

Energy and Natural Resources Saving In The Production of Expanded Glass Granules

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Two processes relating to the preparation section of recycled glass are described with reference to the complete process of manufacturing of foamglass granulates and to their application. The first process consists of crushing the glass from differentiated collection, with simultaneous separation of the extraneous elements mainly consisting of: plastic, aluminium, steel and cork. Implementation of this operation is performed with the Ehinger MUD patented crusher that is able to distinguish the grinding ability of the glass from that of other substances resulting in the fragmentation of the glass and not that of foreign bodies. It is interesting to note that during this operation, substantial frictional forces develop that are useful to reduce and to almost always remove the physical link that exists between glass and other materials. The second process described is that of final refining of the glass which is performed with an Ehinger Impianti vertical axis centrifugal ball mill named RM with a 15 % energy saving compared to traditional ball systems. [1] Recycling is efficient and sustainable, saves energy and natural resources. One kilogram of recycled glass replaces 1.2 kg of virgin raw materials. Therefore glass recycling reduces CO₂ emissions and the demand for natural raw materials. This helps prevent the exploitation of natural resources. Due to technical reasons during the recycling process, a certain amount of glass cannot be recycled by the glass industry to manufacture new products. Poraver® utilizes this cullet and closes a gap in the recycling process. The production of expanded glass starts with ultra-fine grinding of the recycling glass. The preparation of the recycled glass and the fine grinding are crucial to the quality of the foamglass. Glass flower, binder and foaming agent are mixed and moulded into granules. After this the grain is sintered and foamed (expanded) in a rotary kiln. The result is a new product that is used as a raw material for high-quality building materials and industrial products. Expanded glass is used in dry mortar, panels and lightweight concrete as functional lightweight aggregate in construction chemical products and mineral casting. Future applications are becoming evident in the automotive sector and are magnetisable designed in biotechnology as a growth substrate for immobilizing micro-organ.

1. Introduction

The use of foam glass pellets provides a valuable contribution to Environmental Sustainability due to the specific characteristics of the product and the energy savings obtained by using it; this topic is detailed in the 2nd part of the report prepared by the engineer Weinberger. In this first are described plant engineering aspects and in particular those relating to the preparation of the glass.

2. Crushing the glass with simultaneous separation of the extraneous elements

The first operation performed in the treatment of the glass originating from differentiated collection is intended for the production of foamglass pellets and the removal of extraneous elements present in the glass. This operation is essential because it determines both the quality of the end product and the energy efficiency of the production cycle. A clean glass reduces the consumption of the fine grinding system and the energy consumption of the thermal expansion furnace. There are two cleaning methods: dry and wet, the latter however is seldom used as it is very expensive in terms of energy consumption.

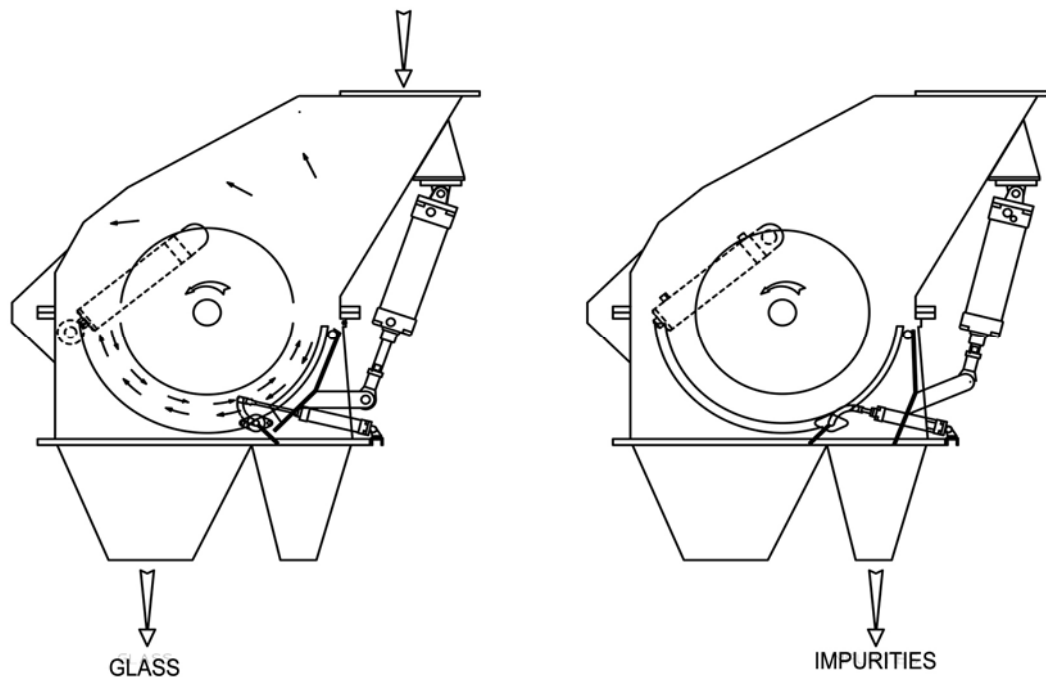


Figure 1: MUD system Phase 1 and Phase 2

This report refers to the dry cleaning system only. This cleaning method is based on the crushing system with simultaneous separation of extraneous elements from the glass by the Ehinger Impianti system called MUD. The traditional approach that first provides a crushing process and subsequently a separation of extraneous elements from the glass is almost overthrown. The basic concept of the MUD system is that it is not possible to obtain a good separation through an initial crushing of glass, followed by a separation. Actually, through the traditional process only the weaker links that keep the glass jointed to extraneous elements can be crushed; during the subsequent treatment these initial shortcomings cannot be overcome. For this reason, the operation of the MUD system provides a processing cycle that can be defined as hybrid: continuous and batch. In the first phase, the material coming from the mill is loaded and only the crushed glass is expelled, which is the most fragile material, while extraneous elements bodies consisting mainly of organic components remain in the mill and are subject to forces of friction (rubbing); the glass that is gradually separated from the organic fraction is continuously conveyed in glass fraction. After a certain period which is determined by the amount of impurities, the system starts the second phase: the loading process is stopped and the non glass particles are expelled in scrap line. The term scrap is related to the production of glass but not in an absolute sense because such scrap can undergo a further separation treatment and can become secondary raw materials; usually, this last part of plant is not provided by the manufacturer of foamglass. To obtain a good separation, the glass must have a humidity below 0.5 % and not be subjected to any previous treatment; otherwise, it must be guaranteed that no additional adherence of extraneous elements to the glass occurred. Principle of operation: the glass is metered and introduced in the mill. Calibrated impact and cutting actions cause the reduction of particle size of the glass that passes through a selection area; organic and metallic materials are not crushed and accumulate in the lower part of the crusher where they are gradually released, by rubbing, from any glass particles that are constantly expelled in the glass fraction. After a certain time, the material loading cycle stops and extraneous elements are expelled in the impurities fraction. After a few seconds, metering is restored and the processing cycle described above repeats.

3. Fine grinding of the glass with centrifugal ball mill RM

The fine grinding of glass is a process that needs a lot of energy and therefore it is important to minimize energy consumption at this stage. The centrifugal ball mill manufactured by Ehinger Impianti with vertical axis and continuous operation called RM is particularly suitable for this purpose. It consists of a grinding zone in which three to six balls that spin around the vertical axis compress the glass that is located between the grinding track and the balls using the centrifugal force generated by the rotation of the balls floating within housing cells. After passing through the grinding area, the material is drawn to the pneumatic separator

above, which sends back the large particles of material to the mill and allows the material with the particle size set to reach the ground glass collection filter. The separator is equipped with all the necessary features to ensure the quality of the product in any operating condition. It is interesting to note that the entire comminution process occurs under vacuum thus avoiding dust release in the environment. By comparing the characteristics of RM mills with those of ball mills with continuous cycle and horizontal axis, which are suitable for this application, we can see that the specific energy consumption referred to "t" value of product is usually below 15 % for RM mills with respect to ball mills with horizontal axis. This advantage decreases slightly for machines with power higher than 132 kW and particle size below 37-44 μm , while the advantage increases gradually with the decrease in the fineness of the product. Absolute number cannot however be determined as the specific energy consumption (kWh/t) changes according to the type of glass, humidity and the presence of extraneous elements. The energy density (kWh/m³) of vertical axis mills is 12 times the energy density of horizontal mills; the volume refers to the gross volume of the grinding chamber. This aspect translates in the need for: greater economic commitment, larger space and greater foundations required for the construction of a plant with a horizontal axis mill. [2]

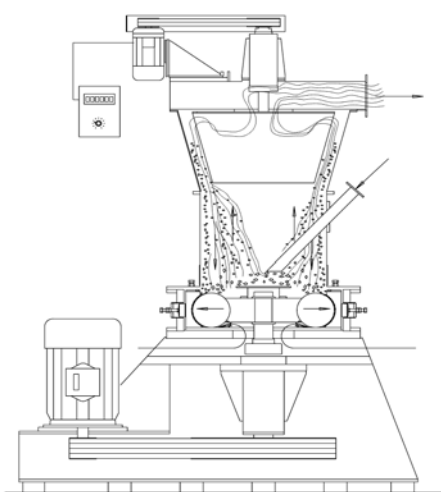


Figure 2: centrifugal ball mill RM

4. Drying the recycled glass

The glass is rarely sufficiently dry when reaching the production facility and it must be dried at least to about 0.5 % in order to be able to separate extraneous elements. The thermal energy dedicated to the drying process is not lost, because after the mixing phase the glass enters the ovens. Usually the flat glasses do not have high moisture content, but the hollow glass, if transported and stored outdoors, can reach to 7 % moisture. When the humidity is too high for the treatment to which the glass must be subjected, we recommend to install a separate dryer before the above processes. If the humidity does not exceed 4-5 % a recent trial performed by Ehinger Impianti technology department has shown that it can dry out and separate the glass from impurities in the MUD separation crusher without compromising the separation process, with a specific energy consumption of approximately 1 kWh/kg of evaporated water. In cases in which the glass is already clean when delivered to the factory, processing with the MUD system is avoided and it is more convenient to dry the glass during final refining with the RM mill. The energy consumption when drying the glass during the refining process is slightly lower.

5. Production and application of Foamglass granulates

Like many other materials glass finds beside its original use new ranges of application if there is a possibility to produce a glass matrix with defined hollow cavities. Not only material is saved and the density is considerably lowered, a new material originates with partly unexpected properties and completely new application possibilities [3]. With the foamglass products current in the market we can make a mayor difference between three types.

Table 1: Foam glass products

Foamglas®	Foam Glass Gravel	Poraver®
lightweight, insulating blocks and panels	loose foam glass aggregate	expanded glass beads

Foamglas® is a lightweight, rigid insulating material in shape of blocks and panels [4].

Foam Glass Gravel is a loose foam glass aggregate. It is produced continuous in a conveyor furnace and after cooling broken into bulk pieces and sized [5].

The third type is Poraver® expanded glass beads, his production properties and applications are shown primarily in the following report [6].

The production of foammglass requires the following raw materials. Glass powder from glass cullet, as well as binding agent and expanding agent.

Binding agent: for the solidification of the green grain made of the cullet glass flour both organic and inorganic binding agents are suited. These binding agents have to be able to create during the mixing and granulation process a grain as solid and as dust free as possible for the further treatment. From the inorganic binding agents especially those of the alkali silicate group and the solutions made of them are suited. In their basic composition they mainly consist of the main oxides of glass. Based on long-term trials and experience, for the Poraver production a modified soda water glass is used.

Expanding agent: If a powdery mix of cullet and binder is melted and this process is stopped at approx. 1,000 °C, a non-refined, grey-opaque glass spotted with gas blisters will be the result. If substances, which are defined in form and amount, and which disintegrate during the temperature increase due to oxidation, reduction, splitting or evaporation, are added to this mix, the result will be foam glass. Materials which in addition are used are carbonates (limestone, sodium carbonate), Nitrates (sodium-, potassium nitrate), sulphates (gypsum, sodium sulphate), organic material (sugar, coal) or metal (tin, zinc). With all these substances it is important that the properties of the basic glass are not changed or by a later application reaction products set up problems (blooming and cracking).

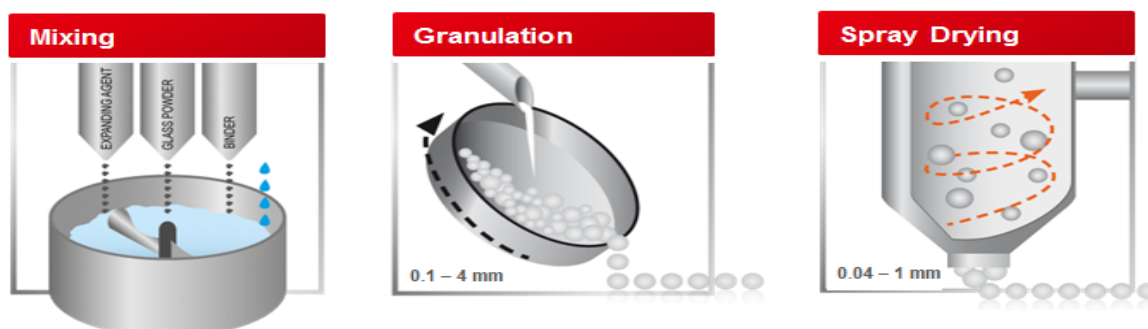


Figure 3: Mixing and agglomeration production processes

As the grain size range of Poraver® extends form 0.04 mm to 6 mm, in five standard and two special grain sizes, two different procedures are foreseen for a targeted and economical production of granulate.



Figure 4: Granulate sizes

The first process is carried out by a granulate mixer with subsequent granulating pan. In the mixer, the glass flour necessary for forming a grading curve is feed over a measuring device into the also measured already pumped-in slurry and mixed. Slurry is a watery solution with 38 to 50 % humidity content, consisting of certain amounts binding agent, expanding agent and glass flour. The humidity of the mass able to granulate has to

have a range between 17 and 19 % wt. From the mixer the primary granulate processes to the granulation dish where the mass starts rolling, which leads to a solidification, rounding and the desired increase in size of green grain (is the non-expanded raw granulate). For being able to handle the green grain in the further process run, its drying to less than 0.2 % rest humidity is necessary. The plate granulation's advantage is its large range of granulates and the big capacity.

A second method to produce green grain is spray drying. In spray dryers the slurry in feed is carried out by adjustable high pressure membrane pumps to the dispersion nozzles. Under a pressure up to max. 60 bar the suspension (slurry) is splitted in fog-like drops and is sprayed into the drying tower against gravitation and against the hot gas stream. Air guide arrangements give a twist-effect to the hot air and regulate the stream inside the tower. On the way to the return point the humidity in the drops evaporates and leaves a green grain with a nearly ideal ball shape and very proportionate surface.

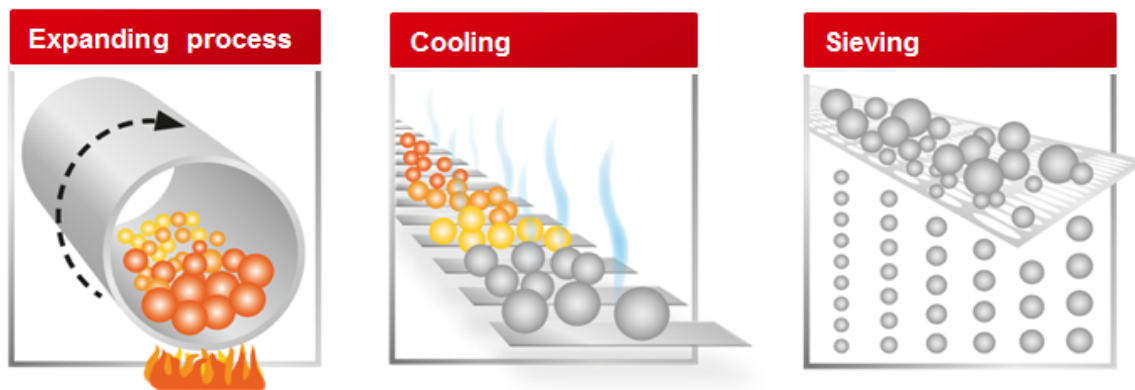


Figure 5: Expanding, cooling and sieving processes

During the process of firing, several different chemical and physical reactions take place, in the course of which the green grain is transformed. Poraver® with its typical characteristics is created. Also in this part of the manufacturing process it is possible to exercise a regulative influence on the later material characteristics and reference values like casting density, raw density, strength and chemical resistance. The foaming ovens are rotary kilns, working according to the counter-stream principle. The temperature inside the oven is measured and controlled automatically. By the burning gases energy and the flame's radiation, the granulate gets more and more heated up during the oven passage; from approx. 600 °C on, the raw materials start to react, gets viscous and sinters. Then the expanding agent reacts and forms gas. Due to the particles' sintering, this gas cannot escape and causes the forming of pores. Only the homogeneous mixing of the raw materials during the green grain production leads to an optimum pore structure. Between 800 – 900 °C an optimum in respect to the number of pores, their size and the thickness of the cell intermediate walls is achieved (lowest casting weight at max. strength). The oven content (PORAVER + separating agent) falls from the oven into the cooler. In the cooler's whirl bed the granulates are cooled down to less than 100 °C. Separating agent: to avoid that the glass granulate did not stick together under heat impact during the firing process, the use of a separating agent is necessary. Separating agent is an inert material which hinders the sticking of the weakening glass grains during the foaming process. Different raw material substances, e. g. lime stone flour / talcum, kaolin, white burning clay, can be used.

6. Actual Applications and new development

Its numerous benefits make Poraver® expanded glass granulate a proven lightweight aggregate in advanced building products and industrial goods. Among others, it is used as a lightweight aggregate in dry mortar, tile adhesive, lightweight concrete, acoustic and lightweight boards, mineral casting or as thermal insulation material [4].

For the further advancement we are working with new compositions to reduce the long time water absorption. First results indicate that it is a possibility to reduce 7 days water absorption from about 40 to 17 % (Vol.).

Magnetic foam glass particles (MFGP). The use of microorganisms is highly versatile. Processes employing microorganisms are important for the production of biofuels, biogas as well as for chemical raw materials or fine chemicals. It is attractive to recover microorganisms with long generation times and high values, e.g. immobilized as a biofilm on a suitable carrier. One special case is the use of magnetic particles as carriers for microorganisms, which allow an elegant separation and recovery of the immobilized microorganisms with

magnetic fields. The formation of stable biofilms on the particles is a necessary premise for this purpose. MFGPs with particle sizes in the range of 0.1 mm up to several mm were developed as new carriers for microorganisms. The density can be adjusted by appropriate modification of the production process. For applications in biogas reactors a density of approximately 1 g cm⁻¹ is preferred to achieve a homogeneous distribution. The MFGPs were investigated by means of two identical laboratory scale fermenters operated with sugar beet silage as a sole substrate under mesophilic conditions. One fermenter was loaded with MFGPs, whereas the second fermenter was used as a reference without magnetic particles. Both fermenters were operated parallel over several months with an increasing organic loading rate. The formation of stable biofilms on the MFGPs was shown to have a notable effect on the process performance. The colonisation of the particles with biogas producing bacteria was proven by light microscopic techniques.

7. Conclusions

The results reported are obtained both from research carried out at trial level and from the experience achieved during the design phase and the operation of the plants. Please note that given the nature of the raw material and the various applications of the end product, it is necessary to examine the whole process from time to time. Therefore, engineering development evolves parallel with the development of the product and vice versa. Considering that the end product provides a significant contribution to environmental sustainability, it is obvious the strong connection with the energy-related aspects of the process. The foam glass in its different physical forms is a product for the protection of the environment, now widely used for the significant performance it offers. The experimentation in progress are showing that the use of foamglass in other sectors can contribute to the environmental and economic sustainability.

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