Z/2) + I1xz + I2xz]$$

$$Iyz = (H/2[YZ(A1 + A2)/3 + (F1z - F2z)(Y/2) + (F1y - F2y)(Y/2) + I1yz + I2yz]$$

Here, *F*1 and *F*2 are the first moments of S1 and S2; I1 and I2 are the second moments of S1 and S2; and *X*, *Y*, and *Z* are the components of the vector from *CM*1 to *CM*2; that is,

$$CM2 - CM1 = Xi + Yj + Zk$$

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