DH Patterns and Fit

TECHNICAL SERVICES – ePATTERN ASTM STANDARD

- Introduction

This document presents readers with an overview of the technical aspects related to the contents and structure of digital patterns according to ASTM standard D6673 / D6963. The aim is to offer pattern makers insight in the data requirements and to provide a platform for data specialists to verify compliance. Although technical, it is not intended to be a programming reference.

Product developers and pattern makers are faced with an increasing demand from factories for ePattern delivery in a readable format or to receive files from producers for modification. Understanding the variety of file formats, standards and the contents of pattern information as well as the method of presentation has become a necessity. The brand representative has the daunting task to communicate requirements across parties. Connecting people and organizations through workable information has proven a professional challenge; acquiring knowledge about digital pattern formats has become a must. To spread familiarity with formats and standards, DH Patterns and Fit hopes to have added value to the need to understand. This document is one in a series on the subject of pattern interchange.

The reader decides how deep he wants his learning to go. The document can be read superficially to create a feel for the scope and structure of the ASTM standard. It can also be used to study specific requirements up to the level of creation of a sample file which adheres to minimum ASTM requirements. Last but not least, it can serve as a reference guide for pattern makers when they evaluate the contents of an ASTM ePattern. Armed with basic knowledge, there is no need to be intimidated.

DH Patterns and Fit advices her clients to check with their factories for the name of the pattern design system and version as well as the support of file formats for import and export. Knowing that you can communicate patterns seamlessly saves time and costs and ensures adherence to your patterns. Actually, the ability to exchange pattern information between factory and brand owner should be one of the essential criteria when evaluating different producers. Restrictions are better known up-front. You don't want it to become a liability under pressure of quality and production readiness.

This document is no substitute for the ASTM standards D6673 / D6963. Please purchase your personal copy of the standards D6673 / D6963 at www.astm.org.

- ASTM[1] Standards for Sewn Products

DXF is the de-facto standard for the interchange of vector files. The apparel industry[2] created data exchange standards on DXF called ASTM-DXF (D6673) and its predecessor ANSI/AAMA-DXF (292). Among others, the standards define the layers and data formats for anything from external cutting lines to text annotation. The optimized DXF data is widely used to import patterns and to export information to foreign pattern design systems, grading systems, nesting programs and fabric cutting machines.

The largest common denominator between systems is the DXF file format and the optimized DXF format by ASTM or AAMA. DH Patterns and Fit provides patterns in standard DXF (all versions) and on request in ASTM-DXF, AAMA-DXF, and in the native format of a wide range of proprietary systems.

Tip: DXF based pattern files can be opened with Adobe Illustrator and easy-to-use low priced DXF viewers such as ABViewer.

For more information see "Technical Services – Digital Patterns", "Technical Services – ePattern Conversion" and "Technical Services – ePattern AAMA Standard".

- ASTM Standards for Sewn Products

The basis for this paper is ASTM standard D6673-10, formally titled "Standard Practice for Sewn Products Pattern Data Interchange – Data format" and ASTM standard D6963 "Standard Terminology Relating to Sewn Products Automation". The standards can be purchased on-line at www.astm.org

- Pattern Structure and File Transfer Format

The ASTM file structure is based on DXF. DXF is developed and maintained by leading CAD/CAM software provider Autodesk, Inc. DXF files can be ASCII or binary. The ASCII file is the most common format and can be opened with a text editor such at Microsoft WordPad. For the DXF Reference Guide see www.autodesk.com

Within the DXF file, ASTM organized information by function on separate layers and different entities such as lines, polylines, points, blocks and text. With the advancement in technology, the DXF structure has evolved. DXF is upgrade compatible; ASTM D6673-10 is based on AutoCAD DXF version R13.

Each ASTM file contains:

- DXF file header, one pattern style per file;
- DXF entities. In DXF terms an entity can be a line, polyline, point, text, etc.;
- Layers to separate DXF information by type and function. Detail information is assigned to one of 23 pre-defined layers and a variety of DXF entities;
- Style System text that is common to all pieces in the pattern and is placed once;
- Pattern pieces. ASTM uses DXF blocks, which contain graphical and textual information, to define a piece. One block per pattern piece;
- Piece System Text that describes each pattern piece and is part of a block;
- Annotation, part of a block, to clarify instructions for production;
- Instructions for further processing for the purpose of grading, nesting, cutting, etc.

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1) 2)

ASTM - American Society for Testing and Materials. AAMA – American Apparel Manufacturing Association. ANSI - American National Standards Institute. AAMA's Apparel Research Committee (ARC) developed initial standards for apparel and sewn products automation. This work has passed through ANSI to the ASTM and is supported by AAMA/ARC to the current work of ASTM International in communication with AAFA's Enterprise Competitiveness Council (ECC). ASTM D6673-10 is the most recent data interchange standard as per date of writing of this document. See www.astm.org for more information. DH is a member of ASTM.

ASTM defines 23 layers for the differentiation of information:

Layer	Definition	Purpose
1	Piece boundary	Outline of each pattern piece and style system text
2	Turn points	Turn points for layers 1, 8, 11, 14
3	Curve points	Curve points for layers 1, 8, 11, 14
4	Notches; V-notch and slit-notch; alignment.	Articulation of molding; I-shape or V-shape: alignment pieces
5	Grade reference and alternate grade reference line(s)	Grading
6	Mirror line	Symmetry of fold
7	Grain line	Direction of fabric grain
8	Internal line(s)	Graphic annotation of placement. Not cut.
9	Stripe reference line(s)	Fabric alignment of stripes
10	Plaid reference line(s)	Fabric alignment of chequers
11	Internal cutouts(s)	Cutline inside of outline
12	Intentionally left blank	-
13	Drill holes	Punch markers
14	Sew line(s)	Line(s) indicate where to stitch
15	Annotation text	Annotation, not style system text (1) or piece system text (1)
80	T-notch	T-shape: slit with T-branch at end of notch
81	Castle notch	U-shape: equal width, rectangular at end of notch
82	Check notch	V-pointed notch, left or right side perpendicular to boundary
83	U-notch	U-shape: equal width, semi-circle at end of notch
84	Piece boundary quality validation curves	ASTM: Mandatory system information for polyline(s) layer 1
85	Internal lines quality validation curves	ASTM: Mandatory system information for polyline(s) layer 8
86	Internal cutouts quality validation curves	ASTM: Mandatory system information for polyline(s) layer 11
87	Sew lines quality validation curves	ASTM: Mandatory system information for polyline(s) layer 14

Note: Layer 0 is not in use.
Layers must be numbered, not named textually.
Each layer is described separately in this document in its own paragraph.

Tip: ASTM files follow the header, layer and entity structure as defined in the Autodesk DXF version R13.
Most generic CAD/CAM programs allow the operator to control the DXF version when exporting the file.
When viewing an unknown pattern, the presence of layers in the "eighties" is a strong indication that is an ASTM file.

- Graphical Elements of a Pattern Piece

A pattern piece block is formed by a set of graphical entities, Piece System Text and annotation. In the following paragraphs each of the graphical elements is discussed in detail by describing layer, function, appearance, DXF element type and special requirements.

The order of discussion of does not necessarily follow the sequence of layers as the numbering is largely a straightforward carry-over from the old AAMA standard which ASTM replaces. Instead, this document attempts to follow the logical method of pattern piece construction.

- Lines and Polylines

ASTM relies on basic graphical DXF elements to transfer pattern information.

The simplest element is a straight line between 2 points (vertices). Lines are used to show the direction of fabric grain (grain line), symmetry (mirror line), or to clarify a construction (internal draw lines), etc.

A polyline is a single element which consists of unstructured combination of connected line segments and arcs. A polyline can be open at both ends or closed to form a shape.

The outline of a pattern piece must always be a closed polyline. Internal draw lines, internal cut lines and sew lines can be a combination of lines and open or closed polylines.

The difference between an open or closed polyline is defined mathematically, not by what you see on the computer screen. For a shape to be closed, the coordinates of start and end point must be an exact match. Interrogation of the polyline characteristics is the only reliable way to find out.

A line is easy to identify. They can be selected and manipulated independent of other elements. When pointing to a line on the screen, most computer systems will confirm the selection in a different color or pattern and highlight the start, midpoint and end vertex. When selecting a polyline, the system will highlight the full string of lines and arcs that make up the polyline. The action will highlight all of the vertices at the connection between segments. In its simplest form, a polyline that consists of one straight segment can be confused with a line. The difference can usually be spotted by a lack of midpoint vertex or seen in an interrogation window.

- Points.

A multitude of points characterize an ePattern. Points are graphical elements that are part of a pattern piece or block. They are placed on different layers dependent on their purpose.

Points are DXF elements at coordinates XYZ. A point is without physical dimension; they stand alone and are not part of any line. The point shows as a cross. The size of the display of the cross is independent of the pattern; it is set in pixels relative to the view window.

Tip: In digital pattern making, a cross is the most common symbol for a DXF point. Some systems have the function to change the appearance of a point to another symbol (circle, square, etc).

Points are used for different functions on different layers. ASTM recognizes points for the purpose of:

		Layer	Function
•	Turn points	Layer 2	Turn points for piece boundary (1), internal lines (8), internal cutouts (11), sew lines (14)
•	Curve points	Layer 3	Curve points for piece boundary (1), internal lines (8), internal cutouts (11), sew lines (14)
•	Notches	Layer 4	Slit and V-notches definition
•	Grading	Layer 5	Grade reference location
•	Stripes	Layer 9	Stripe match points for alignment (optional)
•	Plaids	Layer 10	Plaid match points for alignment (optional)
•	Drill holes	Layer 13	Punch marker location and definition
•	T-notch	Layer 80	T-notch definition
•	Castle-notch	Layer 81	Castle-notch definition
•	Check-notch	Layer 82	Check-notch definition
•	U-notch	Layer 83	U-notch definition

The use of points is addressed in the relevant paragraphs. Grading points are covered in a separate section on grading and grading rules.

- Blocks

ASTM uses the DXF block structure to group all elements of a pattern piece. In DXF terms, a block is a named assembly of information that consists of individual graphical and textual entities such as lines, polylines, points and text. As a result a pattern piece can be manipulated as a whole.

The individual entities which make up a block maintain their own pre-defined layer, line-style, color, etc. The descriptive and behavioral parameters of the pattern piece are defined in the piece system ext. This text is included in the block. There are no ASTM requirements for color, line style, line weight or text size and font.

Note: The use of blocks within blocks is not allowed.

Tip: To change the contents of a block with a generic CAD system, it must be exploded (also called un-grouped, dropped), and re-grouped when the change is complete.

- Functional Elements of an ASTM ePattern

In the ASTM standard, patterns are defined by rules for Style System Text and DXF Blocks. The Style System Text provides information about the pattern as a whole, while the blocks make it possible to identify individual pattern pieces for manipulation, grading, etc.

- Style System Text

ASTM defines the descriptive text that is valid to all pieces in a pattern as "Style System Text". Style System Text (SST) is multiline text placed on layer 1. The SST is mandatory. It is not to be confused with piece system text or general annotation. The text follows a precise syntax which is case sensitive in a mix of upper and lower case characters in ASCII-7[3] (standard keyboard). Style System Text can be viewed on layer 1 of sample ASTM files.

Layer 1	Syntax: Identifier: <Value>	Remarks
Style name	Syntax: Style Name: <string>	identifier and value required
Creation date and time	Syntax: Creation Date: <string>	dd-mm-yyyy
Creation date and time	Syntax: Creation Time: <string>	hh:mm
Author	Syntax: Author: <vendor name>;<application>;<release #>	
Sample size	Syntax: Sample Size: <string>	string not required
Grade rule table name	Syntax: Grade Rule Table: <string>	string not required
Units	Syntax: Units: <METRIC / ENGLISH>	METRIC: mm 2 decimals, ENGLISH: inches 4
Standard version	Syntax: ASTM/D13 Proposal 1 Version: XX	
Curve tolerance	Syntax: Curve Tolerance: <float>	string not required

Note: Curve Tolerance identifier and value determine accuracy in units at turn and curve points during import.
Style Name is for practical reasons limited to 20 characters. Truncation is imposed by the Gerber system.

Example of Style System Text:

> Style Name: Jacket Man 123456
> Creation Date: 01-01-2011
> Creation Time: 12:00
> Author: DH Patterns and Fit;WisePatterns;12.7
> Sample Size: L
> Grade Rule Table:
> Units: METRIC
> ASTM/D13 Proposal 1 Version: XX
> Curve Tolerance: 0.25

Tip: When viewing an unknown pattern, the Style System Text provides immediate file and origin information. The SST is usually found at the pattern file coordinates X=0, Y=0.

- Pattern Pieces or Blocks

In the ASTM standard, pattern pieces are defined as DXF blocks. This makes it possible to identify a pattern piece as a whole for manipulation, grading, etc.

- Piece System Text

Like Style System Text to the full pattern, Piece System Text defines what is valid for each pattern piece. Piece System Text (PST) is part of the block. PST is multiline text placed on layer 1. The PST is mandatory. It is not to be confused with style system text or general annotation.

The text follows a precise syntax which is case sensitive in a mix of upper and lower case characters in ASCII-7 (standard international keyboard).

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[3]   ASCII - American Standard Code for Information Interchange. ASCII 7-bit code contains the characters of the international keyboard, control characters excluded.

Piece System Text can be viewed on layer 1 of sample ASTM files.

Layer 1	Syntax: Identifier: <Value>	Remarks
Piece name	Syntax: Piece Name: <string>	Unique name or number of piece
Quantity	Syntax: Quantity: <R,L>	# Right pieces, # Left pieces
Rotation	Syntax: Rotation: <0..360>	May rotate between 0 and 360 degrees
Flip	Syntax: Flip: <X/Y>	Flip horizontal X, vertical Y
Tilt	Syntax: Tilt: <+/-0..90>	May tilt + or - between 0 and 90 degrees
Fold	Syntax: Fold: <Y/N>	May be placed Y or N on fold of tubular fabric
Material	Syntax: Material: <string>	String is the name of the material for cutting

Note: Piece Name is for practical reasons limited to 20 characters. Truncation is imposed by the Gerber system.

Tip: When viewing an unknown pattern, the Piece System Text provides primary piece instructions.

Example of Piece System Text:

Piece Name: Pocket
Quantity: 1,1
Rotation: 0
Flip: Y
Tilt: 1
Fold: N
Material: Main fabric

- Boundary

The boundary of a pattern piece is placed on layer 1. The boundary, also referred to as cut line, describes the outside edge of the piece. The appearance is that of a closed shape. It is constructed by a closed polyline.

A pattern piece can be presented with or without seam allowance. When presented "without seam allowance" the boundary on layer 1 is formed by the exposed outline of the piece as fabricated. When presented "with seam allowance", the boundary is formed by the allowance. If that case, the exposed fabric outline should be placed on layer 14 for sew lines.

- Sew Lines

Sew lines are placed on layer 14. A sew line indicates where to place stitches. The appearance can vary from a closed shape to a combination of lines.

Often sew lines represent the boundary of a pattern piece as if drawn "without seam allowance". If this is the case, the sew line can become the boundary of the piece "without seam allowance". The sew line can be copied or moved to layer 1 but has to follow the rules of a boundary line, i.e. converted to a closed polyline. Copying the sew line to layer 1 is the same as applying a seam allowance of zero.

Tip: When creating a pattern with a generic CAD system or when the import system is unknown, adding seam allowance may complicate import. Placing the boundary "without seam allowance" on layer 1 may be a good alternative. In that case, layer 14, may still host non-boundary sew lines and optionally a copy of the boundary on layer 1.

If a piece is to be mirrored, but one or more of the sew lines is to be excluded, as is the case in asymmetrical appearance, the line must carry the text attribute NM for "Not Mirrored" at the start point and layer of the element. This is done by placing the text string NM at the XY coordinates of the first vertex of the (poly-) line or point element.

- Internal Lines

Internal lines are placed on layer 8. Internal lines are auxiliary lines to assist in the construction or detailing of a garment; think of logo or pocket placement, connection of pieces, folds, etc. They are not cut. The appearance can vary from a closed shape to a combination of lines. Internal lines are

placed inside the piece boundary and are not part of the boundary. Internal lines are not cut, possibly plotted.

If a piece is to be mirrored, but one or more of the internal lines is to be excluded, as is the case in asymmetrical appearance, the line must carry the text attribute NM for "Not Mirrored" at the start point and layer of the element. This is done by placing the text string NM at the XY coordinates of the first vertex of the (poly) line or point element.

- Internal Cutouts

Internal cutouts are placed on layer 11. Internal cutouts are lines, shapes, open or closed polylines inside - and not-connected to - the piece boundary and indicate where to cut fabric. An internal dart or ventilation opening is considered an internal cutout, not a (slit-) dart. For details, see the paragraph on "Notches". The lines for internal cutouts should not be confused with internal (draw) lines on layer 8.

If a piece is to be mirrored, but one or more of the internal cutouts is not, as is the case in asymmetrical appearance, the cutout must carry the text attribute NM for "Not Mirrored" at the start point of the element. This is done by placing the text string NM at the XY coordinates and layer of the first vertex of the (poly-) line or point element.

- Mirror Line

A mirror line is placed on layer 6. The presence of a mirror line indicates that a piece has to be mirrored to arrive at the full pattern piece. The mirror line is the line of symmetry. It is a straight DXF line segment which is placed over the appropriate (straight) polyline segment – from vertex to vertex - of the boundary (layer 1) of the piece.

Tip: Visually, the presence of a mirror line may not be obvious as it overlaps the boundary polyline on layer 1.
        The use of mirror lines can be avoided by using a full piece representation. This also eliminates the need for excluding asymmetrical objects with the "NM" text string.

- Grain Line

The grain line is placed on layer 7. The grain line indicates the direction of the fabric grain. The grain line is always parallel to the selvage (edge) of the fabric. It is a straight DXF line segment. The line may be freely placed within the boundary or coincide with the placement of the mirror line.

Tip: Visually, the presence of a grain line may not be obvious as it may overlap the mirror line on layer 6.

- Stripe Reference Line and Stripe Match Points

The stripe reference line is placed on layer 9. The stripe line is used to indicate the direction of stripes in the fabric. It is a straight DXF line segment. The line may be freely placed within the boundary or coincide with the placement of the mirror line, grain line or plaid line. A stripe reference line may be placed outside the boundary as long as it is included in the piece block.

Note: Within a block, multiple stripe reference lines may exist. Optionally, the lines may carry a text number at the start point of the element. This is done by placing the text string <number> at the XY coordinates and layer of the first vertex of the line element.

Stripe match points on layer 9 may be used to indicate the alignment points of stripes. The use of stripe match points is optional.

Note: The Y-coordinate of the DXF point is used for the stripe alignment. The X-coordinate is not significant.

Tip: Visually, the presence of a stripe line or match point may not be obvious as it may overlap with other lines or points. The Y-coordinate is significant for matching.

- Plaid Reference Line and Plaid Match Points

The plaid reference line is placed on layer 10. The plaid line is used to indicate the direction of a chequered pattern in the fabric. It is a straight DXF line segment. The line may be freely placed within the boundary or coincide with the placement of the mirror line, grain line or plaid line. The use of plaid match points (see below) for plaid alignment is optional.

Note: Within a block, multiple plaid reference lines may exist. Optionally, the lines may carry a text number at the start point of the element. This is done by placing the text string <number> at the XY coordinates and layer of the first vertex of the line element.

Tip: Visually, the presence of a plaid line or match point may not be obvious as it may overlap with other lines or points.

Plaid match points on layer 10 may be used to indicate the alignment points of chequers. The use of plaid match points is optional. Plaid match points can be used in combination with stripe match points.

Note: The X-coordinate of the DXF point is used for the plaid alignment. The y-coordinate is not significant.

- Drill Holes and Points

Drill holes are placed on layer 13. Drill holes are used to indicate the location of a punch hole, buttonhole, pocket placement, etc. The coordinates of a drill hole is defined by a DXF point element. The point shows as a cross. The size of the display of the cross is independent of the pattern; it is set in pixels relative to the view window.

Visually, the presence of a drill hole may not be obvious as it may overlap with other points or may be placed at an intersection of lines.

If a piece is to be mirrored but one or more of the drill holes is not, as is the case in asymmetrical appearance, the point must carry the text attribute NM for "Not Mirrored" at the XY coordinates and layer of the point. This is done by placing the text string NM at the XY coordinates of the location of the point element.

Note: Optional drill information. A text string with an integer number is optional to indicate drill type. This is done by placing a text string <integer> at the XY coordinates on the layer of the point element. The Z-coordinate of the point can be edited to define the diameter of the punch hole in units (mm (2 decimals) or inches (4 decimals)).
In pattern making, a cross is the most common symbol for a DXF point. Some systems have the function to change the appearance of a point to another symbol (circle, square, etc).

Tip: Usually, base patterns and fit blocks do not carry detailed information for production. Drill holes might have been replaced by internal draw lines. In that case, the placement of drill holes is left to the production site or producer of the detailed pattern.
Annotation can be used to provide drill hole diameter information.

- Notches

Notches are cuts in the fabric from the boundary line inwards (depth). Notches are used to articulate a shape in the fabric. In that case, the notches are also referred to as darts. Often small slit or V-notches are used to create a mark to show how to line up 2 pieces of material to be sewn together.

The ASTM standard recognizes 6 different styles:

- Slit-notch   Split with zero width at the boundary and zero width at the depth.
- V-notch   Symmetrical V-shaped notch with a width at the boundary and zero width at the depth.
- T-notch   Split with zero width at the boundary and symmetrical "T" width at the depth.
- Castle-notch   Rectangular shaped notch with a width at the boundary and equal width at the depth.
- Check-notch   Asymmetrical check-mark shaped notch with a width at the boundary and zero width at the depth.
- U-notch   Shaped as a castle notch but with a semicircle reaching the depth.

There are 3 methods to create notches (darts):

a) Drawn as an internal draw line on layer 8. Lines that make up the notch are not part of the boundary;
b) Drawn as a cutout in the closed polyline boundary on layer 1. The notch is part of the boundary;
c) Specified by notch base points according to ASTM definitions on specified layers.

If a notch type and its dimensions and orientation are defined by means of DXF points, the placement of the points is bound by ASTM rules. This method is usually reserved for advanced pattern design systems.

- Slit-notch   Layer 4
- V-notch   Layer 4
- T-notch   Layer 80
- Castle-notch   Layer 81
- Check-notch   Layer 82
- U-notch   Layer 83

The dimensions and orientation of the notch is carried by the DXF point(s) which define the coordinates of the notch.

- Slit-notch   Point on boundary, angle counter-clockwise from X-axis, depth. No width.
- V-notch   Point at midpoint of width on boundary, angle counter-clockwise from X-axis, depth, width.
- T-notch   Point at depth, angle counter-clockwise from X-axis, depth, width at depth.
- Castle-notch   Point at midpoint on boundary, angle counter-clockwise from X-axis, depth, width.
- Check-notch   Point on boundary, angle + (clockwise opening) or - (counter-clockwise) from X-axis, depth, width.
- U-notch   Point at midpoint on boundary, angle counter-clockwise from X-axis, depth, width.

Note: For specifications of notch attributes associated with the DXF point element, see ASTM standard D6673 and the DXF Reference Guide. For expert evaluation:
- DXF group 30 (Z-coordinate) specifies the depth from base point in the direction of the angle.
- DXF group 39 (thickness) specifies the width at the boundary.
- DXF group 50 specifies the angle counter clockwise relative to the X-axis.
- The shape is defined by the layer on which the notch point is placed.

Tip: When creating notches with a generic CAD system or when the import system is unknown, methods a) and b) are a good alternative for the advanced ASTM method of using points.

- Annotation Text.

Annotation in addition to Piece System Text and Style System text is placed on layer 15. It must be included in the block definition for the pattern piece. Annotation is used to clarify intentions and to communicate instructions to the producers. Examples are zipper line, fold, mirror line, box plead, etc.

Note: Annotation cannot be used as to substitute ASTM instructions. For example the text "mirror line" on layer 15 does not eliminate the need for the mirror line on layer 6.
Annotation text can be in single or multi-line format. The text is not case-sensitive. The backslash character "\" is used to indicate a line break or carriage return.

Tip: It is good practice to place the text selection point inside the boundary.
For readability, the text height for annotation should be 3,5 or 5mm in height.

- Turn Points

Turn points indicate a sudden change of direction in the piece boundary (1), internal lines (8), internal cutouts (11) and sew lines (14). Turn points must be placed on layer 2, irrespective of the layer of the graphics they refer to. Between two turn points, the pattern lines can be straight or curved.

Turn points are used by pattern design systems to verify that the quality of import of the graphics of pattern pieces is within the tolerance specified in the style system text.

Note: If notches are drawn (see Notches, method b), rather than defined by points (method c), turn points defining the notch must be placed (2 points for a slit-notch, 3 points for a V-notch, etc).
If a line coming into the turn point is smoothed, as is the case with curves, turn points mark the end of smoothing.

Tip: When using a generic CAD system to create a pattern, it is good practice to place turn points, just before creating a piece block, as the "finishing touch". When selecting a corner to place a turn point, make sure that vertex selection is active. If two pattern pieces connect, the number and location of turn points should match for the best result.

- Curve Points

Curve points indicate a change of direction in the contour of the piece boundary (1), internal lines (8), and internal cutouts (11) and sew lines (14). Curve points must be placed on layer 3, irrespective of the layer of the graphics they refer to. There are exceptions but typically curved pattern lines run from turn point to turn point.

Curve points are used by pattern design systems to verify that the quality of import of the graphics of pattern pieces is within the tolerance specified in the style system text. The curve points provide input for curve interpolation algorithms embedded in pattern design software. The curve that is produced runs, with tolerance, through the curve points.

Tip: When using a generic CAD system to create a pattern, it is good practice to place curve points, the just before creating a piece block, as the "finishing touch". When placing a point on a curve, ascertain that curve selection is active. If two pattern pieces connect, the number and location of curve points should match for the best result.

- Curve Quality Validation

Comparing curves in the import system with those created in the export system is called validation. Validation is a quality assurance process that is aimed at establishing evidence to a high degree of certainty that the converting system accomplishes its intended requirements within the specified tolerance.

The pattern maker decides on the curves to be used in a design. It is also the originator, who places curve and turn points as fixed positions through which a contour must pass. By specifying sufficient points and stipulating a tolerance, he restricts the import system downstream in making changes to the original pattern.

During conversion of a pattern, the importing software's curve algorithm will reconstruct the contours as accurate as possible. The points and tolerance in the export system guide the automatic regeneration. To do so, sufficient curve points should be defined in the origination system to keep the shape of the regenerated curve within tolerance. It is good practice to add points near the depth of the original curve to prevent "overshoots" or "undershoots" of the new curvature. If omitted, it may lead to undesired bulges.

Alternatively, if no curve algorithm is available, the points on the quality validation curves can be used directly to re-create the originals as polylines.

Note: Curves that are created by a curve algorithm may show intermediate points on the curved contour as a result of a smoothing process

Tip: If there is no software function available to generate quality validation curves in the export system, or the import system lacks an automatic creation and validation utility, a simple "copy & paste" between layers or files may substitute the deficiency.

ASTM standard D6673 defines 4 different quality validation curves. Types exist for the purpose of validation of:

- Piece boundary;
- Internal Lines;
- Internal Cutouts;
- Sew Lines.

The validation curves are separated by purpose on different layers:

Layer	Purpose	Remarks
84	Piece boundary quality validation curves	ASTM: Mandatory system information for polyline(s) layer 1
85	Internal lines quality validation curves	ASTM: Mandatory system information for polyline(s) layer 8
86	Internal cutouts quality validation curves	ASTM: Mandatory system information for polyline(s) layer 11
87	Sew lines quality validation curves	ASTM: Mandatory system information for polyline(s) layer 14

Note: The validation curve must fall with the specified tolerance of the original curve. Two consecutive vertices define a polyline segment.

Tip: The tolerance specifies the perpendicular offset of a software regenerated curve from the previous version. Only the first time that a curve is transferred, the tolerance is applied to the original curve. With any subsequent conversion the tolerance will increase; translations will stack tolerance upon tolerance each time a curve is regenerated. For this reason the tolerance is usually set very small; often in 10th of a mm. The tolerance is specified in the style system text on layer 1.

The layers for quality validation curves (84, 85, 86 and 87) is mandatory. The layers must contain the same quantity of polylines, including, but not limited to, all of the vertices, and in the same order. This implies that as a minimum, a quality validation curve is a direct copy of the polyline which is referenced for validation. In addition, the quality validation curve can contain intermediate vertices. Those vertices must be within tolerance as defined in the style system text.

Quality validation curves are defined with the DXF polyline element. The curve for boundary validation on layer 84 must be a closed polyline.

- Grading

Grading is the method of creating multiple sizes from a sample size. The result is a graded nest.

Grading relies on the presence of:

- Grade reference lines (mandatory);
- Alternate grade reference lines (optional);
- Grade points;
- Grade rule table;
- Style system text entry for the grade rule table name;
- A software program for grading.

- Grade Reference Line and Alternate Grade Reference Lines.

Grade lines are only needed for patterns that will be graded. The grade reference line is a straight line segment which specifies the X-axis for grading a pattern piece. The grade reference line is place on layer 5. The use of the grade reference line is optional; if omitted, grading will follow the X-axis of the DXF coordinate system (horizontal).

Alternate grade reference lines are optional. The alternate grade reference line specifies which orientation to use for the "X" axis of a grade rule. Alternate grade lines must be numbered with a text number. This is done by placing the text string <number> at the XY coordinates of the start point of the line element.

Note: The orientation of a grade rule will be oriented to the grade reference line as the X-axis unless an alternate grade reference line is specified.

Tip: When grading, DH advices the use of grade reference lines. If omitted, the X-axis will not follow rotation of the pattern.

- Grade Points

Grade points are mandatory when grading a pattern. Grade points indicate which spots of a pattern piece to "stretch" or "shrink" to arrive at a larger or smaller size(s) than the sample size of the pattern. Spots between the grade points will be scaled proportionally. Grade points are found on a many different layers.

Each grade point is uniquely identified in the pattern file with a number; the grade rule ID. The same ID is repeated in a grading table which specifies the offset in X and Y direction from the sample reference size for each grade point in units. For this purpose, the grade reference line, or optional alternate grade reference line, defines the orientation of the coordinate system that is to be used. The offset is known as the "growth delta". Fixed points and notches (defined with points, method c) have a "growth delta" of zero.

Identification of the grade point is done by placing the text "# <ID number>" at the XY coordinates on the layer of the point element. The grade rule ID is found at corresponding coordinates on layer 5 or layer 4 for notches. A point without ID is graded proportional to its neighboring grade points, otherwise zero.

Note: The common syntax for the mandatory ID of a grade point is <string1>. However, ASTM supports alternate grade ID's with the syntax <string 1>, <string2>, where <string 1> is the mandatory grade ID and <string2> optional for alternate grade ID.

Grade points may be associated with turn points (layer 2), curve points (3), mirror line endpoints (6), drill holes (13) and points on quality validation curves (84, 85, 86, 87). Because turn and curve points apply to the piece boundary (1), internal lines (8), internal cutouts (11) and sew lines (14), anything can be graded. To include points actively in the grading process, they only need to be assigned a grade rule ID at the corresponding coordinates on layer 5 or layer 4 if related to notches.

- Grading Rule Table

Automated grading is controlled by an external grading file which contains the rules. The name of the grading table to be applied is defined in the style system text. The main body of the table is made up by the "growth delta" for each grade point.

The header of the grading table contains information about origin, units, and sizes. Content of the rule table follows a specific order and syntax. For readability, text is written in uppercase characters.

The common filename extension for the grading table is .RUL. The .RUL file is an ASCII file which can be opened with a text editor such as Microsoft WordPad.

Tip: The sample size is found in the style system text.
          Sample size name found in style system text.
          The units are found in the style system text.
          Metric uses mm with a 2 decimal precision, English in inches with a 4 decimal precision.

Grading rules in *filename*.RUL	Syntax: Identifier: <Value>	Remarks
Syntax: ASTM/D13 PROPOSAL 1 VERSION:xxx		xxx is version number of standard document
Syntax: AUTHOR: author_		name
Syntax: CREATION DATE: dd-mm-yyyy		
Syntax: CREATION TIME: hh:mm		
Syntax: UNITS: ENGLISH / METRIC		METRIC: mm 2 decimals, ENGLISH: inches 4 decimals
Syntax: UNIT FORMAT: <string>		optional. Fractional denominator for English units in table
Syntax: GRADE RULE TABLE: rule table_name		
Syntax: SAMPLE SIZE: size		name
Syntax: NUMBER OF SIZES: n		
Syntax: SIZE LIST: size_name1 size_name2…size_name_n large		same as sample size size_name in rule order from small to includes sample size. size names can be alphabetical, numerical or alphanumerical
Optional information		not case sensitive
Syntax: RULE:		start of every rule

Syntax: RULE: <sep>type<sep>grade_rule_identifier<sep>size_1_growths<sep>size_2_growths … 0,0 …_n-growths

<sep>	separator such as comma, space, tab, newline, CR/LF
type	type equals word "DELTA"
grade_rule_identifier	positive or negative integer
size_n_growths	size growths for grade point in decimal units in order of size list.
	values for X and Y are 0 for sample size.
	The orientation of a grade rule will be oriented to the grade reference line as the X-axis unless an alternate grade reference line is specified.

Example of a grading table:

Header	ASTM/D13Proposal 1 Version: D 6673-04
	AUTHOR: GERBER TECHNOLOGY
	PRODUCT: ACCUMARK
	VERSION: 8.4.1
	CREATION DATE: 26-01-2011
	CREATION TIME: 13:59
	UNITS: METRIC
	GRADE RULE TABLE: B9000
	NUMBER OF SIZES: 8
	SIZE LIST: 34 36 38 40 42 44 46 48
	SAMPLE SIZE: 36
Rules	RULE: DELTA 1
X,Y-34 X,Y-36 X,Y-38 X,Y-40	0.00, 0.00 0.00, 0.00 0.00, 0.00 0.00, 0.00
X,Y-42 X,Y-44 X,Y-46 X,Y-48	0.00, 0.00 0.00, 0.00 0.00, 0.00 0.00, 0.00
	RULE: DELTA 2
0.00, 0.00 for sample size 36	7.00, 0.00 0.00, 0.00 -7.00, 0.00 -14.00, 0.00
X,Y measured from sample size	-20.00, 0.00 -25.98, 0.00 -31.98, 0.00 -37.98, 0.00
	RULE: DELTA 3
	-3.00, 0.00 0.00, 0.00 3.00, 0.00 6.00, 0.00
	10.00, 0.00 14.00, 0.00 17.98, 0.00 21.98, 0.00
	RULE: …
Etcetera	
	RULE: DELTA 3143
	0.00, 0.00 0.00, 0.00 0.00, 0.00 0.00, 0.00
	20.00, 0.00 20.00, 0.00 20.00, 0.00 20.00, 0.00
	END

- Graded Nests

A graded nest is a graphical file(s) that is created by grading software. In a graded nest, multiple blocks with the same piece name form a collection of different sizes within a DXF file. Blocks can be placed freely or stacked on the grade reference line. The order of the blocks follows the size sequence. Each block has a grade reference line. Blocks repeat all points and attribute definitions (ATTDEF) in the same order, quantity and layer as sample size.

Graded pieces must have Piece System Text in their block. Sample size blocks require all piece system text.

Note: Graded size blocks do not include turn points (2), curve points (3), notches (4, 80, 81, 82, 83), and alternate grade lines (5).

Tip: Grading growth can be viewed by placing the blocks that belong to the same piece on top of each other so that the grading lines are coincident.

- Graded Nest Piece System Text

Graded pieces are identified in the graded nests by piece system text which contains name, size and quantity (optional). The text follows a precise syntax which is case sensitive in a mix of upper and lower case characters. Graded nest piece system text can be viewed on layer 1.

Layer 1	Syntax: Identifier: <Value>	Remarks
Piece name	Syntax: Piece Name: <string>	same name as for the sample piece.
Size name	Syntax: Size Name: <string>	size name as in the size list of the grading rule
table		
Syntax: Quantity: <R,L>	# Right pieces, # Left pieces	optional, example: 3,2

- Creating a "Minimum Requirements" ASTM file

A "minimum requirements" ASTM file contains the bare minimum of information to be recognized as compliant with ASTM D6673.

The "Minimum Requirements" have been defined for the purpose of undemanding file conversion and base pattern creation with a generic CAD system. In its simplest form, advanced specifications are kept away from, at the expense of having functions downstream readily available.

The "Minimum Requirements" file is based on DXF Version R13. All information for each pattern piece has to be grouped as a DXF block. The DXF file contains:

Function	DXF element

- Style system text on layer 1 — multiline text

- Blocks for each pattern piece; each block contains: DXF Block
  - o Piece system text on layer 1 — multi-line text
  - o Boundary without seam allowance on layer 1 — closed polyline
  - o Turn points on layer 2 — points
  - o Curve points on layer 3 — points
  - o Grain line on layer 7 — line
  - o Internal cutouts, as applicable, on layer 11 — line(s) and/or (closed) polyline(s)
  and
  - o Quality Validation Curves — line(s) and/or (closed) polyline(s)
    - ▪ Validation curves on layers 84-87 are a copy of the original.

- Optional for each pattern piece block:
  - o Sew lines on layer 14 — line(s) and/or (closed) polyline(s)
  - o Internal lines on layer 8 — line(s) and/or (closed) polyline(s)
  - o Stripe reference line on layer 9 — line and optional match point
  - o Plaid reference line on layer 10 — line and optional match point
  - o Drill holes, without attributes, on layer 13 — points
  - o Annotation text on layer 15 — single or multi-line text

Excluded from the "Minimum Requirements" are:

- Seam allowance;
- Notches. Notches are drawn as part of the boundary or as an internal draw line. It eliminates the use of points and specifications for type, angle, width and depth;
- Grading. Grading is a specialized function. Without grading, many requirements are eliminated;
- Mirroring. Pieces are drawn as a whole. This eliminates the need for mirror lines and the use of the "NM" attribute for non-symmetrical elements;
- Drill holes with type and diameter attributes.

- Restrictions of ASTM D6673-10

The following functions are not supported by ASTM D6673:

- Numerical cutting instructions
- Plotter instructions
- Complete marker-laying
- Spreading information
- Product specifications
- Curve interpolation algorithm
- Curve Quality Validation for Graded Piece Boundaries

When grade rules are applied to pieces with a given sample size, the quality of the resulting graded piece boundaries in the importing system cannot be validated to those of the exporting system.

Note: The standard does not define a common curve interpolation algorithm. It cannot mathematically validate curve quality in the export system. Under such circumstances, the quality of the graded piece polylines can only be validated using a graded nest for the size range.

ASTM 6673 is intended for two-dimensional representation of pattern pieces. It does not define the relationship between pattern pieces or 2D and 3D geometries.

DH Patterns and Fit, Oslo, 2011
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