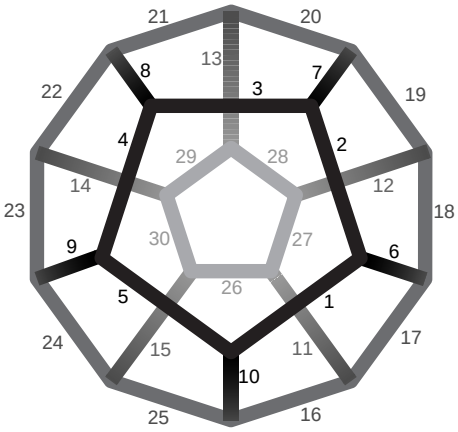
4. VISIOCELL

4.1. The cellular structure of polyurethane foams:

A polyurethane foam is a tri-dimensional structure of interconnected cells. The cell is the basic unit of the foam. The number of cells varies from 20 million up to 20 billion per cubic metre of foam.

The cell presents the shape of a dodecahedron (see figure) made of 30 struts and 12 pentagonal windows. The window is the surface bounded by 5 struts (for example: struts 1, 6, 17, 16, 10).



The strut is the solid material (the polyurethane elastomer) of the foam. The rest of the foam is filled by air.

The properties of the foam depend on the properties of the individual cells, namely:

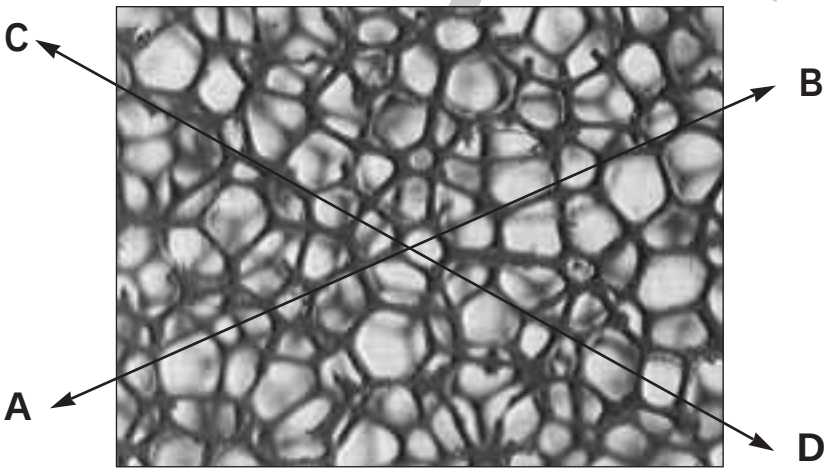
1. The chemical nature of the polyurethane elastomer.
2. The thickness of the struts.
3. The volume of the cell.
4. The presence of residual membranes on the window.
5. The anisotropy of the cell.

The influence of these parameters on the foam properties is fully described in the brochure “Technical Information on Technical Foams”.

4.2 “PPI”: an obsolete unit

The dimension of the cell is a key parameter of the properties of the foam. For many applications, the performance of the foam is directly influenced by the cell size.

For more than 25 years, the cellular structure and the cell size have been defined by the unit “PPI”: pores per inch. The number of pores is counted on a standard length of 1 inch.



This unit can be a little confusing and subjective:

- The “pore” has never been clearly defined. It can be a window or the full section of the cells.
- The size of pore, if it is a window, depends on the vision angle; if it is a cell section, it depends on the location of the section (top, middle or bottom).
- The dispersion of the results is very high. Counting from A to B or from C to D (see picture) can lead to an important difference.
- A cell is a “VOLUME” while the “PPI” is the reduction of this volume to a linear counting of a non-defined unit (the pore).

It is therefore not surprising that the “PPI” has never been recognised as an international unit, neither the methods (direct counting, pressure drop, 3 points methods,...) to evaluate it. It is not surprising too, that each foamer has its own reference scale, and that a foam defined as 80 ppi by one foamer could be defined as 110 PPI by an other, leading to confusing situations in the specifications.

4.3. A new concept

The PPI unit is not accurate enough to satisfy the specification requirements of the new "high tech" developments and application fields of technical foams. A better control of cell size of the foam during the foaming process can therefore only be achieved if the method to measure it is more accurate. This is the background of the new method, "Visiocell", introduced by Recticel.

The development of the Visiocell method is based on 4 criteria:

- Accuracy of at least 1.5 to 2 %.
- Applicable for any foam with regular structure: non reticulated, reticulated, any colour,...
- Cheap equipment to measure the cell diameter.
- Fast and operator independent.

4.4. Schort description

1. Preparation of a horizontally cut foam sample (perpendicular to the foaming rise direction).

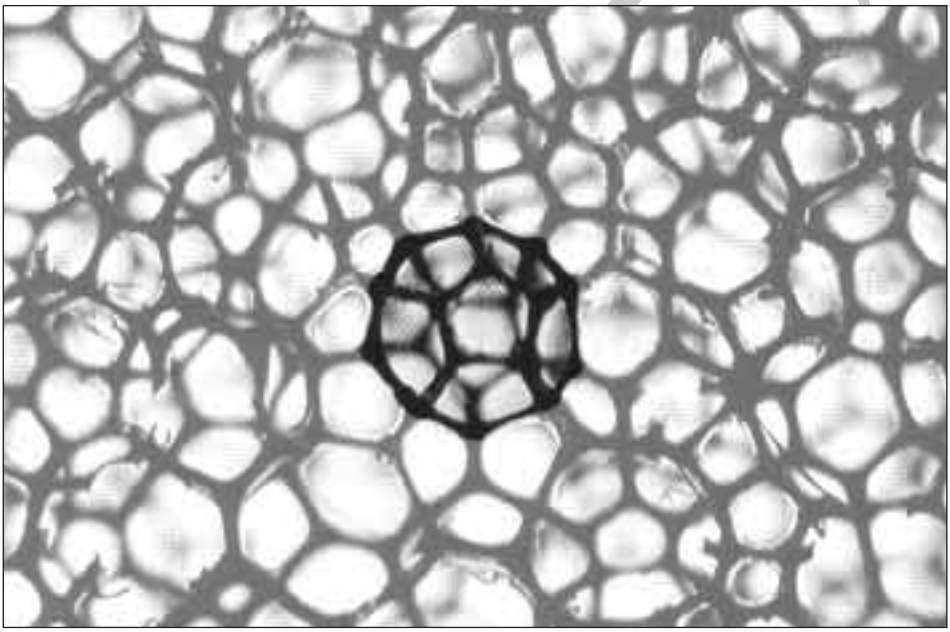
2. Printing a picture with a magnifying camera.

3. Selection of a representative cell showing the maximum diameter. Such a cell is identified by its circular shape made of ten struts and by one or two small pentagon(s) in its centre. These pentagons are the underside and/or upperside window(s).

4. Measurements of the cell diameter by superimposing calibrated rings, printed on transparent paper, on the selected cell.

4.5. Example

A typical picture of a product "Bulpren S" with a cell diameter of approximately 1000 micron is represented below:



The cell in the center of the picture is selected and identified in "bold". This cell presents a circular shape and also shows both small pentagons in its center (windows on upper- and underside).

By superimposing the slide enclosed in the brochure on this cell, one can select the ring of which the size is the closest to the cell.
In the worst case, one can be unsure between 2 rings; the difference of the diameter between 2 rings is maximum 4 %. It means that the cell diameter is measured with an accuracy of approximately 2 % (in the case of this Bulpren S, the accuracy is approximately 20 micron).

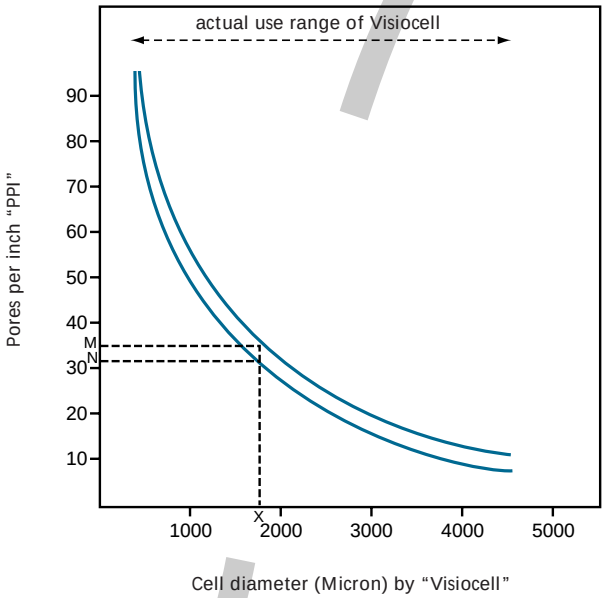
The cell diameter is the average between the internal and external circle of the ring!

It should be noted that the picture and the rings as printed in this example are not calibrated. They are only published to understand the concept of the method. The reason of this non-calibration is explained further.

4.6. Relation between cell diameter by Visiocell and PPI

It is impossible to define or calculate the accurate correlation between the cell diameter by the Visiocell method and the PPI scale because the measurement of the PPI itself is inaccurate.

The graph below gives only a rough indication between the scales:



The function (type y = 1/x) is represented by a double line to express the non-accurate definition of PPI. For a given cell diameter in micron, for example the value X, the PPI may vary from N to M.

4.7. Narrower specifications

As explained above the Visicocell method is very quick and accurate. This allows consequently to reduce the dispersion of the cell diameter within the foam, especially from run to run. It therefore enables Recticel to produce foam within a narrower range of the specifications and to achieve extremely accurate foaming for "high tech" application fields. New technologies have been developed to reach such targets.

Let's take two extreme examples:

Coarse cell: Bulpren S 20

According to the previous ppi scale, the specifications of Bulpren S 20 were 15 to 25 PPI. This PPI range corresponds to a cell diameter (according the Visiocell method) between 3400 and 2200 micron. It means a difference between the maximum and minimum value of 1200 micron on an average value of 2700, i.e. 1200/2700 = 44 %.

With the Visiocell method, one can produce the same standard foam within the range of 3000 and 2400 micron. The range of specifications is 600 micron, i.e. 600/2700 = 23 % of the average value.

It is even possible to further reduce the range of specifications for "high tech" application fields to 400 micron, i.e. 14 % of the average value.

Fine cell: Bulpren S 75

We obtain similar improvements for fine cell structures.

Following PPI scale:
- PPI range: 65-80
- corresponding cell diameter: 750 - 520 micron
- range of specifications: 170 micron on 580 micron average, i.e. 30 %

With Visiocell, for standard foam grade:
- cell diameter range: 640 - 520 micron
- range of specifications: 120 micron on 580 micron average: 20 %

With Visiocell, for high tech foam grade:
- cell diameter range: 620 - 540
- range of specifications: 80 micron on 580 micron average: 14 %

4.8. New identification of reticulated foams

Up to now, most of the reticulated foams were identified by the PPI value. For example, Bulpren S 20 is a standard polyester of 20 PPI.

Since the ppi scale will not be used anymore, we have defined a new denomination code to identify the reticulated foams introducing the cell diameter concept according to the Visiocell method. From now, we will also include in the denomination the density of the foam.

The reticulated foams will therefore be identified by:

Family Name	x	x	y	y	y

- the family name refers to the nature of the formulation and the basic properties of the material, as for example Bulpren S, Bulpren D, Bulpren B,...

- xx refers to the density according to the Recticel Rule: maximum net density plus one (in kg/m^3)

- yyy refers to the cell diameter target in micron measured by the Visiocell method, divided by 10: the higher the number, the higher the cell diameter (For the PPI-scale, the higher the number, the smaller the cell diameter).

The cell diameter, yyy, is always specified by 3 digits, even for values smaller than 1000 micron. A cell diameter, for example of 860 micron, is expressed by the digits 086.

Example: Bulpren S 28112
- Bulpren S = standard polyester reticulated
- 28 = maximum net density: 27 kg/m^3
- 112 = target cell diameter: 1120 micron

Rules of specification range

The cell diameter target - as defined by the code itself - is always the average between the minimum and maximum value of the specification.

Example: for Bulpren S 28112, the target value is 1120 micron.

The minimum and maximum of the specification could be for example 1020-1220 micron or 1000-1240 micron, but never 1000-1220 micron or 1000-1280 micron.

4.9. Actual limitations of the method

The Visiocell method can only be applied for foam with regular cell structure such as for conventional ester foams or specific ether foams with controlled cell size.

Therefore the Visiocell method cannot be applied for:

- foams with extremely fine structure (lower than 400-450 micron). The structures are always irregular. Studies are going on to define a dispersion factor of the irregularity
- foams with double cell structure ("sponge structure")
- standard ether foams (mostly irregular structure)

4.10. “Slides”: exclusive properties of Recticel

The Visiocell method is mainly based on calibrated magnified pictures and calibrated rings, presented on transparent slides.

- The slides are the exclusive property of Recticel. They are printed sheet by sheet from a standard software program.
- The slides are only published by Recticel and identified by a 3D-stamp.
- A slide may never be copied, photocopied or reproduced. Any reproduction can affect the scale... and the results of the measurement.
- The slides and pictures are controlled by a calibrated line.
- Moreover, the diameter of both circles of each ring is calibrated according the cell diameter and the density of the foam.

The calibration of all the documents is essential in the method.
Any non-calibrated document can lead to wrong interpretation on results.

4.11. Procedure for new product development

The specifications of the cell diameter for a new development and application can be defined by 2 different approaches:

1. Calibrated sample:

Recticel has published "Calibrated Sample Boxes". Each box contains a sample of which the cell diameter has been measured by the Visiocell method.

2. Mini-Max reference samples:

The cell diameter of mini-max reference samples from the customers is measured. The specification is defined afterwards.

In most of the cases, the definitive specifications of the cell diameter of a new product are defined by trial-error approach. Foams are produced according to a given target and afterwards the target is adapted following the experience of the customer.