# 2. SALES OF FUNCTIONS



## 2.1. Definition :

Sales of Functions is the key marketing concept of the Business Development of Technical Foams.

The function of a Foam refers to its application field as part of an end product or during an industrial process. Typical examples are : Fireflex as an acoustical part in a compressor; Isoseal LP as an interliner in the pour-in-place process.

The functions of Technical Foams are extremely diversified : water sealing, air sealing, water retention, acoustic, filtration, flame-barrier, design, cavity filling, Nickel-carrier, ... The analysis of the function for any new development is therefore an important step before developing a new formulation or a new product. The analysis of the function is also important to fix the appropriate specification in accordance with end use or transformation process.

From a scientific point of view, the function can be defined as the behaviour of the foam under the influence of an external force. The external force is designed as the “action” ; the behaviour of the foam as the “reaction”.

ACTION ⟶ FOAM ⟶ REACTION

All the functions can be related to this general mechanism.

Examples :

- Comfort is obtained by the deformation of the foam (reaction) under the weight of the body (action).

- The shock absorption is obtained by a fast compression of the cells (Reaction) under the gravity force of a falling object (action).

- The water sealing is obtained by repulsion of the foam to water (reaction) under the pressure of water (action).

- The acoustic absorption is obtained by the visco-elastic deformation of each individual PU cell (reaction) under the air pressure of the sound (action).

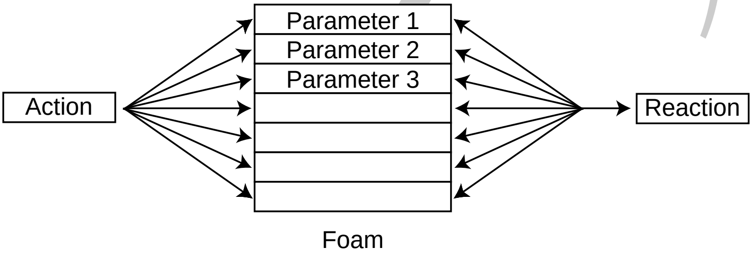
Besides the general survey of all the functions, the study of the mechanism of the function will therefore be the best guide to performant research.

## 2.2. Mechanism of functions :

The study of the mechanism of a function is a difficult task. It requires a wide scientific experience and prospective investigation on physics and physico-chemistry. It is certainly the aim of the Research Center to initiate such a study.

The most relevant example is the Foam Barrier function for the pour-in-place technology. The barrier protects the fabric from the penetration of the pour-in-place emulsion. The efficiency of the barrier is regulated by many parameters : density of the foam barrier, its closed cell content, its pore size, its thickness, its chemical nature, its contact angle, the nature of chemicals of pour-in-place, their viscosity, their reactivity, ...

The methodology of the study of the mechanism is based on a systematic analysis of the influence of each parameter on the function itself, which is illustrated as follows :




The example of Isoseal as barrier may appear difficult. But it is not because Isoseal is a complex case, that the study of other functions is simple. For example, the water retention in a sponge is an extremely complex story : how the performance of water retention can be combined with the ease to release it . What is the influence of double cell, closed cell, soft polyol, wettability, ... ?

Nothing is simple. Everything is so fascinating !

## 2.3. Acoustical treatment :

### 2.3.1. The nature of the sound :

The sound is a physical vibration, transmitted by the air in a frequency range to which the human ear is sensitive.

The sound is characterized by :

- Its amplitude : the higher the pressure of vibration, the higher the amplitude, the higher the loudness. The amplitude is typically expressed in decibel (dB).
  The Decibel scale is logarythmic ; a doubling of the intensity corresponds to an increase of approximately 3 dB.

  Few examples: the loudness of a pneumatic drill is 100 dB ; a near take-off of a jet aircraft is 130 dB ; quiet countryside is 15 dB ; 140 dB becomes painful and dangerous.

- Its frequency : Ultrasonic frequency refers to high frequency ; a bass to low frequency. The frequency is expressed in Hertz, it is the number of vibrations per second. In music, the note “la” is the reference at 430 vibrations per second. The human ear is sensitive between 20 and 18000 Hz.

### 2.3.2. Difference between music and noise :

The music is an organized sound. Only well-defined frequencies
- based in our occidental culture on 12 notes - and their harmonics
(i.e. their multiples) - are emitted in a well-defined rhytm and order.
The noise is a non-organized sound. All types of frequencies are present, without any order.

### 2.3.3. Acoustical treatment types :

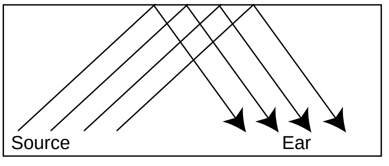
#### 2.3.3.1. **Correction :**

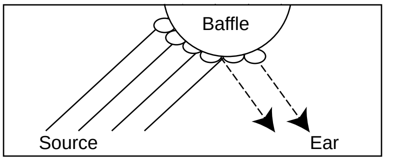
The correction is the control of the sound inside a room.

Typical examples are :

- Reduction of the reverberation in a recording room ;
- Reduction of the noise level in a workshop ;
- Control of the reverberation time in a concert hall.

The noise (or music), emitted in a room by an orchestra or a machine is reduced or controlled for the best convenience of the auditor or the worker ;

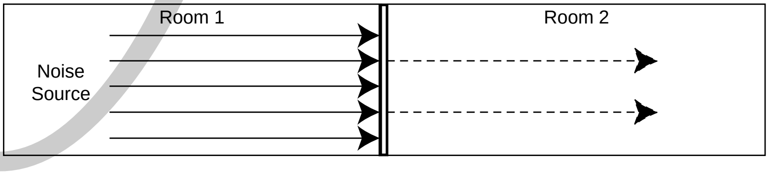



This is achieved by “absorbers” ; they may be baffles, which are suspended to the ceiling, or by absorbers fixed in the walls. The performance of each absorber depends on the frequency spectrum. Anyway, flexible foam, by its cellular structure, is an excellent absorber to reduce or control the reverberation inside a room.

#### 2.3.3.2. **Insulation :**

The insulation is the reduction of the transmission sound from one room to another.




It can be achieved by increasing the mass of the separating wall and/or by including the visco-elastic material, which really breaks the transmission at a certain frequency. PU foam is a good absorber and contributes to the reduction of the transmission, especially when it is associated to other materials.

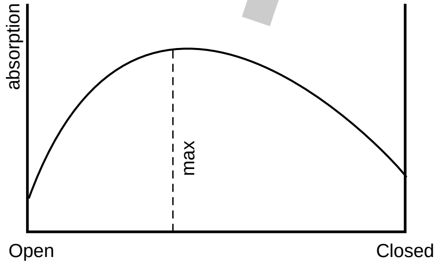
### 2.3.4. Foam as Absorber :

Flexible foams are excellent absorbers. The flexible nature of the foam acts as a tridimensional membrane.
Moreover, the cellular nature of the foam acts as a noise trap.

Two parameters influence the performance of the foam as absorber :

- Cell size : The smaller the size, the higher the absorption surface and the acoustical performance of the foam.

- Air permeability : Completely open cell structure transmits the wave with only little attenuation. On the other hand, a completely closed cell structure reflects the incident wave. The absorption characteristic is also bad. In both extreme cases, there exists an air permeability for which the acoustical absorption is optimal.



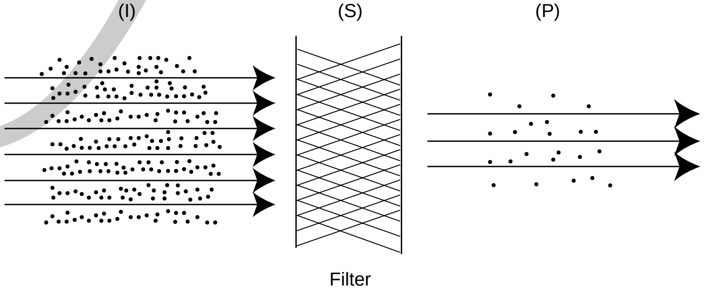

The parameters, cell size and air permeability, always act together.

## 2.4. Air filtration :

By its tridimensional open structure, reticulated foams are ideal support for air filtration.

**Main parameters of Air Filtration**

Particles in suspension in air are partially or totally arrested by the filter. Filtration is characterized by two parameters : the efficiency and the resistance to air flow, illustrated by the following figure :



- Efficiency : The efficiency (E) is the ratio of the number of particles stopped (S) by the filter related to the number of incident particles (I) :

  E = S/I

  The number of particles passing through (P) the filter, is calculated by difference :

  P = I - S

  The efficiency is generally expressed in % : 100 indicates that all the particles are stopped, and none are passing through the filter (I = S and P = O), while 0 % indicates that all the particles are passing through the filter (P = I and S = O).

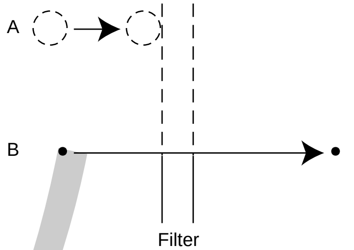
- Resistance to air flow : the resistance of the filter to the air flow is an important engineering factor. The higher the resistance, the higher the power of the ventilation system.

  The air resistance is generally measured by the pressure drop before and after the filter :
  $\Delta$ P = P1 - P2, where $\Delta$ P = Pressure drop
  P1 = Pressure before the filter
  P2 = Pressure after the filter

**<u>Mechanism of filtration :</u>**

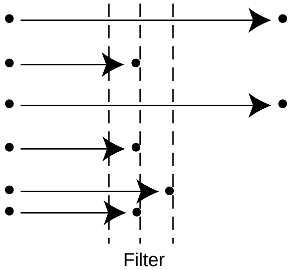
The particles are removed from air and accumulated in the filter structure by 3 basic mechanisms :

<u>- Sifting :</u> When the diameter of the particles is higher than the pore size of the filters, the particle is mechanically arrested by the filter.




Particle A is arrested ; particle B can pass through.

<u>- Collision :</u> Any particle, even when its diameter is smaller than the pore size of the filter, may hit the filter structure and stick on it.

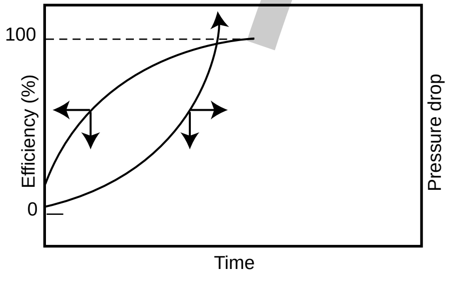


- <u>Interception :</u> By electrostatic force, the particle is attracted by the filter structure. The interception may be increased by surface treatment of the filter (active charcoal) or by loading the filter with electrostatic current.

**<u>Behaviour of the filter</u>**

By absorbing particles, the filter becomes heavier ; the pore size of the filter decreases. The efficiency of the filter increases but the air flow resistance increases too. At saturation, the filter is "full" and all the particles are arrested ... but there is no air flow anymore passing through the filter, therefore no filtration. Then, the filter has to be cleaned and/or replaced.

The standard diagram of the filter characteristics in function of the time is :




**<u>Polyurethane foam</u>**

In comparison with other filter media, polyurethane foams present the advantage of a tridimensional structure, which allows the accumulation of high amount of particles without being blocked. However, the efficiency of polyurethane foam for small particles is relatively low, due to the large pore size of the filter. Polyurethane foam filter is mainly used for prefiltration and/or filtration of coarse particles.

## 2.5. Air Sealing :

As such, conventional flexible PU foams are not suitable for air sealing purposes.
The foams are too open. To be used as airtight gasket, it is necessary to decrease the air permeability of the foam :

- By increasing the closed cell content ;
- By reducing the cell size ;
- By compressing the foam.

The advantage of Flexible Foam is its low resistance to compression, which facilitates its application in the assembling. The use of Flexible Foam for air sealing is however limited to low pressure (ventilation, refrigeration, doors, ...).

ISOSEAL LP is the most common PU foam of Recticel for Air Sealing.

## 2.6. Antistatic and Shielding :

**Antistatic :** The function of the foam is to prevent accumulation of electrostatic charge, which can damage electronic components. To reach the function, one enhances the electrical conductivity of the foam by a factor of 10 to 100.
Static electricity is therefore permanently dissipated.
RECSTAT is the Recticel name for antistatic flexible foam.

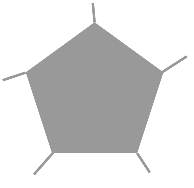
**Shielding :** Electromagnetic interferences are stopped by shielding.
The shield has to be electroconductive ($10^3\ \Omega$ cm).
The property can be reached by impregnation of active charcoal or by laminated metal foil (aluminium foil) on the foam.

## 2.7. Carrier :

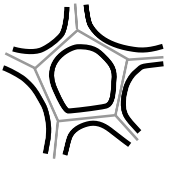
By its cellular structure, a foam is an ideal support to carry and transport liquids or powders. Sponges are the typical application. Other applications are powder puff, ceramic filter, biofiltration, impregnation, ...

### Adsorption and Absorption

The basic mechanism of the carrier function is reached either by absorption which consists in filling the cell or by adsorption which consists in “coating” the rib of the cells.



Absorption of a liquid



Adsorption of a liquid

### Sponges

The mechanism of the interaction between the water and the sponge (foam) structure is not simple. At first, water has to be absorbed during the immersion as fast as possible by the sponge structure. Then, in a second phase, the retention of the water during the transport operation becomes the key parameter. Third property : by pressing or squeezing, the sponge has to release the water (desorption).
Finally, the sponge will be perfect if it can “sweep” the surface.

Absorption, retention and desorption are the three mechanisms of the use of a sponge. All these requirements are contradictory ; one still expects the miracle to have the perfect sponge, based on a PU foam.

### Powder Puff

Powder Puff is another example of the carrier function. In this case, the function of the foam is to transport powder. The same mechanism - absorption (adsorption), retention, desorption - may be applied ... but there is no theory on the efficiency of PU foam for this function. The main property of the foam is its softness, ...

### Ceramic Filter, nickel foam

PU foam is used as the basic structure to coat it with ceramic paste (by impregnation), or with nickel metal (by electrolysis). In both cases, the foam is burned after treatment and the ceramic or nickel residues keep the original structure of the filter. Ceramic filter is used as filter for metal injection ; nickel foam as electrode for rechargeable battery. In both cases, the function of the foam is assimilated to a “carrier” function.

## 2.8. Flame Barrier :

The flame propagation within a tube is strongly dependent of the diameter of the tube, due to the interaction of radical reaction of the flame and the walls of the tube.
The smaller the diameter of the tube, the slower the propagation of the flame ... up to complete extinction.


The flame propagation is faster in tube A than in B.

A window of a cell of polyurethane foam can be considered as a thin section of a tube, and the foam as a 3-dimensional network of tube sections. The flame propagation in such a structure is therefore reduced as in a single tube, and in some cases up to complete extinction of the flame.

Recticel produce two foam grades which are used as foam and flame barrier :
FIREND and SAFOM.

FIREND is an impregnated foam, used in thin layer (10 mm) to protect mattress, cushions, seats. The FIREND carbonizes at high temperature and protects the core of mattress, cushions or seats from burning.

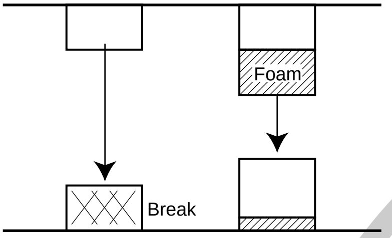
FIREND is, for example, used as flame barrier for aircraft seatings, complying with the FAR regulations.

SAFOM is a reticulated foam with coarse cell. It is used as anti-explosive for fuel tanks by filling completely the cavity of the tank. SAFOM itself has no specific fire retardant properties ; its function consisting in “quenching” the flame in its cellular structure.

## 2.9. Shock absorption (1)

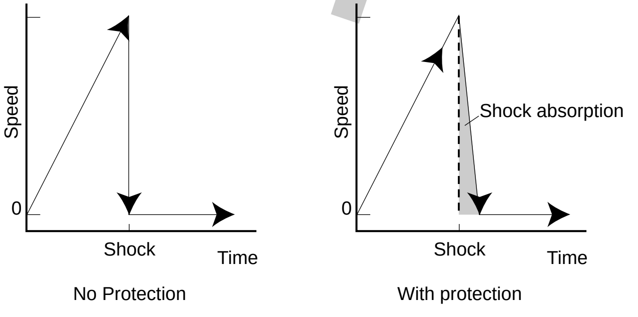
### What is shock absorption ?

When an object is falling at a speed of 50 km/h on a concrete floor, its speed is reduced from 50 km/h to 0 km/h in a fraction of a second. The deceleration is extremely fast, causing damage to the object. By high deceleration, the object is compressed on itself, causing the breakdown and damage.




If the object is protected by a foam layer, the deceleration is reduced.
By contact with the floor, the foam is compressed and absorbs a part of the kinetic energy. The time to reduce the speed from 50 km/h to 0 km/h is much longer ; the deceleration is much slower.

The deceleration is illustrated as follows :




**Factors, influencing the shock absorption :**

The function of the shock absorber is to decrease the deceleration force and therefore, to increase the time between the speed of the object at the moment of the collision and the speed “0” after the collision. Several factors influence the performance of the absorber : its nature, its thickness, its contact surface :

* Hardness of the foam : a too soft foam doesn’t present any resistance to compression. When the object is falling, the foam is compressed at the same speed as the falling object and doesn’t offer any protection. On the reverse, a too hard foam is not compressed, and doesn’t present any protection either.

* Contact surface of the foam : if the contact surface of the foam to protect the object is too small, the foam is compressed instantaneously, leading to no protection. If the surface is too high, the foam is only slightly compressed due to the high overall resistance. In such a case, the foam doesn’t offer the appropriate protection.

* Thickness of the foam : when the thickness of the foam is too small, the foam is compressed to “bottoming” and doesn’t protect the object.

Therefore, for each case, the nature of the product, its surface and its thickness have to be carefully studied in function of the weight of the object, its falling height and the specification to be reached. The approach to fix the ideal shock protection is really an exact science.

**Other packaging protection**

* **Blocking :** it avoids that an object moves in its own packaging.

* **Anti-vibration :**
It prevents that the object is subject to a continuous thrilling, which may be assimilated to a succession of small "shocks". Thrilling, when the vibration frequency of the component is the same as the external vibration, may lead to an amplification of the vibration, called "resonance", which can cause damage. Specific absorbers will reduce this phenomenon.

## 2.10. Impact protection :

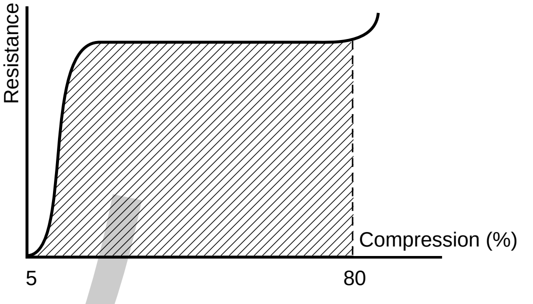
Impact Protection is defined here as the protection of the body against shocks.
In a certain way, the general theory of shock absorption may be used.

However, in impact protection, we consider that the protecting material can be destroyed during the impact and therefore limited to "one shock".

Ideal PU foam for impact protection is brittle foam - like foam glass - of density between 30 and 80 kg/m3 and cell size from 1 to 5 mm.

By impact, the foam is compressed and completely destroyed.
The energy absorption is due to the break-down of the cells.

The graph of "Resistance to Compression" and % compression is represented as follows :




After initial contact, the resistance to compression remains stable up to 80 %.
In this way, a maximum of energy is absorbed.

## 2.11. Thermal insulation :

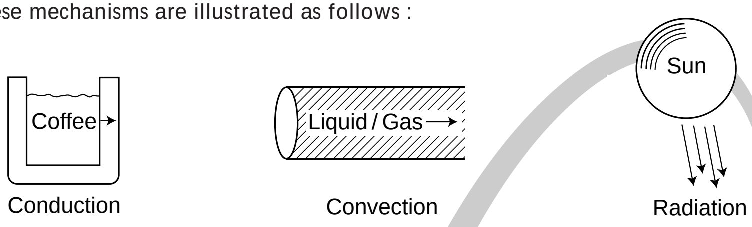
The transfer of heat takes place by 3 mechanisms :

**- Conduction :** It is the transfer of heat within material, from molecule to molecule. By pouring hot coffee in a cold cup, the exterior of the cup becomes hot by conduction within the ceramic of the cup.

**- Convection :** It is the transfer of heat by displacement of a fluid or gas. Central heating system occurs by the transport of hot water or hot air through the pipe system.

- **Radiation :** It is the transfer of heat by electromagnetic forces.
The sun burns the skin by radiation !

These mechanisms are illustrated as follows :




**Polyurethane foam**

Polyurethane foams present good insulation properties : the heat transfer by conduction is low because the foam is made of 3 % solid and 97 % of air. Moreover, the heat transfer by convection is also low because the air is trapped in the cellular structure.

Therefore, the insulation of a PU foam increases by :

- Fine cell structure
- Close cell structure
- Low density

## 2.12. Water filtration :

Water filtration is similar to air filtration.
Suspended particles in water are arrested by the filter, either by adsorption at the surface of the ribs, or by sifting.

Reticulated PU foams, based on polyether, are excellent mechanical water filters for various applications : aquarium, drains, swimming pool, ... As for the air filtration, reticulated PU foams can accumulate an important amount of dust and mechanical impurities before being blocked or saturated.

Reticulated PU foams present other advantages :

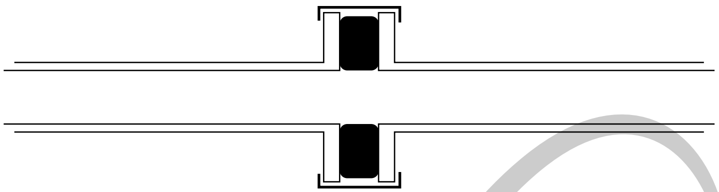
- Easy cleaning (with water jet)
- Easy handling and positioning in a given structure
- Long life

Reticulated PU foam is however not convenient for filtration of important water flow or high water pressure, neither for the purification of drinkable water.

## 2.13. Water sealing, liquid barrier :

Water sealing problems are encountered in all types of markets : building, appliance, automotive, refrigeration, transport. The water, by its low viscosity, penetrates everywhere and always takes the shortest way. Watersealing is not difficult : however, it requires some care.

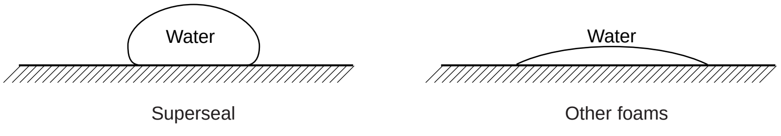
In most of the cases, water sealing is reached by a joint, which - by compression - penetrates the irregularities of the surface and prevents water leakage.



In the water sealing applications, it is absolutely necessary to specify the pressure of the water.

Most of the joints are made of flexible or semi-flexible materials : rubber, EPTM, leather ; the profile of the joints contributes to the sealing function.

SUPERSEAL is the only flexible PU foam - produced by the one shot process - which can be used for water sealing applications. To reach the properties, one uses hydrophobic chemicals ; this can be easily observed by placing a drop of water on the surface.
The spheric shape indicates a water repulsion effect :




Moreover, SUPERSEAL has a very fine cell structure, which contributes to the water repellancy by a negative capillarity process.

Flexible foam as sealing material has the advantage of low hardness.
Assembling of structures, using soft joints, becomes easy.

**Liquid barrier (pour-in-place)**

Barrier for pour-in-place application is a derivative function of liquid sealing.
The foam prevents penetration of the pour-in-place emulsion, and protects the textile.
To reach these properties, the foam will have low permeability, closed cell content and small cell size.

## 2.14. Miscellaneous :

Foams are also used in miscellaneous applications, which do not require extensive explanation.

| **Function** | **Example** |
|---|---|
| - Housing | - RIM products |
| - Design, Padding | - Shoulder Pads |
| - Cavity Filling | - Sunvisors |
| - Gasketing (anti-noise) | - Any small piece |
| - Polishing, Scouring | - Pottscorer disk |
| - Protection against dust | - Any foam with skin |
| - Acoustical transparancy | - Bulpren HiFi |