

GLASS, GLASS TECHNOLOGY AND MANUFACTURING PROCESS

Summary of the material for the **GLASSCUTTER** educational programme



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1 GLASS

Glass is a hard synthetic material, which is produced by cooling melt and is in an amorphous (non-crystalline) solid state (Bek 2008, 20).

Glass is a product of melting silicon dioxide with other oxide alloys and is hard and fragile at room temperature.

1.1 Materials

Usually raw materials for glass production come in shape of salts/have salt structures which disintegrate at melting temperature. We divide them in two large groups:

- base materials (glass makers, melts, stabilizers) and
- Auxiliary materials (fining agents, dyes, discoloration agents, opal glass and melting accelerators).

The basic materials for glass production are:

- quartz sand (silicon oxide (SiO_2)),
- soda (sodium carbonate (Na_2CO_3)),
- limestone (calcium carbonate (CaCO_3)),
- potash (potassium carbonate (K_2CO_3)),
- dolomite (calcium magnesium carbonate ($\text{MgCa}(\text{CO}_3)_2$)),
- crushed glass forms 25-30% of the whole mixture and has to be of the right size; the crushed glass pieces must not be too large and also not too small, since the latter make the clarification process more difficult

Auxiliary materials are added to basic materials:

- *Materials for glass discoloring and clarification of glass mixture (manganese dioxide),*
- *Materials for coloring* are metal oxides,
- *Materials for opaque glass texture* (titanium and zirconium oxide).

To be considered as an ingredient for a specific technological process, material needs to meet the following conditions (Bek 2008, 22):

- it has to contain a high percentage of compounds, which serve as part of a new matter being produced,
- it has to have a constant chemical composition,
- it has to contain the lowest possible amount of impurities, which could harm the quality of the product or make the production procedure more difficult,
- the supplies need to be large enough to allow an undisturbed production for a long period of time,
- the price must ensure profitable production.

Materials for glass must be of suitable grain size of 0,1 – 0,3 mm.

1.2 Glass types

We know sodium, quartz, lead, borosilicate and potassium glass types.

Sodium glass is common glass and is mostly used for glasses, bottles and window glass. It melts easily and softens at temperatures of 500 to 600°C.

Quartz glass is used for halogen lightbulbs and ultraviolet microscopes. It is made without any additives. It has a very low elasticity coefficient, which means it does not break at high temperature changes.

Lead glass is used for optical objects. It is difficult to melt.

Borosilicate glass is used in laboratories and households due to its resistance to temperature changes and chemicals.

Potassium glass is used for test tubes as “Bohemian crystal glass” and “crown glass” for optical devices. It’s hard to melt, since the melting temperature needs to be 700-800°C.

1.3 Chemical and physical properties of glass

Amorphous (non-crystalline) materials like glass lack any long-range translational periodicity and possess a high degree of short-range order (“super cooled liquid”). Therefore, the melting point is not fixed, with softening occurring in wider temperature ranges. The glass melting point is between 500°C and 1650°C, depending on its structure.

Glass can be shaped with different techniques like blowing, rolling, stretching and casting.

It is hygienic since it does not assume any flavor the taste of its content. It also has no odor; its surface is smooth and easy to clean. Glass also does not let any gas through its surface.

Under low loads it reacts in elastically, while it crushes under heavy loads. Glass also acts as an isolator and conducts heat poorly. It is resistant to almost all chemical impacts.

1.4 Glass production and processing

1.4.1 Chemical production and processing of glass

The main ingredient of glass is quartz, also known as silicon dioxide (SiO_2). Sand acts as glass foundation, by creating a glass web, with the help of color oxides. Due to coloring factors of color oxides, sand can only contain 0.01 – 0,03% of iron oxide. Quartz is the main ingredient of almost all types of glass and it sets the basic properties and structure of glass.

To make glass production cheaper, sand is mixed with additives like soda (Na_2CO_3). This lowers the high melting point of the quartz.

Limestone (CaCO_3) is added to sand and soda to increase structural integrity and chemical resistance.

1.4.2 Technical production and processing of glass

Waste glass is added to finely grinded materials in quantities ranging from 20-50%. This mixture is then melted in the furnace by generator gas. The melting procedure is vital for the later purity of the glass.

After sintering – i.e. the compacting and forming of the material, which causes the formation of gases, the mixture becomes a non-homogenous mixture full of bubbles. Bubbles disappear during the purification process. In the end, the melt is cooled down to approximately 1100°C , which increase strength and enables further processing.

2 BATCH PROCESSING SYSTEM (BATCH HOUSE)

2.1 BATCH HOUSE DESCRIPTION

A batch house is a plant made for storing and preparation of the glass mixture. It contains large (15 or 24 m³) or small (7 m³) siloes. Siloes are cone-shaped, with a pipe attached on the bottom. The pipe contains a snail or vibrator for the transport of the mixture towards the scale. Under the siloes there are three scales (the smallest has a capacity of 24kg, the largest of 500 kg) and five dispensers (with an ability to dispense from the same scale to different dispensers to ensure accuracy). Dispensers are emptied into the mixer, which is then emptied into iron containers with a capacity of 500kg. Iron containers are used to deliver the mixture to the furnaces. The procedure is fully automated, but can be operated manually in case of a malfunction.

2.2 Materials and shards

Table 1: Raw Material names

Symbol	Name	Old name
SiO ₂	Silicon dioxide	Quartz sand
PbO	Lead oxide	Litharge
K ₂ CO ₃	Potassium carbonate	Potash
Na ₂ CO ₃	Sodium carbonate	Soda
KNO ₃	Potassium nitrate	Saltpeter
Sb ₂ O ₃	Antimony trioxide	
BaCO ₃	Barium carbonate	
ZnO	Zinc oxide	
Na ₂ B ₄ O ₇ * 5H ₂ O	Sodium tetra borate pentahydrate	Borax
CaCO ₃	Calcium carbonate	calcite
Na ₂ SO ₄	Sodium sulfate	

The raw materials can be divided in different ways. One possible division is:

1. **Basic materials;** include substances that form glass (sand), and materials that enable melting at lower temperatures and provide stability to glass.
2. **Materials for glass fining;** their task is to remove all gas bubbles from the glass melt and to make glass melt homogenous (even) with help of mixing procedure.

3. **Glass decolorizers**; materials used to remove colors from glass caused by iron alloys, which create blue or green shade in glass. They can be processed in a chemical or physical procedure. Physical decolorization provides complementary colors. Green color provided by iron oxide, is neutralized by adding oxides that produce red, blue and purple colors. This provides glass with colorlessness. The main source of iron is crushed glass, since it gets contaminated with iron during the transport from the batch house to the furnace, and during the crushing procedure in mills. Chrome presents the biggest problem with colorization, since even the smallest quantities produce strong glass colorization. It also can't be removed with magnets, used for removal of iron from shattered glass. The source of chrome can be glass molds.

3 GLASS MELTING FURNACE

3.1 Chemical procedure of melting

The melting process can be divided in different phases:

1. Silicon shaping; temperatures from 00 - 400°C, water evaporation (moisture from mixture, crystal bound water), disintegration of carbonates and sulfates, chemical reaction of alkali with quartz sand. The powder mixture becomes an opaque sintered mass which looks of hard foam,
2. Glass forming; temperatures from 1100 - 1200°C, silicates melt completely; remains of sand that have not reacted disintegrate. This procedure takes 60 -70% of the whole melting time; each raise in temperature shortens the process; materials for melting acceleration disintegrate into gas, which mixes the melt.
3. Glass fining; the process of removing gas bubbles takes place at temperatures of 1400 -1500°C; the bubbles result from the air present in the melt, carbon dioxide, sulfur dioxide, oxygen, nitrogen and water vapors; the bigger the bubbles and the more fluent the glass, easier it is to fine the glass; other factors that are important at this stage are the temperature, time, mixing and additives;
4. Glass forming; occurs at same time as glass fining; important factors for this process are the temperature and elimination of bubbles.
5. Molten glass needs to be cooled down to a temperature acceptable for further processing; it has to be cooled down gradually to prevent gas disintegration. Melt needs to be thoroughly mixed to ensure adequate homogeneity (without vind).

3.2 Physical processes in the furnace

In addition to chemical reactions, there is a series of physical processes needed to form glass. Batch charger feeds furnaces with constant flow of mixture, after the process melt is removed at withdraw stations. Between these two procedures there is a constant flow of the melt, due to differences in the melt weight and temperature differences in different parts of the furnace. The highest temperature position (dew point) and the movement of flows depend on the temperature curve in the furnace. Gas bath furnaces are heated with natural gas through burners. The highest heat intensity is in the area of the flame. For this reason, it is desired to have the shortest flame possible to ensure short combustion time, higher temperature and a better heat transfer. If the flame is too long, the furnace walls can be damaged. To prevent contact between different flames, opposite burners are shifted. Flame must not be pointed towards glass melt.

The powder mixture conducts heat poorly, its surface is covered with a layer of melt, while heating of core is slowed down. With prolonged exposure to heat, the melt becomes more heat-conductive and increases in size. A movement of melt occurs on the surface due to higher temperatures. Foam forms on the surface of the melt, towards the end of the process, but disintegrates at higher temperatures and the melting process is completed. A glass fining process follows, with the highest temperatures in the whole process. Simultaneously, a homogenization process is active to ensure even melt.

At worksites melt needs to be cooled down properly. This is ensured with the use of agitators, to prevent the forming of new flows for temperature transfers.

3.3 Silo and feeder

A constant level of mixture needs to be maintained in the silo to prevent stratification. It should be thermally insulated, to remove temperature influence from the furnace, which could cause a mixture reaction in the silo. A vibrator is located underneath the silo to feed the conical sink of the feeder. The sink has a mixture level measuring device to signal the vibrator to feed more mixture into sink. A hydraulic cylinder is located underneath the sink to push the mixture onto a spoon (fireproof plate that connects the feeder with the furnace). With the regulation of hydraulic cylinder speed and amplitude fluctuations, the amount of mixture feed to the furnace can be changed. The hydraulic cylinder is connected with the glass melt level gage, which provides a signal according to the melt level fluctuation. If the level is too low, the

hydraulic cylinder pushes the mixture with a set speed and stops when the desired level is achieved. The feeding device spoon is cooled with soft water; in case of power shortage it can be cooled with tap water. The feeding device sink can get stuck due to wet mixture or to large glass shards. Feeding can be operated manually.

3.4 Melting space

A carpet mixture layer is a non-melted mixture at the entrance of the furnace (next to the feeding device). To provide good melting conditions, the carpet needs to be thin and wide along the whole length of the furnace. It is created by adding cold mixture to the procedure, which causes slower melting of the mixture and ensures better quality of the glass. The carpet mixture does not exist, if the temperature is set too high or if there is no output from the furnace. If the carpet is too long or too short, this indicates that there are irregularities in the furnace operation.

3.5 Temperature regime- burner settings

The glass mixture needs to be heated to the melting and fining (highest) temperature, then slowly cooled down to the work/working temperature. The temperature layout in the furnace is regulated with settings of burners. Fuel used to power burners is natural gas due to its low ecological imprint.

3.6 Workstation

The glass melt proceeds towards workstations. Flow physically separates the melting room from workstations and enables the cooling of the melt and at the same time enables flows to travel in both ways. Furnaces are distinguished according to the number of workstations and their size.

3.7 Recuperator

Next to the furnace there are two recuperators. They act as an intake for smoke gas from the melting room and travel from the top towards the bottom. This transmits heat, which flows in the same direction (counter flow would heat the top of the recuperator too much, which would demand for higher quality construction material of the recuperator and that would increase investment costs, it would, however, lead to higher efficiency). The temperature of intake gases is around 1400°C.

3.8 Cooling

There are a water-cooling system and an air cooling system installed.

The water cooling system operates in a closed circuit and uses soft water. It is used for cooling the feeder device spoon, drainage opening, agitators and level measuring system.

Air is used to cool the wall next to the feeder and to cool down the bottom and sides of melting room.

3.9 KP1, KP2 and KP3

All information listed above is generally used for gas furnaces. All three furnaces are continuous tub furnaces. They use natural gas for heating. The melt is moving around due to currents caused by heat differences.

3.10 Ceramic kilns

In ceramic kilns the process is led batch wise. The melting process is also different from the process in continuous furnaces, mixing is done mechanically.

3.11 Electric furnace

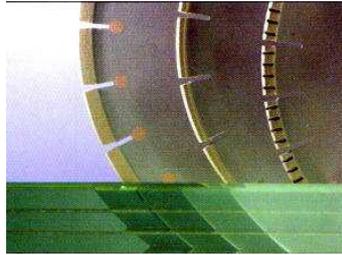
In this type of furnace the chemical reactions to produce glass are the same as in gas furnaces, the only difference in comparison with gas furnaces is in the process of melting. Here, melting is done in a vertical direction, instead of a horizontal process of a gas furnace. The vaporizing process is much slower than in gas furnaces. Electrically heated furnaces and canals are using released heat, based on a Joule effect reaction. This is achieved by submerging electrodes directly into the melt. Glass acts as user and electrical current causes temperature to rise; this result in the melting and fining of the mixture.

4 COLD TREATMENT OF GLASS

To satisfy one out of three conditions for “consumer satisfaction”, we need to make sure our products achieve the desired quality.

To achieve these levels of quality, work has to be done as follows:

- Hot and cold treatment of glass needs to adapt to the acid polishing process resulting in short programs using weak acid. This type of acid polishing results in sharp edges and high quality surface.
- Products need to be treated with proper grinding materials according to programmes.
- Products are processed with following abrasives:
 - Diamond saw



- o Diamond plate



- o Diamond “plano” plate



- o Diamond cones



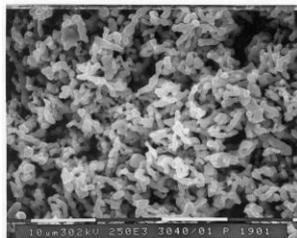
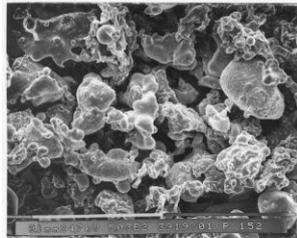
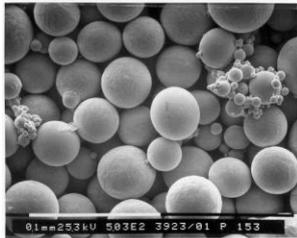
- o Sanding belts
- o Polish belts
- o Vidia wheels
- o Diamond discs
- o Fine sand used for sanding (SiC)
- o Grindstone
 - Natural stone,
 - SiC,
 - Noble corundum
 - Natural corundum- Al₂O₃.

4.1 Diamond discs

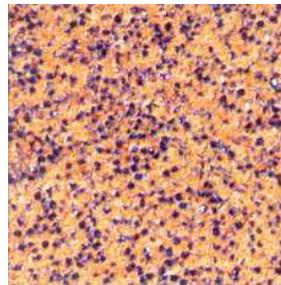
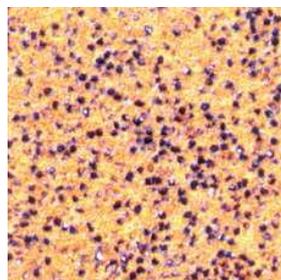
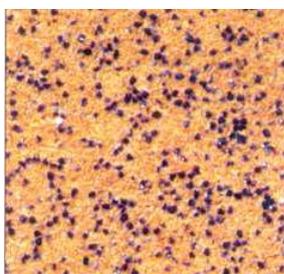
Diamond disc are designated for product cutting, decorative sanding, edging, drilling and outlining.

Specification of diamond discs:

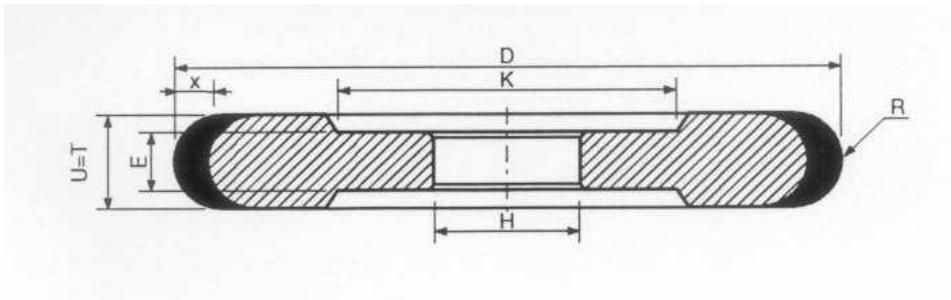
- Granulation: D-25, 39,46,54,91,107,126,151,181,252,301 in 427. Size of grains is measured in μm (10^{-6}).
- Binders: bakelite, metal and galvan.



- Concentration C-15 – C-200. Concentration means number of diamond grains per cm^3 .



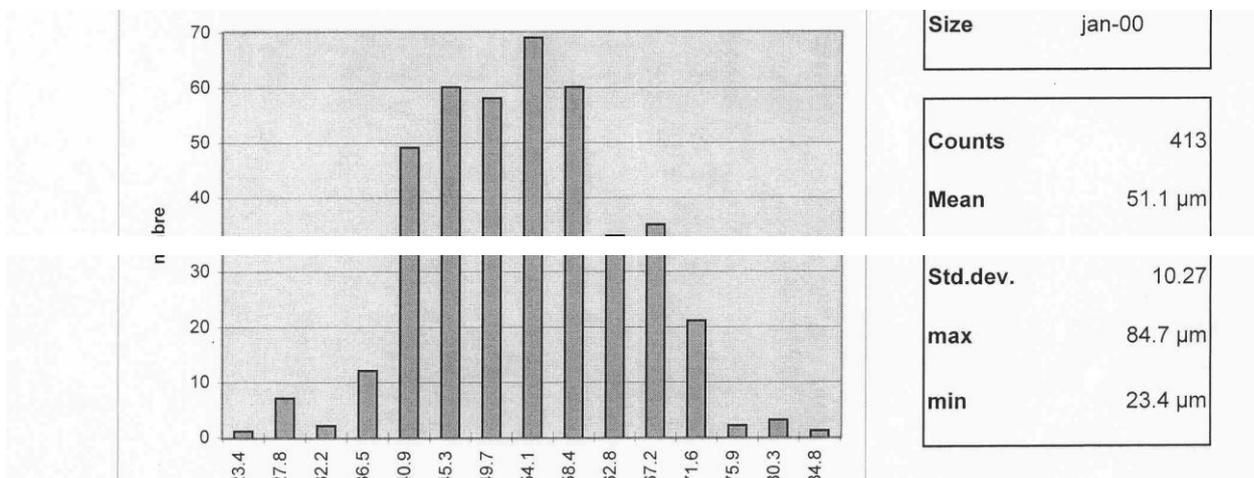
- Profiles: angular ($85-140^\circ$), radius (R-5,8,10,16,20,30,50,60), straight.
- Types: 1EE1, 9EE1, **9FF1**, 14EE1, 14FF1.



- Holders: metal, grey alloy and aluminum

After sanding with diamond discs, we need to consider:

- o Same size diamond grains percentage should be as big as possible (gauss curve).



- o Peripheral speed, recommended 20m/s,
- o Engine power,
- o Cooling of diamond discs,
- o Proper recovery.

Manufacturers of diamond discs: SWATY, WENDT, VIP BOHEMIA, WINTER, EFFGEN, DIAMET.

4.2 Sanding belts for glasscutting

Sanding belts are used for cutting or cleaning the glass surfaces that were previously cut with diamond discs. There are different types of sanding belts for wet and dry polishing.

Specifications of sand belts used are:

- Sanding material: SiC in corundum
- Granulation: P-100,150,180,220,240,280,320,400.
- Linen:
 - o Dry sanding:
 - JA 165 AA
 - JA 344 AA
 - K35 SF
 - J FLEX
 - RB X- FLEX
 - U-243
 - o Wet sanding:
 - KT 62 W
 - SU 42 R
 - RB 555X KORK
 - 217 EA
 - 237 AA
 - 272 LA

Suppliers of sanding belts are: EMEND, COMET, EKAMAND, BOHR, HERMES, TRIZACT

4.3 Finishing of glass products

Finishing of glass products includes the following phases:

- Cap cutting,
- Bottom sanding,
- Top sanding,
- Outer and inner trimming,
- Bottom trimming,
- Bottom and top polishing,
- Melting down the edges.

Machines for finishing of glass products:

- POLY-12 injecting programme for shoulder cutting and sanding of bottoms;
- TR-3 for cap cutting and sanding of tops and trimming;
- GS-4 for bottom sanding;
- COMBI 12 (new bibok) for cap cutting and top sanding, mostly for glasses and challises with up to 3 mm thickness;
- COMBI 6 and COMBI 6 LASER for cap cutting and sanding and trimming of tops;
- PLANO MACHINES for sanding of tops and bottoms;
- HORIZONTAL AND VERTICAL SANDING MACHINES: for edge sanding;
- SANDING MACHINES inner edge sanding;
- GLASS FUSING MACHINE for flame polishing of edges.

Sanding materials for finishing glass products in cutting:

- Diamond discs, D-15/30,39,46,54,64,91,126,151,181,252 and 301. Dimensions: 150x30x10
- Flexible diamond discs D-25,39,46 in 64. Dimensions 200x30/40x0,5
- Diamond cones D-39 in 46. Different cones: 25,45,120
- Sanding powder: SiC – P-120,180 and 240
- Polish sand: Float and CER Oxide
- Sanding belts: P-220-P400
- Polish belts: KORK.

Treatment demands:

- Sanding within tolerances,
- Parallelism of top and bottom,
- Smooth surface without marks,
- Even edges,
- Stability.

4.4 Hand glasscutting

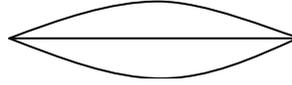
Elements:

1. Labeling

- All products for hand cutting need to be properly marked. Horizontal and vertical lines are marked, so worker knows what sample is designated for a specific product.
- Markings can be also made with plastic, which has guidelines samples.
- Straight surfaces are marked with the help of screen printing.
- Waterproof markers in green color are used for labeling.
- Errors:
 - Lines are too thick
 - Uneven division of vertical and horizontal lines
 - Low quality of markings, resulting in mark wipes during cutting.

2. Grain pattern

- Grain patterns are made with cutting discs, with side profile. They are shaped by applying pressure on the disc. The size and profile of discs determine the size and shape of grain patterns.



- The grain pattern can be bigger, but for that the product needs to be pressed and pulled across the sanding disc.
- Materials:
 - Diamond discs, granulation D-39,
 - Artificial stones, normal corundum NK 120.
- Profiles:
 - Angular, od 90-140°.
- Errors:
 - Uneven size of grain patterns,
 - Grain patterns that are sanded sideways or uneven in shape,
 - Double lines in middle of grain pattern,
 - The profile of sanding discs is worn-out, resulting in a non-existing middle line or too rounded edges.

3. Circle

- Circles are cut with discs with radial profile. They are created by applying pressure. Size and radius of disc set the circle size. It always has to be round.



- Materials:
 - Diamond disc, granulation D-39,
 - Artificial stones, normal corundum NK 120.
- Profiles:
 - Radius , R 20-60.
- Errors:
 - Uneven size of circle,
 - Cuts, transition is noticed,
 - Circle is not round but oval.

4. Leaf

- Leafs are made with discs, which have angular or straight profiles with 45° edges. Leaf contains shape of bottom, belly, and top. Leafs are shaped with applying pressure to disc and pulling it through up and down.
- Materials:
 - Diamond disc, granulation D-39,
 - Artificial stones, normal corundum NK 120.
- Profiles:
 - Angular, from 130-140°,
 - Straight, edge cut at 45°
- Errors:
 - Uneven size of leaves,
 - Leaf cut too deep,
 - Leaf shape is not correct with errors.
- Profile of sanding discs is worn-out, resulting in leaf with correct peaks.

5. Cutting of straight and curved lines under and above the cut

6. Precutting and smoothing of cuts

7. Precutting and smoothing of crosses

8. Precutting and smoothing of a star on bottom

9. Precutting and smoothing of net

10. Precutting and smoothing of edges

11. Precutting, cleaning and smoothing of pedestal

12. Cutting of the star on 16

13. Cutting of brilliant net, net on 8

14. Plaid net on 8

15. Plaid net on 16

16. Plaid net on 4

17. Mechanical polishing

18. Brushing the sharp parts with specific textiles

These processes are made with following materials:

- Diamond discs with different angles and radiuses, granulation D-25, 39,181 and 252.
- Cutting belts, P-240, 280, 320 and 400.
- Stones, noble and natural corundum.
- Diamond saw D-107 and 181.
- Cutting wheels POLPUR-
 - Pink, violet, orange, green, black, blue in white.
- Polish sands.
- Float and cerium oxide.

Processing demands:

- Appropriate peripheral speed
- Correct recovery
- Sharp cutting discs, servicing on time
- Steady discs during cutting, appearance of burned edges
- Appropriate cooling, enough water supply

Errors:

- Edging,

- Footing repairs are made with diamond disc D-39. The transition between straight part and round shape needs to be cut with belt P-400 for water cutting.
- Olives and edges are sanded by hand and cleared by belt P-400, with the technology of water or dry cutting.
- Products treated by hot processing, need to be cleaned by belt P-280; round surface and P-400, wooden belt RB 300, P 100 and TRAZACT- straight surface or polpur wheels LAPI.
- Challises and glasses with scissors marks, uneven surface, mechanical damage or dots are cleaned with belt P-400(stronger polishing) or wooden belt (WWRD). The same applies to the cleaning of bottoms.
- Faults in challises or glasses in the inner part are cleaned with polpur wheels “ORANGE”. Faults in the inner parts of vases or bowls are cleaned with belts P-400, wooden belts RB 300 P-100 and blue and grey belts TRAZACT.

- Products need to be cleaned before acid polishing.
- Products are separated based on type of polishing process, they are divided into different classes, noted in working tasks with specified procedure of polishing.
- Products with faults after acid polishing are fixed mechanically with wooden belt RB 300 P-100 and polpur wheels LAPI ORANGE, cutting belts Trazact A05 and with sand cerium oxide FG-50.

5 QUALITY CONTROL

5.1 Definition of quality

Different sources define the meaning of quality in different ways. One of the more practical definitions is: “in accordance with the demands”. Considering that glass products are mostly made by hand, it is hard to determine the exact demands. Due to this reason, quality is defined by “the maximum allowed”.

Standard ISO 9001:

Quality is a degree at which the combined characteristics of a product meet the quality demands.

Demand is the need or expectation of buyers.

Demands are stated in a general acknowledged way (product for storing liquids can't have holes) or as requirements. Mandatory requirements must be set in a way that is easily understandable (dimensions, samples, etc.) and need to be acknowledged in a comprehensive way by the production. Quality checks have to be performed throughout the whole process (inter-phase check) and at the end of the process (final check). All products that do not meet the requirements need to be excluded.

Characteristics are features that define a product and can be checked.

5.2 Characteristics

Quality of our products is achieved by:

1. **Glass quality:** defined with color of the glass, quantity and size of bubbles and stones “vind”
2. **Shape and dimension of the product**

3. **Pattern on product** (in structure, sandblasted, sanded, drawn): layout, dimension of the pattern(height, width, angle of sanding), composition of the pattern
4. **Product functionality**
5. **Surface of the product**
6. **Equipment of the product**

For each of the characteristics exact requirements must be set. All demands that variate from the acknowledged one are considered as errors and products must be discarded. Below you can see typical characteristics and errors that occur during production in industry like ours.

5.2.1. Glass quality

During the process of melting and shaping of the glass (preparation of mixture, transportation, hot molding), different faults can occur in the glass. Quality of the glass is defined with maximum allowed number of faults and their size. Possible faults: stones, bubbles, vind.

Stones

Hard bright dots inside the product, caused by irregularities during the preparation of the mixture (white dots), crystallization during the melting process (glass like dots), disintegration of fireproof materials from the furnace structure (white, brown, red dots), fall of the agitator shaft into the workspace (dark dots). All these faults occur locally on some products. In case of an irregularly melted glass mixture, faults can be noticed on all workspaces and products, accompanied with small bubbles and vind.

Pebble or inclusion in the glass can be formed as result of incorrect treatment. They are of dark (black) color, and are caused by metal shards from:

- rust on blow pipe,
- blow pipe made from incorrect material,
- rust on bowl for pipes for vacuum gatherer (can be seen after polish),
- bright pebbles are results of glass particle that are attached to the product during processing.

Bubbles

Bubbles can be formed as a result of bad melting of the mixture- glass fault and as a result of incorrect processing- glass fault. If they are result of bad melting, bubbles occur on all products. They are of small in size and spread throughout whole product. Bubbles can be formed by agitators that are very old or due to their too high rotation speed. They can also be the result of the reboil process. Bubbles are considered as a fault, when their size is over 1mm and they can be found only on one part of the product.

Vind

Is a line or an area on the product with different angles of refraction.

Vind faults are caused by:

- a new furnace- reaction between glass and fireproof materials of the furnace (can happen with old furnaces also),
- fault during mixture preparation,
- inadequate temperature regime of melting,
- an increase in take out of the material,

- take out fluctuations.

Vind can also be result of a fault during processing of product:

- accumulation on old cooled glass,
- accumulation on edge of workspace,
- incorrect position of fireclay ring in the pot
- uncleaned glass surface in the pot.

Vind that is a result of faults during processing occurs only at separate working brigades and not on the whole process lines. Vind is always present in the pot and on workspace, but can be avoided by correct handling.

Color

Color is compared with standards. Glass can be colored due to the presence of metal oxides that are present in materials, glass shards or as a result of small trash particles. Glass is usually colored green or blue.

Over cooling

During the process of hot molding, high tensions are formed throughout the product. This can result in product failing, during the process of cooling or during sanding and polishing. It can also happen during the usage of product. That's why it is important that products are cooled correctly and that process is daily monitored.

Proper tension decrease can be checked with the help of polarized light on the polariscopic machine. This needs to be done daily, by using random test samples from production line. Products can also be tested by using SHOCK tests, which are performed in a lab.

5.2.2. Product shape and dimension

The product shape and dimensions are two very important characteristics and are used as basic guidelines for production. Dimensions are marked on the drawing of the product and have to be strictly set.

Dimensions can vary according to the product type: height, width, diameter of the bottom and top, diameter of the disc, thickness of the foot, edge, wall, etc. Tolerances have to be added to the median value of the dimension. This means that if product is made within tolerances, it is considered suitable.

Example: The height of the product on the picture is 187 ± 2 mm. The product height can be 185-189mm; everything below or above this height is not consistent and is discarded.

Weight is also an important dimension in the glass industry. The set tolerance for weight of hand made products is $\pm 15\%$, according to the median set weight and $\pm 10\%$ in machine production.

In order to avoid discarding of too many products, it is very important that the dimensions are checked in the starting phases of production.

