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Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification —

Part 3: Output

Technologies de l'information — Infographie — Interfaces pour l'infographie — Spécifications fonctionnelles —

Partie 3: Sortie

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Contents

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 9636-3 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology.*

ISO/IEC 9636 consists of the following parts, under the general title *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification:*

— *Part 1: Overview, profiles, and conformance*
— *Part 2: Control*
— *Part 3: Output*
— *Part 4: Segments*
— *Part 5: Input and echoing*
— *Part 6: Raster*

Annexes A and B form an integral part of this part of ISO/IEC 9636. Annexes C , D, E, F, G, and H are for information only.

Introduction

This part of ISO/IEC 9636 describes the functions needed for generating and displaying graphical output.

The functional capability incorporated in this part of ISO/IEC 9636 is concerned with graphic primitives and their associated attributes, control over the graphic object output pipeline, and the rendering of graphic objects. It should at least be read in conjunction with the overview in ISO/IEC 9636-1, and the general control functions detailed in ISO/IEC 9636-2.

The functional capability described in this part of ISO/IEC 9636 applies to CGI Virtual Devices of class OUTPUT and OUTIN.

Information technology – Computer graphics – Interfacing techniques for dialogues with graphical devices (CGI) – Functional specification –

Part 3:
Output

1 Scope

This part of ISO/IEC 9636 establishes those functions of the Computer Graphics Interface concerned with output primitives and associated attributes and controls for creating graphical pictures.

This part of ISO/IEC 9636 is part 3 of ISO/IEC 9636, and should be read in conjunction with ISO/IEC 9636-1 and ISO/IEC 9636-2. The relationship of this part of ISO/IEC 9636 to the other parts of ISO/IEC 9636 is described in ISO/IEC 9636-1 and in clause 4.

The functionality described in this part of ISO/IEC 9636 pertains to OUTPUT and OUTIN classes of CGI Virtual Device.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO/IEC 9636. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO/IEC 9636 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 646 : 1983 *Information processing – ISO 7-bit coded character set for information interchange.*

ISO 2022 : 1986 *Information processing – ISO 7-bit and 8-bit coded character sets – Code extension techniques.*

ISO 8632-1 : 1987 *Information processing systems – Computer graphics – Metafile for the storage and transfer of picture description information (CGM) – Part 1: Functional specification.*

ISO/IEC 9541-1 : -[1)] *Information technology – Font information interchange – Part 1: Architecture.*

ISO/IEC 9541-2 : -[1)] *Information technology – Font information interchange – Part 2: Interchange format.*

ISO/IEC 9541-3 : -[1)] *Information technology – Font information interchange – Part 3: Glyph shape representation.*

ISO/IEC 9592-1 : 1989 *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 1: Functional description.*

ISO/IEC 9636-1 : 1991 *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification — Part 1: Overview, profiles, and conformance.*

ISO/IEC 9636-2 : 1991 *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification — Part 2: Control.*

ISO/IEC 9636-4 : 1991 *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification — Part 4: Segments.*

ISO/IEC 9636-5 : 1991 *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification — Part 5: Input and echoing.*

ISO/IEC 9636-6 : 1991 *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Functional specification — Part 6: Raster.*

ISO/IEC 9637-1 : -[1)] *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Data stream binding — Part 1: Character encoding.*

ISO/IEC 9637-2 : -[1)] *Information technology — Computer graphics — Interfacing techniques for dialogues with graphical devices (CGI) — Data stream binding — Part 2: Binary encoding.*

ISO/IEC TR 9973 : 1988 *Information processing — Procedures for registration of graphical items.*

1) To be published.

3 Concepts

3.1 Introduction

This part of ISO/IEC 9636 covers the device-independent graphic object output functionality of the CGI. It covers primitive functions, attributes, object formation and subsequent processing, and related control and inquiry functionality. This functionality is divided into the following areas:

- *Graphic primitive functions*, which describe the geometry of the components of a picture in the CGI.
- *Attribute functions*, which set modal values in state lists that are used to determine certain properties (including visual aspects) of these geometric picture components.
- *General attribute and output control functions*, which specify the modes of operation of certain other functions, control some aspects of the device's operation with respect to graphic objects and attribute functions, and which provide facilities for the construction of compound objects.
- *Retrieval function*, which returns information useful for the positioning of text objects.
- *Output inquiry functions*, which provide access to the description tables and state lists concerned with output and attributes.

3.2 General output concepts

3.2.1 Types of graphic primitive functions

The CGI defines graphic primitive functions for the specification of the geometry of the components of a picture.

These graphic primitive functions, grouped according to primitive type: line, marker, text, fill, and image, are as follows:

Line functions:	*Fill functions:*
POLYLINE	POLYGON
DISJOINT POLYLINE	POLYGON SET
CIRCULAR ARC 3 POINT	RECTANGLE
CIRCULAR ARC CENTRE	CIRCLE
CIRCULAR ARC CENTRE REVERSED	CIRCULAR ARC 3 POINT CLOSE
ELLIPTICAL ARC	CIRCULAR ARC CENTRE CLOSE
CONNECTING EDGE	ELLIPSE
	ELLIPTICAL ARC CLOSE
Marker function:	*Text functions:*
POLYMARKER	TEXT
	APPEND TEXT
	RESTRICTED TEXT
Image function:	*Generalized drawing primitive function:*
CELL ARRAY	GENERALIZED DRAWING PRIMITIVE (GDP)

NOTE – GDP does not have an explicit primitive type, but rather an instance of GDP may generate a primitive of one of the above primitive types depending on the specific GDP identifier.

See ISO/IEC 9636-1, 5.2.1 for an overall description of graphic primitives in relationship to the CGI Graphic Object Pipeline.

3.2.2 Attributes and controls

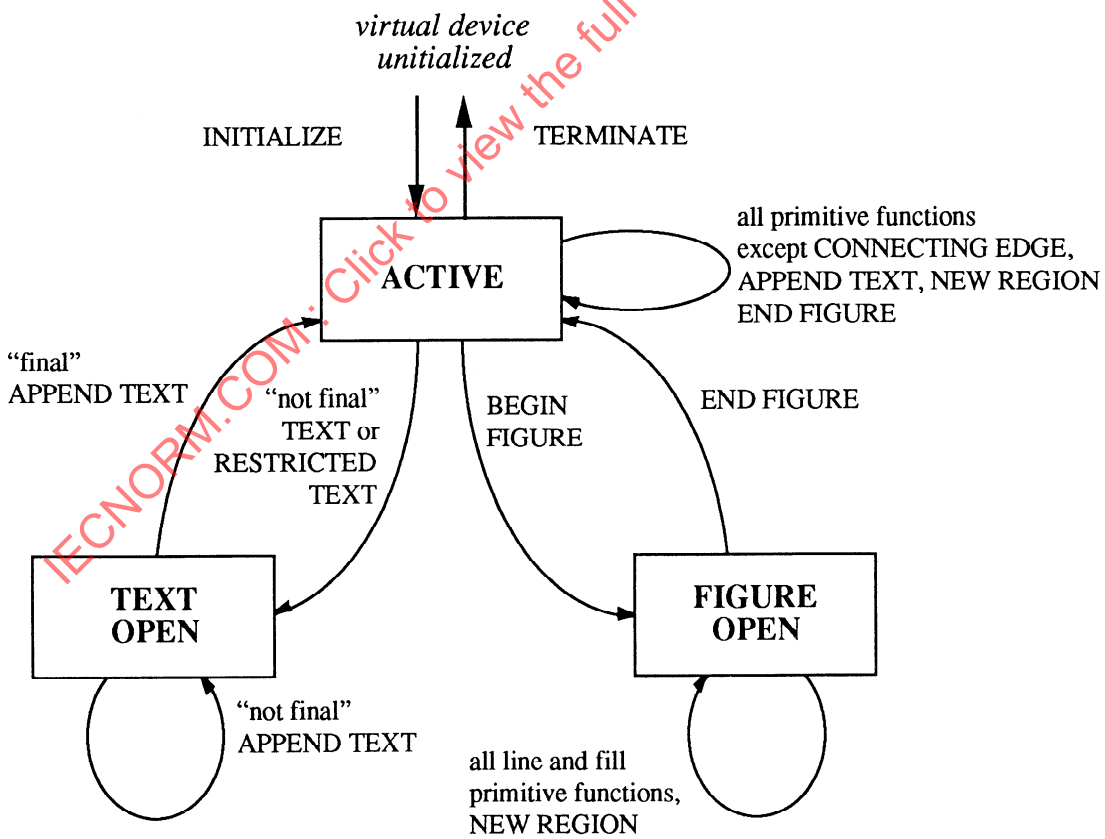
Primitives have attribute values associated with them as they pass through the Graphic Object Pipeline. Once a set of attribute values has been associated with a primitive the complete entity is referred to as a graphic object. Some of these attribute values determine the appearance of primitives when they are rendered as graphic objects. See ISO/IEC 9636-1, 5.2.1 for an overview of where attribute values are associated and used within the Graphic Object Pipeline.

Control functions are also defined in this part of ISO/IEC 9636 and provide control over other operations of the Graphic Object Pipeline, e.g. colour table. Some of these control functions also set corresponding entries in CGI state lists, but these control values are not associated with graphic primitives.

3.2.3 Output states

The Output State entry in the General Attributes and Output Control State List applies to the functions defined in this part of ISO/IEC 9636. The Output State may have only one of the values ACTIVE, TEXT OPEN, or FIGURE OPEN, the normal state being ACTIVE. It is set to state TEXT OPEN during the construction of a compound text object and to state FIGURE OPEN during the construction of a closed figure object. Figure 1 illustrates the output states of this part of ISO/IEC 9636 and indicates which functions result in a state transition.

State restrictions are defined in Output State TEXT OPEN for all primitive functions which do not contribute to compound text (see table 2). In particular, in Output State TEXT OPEN, all graphic primitive functions except APPEND TEXT are prohibited. Similarly, in Output State FIGURE OPEN, primitive functions which do not contribute to the construction of closed figures (i.e. all but line and fill type primitives) are prohibited (see table 3). In Output State ACTIVE, primitive functions which are relevant only in the state TEXT OPEN and FIGURE OPEN are prohibited (see table 1). There are no state restrictions applicable to attribute setting functions in any of these states.



NOTE – Whether or not a particular GDP is allowed in any of the output states is dependent on the specification of the GDP and its defined effect on the Output State entry in the General Attributes and Output Control State List.

Figure 1 – Output state diagram (for primitive functions)

Table 1 – Functions Not Allowed in Output State ACTIVE

APPEND TEXT	CONNECTING EDGE
END FIGURE	NEW REGION

Table 2 – Functions Not Allowed in Output State TEXT OPEN

POLYLINE	CIRCULAR ARC CENTRE
DISJOINT POLYLINE	CIRCULAR ARC CENTRE REVERSED
CIRCULAR ARC 3 POINT	ELLIPTICAL ARC
CONNECTING EDGE	
POLYGON	CIRCULAR ARC 3 POINT CLOSE
POLYGON SET	CIRCULAR ARC CENTRE CLOSE
RECTANGLE	ELLIPSE
CIRCLE	ELLIPTICAL ARC CLOSE
BEGIN FIGURE	END FIGURE
NEW REGION	
TEXT	RESTRICTED TEXT
POLYMARKER	CELL ARRAY

Table 3 – Functions Not Allowed in Output State FIGURE OPEN

TEXT	POLYMARKER
RESTRICTED TEXT	CELL ARRAY
APPEND TEXT	BEGIN FIGURE

3.3 Individual and bundled attribute values

3.3.1 Introduction

The appearance of a graphic object is determined by a number of attribute values associated with the object. These attribute values control both the geometric and non-geometric aspects of the object. In addition, there is an attribute value which is used to identify an object or group of objects in a segment (see ISO/IEC 9636-4 for the definition of pick identifier).

These attribute values are set modally and have entries in primitive type specific state lists. Individual specification of these attributes is provided by separately defined CGI functions. A subsequent change of the state list entry for an attribute will not affect the value associated with any existing graphic objects. Attribute values associated from such state list entries are referred to as individual attribute values.

Some attribute values may, in addition to this modal specification, be grouped into bundle entries in various bundle tables. Bundle tables are defined for line, marker, text, fill, and edge. A particular bundle entry can be selected for use with an object via a bundle index attribute. There is a bundle index attribute value for each primitive type (with the exception of the image type).

Whether the value for a particular attribute is a directly associated modal value or whether it is indirectly referenced by means of a bundle index attribute value and subsequently obtained from the referenced bundle is determined by a further set of attributes, called aspect source flags (ASFs). Each ASF may take either the value INDIVIDUAL or BUNDLED and allows the distinction to be made for each of the attribute values which may be bundled.

A number of bundles are predefined when the CGI Virtual Device is initialized. Each such predefined bundle shall be visually distinguishable from that of the other predefined bundles for a given primitive type when all aspect source flags are BUNDLED. These and other bundles may subsequently be redefined by the client. Bundles may be deleted by the client. However, the predefined bundle with index 1 cannot be deleted.

If the values of a bundle are changed and that bundle is already in use, a modification of the rendered picture may result. Whether such modification of the rendered picture occurs immediately on execution of the changing function or at some later time is determined by the Implicit Segment Regeneration Mode (see ISO/IEC 9636-4) and is dependent on whether the Virtual Device has segment capabilities. The Dynamic Modification Accepted For entries in the output description tables of an implementation indicate which changes may be performed immediately or may lead to subsequent regeneration.

3.3.2 Modes of attribute specification and selection

In CGI state lists, the values for attributes controlled by specification or selection modes are stored in the mode in which they were last specified (or the mode corresponding to the default value) along with the value of the corresponding mode. The corresponding attributes in the bundle tables are also stored in the mode in which they were specified, along with the specification mode. When the attribute value is associated with a primitive, during object formation, the mode in which it was set is also associated. The stored mode acts as a data type identification, and is used for that purpose in the inquiry functions based on the state list. These stored values are thereafter independent of the current specification or selection mode on the General Attributes and Output Control State List.

3.4 Colour

3.4.1 Direct and indexed modes

The CGI provides two mechanisms for colour selection:

- Direct, in which the colour is defined by providing values for the normalized weights of the RGB components, and
- Indexed, in which the colour is defined by an index into a table of colour values.

Selection of one of these mechanisms may be achieved using the function COLOUR SELECTION MODE. It is possible to have both direct and indexed colour in use simultaneously in the same picture on devices which implement direct colour selection for object colour attributes.

3.4.1.1 Direct colour and COLOUR VALUE EXTENT

For direct colour specification, the CGI uses the RGB additive colour model. Each colour specifier is a three-tuple of values providing the normalized weight of the red, green, and blue components of the desired colour.

The integer components of a client specified CD value are normalized to a three-tuple of abstract RGB colour values, each of which is a real number in the range [0.0, 1.0]. The normalization also has the property that any 3-tuple with 3 identical components, (x,x,x), represents equal weights of the red, green, and blue components. For any given component, one end of the range (0.0) indicates that none of that component is included, and the other end (1.0) indicates that the maximum intensity of that component is included in the colour, with an infinite number of component values in between. (0,0,0) thus represents black, (1,1,1) represents white, and (x,x,x) with x between 0 and 1 represents a grey.

The abstract minimum colour value of (0,0,0) is represented by (min_red, min_green, min_blue) and the abstract maximum colour value of (1,1,1) is represented by (max_red, max_green, max_blue). These minimum and maximum values are specified with the COLOUR VALUE EXTENT function which defines a linear mapping of these values onto the device's abstract colour range.

Although CGI supports only the RGB colour model, it provides entries in the Output Control Description Table for constants which are necessary for conversion of colour values between the CIE colour model and RGB colour model. A client may inquire these values and use them in performing the colour model conversion. (See ISO/IEC 9592-1, annex I.)

3.4.1.2 Indexed colour and COLOUR TABLE

The colour table used with indexed colour selection is a contiguous set of colour values indexed from the range [0, colour table size - 1]. It is initialized in the following manner: index 0 contains an implementation-dependent background colour; index 1 and greater contain implementation-dependent foreground colours. The COLOUR TABLE function is provided for changing the contents of the colour table by specifying the colour by RGB values as described above. The COLOUR TABLE function may be used at various times throughout the specification of a picture. However, whether changes in the colour table

affect the appearance of any rendered graphic objects that use the affected indices is indicated by the Dynamic Modification Accepted For Colour Table entry in the Output Control Description Table.

3.4.1.3 Gamma correction

There is no gamma correction nor specification of the source colours implied for the tri-stimulus values for direct colour specification. This degree of control over colour may be available on an implementation-dependent basis through the use of ESCAPE functions.

3.4.1.4 Colour and monochromatic devices

All devices capable of displaying output are considered to have at least two colours – the background and the foreground. The drawing medium will always count as one colour for the Number of Simultaneously Available Direct Colours, Number of Simultaneously Available Indexed Colours, and Number of Available Colours entries in the Output Description Table. Therefore, none of the colour counts may be less than two.

Interpretation of the Number of Simultaneously Available Direct Colours or the Number of Simultaneously Available Indexed Colours, when either is greater than two, depends on whether the device is monochromatic. If the Monochromatic Device entry in the Output Control Description Table is NO, then the device is capable of rendering at least two different foreground colours (varying in either hue or saturation) but not differing exclusively in intensity (such as light green, dark green). If the Monochromatic Device entry is YES, then the interpretation of the Number of Simultaneously Available Direct Colours when colour selection mode is DIRECT and the Number of Simultaneously Available Indexed Colours when colour selection mode is INDEXED is taken to mean the number of steps in a single colour intensity scale whose low value is closest to the default background colour (or drawing medium for those devices without background colour capability) and whose high value has maximum contrast relative to the default background colour.

3.4.1.5 Transparency and auxiliary colour

Various graphic primitives have "holes" which may or may not be rendered. Examples of such "holes" include gaps in dashed lines or edges, the background of a character cell, and the spaces between lines in a hatched fill primitive.

Two of the general attributes which are associated with graphic primitives as they enter the graphic object pipeline are TRANSPARENCY and AUXILIARY COLOUR. The associated TRANSPARENCY attribute value determines whether the drawing of the "holes" occurs. If this attribute value is TRANSPARENT, those portions of the object which are considered to be "holes" will not be drawn; hence, potentially affected portions of the graphic picture remain unchanged. If this attribute value is OPAQUE, those portions of the object which are considered to be "holes" will be drawn; hence, affected portions of the graphic picture will be modified. The associated AUXILIARY COLOUR attribute value is used in determining the colour of the "holes". The DRAWING MODE attribute associated with the object is not applied (see 3.4.1.6) until after the application of TRANSPARENCY and AUXILIARY COLOUR.

When TRANSPARENCY is OPAQUE, non-solid (e.g. dot-dash) lines or edges, text, and hatched interiors for fill objects are rendered as two separate point sets in abstract DC space: one with the normal associated colour attribute values and the other with the associated auxiliary colour attribute value.

3.4.1.6 Overwrite capability, colour realization, and DRAWING MODE

Due to inherent technology differences, the physical devices used as the display for CGI Virtual Devices differ in their behaviour when something is rendered in the same physical location on the drawing surface as previously rendered output or displayed on the display surface at the same location as previously displayed output.

Raster technology devices can overwrite the contents of the drawing surface, so that each object rendered "in front of" previously rendered ones (see the lower right-hand picture shown in figure 2). Vector devices cannot usually do this: the Colour Overwrite entry in the Output Control Description Table indicates whether the Virtual Device has this capability.

Output rendered on the drawing surface will ultimately be displayed on the display surface; it may be mixed additively or subtractively on the display surface with which previously displayed output (see the lower left-hand picture shown in figure 2). The Colour Realization entry in the Output Control Description Table indicates which colour mixing is used.

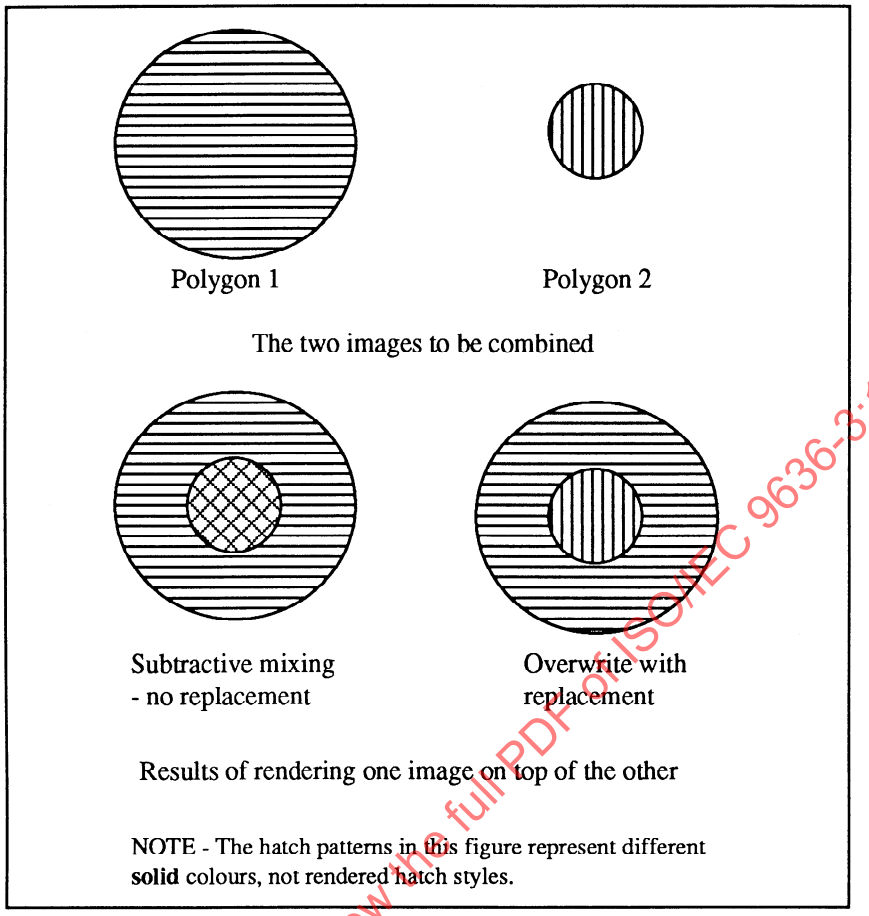


Figure 2 – Overwrite capability

Device offering functionality defined in ISO/IEC 9636-6 provide an additional means of controlling colour mixing on the drawing surface – the drawing mode. For these devices, the Colour Overwrite Capability is typically YES, and hence the DRAWING MODE function fully controls the colour mixing on the drawing surface.

3.4.2 Background colour

The drawing surface is set to the background colour by PREPARE DRAWING SURFACE or by a regeneration prior to any rendering. The CGI provides several ways of specifying the background colour. The implemented ways are indicated by the Background Colour Capability entry in the Output Control Description Table.

Four levels of background colour capability are defined, as follows:

NONE: The device is not capable of changing the background colour, e.g. this is a property of the media on which the picture is drawn. (In this case, the BACKGROUND COLOUR function need not be provided.)

INDEX 0: The device has a background colour which is always associated with colour index 0. Changing the setting of colour table entry 0 will perform the desired change. (In this case, the BACKGROUND COLOUR function need not be provided.)

INDEXED: The device has a background colour which is always associated with a colour index, which can be changed by the client. In this case, the BACKGROUND COLOUR function which accepts only CI values shall be provided. The default colour index for background colour is 0.

FULL: The device has the capability of using either an indexed colour for background colour or a direct colour which is not associated with any colour table entry. In this case, the BACKGROUND COLOUR function

with full support of the CO data type shall be provided. The default is specified in INDEXED mode with value 0.

3.5 Graphic objects

This part of ISO/IEC 9636 defines the functions which create graphic primitives in the Graphic Object Pipeline. A graphic primitive becomes a graphic object when the appropriate attribute values are associated with the primitive. Graphic objects are passed down the Graphic Object Pipeline for further refinement, storage, and rendering.

An outline of this process is given in ISO/IEC 9636-1, 5.2.1. The following sub-clauses provide further details of this process.

3.5.1 Compound objects

In addition to the graphic primitive functions listed in 3.2.1, this part of ISO/IEC 9636 defines functions that provide a client of the CGI with means to create compound objects from several of the other graphic primitives. The following classes of compound object are defined: compound text and closed figures. The functions that may be used to specify compound objects are listed in table 4.

Table 4 – Contributing Primitives to Compound Objects

Object Class	Initiating Function	Functions allowed in open state	Other Functions	Closing Function
Compound Text	TEXT (Note 1) RESTRICTED TEXT (Note 1) GDP (Note 4)	APPEND TEXT GDP (Note 4)		APPEND TEXT (Note 2) GDP (Note 4)
Closed Figure	BEGIN FIGURE	Line Functions Fill Functions (Note 3) GDP (Note 4)	NEW REGION	END FIGURE

NOTES

1) Final/not-final flag is NOT FINAL; the primitive defines the reference point of the entire compound text object; the text primitive is entered in the text buffer.
2) Final/not-final flag is FINAL; the text primitive is entered in the text buffer before the compound text object is closed.
3) All primitives of the identified primitive types may be included.
4) Whether a GDP may contribute to compound text or closed figures, and how it interacts with the Output State is specified with the definition of the GDP in the International Register of Graphical Items or in the implementation documentation.

3.5.2 Global and local attributes

For the purposes of compound object formation, a further classification of attributes into either global or local attributes is introduced.

Global attributes are those whose values are associated with a completed compound object (e.g. fill colour, drawing mode). Global attributes apply to a compound object as a whole.

Local attributes are those whose values are separately associated with the graphic primitives that make up a compound object (e.g. text colour, edge type, drawing mode). Local attributes apply separately to the component graphic primitives of a compound object.

3.5.3 Detail of graphic object formation

In ISO/IEC 9636-1, 5.2.1 the formation of graphic objects is described as occurring in a single step. This subclause further defines the details of this formation to include the formation of compound graphic objects (see figure 3).

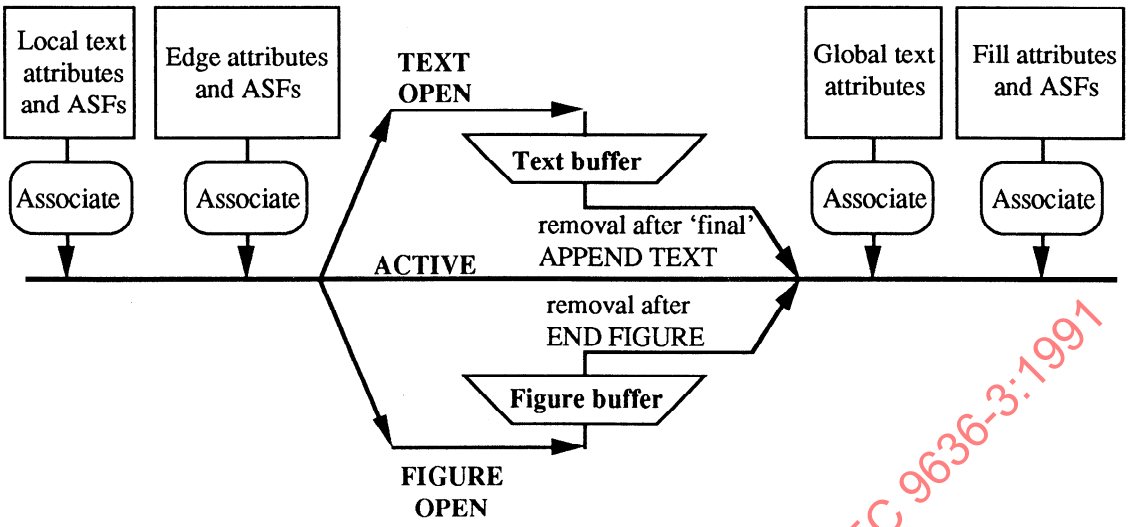


Figure 3 – Detail of the graphic object pipeline for compound objects

While a compound object is being formed, graphic primitives have their local attribute values associated and are then conceptually stored in an intermediate buffer. When the function that closes the compound object is executed, the contents of the intermediate buffer are combined and the graphic object is completed by association of the relevant global attribute values.

The process of compound object formation is not affected by, and does not itself affect, any process further down the pipeline defined in ISO/IEC 9636-1, 5.2.1.

3.6 Clipping associated with graphic objects

The general attribute values, CLIP RECTANGLE and CLIP INDICATOR, along with any applicable object clipping mode attribute values, are associated with a primitive as it enters the Graphic Object Pipeline. These attribute values control the subsequent form of clipping applied to the graphic object. The CLIP RECTANGLE is associated as the clip region.

If the CLIP INDICATOR is OFF, the effective clip region is the VDC range. If the CLIP INDICATOR is ON, the effective clip region is the intersection of the clip region associated with the graphic object and the VDC extent.

There are three different object clipping modes which specifically apply to lines, markers, and edges. These are maintained in CGI state lists and are manipulated by means of the functions LINE CLIPPING MODE, EDGE CLIPPING MODE, and MARKER CLIPPING MODE. When the CLIP INDICATOR associated with a graphic object is ON, only those parts of a graphic object that are considered inside the effective clip region are rendered. The object clipping modes allow the client to be more precise in how clipping is applied to graphic objects.

An object clipping mode may be either LOCUS, SHAPE, or LOCUS THEN SHAPE. Conceptually, a locus is a mathematical object like a point or line segment, while a shape is an area in two-dimensional space. Loci are zero-dimensional or one-dimensional subsets of real-valued two-dimensional space. For markers and text, they are points. For lines, they are the individual line segments or portions of arcs. Shapes reflect the realization of geometric attributes such as LINE TYPE and LINE WIDTH and are generally two-dimensional subsets of real-valued space.

When a width or size specification mode is SCALED, the rendering of shape proceeds in DC space after application of the VDC-to-Device Mapping. When a width or size specification mode is VDC, the abstract rendering of shape proceeds in VDC space before application of segment and copy transformations and the VDC-to-Device Mapping. This abstract shape is then transformed point by point and mapped to DC space for shape clipping.

The effect of each object clipping mode is as follows:

- LOCUS clipping is applied for each portion of a graphic object based on its mathematical location and is independent of the area it will occupy after rendering. For example, no portion of a line segment is rendered if the entire ideal mathematical line segment lies outside the effective clip region (even if its line width would carry some portion of the rendering of it into the effective clip region). No portion of a marker is rendered if its location point lies outside the effective clip region.

If LOCUS clipping is used, the rendering is applied to the clipped locus of the graphic object. The resulting rendered shape areas may therefore extend outside the effective clip region.

- SHAPE clipping is applied after the abstract rendering of shape in real DC space. The two-dimensional point set associated with the graphic object is intersected with the effective clip region, which has been transformed to abstract DC space.
- LOCUS THEN SHAPE clipping allows the client to specify that both LOCUS and SHAPE clipping be applied to graphic objects as described above. In this case, the rendered shape will not extend outside the effective clip region.

Fill, text, and image objects do not have associated object clipping mode values (although the edge of a fill object does). Clipping for fill and image objects is always consistent with SHAPE clipping.

For text objects, the type of clipping is determined by the associated text precision value:

- For STRING precision text, clipping may proceed, on a per string basis, in a manner consistent with LOCUS clipping.
- For CHARACTER precision text, clipping may proceed, on a per character basis, in a manner consistent with LOCUS clipping.
- For STROKE precision text, the clipping always proceeds in a manner consistent with SHAPE clipping.

Note that a Virtual Device is always allowed by ISO/IEC 9636 to use SHAPE clipping for any text precision.

Drawing Surface Clipping (see ISO/IEC 9636-2, 3.3.7) applies to all types of graphic objects. The drawing surface clipping always corresponds to SHAPE clipping, as described above.

3.6.1 Rendering pipelines for clipping

Figure 4 illustrates the effect that object clipping modes and specification modes have on the Graphic Object Pipeline presented in ISO/IEC 9636-1. Any conceptual changes to the pipeline apply on a per object basis; that is, each object passing down the pipeline may have different clipping modes and specification modes and therefore apparently traverse a different variation of the pipeline.

Conceptually, the object clipping modes determine the presence or absence within the pipeline of the *Apply Locus Clipping* and *Apply Shape Clipping* operations. For LOCUS THEN SHAPE clipping, both operations are present. For LOCUS clipping, only the *Apply Locus Clipping* operation is present. For SHAPE clipping, only the *Apply Shape Clipping* operation is present.

The effect of the width and size specification modes for lines, markers, and edges on the pipeline is dependent also on the corresponding clipping modes.

If the specification mode is VDC, the operation *Render Shape* takes place prior to the application of the associated transformation and the VDC-to-Device Mapping so that the VDC specification of the shape is properly transformed and mapped to device coordinates. In addition, if the object clipping mode is one of LOCUS or LOCUS THEN SHAPE, the transformed and clipped locus of a graphic object is transformed by the inverse associated transformation in order that the *Render Shape* operation is applied correctly. The associated transformation is then applied to the rendered shape of the object.

The combination VDC/SHAPE also applies to fill, text, and, image objects.

If the specification mode is SCALED, the operation *Render Shape* takes place following the application of the VDC-to-Device Mapping. In this case, when the object clipping mode includes LOCUS, the associated transformation is only applied once.

VDC sizes will change proportionally with the size of the device viewport (assuming that the VDC extent remains unchanged). VDC sizes are also affected by the copy and segment transformations. For SCALED sizes, the size remains fixed with respect to the drawing surface.

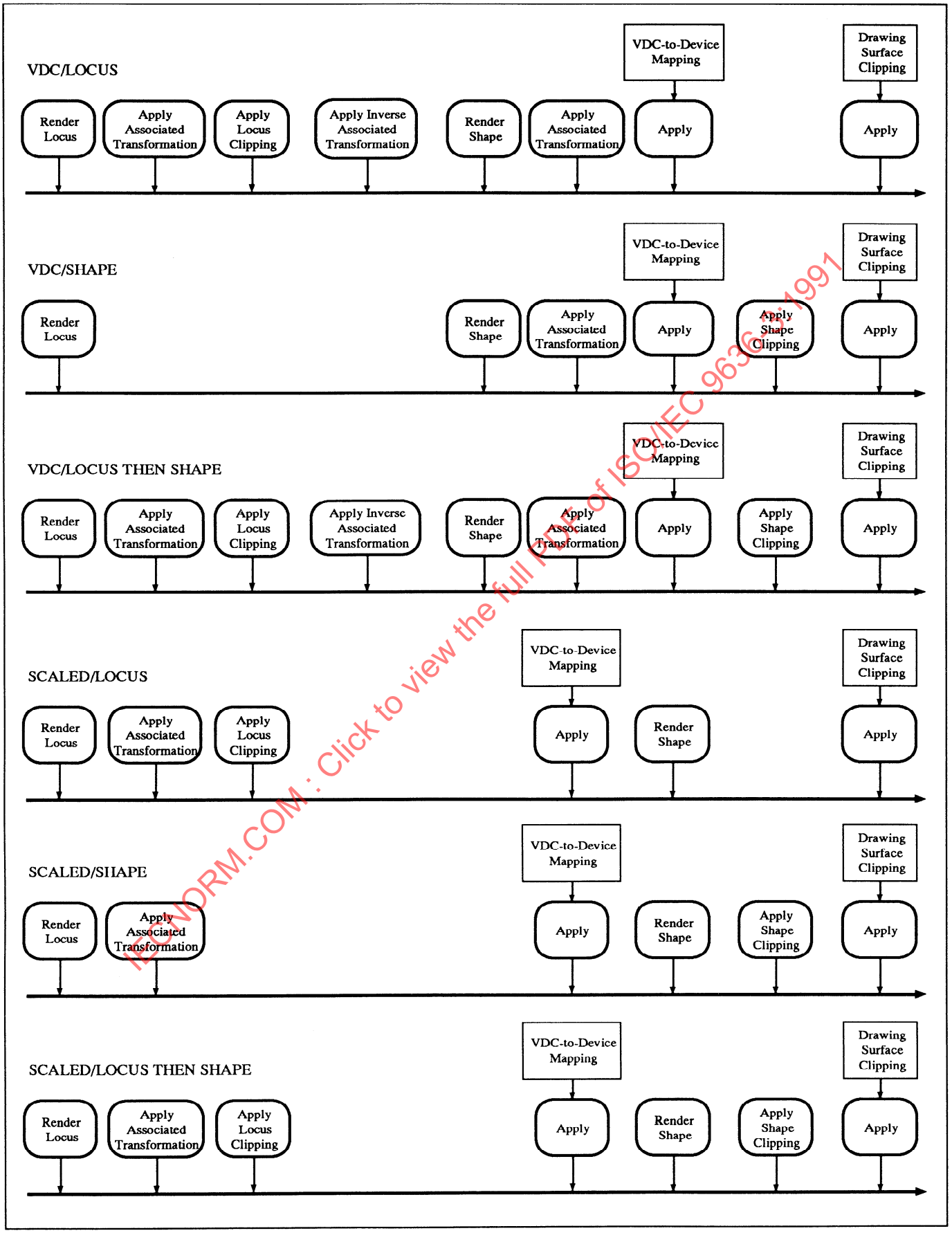


Figure 4 – Rendering pipelines for size specification mode/clipping mode combinations

3.7 Line primitives

3.7.1 Line functions

The CGI defines two general line functions, several line functions relating to circles and ellipses which generate line primitives, and a special line function which generates a line primitive that is only used within the FIGURE OPEN state.

POLYLINE — generates a set of connected straight line segments defined by a list of points, starting with the first point, drawing a line segment to each successive point, ending at the last point;

DISJOINT POLYLINE — generates a set of unconnected straight line segment defined by a list of point pairs, drawing from the first to the second, the third to the fourth, etc.;

CIRCULAR ARC CENTRE
CIRCULAR ARC CENTRE REVERSED
CIRCULAR ARC 3 POINT — these functions each generate a single circular arc; but provide alternative parameterizations of the arc; they are described in 5.2 (and in annex D);

ELLIPTICAL ARC — generates a single elliptical arc; the parameterization of the arc is described in 5.2 (and in annex D);

CONNECTING EDGE — used only in closed figure construction, this special line function adds an edge portion and an explicit boundary portion to the closed figure – it effectively converts what would have been the next implicit boundary portion to an explicit boundary portion. See 3.10.5.

3.7.2 Line attributes

The appearance of line primitives is described by specific line attributes and other general attributes.

LINE TYPE — determines the type of line (e.g. solid, dotted, or dashed), with which the shape of a line object is rendered;

SPECIFICATION MODE OF LINE WIDTH — determines whether the line width attribute value is interpreted as a DC scaling factor or a VDC width during rendering; see 3.7.3;

LINE WIDTH — determines the width of line with which the shape of a line object is rendered;

LINE COLOUR — determines the colour with which a line object is rendered. The colour selection mode in which the line colour was specified determines whether the LINE COLOUR attribute value is interpreted as a direct or indexed colour value during rendering. See 3.4 for a description of how colours are defined in the CGI;

LINE CLIPPING MODE — determines the type of object clipping to be performed during rendering; see 3.7.4;

LINE BUNDLE INDEX — determines the line bundle to be used during rendering when the corresponding line ASF attribute values are BUNDLED. The following line attribute values may be bundled: LINE TYPE, LINE WIDTH, and LINE COLOUR;

Line ASFs — determine which attribute values of the line bundle referenced by the LINE BUNDLE INDEX attribute are to be used during rendering when the corresponding ASF attribute value is BUNDLED. The following line ASFs are defined: LINE TYPE ASF, LINE WIDTH ASF, and LINE COLOUR ASF.

3.7.2.1 General attributes

CLIP INDICATOR — determines whether object clipping is to be applied to the line object;

CLIP RECTANGLE — used in determining the effective clip region to be applied to a line object if the associated CLIP INDICATOR is ON;

AUXILIARY COLOUR	determines the colour to render the gaps in a line for line types other than solid, if the TRANSPARENCY attribute value is OPAQUE. The colour selection mode in which the auxiliary colour was specified determines whether the AUXILIARY COLOUR attribute value is interpreted as a direct or indexed colour value during rendering;
TRANSPARENCY	determines whether gaps in the shape of a broken line type are rendered using the AUXILIARY COLOUR attribute value. If the TRANSPARENCY attribute value is TRANSPARENT, any previously drawn parts of the picture are unaffected in line gaps;
DRAWING MODE	determines how the rendered (and rastered) object is mixed with what already exists on the drawing surface (defined in ISO/IEC 9636-6);
PICK IDENTIFIER	(defined in ISO/IEC 9636-4).

3.7.3 Line geometry

The width of a line is determined by the LINE WIDTH attribute value. The LINE WIDTH attribute value is interpreted using the line width specification mode, which can take one of two values, SCALED or VDC. If the specification mode is SCALED, the width is interpreted as the nominal device-dependent line width multiplied by the given LINE WIDTH attribute value; thus, the line width is not affected by any transformations. If the specification mode is VDC, the width is interpreted in VDC units and is subject to segment and copy transformations and the VDC-to-Device Mapping; these transformations and the VDC-to-Device Mapping are applied after the abstract rendering of VDC line width and line type in VDC space.

3.7.3.1 Degeneracy of line objects

Degeneracy of line objects may arise either due to the client's specifications or unintentionally due to round-off error in transforming coordinate data.

If the Virtual Device cannot render a line of the exact specified width, the closest implemented width will be used. When line width is specified in VDC, then if, after its transformation to device coordinates, the resulting width is less than the Minimum Scaled Line Width, the Minimum Scaled Line Width is used; if the resulting width is greater than the Maximum Scaled Line Width, the Maximum Scaled Line Width is used. In general, if the abstract rendering of the locus of a line primitive degenerates to a zero-dimensional point set, at least a dot shall be rendered.

There are several ways in which an arc may degenerate. A circular arc 3 point or elliptical arc is non-degenerate if and only if the three specifying points are non-collinear. If the three points are all coincident, a dot is rendered. If the three points are collinear, the circular arc has zero curvature and a line is rendered from the starting point through the intermediate point to the ending point. If the points specifying an elliptical arc are collinear, an implementation-dependent straight line is rendered.

A circular arc with a radius of zero is rendered as a dot.

3.7.4 Line clipping

Line object clipping is controlled by the LINE CLIPPING MODE attribute, which can have one of three possible values: LOCUS, SHAPE, or LOCUS THEN SHAPE. However, object clipping only applies if the associated CLIP INDICATOR attribute is ON.

For LOCUS clipping, the mathematical locus of the line is clipped at its intersection with the effective clip region associated with the graphic object before shape rendering is applied. Hence, part of the shape of a line may appear outside the effective clip region.

For SHAPE clipping, the shape of the rendered line is clipped at its intersection with the effective clip region (i.e. nothing is drawn outside the effective clip region).

For LOCUS THEN SHAPE clipping, the mathematical locus of the line is clipped as with locus clipping, and then subsequently the rendered shape of the clipped locus is again clipped. Note that since the mathematical locus of the line may have changed as a result of locus clipping, subsequent shape rendering and clipping may produce a different appearance in a line from either of the other two clipping modes.

3.7.5 Allowed latitude

The following levels of Line Type Continuity are permitted for a CGI Virtual Device: RESTART, CONTINUOUS, and OTHER. The implemented level of support is indicated by the Line/Edge Type Continuity Capability entry in the Primitive Support Description Table.

- A level of RESTART indicates that the line type pattern is restarted at each vertex of a line object except for the last vertex;
- A level of CONTINUOUS indicates that the Virtual Device maintains the line type continuously across all vertices of a single line object except for the first and last vertices;
- A level of OTHER indicates that another method has been used (for example, guaranteeing some continuity and that end points of each line segment of line object are always drawn).

The preferred behaviour is CONTINUOUS.

3.8 Marker primitive

3.8.1 Marker function

The CGI provides a single marker function which generates a marker primitive:

POLYMARKER generates a symbol of a specific type at each point specified in a list of points.

3.8.2 Marker attributes

The appearance of marker primitives is described by specific marker attributes and other general attributes.

MARKER TYPE determines the type of marker (e.g. dot, plus, or asterisk), with which a marker object is rendered;

SPECIFICATION MODE OF MARKER SIZE determines whether the marker size attribute value is interpreted as a scaling factor or a VDC size during rendering. See 3.8.3;

MARKER SIZE determines the size of markers with which a marker object is rendered;

MARKER COLOUR determines the colour with which a marker object is rendered. The colour selection mode in which the marker colour was specified determines whether the MARKER COLOUR attribute value is interpreted as a direct or indexed colour value during rendering. See 3.4 for a description of how colours are defined in the CGI;

MARKER CLIPPING MODE determines the type of object clipping to be performed during rendering; see 3.8.4;

MARKER BUNDLE INDEX determines the marker bundle to be used during rendering when the corresponding marker ASF values are BUNDLED. The following marker attribute values may be bundled: MARKER TYPE, MARKER SIZE, and MARKER COLOUR;

Marker ASFs determine which attribute values of the marker bundle referenced by the MARKER BUNDLE INDEX attribute are to be used during rendering when the corresponding ASF attribute value is BUNDLED. The following marker ASFs are defined: MARKER TYPE ASF, MARKER SIZE ASF, and MARKER COLOUR ASF.

3.8.2.1 General attributes

CLIP INDICATOR determines whether object clipping is to be applied to the marker object;

CLIP RECTANGLE used in determining the effective clip region to be applied to a marker object if the associated CLIP INDICATOR is ON;

AUXILIARY COLOUR determines the colour to render the portions of a marker object, other than the foreground of a marker glyph, if the TRANSPARENCY attribute value is OPAQUE. The colour selection

	mode in which the auxiliary colour was specified determines whether the AUXILIARY COLOUR attribute value is interpreted as a direct or indexed colour value during rendering;
TRANSPARENCY	determines whether the portions of a marker object, other than the foreground of a marker glyph, are rendered using the AUXILIARY COLOUR attribute. If the TRANSPARENCY attribute value is TRANSPARENT, any previously drawn parts of the picture are unaffected by these portions of a marker object;
DRAWING MODE	determines how the rendered (and rastered) object is mixed with what already exists on the drawing surface (defined in ISO/IEC 9636-6);
PICK IDENTIFIER	(defined in ISO/IEC 9636-4).

3.8.3 Marker geometry

The locus of a marker is defined to be the single point which positions it. The rendering of the marker relative to its locus, which extends in two-dimensional space, is its shape.

The size of a marker is determined by the MARKER SIZE attribute value. The MARKER SIZE attribute value is interpreted using one of two specification modes, SCALED or VDC. If the specification mode is SCALED, the size is interpreted as the nominal device-dependent marker size multiplied by the given marker size attribute value; hence, the marker size is not affected by any transformations. If the specification mode is VDC, the size is interpreted in VDC units and is subject to segment and copy transformations and the VDC-to-Device Mapping.

The shape of markers is never affected by transformations (e.g. a circle used as a marker type shall always appear as a circle when rendered). Only the marker size (except in the case of marker type 1 (dot)) may be transformed. The transformation of marker size may be described as follows: consider the ratio of the length of a vector after transformation to its length before; choose a vector which maximizes this ratio. The resulting ratio is the Euclidean norm of the (2 x 2) transformation matrix. This ratio is used to scale the marker.

3.8.3.1 Degeneracy of marker objects

Degeneracy of marker objects may arise either due to the client's specifications or unintentionally due to round-off error in transforming coordinate data.

If the Virtual Device cannot render a marker of the exact specified size, the closest available size shall be used.

3.8.4 Marker clipping

Marker object clipping is controlled by the MARKER CLIPPING MODE attribute, which can have one of three possible values: LOCUS, SHAPE, or LOCUS THEN SHAPE. However, object clipping only applies if the associated CLIP INDICATOR attribute value is ON.

For LOCUS clipping, the mathematical loci of the markers (i.e. the defining points) are clipped at the intersection with the effective clip region associated with the graphic object before shape rendering is applied. Hence, part of the shape of a marker may appear outside the effective clip region. No portion of a marker symbol is rendered if its defining point lies outside of the effective clip region.

For SHAPE clipping, the shape of the rendered marker symbols is clipped at the intersection with the effective clip region (i.e. nothing is drawn outside the effective clip region). Portions of a marker symbol may appear inside the effective clip region even though that symbol's locating point is outside.

For LOCUS THEN SHAPE clipping, the mathematical loci of the markers are clipped as with locus clipping, and then subsequently the rendered shapes of the markers are again clipped as in SHAPE clipping to assure no portion of a marker shape is rendered outside the effective clip region.

3.9 Text primitives

3.9.1 Text functions

Text display in the CGI is produced by either a "simple" or "compound" text object. A compound text object is one that requires several text primitives to fully specify and is aligned and displayed as a single unit. The CGI provides the following text functions:

TEXT	generates a text primitive (which may begin a compound text object) aligned to a particular point;
RESTRICTED TEXT	generates a text primitive (which may begin a compound text object) aligned to a particular point and constrained within a given area specified as a parallelogram;
APPEND TEXT	generates a text primitive which appends the specified character string to the compound text object under construction.

3.9.2 Usage of text functions (compound text)

Each text function has a "not final/final" flag that indicates whether the generated text primitive contributes to the construction (i.e. as the start, continuation, or completion) of a compound text object.

If the Output State in the General Attributes and Output Control State List is ACTIVE and a TEXT or RESTRICTED TEXT function with the "not final/final" flag set to FINAL is invoked, a text primitive is generated which produces a simple text object, the appearance of which is controlled by the current text attributes.

If the Output State is ACTIVE and a TEXT or RESTRICTED TEXT function with the "not final/final" flag set to NOT FINAL is invoked, the Output State is set to TEXT OPEN and the construction of a compound text object is begun with the created text primitive. Subsequent APPEND TEXT functions contribute text primitives to the construction of the compound text object. A final APPEND TEXT function, that is, one with the "not final/final" flag set to FINAL, completes the compound text construction. The Output State is then set to state ACTIVE.

During the Output State TEXT OPEN, "local" text attributes from the Text Attributes State List and General Attributes and Output Control State List are associated with the individual text primitives generated by the various invocations of TEXT, RESTRICTED TEXT, and APPEND TEXT. The "global" text attributes from the Text Attributes State List are associated with the text object on completion of the compound text.

In general, a compound text object can only be rendered *after* its completion because of text alignment and the way in which attribute changes affect the definition of the text extent parallelogram. Note that the text extent parallelogram specified in the RESTRICTED TEXT function is not affected by any attribute changes.

3.9.2.1 Usage of GDP

A GDP which is defined as a text primitive may, in accordance with the GDP definition, cause transitions of the Output State to or from TEXT OPEN or contribute to compound text objects. Any variation or special handling applicable to a GDP in state TEXT OPEN shall be documented explicitly in the GDP description.

3.9.3 Text attributes

The appearance of all text primitives is described by specific text attributes and other general attributes.

3.9.3.1 Local text attributes

The following attributes are "local" for text primitives, that is, they are associated with text primitives which produce simple text objects and with individual text primitives which contribute to the construction of compound text objects.

CHARACTER HEIGHT	determines the height of the character body measured along the character up vector for the text object (see 3.9.4);
CHARACTER EXPANSION FACTOR	determines the width/height ratio of the characters of a text object (see 3.9.4);

CHARACTER SPACING determines the length of space between characters of a text object when rendered (see 3.9.4);

TEXT FONT INDEX determines the font to use in rendering the text string (see 3.9.6);

ALTERNATE CHARACTER SET INDEX determines an alternate character set which may be used within the text string (see 3.9.6);

CHARACTER SET INDEX determines the normal character set used for characters in the text string (see 3.9.6);

TEXT COLOUR determines the colour with which the text object is rendered. The colour selection mode in which the text colour was specified determines whether the TEXT COLOUR attribute value is interpreted as a direct or indexed colour value during rendering. See 3.4 for a description of how colours are defined in the CGI;

TEXT BUNDLE INDEX determines the text bundle to be used during rendering if any of the text ASF attribute values are BUNDLED. The following text attribute values may be bundled: TEXT FONT INDEX, TEXT PRECISION, CHARACTER SPACING, CHARACTER EXPANSION FACTOR, and TEXT COLOUR;

Text ASFs determine which attribute values of the text bundle referenced by the TEXT BUNDLE INDEX attribute are to be used during rendering when the corresponding ASF attribute value is BUNDLED. The following text ASFs are defined: TEXT FONT INDEX ASF, TEXT PRECISION ASF, CHARACTER SPACING ASF, CHARACTER EXPANSION FACTOR ASF, and TEXT COLOUR ASF;

3.9.3.2 Global text attributes

The following attributes are global for text primitives, that is, they are associated with text primitives which produce simple text objects and with complete compound text objects as a whole.

CHARACTER ORIENTATION determines the character up vector and character base vector for the text object when rendered (see 3.9.4);

TEXT PRECISION determines the requested rendering quality of the text object;

TEXT PATH determines the "writing" direction of the characters of the text string with respect to character orientation (see 3.9.4);

TEXT ALIGNMENT determines the position of the text extent parallelogram in relation to the text position (see 3.9.4);

CHARACTER CODING ANNOUNCER determines the interpretation of the string parameter and techniques for switching character sets according to ISO 2022 (see 3.9.6).

3.9.3.3 General attributes

The following general attributes are associated with text primitives – AUXILIARY COLOUR and TRANSPARENCY as local attributes; CLIP INDICATOR, CLIP RECTANGLE, PICK IDENTIFIER, and DRAWING MODE as global attributes.

CLIP INDICATOR determines whether object clipping is to be applied to the text object;

CLIP RECTANGLE used in determining the effective clip region to be applied to a text object if the associated CLIP INDICATOR is ON;

AUXILIARY COLOUR determines the colour to render the portions of the body of a character, other than the foreground of a character glyph, if the TRANSPARENCY attribute value is OPAQUE. The colour selection mode in which the auxiliary colour was specified determines whether the AUXILIARY COLOUR attribute value is interpreted as a direct or indexed colour value during rendering;

TRANSPARENCY determines whether the portions of the body of a character, other than the foreground of a character glyph are rendered using the AUXILIARY COLOUR attribute value. If the TRANSPARENCY attribute value is TRANSPARENT, any previously drawn parts of the picture are unaffected by these portions of characters;

Text primitives **Concepts**

DRAWING MODE	determines how the rendered (and rastered) object is mixed with what already exists on the drawing surface (defined in ISO/IEC 9636-6);
PICK IDENTIFIER	(defined in ISO/IEC 9636-4).

3.9.4 Text geometry

The character body reference lines are illustrated in figure 5. The character body normally encloses all of the drawn parts (kerning excepted) of all characters in the font (that is, no descender extends lower than the bottom reference line, and no accent mark or oversized symbol extends higher than the top reference line). The left and right reference lines of the character body may be defined on a per character basis to accommodate variable widths and proportional spacing. The body exceeds the actual character symbol width and height as necessary to provide adequate white space between characters both vertically and horizontally.

NOTE – This insures that text is readable and adequately separated when adjacent character bodies are flush (i.e. when CHARACTER SPACING is 0) and multiline text can be created using continuous values of TEXT ALIGNMENT without causing vertical overlaps in a one-way output environment.

In some cases, a font may have been designed so that some elements (i.e. "bowls" and "arms") of the font may extend beyond the character body horizontally; however, the RESTRICTED TEXT function still requires that all visible portions of the character be confined to the text extent parallelogram.

3.9.4.1 Character sizing and orientation

The CHARACTER HEIGHT attribute specifies the VDC distance between the capline and baseline of the font (see figures 5 and 6) measured along the character up vector. Note that if the character up vector is not perpendicular to the character base vector, the distance from the baseline to the capline measured perpendicular to the baseline will be less than the CHARACTER HEIGHT attribute. The CHARACTER HEIGHT attribute also affects the character width in such a way that the aspect ratio of the character body is not changed.

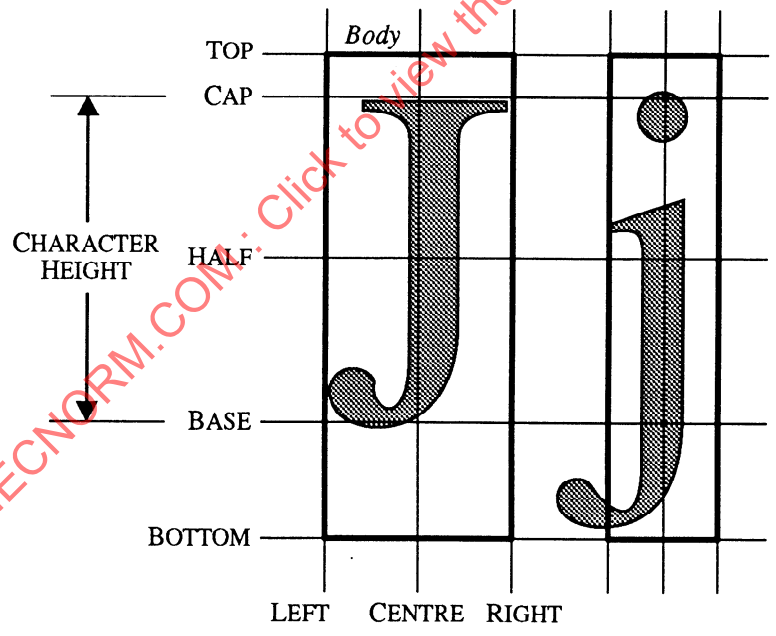


Figure 5 – Character body reference lines

Figure 6 – CHARACTER HEIGHT and CHARACTER EXPANSION FACTOR

The CHARACTER EXPANSION FACTOR attribute specifies the deviation of the width to height ratio of the characters from the ratio indicated by the font designer (see figure 6).

The CHARACTER SPACING attribute specifies how much additional space is to be inserted between two adjacent character bodies (see figure 7). If the value of CHARACTER SPACING is zero, the character bodies are arranged flush with one another along the TEXT PATH with only the inter-character spacing designated by the font designer. If the value of CHARACTER SPACING is positive, additional space is inserted between character bodies. If the value of CHARACTER SPACING is negative, adjacent character bodies overlap although the character symbols themselves might not. Character spacing is specified as a fraction of the CHARACTER HEIGHT.

The CHARACTER ORIENTATION attribute specifies the character up vector and base vector, which determine the orientation and skew of the characters, and also determine the sense of RIGHT, LEFT, UP, and DOWN for TEXT PATH and TEXT ALIGNMENT (see figures 8 and 9).

The Virtual Device uses the ratio of the length of the transformed base vector to the length of the transformed up vector to scale the CHARACTER SPACING for text paths RIGHT and LEFT, and the CHARACTER EXPANSION FACTOR in all cases, before these are used to display the text.

3.9.4.2 Text path

TEXT PATH has the possible values of RIGHT, LEFT, UP, and DOWN. It specifies the writing direction of the text string (see figures 7 and 15).

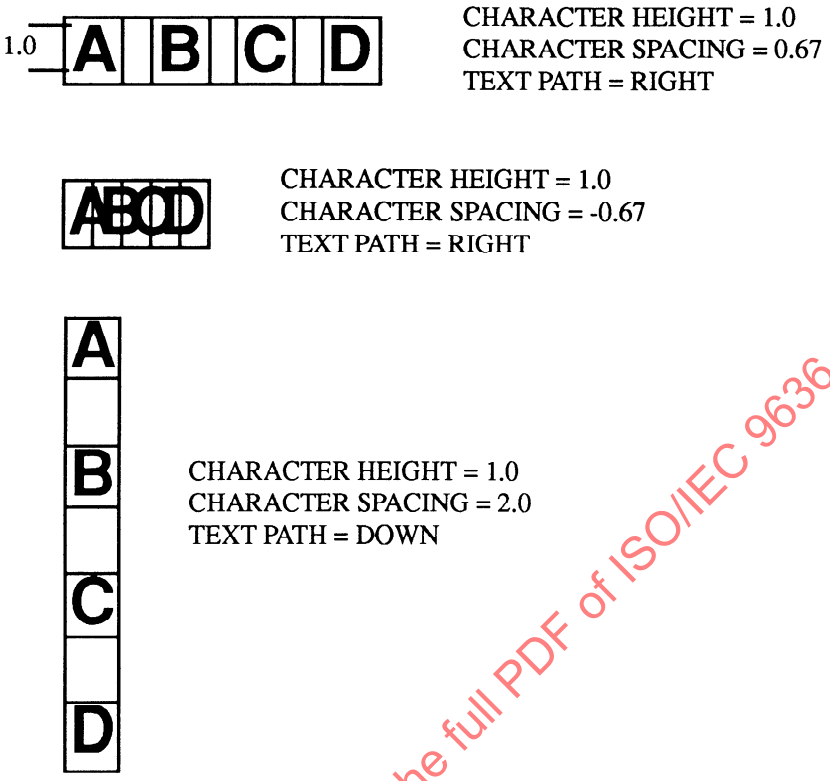


Figure 7 – CHARACTER SPACING

RIGHT	means in the direction of the character base vector.
LEFT	means 180° from the character base vector.
UP	means in the direction of the character up vector.
DOWN	means 180° from the character up vector.

For the UP and DOWN text path directions, the characters are arranged so that the centres of the character bodies are on a straight line in the direction of the character up vector. For the LEFT and RIGHT text path directions, the characters are arranged so that the baselines of the characters are on a straight line parallel to the direction of the character base vector.

NOTE – because of the effect on TEXT PATH, it is recommended that skewed character orientation vectors *not* be used to simulate slanted or italicized fonts when TEXT PATH is UP or DOWN.

These composition rules also apply when characters of different heights, expansion factors, or fonts are intermixed in a compound text object by means of attribute changes between a TEXT function and subsequent APPEND TEXT functions.

3.9.4.3 Text alignment

When aligning a text object, alignment of text is with respect to a text extent parallelogram relative to CHARACTER ORIENTATION, which is derived by joining the character bodies of the characters in the string according to the current status of the attributes and the composition rules described. The text extent parallelogram is the smallest parallelogram with sides parallel to the character orientation vectors and containing all of the character bodies in the text object.

The TEXT ALIGNMENT attribute controls the positioning of the text extent parallelogram in relation to the text position (see figures 10, 11, 12, and 13).

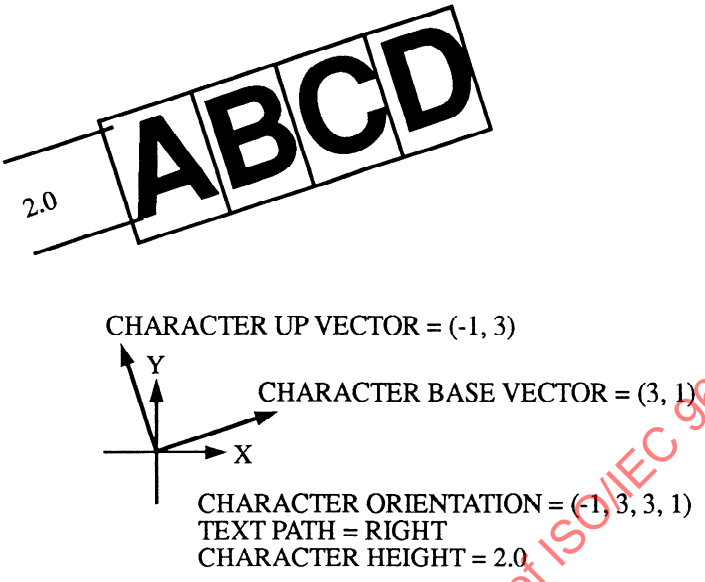


Figure 8 – CHARACTER ORIENTATION

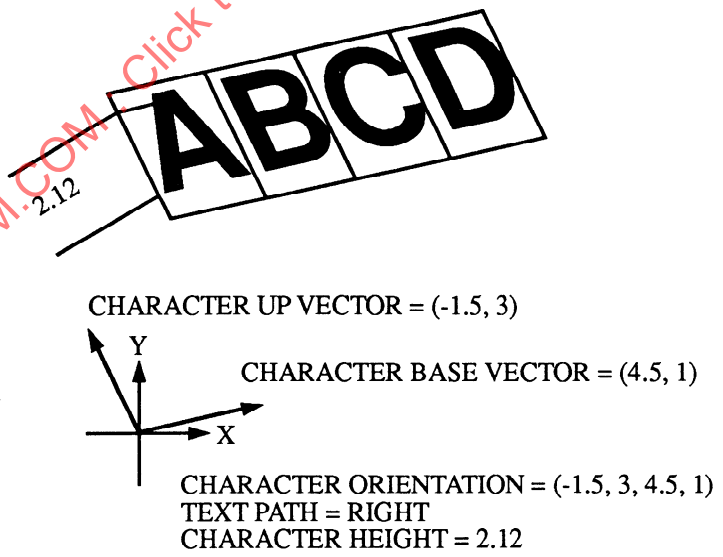


Figure 9 – CHARACTER HEIGHT and CHARACTER ORIENTATION with skewed orientation vectors

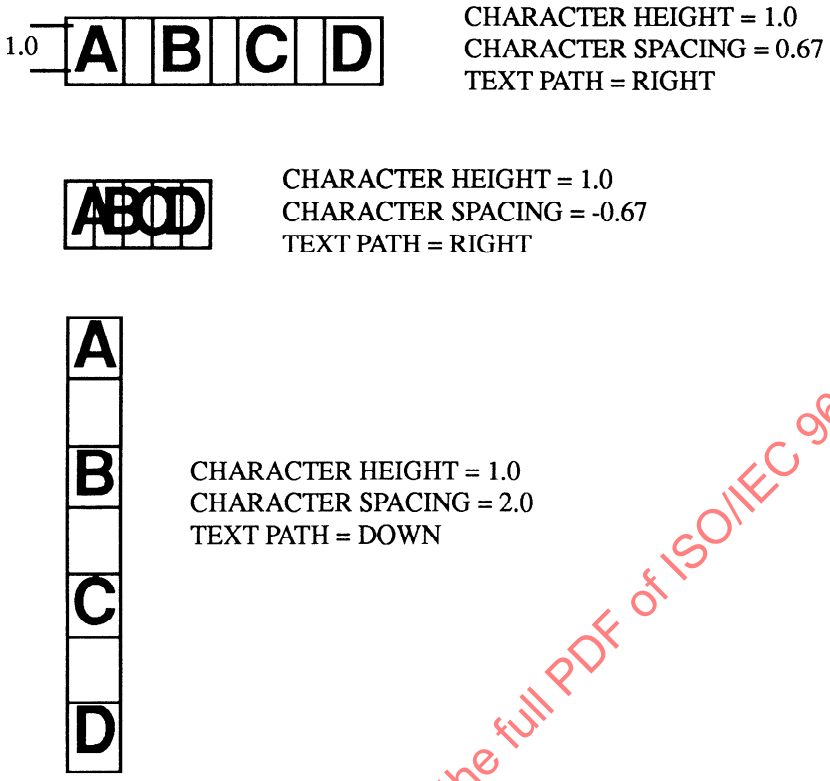


Figure 7 – CHARACTER SPACING

RIGHT means in the direction of the character base vector.

LEFT means 180° from the character base vector.

UP means in the direction of the character up vector.

DOWN means 180° from the character up vector.

For the UP and DOWN text path directions, the characters are arranged so that the centres of the character bodies are on a straight line in the direction of the character up vector. For the LEFT and RIGHT text path directions, the characters are arranged so that the baselines of the characters are on a straight line parallel to the direction of the character base vector.

NOTE – because of the effect on TEXT PATH, it is recommended that skewed character orientation vectors *not* be used to simulate slanted or italicized fonts when TEXT PATH is UP or DOWN.

These composition rules also apply when characters of different heights, expansion factors, or fonts are intermixed in a compound text object by means of attribute changes between a TEXT function and subsequent APPEND TEXT functions.

3.9.4.3 Text alignment

When aligning a text object, alignment of text is with respect to a text extent parallelogram relative to CHARACTER ORIENTATION, which is derived by joining the character bodies of the characters in the string according to the current status of the attributes and the composition rules described. The text extent parallelogram is the smallest parallelogram with sides parallel to the character orientation vectors and containing all of the character bodies in the text object.

The TEXT ALIGNMENT attribute controls the positioning of the text extent parallelogram in relation to the text position (see figures 10, 11, 12, and 13).

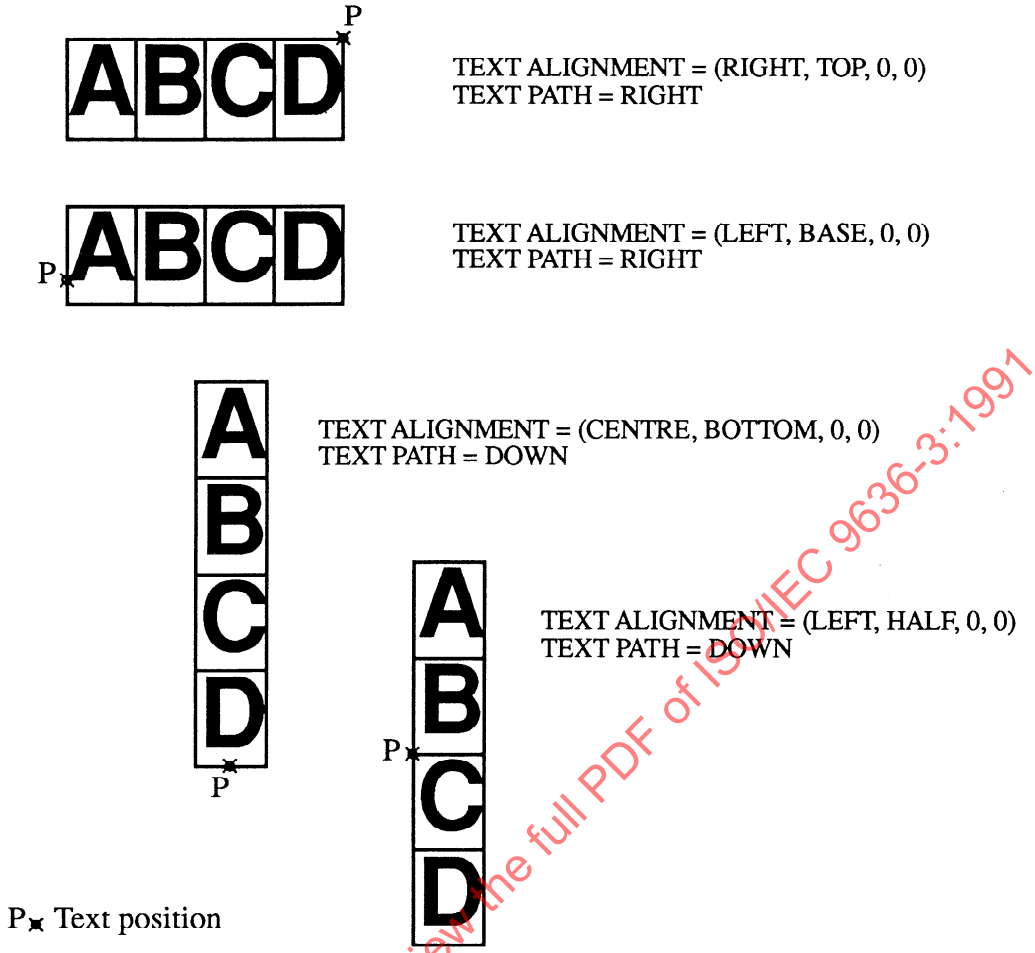


Figure 10 – Discrete text alignment

The horizontal alignment type of TEXT ALIGNMENT has five possible values: LEFT, CENTRE, RIGHT, NORMAL HORIZONTAL, and CONTINUOUS HORIZONTAL. If the horizontal alignment type is LEFT, the left side of the text extent parallelogram passes through the text position. Similarly, if the value is RIGHT, the right side of the text extent parallelogram passes through the text position. If the horizontal alignment type is CENTRE, the text position lies on a line parallel to and mid-way between the left and right sides of the text extent parallelogram. In this case, if TEXT PATH equals UP or DOWN, the straight line passing through the centrelines of the characters also passes through the text position.

If the horizontal alignment type is CONTINUOUS HORIZONTAL, the text position lies on a line parallel to the ends of the text extent parallelogram whose relative position with respect to the left and right ends of the text extent parallelogram is specified by the continuous horizontal alignment parameter. A value of 0.0 corresponds to the left end and a value of 1.0 corresponds to the right end. Negative values and values in excess of 1.0 are allowed. (See figure 11.)

The vertical alignment type of TEXT ALIGNMENT has seven possible values: TOP, CAP, HALF, BASE, BOTTOM, NORMAL VERTICAL, and CONTINUOUS VERTICAL. A vertical alignment type of TOP, CAP, HALF, BASE, or BOTTOM causes the text to be placed such that the corresponding reference line of one of the character bodies in the text string passes through the text position. In cases where this may be different for different characters, the ambiguity is resolved in accordance with tables 5 and 6.

If the vertical alignment type is CONTINUOUS VERTICAL, the text position lies on a line parallel to the top of the text extent parallelogram whose relative position with respect to the bottom and top of the text extent parallelogram is specified by the continuous vertical alignment parameter. A value of 0.0 corresponds to the bottom side and a value of 1.0 corresponds to the top side. Negative values and values in excess of 1.0 are allowed. (See figure 11.)

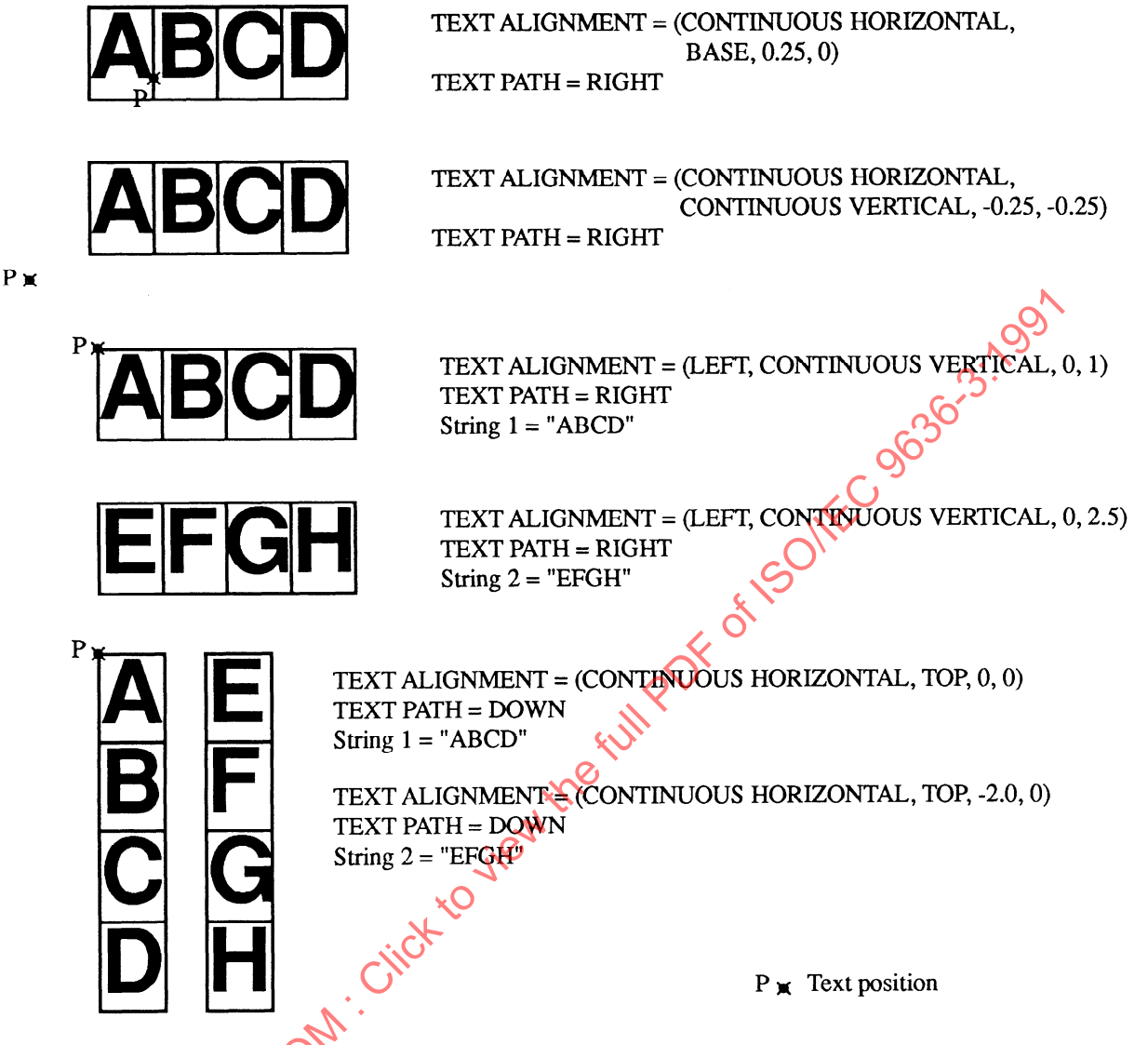


Figure 11 – Continuous text alignment

For both horizontal and vertical alignment types, normal values are converted to the appropriate value for the current text path (as indicated with the description of the TEXT ALIGNMENT function in clause 5) at the time of a text object's elaboration and thereafter treated as defined above.

Table 5 – Definition of alignment points: TEXT PATH = LEFT or RIGHT

TOP	topline farthest from the baseline
CAP	capline farthest from the baseline
HALF	halfline farthest from the baseline
BOTTOM	bottomline farthest from the baseline
LEFT	leftmost edge of leftmost character body
RIGHT	rightmost edge of rightmost character body
CENTRE	halfway between LEFT and RIGHT as defined above

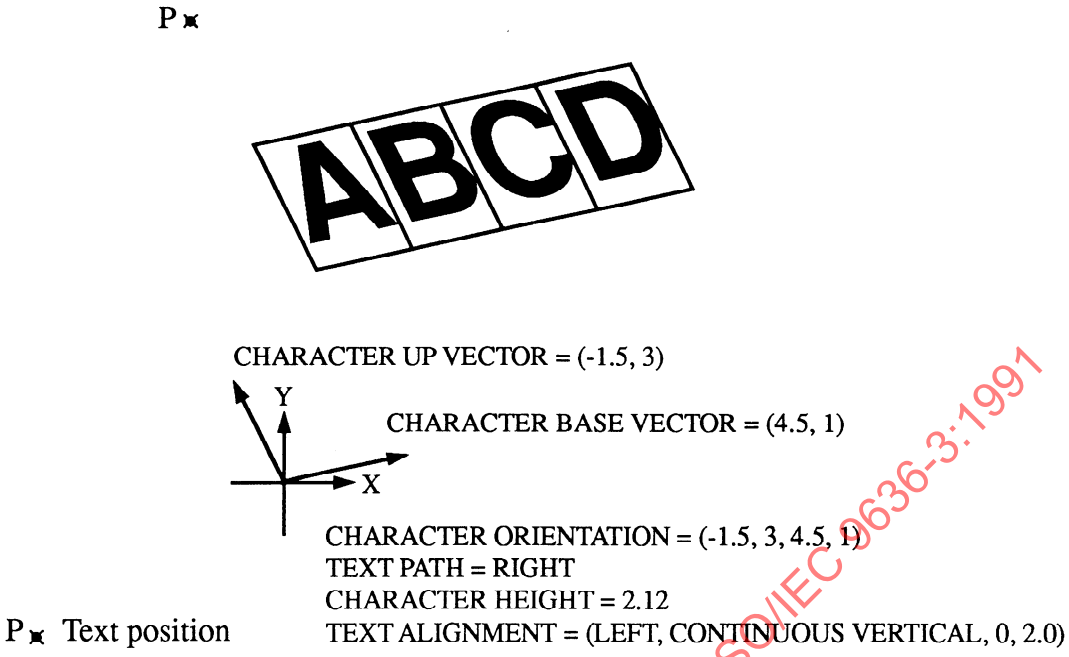


Figure 12 – Continuous text alignment with skewed orientation vectors

Table 6 – Definition of alignment points: TEXT PATH = UP or DOWN

TOP	topline of topmost character
CAP	capline of topmost character
HALF	halfway between halflines of topmost and bottommost character
BASE	baseline of bottommost character
BOTTOM	bottomline of bottommost character
LEFT	left edge farthest from the centre line
RIGHT	right edge farthest from the centre line

Note that the relationship of topline to capline, bottomline to baseline, and the placement of the halfline are font-dependent. It is for this reason that the various defining lines of the text extent parallelogram need not be derived from the same character body. This is a function of the CHARACTER HEIGHT, TEXT FONT INDEX, and CHARACTER EXPANSION FACTOR changes within a string.

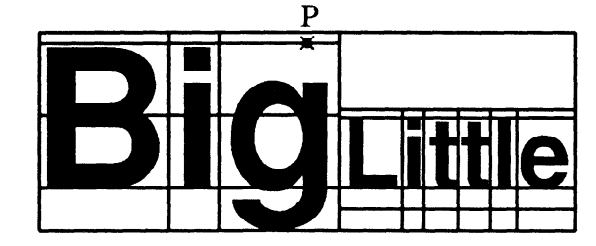
The continuous values of alignment allow the display of multiline text, and may ensure that the ascenders of one row and the descenders of the next do not overlap. Use of continuous horizontal and continuous vertical alignments provides this ability for all values of TEXT PATH. Since inquiry of the dimensions of the text extent parallelogram cannot be provided in a one-way output environment, other means have been provided to align more than one row of characters to the same text position. This means that the alignment parameters are permitted to exceed the maximum dimensions of the text extent parallelogram. Use of a continuous parameter allows specification of inter-row space, analogous to intercharacter space (see figure 11).

As an example of the set of the continuous alignment attributes, consider the display of four rows of left-justified text, each specified by a single TEXT function. To ensure that ascenders and descenders do not interfere between rows and that, in addition, there is a space of at least one-half the maximum size of a character between the descenders of one row with raised accent marks or oversized symbols of another row, the TEXT ALIGNMENT function should set the horizontal and vertical alignment types to (LEFT, CONTINUOUS VERTICAL) and the continuous vertical alignment value to 0.0. Then, the first row is output with the text position equal to the lower-left corner of the string. The continuous vertical alignment value can then be set to 1.5, and the second row output with the same text position. This places the second row below the first row because of

the change in alignment. The last two rows are output in the same way with the continuous vertical alignment value set to 3.0 and 4.5, and the text position parameters to the TEXT function unchanged. A value of 1.0 assures no overlap between rows; a value greater than 1.0 guarantees additional space. A similar use of CONTINUOUS HORIZONTAL alignment can be made when the text path is DOWN.

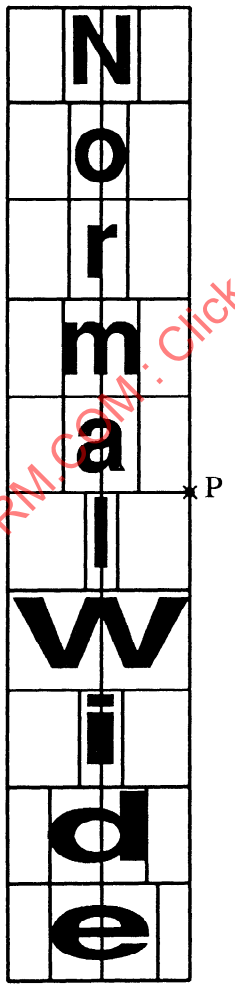
Figure 13 illustrates examples of the use of APPEND TEXT in combination with discrete text alignment attribute values.

The foregoing examples have been illustrated for the case of the character up vector and the character base vector being orthogonal (i.e. the text extent parallelogram is a rectangle). When these orientation vectors are not orthogonal, the text extent parallelogram's sides remain parallel to the two orientation vectors. The centreline is skewed to remain parallel with the left and right edges of the text extent parallelogram. The height of the text extent parallelogram is measured along the skewed edge (not perpendicular to the baseline). The TEXT PATH value RIGHT is in the direction of the character base vector and TEXT PATH value LEFT is in the opposite direction.



TEXT ALIGNMENT = (CENTRE, CAP, 0, 0)
TEXT PATH = RIGHT
CHARACTER HEIGHT = 2.0
String = "Big"

CHARACTER HEIGHT = 1.0
Appended String = "Little"



TEXT ALIGNMENT = (RIGHT, HALF, 0, 0)
TEXT PATH = DOWN
CHARACTER HEIGHT = 1.0
CHARACTER EXPANSION FACTOR = 1.0
String = "Normal"

CHARACTER EXPANSION FACTOR = 2.0
Appended String = "Wide"

P Text position

Figure 13 – Discrete text alignment with appended text and proportional spacing

3.9.4.4 Text precision

The fidelity with which the text attributes are realized on the CGI Virtual Device is controlled by the text precision attribute. Text precision may have one of the following possible values:

STRING: The starting position of the entire text string is evaluated correctly. The pick identifier and the text colour of the text string are also evaluated correctly. The realization of other text attributes is allowed to differ from that specified. Clipping of a text string whose text extent parallelogram intersects the boundary of the effective clip region is implementation-dependent.

CHARACTER: The position of each character of the rendered text string and the placement and orientation of the rendered text string satisfies the relevant text attributes, as described above. The skew, orientation, and size of each individual character is allowed to differ from that specified by the relevant text attributes. All characters of the text string which lie either entirely inside or outside the effective clip region are clipped as appropriate. Clipping of characters whose character body intersects the boundary of the effective clip region is implementation-dependent.

STROKE: The placement, skew, orientation, and size of all characters of the text string satisfies all the text attributes, as described above. Characters are clipped to the geometric accuracy of the Virtual Device as in SHAPE clipping.

During compound text construction, when text precision is changed explicitly or as a result of a change in the text bundle index, the highest text precision value that has been used during the definition of the compound text object is used.

3.9.4.5 Restricted text

The text attributes apply in the same way to a text object formed from the RESTRICTED TEXT function. Determination of the extent of a string is generally not possible in a 1-way output environment, hence the RESTRICTED TEXT function specifies the size of a text extent parallelogram. If the text string, as displayed by the current text attributes, would exceed the parallelogram derived from this parameter, then the text attributes CHARACTER EXPANSION FACTOR, CHARACTER SPACING, TEXT FONT INDEX, TEXT PRECISION, and CHARACTER HEIGHT are adjusted in an implementation-dependent manner so that all of the specified text string fits within the parallelogram and the extent of the displayed string does not exceed the parallelogram.

3.9.4.6 Degeneracy of text objects

Degeneracy of text objects may arise either due to the client's specifications or unintentionally due to round-off error in transforming coordinate data. However, specifying a vector of length zero for the character up vector or character base vector is prohibited. Furthermore, since only the directions and length ratio for those vectors affect rendering, an implementation should maintain a scaling of the vectors during transformation such that any problem of accidental rounding to zero (or loss of precision) is avoided.

If the Virtual Device cannot render a text object at the exact specified character height, the next smaller available implemented height will be used. If no such height is available, the next larger height available will be used.

3.9.5 Text clipping

The type of clipping that may be applied to text is dependent upon the TEXT PRECISION attribute value associated with a text graphic object, as follows:

- For STRING precision text, clipping may proceed on a per string basis, in a manner consistent with LOCUS clipping.
- For CHARACTER precision text, clipping may proceed on a per character basis, in a manner consistent with LOCUS clipping.
- For STROKE precision text, clipping always proceeds in a manner consistent with SHAPE clipping.

Note that a Virtual Device is always allowed by ISO/IEC 9636 to use SHAPE clipping for all text precisions.

3.9.6 Text fonts and character sets

3.9.6.1 Fonts in the CGI

Selection of a font (that is, the style of the characters to be displayed) from among available fonts is achieved using the TEXT FONT INDEX function. The assignment of particular font names to font indices used as values of the parameter to TEXT FONT INDEX is achieved using the function FONT LIST. The FONT LIST function may be used at various times throughout the specification of a picture. Whether changes of the List of Font Names affect the appearance of any rendered text is indicated by the Dynamic Modification Accepted For Font List entry in the Text Description Table.

The choice of character font is determined independently of the character set. However, the specified font and the character sets being used should be related in order to display meaningful text strings. Roman and Gothic are examples of commonly used fonts for Latin-based alphabets.

3.9.6.2 Using multiple character sets

There are several methods for specifying a string containing characters from different character sets. The method used is determined by the CHARACTER CODING ANNOUNCER function. The default or normal technique is to use the CHARACTER SET INDEX function, and restrict the contents of the text strings to printing characters and spaces (format effector control codes such as CR and LF are permitted, but their interpretation is implementation-dependent). Other settings of the CHARACTER CODING ANNOUNCER function or use of the ALTERNATE CHARACTER SET INDEX function permit standardized use of 8-bit characters between SI, SO, and ESC control codes within the text string, in accordance with ISO 2022. The ALTERNATE CHARACTER SET INDEX function is used to select a character set to be used as both the G1 set and the G2 set. The G1 set is used both for 8-bit characters in columns 10-15 of the code table, and with the SO control code. The assignment of particular character sets to the index parameter of both CHARACTER SET INDEX and ALTERNATE CHARACTER SET INDEX is done with the CHARACTER SET LIST function. These assignments are performed during the generation of the text primitive and are not affected by any later changes resulting from an invocation of the CHARACTER SET LIST function.

These code extension techniques apply to string parameters of text functions. For strings which are part of a data record of an ESCAPE, GET ESCAPE, or GDP function, whether or not the code extension technique applies is specified in the description of the particular escape or GDP.

3.9.7 Errors in TEXT OPEN state

3.9.7.1 Non-contributing functions

Attribute and control functions not directly contributing to the construction of compound text objects are permitted during TEXT OPEN state, and have their normal effect on the corresponding state list entries. Non-contributing primitives cause an error and are ignored.

3.9.7.2 Overflow of the text buffer

When overflow occurs during TEXT OPEN state, a single error is generated and the CGI device stays in state TEXT OPEN. Subsequent primitives which would have contributed to the compound text are ignored without generating additional errors; other behaviour and error conditions defined for TEXT OPEN state remain the same after overflow. When an APPEND TEXT with the "not final/final" flag of FINAL is invoked, as much of the compound text as had been entered into the text buffer when the overflow occurred is used and global attribute values in effect are associated with it before it is passed on down the pipeline.

3.9.8 Allowed latitude

The following levels of compound text support are permitted for a CGI Virtual Device: NONE, GLOBAL, and LOCAL. The implemented level of support is indicated by the Compound Text Capability entry in the Primitive Support Description Table.

- A level of NONE indicates that the Virtual Device does not support compound text objects in any form. That is, the functions TEXT and RESTRICTED TEXT are only permitted with the "not final/final" flag set to FINAL; APPEND TEXT is not supported.

- A level of GLOBAL indicates that the Virtual Device does not support local text attribute changes between text primitives contributing to a compound text object. All associated attribute values are taken from the state lists at the time of the "final" APPEND TEXT.
- A level of LOCAL indicates full support of compound text objects as described in 3.9.2.

3.10 Fill primitives

3.10.1 Fill functions

The CGI provides the following functions which generate fill primitives:

POLYGON defines an area bounded by lines defined by a list of points;

POLYGON SET defines a set of areas bounded by lines defined by a list of points and subject to edge control flags;

RECTANGLE defines a rectangular area oriented parallel to the VDC axes;

CIRCLE defines a circle specified by a centre point and a radius;

CIRCULAR ARC CENTRE CLOSE
CIRCULAR ARC THREE POINT CLOSE defines a subregion of a circle specified by one of two parameterizations and a close type that selects between either PIE or CHORD style closure;

ELLIPSE defines an ellipse specified by a centre point and a conjugate radius pair;

ELLIPTICAL ARC CLOSE defines a subregion of an ellipse specified by a centre point, a conjugate radius pair, and start and end vectors, together with a closure flag that selects between either PIE or CHORD style closure.

In addition to the above fill primitives, an arbitrary filled region may be constructed as a compound object using line and fill primitives and the closed figure control functions as described in 3.10.5. Closed figure objects are filled in the same manner as other fill objects and use the same set of fill attributes.

3.10.2 Fill attributes

The appearance of fill primitives is determined by specific fill attributes, and other general attributes. (See 3.10.5 for a description of the association of fill attributes in closed figures.)

3.10.2.1 Interior attributes

INTERIOR STYLE determines the style of filling of the interior of a fill object (see below);

FILL COLOUR determines the colour in which filling is performed for interior styles HOLLOW, SOLID, or HATCH. The colour selection mode in which the fill colour was specified determines whether the FILL COLOUR attribute value is interpreted as a direct or indexed colour value during rendering. See 3.4 for a description of how colours are defined in the CGI;

HATCH INDEX determines the hatch style to be used if the interior style is HATCH;

PATTERN INDEX determines the pattern entry in the pattern table to be used if the interior style is PATTERN;

FILL BITMAP IDENTIFIER determines the bitmap to be used if the interior style is BITMAP. The value of Fill Bitmap Identifier in the Fill Attributes State List is specified by the function FILL BITMAP defined in ISO/IEC 9636-6;

FILL BITMAP determines the bitmap region to be used if the interior style is BITMAP. The value of Fill Bitmap Region in the Fill Attributes State List is defined by the function FILL BITMAP specified in ISO/IEC 9636-6;

FILL BUNDLE INDEX determines the fill bundle to be used during rendering when the corresponding fill ASF values are BUNDLED. The following fill attribute values may be bundled: INTERIOR STYLE, FILL COLOUR, HATCH INDEX, PATTERN INDEX, FILL BITMAP IDENTIFIER, and FILL BITMAP REGION;

Fill ASFs determine which attribute values of the fill bundle referenced by the FILL BUNDLE INDEX attribute are to be used during rendering when the corresponding ASF attribute value is BUNDLED. The following fill ASFs are defined: INTERIOR STYLE ASF, FILL COLOUR ASF, HATCH INDEX ASF, PATTERN INDEX ASF, and FILL BITMAP ASF. The FILL BITMAP ASF controls both fill bitmap attributes;

PATTERN SIZE determines the spatial repeat period of the pattern during rendering if the interior style is PATTERN;

FILL REFERENCE POINT determines the origin position of the pattern or bitmap repetition if the interior style is PATTERN or BITMAP.

The fill interior style is used to determine the style in which fill objects are to be filled. It has the following values:

HOLLOW: the interior is not filled, but the clipped boundary of the fill object is rendered using the associated FILL COLOUR;

SOLID: the interior is filled using the associated FILL COLOUR;

PATTERN: the interior is filled with repetitions of the pattern selected from the pattern table by the PATTERN INDEX function; the repetitions have their origin at the FILL REFERENCE POINT attribute value and their size and shape are determined by the PATTERN SIZE attribute value;

HATCH: the interior is filled with the hatch style selected by the associated HATCH INDEX, rendered in the associated FILL COLOUR;

EMPTY: no representation of the interior is rendered;

BITMAP: the interior is filled with repetitions of the bitmap region determined by the FILL BITMAP IDENTIFIER and FILL BITMAP functions. The origin of the repetitions is specified by the FILL REFERENCE POINT function.

For interior style PATTERN, the pattern is defined by a pattern table entry selected by the pattern index, which specifies an array (nx, ny) of colour specifiers. The size, shape, and start position of the pattern are specified by a pattern parallelogram, as defined by pattern width and height vectors located relative to the associated FILL REFERENCE POINT. The pattern parallelogram is conceptually divided into cells; nx cells in the width vector direction and ny cells in the height vector direction. Each cell is thus (pattern width/nx) wide and (pattern height/ny) high, as measured parallel to the sides of the pattern parallelogram.

The pattern parallelogram for interior style BITMAP, which is the Fill Bitmap Region defined through use of the FILL BITMAP function, is always rectangular and never transforms. See the FILL BITMAP function described in ISO/IEC 9636-6, 5.3.2 for specification of how the associated attributes of TRANSPARENCY and AUXILIARY COLOUR are applied in rendering this interior style.

The array of colours of the selected pattern is mapped onto the array of cells as follows: for interior style PATTERN, the colour array element (1, ny) is mapped to the pattern parallelogram cell which is located at the associated FILL REFERENCE POINT; for interior style BITMAP, pixel (1, ny) of the FILL BITMAP is located at the FILL REFERENCE POINT. Colour array elements with increasing first dimension are associated with successive cells in the direction of the width vector, and colour array elements with decreasing second dimension are associated with successive cells in the direction of the height vector. In this way, each of the nx*ny colour array elements is associated with one of the nx*ny cells of the pattern box.

Conceptually, the pattern parallelogram so defined is replicated in directions parallel to the vectors of the PATTERN SIZE until the interior of a fill object to which the pattern is to be applied is completely covered.

3.10.2.2 Edge attributes

EDGE TYPE determines the type of edge (e.g. solid, dotted, or dashed) with which a fill object is rendered if the edge visibility is VISIBLE;

SPECIFICATION MODE OF EDGE WIDTH determines whether the EDGE WIDTH attribute value is interpreted as a scaling factor or a VDC width during rendering (see 3.10.3);

EDGE WIDTH determines the width of edge with which a fill object is rendered if the edge visibility is VISIBLE;

EDGE VISIBILITY determines the visibility of the edges of a fill object when rendered;

EDGE COLOUR determines the colour with which the edges of a fill object are rendered if the edge visibility is VISIBLE. The colour selection mode in which the edge colour was specified determines whether the EDGE COLOUR attribute value is interpreted as a direct or indexed colour value during rendering;

EDGE CLIPPING MODE determines the type of object clipping to be performed during rendering (see 3.10.4);

EDGE BUNDLE INDEX determines the edge bundle to be used during rendering when the corresponding edge ASF values are BUNDLED. The following edge attribute values may be bundled: EDGE TYPE, EDGE WIDTH, EDGE COLOUR, and EDGE VISIBILITY;

Edge ASFs determine which attribute values of the edge bundle referenced by the EDGE BUNDLE INDEX attribute are to be used during rendering when the corresponding ASF attribute value is BUNDLED. The following edge ASFs are defined: EDGE TYPE ASF, EDGE WIDTH ASF, EDGE COLOUR ASF, and EDGE VISIBILITY ASF.

3.10.2.3 General attributes

The following general attributes are associated with fill primitives – AUXILIARY COLOUR, TRANSPARENCY, and DRAWING MODE as local attributes for edges, and global attributes for interiors; CLIP INDICATOR, CLIP RECTANGLE, and PICK IDENTIFIER as global attributes (see 3.10.5).

CLIP INDICATOR determines whether object clipping is to be applied to the fill object;

CLIP RECTANGLE used in determining the effective clip region to be applied to a fill object if the associated CLIP INDICATOR is ON;

AUXILIARY COLOUR determines the colour to render the gaps in a line for edge types other than solid, or gaps between hatch lines for interior style HATCH, if the TRANSPARENCY attribute value is OPAQUE. The colour selection mode in which the auxiliary colour was specified determines whether the AUXILIARY COLOUR attribute value is interpreted as a direct or indexed colour value during rendering;

TRANSPARENCY determines whether gaps in a broken edge or between hatch lines are rendered using the AUXILIARY COLOUR attribute value. If the TRANSPARENCY attribute value is TRANSPARENT, any previously drawn parts of the picture lying within the gaps are unaffected;

DRAWING MODE determines how the rendered (and/or rasterized) object is mixed with what already exists on the drawing surface (defined in ISO/IEC 9636-6);

PICK IDENTIFIER (Defined in ISO/IEC 9636-4.)

3.10.3 Fill geometry

3.10.3.1 Definition of fill object interior

For all fill objects in the CGI (including closed figures) a parity fill algorithm is used to determine those portions of the interior as follows:

- Any given point is considered inside the region if a ray cast from the given point to infinity, such that it misses all vertices and arc endpoints used to define the explicit and implicit boundary portions of the region and never intersects an arc tangentially, intersects the unclipped boundary of the region an odd number of times. Note that the ray may intersect the boundary at a single point multiple times if the boundary passes through that point multiple times.

3.10.3.2 Interaction of edge, boundary, and interior

Fill objects have a single edge which, in the case of closed figures and POLYGON SETs, may consist of several edge portions depending on the exact nature of the fill object constructed. Each edge portion has associated edge attribute values. Parts of edge portions which are clipped are discarded. Clipping of edges is performed identically to clipping of line objects, although controlled by a separate object clipping mode.

The boundary, which is rendered only in the case of interior style HOLLOW, is considered to be the representation of the interior. It is not a rendering of the edge.

If the edge portion is visible, it is rendered "in front of" the interior, i.e. the edge takes precedence over the interior when rendered. In the case of interior style HOLLOW, implicit and explicit boundary portions may be partly visible, in addition to rendered edges.

3.10.3.3 Rendering edges

Edges are rendered using edge attributes in the same way as lines are rendered using line attributes (with the exception of edge visibility). In particular, edge widths are treated in the same way as line widths (see 3.7.3).

3.10.3.4 Transformation of fill objects

Rectangles, circular, and elliptical fill objects are abstractly rendered before transformations are applied. Therefore, the entire abstract locus of these fill objects is subject to transformation. After transformation, angles in polygons may be altered: rectangles may become parallelograms, and circles may become ellipses. Transformation does not affect rendering of the interior if HOLLOW, SOLID, EMPTY, or BITMAP interior style has been selected. The implementation of the transformation of patterns is subject to allowed latitude, with the preferred behaviour that they are transformed. Hatch lines may be transformed according to the definition of the specific hatch index being used.

3.10.3.5 Degeneracy in fill objects

Degeneracy of fill objects (primitives) may arise either due to the client's specifications or unintentionally due to round-off error in transforming coordinate data.

There are a number of ways in which a region of a fill object may be reduced to one with zero area, e.g. a POLYGON where all the points are coincident or collinear. It is also possible to generate a POLYGON or POLYGON SET where a sub-region of the fill object has zero area, although the fill object, taken as a whole, is not degenerate.

Wherever such degeneracy arises, the Virtual Device shall render such a region as a dot if zero-dimensional (e.g. for a CIRCLE whose radius is or rounds off to zero) or a line if one-dimensional (e.g. for a RECTANGLE with one side of zero length but not both). This dot or line is subject to the interior attributes if edge visibility is INVISIBLE, and is subject to the edge attributes if edge visibility is VISIBLE. Note that if edge visibility is INVISIBLE and interior style is EMPTY, the degenerate region will be invisible, as would a non-degenerate fill object.

A closed circular arc 3 point or elliptical arc is non-degenerate if and only if the three specifying points yield three distinct points which are non-collinear. If the three points are all coincident, a dot is rendered. If only two distinct points are specified, a line is rendered between the points. If the three points are collinear, the arc has zero curvature; if close type is CHORD, a line is rendered from the starting point through the intermediate point to the ending point; if close type is PIE, nothing is rendered.

When such a degenerate fill primitive (or region of POLYGON SET) is invoked in FIGURE OPEN state, the implicit NEW REGIONs are performed nonetheless.

The treatment for the degeneracy of edges is analogous to the treatment for degeneracy of lines (see 3.7.3.1).

3.10.4 Fill clipping

3.10.4.1 Interior clipping

When a fill object is clipped using the associated effective clip region, the resulting new clip boundary portions become part of the fill object boundaries (see figure 14). Clip boundary portions are treated in the same way as implicit boundary portions during rendering. Note that the drawing surface clipping does not contribute new clip boundary portions.

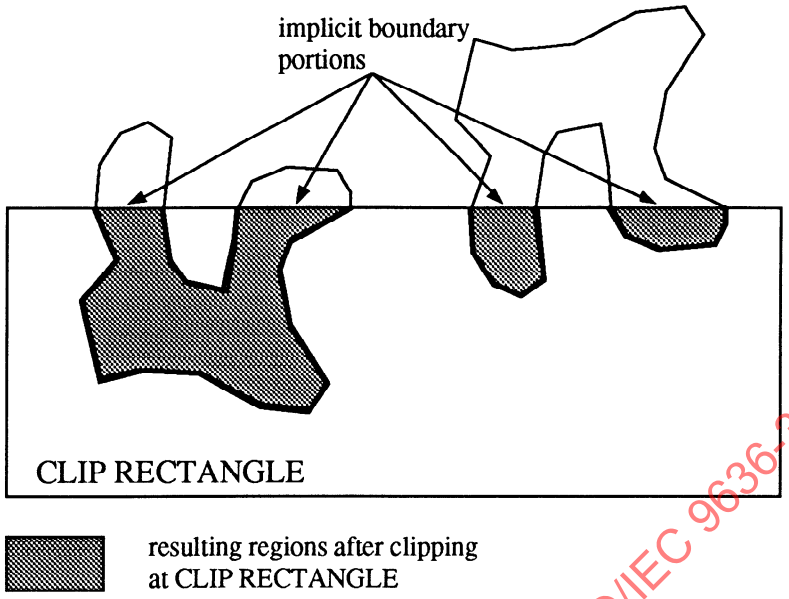


Figure 14 – Examples of fill object clipping

3.10.4.2 Edge clipping

The EDGE CLIPPING MODE attribute specifies how clipping applies to the edges of fill objects. The EDGE CLIPPING MODE attribute has the same enumeration as LINE CLIPPING MODE. Edge clipping is defined according to EDGE CLIPPING MODE analogously to line clipping (see 3.7.4).

3.10.5 Closed figures

3.10.5.1 Construction of closed figures

A closed figure is a fill type compound object which the client constructs on the device side of the interface by invoking BEGIN FIGURE, an ordered sequence of line and fill primitives (and optionally attributes and NEW REGION functions), and END FIGURE. Edge attribute values are associated locally with the edge portions and fill interior attribute values are associated globally with the complete graphic object; in addition, certain general attribute values are associated locally with edge portions and globally with the interior of the fill object. The entire fill object is considered as a single unit during subsequent processing and rendering.

3.10.5.1.1 Closure point

The first point of the first line primitive in a new region is the closure point for that region. The Virtual Device retains this closure point for use in closing the region. When the region is closed (with a NEW REGION or END FIGURE function, or by invoking a fill primitive which begins a new region) an implicit boundary portion from the last point of the last line primitive in the region to this closure point is added to the closed figure by the Virtual Device unless these points are already coincident.

3.10.5.1.2 Regions

A closed figure consists of one or more regions. A region has a closed boundary which may be concave, convex, and self intersecting. A region is formed either by invoking a fill primitive in FIGURE OPEN state (which closes the last region and contributes one or more complete regions), by invoking NEW REGION to start new regions to be formed from line primitives, or by a final invocation of END FIGURE. A closed figure constructed from only line primitives without use of NEW REGION consists of a single region.

The NEW REGION function may occur at any time during the closed figure construction. If the current region is closed, the function is ignored. If the current region is open, an implicit boundary portion is added from the last point of the last primitive to the current closure point unless CONNECTING EDGE has been invoked after the last line primitive, in which case, an explicit boundary portion and edge portion is added by the CONNECTING EDGE line primitive.

3.10.5.2 Boundaries and edges

The boundary of each region consists of a combination of explicit and implicit boundary portions. Explicit boundary portions always contribute to the edge of a region.

3.10.5.2.1 Explicit boundary portions

Explicit boundary portions and edge portions are those added by client invocation of primitives in state FIGURE OPEN. These are generated in the following situations:

- For fill primitives other than POLYGON SET, the complete edge becomes an explicit boundary portion in the closed figure.
- For POLYGON SET, the portions of the edge with the edge-out flag VISIBLE or CLOSE VISIBLE contribute explicit boundary portions.
- For line primitives, those portions which would be rendered if the state were not FIGURE OPEN become explicit boundary portions when incorporated into a closed figure.
- For DISJOINT POLYLINE in particular, only the segments from the first point to the second point, from the third point to the fourth point, and so on, become explicit boundary portions when incorporated into a closed figure.
- A CONNECTING EDGE primitive which precedes an action which would normally have added an implicit boundary portion to the closed figure either to close a region (including closing the closed figure itself) or to connect two line primitives results in the portion added being an explicit boundary portion. CONNECTING EDGE preceding or following DISJOINT POLYLINE or POLYGON SET does not affect the interpretation of those functions with respect to boundaries and edges except to introduce an explicit boundary portion connecting to the first point of a DISJOINT POLYLINE or POLYGON SET.

Explicit boundary portions and edge portions have associated edge attribute values taken from the Edge Attributes State List. These state list entries can be changed between the line and fill primitives that result in edge portions in a closed figure, and hence each edge portion has a distinct set of attribute values associated with it.

3.10.5.2.2 Implicit boundary portions

Edge attributes are never associated with implicit boundary portions. Implicit boundary portions are only rendered for interior style HOLLOW and are a special representation of the interior, not a representation of any portion of the edge.

Implicit boundary portions are added by the CGI device to the closed figure definition under the following circumstances:

- When NEW REGION, END FIGURE, or a fill primitive is invoked and the current region has not been explicitly closed and CONNECTING EDGE has not been invoked since the last line primitive: an implicit boundary portion is added from the last point of the last primitive to the current closure point to close the region.
- When the last point of the preceding line primitive is not coincident with the first point of the current line primitive, an implicit boundary portion is created to connect the last point of the preceding line primitive to the first point of the current line primitive if CONNECTING EDGE has not been invoked between the preceding and current line primitive.
- When portions of a DISJOINT POLYLINE primitive would not normally be rendered (i.e. from the second point to the third point, from the fourth point to the fifth point, and so on), implicit boundary portions are added between these points. (These are additional to the ones which may be added to connect to a preceding or following line primitive or to effect region closure after the disjoint polyline.)
- The portions of the boundary of a POLYGON SET primitive with the edge-out flag INVISIBLE or CLOSE INVISIBLE.

3.10.5.2.3 Conditions under which no boundary or edge is added

No boundary or edge portion is ever created connecting two regions, regardless of how those regions were created or closed.

3.10.5.3 Contribution of primitive functions to the closed figure

3.10.5.3.1 Contribution of line functions to the closed figure

For line primitives, the "first point" of a line primitive is connected to the "last point" of the preceding line primitive, and the connecting implicit boundary portion becomes part of the boundary of the closed figure. For each of the CGI supported line primitives the first and last points are defined to be as follows:

POLYLINE p1, p2, ..., pn:
p1 is the first point; pn is the last point.

DISJOINT POLYLINE p1, p2, ..., pn:
p1 is the first point; pn is the last point.

CIRCULAR ARC 3 POINT p1, p2, p3:
p1 is the first point; p3 is the last point.

CIRCULAR ARC CENTRE ...:
CIRCULAR ARC CENTRE REVERSED...:
The first point is the intersection of the circle with the ray (dx start, dy start) from the centre point (i.e. the clockwise end of the arc for CIRCULAR ARC CENTRE, the anti-clockwise end of the arc for CIRCULAR ARC CENTRE REVERSED); the last point is the intersection of the circle with the ray (dx end, dy end) from the centre point (i.e. the anti-clockwise end of the arc for CIRCULAR ARC CENTRE, the clockwise end of the arc for CIRCULAR ARC CENTRE REVERSED).

ELLIPTICAL ARC ...:
The first point is the intersection of the ellipse with the ray (dx start, dy start) from the centre point; the last point is the intersection of the ellipse with the ray (dx end, dy end) from the centre point.

GENERALIZED DRAWING PRIMITIVE...:
For GDPs which generate line primitives, the first point is the first point of the point list; and the last point is the last point of the point list, unless explicitly stated otherwise in the GDP registration or other documentation.

CONNECTING EDGE:
If the region is open, the starting point of the connecting edge is the last point of the last line primitive, and the ending point of the connecting edge is either the first point of the following primitive or the current closure point as described above. If the connecting edge would be of zero length (i.e. if the two points it connects are coincident), the function is ignored. As with other line primitives, the edge attribute values in effect at the time it is invoked are associated with any edge portion generated by this function.

If the current region is not open, invocations of the CONNECTING EDGE function are ignored (i.e. CONNECTING EDGE cannot be used to connect regions).

CONNECTING EDGE is a line primitive, not a modal setting–it should be invoked once for each connecting edge desired in the closed figure.

Invoking CONNECTING EDGE more than once after a line primitive results in the first instance (with its associated local attributes) being used.

The theoretical zero-width definitions of the line primitives, not their finite-width renditions on the drawing surface, are used to define the explicit boundary portions of the closed figure. In particular, clipping does not apply to the construction of the closed figure, and the gaps or spaces of the edge type or the rendered width of the edge width do not affect the definition of the boundary of the closed figure.

3.10.5.3.2 Contribution of fill functions to the closed figure

Each fill primitive contributes a complete region to the figure (POLYGON SET may contribute more than one), after first closing the current region if one is open. The CGI device performs an implicit NEW REGION before and after a fill primitive invoked in FIGURE OPEN state. (I.e. the new region resulting from a fill primitive is closed, and the next primitive begins a new region.)

The unclipped boundary of each fill primitive contributes to the unclipped boundary of the closed figure.

POLYGON SET primitives contribute to closed figure construction as follows:

- A POLYGON SET is considered to contribute one or more complete regions. If the current region has not been closed, an implicit NEW REGION is performed before the POLYGON SET is added to the figure definition. If the POLYGON SET does not end with a point whose edge-out flag is CLOSE VISIBLE or CLOSE INVISIBLE, an implicit NEW REGION is performed after the POLYGON SET.

- Sequences of points with edge-out flag VISIBLE are treated as if they were polylines, terminating with the first point with a different edge-out flag. Each such polyline becomes an edge portion of the boundary of the figure. The edge attribute values (including EDGE VISIBILITY) in effect when POLYGON SET is invoked are associated with any edge portion added in this way.
- Sequences of points with edge-out flag INVISIBLE contribute implicit boundary portions which are polylines joining the points in the sequence, but not edges. Edge attribute values are not associated with these.
- Points with edge-out flag CLOSE INVISIBLE generate the equivalent of a NEW REGION, generating an implicit boundary portion from this point to the current closure point if these are not coincident, and closing the current region.
- Points with edge-out flag CLOSE VISIBLE generate the equivalent of a CONNECTING EDGE followed by a NEW REGION, resulting in an edge portion from this point to the current closure point if these are not coincident. The edge attribute values (including EDGE VISIBILITY) in effect when POLYGON SET is invoked are associated with any edge portion added in this way.
- POLYGON SET does not affect the value of the Edge Visibility entry in the state list.

3.10.5.3.3 GDP

A GDP which is defined as a line primitive shall specify the first point as the first point of the point list and the last point as the last point of the point list, unless explicitly stated otherwise in the GDP registration, with respect to closed figure construction. Such GDPs are assumed to contribute to a closed figure a boundary corresponding to the unclipped locus which would be rendered if the function were invoked when not in FIGURE OPEN state. Any other behaviour shall be documented explicitly in the GDP description. A GDP which is defined as being a fill primitive is treated as in the previous section. Any variation or special handling in state FIGURE OPEN shall be documented explicitly in the GDP description.

3.10.5.4 Local and global attributes of closed figures

Local attributes are those associated with each individual edge portion, and that can vary between each edge portion within the closed figure object. The local attributes for the edge portions of closed figures are the set of edge attributes (excluding EDGE CLIPPING MODE) and the general attributes AUXILIARY COLOUR, TRANSPARENCY and DRAWING MODE.

Global attributes are those associated with the closed figure object as a whole rather than its component parts. The functions which set their state list values may be invoked during FIGURE OPEN state, and have their usual effect on the corresponding state list entries. The values associated with the closed figure are those in the state list when END FIGURE is invoked to complete the object formation (even in the event of figure buffer overflow during construction). Global attributes of closed figures are the set of fill interior attributes, the EDGE CLIPPING MODE attribute, the general attributes CLIP INDICATOR, CLIP RECTANGLE, and PICK IDENTIFIER, and the general attributes AUXILIARY COLOUR, TRANSPARENCY, and DRAWING MODE, which apply to the interior of the closed figure. In order to use a different value of one of the last three general attributes for the interior from that for any of the edge portions, the appropriate attribute function should be invoked just prior to invoking END FIGURE with the value to be used for the interior.

3.10.5.5 Errors in FIGURE OPEN state

3.10.5.5.1 Non-contributing functions

Non-contributing primitives cause an error and are ignored. Attribute and control functions not directly contributing to the construction of the closed figure object are permitted, and have their normal effect on the corresponding state list entries.

3.10.5.5.2 Overflow of the figure buffer

When overflow occurs during FIGURE OPEN state, a single error is generated and the CGI device stays in state FIGURE OPEN. Subsequent primitives which would have contributed to the closed figure are ignored without generating additional errors; other behaviour and error conditions defined for FIGURE OPEN state remain the same after overflow. When END FIGURE is invoked, as much of the closed figure as had been entered into the buffer when the overflow occurred is closed and global attribute values in effect are associated with it before it is passed on down the pipeline.

3.10.5.5.3 Abandonment of the closed figure definition

If VDC TYPE or any function which changes the VDC-to-Device Mapping is invoked in FIGURE OPEN state, the closed figure under construction is abandoned and the Virtual Device ignores subsequent primitives which would have contributed to the closed figure until the receipt of END FIGURE causes the transition out of FIGURE OPEN state. Other behaviour and error conditions defined for FIGURE OPEN state remain the same in this case.

Invoking INITIALIZE in FIGURE OPEN state causes the closed figure to be abandoned, the figure buffer to be cleared, and a transition out of state FIGURE OPEN.

3.10.5.6 Examples

Annex E gives some examples of the use of closed figures.

3.10.6 Allowed latitude

3.10.6.1 Interior styles

An implementation is only required to support interior style HOLLOW. The list of interior styles supported is recorded in the Fill Description Table.

When the number of pixels in the region specified by PATTERN SIZE is insufficient for displaying the selected pattern at one pattern cell per pixel, the CGI allows some latitude. The preferred behaviour is to use as much of the pattern as possible. Sampling, or otherwise condensing the pattern, is also permitted, and is indicated by the Pattern Fill Fallback entry in the Fill Description Table.

The implementation of the transformation of patterns is subject to allowed latitude, with the preferred behaviour that they are transformed.

3.10.6.2 Global and local attributes of closed figures

An implementation need not distinguish between global and local attributes in the construction of closed figure objects. The level of support provided by an implementation is indicated by the Closed Figure Capability entry in the Primitive Support Description Table as follows:

- A level of NONE indicates that the Virtual Device does not support closed figures in any form.
- A level of GLOBAL indicates that the Virtual Device does not support local edge attribute changes during the FIGURE OPEN state. That is, all local attributes are treated as global attributes of the closed figure. (I.e. the values used are those in effect at the time that END FIGURE function is invoked.)
- A level of LOCAL indicates full support of closed figures as described in 3.10.5.

3.10.6.3 Edge continuity and edge width

The following levels of Edge Type Continuity are permitted for a CGI Virtual Device: RESTART, CONTINUOUS, and OTHER. The implemented level of support is indicated by the Line/Edge Type Continuity Capability entry in the Primitive Support Description Table.

- A level of RESTART indicates that the edge type pattern is restarted at each vertex of the visible edge of a fill object except the last vertex;
- A level of CONTINUOUS indicates that the Virtual Device maintains the edge type continuously across all vertices of the visible edge of a single fill object except the first and last vertices;
- A level of OTHER indicates that another method has been used (for example, guaranteeing some continuity and that end points of each visible edge are always drawn).

ISO/IEC 9636 allows latitude in the alignment of a finite width realized edge with respect to the boundary. The preferred behaviour is to centre the line on the boundary; an allowed latitude is to render the edge everywhere inside and contiguous to the boundary.

3.11 Image primitive

3.11.1 Image function

The CGI provides a single image function which generates an image primitive:

CELL ARRAY	defines a two-dimensional array of coloured cells and their position and shape in VDC space.

3.11.2 Image attributes

The appearance of an image primitive is determined by the defining colour values of the image data and the following general attributes:

3.11.2.1 General attributes

CLIP INDICATOR	determines whether object clipping is to be applied to the image object;
CLIP RECTANGLE	used in determining the effective clip region to be applied to an image object if the associated CLIP INDICATOR is ON;
DRAWING MODE	determines how the rendered (and rasterized) object is mixed with what already exists on the drawing surface (as defined in ISO/IEC 9636-6);
PICK IDENTIFIER	(defined in ISO/IEC 9636-4).

3.11.3 Image primitive geometry

A CELL ARRAY is specified by three corner points (P, Q, R), which define a parallelogram in VDC space, and a list of cell colour specifiers. P and Q delimit endpoints of a diagonal of the parallelogram, and R defines a third corner. This area is subdivided into nx*ny contiguous parallelograms as follows. The edge from P to R is subdivided into nx equal intervals, and the edge from R to Q is subdivided into ny equal intervals. The colour list consists of nx*ny cell colour specifiers, conceptually organized as a two-dimensional array of dimensions nx and ny, representing the column and row dimensions respectively. The first array element is mapped to the cell at corner P, and the last array element is mapped to the cell at corner Q. Incrementing the first index of the array corresponds to moving along the direction from P to R. Incrementing the second index of the array corresponds to moving along the direction from R to Q.

The specification of the three points P, Q, and R may result in the CELL ARRAY being rotated, mirrored, or skewed into a parallelogram.

3.11.3.1 Degeneracy of image objects

Degeneracy of image objects may arise either due to the client's specifications or unintentionally due to round-off error in transforming coordinate data.

If the parallelogram specified for a CELL ARRAY degenerates to a region of zero area (points coincident), a dot is rendered. A line is rendered if the parallelogram degenerates to a one-dimensional region, that is, the three points are collinear. The dot or line is rendered using implementation-dependent line attributes.

3.11.4 Image clipping

The clipping of an image object proceeds in a manner consistent with SHAPE clipping.

3.11.5 Allowed latitude

This part of ISO/IEC 9636 allows latitude for whether an implementation is able to fill a CELL ARRAY primitive with the contents of its array of coloured cells, and whether it is able to perform general transformations of the array of cells. The implemented levels of support are indicated by the Cell Array Fill Capability, Cell Array Alignment Capability, and Cell Array Rendering Technique entries in the Primitive Support Description Table.

The entry Cell Array Fill Capability indicates one of:

- FILLED (preferred behaviour), to mean that the implementation is able to render the array of coloured cell;
- OUTLINED, to mean that the implementation is only able to render the outline of the array of coloured cells.

The entry Cell Array Alignment Capability indicates one of:

- SKEWED (preferred behaviour), to mean that the implementation is able to transform and render a potentially non-rectangular CELL ARRAY primitive;
- AXIS ALIGNED, to mean that the implementation is only able to render a CELL ARRAY whose outline, after transformation, is aligned with the coordinate system axes. An implementation, that supports axis aligned CELL ARRAY's only ignores the point R defining the parallelogram and uses the axis aligned rectangle defined by points P and Q.

The entry Cell Array Rendering Technique indicates one of:

- EXACT (preferred behaviour), when displaying the image object on a raster device, all pixels whose centres lie beneath any part of a cell (including its mathematical boundary) are given the colour of that cell. The colour of a pixel whose centre is precisely on the boundary between two cells is implementation-dependent;
- OTHER, the image object is rendered using some other technique (for example, using dithering or Floyd-Steinberg error diffusion).

3.12 Generalized Drawing Primitives

3.12.1 GDP function

The CGI supports access to special geometric output capabilities of devices and workstations through the GENERALIZED DRAWING PRIMITIVE (GDP). By definition, a GDP function is restricted to be only those functions which contribute to the geometry of non-standard graphic objects.

A GDP includes a list of VDC points as a parameter. Zero or more of the attribute sets of the standardized graphic primitives may affect the appearance of a particular GDP. These are the sets of attributes appropriate for the specified GDP function and are selected for the GDP as part of the definition of the GDP.

Note that, if a GDP requires attributes other than those which are already defined in ISO/IEC 9636, an ESCAPE function may be used to specify these attributes. Other types of parameters can be passed to the GDP in a data record. The format of this data record is defined in the definition of the GDP.

Non-negative GDP identifiers are reserved for registration in the ISO International Register of Graphical Items; negative values are available for private use.

See 3.9.2.1 and 3.10.5.3.3 for descriptions of the use of a GDP with compound text and closed figure objects, respectively.

3.13 Inquiry

3.13.1 State lists and description tables

Output inquiry functions, as described in clause 6 of this part of ISO/IEC 9636, provide the client with the means to access the information in the output description tables and output state lists.

Details about the relationship between a description table or state list and the corresponding inquiry function(s) are described in ISO/IEC 9636-1.

3.14 Retrieval

3.14.1 Retrieval of text extent

The GET TEXT EXTENT function is provided to permit the client to obtain the concatenation point and delimiting text extent parallelogram of a text string (see figure 15). This function is particularly useful when the Virtual Device supports kerning or proportional spacing, which make it difficult for the client to predict the extent of a text string.

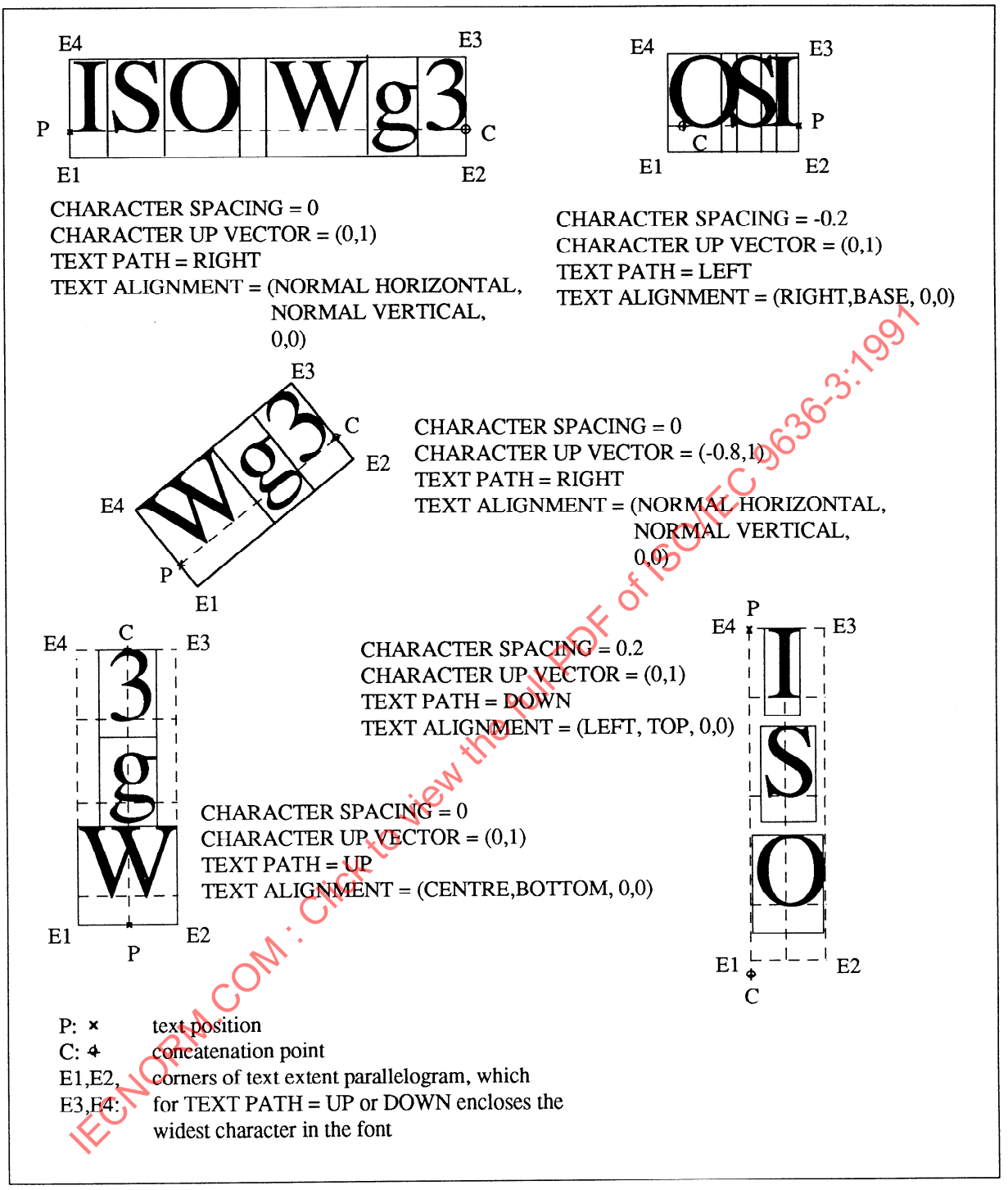


Figure 15 – Examples of replies to GET TEXT EXTENT with different text attributes

4 Interactions with other parts of ISO/IEC 9636

This clause identifies the interactions between the functions defined in this part and the other parts of ISO/IEC 9636.

4.1 Interactions with all other parts of ISO/IEC 9636

4.1.1 Character set and font selection

The character set and font selection mechanism are defined in this part of ISO/IEC 9636 for use in rendering text elements on the drawing surface.

Where no explicit mention is made in the other parts of ISO/IEC 9636, it is to be assumed that any other string parameter is intended to be interpreted without recourse to the character set and font selection mechanism, but that implementation-dependent use of such mechanisms is not prohibited. For example, this paragraph applies to the string parameter of the MESSAGE function.

Each function defined in another part of ISO/IEC 9636 which relies upon the character set or font selection mechanism defined in this part of ISO/IEC 9636 shall state so explicitly.

Functions which define the character set or font selection mechanism:

CHARACTER CODING ANNOUNCER
CHARACTER SET INDEX
ALTERNATE CHARACTER SET INDEX
CHARACTER SET LIST
TEXT FONT INDEX
FONT LIST
TEXT BUNDLE INDEX
ASPECT SOURCE FLAGS

4.2 Interactions with ISO/IEC 9636-2 (Control)

4.2.1 Effect of INITIALIZE

The INITIALIZE function sets all entries of the state lists defined in this part of ISO/IEC 9636 to their default values. All bundles which were created or configured with <primitive type> REPRESENTATION functions are removed, leaving only the predefined bundles, restored to their predefined values. The colour table is also returned to its default values.

The List of Font Names and List of Current Character Sets entries are restored to their default values. Note that ISO/IEC 9636 does not specify any effect on the presence or absence of the font data itself; that is, font data which is down-loaded to a device outside of CGI control or by use of ESCAPE functions need not be removed by the INITIALIZE function.

The INITIALIZE function sets, by default, the G0 set into positions 2/1 through 7/14 of the 7-bit or 8-bit code chart and the G1 set into positions 10/1 through 15/14 (or 10/0 through 15/15 if the G1 set is a 96-character set).

If the CGI was in an Output State other than ACTIVE, any compound object being constructed is abandoned without causing rendering. The closed figure buffer referred to in the text is left empty after INITIALIZE is executed.

There are no state restrictions on the use of INITIALIZE and TERMINATE, i.e. INITIALIZE and TERMINATE may be used at any time (see ISO/IEC 9636-2, 5.2.1).

4.2.2 Effect of VDC Extent and VDC Type

There are several attributes defined in this part of ISO/IEC 9636 whose defaults depend on the default value of the VDC Extent. These defaults do not dynamically track changes in the VDC Extent initiated by the client. It is expected that the client

who uses other than the default value of VDC Extent will set attributes such as CHARACTER HEIGHT to values which have sensible interpretation in the selected coordinate space.

When VDC Type changes, all state list entries specified by parameters using data type VDC or P are reset to their default values in the new VDC type. For attributes stored using SAVE PRIMITIVE ATTRIBUTES, the VDC Type is stored along with the attribute values set and so a change in VDC Type does not affect the stored values. An error will occur, however, if an attempt is made to restore the saved attribute set if the stored VDC Type does not match the current VDC Type.

If the client changes the VDC Type or the VDC-to-Device Mapping in the middle of compound object construction, that compound object is abandoned without causing rendering and the Virtual Device ignores subsequent boundary definition functions until the client resets the Output State to ACTIVE.

4.3 Interactions with ISO/IEC 9636-4 (Segments)

4.3.1 CLIP RECTANGLE, CLIP INDICATOR, and COPY SEGMENT

When segments are copied using the function COPY SEGMENT, the eventual application of the associated copy transformation may result in the effective clip region associated with an object becoming a convex polygonal region. See ISO/IEC 9636-4, 5.2.5 for a description of this effect.

4.3.2 LINE WIDTH and EDGE WIDTH

If the specification mode is SCALED, the width of lines and edges is not affected by transformations, specifically, the VDC-to-Device Mapping, the copy transformation, and the segment transformation. If the specification mode is VDC, the width is subject to the segment and copy transformations and the VDC-to-Device Mapping. Note that the transformations are applied after the abstract rendering of VDC line and edge width and line and edge type in VDC space.

NOTE – When transformations are applied the individual dashes of a VDC wide line or edge may be transformed into parallelograms.

4.3.3 MARKER SIZE

The rendering of the shape of a marker is not affected by the segment or copy transformations. Neither the shape nor the orientation of the marker symbol is altered. If specified in VDCs, the size of a marker (with the exception of marker type 1 (dot)) is subject to the segment transformation, the copy transformation, and the VDC-to-Device Mapping.

4.3.4 PICK IDENTIFIER

Graphic objects stored in segments have an associated PICK IDENTIFIER attribute, which may be used to identify individual graphic objects, or groups of objects during a pick operation.

4.3.5 Dynamic modification

For some entries in the description tables a Dynamic Modification Accepted For value may be specified by the implementation. This entry indicates dynamic behaviour which is controlled by the Implicit Regeneration Mode, specified in ISO/IEC 9636-4.

4.3.6 Segment open state

Graphic objects created while the Segment Open State is YES can alter the Segment Open State to OVERFLOW, as specified in ISO/IEC 9636-4.

4.4 Interactions with ISO/IEC 9636-5 (Input)

The output states associated with this part of ISO/IEC 9636 are orthogonal to the input states associated with ISO/IEC 9636-5. There are no specified interactions between ISO/IEC 9636-3 and the standardized functions and features specified in ISO/IEC 9636-5.

However, an implementation may wish to make use of some of the attributes specified for output when defining implementation-dependent echoes.

4.5 Interactions with ISO/IEC 9636-6 (Raster)

4.5.1 State related restrictions

There are no constraints on any functionality as defined in ISO/IEC 9636-6 as a result of TEXT OPEN or FIGURE OPEN states. In particular, the compound objects described in this part of ISO/IEC 9636 (closed figures and compound text) do not affect the drawing or display bitmap until their specification is complete.

4.5.2 Interior style BITMAP

The interior style BITMAP is provided for use on raster devices. The function FILL BITMAP is defined in ISO/IEC 9636-6, and is used to select the bitmap index and bitmap region to be used as the fill pattern when interior style is BITMAP. The capability of the Virtual Device with respect to BITMAP interior style is contained in a Raster Description Table in ISO/IEC 9636-6, but the identifier of the current Fill Bitmap is maintained in the Fill Bitmap Identifier entry in the Fill Attribute State List defined in this part of ISO/IEC 9636.

Predefined bundles shall not specify interior style BITMAP as there are no predefined fill bitmaps. Restrictions on the use of BITMAP interior style in defining and using fill bundles are documented in ISO/IEC 9636-6.

The interpretation of other attributes such as TRANSPARENCY, AUXILIARY COLOUR, and FILL REFERENCE POINT when using fill bitmaps are documented in ISO/IEC 9636-6.

4.5.3 Drawing modes

Drawing modes are provided for use on raster devices to allow the CGI client to select the way in which pixels (the values maintained in the bitmaps) are combined during drawing operations. In particular, the DRAWING MODE attribute defined in ISO/IEC 9636-6 is associated with all graphic objects and applies to the rendering of graphic objects into a bitmap.

5 Abstract specification of functions

5.1 Introduction

The CGI functions related to output of graphic primitives are discussed in this clause.

The format used throughout this clause to define the CGI function set separates function behaviour from implementation. Each function is named, its parameters are described, and their data types are listed, and a specification of its effect and of any error it may detect is given.

The functions defined in this clause are

- Graphic Primitive Functions, which define the geometric components of a picture in the CGI.
- Attribute Functions, which define the appearance of graphic primitives.
- Control Functions, which specify the modes of operation of certain other functions and control some aspects of the device's operation.
- The GET TEXT EXTENT function, which returns information about a text string.

5.1.1 Data types employed

The abstract specifications of functions detail the functions in terms of input and output parameters. The data type of each parameter is selected from a standard set and is identified in the functional specification by a standard abbreviation.

The data types and the abbreviations used in this part of ISO/IEC 9636 are taken from the complete list of data types in ISO/IEC 9636-1, 5.2.10.

5.2 Graphic primitive functions

5.2.1 POLYLINE

Parameters:

In point list (n > 0) nP

Effect:

A line primitive is defined, consisting of the sequence of connected straight lines from the first point in the *point list* to the second point, from the second point to the next point, … , and from the next-to-last point to the last point.

See 3.7, in particular, 3.7.3.1 for line degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.2 DISJOINT POLYLINE

Parameters:

In	point list	(n > 0)	nP

Effect:

A line primitive is defined, consisting of the sequence of unconnected straight lines from the starting point to the second point, from the third point to the fourth point, ... , ending with either the straight line from the second from last point to the next from last point, or from the next-to-last point to the last point.

See 3.7, in particular, 3.7.3.1 for line degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.3 CIRCULAR ARC 3 POINT

Parameters:

In	starting point	P
In	intermediate point	P
In	ending point	P

Effect:

A line primitive consisting of a circular arc is defined from the *starting point*, through the *intermediate point*, to the *ending point*.

See 3.7, in particular, 3.7.3.1 for line degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.4 CIRCULAR ARC CENTRE

Parameters:

In	centre point		P
In	dx start, dy start, dx end, dy end		4VDC
In	radius	(≥ 0)	VDC

Effect:

A line primitive consisting of a circular arc is defined as follows:

A start ray is constructed from the *centre point*, taking *dx start* and *dy start* as a direction vector from the *centre point*. An end ray is constructed similarly, using *dx end* and *dy end* as a direction vector from the *centre point*.

The specified *radius* and *centre point* define a circle. The arc is defined in the positive angular direction (as measured in VDC space when the graphic object is created) from the intersection of the circle and the start ray (as obtained by measuring a distance *radius* along the start ray from the *centre point*) to the intersection of the circle and the end ray. The start and end rays are not drawn.

If the start ray and the end ray are coincident, a 360° arc is defined. Note that this circle is not filled.

See 3.7, in particular, 3.7.3.1 for line degeneracy.

Errors:

Error identifier: 3:310
Cause: dx start and dy start, or dx end and dy end, may not be zero at the same time
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.5 CIRCULAR ARC CENTRE REVERSED

Parameters:

In	centre point		P
In	dx start, dy start, dx end, dy end		4VDC
In	radius	(≥ 0)	VDC

Effect:

A line primitive consisting of a circular arc is defined as in CIRCULAR ARC CENTRE, except that the arc is defined in the negative angular direction (as measured in VDC space when the graphic object is created) from the intersection of the circle and the start ray (as obtained by measuring a distance *radius* along the start ray from the *centre point*) to the intersection of the circle and the end ray. The start and end rays are not drawn.

If the start ray and the end ray are coincident, a 360° arc is defined. Note that this circle is not filled.

See 3.7, in particular, 3.7.3.1 for line degeneracy.

NOTE – This function exists primarily because the direction in which the locus is defined (start to finish) is crucial in closed figure construction. However, direction may also be significant with certain line types or drawing modes for rendering. Note also that CIRCULAR ARC CENTRE followed by CIRCULAR ARC CENTRE REVERSED with precisely the same parameter values results in a full circle, not the same arc drawn in opposite directions.

Errors:

Error identifier: 3:310
Cause: dx start and dy start, or dx end and dy end, may not be zero at the same time
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.6 ELLIPTICAL ARC

Parameters:

In	centre point	P
In	first conjugate radius endpoint	P
In	second conjugate radius endpoint	P
In	dx start, dy start, dx end, dy end	4VDC

Effect:

A line primitive consisting of an elliptical arc is defined as follows:

The *centre point* specifies the centre of an ellipse. The conjugate radius endpoints include one endpoint from each conjugate radius; together with the *centre point*, they define the two conjugate radii of the ellipse.

A start ray is constructed from the *centre point*, taking *dx start* and *dy start* as a direction vector from the *centre point*. An end ray is constructed similarly, using *dx end* and *dy end* as a direction vector from the *centre point*. The start and end rays are not drawn.

The defined arc begins at the intersection of the ellipse and the start ray and follows the ellipse to the intersection of the ellipse and the end ray in the direction defined as follows. Let the *centre point* be labelled M, the *first conjugate radius endpoint* P1, and the *second conjugate radius endpoint* P2, then the line segments M-P1 and M-P2 define two conjugate radii, referred to in what follows as the first conjugate radius and the second conjugate radius respectively. The conjugate radii meet at M and define two angles: the sum of the two angles is 360°, one angle is less than 180° and the other is greater than 180°. The definition of the elliptical arc is in the direction from the first conjugate radius to the second conjugate radius through the smaller of these two angles.

If the start ray and end ray are coincident, the full ellipse is defined.

See 3.7, in particular, 3.7.3.1 for line degeneracy.

Errors:

Error identifier: 3:310
Cause: dx start and dy start, or dx end and dy end, may not be zero at the same time
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.7 CONNECTING EDGE

Parameters:

none

Effect:

If the Virtual Device is in state FIGURE OPEN and the current region is not closed, an explicit boundary portion and edge portion is created connecting the last point of the last line primitive with either the closure point (if followed by NEW REGION, END FIGURE, or a fill primitive) or the first point of the next line primitive. If the points connected are coincident, no edge portion or boundary portion is added.

If no region is open, this function is ignored and no error is generated.

If multiple invocations of this function precede the function which causes the edge portion to be added, the first instance (along with the associated attributes) is used.

See 3.10.5.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:303
Cause: Function not allowed in Output State ACTIVE
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.8 POLYMARKER

Parameters:

In	point list	(n > 0)	nP

Effect:

A marker primitive consisting of a sequence of markers is defined to identify all of the positions in the point list.

See clause 3.8, in particular, 3.8.3.1 for marker degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

5.2.9 TEXT

Parameters:

In	point		P
In	flag	(NOT FINAL, FINAL)	E
In	string		S

Effect:

The TEXT function defines a text primitive which, depending on the *flag* parameter, may also begin the construction of a compound text object.

If *flag* is FINAL, the *string* parameter constitutes the entire text string and a simple text primitive is created.

If *flag* is NOT FINAL, the Output State in the General Attributes and Output Control State List is changed from ACTIVE to TEXT OPEN. The *string* and *point* parameters and following APPEND TEXT strings define a compound text object. The compound text object is completed on receipt of an APPEND TEXT function with flag set to FINAL and the Output State is then restored to state ACTIVE.

See 3.9, in particular, 3.9.4.6 for text degeneracy.

Errors:

Error identifier: 3:306
Cause: Function does not support a flag value of NOT FINAL
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

Error identifier: 6:303
Cause: Text buffer overflowed
Reaction: If flag is NOT FINAL, Output State remains TEXT OPEN; further contributing primitives ignored. If flag is FINAL, as much of the compound text object as has been accumulated is used in completing the compound text construction; the Output State is changed to ACTIVE.

5.2.10 RESTRICTED TEXT

Parameters:

In	extent: delta width, delta height		2VDC
In	point		P
In	flag	(NOT FINAL, FINAL)	E
In	string		S

Effect:

The RESTRICTED TEXT function defines a text primitive in the same way as does the TEXT function. However, the text primitive (or compound text object) is constrained to be within a parallelogram determined by the *extent* parameters, the *point* parameter and the associated character orientation vectors.

The *delta width* is a distance along the direction of the character base vector. The *delta height* is a distance along the direction of the character up vector.

See 5.2.9 and 3.9.4.5.

Errors:

Error identifier: 3:306
Cause: Function does not support a flag value of NOT FINAL
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

Error identifier: 6:303
Cause: Text buffer overflowed
Reaction: If flag is NOT FINAL, Output State remains TEXT OPEN; further contributing primitives ignored. If flag is FINAL, as much of the compound text object as has been accumulated is used in completing the compound text construction; the Output State is changed to ACTIVE.

5.2.11 APPEND TEXT

Parameters:

In	flag	(NOT FINAL, FINAL)	E
In	string		S

Effect:

The APPEND TEXT function is used in the definition of a compound text object. If *flag* is NOT FINAL, a text primitive for the *string* parameter is generated and accumulated with the construction of a compound text object.

If *flag* is FINAL, a text primitive for the *string* parameter is generated and accumulated with the compound text object and the compound text construction is completed; the Output State is changed from TEXT OPEN to state ACTIVE.

See 5.2.9, 5.2.10, and 3.9.

Errors:

Error identifier: 3:306
Cause: Function does not support a flag value of NOT FINAL
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

Error identifier: 5:303
Cause: Function not allowed in Output State ACTIVE
Reaction: Function ignored.

Error identifier: 6:303
Cause: Text buffer overflowed
Reaction: If flag is NOT FINAL, Output State remains TEXT OPEN; further contributing primitives ignored. If flag is FINAL, as much of the compound text object as has been accumulated is used in completing the compound text construction; the Output State is changed to ACTIVE.

5.2.12 POLYGON

Parameters:

In	point list	(n > 0)	nP

Effect:

A fill primitive with a polygonal boundary is defined. The boundary is defined by connecting each vertex in the ordered *point list* to its successor and the last to the first by straight edges. The polygonal region is not restricted to a simple region – the boundary may intersect itself or have partly or wholly coincident edges.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:302
Cause: Number of points in polygon is too large
Reaction: The maximum number of points are used.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.13 POLYGON SET

Parameters:

In flagged point list ((n > 0), (INVISIBLE, VISIBLE, CLOSE INVISIBLE, CLOSE VISIBLE)) n[P,E]

Effect:

This function defines a set of closed polygons. Each polygon is defined by a collection of straight edges, each of which may be visible or invisible.

The *flagged point list* is processed sequentially. The first point starts the first polygon of the set, and becomes the current closure point. Each point in the list is connected either to its successor in the list, or to the current closure point, (but not both), with either a visible or invisible edge.

An edge out flag is associated with each point in the point list. The possible values for the flag and the corresponding actions are:

INVISIBLE: the line from point n to point n+1 defines an edge which is invisible.

VISIBLE: the line from point n to point n+1 defines an edge which is visible.

CLOSE INVISIBLE: the line from point n to the current closure point defines an edge which is not visible. The next point in the list begins a new polygon region and becomes the new current closure point. The next point in the list is not connected to any previous point; that is, no line is generated to it from a previous point.

CLOSE VISIBLE: is identical to CLOSE INVISIBLE, except that the added closing edge is visible.

If the edge out flag of the last point in the list is VISIBLE, it is treated as CLOSE VISIBLE; if the edge out flag is INVISIBLE, it is treated as CLOSE INVISIBLE.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.14 RECTANGLE

Parameters:

In corner points 2P

Effect:

A rectangular fill primitive with sides oriented parallel to the VDC axes, specified by *corner points* representing the diagonally opposite corners is defined.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.15 CIRCLE

Parameters:

In	centre point		P
In	radius		(≥ 0)
	VDC		

Effect:

A circular fill primitive of the specified *radius* centred at the specified VDC *centre point* position is defined.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.16 CIRCULAR ARC 3 POINT CLOSE

Parameters:

In	starting point		P
In	intermediate point		P
In	ending point		P
In	close type	(PIE, CHORD)	E

Effect:

A fill primitive with a circular arc for a portion of its boundary is defined. The arc portion is defined as in the CIRCULAR ARC 3 POINT line primitive.

If *close type* is CHORD, the boundary of the fill primitive is completed by the line segment from the *starting point* of the arc to the *ending point*.

If *close type* is PIE, the boundary of the fill primitive is completed by the two line segments from the centre to the *starting point* and *ending point*.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.17 CIRCULAR ARC CENTRE CLOSE

Parameters:

In	centre point		P
In	dx start, dy start, dx end, dy end		4VDC
In	radius	(≥ 0)	VDC
In	close type	(PIE, CHORD)	E

Effect:

A fill primitive with a circular arc for a portion of its boundary is defined. The arc portion is defined as in the CIRCULAR ARC CENTRE line primitive.

If *close type* is CHORD, the boundary of the fill primitive is completed by the line segment from the *starting point* of the arc to the *ending point*.

If *close type* is PIE, the boundary of the fill primitive is completed by the two line segments from the *centre point* to the *starting point* and *ending point*.

If the start ray and end ray are coincident, a circle is rendered. If the *close type* is PIE and EDGE VISIBILITY is VISIBLE, the boundary of the fill object defined to include the line segments connecting the *centre point* to the circle along the start and end ray is rendered.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 3:310
Cause: dx start and dy start, or dx end and dy end, may not be zero at the same time
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.18 ELLIPSE

Parameters:

In	centre point	P
In	first conjugate radius endpoint	P
In	second conjugate radius endpoint	P

Effect:

An elliptical fill primitive is defined as follows:

Centre point specifies the centre of an ellipse. The conjugate radius endpoints include one endpoint from each conjugate radius; together with *centre point*, they define the two conjugate radii of the ellipse.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.19 ELLIPTICAL ARC CLOSE

Parameters:

In	centre point		P
In	first conjugate radius endpoint		P
In	second conjugate radius endpoint		P
In	dx start, dy start, dx end, dy end		4VDC
In	close type	(PIE, CHORD)	E

Effect:

A fill primitive with an elliptical arc for a portion of its boundary is defined. The arc portion is defined in the same way as in the ELLIPTICAL ARC line primitive.

If *close type* is CHORD, the boundary of the fill primitive is completed by the line segment from the starting point of the arc to the ending point.

If *close type* is PIE, the boundary of the fill primitive is completed by the two line segments from the *centre point* to the starting point and ending point.

If the start ray and end ray are coincident, the ellipse is rendered. IF *close type* is PIE and EDGE VISIBILITY is VISIBLE, the boundary of the fill object is defined to include the line segments connecting the *centre point* to the ellipse along the start and end rays.

See 3.10, in particular, 3.10.3.5 for fill degeneracy.

Errors:

Error identifier: 3:310
Cause: dx start and dy start, or dx end and dy end, may not be zero at the same time
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.2.20 CELL ARRAY

Parameters:

In	corners of parallelogram: P, Q, R		3P
In	dimensions nx, ny	(nx,ny > 0)	2I
In	local colour precision requirement	(≥ 0)	I
In	cell colour specifiers		nx*ny CO

Effect:

An image primitive is defined as follows:

The points P, Q, and R define an arbitrary parallelogram. P and Q delimit the endpoints of a diagonal of the parallelogram, and R defines a third corner.

NOTE – implementations that only support axis aligned CELL ARRAY's ignore point R.

The *local colour precision requirement* parameter specifies the precision requirement for the *cell colour specifiers*. The precision requirement is for either indexed or direct colour, according to the Colour Selection Mode.

If the Colour Selection Mode is INDEXED, then a positive value for *local colour precision requirement* specifies the minimum number of bits required to specify a colour index, and a value of zero means to impose the same requirement as that for the Colour Index Precision in the Control State List.

If the Colour Selection Mode is DIRECT, then a positive value for *local colour precision requirement* specifies the minimum number of bits required to specify each component of an RGB triple, and a value of zero means to impose the same requirement as that for the Colour Precision in the Control State List.

NOTE – This primitive requires the need for resampling existing information, as cells are logical entities, not tied to any physical dimensions. Scaling, rotation, or mirroring of fields within a picture may be performed using this primitive.

See 3.11, in particular, 3.11.3.1 for image degeneracy.

Errors:

Error identifier: 3:311
Cause: Local colour precision requirement not achievable
Reaction: Function ignored.

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

5.2.21 GENERALIZED DRAWING PRIMITIVE (GDP)

Parameters:

In	identifier	(-n..-1,1..n)	I
In	point list	($n \geq 0$)	nP
In	data record		D

Effect:

A Generalized Drawing Primitive (GDP) is specified by the *identifier*, the *point list*, and the *data record*. The appearance of the GDP is determined by zero or more of the attribute sets of the standard graphic primitives, depending on the particular GDP. The parameters of the GDP are interpreted and utilized in a device-dependent manner.

A GDP must treat transformations in a manner consistent with ISO/IEC 9636.

Non-negative values of the identifier are reserved for registration and future standardization; negative values are available for private use.

NOTE – GDP provides convenient access to non-standard graphic primitives that a device may support. The distinction between GDP and ESCAPE has been made to distinguish between functions which create graphic primitives, that is, contribute to the geometry of graphic object creation, and others.

Error 5:301 is only detected if the GDP does not contribute to compound text. Error 5:302 is only detected if the GDP does not contribute to closed figures.

See 3.12.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

Error identifier: 6:301
Cause: Function exceeds a limit specified in the description tables
Reaction: As much as possible from the beginning of the implied content will be used, the remainder will be discarded.

Error identifier: 6:303
Cause: Text buffer overflowed
Reaction: If flag is NOT FINAL, Output State remains TEXT OPEN; further contributing primitives ignored. If flag is FINAL, as much of the compound text object as has been accumulated is used in completing the compound text construction; the Output State is changed to ACTIVE.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.3 Attribute functions

5.3.1 LINE BUNDLE INDEX

Parameters:

In	line bundle index	(1..n)	IX

Effect:

The Line Bundle Index entry in the Line Attributes State List is set to the value specified.

Errors:

Error identifier: 3:312
Cause: Requested bundle not available
Reaction: Mapped to default.

5.3.2 LINE TYPE

Parameters:

In	line type	(-n..-1,1..n)	IX

Effect:

The Line Type entry in the Line Attributes State List is set to the value specified.

The standardized line types are:

1) solid
2) dash

3) dot
4) dash dot
5) dash dot dot

Values above 5 are reserved for registration; negative values are available for private use.

Errors:

Error identifier: 3:313
Cause: Requested line type not available
Reaction: Mapped to default.

5.3.3 LINE WIDTH

Parameters:

In	line width specifier	(≥ 0)	SS

Effect:

The Line Width entry in the Line Attributes State List is set as specified. The *line width specifier* may be either an absolute line width (in VDCs) or a line width scale factor.

The Specification Mode of Line Width entry in the Line Attributes State List is replaced by the Line Width Specification Mode in the General Attributes and Output Control State List.

5.3.4 LINE COLOUR

Parameters:

In	line colour specifier	CO

Effect:

The Line Colour entry in the Line Attributes State List is set to the value specified.

The Selection Mode of Line Colour entry in the Line Attributes State List is replaced by the Colour Selection Mode in the General Attributes and Output Control State List.

5.3.5 LINE CLIPPING MODE

Parameters:

In	clipping mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E

Effect:

The Line Clipping Mode in the Line Attributes State List is set to the value specified.

See 3.6 and 3.7.4 for a description of line object clipping.

Errors:

Error identifier: 3:301
Cause: Requested clipping mode not supported.
Reaction: Mapped to default.

5.3.6 MARKER BUNDLE INDEX

Parameters:

In	marker bundle index	(1..n)	IX

Effect:
The Marker Bundle Index entry in the Marker Attributes State List is set to the value specified.

Errors:
Error identifier: 3:312
Cause: Requested bundle not available
Reaction: Mapped to default.

5.3.7 MARKER TYPE

Parameters:

In	marker type	(-n..-1,1..n)	IX

Effect:
The Marker Type entry in the Marker Attributes State List is set to the value specified.

The standardized marker types are:

1) dot (.)
2) plus (+)
3) asterisk (*)
4) circle (o)
5) cross (x)

Values above 5 are reserved for registration; negative values are available for private use. The standardized markers are centred at the marker position. The marker type 1 (dot) is intended always to be rendered as the smallest visible point on the drawing surface. A marker's shape is invariant under transformation. See 3.8.3.

Errors:
Error identifier: 3:314
Cause: Requested marker type not available
Reaction: Mapped to default.

5.3.8 MARKER SIZE

Parameters:

In	marker size specifier	(≥ 0)	SS

Effect:
The Marker Size entry in Marker Attributes State List is set to the value specified. The marker size specifier may be either an absolute marker size (in VDCs) or a marker size scale factor. If absolute marker size is given, the specified size is the maximum extent of the marker.

The Specification Mode of Marker Size entry in the Marker Attributes State List is replaced by the Marker Size Specification Mode in the General Attributes and Output Control State List.

The effect of a VDC marker size on private marker types is implementation-dependent.

5.3.9 MARKER COLOUR

Parameters:

In	marker colour specifier	CO

Effect:
The Marker Colour entry in the Marker Attributes State List is set to the value specified.

The Selection Mode of Marker Colour entry in the Marker Attributes State List is replaced by the Colour Selection Mode in the General Attributes and Output Control State List.

5.3.10 MARKER CLIPPING MODE

Parameters:

In	clipping mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E

Effect:

The Marker Clipping Mode in the Marker Attributes State List is set to the value specified.

See 3.6 and 3.8.4 for a description of marker object clipping.

Errors:

Error identifier: 3:301
Cause: Requested clipping mode not supported.
Reaction: Mapped to default.

5.3.11 TEXT BUNDLE INDEX

Parameters:

In	text bundle index	(1..n)	IX

Effect:

The Text Bundle Index entry in the Text Attributes State List is set to the value specified.

Errors:

Error identifier: 3:312
Cause: Requested bundle not available
Reaction: Mapped to default.

5.3.12 TEXT FONT INDEX

Parameters:

In	font index	(1..n)	IX

Effect:

The Text Font Index entry in the Text Attributes State List is set to the value specified. It is an index into the List of Font Names entry in the General Attributes and Output Control State List indicating which character font is to be used.

Errors:

Error identifier: 3:318
Cause: Requested text font not available
Reaction: Mapped to default or to a more appropriate font (see annex C.4).

5.3.13 TEXT PRECISION

Parameters:

In	text precision	(STRING, CHARACTER, STROKE)	E

Effect:

The Text Precision entry in the Text Attributes State List is set to the value specified.

This provides control over the fidelity of the rendering of text attributes. See 3.9.4.4 and 3.9.5 for a description of text precision.

5.3.14 CHARACTER EXPANSION FACTOR

Parameters:

In	character expansion factor	(> 0)	R

Effect:

The Character Expansion Factor entry in the Text Attributes State List is set to the value specified.

The character expansion factor specifies the deviation of the width/height ratio of the character from the ratio indicated by the font designer.

See 3.9.4.

5.3.15 CHARACTER SPACING

Parameters:

In	character spacing	R

Effect:

The Character Spacing entry in the Text Attributes State List is set to the value specified.

The parameter specifies the desired space to be added between character bodies of a text string, which is in addition to any inter-character spacing provided by the font within the character's body. A negative value implies that characters may overlap. The value specified is interpreted as a function of the Character Height entry in the Text Attributes State List.

See 3.9.4, including 3.9.4.1.

5.3.16 TEXT COLOUR

Parameters:

In	text colour specifier	CO

Effect:

The Text Colour entry in the Text Attributes State List is set to the value specified.

The Selection Mode of Text Colour entry in the Text Attributes State List is replaced by the Colour Selection Mode in the General Attributes and Output Control State List.

5.3.17 CHARACTER HEIGHT

Parameters:

In	character height	(≥ 0)	VDC

Effect:

The Character Height entry in the Text Attributes State List is set to the value specified.

The parameter specifies the desired height of the character body, from baseline to capline, measured along the character up vector in VDC units. Note that if the character up vector is not perpendicular to the character base vector, the distance from baseline to capline measured perpendicular to the baseline will be less than the CHARACTER HEIGHT.

If the requested Character Height is not available, the realized value shall be the closest value equal to or smaller than the requested one. A requested value smaller than the minimum available, including a requested height of zero, is not an error; in this situation characters are rendered as a series of dots or lines or as invisible.

See 3.9.4.

5.3.18 CHARACTER ORIENTATION

Parameters:

In	character up vector (V)	($length \neq 0$; V, V' not parallel)	2VDC
In	character base vector (V')	($length \neq 0$; V, V' not parallel)	2VDC

Effect:

The Character Orientation entry in the Text Attributes State List is set to the values specified.

The two vectors define the orientation and skew of the character body. See 3.9.4.

5.3.19 TEXT PATH

Parameters:

In	text path	(RIGHT, LEFT, UP, DOWN)	E

Effect:

The Text Path entry in the Text Attributes State List is set to the value specified.

Text Path determines the writing direction of a text string relative to the character up vector and character base vector (see CHARACTER ORIENTATION). See 3.9.4.

5.3.20 TEXT ALIGNMENT

Parameters:

In	horizontal alignment type	(NORMAL HORIZONTAL, LEFT, CENTRE, RIGHT, CONTINUOUS HORIZONTAL)	E
In	vertical alignment type	(NORMAL VERTICAL, TOP, CAP, HALF, BASE, BOTTOM, CONTINUOUS VERTICAL)	E
In	continuous horizontal alignment		R
In	continuous vertical alignment		R

Effect:

The Horizontal Text Alignment, Vertical Text Alignment, Continuous Horizontal Alignment, and Continuous Vertical Alignment entries in the Text Attributes State List are set to the values specified.

If *horizontal alignment type* is CONTINUOUS HORIZONTAL, the *continuous horizontal alignment* parameter becomes significant. The *continuous horizontal alignment* is a fraction of the side of the text extent parallelogram perpendicular to the character up vector.

If *vertical alignment type* is CONTINUOUS VERTICAL, the *continuous vertical alignment* parameter becomes significant. The *continuous vertical alignment* parameter is a fraction of the side of the text extent parallelogram parallel to the character up vector.

The NORMAL alignment types are dependent on the associated TEXT PATH at the time of the elaboration of the text primitives.

Table 7 – Definition of NORMAL Text Alignment

Text Path	NORMAL HORIZONTAL	NORMAL VERTICAL
RIGHT	LEFT	BASE
LEFT	RIGHT	BASE
UP	CENTRE	BASE
DOWN	CENTRE	TOP

The *continuous horizontal alignment* and *continuous vertical alignment* parameters may exceed the range of 0.0 to 1.0 in order to align a string with a coordinate outside its text extent parallelogram. See 3.9.4.

5.3.21 CHARACTER SET INDEX

Parameters:

In	character set index	(1..n)	IX

Effect:

The Character Set Index entry in the Text Attributes State List is set as specified. The character set in the Character Set List entry of the General Attributes and Output Control State List referenced by this index becomes the currently designated G0 set.

NOTE – The INITIALIZE function sets, by default, the G0 set into positions 2/1 through 7/14 of the 7-bit or 8-bit code chart.

Errors:

Error identifier: 3:323
Cause: Requested character set index is not available
Reaction: Mapped to default or to a more appropriate character set (see annex C.4).

5.3.22 ALTERNATE CHARACTER SET INDEX

Parameters:

In	alternate character set index	(1..n)	IX

Effect:

The Alternate Character Set Index entry in the Text Attributes State List is set as specified. The character set in the Character Set List entry of the General Attributes and Output Control State List referenced by this index becomes the currently designated G1 and G2 sets.

The designated alternative character set is used to display 8-bit bytes whose most significant bit is set when those bytes occur within the string parameters of the text functions.

See 3.9.6.2.

NOTE – The INITIALIZE function invokes, by default, the G1 set into positions 10/1 through 15/14 (or 10/0 through 15/15 if the G1 set is a 96-character set).

Errors:

Error identifier: 3:323
Cause: Requested character set index is not available
Reaction: Mapped to default or to a more appropriate character set (see annex C.4).

5.3.23 CHARACTER CODING ANNOUNCER

Parameters:

In	coding technique	(BASIC 7-BIT, BASIC 8-BIT, EXTENDED 7-BIT, EXTENDED 8-BIT, PRIVATE)	E

Effect:

The parameter *coding technique* identifies the code extension technique and environment requested by the CGI client and is stored in the Text Attributes State List.

If an implementation permits text strings to be encoded by any other technique, the technique shall be announced with PRIVATE.

These code extension capabilities apply only to the string parameters of text functions (TEXT, APPEND TEXT, and RESTRICTED TEXT), unless stated explicitly in the function description of a function with a string parameter using this capability.

Errors:
Error identifier: 3:317
Cause: Requested character coding announcer not supported
Reaction: Function ignored.

5.3.24 FILL BUNDLE INDEX

Parameters:
In fill bundle index (1..n) IX

Effect:
The Fill Bundle Index entry in the Fill Attributes State List is set to the value specified.

See 3.10.2.

Errors:
Error identifier: 3:312
Cause: Requested bundle not available
Reaction: Mapped to default.

5.3.25 INTERIOR STYLE

Parameters:
In interior style (HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP) E

Effect:
The Interior Style entry of the Fill Attributes State List is set to the value specified.

See 3.10.2.

5.3.26 FILL COLOUR

Parameters:
In fill colour specifier CO

Effect:
The Fill Colour entry in the Fill Attributes State List is set to the specified value.

The Selection Mode of Fill Colour entry in the Fill Attributes State List is replaced by the Colour Selection Mode in the General Attributes and Output Control State List.

See 3.10.2.

5.3.27 HATCH INDEX

Parameters:
In hatch index (-n..-1,1..n) IX

Effect:
The Hatch Index entry in the Fill Attributes State List is set to the value specified.

The standardized hatch indices are:

1) horizontal equally spaced parallel lines, not transformable
2) vertical equally spaced parallel lines, not transformable
3) positive slope equally spaced parallel lines, not transformable

4) negative slope equally spaced parallel lines, not transformable
5) horizontal/vertical crosshatch, not transformable
6) positive slope/negative slope crosshatch, not transformable

Values above 6 are reserved for registration; negative values are available for private use. The effect of transformations of hatch lines (i.e. transformable, not transformable) is included in the register as part of the definition of a registered hatch index.

The associated FILL COLOUR attribute value determines the colour of the hatch lines.

Errors:

Error identifier: 3:319
Cause: Requested hatch style not available
Reaction: Mapped to default.

5.3.28 PATTERN INDEX

Parameters:

In	pattern index	(1..n)	IX

Effect:

The Pattern Index entry in the Fill Attributes State List is set to the value specified.

The *pattern index* references a pattern entry from the List of Patterns in the Fill Attributes State List.

Errors:

Error identifier: 3:320
Cause: Requested pattern not available
Reaction: Mapped to default.

5.3.29 FILL REFERENCE POINT

Parameters:

In	reference point	P

Effect:

The Fill Reference Point entry in the Fill Attributes State List is set to the value specified.

For fill objects with Interior Style of either PATTERN or BITMAP, the Fill Reference Point is used for alignment of the pattern of fill bitmap, as specified in 3.10.2.1.

For an interior style value of HATCH, the Fill Reference Point provides a common origin for the hatch patterns in all subsequent hatched fill objects; whether the Fill Reference Point is aligned with a hatch line or another arbitrary point in the hatch pattern is implementation-dependent. The common origin for hatched fill objects means that separate fill objects that have the same hatch index and that abut have a visually continuous hatch pattern across common boundaries.

See 3.10.2.

5.3.30 PATTERN SIZE

Parameters:

In	pattern height vector	(length ≠ 0)	2VDC
In	pattern width vector	(length ≠ 0)	2VDC

Effect:

The Pattern Size entry in the Fill Attributes State List is set to the values specified. This is used during rendering of fill objects with interior style PATTERN.

Pattern Size is specified as two vectors, a height vector and a width vector. In general, the pattern size vectors and the fill reference point define a parallelogram located in VDC, termed the pattern box.

See 3.10.2 for a description of pattern fill.

5.3.31 EDGE BUNDLE INDEX

Parameters:

In	edge bundle index	(1..n)	IX

Effect:

The Edge Bundle Index entry in the Edge Attributes State List is set to the value specified.

Errors:

Error identifier: 3:312
Cause: Requested bundle not available
Reaction: Mapped to default.

5.3.32 EDGE TYPE

Parameters:

In	edge type indicator	(-n..-1,1..n)	IX

Effect:

The Edge Type entry in the Edge Attributes State List is set to the value specified.

The *edge type indicator* has the same correspondence between type and representation as Line Type.

See 3.7.5 for continuity alternatives.

The standardized edge types are:

1) solid
2) dash
3) dot
4) dash dot
5) dash dot dot

Values above 5 are reserved for registration; negative values are available for private use.

Errors:

Error identifier: 3:321
Cause: Requested edge type not available
Reaction: Mapped to default.

5.3.33 EDGE WIDTH

Parameters:

In	edge width specifier	(≥ 0)	SS

Effect:

The Edge Width entry in the Edge Attributes State List is set to the value specified. This may be specified as either an absolute edge width (in VDCs) or an edge width scale factor.

The Specification Mode of Edge Width entry in the Edge Attributes State List is replaced by the Edge Width Specification Mode in the General Attributes and Output Control State List.

5.3.34 EDGE COLOUR

Parameters:

In edge colour specifier CO

Effect:

The Edge Colour entry in the Edge Attributes State List is set to the value specified.

The Selection Mode of Edge Colour entry in the Edge Attributes State List is replaced by the Colour Selection Mode in the General Attributes and Output Control State List.

5.3.35 EDGE CLIPPING MODE

Parameters:

In clipping mode (LOCUS, SHAPE, LOCUS THEN SHAPE) E

Effect:

The Edge Clipping Mode entry in the Edge Attributes State List is set to the value specified.

See 3.10.4.2 for a description of edge clipping.

Errors:

Error identifier: 3:301
Cause: Requested clipping mode not supported.
Reaction: Mapped to default.

5.3.36 EDGE VISIBILITY

Parameters:

In edge visibility (INVISIBLE, VISIBLE) E

Effect:

The Edge Visibility entry in the Edge Attributes State List is set to the value specified.

For fill objects, edges are only rendered if the associated EDGE VISIBILITY attribute value is VISIBLE. For POLYGON SET, individual edges are rendered if and only if the value of EDGE VISIBILITY attribute is VISIBLE and the corresponding edge-out flag indicates a visible edge. For closed figures, EDGE VISIBILITY is a local attribute which also applies to CONNECTING EDGE.

5.4 General attribute and output control functions

5.4.1 CLIP INDICATOR

Parameters:

In clip indicator (OFF, ON) E

Effect:

The Clip Indicator entry in the General Attributes and Output Control State List is set to the value specified.

The current value of the Clip Indicator is associated with all graphic objects as they enter the Graphic Object Pipeline. See 3.6 for information on how the clip indicator affects subsequent rendering of an object.

5.4.2 CLIP RECTANGLE

Parameters:

In	first corner (*P*), second corner (P')	($P_x \neq P'_x$, $P_y \neq P'_y$)	2P

Effect:

The Clip Rectangle entry in the General Attributes and Output Control State List is set to the value specified.

The clip rectangle is specified by a pair of VDC points. The two points define the interior and boundary of the clip rectangle as a rectangle with sides parallel to the VDC axes, with two diagonally opposite corners given by the first and second corner point parameters.

The current Clip Rectangle is associated with all graphic objects as they enter the Graphic Object Pipeline. See 3.6 for information on how the CLIP RECTANGLE attribute affects subsequent rendering of an object.

5.4.3 LINE WIDTH SPECIFICATION MODE

Parameters:

In	line width specification mode	(VDC, SCALED)	E

Effect:

The Line Width Specification Mode entry in the General Attributes and Output Control State List is set to the specified value.

The two modes supported are a measure in VDC and a scaling factor to be applied to the device-dependent nominal line width. The value of Line Width Specification Mode determines the interpretation of the parameter of subsequent LINE WIDTH functions.

Errors:

Error identifier:	3:302
Cause:	Line width specification mode not supported
Reaction:	All functions with affected parameters are ignored until a supported mode is selected with this function, or until the mode is reset to its default by INITIALIZE.

5.4.4 EDGE WIDTH SPECIFICATION MODE

Parameters:

In	edge width specification mode	(VDC, SCALED)	E

Effect:

The Edge Width Specification Mode entry in the General Attributes and Output Control State List is set to the specified value.

The two modes supported are a measure in VDC and a scaling factor to be applied to the device-dependent nominal edge width. The value of Edge Width Specification Mode determines the interpretation of the parameter of subsequent EDGE WIDTH functions.

Errors:

Error identifier:	3:303
Cause:	Edge width specification mode not supported
Reaction:	All functions with affected parameters are ignored until a supported mode is selected with this function, or until the mode is reset to its default by INITIALIZE.

5.4.5 MARKER SIZE SPECIFICATION MODE

Parameters:

In	marker size specification mode	(VDC, SCALED)	E

Effect:

The Marker Size Specification Mode entry in the General Attributes and Output Control State List is set to the specified value.

The two modes supported are a measure in VDC and a scaling factor to be applied to the device-dependent nominal marker size. The value of Marker Size Specification Mode determines the interpretation of the parameter of subsequent MARKER SIZE functions.

Errors:

Error identifier: 3:304
Cause: Marker width specification mode not supported
Reaction: All functions with affected parameters are ignored until a supported mode is selected with this function, or until the mode is reset to its default by INITIALIZE.

5.4.6 COLOUR SELECTION MODE

Parameters:

In	colour selection mode	(INDEXED, DIRECT)	E

Effect:

The Colour Selection Mode entry in the General Attributes and Output Control State List is set to the value specified.

The two modes of colour selection supported are INDEXED (i.e. colour table indices), and DIRECT (i.e. red, green, blue colour values).

The Colour Selection Mode may be changed at any time provided both modes are supported. All functions with input parameters of data type CO use the Colour Selection Mode.

Errors:

Error identifier: 3:305
Cause: Colour selection mode not supported
Reaction: All functions with affected parameters are ignored until a supported mode is selected with this function, or until the mode is reset to its default by INITIALIZE.

5.4.7 COLOUR VALUE EXTENT

Parameters:

In	minimum colour values	CD
In	maximum colour values	CD

Effect:

The Colour Value Extent entry in the General Attributes and Output Control State List is set to the values specified. The parameters represent an extent which bounds all direct colour values that will be encountered in the CGI data stream.

The *minimum colour values* parameter is specified as (min_red, min_green, min_blue) and corresponds to the abstract RGB specification of (0,0,0), which indicates zero intensity of each of the RGB components and represents black. The *maximum colour values* parameter is specified as (max_red, max_green, max_blue) and corresponds to the abstract RGB specification of (1,1,1), which indicates the maximum ideal intensity for each of the RGB components and represents white.

The CGI maps or re-normalizes the range of colour direct values specified in COLOUR VALUE EXTENT onto the device's direct colour range to achieve the mapping of the *minimum colour values* to black and of the *maximum colour values* to white, with a linear distribution of the intervening steps. Normally, the first parameter will be (0,0,0) and the

second parameter of the form (k,k,k). In this case, values of the form (i, i, i) where $0 \leq i \leq k$, represent different intensities or shades of grey. Where the parameters are irregular, the RGB values corresponding to grey scales should be derived linearly from the minimum and maximum values of each of the three ranges.

5.4.8 BACKGROUND COLOUR

Parameters:

In colour specifier CO

Effect:

The Background Colour entry in the General Attributes and Output Control State List is set to the value specified.

This specified colour is used by PREPARE DRAWING SURFACE or when a regeneration occurs to clear the entire drawing surface prior to any drawing.

Errors:

Error identifier: 3:315
Cause: The colour specifier is not supported for the device's Background Colour Capability
Reaction: Function ignored.

5.4.9 AUXILIARY COLOUR

Parameters:

In auxiliary colour specifier CO

Effect:

The Auxiliary Colour entry in the General Attributes and Output Control State List is set to the value specified.

The AUXILIARY COLOUR attribute is only used when the associated TRANSPARENCY attribute is set to OPAQUE.

See 3.4 for a general description of transparency and auxiliary colour. See 3.7, 3.8, 3.9, and 3.10 for a description of the effects of auxiliary colour and transparency on line, marker, text and fill primitives respectively.

5.4.10 TRANSPARENCY

Parameters:

In transparency switch (OPAQUE, TRANSPARENT) E

Effect:

The Transparency entry in the General Attributes and Output Control State List is set to the value specified.

When Transparency is OPAQUE, portions of line, marker, text or fill objects which are not considered to be part of the object's foreground shape are rendered using the Auxiliary Colour attribute value. When Transparency is TRANSPARENT, these portions have no effect on the image on the drawing surface.

See 3.4 for a general description of transparency and auxiliary colour. See 3.7, 3.8, 3.9, and 3.10 for a description of the effects of auxiliary colour and transparency on line, marker, text and fill primitives respectively.

Errors:

Error identifier: 3:603
Cause: Unsupported drawing mode / transparency requested
Reaction: The default drawing mode and transparency will be used.

5.4.11 COLOUR TABLE

Parameters:

In	starting index	(0..n)	CI
In	colour list	(n > 0)	nCD

Effect:

The *colour list* values are stored, in the order specified, into consecutive locations in the colour table beginning at the *starting index*. Only the specified colour table entries are changed.

If a specified colour value is not available, the Virtual Device maps it to the nearest available colour in an implementation-dependent manner.

Errors:

Error identifier: 6:308
Cause: Too many colour specifiers
Reaction: As many colour specifiers as possible are used, the rest are discarded.

5.4.12 LINE REPRESENTATION

Parameters:

In	line bundle index	(1..n)	IX
In	line type indicator	(-n..-1,1..n)	IX
In	line width specifier		SS
In	line colour specifier		CO

Effect:

In the List of Line Bundle Indices in the Line Attributes State List, the given *line bundle index* is associated with the values of the specified parameters.

Line Type: produces line types as indicated in the LINE TYPE attribute function.

Line Width: specifies line width in the current Line Width Specification Mode. The value is stored in the bundle table along with that mode; the specification is therefore immune to subsequent changes by the LINE WIDTH SPECIFICATION MODE function.

Line Colour: specifies the line colour in the current Colour Selection Mode. The value is stored in the bundle table along with that mode; the specification is therefore immune to subsequent changes to the selection mode.

When line objects are rendered the LINE BUNDLE INDEX attribute value refers to an entry in the line bundle table. Which attribute values in the selected bundle entry are used depends upon the setting of the corresponding ASFs, see the ASPECT SOURCE FLAGS function.

See 3.3.

Errors:

Error identifier: 3:313
Cause: Requested line type not available
Reaction: Mapped to default.

5.4.13 MARKER REPRESENTATION

Parameters:

In	marker bundle index	(1..n)	IX
In	marker type indicator	(-n..-1,1..n)	IX
In	marker size specifier		SS
In	marker colour specifier		CO

Effect:

In the List of Marker Bundle Indices in the Marker Attributes State List, the given *marker bundle index* is associated with the values of the specified parameters.

Marker Type: produces marker types as indicated in the MARKER TYPE attribute function.

Marker Size: specifies marker size in the current Marker Size Specification Mode; the value is stored in the bundle table along with that mode. The specification is therefore immune to subsequent changes by the MARKER SIZE SPECIFICATION MODE function.

Marker Colour: specifies the marker colour in the current Colour Selection Mode; the value is stored in the bundle table along with that mode. The specification is therefore immune to subsequent changes to the selection mode.

When marker objects are rendered the MARKER BUNDLE INDEX attribute value refers to an entry in the marker bundle table. Which attribute values in the selected bundle entry are used depends upon the setting of the corresponding ASFs, see the ASPECT SOURCE FLAGS function.

See 3.3.

Errors:

Error identifier: 3:314
Cause: Requested marker type not available
Reaction: Mapped to default.

5.4.14 TEXT REPRESENTATION

Parameters:

In	text bundle index	(1..n)	IX
In	text font index	(1..n)	IX
In	text precision	(STRING, CHARACTER, STROKE)	E
In	character spacing		R
In	character expansion factor	(> 0)	R
In	text colour specifier		CO

Effect:

In the List of Text Bundle Indices in the Text Attributes State List, the given *text bundle index* is associated with the values of the specified parameters.

Text Font Index: specifies the text font as indicated in the TEXT FONT INDEX attribute function.

Text Precision: specifies the text precision as indicated in the TEXT PRECISION attribute function.

Character Expansion Factor: specifies the character expansion factor as indicated in the CHARACTER EXPANSION FACTOR attribute function.

Character Spacing: specifies the character spacing as indicated in the CHARACTER SPACING attribute function.

Text Colour: specifies the text colour in the current Colour Selection Mode; the value is stored in the bundle table along with that mode. The specification is therefore immune to subsequent changes to the selection mode.

When text is rendered the TEXT BUNDLE INDEX attribute refers to an entry in the text bundle table. Which attribute values in the selected bundle entry are used depends upon the setting of the corresponding ASFs, see the ASPECT SOURCE FLAGS function.

See 3.3.

Errors:

Error identifier: 3:318
Cause: Requested text font not available
Reaction: Mapped to default or to a more appropriate font (see annex C.4).

5.4.15 FILL REPRESENTATION

Parameters:

In	fill bundle index	(1..n)	IX
In	interior style	(HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP)	E
In	fill colour specifier		CO
In	hatch index	(-n..-1,1..n)	IX
In	pattern index	(1..n)	IX
In	fill bitmap identifier		BN
In	fill bitmap region		2P

Effect:

In the List of Fill Bundle Indices in the Fill Attributes State List, the given *fill bundle index* is associated with the values of the specified parameters.

Interior Style: specifies the interior style as indicated in the INTERIOR STYLE attribute function.

Fill Colour: specifies the fill colour in the current Colour Selection Mode; the value is stored in the bundle table along with that mode. The specification is therefore immune to subsequent changes to the Colour Selection Mode.

Hatch Index: specifies the hatch index as indicated in the HATCH INDEX attribute function.

Pattern Index: specifies the pattern index as indicated in the PATTERN INDEX attribute function.

Fill Bitmap Identifier: specifies the fill bitmap as indicated in the FILL BITMAP function defined in ISO/IEC 9636-6.

Fill Bitmap Region: specifies the fill bitmap region as indicated in the FILL BITMAP function defined in ISO/IEC 9636-6.

When fill objects are displayed the FILL BUNDLE INDEX attribute refers to an entry in the fill bundle table. Which attribute values in the selected bundle entry are used depends upon the setting of the corresponding ASFs, see the ASPECT SOURCE FLAGS function.

See 3.3.

Errors:

Error identifier: 3:319
Cause: Requested hatch style not available
Reaction: Mapped to default.

Error identifier: 3:320
Cause: Requested pattern not available
Reaction: Mapped to default.

5.4.16 EDGE REPRESENTATION

Parameters:

In	edge bundle index	(1..n)	IX
In	edge type indicator	(-n..-1,1..n)	IX
In	edge width specifier		SS
In	edge colour specifier		CO
In	edge visibility	(INVISIBLE, VISIBLE)	E

Effect:

In the List of Edge Bundle Indices in the Edge Attributes State List, the given *edge bundle index* is associated with the values of the specified parameters.

Edge Type: specifies the edge type as indicated in the EDGE TYPE attribute function.

Edge Width: specifies edge width in the current Edge Width Specification Mode; the value is stored in the bundle table along with that mode. The specification is therefore immune to subsequent changes by the EDGE WIDTH SPECIFICATION MODE function.

Edge Colour: specifies the edge colour in the current Colour Selection Mode; the value is stored in the bundle table along with that mode. The specification is therefore immune to subsequent changes to the selection mode.

Edge Visibility: specifies the edge visibility as indicated in the EDGE VISIBILITY attribute function.

When fill objects are displayed the EDGE BUNDLE INDEX attribute refers to an entry in the edge bundle table. Which attribute values in the selected bundle entry are used depends upon the setting of the corresponding ASFs, see the ASPECT SOURCE FLAGS function.

See 3.3.

Errors:

Error identifier: 3:321
Cause: Requested edge type not available
Reaction: Mapped to default.

5.4.17 DELETE BUNDLE REPRESENTATION

Parameters:

In	bundle table type	(LINE, MARKER, TEXT, FILL, EDGE)	E
In	bundle index	(2..n)	IX

Effect:

The bundle specified by the given *bundle table type* and *bundle index* is deallocated. The client may not, however, delete the bundle associated with index 1.

DELETE BUNDLE REPRESENTATION informs the CGI Virtual Device that the client has no further need of the specified bundle representation. The Virtual Device may use this information as an indication to free the memory allocated to a bundle representation in a dynamic memory allocation implementation.

Errors:

Error identifier: 3:307
Cause: Attempt to delete a non-existent item
Reaction: Function ignored.

5.4.18 ASPECT SOURCE FLAGS

Parameters:

In	list of ASF type/value pairs	(*see below*, (INDIVIDUAL, BUNDLED))	n[E,E]

Effect:

The designated Aspect Source Flags (ASFs) in the General Attributes and Output Control State List are set to the values indicated by the list parameter. The following ASF types are defined:

LINE TYPE ASF	LINE WIDTH ASF
LINE COLOUR ASF	MARKER TYPE ASF
MARKER SIZE ASF	MARKER COLOUR ASF
TEXT FONT INDEX ASF	TEXT PRECISION ASF
CHARACTER EXPANSION FACTOR ASF	CHARACTER SPACING ASF
TEXT COLOUR ASF	INTERIOR STYLE ASF
FILL COLOUR ASF	HATCH INDEX ASF
PATTERN INDEX ASF	EDGE TYPE ASF

EDGE WIDTH ASF	EDGE COLOUR ASF
EDGE VISIBILITY ASF	FILL BITMAP ASF

If the ASF for a particular attribute of a primitive is set to INDIVIDUAL, the attribute is controlled by the value of the corresponding individually specified attribute value of the primitive. If the ASF is set to BUNDLED, the attribute is specified by the corresponding attribute value in the bundle referenced by the associated bundle index for the primitive.

Changing the value of an ASF has no retro-active effect on any previously created graphic objects.

5.4.19 PATTERN TABLE

Parameters:

In	pattern table index	(1..n)	IX
In	pattern dimensions nx,ny	(> 0)	2I
In	local colour precision requirement	(≥ 0)	I
In	pattern colour specifiers		nx*ny CO

Effect:

The representation in the Pattern Table entry of the Fill Attributes State List, with the given *pattern table index*, is associated with the specified values.

The *pattern colour specifiers* consists of nx*ny colour specifiers, conceptually organized as a two-dimensional array with dimensions nx and ny representing the column and row dimensions respectively.

The *local colour precision requirement* parameter specifies the precision requirement for the *pattern colour specifiers*. The precision requirement is for either indexed or direct colour, according to the Colour Selection Mode.

If the Colour Selection Mode is INDEXED, then a positive value for *local colour precision requirement* specifies the minimum number of bits required to specify a colour index, and a value of zero means to impose the same requirement as that for the Colour Index Precision in the Control State List.

If the Colour Selection Mode is DIRECT, then a positive value for *local colour precision requirement* specifies the minimum number of bits required to specify each component of an RGB triple, and a value of zero means to impose the same requirement as that for the Colour Precision in the Control State List.

Errors:

Error identifier: 3:311
Cause: Local colour precision requirement not achievable
Reaction: Function ignored.

Error identifier: 6:309
Cause: Specified pattern is too large to store
Reaction: An implementation dependent pattern is used.

5.4.20 DELETE PATTERN

Parameters:

In	pattern table index	(2..n)	IX

Effect:

The Pattern Table entry in the Fill Attributes State List referenced by the specified *pattern table index* is deleted.

The client may not, however, delete the pattern associated with index 1.

Errors:

Error identifier: 3:307
Cause: Attempt to delete a non-existent item
Reaction: Function ignored.

5.4.21 FONT LIST

Parameters:

In	list of font names	(n > 0)	nSF

Effect:

The *list of font names* is stored in the List of Font Names entry in the General Attributes and Output Control State List. Selection of named fonts is achieved using the Text Font Index. The first font defined in the font list is assigned to index 1, the second to index 2, etc.

The *list of font names* may contain the names of type faces registered with the Registration Authority, or they may be private names.

Errors:

Error identifier: 3:322
Cause: At least one font is not supported.
Reaction: Gaps are left in the List of Font Names entry.

Error identifier: 6:305
Cause: Font table overflow
Reaction: As many fonts are retained as possible, starting from index 1.

5.4.22 CHARACTER SET LIST

Parameters:

In	list of character sets	(n > 0)	nCS

Effect:

The list is stored in the Character Set List entry in the General Attributes and Output Control State List. It specifies the designation sequence for the character set type that can be indexed in subsequent CHARACTER SET INDEX and ALTERNATE CHARACTER SET INDEX functions and establishes the character set index value that is associated with each of these character sets.

Increasing character set indices, starting from 1 and incrementing by 1, identify the corresponding character set declarations in sequence in the given list.

Errors:

Error identifier: 3:316
Cause: At least one of the character sets is not supported
Reaction: Function ignored.

Error identifier: 6:306
Cause: Character set list overflow
Reaction: As many character sets are retained as possible, starting from index 1.

5.4.23 SAVE PRIMITIVE ATTRIBUTES

Parameters:

In	attribute set identifier	ASN

Effect:

This function allows the client to save under the given name a copy of the current state list entries for those individual primitive attributes and general attributes listed in the following table. The VDC TYPE in effect when these values are saved is also stored.

Table 8 lists the attributes that are saved by the function SAVE PRIMITIVE ATTRIBUTES and restored by the function RESTORE PRIMITIVE ATTRIBUTES.

Table 8 – Attributes Saved and Restored

LINE BUNDLE INDEX	EDGE BUNDLE INDEX
LINE TYPE	EDGE TYPE
LINE WIDTH (Note 1)	EDGE WIDTH (Note 1)
LINE COLOUR (Note 1)	EDGE COLOUR (Note 1)
LINE CLIPPING MODE	EDGE VISIBILITY
MARKER BUNDLE INDEX	EDGE CLIPPING MODE
MARKER TYPE	CHARACTER SET INDEX
MARKER SIZE (Note 1)	ALTERNATE CHARACTER SET INDEX
MARKER COLOUR (Note 1)	CHARACTER CODING ANNOUNCER
MARKER CLIPPING MODE	CHARACTER EXPANSION FACTOR
FILL BUNDLE INDEX	CHARACTER SPACING
FILL COLOUR (Note 1)	CHARACTER HEIGHT
FILL REFERENCE POINT	CHARACTER ORIENTATION
INTERIOR STYLE	TEXT BUNDLE INDEX
HATCH INDEX	TEXT FONT INDEX
FILL BITMAP	TEXT PRECISION
PATTERN INDEX	TEXT COLOUR (Note 1)
PATTERN SIZE	TEXT PATH
PICK IDENTIFIER	TEXT ALIGNMENT
CLIP INDICATOR	ASPECT SOURCE FLAGS
CLIP RECTANGLE	AUXILIARY COLOUR (Note 1)
DRAWING MODE	TRANSPARENCY

NOTE –

1) The specification mode or selection mode of the current value is also stored. If the attribute set identifier is already in use, the values saved under that name are replaced by the current values and no error is generated. The following are excluded from the list of items saved: bundle tables, character set list, font list, colour table, pattern table.

Errors:

Error identifier: 6:307
Cause: Attribute set storage overflow
Reaction: Function ignored.

5.4.24 RESTORE PRIMITIVE ATTRIBUTES

Parameters:

In attribute set name ASN

Effect:

Restores the individual primitive attributes and general attribute values saved in the named attribute set by the SAVE PRIMITIVE ATTRIBUTES function. (See table 8.)

Errors:

Error identifier: 3:308
Cause: No such attribute set
Reaction: Function ignored.

Error identifier: 3:309
Cause: Attempt to restore an attribute set which was saved with VDC Type different to the current VDC Type
Reaction: Function ignored.

5.4.25 DELETE PRIMITIVE ATTRIBUTE SAVE SET

Parameters:

In attribute set name ASN

Effect:

The values associated with the given attribute set name are deallocated.

DELETE PRIMITIVE ATTRIBUTE SAVE SET informs the CGI Virtual Device that the client has no further need of the specified attribute set. The Virtual Device may use this information as an indication to free the memory allocated to the attribute set in a dynamic memory allocation implementation.

Errors:

Error identifier: 3:307
Cause: Attempt to delete a non-existent item
Reaction: Function ignored.

5.4.26 BEGIN FIGURE

Parameters:

none

Effect:

The Output State of the Virtual Device set to state FIGURE OPEN, and closed figure construction may proceed.

Closed figure construction is completed by the END FIGURE function.

See 3.10.5.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:302
Cause: Function not allowed in Output State FIGURE OPEN
Reaction: Function ignored.

5.4.27 END FIGURE

Parameters:

none

Effect:

The END FIGURE function completes the construction of a closed figure by first closing the current region if it is open by performing an implicit NEW REGION, and then associating global attributes with the compound object.

The Output State of the Virtual Device is changed from state FIGURE OPEN to state ACTIVE.

See 3.10.5.

Errors:

Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:303
Cause: Function not allowed in Output State ACTIVE
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.4.28 NEW REGION

Parameters:
none

Effect:
The NEW REGION function provides control of region construction within closed figures. The Output State of the Virtual Device is not affected by this function.

If the current region is open, this function closes it. If the last point of the last line primitive is not coincident with the current closure point, then an implicit boundary portion is added to connect the two, unless an explicit boundary and edge portion was added following that line primitive by using a CONNECTING EDGE primitive.

The first point of the next line primitive following a NEW REGION function becomes the closure point for the new region.

See 3.10.5.

Errors:
Error identifier: 5:301
Cause: Function not allowed in Output State TEXT OPEN
Reaction: Function ignored.

Error identifier: 5:303
Cause: Function not allowed in Output State ACTIVE
Reaction: Function ignored.

Error identifier: 6:304
Cause: Figure buffer overflowed
Reaction: As much as possible of the closed figure is rendered.

5.5 Retrieval functions

5.5.1 GET TEXT EXTENT

Parameters:

In	text position		P
In	character string		S
Out	response validity	(INVALID, VALID)	E
Out	concatenation validity	(INVALID, VALID)	E
Out	concatenation point		P
Out	text extent parallelogram		4P

Effect:
The *character string* is evaluated as if it were the parameter to a TEXT function with *flag* set to FINAL in order to compute the extent of the string and the concatenation point. All text attributes, general attributes, and controls are applied as described for TEXT. In particular, code extension techniques used for TEXT objects are applicable.

The parallelogram is returned as four corner points in anti-clockwise order. For text precisions STRING and CHARACTER, the *text extent parallelogram* is an approximation to that defined in 3.9.4, being the minimum

parallelogram, whose sides are parallel to the character base and character up vectors, and which completely encloses the character bodies of the displayed string.

The *concatenation point* can be used as the origin of a subsequent TEXT object for concatenation of character strings. Where meaningful, it is computed such that enough inter-character space is included to position a concatenated string correctly.

Control characters in the character string have the same implementation-dependent effect on the computation of the *text extent parallelogram* and the *concatenation point* as they do on the rendering of the character string in the TEXT function.

If the Virtual Device is unable for any reason to calculate the *concatenation point* then a *response validity* of VALID and the *concatenation validity* of INVALID are returned; in this case, the *text extent parallelogram* returned is valid and the *concatenation point* is undefined.

6 Output inquiry functions

6.1 Introduction

This describes the abstract functional specification of the Output Inquiry functions of the CGI.

The abstract names of these functions begin either with INQUIRE or LOOKUP. Those functions whose names start with INQUIRE will only return the values of one or more entries in a description table or state list. Those functions whose names start with LOOKUP are used to determine if support exists for GDPs and for determining the current values of ASFs.

See ISO/IEC 9636-1, 5.2.7.

6.1.1 Data types employed

The abstract specifications of functions detail the functions in terms of input and output parameters. The data type of each parameter is selected from a standard set and is identified in the functional specification by a standard abbreviation. Both the data types and the abbreviations are taken from the complete list in ISO/IEC 9636-1, 5.2.10.

6.1.2 Validity of returned information

For all the inquiry functions specified in this subclause, if any of the inquired information is available, the response validity flag is returned as VALID and the values specified in the output parameters are returned. In the case of a VALID response, if there is any possibility that any of the individual parameters within the response are not valid, then the response itself will contain additional (always valid) parameters which indicate which of the other returned parameters are valid.

If the inquired information is not available or the inquiry function is unsupported, the response validity flag is returned as INVALID and the specified output parameters are undefined. No other meaning should be applied to these other output parameters.

6.2 Primitive support description table

6.2.1 INQUIRE PRIMITIVE SUPPORT LEVELS

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	maximum number of points for polyline	(-1, 128..n)	I
Out	maximum number of points for disjoint polyline	(-1, 0..n)	I
Out	maximum number of points for polygon	(-1, 0..n)	I
Out	maximum number of points for polygon set	(-1, 0..n)	I
Out	maximum number of points for polymarker	(-1, 128..n)	I
Out	maximum number of characters for text	(-1,80..n)	I
Out	maximum number of cell colour specifiers for cell array	(-1,0..n)	I
Out	line/edge type continuity capability	(RESTART, CONTINUOUS, OTHER)	E
Out	cell array fill capability	(OUTLINED, FILLED)	E
Out	cell array alignment capability	(AXIS ALIGNED, SKEWED)	E
Out	cell array rendering technique	(OTHER, EXACT)	E
Out	compound text capability	(NONE, GLOBAL, LOCAL)	E
Out	closed figure capability	(NONE, GLOBAL, LOCAL)	E

Effect:

See 6.1.2.

6.2.2 LOOKUP GDP SUPPORT

Parameters:

In	list of GDP identifiers	(-n..-1, 1..n)	nI
Out	response validity	(INVALID, VALID)	E
Out	list of support indicators	(NO, YES)	nE

Effect:

This function returns information about support for GDPs. It is used to determine whether or not each GDP identifier in the given *list of GDP identifiers* is supported. The number of elements in and the ordering of the returned list correspond to the *list of GDP identifiers*.

See 6.1.2.

6.2.3 INQUIRE GDP ATTRIBUTES

Parameters:

In	GDP identifier	(-n..-1, 1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	number of valid applicable attribute groups	(0..5)	I
Out	array of applicable attribute groups	(LINE, MARKER, TEXT, FILL, EDGE)	5E

Effect:

See 6.1.2.

6.3 Line description table

6.3.1 INQUIRE LINE CAPABILITY

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of predefined line bundles	(1..n)	I
Out	number of settable line bundles	(-1, 0..n)	I
Out	maximum line bundle index	(1..n)	IX
Out	dynamic modification accepted for line bundles	(IRG, CBS, IMM)	E
Out	nominal scaled line width	(> 0)	DC
Out	minimum scaled line width	(> 0)	DC
Out	maximum scaled line width	(> 0)	DC
Out	number of valid line clipping modes	(1..3)	I
Out	array of available line clipping modes	(LOCUS, SHAPE, LOCUS THEN SHAPE)	3E

Effect:

See 6.1.2.

6.3.2 INQUIRE LIST OF AVAILABLE LINE TYPES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I

Out	list of line types		nIX

Effect:
See 6.1.2.

6.3.3 INQUIRE LIST OF AVAILABLE SCALED LINE WIDTHS

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I
Out	list of scaled line widths		nDC

Effect:
See 6.1.2.

6.4 Marker description table

6.4.1 INQUIRE MARKER CAPABILITY

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of predefined marker bundles	(1..n)	I
Out	number of settable marker bundles	(-1, 0..n)	I
Out	maximum marker bundle index	(1..n)	IX
Out	dynamic modification accepted for marker bundles	(IRG, CBS, IMM)	E
Out	nominal scaled marker size	(> 0)	DC
Out	minimum scaled marker size	(> 0)	DC
Out	maximum scaled marker size	(> 0)	DC
Out	number of valid marker clipping modes	(1..3)	I
Out	array of available marker clipping modes	(LOCUS, SHAPE, LOCUS THEN SHAPE)	3E

Effect:
See 6.1.2.

6.4.2 INQUIRE LIST OF AVAILABLE MARKER TYPES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I
Out	list of marker types		nIX

Effect:
See 6.1.2.

6.4.3 INQUIRE LIST OF AVAILABLE SCALED MARKER SIZES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I
Out	list of scaled marker sizes		nDC

Effect:

See 6.1.2.

6.5 Text description table

6.5.1 INQUIRE TEXT CAPABILITY

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of predefined text bundles	(1..n)	I
Out	number of settable text bundles	(-1, 0..n)	I
Out	maximum text bundle index	(1..n)	IX
Out	dynamic modification accepted for text bundles	(IRG, CBS, IMM)	E
Out	maximum length of font list	(-1, 1..n)	I
Out	dynamic modification accepted for font list	(IRG, CBS, IMM)	E
Out	maximum length of character set list	(-1, 1..n)	I

Effect:

See 6.1.2.

6.5.2 INQUIRE LIST OF AVAILABLE CHARACTER SETS

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
In	maximum characters per string	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I
Out	list of available character sets		nCS

Effect:

See 6.1.2.

6.5.3 INQUIRE LIST OF AVAILABLE TEXT FONTS

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
In	maximum characters per string	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I
Out	list of font names		nSF

Effect:
See 6.1.2.

6.5.4 INQUIRE FONT CAPABILITIES

Parameters:

In	font name		SF
In	precision	(STRING, CHARACTER, STROKE)	E
Out	response validity	(INVALID, VALID)	E
Out	minimum character expansion factor	(> 0)	R
Out	maximum character expansion factor	(> 0)	R
Out	minimum character spacing		R
Out	maximum character spacing		R
Out	minimum character height	(> 0)	DC
Out	maximum character height	(> 0)	DC
Out	skewed vector support	(NO, YES)	E
Out	mirrored character support	(NO, YES)	E
Out	number of text path elements	(1..4)	I
Out	array of supported text paths	(RIGHT, LEFT, UP, DOWN)	4E
Out	number of horizontal text alignment elements	(1..5)	I
Out	array of supported horizontal text alignments	(NORMAL HORIZONTAL, LEFT, CENTRE RIGHT, CONTINUOUS HORIZONTAL)	5E
Out	number of vertical text alignment elements	(1..7)	I
Out	array of supported vertical text alignments	(NORMAL VERTICAL, TOP, CAP, HALF BASE, BOTTOM, CONTINUOUS VERTICAL)	7E

Effect:
See 6.1.2.

6.5.5 INQUIRE LIST OF AVAILABLE CHARACTER EXPANSION FACTORS

Parameters:

In	font name		SF
In	precision	(STRING, CHARACTER, STROKE)	E
In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(0..n)	I
Out	list of character expansion factors		nR

Effect:
An empty list implies a continuous range of character expansion factors.

See 6.1.2.

6.5.6 INQUIRE LIST OF AVAILABLE CHARACTER SPACINGS

Parameters:

In	font name		SF
In	precision	(STRING, CHARACTER, STROKE)	E
In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E

Out	total number of list elements in description table	(0..n)	I
Out	list of character spacings		nR

Effect:
An empty list implies a continuous range of character expansion factors.

See 6.1.2.

6.5.7 INQUIRE LIST OF AVAILABLE CHARACTER HEIGHTS

Parameters:

In	font name		SF
In	precision	(STRING, CHARACTER, STROKE)	E
In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(0..n)	I
Out	list of character heights		nDC

Effect:
An empty list implies a continuous range of character expansion factors.

See 6.1.2.

6.5.8 INQUIRE LIST OF AVAILABLE CHARACTER ORIENTATIONS

Parameters:

In	font name		SF
In	precision	(STRING, CHARACTER, STROKE)	E
In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(0..n)	I
Out	list of character orientations		n4VDC

Effect:
An empty list implies a continuous range of character expansion factors.

See 6.1.2.

6.6 Fill description table

6.6.1 INQUIRE FILL CAPABILITY

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of predefined fill bundles	(1..n)	I
Out	number of settable fill bundles	(-1, 0..n)	I
Out	maximum fill bundle index	(1..n)	IX
Out	dynamic modification accepted for fill bundles	(IRG, CBS, IMM)	E
Out	number of interior style elements	(1..6)	I
Out	array of available interior styles	(HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP)	6E

Out	number of predefined patterns	(1..n)	I
Out	number of settable patterns	(-1, 0..n)	I
Out	maximum pattern index	(1..n)	IX
Out	dynamic modification accepted for pattern table	(IRG, CBS, IMM)	E
Out	preferred pattern size divisor	(1..n)	I
Out	maximum pattern size	(-, 1..n)	2I
Out	pattern transformation support	(NONE, UNSKEWED, FULL)	E
Out	pattern fill fallback	(CONDENSE, TRUNCATE)	E

Effect:
See 6.1.2.

6.6.2 INQUIRE LIST OF AVAILABLE HATCH STYLES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I
Out	list of hatch styles	(-n..-1, 1..n)	nIX

Effect:
See 6.1.2.

6.7 Edge description table

6.7.1 INQUIRE EDGE CAPABILITY

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of predefined edge bundles	(1..n)	I
Out	number of settable edge bundles	(-1, 0..n)	I
Out	maximum edge bundle index	(1..n)	IX
Out	dynamic modification accepted for edge bundles	(IRG, CBS, IMM)	E
Out	nominal scaled edge width	(> 0)	DC
Out	minimum scaled edge width	(> 0)	DC
Out	maximum scaled edge width	(> 0)	DC
Out	number of valid edge clipping modes	(1..3)	I
Out	array of available edge clipping modes	(LOCUS, SHAPE, LOCUS THEN SHAPE)	3E
Out	realization of edge width	(INTERIOR, CENTRED)	E

Effect:
See 6.1.2.

6.7.2 INQUIRE LIST OF AVAILABLE EDGE TYPES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(1..n)	I

Out	list of edge types		nIX

Effect:
See 6.1.2.

6.7.3 INQUIRE LIST OF AVAILABLE SCALED EDGE WIDTHS

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of list elements in description table	(0..n)	I
Out	list of edge widths		nDC

Effect:
An empty *list of edge widths* implies a continuous range of edge widths.

See 6.1.2.

6.8 Output control description table

6.8.1 INQUIRE COLOUR CAPABILITY

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of simultaneously available direct colours	(0, 2..n)	I
Out	number of simultaneously available indexed colours	(2..n)	I
Out	number of available colours	(2..n)	I
Out	number of available intensities	(1..n)	3I
Out	colour selection mode availability	(INDEXED ONLY, INDEXED AND DIRECT)	E
Out	dynamic modification accepted for colour table	(IRG, CBS, IMM)	E
Out	colour overwrite capability	(NO, YES)	E
Out	colour realization	(ADDITIVE, SUBTRACTIVE)	E
Out	monochromatic device	(NO, YES)	E
Out	background colour capability	(NONE, INDEX 0, INDEXED, FULL)	E

Effect:
See 6.1.2.

6.8.2 INQUIRE CIE CHARACTERISTICS

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	CIE 1931 chromaticity coordinates for red primary		2R
Out	CIE 1931 chromaticity coordinates for green primary		2R
Out	CIE 1931 chromaticity coordinates for blue primary		2R
Out	CIE 1931 tristimulus values for reference white		3R

Effect:
See 6.1.2.

6.8.3 INQUIRE MAXIMUM NUMBER OF SIMULTANEOUSLY SAVED ATTRIBUTE SETS

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	maximum number of simultaneously saved attribute sets	(-1, 0..n)	IF

Effect:

See 6.1.2.

6.8.4 INQUIRE ARRAY OF SUPPORTED CHARACTER CODING ANNOUNCERS

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	number of valid character coding announcers	(1..5)	I
Out	array of valid character coding announcers	(BASIC 7-BIT, BASIC 8-BIT, EXTENDED 7-BIT, EXTENDED 8-BIT, PRIVATE)	5E

Effect:

See 6.1.2.

6.9 Line attribute state list

6.9.1 INQUIRE LINE ATTRIBUTES

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	line bundle index	(1..n)	IX
Out	line type	(-n..-1, 1..n)	IX
Out	specification mode of line width	(VDC, SCALED)	E
Out	line width	(≥ 0)	SS
Out	selection mode of line colour	(INDEXED, DIRECT)	E
Out	line colour		CO
Out	line clipping mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E

Effect:

See 6.1.2.

6.9.2 INQUIRE LIST OF LINE BUNDLE INDICES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(0..n)	I
Out	list of line bundle indices		nIX

Effect:

See 6.1.2.

6.9.3 INQUIRE LINE REPRESENTATION

Parameters:

In	line bundle index	(1..n)	IX
Out	response validity	(INVALID, VALID)	E
Out	line type	(-n..-1, 1..n)	IX
Out	specification mode of line width	(VDC, SCALED)	E
Out	line width	(≥ 0)	SS
Out	selection mode of line colour	(INDEXED, DIRECT)	E
Out	line colour		CO

Effect:

See 6.1.2.

6.10 Marker attribute state list

6.10.1 INQUIRE MARKER ATTRIBUTES

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	marker bundle index	(1..n)	IX
Out	marker type	(-n..-1, 1..n)	IX
Out	specification mode of marker size	(VDC, SCALED)	E
Out	marker size	(≥ 0)	SS
Out	selection mode of marker colour	(INDEXED, DIRECT)	E
Out	marker colour		CO
Out	marker clipping mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E

Effect:

See 6.1.2.

6.10.2 INQUIRE LIST OF MARKER BUNDLE INDICES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(0..n)	I
Out	list of marker bundle indices		nIX

Effect:

See 6.1.2.

6.10.3 INQUIRE MARKER REPRESENTATION

Parameters:

In	marker bundle index	(1..n)	IX
Out	response validity	(INVALID, VALID)	E
Out	marker type	(-n..-1, 1..n)	IX
Out	specification mode of marker size	(VDC, SCALED)	E
Out	marker size	(≥ 0)	SS

Out	selection mode of marker colour	(INDEXED, DIRECT)	E
Out	marker colour		CO

Effect:
See 6.1.2.

6.11 Text attribute state list

6.11.1 INQUIRE TEXT ATTRIBUTES

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	text bundle index	(1..n)	IX
Out	text font index	(1..n)	IX
Out	font precision	(STRING, CHARACTER, STROKE)	E
Out	character expansion factor	(> 0)	R
Out	character spacing		R
Out	selection mode of text colour	(INDEXED, DIRECT)	E
Out	text colour		CO
Out	character height	(≥ 0)	VDC
Out	character up vector	(length ≠ 0)	2VDC
Out	character base vector	(length ≠ 0)	2VDC
Out	text path	(RIGHT, LEFT, UP, DOWN)	E
Out	horizontal text alignment	(NORMAL HORIZONTAL, LEFT, CENTRE, RIGHT, CONTINUOUS HORIZONTAL)	E
Out	continuous horizontal alignment		R
Out	vertical text alignment	(NORMAL VERTICAL, TOP, CAP, HALF, BASE, BOTTOM, CONTINUOUS VERTICAL)	E
Out	continuous vertical alignment		R
Out	character set index	(1..n)	IX
Out	alternate character set index	(1..n)	IX
Out	character coding announcer	(BASIC 7-BIT, BASIC 8-BIT, EXTENDED 7-BIT, EXTENDED 8-BIT, PRIVATE)	E

Effect:
See 6.1.2.

6.11.2 INQUIRE LIST OF TEXT BUNDLE INDICES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(0..n)	I
Out	list of text bundle indices		nIX

Effect:
See 6.1.2.

6.11.3 INQUIRE TEXT REPRESENTATION

Parameters:

In	text bundle index	(1..n)	IX
Out	response validity	(INVALID, VALID)	E
Out	text font index	(1..n)	IX
Out	text precision	(STRING, CHARACTER, STROKE)	E
Out	character expansion factor	(> 0)	R
Out	character spacing		R
Out	selection mode of text colour	(INDEXED, DIRECT)	E
Out	text colour		CO

Effect:

See 6.1.2.

6.12 Fill attribute state list

6.12.1 INQUIRE FILL ATTRIBUTES

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	fill bundle index	(1..n)	IX
Out	interior style	(HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP)	E
Out	selection mode of fill colour	(INDEXED, DIRECT)	E
Out	fill colour		CO
Out	hatch index	(-n..-1,1..n)	IX
Out	pattern index	(1..n)	IX
Out	fill bitmap identifier		BN
Out	fill bitmap region		2P
Out	fill reference point		P
Out	pattern size		4VDC

Effect:

See 6.1.2.

6.12.2 INQUIRE PATTERN DIMENSIONS

Parameters:

In	pattern index	(1..n)	IX
In	local colour precision requirement	(1..32)	I
Out	response validity	(INVALID, VALID)	E
Out	number of horizontal samples	(1..n)	I
Out	number of vertical samples	(1..n)	I
Out	local colour precision	(1..32)	I
Out	selection mode of colour specifiers	(INDEXED, DIRECT)	E

Effect:

The output parameter *local colour precision* is a value appropriate for use in the function INQUIRE PATTERN in order to retrieve the colour specifiers relating to the selected pattern. See 6.1.2.

6.12.3 INQUIRE PATTERN

Parameters:

In	pattern index	(1..n)	IX
In	local colour precision	(1..32)	I
Out	response validity	(INVALID, VALID)	E
Out	list of colour specifiers		nCO

Effect:

The function INQUIRE PATTERN DIMENSIONS may be used to obtain a *local colour precision* value that is appropriate for retrieving the *list of colour specifiers*. See 6.1.2.

6.12.4 INQUIRE LIST OF PATTERN INDICES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(0..n)	I
Out	list of pattern indices		nIX

Effect:

See 6.1.2.

6.12.5 INQUIRE LIST OF FILL BUNDLE INDICES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number in elements in state list	(0..n)	I
Out	list of fill bundle indices		nIX

Effect:

See 6.1.2.

6.12.6 INQUIRE FILL REPRESENTATION

Parameters:

In	fill bundle index	(1..n)	IX
Out	response validity	(INVALID, VALID)	E
Out	interior style	(HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP)	E
Out	selection mode of fill colour	(INDEXED, DIRECT)	E
Out	fill colour		CO
Out	hatch index	(-n..-1,1..n)	IX
Out	pattern index	(1..n)	IX
Out	fill bitmap identifier		BN
Out	fill bitmap region		2P

Effect:

See 6.1.2.

6.13 Edge attribute state list

6.13.1 INQUIRE EDGE ATTRIBUTES

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	edge bundle index	(1..n)	IX
Out	edge visibility	(INVISIBLE, VISIBLE)	E
Out	edge type	(-n..-1, 1..n)	IX
Out	specification mode of edge width	(VDC, SCALED)	E
Out	edge width	(≥ 0)	SS
Out	selection mode of edge colour	(INDEXED, DIRECT)	E
Out	edge colour		CO
Out	edge clipping mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E

Effect:

See 6.1.2.

6.13.2 INQUIRE LIST OF EDGE BUNDLE INDICES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(0..n)	I
Out	list of edge bundle indices		nIX

Effect:

See 6.1.2.

6.13.3 INQUIRE EDGE REPRESENTATION

Parameters:

In	edge bundle index	(1..n)	IX
Out	response validity	(INVALID, VALID)	E
Out	edge visibility	(INVISIBLE, VISIBLE)	E
Out	edge type	(-n..-1, 1..n)	IX
Out	specification mode of edge width	(VDC, SCALED)	E
Out	edge width	(≥ 0)	SS
Out	selection mode of edge colour	(INDEXED, DIRECT)	E
Out	edge colour		CO

Effect:

See 6.1.2.

6.14 General attributes and output control state list

6.14.1 INQUIRE OUTPUT STATE

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	output state	(ACTIVE, TEXT OPEN, FIGURE OPEN)	E
Out	line width specification mode	(VDC, SCALED)	E
Out	marker size specification mode	(VDC, SCALED)	E
Out	edge width specification mode	(VDC, SCALED)	E

Effect:

See 6.1.2.

6.14.2 INQUIRE OBJECT CLIPPING

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	clip indicator	(OFF, ON)	E
Out	clip rectangle		2P

Effect:

See 6.1.2.

6.14.3 INQUIRE LIST OF ATTRIBUTE SET NAMES IN USE

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(0..n)	I
Out	list of attribute set names		nASN

Effect:

See 6.1.2.

6.14.4 INQUIRE COLOUR STATE

Parameters:

Out	response validity	(INVALID, VALID)	E
Out	colour selection mode	(INDEXED, DIRECT)	E
Out	colour value extent		2CD
Out	selection mode of auxiliary colour	(INDEXED, DIRECT)	E
Out	auxiliary colour		CO
Out	transparency	(OPAQUE, TRANSPARENT)	E
Out	selection mode of background colour	(INDEXED, DIRECT)	E
Out	background colour		CO

Effect:
See 6.1.2.

6.14.5 INQUIRE LIST OF COLOUR TABLE ENTRIES

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total number of elements in state list	(1..n)	I
Out	list of colour table entries		nCD

Effect:
See 6.1.2.

6.14.6 INQUIRE FONT LIST

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
In	maximum characters per string	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total length of longest string present	(1..n)	I
Out	total number of elements in state list	(1..n)	I
Out	list of font names		nSF

Effect:
See 6.1.2.

6.14.7 INQUIRE CHARACTER SET LIST

Parameters:

In	number of list elements requested	(0..n)	I
In	index (within list) of first element to return	(1..n)	I
In	maximum characters per string	(1..n)	I
Out	response validity	(INVALID, VALID)	E
Out	total length of longest string present	(1..n)	I
Out	total number of elements in state list	(1..n)	I
Out	list of character sets		nCS

Effect:
See 6.1.2.

6.14.8 LOOKUP ASPECT SOURCE FLAGS

Parameters:

In	list of ASF types requested	*(see below)*	nE
Out	response validity	(INVALID, VALID)	E
Out	list of ASF values	(INDIVIDUAL, BUNDLED)	nE

Effect:
The number of elements in and ordering of the return list correspond to the *list of ASF types requested*.

See 5.4.18 for a list of the possible enumerated values for ASF types. See 6.1.2.

7 CGI description tables and state lists

This clause contains the description tables and state lists which define the portion of the Virtual Device relating to output primitives and attributes, and the related control functions.

The information in the description tables and state lists is available to a client by means of inquiry functions. The abstract specifications of these functions are found in clause 6.

Note that where the data type of an entry depends on a corresponding specification mode (Line Width, Edge Width, Marker Size) or selection mode (any Colour), the state list always contains the mode in which the value was last set. The default values, (for example, for the bundle definitions) will also have the mode fields stored by the implementation which correspond to the default definitions.

If this part of ISO/IEC 9636 allows latitude for certain description table entries, the preferred entries are designated by the entry being underlined.

7.1 Description tables

7.1.1 Primitive support

Table 9 – Primitive Support Description Table

Entry	Possible Values	Data Type
Primitive Support:		
Maximum Number of Points for Polyline	(-1, 128..n)(Note 1)	I
Maximum Number of Points for Disjoint Polyline	(-1, 0..n)(Note 1)	I
Maximum Number of Points for Polygon	(-1, 0..n)(Note 1)	I
Maximum Number of Points for Polygon Set	(-1, 0..n)(Note 1)	I
Maximum Number of Points for Polymarker	(-1, 128..n)(Note 1)	I
Maximum Number of Characters for Text	(-1, 80..n)(Note 1, 2)	I
Maximum Number of Cell Colour Specifiers for Cell Array	(-1, 1..n) (Note 1)	I
Line/Edge Type Continuity Capability	(RESTART, CONTINUOUS, OTHER)	E
Cell Array Fill Capability	(OUTLINED, FILLED)	E
Cell Array Alignment Capability	(AXIS ALIGNED, SKEWED)	E
Cell Array Rendering Technique	(OTHER, EXACT)	E
Compound Text Capability	(NONE, GLOBAL, LOCAL) (Note 3)	E
Closed Figure Capability	(NONE, GLOBAL, LOCAL) (Note 3)	E
Generalized Drawing Primitive Support:		
List of Supported GDP Identifier	(-n..-1, 1..n)	nI
Generalized Drawing Primitive Attributes:		
List of GDP Attribute Groups each containing:		
GDP Identifier	(-n..-1, 1..n)	I
Number of Applicable Attribute Groups	(0..5)	I
Array of Applicable Attribute Groups	(LINE, MARKER, TEXT, FILL, EDGE)	5E

NOTES

1) For entries denoting the maximum number supported, zero indicates no support, and -1 indicates either no restriction on length of list orsupport limited only by available memory (for implementations using dynamic memory allocation).

2) If compound text is supported, the number of characters pertains to the entire string so constructed rather than the parameters of the individual functions. If LOCAL compound text capability is supported, this entry indicates the buffering capability assuming no internal text attribute changes. Depending on the details of the implementation, internal text attribute changes may be stored in the same buffer as the text strings, and thus affect the amount of space available.

3) For both compound text and closed figures, the value GLOBAL indicates that the compound object can be constructed, but without internal attribute changes (text attributes or edge attributes, respectively).

7.1.2 Attributes

Table 10 – Line Description Table

Entry	Possible Values	Data Type
Line Capability:		
Number of Predefined Line Bundles	(1..n)	I
Number of Settable Line Bundles	(-1, 0..n) (Note 1)	I
Maximum Line Bundle Index	(1..n)	IX
Dynamic Modification Accepted For Line Bundles	(IRG, CBS, IMM)	E
Nominal Scaled Line Width	(> 0)	DC (Note 2)
Minimum Scaled Line Width	(> 0)	DC (Note 2)
Maximum Scaled Line Width	(> 0)	DC (Note 2)
Number of Valid Line Clipping Modes	(1..3)	I
Array of Available Line Clipping Modes	(LOCUS, SHAPE, LOCUS THEN SHAPE)	3E
Available Line Types:		
List of Available Line Types		nIX
Available Scaled Line Widths:		
List of Available Scaled Line Widths	(Notes 2, 3)	nDC

NOTES

1) Zero indicates no support, -1 indicates support limited only by available memory (for implementations using dynamic memory allocation).
2) These values are measured in the physical device coordinates native to the device. Note that the device metric may not be uniform as, for example, a raster device with x pixel spacing differing from y pixel spacing using pixel addresses as device coordinates. Note that the minimum scaled size is also the minimum VDC size after conversion to device coordinates.
3) An empty list means that the range is continuous.

Table 11 – Marker Description Table

Entry	Possible Values	Data Type
Marker Capability:		
Number of Predefined Marker Bundles	(1..n)	I
Number of Settable Marker Bundles	(-1, 0..n) (Note 1)	I
Maximum Marker Bundle Index	(1..n)	IX
Dynamic Modification Accepted For Marker Bundles	(IRG, CBS, ,IMM)	E
Nominal Scaled Marker Size	(> 0)	DC (Note 2)
Minimum Scaled Marker Size	(> 0)	DC (Note 2)
Maximum Scaled Marker Size	(> 0)	DC (Note 2)
Number of Valid Marker Clipping Modes	(1..3)	I
Array of Available Marker Clipping Modes	(LOCUS, SHAPE, LOCUS THEN SHAPE)	3E
Available Marker Types:		
List of Available Marker Types		nIX
Available Scaled Marker Sizes:		
List of Available Scaled Marker Sizes	(Notes 2, 3)	nDC

NOTES

1) Zero indicates no support, -1 indicates support limited only by available memory (for implementations using dynamic memory allocation).
2) These values are measured in the physical device coordinates native to the device. Note that the device metric may not be uniform as, for example, a raster device with x pixel spacing differing from y pixel spacing using pixel addresses as device coordinates. Note that the minimum scaled size is also the minimum VDC size after conversion to device coordinates.
3) An empty list means that the range is continuous.

Table 12 – Text Description Table

Entry	Possible Values	Data Type
Text Capability:		
Number of Predefined Text Bundles	(1..n)	I
Number of Settable Text Bundles	(-1, 0..n) (Note 1)	I
Maximum Text Bundle Index	(1..n)	IX
Dynamic Modification Accepted For Text Bundles	(IRG, CBS, IMM)	E
Maximum Length of Font List	(-1,1..n) (Note 1)	I
Dynamic Modification Accepted For Font List	(IRG, CBS, IMM)	E
Maximum Length of Character Set List	(-1,1..n) (Note 1)	I
Available Character Sets:		
List of Available Character Sets		nCS
Available Text Fonts:		
List of Available Text Fonts		nSF
For Each Text Font/Precision Pair:		
Font Name		SF
Precision	(STRING, CHARACTER, STROKE)	E
Font Capabilities:		
Minimum Character Expansion Factor	(> 0)	R
Maximum Character Expansion Factor	(> 0)	R
Minimum Character Spacing		R
Maximum Character Spacing		R
Minimum Character Height	(> 0)	DC
Maximum Character Height	(> 0)	DC
Skewed Vector Support	(NO, YES)	E
Mirrored Character Support	(NO, YES)	E
Number of Supported Text Paths	(1..5)	I
Array of Supported Text Paths	(RIGHT, LEFT, UP, DOWN)	4E
Number of Supported Horizontal Text Alignments	(1..5)	I
Array of Supported Horizontal Text Alignments	(NORMAL HORIZONTAL, LEFT, CENTRE, RIGHT, CONTINUOUS HORIZONTAL)	5E
Number of Supported Vertical Text Alignments	(1..7)	I
Array of Supported Vertical Text Alignments	(NORMAL VERTICAL, TOP, CAP, HALF, BASE, BOTTOM,CONTINUOUS VERTICAL)	7E
Available Character Expansion Factors:		
List of Available Character Expansion Factors	(Note 3)	nR
Available Character Spacings:		
List of Available Character Spacing	(Note 3)	nR
Available Character Heights:		
List of Available Character Heights	(Notes 2, 3)	nDC
Available Character Orientations:		
List of Available Character Orientations	(Note 3)	n4VDC

NOTES

1) Zero indicates no support, -1 indicates support limited only by available memory (for implementations using dynamic memory allocation).

2) These values are measured in the physical device coordinates native to the device. Note that the device metric may not be uniform as, for example, a raster device with x pixel spacing differing from y pixel spacing using pixel addresses as device coordinates. Note that the minimum scaled size is also the minimum VDC size after conversion to device coordinates.

3) An empty list means that the range is continuous.

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Table 14 – Edge Description Table — (concluded)

Entry	Possible Values	Data Type
Available Scaled Edge Widths: List of Available Scaled Edge Widths	(Notes 2, 3)	nDC

NOTES

1) Zero indicates no support, -1 indicates support limited only by available memory (for implementations using dynamic memory allocation).
2) These values are measured in the physical device coordinates native to the device. Note that the device metric may not be uniform as, for example, a raster device with x pixel spacing differing from y pixel spacing using pixel addresses as device coordinates. Note that the minimum scaled size is also the minimum VDC size after conversion to device coordinates.
3) An empty list means that the range is continuous.

7.1.3 Font characteristics

The artistic and metric information and character complement considerations required for a text font are complex and non-obvious. ISO/IEC JTC1/SC18/WG8 has in process standards activities in the font specification and description area. The CGI will adopt the font description mechanisms eventually promulgated in what is currently ISO/IEC 9541, "Font information interchange." Description tables including the information required in ISO/IEC 9541 may be included in a future version of ISO/IEC 9636.

7.1.4 Output control

Table 15 – Output Control Description Table

Entry	Possible Values	Data Type
Colour Capability:		
Number of Simultaneously Available Direct Colours	(0, 2..n) (Note 4)	I
Number of Simultaneously Available Indexed Colours	(2..n)	I
Number of Available Colours	(2..n)	I
Number of Available Intensities	(Note 2)	3I
Colour Selection Mode Availability	(INDEXED ONLY, INDEXED AND DIRECT)	E
Dynamic Modification Accepted For Colour Table	(IRG, CBS, IMM)	E
Colour Overwrite Capability	(NO, YES)	E
Colour Realization	(ADDITIVE, SUBTRACTIVE)	E
Monochromatic Device	(NO, YES)	E
Background Colour Capability	(NONE, INDEX 0, INDEXED, FULL)	E
CIE Characteristics: (Note 3)		
CIE 1931 Chromaticity Coordinates for Red Primary		2R
CIE 1931 Chromaticity Coordinates for Green Primary		2R
CIE 1931 Chromaticity Coordinates for Blue Primary		2R
CIE 1931 Tristimulus Values for Reference White		3R
Output Capability:		
Maximum Number of Simultaneously Saved Attribute Sets	(-1,1..n) (Note 1)	I
Number of Valid Character Coding Announcers	(1..5)	I
Array of Valid Character Coding Announcer Values	(BASIC 7-BIT, BASIC 8-BIT, EXTENDED 7-BIT, EXTENDED 8-BIT, PRIVATE)	5E

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Table 15 – Output Control Description Table — (concluded)

Entry	Possible Values	Data Type
NOTES 1) Zero indicates no support, -1 indicates support limited only by available memory (for implementations using dynamic memory allocation). 2) For colour devices, this entry gives the number of levels of red, green, and blue supported for both direct and indexed colour; and for monochromatic devices, the first element of the three-tuple specifies the number of (monochromatic) intensities. The value of Number of Simultaneously Available Direct Colours will have been determined in accordance with the following: For a monochromatic device, it is the first element of the entry Number of Available Intensities; for a colour device using direct colours in the frame buffer, it is the product of the three elements of Number of Available Intensities; for a colour device using a hardware colour table, it is the size of that colour table. 3) Although CGI supports only the RGB colour model, these values are suitable for use in the conversion of colour values between 1931 CIE colour model and the RGB colour model. 1931 CIE colour model is the basic colour model from which all other CIE colour models are derived. The transformation from any CIE colour model to RGB is composed of a transformation to CIE 1931 followed by a transformation from CIE 1931 to RGB. The parameters provided are sufficient to describe this transformation. (ISO/IEC 9592-1, annex I provides an example of such a transformation.) 4) Support for Direct Colour is not required; zero indicates no support.		

7.2 State lists

7.2.1 Attributes

Table 16 – Line Attributes State List

Entry	Possible Values	Data Type	Default
Line Attributes:			
Line Bundle Index	(1..n)	IX	1
Line Type	(-n..-1,1..n) (Note 1)	IX	1
Specification Mode of Line Width	(VDC, SCALED)	E	SCALED
Line Width	(≥ 0)	SS	1.0 (R)
Selection Mode of Line Colour	(INDEXED, DIRECT)	E	INDEXED
Line Colour	*(imp.dep)*	CO	1 (CI)
Line Clipping Mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E	*(imp.dep)*
Line Bundle Indices:			
List of Line Bundle Indices	(1..n)	nIX	
Line Representations:			
List of Line Bundles each containing:			
Line Type	(-n..-1,1..n)(Note 1)	E	(Note 2)
Specification Mode of Line Width	(VDC, SCALED)	E	(Note 2)
Line Width	(≥ 0)	SS	(Note 2)
Selection Mode of Line Colour	(INDEXED, DIRECT)	E	(Note 2)
Line Colour	*(imp.dep)*	CO	(Note 2)

NOTES
1) The range of line types supported is implementation-dependent; standardized line types are 1..5.
2) Default content of each representation is implementation-dependent. The default for the list of indices at CGI initialization corresponds to the predefined line bundle indices.

Table 17 – Marker Attributes State List

Entry	Possible Values	Data Type	Default
Marker Attributes:			
Marker Bundle Index	(1..n)	IX	1
Marker Type	(-n..-1, 1..n)(Note 1)	IX	3
Specification Mode of Marker Size	(VDC, SCALED)	E	SCALED
Marker Size	(≥ 0)	SS	1.0 (R)
Selection Mode of Marker Colour	(INDEXED, DIRECT)	E	INDEXED
Marker Colour	*(imp.dep)*	CO	1 (CI)
Marker Clipping Mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E	*(imp.dep)*
Marker Bundle Indices:			
List of Marker Bundle Indices	(1..n)	nIX	
Marker Representations:			
List of Marker Bundles each containing:			
Marker Type	(-n..-1,1..n)(Note 1)	IX	(Note 2)
Specification Mode of Marker Size	(VDC, SCALED)	E	(Note 2)
Marker Size	(≥ 0)	SS	(Note 2)
Selection Mode of Marker Colour	(INDEXED, DIRECT)	E	(Note 2)
Marker Colour	*(imp.dep)*	CO	(Note 2)

NOTES

1) The range of marker types supported is implementation-dependent; standardized marker types are 1..5.

2) Default content of each representation is implementation-dependent. The default for the list of indices at CGI initialization corresponds to the predefined marker bundle indices.

Table 18 – Text Attributes State List

Entry	Possible Values	Data Type	Default
Text Attributes:			
Text Bundle Index	(1..n)	IX	1
Text Font Index	(1..n)	IX	1
Text Precision	(STRING, CHARACTER, STROKE)	E	STRING
Character Expansion Factor	(> 0)	R	1.0
Character Spacing		R	0.0
Selection Mode of Text Colour	(INDEXED, DIRECT)	E	INDEXED
Text Colour	*(imp.dep)*	CO	1 (CI)
Character Height	(≥ 0)	VDC	(Note 1)
Character Orientation (up, base)		4VDC	(0, 1, 1, 0)
Text Path	(RIGHT, LEFT, UP, DOWN)	E	RIGHT
Horizontal Text Alignment	(NORMAL HORIZONTAL, LEFT, CENTRE, RIGHT, CONTINUOUS HORIZONTAL)	E	NORMAL HORIZONTAL
Continuous Horizontal Alignment		R	1.0
Vertical Text Alignment	(NORMAL VERTICAL, TOP, CAP, HALF, BASE, BOTTOM, CONTINUOUS VERTICAL)	E	NORMAL VERTICAL
Continuous Vertical Alignment		R	1.0
Character Set Index	(1..n)	IX	1
Alternate Character Set Index	(1..n)	IX	1
Character Coding Announcer	(BASIC 7-BIT, BASIC 8-BIT, EXTENDED 7-BIT, EXTENDED 8-BIT, PRIVATE)	E	BASIC 7-BIT
Text Bundle Indices:			
List of Text Bundle Indices	(1..n)	nIX	

Table 18 – Text Attributes State List – (concluded)

Entry	Possible Values	Data Type	Default
Text Representations:			
List of Text Bundles each containing:			
Text Font Index	(1..n)	IX	(Note 2)
Text Precision	(STRING, CHARACTER, STROKE)	E	(Note 2)
Character Expansion Factor	(> 0)	R	(Note 2)
Character Spacing		R	(Note 2)
Selection Mode of Text Colour	(INDEXED, DIRECT)	E	(Note 2)
Text Colour	*(imp.dep)*	CO	(Note 2)

NOTES

1) Default is 1/100 of the longest side of the rectangle defined by the default VDC EXTENT.

2) Default content of each representation is implementation-dependent. The default for the list of indices at CGI initialization corresponds to the predefined text bundle indices.

Table 19 – Fill Attributes State List

Entry	Possible Values	Data Type	Default
Fill Attributes:			
Fill Bundle Index	(1..n)	IX	1
Interior Style	(HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP)	E	HOLLOW
Selection Mode of Fill Colour	(INDEXED, DIRECT)	E	INDEXED
Fill Colour	*(imp.dep)*	CO	1 (CI)
Hatch Index	(-n..-1,1..n)	IX	1
Pattern Index	(1..n)	IX	1
Fill Bitmap Identifier		BN	0 (Note 1)
Fill Bitmap Region		2P	
Fill Reference Point		P	(0, 0)
Pattern Size		4VDC	(0, h, w, 0) (Note 2)
Fill Bundle Indices:			
List of Fill Bundle Indices	(1..n)	nIX	
Pattern Indices:			
List of Pattern Indices	(1..n)	nIX	
Fill Representations:			
List of Fill Bundles each containing:			
Interior Style	(HOLLOW, SOLID, PATTERN, HATCH, EMPTY, BITMAP)	E	(Note 4)
Selection Mode of Fill Colour	(INDEXED, DIRECT)	E	(Note 4)
Fill Colour	*(imp.dep)*	CO	(Note 4)
Hatch Index	(-n..-1,1..n)	IX	(Note 4)
Pattern Index	(1..n)	IX	(Note 4)
Fill Bitmap Identifier		BN	(Notes 1,4)
Fill Bitmap Region		2P	(Notes 1,4)
Pattern Table Contents:			

Table 20 – Fill Attributes State List — (concluded)

Entry	Possible Values	Data Type	Default
Pattern Table Contents:			
List of Patterns each containing:			
Number of Horizontal Samples	(1..nx)	I	(Note 3)
Number of Vertical Samples	(1..ny)	I	(Note 3)
Selection Mode of Colour Specifiers	(INDEXED, DIRECT)	E	(Note 5)

NOTES
1) The value 0 here is defined to correspond to a mapped bitmap of one pixel having the Mapped Bitmap Foreground Colour.
2) Where h = height and w = width of the default VDC extent.
3) Only the first pattern in the table has a predefined default: solid (nx=ny=1) colour index 1. Other pattern defaults are implementation-dependent.
4) Default content of each representation is implementation-dependent. The default for the list of indices at CGI initialization corresponds to the predefined fill bundle indices.
5) The list of pattern indices defaults to those predefined.

Table 20 – Edge Attributes State List

Entry	Possible Values	Data Type	Default
Edge Attributes:			
Edge Bundle Index	(1..n)	IX	1
Edge Visibility	(INVISIBLE, VISIBLE)	E	INVISIBLE
Edge Type	(-n..-1, 1..n)(Note 1)	IX	1
Specification Mode of Edge Width	(VDC, SCALED)	E	SCALED
Edge Width	(≥ 0)	SS	1.0 (R)
Selection Mode of Edge Colour	(INDEXED, DIRECT)	E	INDEXED
Edge Colour	*(imp.dep)*	CO	1 (CI)
Edge Clipping Mode	(LOCUS, SHAPE, LOCUS THEN SHAPE)	E	*(imp.dep)*
Edge Bundle Indices:			
List of Edge Bundle Indices	(1..n)	nIX	
Edge Representations:			
List of Edge Bundles each containing:			
Edge Visibility	(INVISIBLE, VISIBLE)	E	(Note 2)
Edge Type	(-n..-1, 1..n)(Note 1)	E	(Note 2)
Specification Mode of Edge Width	(VDC, SCALED)	E	(Note 2)
Edge Width	(≥ 0)	SS	(Note 2)
Selection Mode of Edge Colour	(INDEXED, DIRECT)	E	(Note 2)
Edge Colour	*(imp.dep)*	CO	(Note 2)

NOTES
1) The range of edge types supported is implementation-dependent; standardized edge types are 1..5.
2) Default content of each representation is implementation-dependent. The default for the list of indices at CGI initialization corresponds to the predefined edge bundle indices.

7.2.2 General attributes and output control

Table 21 – General Attributes and Output Control State List

Entry	Possible Values	Data Type	Default
Output State:			
Output State	(ACTIVE, TEXT OPEN, FIGURE OPEN)	E	ACTIVE
Line Width Specification Mode	(VDC, SCALED)	E	SCALED
Marker Size Specification Mode	(VDC, SCALED)	E	SCALED
Edge Width Specification Mode	(VDC, SCALED)	E	SCALED
Clipping:			
Clip Indicator	(OFF, ON)	E	ON
Clip Rectangle		2P	(Note 5)
Attribute Set Names in use:			
List of Attribute Set Names		nASN	empty
Colour State:			
Colour Selection Mode	(INDEXED, DIRECT)	E	INDEXED
Colour Value Extent		2CD	*(imp.dep)*
Selection Mode of Auxiliary Colour	(INDEXED, DIRECT)	E	INDEXED
Auxiliary Colour	*(imp.dep)*	CO	0 (CI)
Transparency	(OPAQUE, TRANSPARENT)	E	*(imp.dep)*
Selection Mode of Background Colour	(INDEXED, DIRECT)	E	INDEXED
Background Colour	*(imp.dep)*	CO	0 (CI)
Colour Table Contents:			
List of Colour Table Entries	*(imp.dep)*	nCD	(Note 1)
Current fonts:			
List of Font Names	*(imp.dep)*	nSF	(Note 2)
Current Character Sets:			
List of Current Character Sets		nCS	(Note 3)
Aspect Source Flags:			
List of Aspect Source Flags for each defined ASF type:			
ASF Type	(Note 4)	E	
ASF Value	(INDIVIDUAL, BUNDLED)	E	INDIVIDUAL

NOTES

1) Default colour table is an implementation-dependent background colour in index 0, and implementation-dependent foreground colours in indices numbered 1 or greater.
2) Default font capable of displaying the default character set.
3) Character set 1 is standard national set based on ISO 646.
4) The list of possible values for the enumerated ASF type maybe found under 5.4.18.
5) The default for Clip Rectangle is the same as the default for VDC Extent.

Annex A

(normative)

Formal grammar of the functional specification

A.1 Introduction

This grammar is a formal definition of the Output portion of standard CGI syntax. It shows all productions regardless of the encoding scheme. The terminal symbols correspond to the CGI basic abstract data types. Encoding and representation details of these can be found in ISO/IEC 9637.

A.2 Notation used

<symbol>	- nonterminal
<SYMBOL>	- terminal
<symbol>*	- 0 or more occurrences
<symbol>+	- 1 or more occurrences
<symbol>o	- 0 or 1 occurrences
<symbol>(n)	- exactly n occurrences; n ≥ 2
<symbol-1> ::= <symbol-2>	- symbol-1 has the syntax of symbol-2
<symbol-1> | <symbol-2>	- symbol-1 or alternatively symbol-2
<symbol: meaning>	- symbol with the stated meaning
comment	- explanation of a symbol or a production
returned: <symbol>*	- output parameter(s)

A.3 Detailed grammar

```
<part 3 function>     ::=  <output primitive function>
                         |  <output attribute function>
                         |  <output general attribute function>
                         |  <output control function>
                         |  <output retrieval function>
                         |  <output inquiry function>
```

A.3.1 Output primitives functions

```
<output primitive function>
                      ::=  <line function>
                         |  <marker function>
                         |  <fill function>
                         |  <text function>
                         |  <image function>
                         |  <gdp function>

<line function>       ::=  <POLYLINE>
                                  <point>+
                         |  <DISJOINT POLYLINE>
                                  <point>+
```

```
                    |  <CIRCULAR ARC 3 POINT>
                           <point>(3)
                    |  <CIRCULAR ARC CENTRE>
                           <point>
                           <vdc value>(4)
                           <vdc value: radius>
                    |  <CIRCULAR ARC CENTRE REVERSED>
                           <point>
                           <vdc value>(4)
                           <vdc value: radius>
                    |  <ELLIPTICAL ARC>
                           <point>(3)
                           <vdc value>(4)
                    |  <CONNECTING EDGE>

<marker function>   ::=  <POLYMARKER>
                           <point>+

<fill function>     ::=  <POLYGON>
                           <point>+
                    |  <POLYGON SET>
                           <edge pair>+
                    |  <RECTANGLE>
                           <point>(2)
                    |  <CIRCLE>
                           <point>
                           <vdc valuc: radius>
                    |  <CIRCULAR ARC 3 POINT CLOSE>
                           <point>(3)
                           <close type>
                    |  <CIRCULAR ARC CENTRE CLOSE>
                           <point>
                           <vdc value>(4)
                           <vdc value: radius>
                           <close type>
                    |  <ELLIPSE>
                           <point>(3)
                    |  <ELLIPTICAL ARC CLOSE>
                           <point>(3)
                           <vdc value>(4)
                           <close type>

<text function>     ::=  <TEXT>
                           <point>
                           <text final flag>
                           <BDT_STRING>
                    |  <RESTRICTED TEXT>
                           <vdc value: extent parallelogram>(2)
                           <point>
                           <text final flag>
                           <BDT_STRING>
                    |  <APPEND TEXT>
                           <text final flag>
                           <BDT_STRING>

<image function>    ::=  <CELL ARRAY>
                           <point: P, Q, R>(3)
                           <BDT_INTEGER: nx, ny dimensions>(2)
```

```
                                <local colour prec requirement>
                                <colour specifier>*          nx × ny colours

<gdp function>          ::=  <GDP>
                                <identifier>
                                <point>*
                                <data record>

<data record>           ::=  <typed sequence>*

<typed sequence>        ::=  <data type index>
                             <element count>
                             <data item: of data type index>*

<data item>             ::=  <data record>
                        |    <BDT_COLOUR_INDEX>
                        |    <BDT_COLOUR_DIRECT>
                        |    <BDT_CSN_VALUE>
                        |    <enumerated> refer to list of terminal enumerated values
                        |    <BDT_INTEGER>
                        |    <BDT_ICO_VALUE>
                        |    <BDT_FIXED_INTEGER_8>
                        |    <BDT_FIXED_INTEGER_16>
                        |    <BDT_FIXED_INTEGER_32>
                        |    <BDT_INDEX>
                        |    <BDT_REAL>
                        |    <BDT_STRING>
                        |    <BDT_FIXED_STRING>
                        |    <vdc value>
                        |    <vc value>

<element count>         ::=  <BDT_INTEGER: number of elements in list>

<data type index>       ::=  <BDT_INDEX>

<point>          ::=  <vdc value>(2)

<vdc value>      ::=  <BDT_REAL> | <BDT_INTEGER>

<edge pair>      ::=  <point> <edge out flag>

<edge out flag: enumerated>  ::=  <INVISIBLE>
                             |    <VISIBLE>
                             |    <CLOSE INVISIBLE>
                             |    <CLOSE VISIBLE>

<extent>         ::=  <vdc value>(2)

<text final flag: enumerated>     ::=  <NOT FINAL> | <FINAL>

<close type: enumerated>          ::=  <PIE> | <CHORD>

<local colour prec requirement>   ::=  <BDT_INTEGER>
```

A.3.2 Output attribute functions

```
<output attribute function> ::=  <line attribute function>
                            |    <marker attribute function>
                            |    <text attribute function>
                            |    <interior attribute function>
                            |    <edge attribute function>
```

```
<line attribute function>::=   <LINE BUNDLE INDEX>
                                   <BDT_INDEX>
                             |  <LINE TYPE>
                                   <BDT_INDEX>
                             |  <LINE WIDTH>
                                   <size specifier>
                             |  <LINE COLOUR>
                                   <colour specifier>
                             |  <LINE CLIPPING MODE>
                                   <clip mode>

<clip mode: enumerated>::=   <LOCUS>
                           |  <SHAPE>
                           |  <LOCUS THEN SHAPE>

<size specifier>          ::=  <vdc value> | <BDT_REAL>

<marker attribute function> ::=  <MARKER BUNDLE INDEX>
                                       <BDT_INDEX>
                                 |  <MARKER TYPE>
                                       <BDT_INDEX>
                                 |  <MARKER SIZE>
                                       <size specifier>
                                 |  <MARKER COLOUR>
                                       <colour specifier>
                                 |  <MARKER CLIPPING MODE>
                                       <clip mode>

<text attribute function>     ::=  <TEXT BUNDLE INDEX>
                                       <BDT_INDEX>
                                 |  <TEXT FONT INDEX>
                                       <BDT_INDEX>
                                 |  <TEXT PRECISION>
                                       <text precision>
                                 |  <CHARACTER EXPANSION FACTOR>
                                       <BDT_REAL>
                                 |  <CHARACTER SPACING>
                                       <BDT_REAL>
                                 |  <TEXT COLOUR>
                                       <colour specifier>
                                 |  <CHARACTER HEIGHT>
                                       <vdc value>
                                 |  <CHARACTER ORIENTATION>
                                       <vdc value>(4)
                                 |  <TEXT ALIGNMENT>
                                       <horizontal alignment type>
                                       <vertical alignment type>
                                       <BDT_REAL: continuous alignment values>(2)
                                 |  <CHARACTER SET INDEX>
                                       <BDT_INDEX>
                                 |  <ALTERNATE CHARACTER SET INDEX>
                                       <BDT_INDEX>
                                 |  CHARACTER CODING ANNOUNCER>
                                       <coding technique>
                                 |  <TEXT PATH>
                                       <text path>

<text precision: enumerated> ::=  <STRING> | <CHARACTER> | <STROKE>
```

Formal grammar of the functional specification **Detailed grammar**

<coding technique: enumerated> ::= <BASIC 7-BIT>
| <BASIC 8-BIT>
| <EXTENDED 7-BIT>
| <EXTENDED 8-BIT>
| <PRIVATE>

<text path: enumerated> ::= <RIGHT>
| <LEFT>
| <UP>
| <DOWN>

<horizontal alignment: enumerated> ::= <NORMAL HORIZONTAL>
| <LEFT>
| <CENTRE>
| <RIGHT>
| <CONTINUOUS HORIZONTAL>

<vertical alignment: enumerated> ::= <NORMAL VERTICAL>
| <TOP>
| <CAP>
| <HALF>
| <BASE>
| <BOTTOM>
| <CONTINUOUS VERTICAL>

<interior attribute function> ::= <FILL BUNDLE INDEX>
<BDT_INDEX>
| <INTERIOR STYLE>
<interior style>
| <FILL COLOUR>
<colour specifier>
| <HATCH INDEX>
<BDT_INDEX>
| <PATTERN INDEX>
<BDT_INDEX>
| <FILL REFERENCE POINT>
<point>
| <PATTERN SIZE>
<vdc value>(4)

<interior style: enumerated> ::= <HOLLOW>
| <SOLID>
| <PATTERN>
| <HATCH>
| <EMPTY>
| <BITMAP>

<edge attribute function> ::= <EDGE BUNDLE INDEX>
<BDT_INDEX>
| <EDGE TYPE>
<BDT_INDEX>
| <EDGE WIDTH>
<size specifier>
| <EDGE COLOUR>
<colour specifier>
| <EDGE CLIPPING MODE>
<clip mode>
| <EDGE VISIBILITY>
<edge visibility>

<edge visibility: enumerated>::= <INVISIBLE> | <VISIBLE>

A.3.3 Output general attribute functions

<output general attribute function>::= <clip function>
| <auxiliary colour function>
| <transparency function>

<clip function> ::= <CLIP INDICATOR>
<on off flag: clip indicator>
| <CLIP RECTANGLE>
<point: first and second corner>(2)

<auxiliary colour function> ::= <AUXILIARY COLOUR>
<colour specifier>

<transparency function> ::= <TRANSPARENCY>
<transparency>

<transparency: enumerated> ::= <OPAQUE> | <TRANSPARENT>

<on off flag: enumerated> ::= <OFF> | <ON>

A.3.4 Output control functions

<output control function> ::= <colour control function>
| <font and character function>
| <specification mode function>
| <bundle representation function>
| <asf function>
| <pattern table function>
| <closed figure function>
| <save set function>
| <delete representation function>

<colour control function> ::= <BACKGROUND COLOUR>
<colour specifier: background colour>
| <COLOUR TABLE>
<BDT_COLOUR_INDEX: starting index>
<BDT_COLOUR_DIRECT>+
| <COLOUR SELECTION MODE>
<colour selection mode>
| <COLOUR VALUE EXTENT>
<BDT_COLOUR_DIRECT: min and max>(2)

<colour selection mode: enumerated>::= <INDEXED> | <DIRECT>

<colour specifier> ::= <BDT_COLOUR_INDEX> | <BDT_COLOUR_DIRECT>

<font and character function> ::= <FONT LIST>
<BDT_FIXED_STRING: font name>*
| <CHARACTER SET LIST>
<character set definition>*

<character set definition> ::= <char set> <BDT_STRING: designation sequence>

<char set: enumerated> ::= <94 CHARACTER SET>
| <96 CHARACTER SET>
| <94 CHARACTER MULTIBYTE SET>
| <96 CHARACTER MULTIBYTE SET>
| <COMPLETE CODE>

Formal grammar of the functional specification **Detailed grammar**

<specification mode function> ::= <LINE WIDTH SPECIFICATION MODE>
<size specification mode>
| <EDGE WIDTH SPECIFICATION MODE>
<size specification mode>
| <MARKER SIZE SPECIFICATION MODE>
<size specification mode>

<size specification mode: enumerated> ::= <VDC> | <SCALED>

<bundle representation function> ::= <LINE REPRESENTATION>
<line bundle>
| <MARKER REPRESENTATION>
<marker bundle>
| <TEXT REPRESENTATION>
<text bundle>
| <FILL REPRESENTATION>
<fill bundle>
| <EDGE REPRESENTATION>
<edge bundle>

<line bundle> ::= <BDT_INDEX: bundle index>
<BDT_INDEX: line type>
<size specifier: line width>
<colour specifier: line colour>

<marker bundle> ::= <BDT_INDEX: bundle index>
<BDT_INDEX: marker type>
<size specifier: marker size>
<colour specifier: marker colour>

<text bundle> ::= <BDT_INDEX: bundle index>
<BDT_INDEX: font index>
<text precision>
<BDT_REAL: character spacing>
<BDT_REAL: character expansion factor>
<colour specifier: text colour>

<fill bundle> ::= <BDT_INDEX: bundle index>
<interior style>
<colour specifier: fill colour>
<BDT_INDEX: hatch>
<BDT_INDEX: pattern>
<BDT_CSN_VALUE: fill bitmap identifier>
<point: fill bitmap region>(2)

<edge bundle> ::= <BDT_INDEX: bundle index>
<BDT_INDEX: edge type>
<size specifier: edge width>
<colour specifier: edge colour>
<edge visibility>

<asf function> ::= <ASPECT SOURCE FLAGS>
<asf pair>+

<asf pair> ::= <asf type> <asf>

<asf type: enumerated> ::= <LINE TYPE ASF>
| <LINE WIDTH ASF>
| <LINE COLOUR ASF>
| <MARKER TYPE ASF>
| <MARKER SIZE ASF>

| <MARKER COLOUR ASF>
| <TEXT FONT INDEX ASF>
| <TEXT PRECISION ASF>
| <CHARACTER EXPANSION FACTOR ASF>
| <CHARACTER SPACING ASF>
| <TEXT COLOUR ASF>
| <INTERIOR STYLE ASF>
| <FILL COLOUR ASF>
| <HATCH INDEX ASF>
| <PATTERN INDEX ASF>
| <EDGE TYPE ASF>
| <EDGE WIDTH ASF>
| <EDGE COLOUR ASF>
| <EDGE VISIBILITY ASF>
| <FILL BITMAP ASF>

<asf: enumerated> ::= <INDIVIDUAL> | <BUNDLED>

<pattern table function> ::= <PATTERN TABLE>
<BDT_INDEX>
<BDT_INTEGER: nx, ny dimensions>(2)
<local colour prec requirement>
<colour specifier>* nx × ny colours.)

<closed figure function> ::= <BEGIN FIGURE>
| <NEW REGION>
| <END FIGURE>

<save set function> ::= <SAVE PRIMITIVE ATTRIBUTES>
<attribute set name>
| <RESTORE PRIMITIVE ATTRIBUTES>
<attribute set name>
| <DELETE PRIMITIVE ATTRIBUTE SAVE SET>
<attribute set name>

<attribute set name> ::= <BDT_CSN_VALUE>

<delete representation function>::= <DELETE BUNDLE REPRESENTATION>
<bundle table type>
<BDT_INDEX: bundle index>
| <DELETE PATTERN>
<BDT_INDEX: pattern index>

<bundle table type: enumerated> ::= <LINE>
| <MARKER>
| <TEXT>
| <FILL>
| <EDGE>

A.3.5 Output retrieval functions

<output retrieval function> ::= <GET TEXT EXTENT>
<point: text position>
<BDT_STRING>
returned:
<response validity>
<validity flag: concatenation validity>
<point: concatenation point>
<point: extent parallelogram>(4)

<response validity> ::= <validity flag>

<validity flag: enumerated> ::= <INVALID> | <VALID>

A.3.6 Output inquiry functions

<inquiry function> ::= <inquire primitive support levels>
| <inquire gdp attributes>
| <inquire line capability>
| <inquire list of available line types>
| <inquire list of available scaled line widths>
| <inquire marker capability>
| <inquire list of available marker types>
| <inquire list of available scaled marker sizes>
| <inquire text capability>
| <inquire list of available character sets>
| <inquire list of available text fonts>
| <inquire font capabilities>
| <inquire list of available character expansion factors>
| <inquire list of available character spacings>
| <inquire list of available character heights>
| <inquire list of available character orientations>
| <inquire fill capability>
| <inquire list of available hatch styles>
| <inquire edge capability>
| <inquire list of available edge types>
| <inquire list of available scaled edge widths>
| <inquire colour capability>
| <inquire cie characteristics>
| <inquire array of supported character coding announcers>
| <inquire maximum number of simultaneously saved attribute sets>
| <inquire line attributes>
| <inquire list of line bundle indices>
| <inquire line representation>
| <inquire marker attributes>
| <inquire list of marker bundle indices>
| <inquire marker representation>
| <inquire text attributes>
| <inquire list of text bundle indices>
| <inquire text representation>
| <inquire fill attributes>
| <inquire pattern dimensions>
| <inquire pattern>
| <inquire list of pattern indices>
| <inquire list of fill bundle indices>
| <inquire fill representation>
| <inquire edge attributes>
| <inquire list of edge bundle indices>
| <inquire edge representation>
| <inquire output state>
| <inquire list of attribute set names in use>
| <inquire colour state>
| <inquire list of colour table entries>
| <inquire font list>
| <inquire character set list>
| <inquire object clipping>

| <lookup aspect source flags>
| <lookup gdp support>

<inquire primitive support levels>
::= <INQUIRE PRIMITIVE SUPPORT LEVELS>
returned:
<response validity>
<BDT_INTEGER: max number of points for polyline>
<BDT_INTEGER: max number of points for disjoint polyline>
<BDT_INTEGER: max number of points for polygon>
<BDT_INTEGER: max number of points for polygon set>
<BDT_INTEGER: max number of points for polymarker>
<BDT_INTEGER: max number of characters for text>
<BDT_INTEGER: max number of cells for cell array>
<line edge continuity capability>
<cell array fill capability>
<cell array alignment capability>
<cell array rendering technique>
<compound object capability: compound text>
<compound object capability: closed figures>

<line edge continuity capability: enumerated>
::= <RESTART> | <CONTINUOUS> | <OTHER>

<cell array fill capability: enumerated>
::= <OUTLINED> | <FILLED>

<cell array alignment capability: enumerated>
::= <AXIS ALIGNED> | <SKEWED>

<cell array rendering technique: enumerated>
::= <OTHER> | <EXACT>

<compound object capability: enumerated>
::= <NONE> | <GLOBAL> | <LOCAL>

<inquire gdp attributes> ::= <INQUIRE GDP ATTRIBUTES>
<BDT_INTEGER: gdp identifier>
returned:
<response validity>
<BDT_INTEGER: number of applicable groups>
<bundle table type>(5)

<inquire line capability> ::= <INQUIRE LINE CAPABILITY>
returned:
<response validity>
<BDT_INTEGER: number of predefined bundles>
<BDT_INTEGER: number of settable bundles>
<BDT_INDEX: max bundle index>
<dynamic modification flag>
<dc value: nominal, min, max>(3)
<BDT_INTEGER: number of available line clipping modes>
<clipping mode>(3)

<dynamic modification flag: enumerated>
::= <IRG> | <CBS> | <IMM>

<inquire list of available line types>
::= <INQUIRE LIST OF AVAILABLE LINE TYPES>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>

returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<BDT_INDEX: line type>*

<inquire list of available scaled line widths>
::= <INQUIRE LIST OF AVAILABLE SCALED LINE WIDTHS>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>
returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<dc value: scaled line width>*

<inquire marker capability>
::= <INQUIRE MARKER CAPABILITY>
returned:
<response validity>
<BDT_INTEGER: number of predefined bundles>
<BDT_INTEGER: number of settable bundles>
<BDT_INDEX: max bundle index>
<dynamic modification flag>
<dc value: nominal, min, max>(3)
<BDT_INTEGER: number of available marker clipping modes>
<clipping mode>(3)

<inquire list of available marker types>
::= <INQUIRE LIST OF AVAILABLE MARKER TYPES>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>
returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<BDT_INDEX: marker type>*

<inquire list of available scaled marker sizes>
::= <INQUIRE LIST OF AVAILABLE SCALED MARKER SIZES>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>
returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<dc value: scaled marker size>*

<inquire text capability>
::= <INQUIRE TEXT CAPABILITY>
returned:
<response validity>
<BDT_INTEGER: number of predefined bundles>
<BDT_INTEGER: number of settable bundles>
<BDT_INDEX: max bundle index>
<dynamic modification flag: for text bundle>
<BDT_INTEGER: max length of font list>
<dynamic modification flag: for font list>
<BDT_INTEGER: max length of character set list>

<inquire list of available character sets>
::= <INQUIRE LIST OF AVAILABLE CHARACTER SETS>
<BDT_INTEGER: number of list elements requested>

<BDT_INTEGER: index within list>
<BDT_INTEGER: max characters per string>
returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<character set definition>*

<inquire list of available text fonts>
::= <INQUIRE LIST OF AVAILABLE TEXT FONTS>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>
<BDT_INTEGER: max characters per string>
returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<BDT_FIXED_STRING: font name>*

<inquire font capabilities>
::= <INQUIRE FONT CAPABILITIES>
<BDT_FIXED_STRING: font name>
<text precision>
returned:
<response validity>
<BDT_REAL: min, max character expansion>(2)
<BDT_REAL: min, max character spacing>(2)
<dc value: min, max character height>(2)
<skewed character support>
<mirrored character support>
<BDT_INTEGER: number of text path elements>
<text path>(4)
<BDT_INTEGER: number of horizontal alignments>
<horizontal alignment>(5)
<BDT_INTEGER: number of vertical alignments>
<vertical alignment>(7)

<skewed character support> ::= <yes no flag>

<mirrored character support> ::= <yes no flag>

<yes no flag: enumerated> ::= <NO> | <YES>

<inquire list of available character expansion factors>
::= <INQUIRE LIST OF AVAILABLE CHARACTER EXPANSION FACTORS>
<BDT_FIXED_STRING: font name>
<text precision>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>
returned:
<response validity>
<BDT_INTEGER: total number of list elements present in table>
<BDT_REAL: character expansion factor>*

<inquire list of available character spacings>
::= <INQUIRE LIST OF AVAILABLE CHARACTER SPACINGS>
<BDT_FIXED_STRING: font name>
<text precision>
<BDT_INTEGER: number of list elements requested>
<BDT_INTEGER: index within list>
returned:
<response validity>