Foaming Fundamentals

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1. HISTORY & PERSPECTIVE

Flexible Polyurethane Foam (PU-foam) was first introduced for special purposes in the late 1950's. PUfoam Consumer Products were introduced in the early 1960's on a large scale in several industrial countries.

The new material soon gained great interest and common acceptance as a replacement for rubber and fibre materials. Compared with Latex foam products, flexible PU-foam is superior in many ways. It can be produced in densities ranging from about 12 to 50 kgs/cbm. It has a higher tear strength, better resistance to oxidation, aging as well as fire, and its open cell-structure enables it to absorb and emit humidity, e.g. body heat/humidity.

Market demands increased rapidly, new products and applications were developed, and raw materials were improved and diversified accordingly.

In order to meet this international demand, existing factories expanded and many new plants were put into operation, so that now large quantities of foam are being produced and consumed in most countries of the world. There is now a wide variety of different types of foam available for various applications.

The opening of new markets and market segments, the ongoing introduction of new applications and increasing transport costs still make it interesting and profitable to expand in the foaming industry in most countries.

It must be concluded, therefore, that foaming industry has proven to be one of the most expanding and profitable light industries in the world and that it seems to continue to be so for a long time to come.
It should be added also that the investment required for setting up a foaming industry is rather limited in comparison with most other industries, and that the return is, therefore, quite favorable.

2. RAW MATERIALS FOR FLEXIBLE PU-FOAM

The required chemicals are available from a number of suppliers under different trade names, but can be identified in general terms as follows:

2.1. POLYOL

Also referred to as "Polyether Resin" or just "Resin". This is the major component in all formulations.

Foam formulations are always based on 100 parts by weight (p.b.w.) of Polyol, and the ratio of all other components are calculated on this basis, in accordance with the quality of foam to be produced.

2.2. T.D.I. (Toluene-Di-Isocyanate)

Is the second major component, and is used at a ratio between approx. 40 to 65 p.b.s.

this ingredient is very toxic, and the manufacturer's safety instructions must be strictly observed at all times.

3. WATER
Is initiating the chemical reaction between Polyol and T.D.I., producing carbon dioxide and forming the basic polymer of the foam.

The proportion of water (usually between 2 and 5 p.b.w.) determines the final foam density.

Good quality mains water may be used, but in case of impurities, or highly acid or alkaline water, it is advised to use pre-treated water.

4. AMINE CATALYST
Is used at a ratio of approx. 0.10 to 0.60 p.b.w. in order to accelerate gas production.

5. TIN CATALYST

Also known as "Stannous Octate" - is used at a ratio of approx. 0.20 to 0.40 p.b.w. in order to improve the cross-linking of cells.

6. SILICONE STABILIZER
Is used at a ratio of approx. 0.70 to 2.0 p.b.w. in order to stabilize the cell structure and influence the size of the cells.

7. AIR
Is used as a blowing agent to achieve an open cell structure, being decisive for course or fine cell structure.

Moreover, the following components may be used:

8. BLOWING AGENT
Either Freon-ll (Fluorocarbon) or Methylenechloride is used at a ratio of approx. 5-20 p.b.w. as an additional blowing agent in order to achieve low density or soft "feeling".

9. COLOURANTS
To be used to produce foams of different colours for quality identification and/or sales attraction.

10. FLAME RETARDANTS
To achieve fire-safe materials.

11. THE FILLERS
To achieve special properties and reduce costs.

All chemicals are fairly low viscous liquids, and are supplied in bulk tanks, drums, cans or plastic containers.

Supply in drum is by far the most common.

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3. FOAMING - Discontinuous & Continuous

3.1. FOAMING PRINCIPLES

In principle, foam will emerge when the mentioned chemical components are mixed together. Actually, it is the addition of water to T.D.I., which triggers the chemical reaction, which results in foam in a matter of seconds.

Obviously a carefully controlled reaction is necessary in order to obtain foam of desired and consistent quality, and various types of equipment have been developed for industrial foam production. Usually the individual chemicals are prepared for use in feeding tanks, from where they are metered and forwarded by pumps or pressure to a mixing vessel, where they are mechanically mixed together, and then dispensed onto a conveyor or into a mould, where the foam formation 1akes place.

After the actual formation of the foam, it needs to cure for several hours before further handling.

3.2. DISCONTINUOUS FOAMING

is characterized by the use of moulds, being filled one by one, and can be evaluated as follows:

Advantages:

* Well suited for finished products having complex or odd shapes.
* Well suited for finished products in combination with other materials (such as seats and chairs with steel tube and spring interiors).
* Well suited for small-scale production.
* Flexible production (formulation can be changed from one block to the next).
* Limited investment.
* Well suited for special production and tests.
* Moulds can be customized in size and shape.
* Block cutting machine not required

Disadvantages:

* Highly controlled processing is required.
* Labor- and time-consuming production procedure.
* Skins on all faces of the block (increased block trimming work).
* Higher chemical consumption (waste after each shot).
* Expenditure for polyol and solvent to flush machine after each shot.
* Not well suited for large-scale production.

3.3. CONTINUOUS FOAMING

Also known as "Slabstock Foaming" is characterized by the use of a moving conveyor onto which the chemical mixture is being dispensed, thereby forming a continuous block, which can then be cut off in required lengths.

MPT

Advantage:

* Continuous method, i.e. large production on same machine settings, thus ensuring Consistent quality throughout the production.
* Well suited for large-scale production.
* Time- and labor-saving production procedure.
* Different block-size obtainable, since block width is adjustable.
* Built-in extra capacity to be utilized inexpensively.
* Production costs low.

Disadvantage:

* Not suited for products having very complex or odd shapes, nor together with other materials.
* Not well suited for very small productions.
* Requires a block cut-off machine (extra cost).
* Usually higher investment than Block Moulding.
* High start and stop costs when limited production volume is required.
* High cost in case of production failure.

4. PLANNING A SLABSTOCK FOAMING FACTORY

4.1. PRECONDITIONS

Certain important preconditions have to be laid down in order to decide how to design and equip a specific foaming factory. It is thus essential to know the following:

* Planned annual production capacity.
* Planned finished products divided into groups and their proportion of the total production.
* Planned types and densities of foam.
* Required block sizes/widths.
* Climatic conditions.
* Planned expansions.

Moreover, there are many other factors, which have to be considered carefully and incorporated in the basic planning of the plant.

4.2. AREA AND BUILDINGS

The factors governing the location and size of a foaming factory are many, and may vary considerably:

Price of real estate, size of intended production, infrastructure and communication facilities, market vicinity and transport routes, personnel matters, potential competition, duty and taxation considerations and many others.

4.3. UTILITIES

4.3.1. Electric Power

The total requirement depends very much on the types and extent of production machinery to be installed. It may also be necessary to take power required for aircondition units into consideration. It is imperative that the actual foaming process is never interrupted, e.g. by power failures, since it is a continuous process.
It may be recommended in some cases, therefore, to install a generating plant at the factory.

4.3.2. Water

An ordinary industrial water supply will suffice, since for the foaming process only a few hundred litres of water per hour is required. The water should be reasonably pure, but the requirements are not really strict. If in doubt, a water analysis should be carried out to determine, if additional treatment of the water will be necessary. Water installations for fire safety should be considered, and the amounts of water for this purpose will be much higher than for the total production.

4.3.3. Compressed Air

A compressor and perhaps air drying equipment should be installed near the foaming machine.

4.3.4. Expansion potential

The experience gained over the last 20 years shows that foaming plants were never built too large, but often without proper expansion possibilities. The still decreasing demand for PU-foam in most parts of the world - especially in developing countries makes it important to consider future expansions already when planning the initial plant. Adequate, additional space, electric power installations etc. should, therefore, be planned for future expansion.

5. PLANT LAYOUT

A foaming factory consists of the following main sections:

1. Raw Material Storage
2. Foam Production
3. Foam Curing
4. Foam conversion & Finishing
5. Foam Waste Reclamation
6. Product Finish
7. Finished Products
8. Storage Offices & Personnel facilities

The attached Plant Layout is to be considered a suggestion and guidance, and serving as an illustrative example only.
The layout also suggests where to extend the factory, if required later.

5.1. PRODUCTION FLOW

An efficiently operated and successful factory should have a planned production flow line. This reduces handling and storage problems, minimizes labor requirements and increases productivity and profitability. Overcrowded working areas are also inefficient and hazardous.

6. BUILDINGS

Safety reasons demand that the distances between the buildings are strictly observed. All buildings should be provided with concrete floors for industrial load, i.e. 500 kgs/sq.meter., with a sufficient number of emergency exits to allow both personnel and materials to be saved in the event of danger. Fire extinguishing equipment of adequate capacity shall be available in a suitable number in suitable places.

For technical reasons, all buildings should be designed with a ground floor only.

6.1. RAW MATERIAL STORAGE

6.1.1. Storage Capacity

The stock of raw materials, and thereby the size of the required storage space, depends on the planned productive output of the factory, and the transport and delivery time for new supplies. Since foaming will have to stop, if just one component is not available, it is essential to keep a certain minimum stock for safety reasons, in case delivery of new raw material should be delayed for any reason.

On the other hand, the relatively high value of the chemicals in question as well as the limited storage time allowed before a quality deterioration, makes it attractive to keep the stock at a minimum.

Special care should be taken not to order excessive amounts than required of the smaller ingredients, such as amine tin and silicone since these chemicals have a limited storage life, and once opened, they quickly hydrolyze and lose some of their chemical activity.

A reasonable balance can often be achieved by means of a supply contract covering several months' consumption, but with frequent partial shipments. This procedure renders lowest possible price, minimum investment in own stock, short interval between supplies, short storage-life of chemicals, and small storage facilities.

6.1.2. Storage conditions

Prolonged outdoor storage should be avoided due to undesired temperature variations (water condensation and drum corrosion). As a minimum precaution the drums should be stored under a light roof-structure, and covered by foam slabs.
Under no circumstances must the temperature of T.D.I. be allowed to fall below 17 degrees C.

6.1.3. Temperature Control

The principle of first in first out must be applied at all times in order to prevent aging chemicals.

The temperature of the store room should range between 18 and 28 degrees C.

6.1.4. Tank Room

The temperature of the tank room should range between 20 and 25 degrees C, and not fluctuate by more than +/- 2 degrees C, since this should also be the foaming temperature. Temperature control equipment is, therefore, likely to be required for the tank room in most cases. A suitable number of drums for several days' production should always be kept available in the tank room at the required temperature, ready for filling into the tanks.

Whenever drums are emptied, they should be put outside, and immediately replaced by new, full drums from the general store, in order for these to reach the correct temperature as soon as possible.
The capacity of the tanks is decisive for the amount of foam, which can be produced in one charge, and they should have a certain excess capacity, therefore, since large runs are always more economical and efficient.

For large production runs it may be advisable to install two tanks for each component, and to fill one tank while feeding the foaming machine from the other and vice versa.

The tanks should be installed as close to the foaming machine control panel as possible, thereby reducing the feeding pipes as short as possible.

6.1.5. Paper

Kraft paper of 80 to 100 gram/sq.mt. density is used to line the conveyor and sidewalls of the foaming machine, as otherwise the chemicals would stick directly to the machine.

The paper rolls must be handled with care at all times to prevent damage. They must be stored in a horizontal position in a clean, dry room.

6.2. FOAM PRODUCTION

The foaming machine and block cut-off machine should be installed in a separate building or room, due to fire- and health safety reasons. In hot climates it may be necessary to air-condition a limited area at the inlet of the foaming machine.
The foaming room should also be well ventilated, due to toxic and unpleasant fumes from the foaming process.
The foaming room should be made as small as possible, but allowing sufficient walking space throughout, e.g. approx. 2 mtrs machine-to-wall distance.

6.2.1. Preparation & Control

Adequate space should also be provided for chemical mixing, cleaning, quality control and various other work, - either in the foaming room, the tank room or a small separate room.

Foaming is a chemical process, in which high accuracy is of the utmost importance for the quality of the finished foam.

Since also the relatively high value of the chemical raw materials and the safety aspect must be considered, it is essential to have certain ancillary equipment available, such as:

- Weighing Scale with a capacity of 0-100 kgs or more, preferably with 5-gram increments. This is to be used for the calibration of metering pumps, and for preparing the catalysts.
- Laboratory Weighing Scale with a capacity of 0-20 kgs with 1 gram increments. This is required for the accurate weighing of the small pre-foaming tests of formulations and chemicals. Also density control is carried out by weighing foam pieces on this scale.
- Working table with washbasin.
- Mixer and mixing vessels for the catalysts.

This area/room and all equipment used should be kept clean and in good working order - and free from all other production at all times.

6.2.3. Block Cut-Off

While the foam slab is being produced continuously, it is cut off to required lengths (e.g. 2 mtrs) by means of a block cut-off machine, which is installed in the conveyor system of the foaming machine. Fully-automatic, semi-automatic and manually operated machines are available for this purpose.

6.3. FOAM CURING

After the freshly made foam blocks have been cut off to required lengths, they are transported to the curing area by conveyor or manual trolleys, where they are to cure for about 24 hours, i.e. until the same time the following day.

This is due to the ongoing exothermic reaction inside the blocks. The curing building should be a separate, light structure building with good ventilation and at least 10 mtrs away from the nearest building.

This serves as a safety precaution, since there is a risk that the newly made blocks may catch fire by self-ignition, if for example the formulation has not been correct for any out of many reasons. In any case an exothermic reaction continues inside the blocks, where the temperature will reach about 150 degrees C during normal reaction. The insulation properties of the foam slow down the heat dissipation from the center of the blocks.

6.3.1. End Blocks

The first as well as the last 1-2 mtrs of foam being produced always have an uncontrolled composition of chemicals, and are, therefore, particularly risky. These block ends should, therefore, be put in a special area outside in the open.

6.3.2. Normal Blocks

All other blocks should be arranged separately with 15-20 cms open space on all sides of each block, allowing maximum air cooling, thus 1 ton of foam will occupy about 70 sq.mtrs of floor space.

Only after 24 hours should the blocks be stacked on top of each other in the block store, or brought into the conversion building(s).

Sufficient wa1king space between the blocks should always be provided.

It should be observed that the size of the curing area sets the limit to how much foam can be produced at anyone time, since when this area has been filled with blocks, the foaming has to be stopped for about 24 hours.

The size of the curing area will usually be a compromise between a minimum limited by turnover and a maximum limited by the investment and/or land available.

Foaming quality (density, resilience, cell structure etc.) as well as block dimensions should be fixed in accordance with the subsequent end products, in order to limit waste and storage to a minimum.

6.4. FOAM CONVERSION & -FINISHING

6.4.1. Finished Product Variety

In this section a great variety of semi-finished and finished foam products can be made, such as: slabs, sheets, profiled items, mattresses, cushions, pillows, upholstered items for furniture, vehicles, railway wagons and boats, temperature-vibration- and noise insulation materials, packing material, carpet underlay, car- and bath sponges, sanitary pads, clothing items, such as shoulder pads and textile lining, leather- and PVC-backing for handbags, suitcases and shoes, painting rolls, dolls and toy animals, and much more.

Specialized machines are available for converting foam into all of these products and besides there is an ongoing development of new products and equipment.

6.4.2. Foam Conversion Equipment

The cutting of flexible PO-foam should be done with good quality machines, specially designed for this purpose.

A great variety of such machines have been developed based on the requirements and experiences of professional users.

Accurate and reliable conversion machines are a wise investment, which soon recover their costs in high and steady output and greatly reduced scrap losses.

6.4.3. Space Requirements

Space requirements depend on the extent of the production and not less on the end products made, and their relative proportion of the total production.

To ensure an optimal flow of material, the individual machines as well as intermediary storage of foam should be placed in accordance with a thoroughly conceived plan.

6.4.4. Block Transportation

the foam blocks are brought to the conversion section from the curing area or block store by conveyor, forklift truck or manual trolleys.

6.4.5 Block Edge Trimming

Usually the blocks are first trimmed and cut to overall size required for further conversion into a great variety of semi-finished and finished products.

The most rational way of trimming the blocks, i.e. removing the side skins and at the same time obtaining a fixed width, is by moving the blocks on a conveyor with adjustable, vertical cutting sections on both sides.

Thus the cutting/trimming operation is performed on both sides during the transport of the blocks to further conversion, e.g. stack slitting, thereby saving on time, handling, space and labor. The blocks can also be trimmed one side at a time by means of a manual vertical-cutting machine. This is the traditional way, which is somewhat awkward, however, in comparison with the above method.

6.4.6. Horizontal Slitting

After having cut the blocks to size, they can be slit into sheets and mattresses on horizontal slitting machines.

There are different types of these machines, such as:

* The conventional Slitting Machine,
  which cuts sheets one by one, i.e. each sheet has to be removed after having been slit, before the next sheet can be cut. This type of machine has a rugged knife-gib, and is available with or without various automatic controls.
* The Stack slitting Machine,
  which slits the block into a stack of sheets, i.e. the sheets can be left on the machine until part of or the entire block has been converted into sheets. This type of machine has a thin knife-guide, and is usually automatically operated. There are also a number of specialized slitters available for specific purposes and materials.

6.4.7. Vertical Cutting

Vertical cutting machines (band knives) are used for all kinds of cutting work, and are the most frequently used types of machines, due to their versatility.

Machines are available in fully and semi-automatic as well as manual versions, and with different dimensions and equipment to meet most requirements.

Typical products made on these machines are cushions and sheets for furniture and vehicles, insulation, packing, sponges, pads, clothing items, toys, sealing strips and the like.

6.4.8. Specialized Cutting

A number of specialized machines have been developed to facilitate the manufacture of certain products:

* Bevel Cutting Machines,
  for furniture- and insulation items, profiles and padding.
* Peeling Machines,
  with rewinding, so that foam can be supplied on rolls for continuous quilting and laminating with textile materials. Or for carpet underlay or packing material.
* Profile Slitting Machines,
  for special mattresses and furniture, insulation and packing.
* Edge Profiling Machines,
  for profiling/curving edges of furniture cushions and the like.
* Contour Cutting Machines,
  for cutting complicated items with small curves for furniture, packing and lining.
* Cross .Cutting Machines,
  for cutting sanitary washing pads in stacks of thin sheets.
* Punching Presses,
  for toys, packing and insulation items.