Research Group

InfoMine

Association of Independent Consultants and Experts in Field of Mineral Resources,
Metallurgy and Chemical Industry

Food Container Glass Market Research in Russia

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Annotation

The report is devoted to studying of current standing of Russian market of container glass for food industry. The report includes 7 Sections, 160 pages, including 70 Tables, 24 Figures and Appendix. The report is a desk study. As information sources, data of Federal Service of State Statistics (Rosstat), Federal Customs Service of Russia (FCS), State Balances of Mineral Resources, official domestic railage statistics of Ministry of Railways of Russia, data of company-leading players of glass market, the sector and regional press, annual and quarterly repots of companies, internet-sites of company-producers and consumers of the products, as well as own InfoMine database were used.

The first Section of the report is devoted to characteristics of current standing of world market of container glass.

The second Section presents technologies of production of glass, describes the main processes and available methods of obtaining container glass. The Section also presents review of Russian market of equipment for production of container glass, including description of leading Russian and foreign producers, presents performance specifications of production facilities, offered by the companies.

The third Section describes sources of raw materials for production of glass. The Section presents data on reserves quartz sands, carbonate raw materials and feldspar, data on volumes of production of the main components of glass charge, volumes and flows of supplies of these resources.

The fourth Section is devoted to analysis of production of container glass in Russia. The Section presents statistical data on production of the products for the period of 1997-8 months of 2007, description of commodity structure of production of container glass for food industry, regional structure of the production, and describes the main enterprise-producers of container glass with data on available capacities, volumes of production of the products in 2006, current standing and prospects of development. Besides the Section describes projects on construction of new container glass productions in Russia and presents forecast of production of container glass in Russia up to 2012.

The fifth Section presents analysis of foreign trade of Russian companies in container glass. It presents data on volumes of supplies of bottles and glass cans in bulk and in money terms, estimation of regional structure of export and import, volumes and flows of supplies of leading exporters and importers of the products.

The sixth Section is devoted to evaluation of domestic consumption of container glass for food industry. It presents supply-demand balance of container glass, analyses regional structure of the consumption. Besides, the Section presents data on dynamics of production volumes in the main end-uses and volumes of railage supplies of container glass to the greatest consumers.

The seventh Section of the report describes available tendencies of development of market of container glass for food industry and presents forecast of consumption of the products in Russia up to 2012.

The Appendix presents contact data on leading Russian producers of container glass.

INTRODUCTION

The standard definition of a glass (or vitreous solid) requires the solid phase to be formed by rapid melt quenching. Glass is therefore formed via a supercooled liquid and cooled sufficiently rapidly (relative to the characteristic crystallisation time) from its molten state through its glass transition temperature, Tg, that the supercooled disordered atomic configuration at Tg, is frozen into the solid state. Generally, the structure of a glass exists in a metastable state with respect to its crystalline form, although in certain circumstances, for example in atactic polymers, there is no crystalline analogue of the amorphous phase. By definition as an amorphous solid, the atomic structure of a glass lacks any long range translational periodicity. However, by virtue of the local chemical bonding constraints glasses do possess a high degree of short-range order with respect to local atomic polyhedra. It is deemed that the bonding structure of glasses, although disordered, has the same symmetry signature (Hausdorff-Besicovitch dimensionality) as for crystalline materials.

In the technical sense, glass is an inorganic product of fusion which has been cooled to a rigid condition without crystallizing. Many glasses contain silica as their main component and glass former.

In the scientific sense the term glass is often extended to all amorphous solids (and melts that easily form amorphous solids), including plastics, resins, or other silica-free amorphous solids. In addition, besides traditional melting techniques, any other means of preparation are considered, such as ion implantation, and the sol-gel method. However, glass science commonly includes only inorganic amorphous solids, while plastics and similar organics are covered by polymer science, biology and further scientific disciplines.

Glass is classified in accordance with its composition or designation. In composition, one- and multi-component glasses are distinguished. The most widespread of the glasses, dominating at current global market, is silica glass, composed of (SiO_2) exclusively (quartz glass) or with additives of some other components, providing special and improved properties of glass.

In designation, the following kinds of glass are distinguished:

- building (flat and architectural-building);
- container (glass jars and bottles);
- household (glassware);
- technical (optical, chemical-laboratory, medical, electro-insulating);
- glass fiber.

1. Characteristics of current standing of world market of container glass

Container glass refers to large-tonnage products. In common sense, to glass containers refer vessels for food products (bottles, jars), as well as medical (for packing drugs), perfumery and chemical (for storing chemicals) containers Notice that around 99% of total production of container glass in the world (in weight) belong to containers for food products.

Production volume of container glass can be estimated both in weight (kg, tonne) and in conventional bottles (as the conventional unit, a bottle of capacity of 0.5 l is taken).

By now in the world, a huge quantity of plant-producers of glass containers operate that is owed both by high demand for the products and rather simple process of glass containers manufacture and relatively low capital expenses on organising the production (compared with other kinds of glass).

From estimates of experts, in 2005 in the world, at least 60 mln t of container glass were manufactured that corresponded around 90%-utilisation of operating capacities. Taking into account that weight of bottles of volume 0.5 l is equal to 0.36 kg, one can say that the above-mentioned production volume is equivalent to around 167 bln of conventional bottles.

The greatest producer of container glass in the world is concern ***Owens-Illinois***, having 83 plants in 22 countries. The company is a leader in production of container glass in Europe, North and South America, Asian-Pacific Region. In USA the concern controls 2/3 of bottles market, whereas in the world it controls around a half of the global market.

Volumes of production and consumption of container glass ***in USA*** in 2002-2006 are given in Table 1-2. As seen from the data, in 2002-2004 in USA volumes of consumption of container glass decreased that encouraged leading American producers to penetrate into new emerging markets of the products, including Russian. For instance, in 2005 Owens-Illinois purchased large glass plant "Ost-Tara" in Moscow region.

Table 1. Commodity pattern of production of container glass in USA in 2002-2006 , bln pieces

Product	*Volume of production, bln pieces*					*Share in 2006, %*
	2002	*2003*	*2004*	*2005*	*2006*	
Bottles for beer	18.9	20.0	19.8	19.8	21.0	*59.0*
Glass containers for preserving and food products	7.1	6.8	6.4	6.1	5.8	*16.2*
Glass containers for non-alcoholic drinks	3.2	2.9	3.0	3.1	3.1	*8.8*
Bottles for liquors and alcoholic cocktails	3.2	2.2	2.3	2.3	2.2	*6.3*
Bottles for wine	1.8	1.8	1.9	1.9	1.9	*5.4*
Other kinds of container glass	1.6	1.4	1.3	1.9	1.6	*4.3*
Production, total	**35.8**	**35.1**	**34.7**	**35.1**	**35.6**	***100.0***

Source: US CENSUS Bureau

Table 2. Commodity pattern of consumption of container glass in USA in 2002-2006 , bln pieces

Product	*Volume of consumption, bln pieces*					*Share in 2006, %*
	2002	*2003*	*2004*	*2005*	*2006*	
Glass containers for preserving and food products	6.8	6.8	6.5	6.3	5.9	*16.9*
Glass containers for non-alcoholic drinks	3.5	2.8	3.0	3.2	3.1	*8.8*
Bottles for beer	18.7	19.1	19.6	19.7	20.4	*58.5*
Bottles for liquors and alcoholic cocktails	3.1	2.4	2.3	2.4	2.0	*6.1*
Bottles for wine	1.7	1.8	1.8	1.9	1.9	*5.4*
Other kinds of container glass	1.5	1.4	1.3	1.8	1.5	*4.3*
Consumption, total	**35.3**	**34.3**	**34.5**	**35.3**	**34.8**	***100.0***

Source: US CENSUS Bureau

European glass container industry demonstrated in latest 3 years moderate but steady increase of production volume. In the period of 1999-2004, volume of the production in bulk grew by 1.2% annually in average (in spite of decreasing the rate to 0.3% in 2003 that reflected overall negative tendencies in European economy). From expert estimates, volume of production of container glass in Europe in 2005 was around 19.0-19.5 mln t that corresponds to a third of total world production.

Many independent glass container producers operate in Europe, but the bulk of glass containers in the continent is manufactured by great holding companies, companies, the largest of which are:

- *Saint Gobain*, owning 18 enterprises, 6 of which are located in France, 6 – in Italy, 5 – in Germany and 1 – in Spain;
- European subdivisions of the greatest global glass container producer *Owens-Illinois* (12 plants);
- *VetroPack* (6 plants);
- *Ardagh Glass* (22 plant).

Glass industry of European countries is characterised by high technological level of the production, and a large share of produced container glass is exported from the region.

Active attempts to introduce plastic containers at European countries markets in latest years can not, nevertheless, oust glass containers from market of containers for food products. End-users – people – traditionally choose glass containers for food, considering it the most health and environment-friendly (that is actually true).

The main consumers of glass in Europe are large brewing companies (Heineken, Budweiser, Pauleiner and other), producers of champagne and wine, strong alcoholic and non-alcoholic drinks (Coca-Cola, Pepsi), as well as mineral water. Notice that some of such companies (for instance, Heineken), possess own glass container plants.

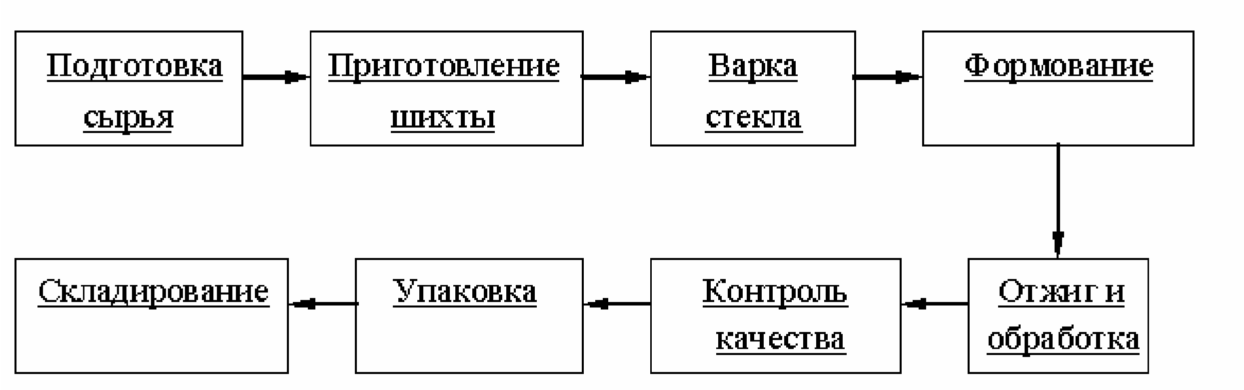
2. Technology of glass production in Russia and in the world and applied equipment

2.1. Technology of glass production

Glass is obtained by the fusion of several inorganic substances. The fused mass is cooled to ambient temperature at a rate fast enough to prevent crystallisation, i.e., the molecules cannot arrange themselves into a crystalline pattern. The fast rate of cooling to prevent crystallisation applies to transparent glasses.

Traditional process of glass production consists in preparing raw materials, making batch, melting glass in melting furnace, cooling glass melt, forming glass products, annealing and special treatment (thermic, chemical or mechanical); then the glass is subjected to inspection, is packed and stored (Fig. 1).

Figure 1. Typical process flow sheet of commercial glass production



Raw material preparation-Batch preparation-Glass melting-Glass forming

Storing - Packing - Inspection - Annealing and treatment

Source: GNIIS

Preparation of resources

The glass resources preparation is conducted at glass plants directly, including the following operations:

– Crushing and milling materials, arriving lumpy (dolomite, limestone and other);

– Drying wet resources incoming (sand, dolomite, limestone);

– Screening all the incoming raw materials.

Sand, arriving from concentrators, is subjected to screening only. After screening, all raw materials are fed to storage tanks (silos), from which they go to batching.

Preparation of glass batch

Glass batch is uniform mix of prepared and weighted to pre-set formulation raw materials.

At present time, glass plants prepare batch in mechanized shops, implementing complete cycle of operations on preparing and averaging raw materials, which include raw materials storehouse and batching-mixing bay. The bay is composed of feed hoppers of resources, a bay of transferring raw materials from storage tanks to feed hoppers and batching-mixing line, which includes automatic scales, mixers, conveyors and batch storage tanks.

The main stages of preparing glass batch are:

- batching components;
- mixing and wetting of batch;
- introducing broken glass (cullet or recycled glass);
- inspection (quality control).

Batching components of glass batch

Batching batch components is implemented by batchers, which are to provide high preciseness of the process, high productivity, reliability and flexible changeover.

Three main process flow schemes of batching are applied:

- linear positioning batchers under feed hoppers with supply of weighted components to horizontal collecting conveyor;
- linear positioning of feed hoppers with batching all batch components into truck scales;
- tower positioning of feed hoppers with batching all batch components by a single scales.

Notice that the latter scheme found wide application abroad, but is not used at Russian plants.

Mixing and wetting of glass batch

The weighted to pre-set formulation batch components are fed by belt conveyor to batcher, positioned under weighting line.

The following devices are used for mixing in world practice:

– disk mixers with moving and fixed cups;
– horizontal or tilted axis drum or conical mixers;
– double mixing screws;
– air blenders.

Disk mixers found the widest application in glass industry.

Wetting of batch is conducted at mixing stage to reach moisture of 3.5-4.5% to provide optimal conditions of batch transportation, feeding into furnace and glass melting.

At glass plants, the following variants of batch wetting are applied:

– preliminary wetting of sand only with following feeding other components to mixer;

– preliminary wetting of sand+dolomite mix only with following feeding other components to mixer;

– wetting the whole batch in the mid of the mixing process (this method found the widest application).

Introducing broken glass into batch

Traditionally the feed for glass melting furnace is composed of 75-85% of batch and 15-25% of broken glass. But in the latest decade, in Russia, the proportion changed considerably, and now the share of broken glass increased up to 30-50% and even more.

The following variants of introducing broken glass to batch are applied:

– mixing of broken glass with batch in mixers, for that broken glass is preliminarily crushed to size below 10-15 mm to provide required liquidity

– creation of layers of batch and broken glass at belt conveyor, from which they go to feeder hopper, mixing when throwing off;

– mixing of broken glass with batch in special mixer, located nearby doghouse of glass-melting furnace (the variant is widely used in foreign projects);

– loading batch on underlying layer of broken glass by rotor feeders (the variant requires the most complicated mechanical equipment that hinders its wide application).

Quality control of glass batch

The main quality data of glass batch are its compliance to preset formulation and chemical homogeneity.

There are two variants of batch quality control: monitoring and periodical (Table 3).

Table 3. Procedure of batch sampling for quality control (inspection)

Inspection parameters	***Monitoring***	***Periodical inspection***
Inspection goal	Inspection of batch compliance to preset formulation	Inspection of operation of mixer and batch homogeneity
Inspected parameters	Soda, sum of calcium and magnesium carbonates, sum of components, insoluble in HCl, sodium sulfate, moisture	–
Sampling site	On exit from mixer, feeder bunker, conveyor	Mixer, batch wagon, feeder bunker, conveyor
Mass of average sample, kg	Up to 10	2-10
Mass of individual sample, kg	0.2	0.2
Quantity of individual samples	4-6	Up to 10
Mass of laboratory sample, g	100	100

Source: GNIIS

Batch sampling for inspection analysis is conducted after completing batch mixing.

The most progressive method of batch inspection is X-ray spectrum analysis. Only this method allows to measure content of oxides in batch with preciseness of

0.2-0.3% for 30 minutes, whereas common chemical analysis requires at least 45-90 minutes.

Glass melting

Glass is obtained by the fusion of several inorganic substances. The fused mass is cooled to ambient temperature at a rate fast enough to prevent crystallisation, i.e., the molecules cannot arrange themselves into a crystalline pattern. The fast rate of cooling to prevent crystallisation applies to transparent glasses.

5 main stages of glass are distinguished:

1) Silicate-formation, when silicates and other intermediate compounds originate. For common chemistry glasses, the stage is finished at temperature 950-1150^{O}C;

2) Glass formation, during which cake, formed at the first stage, is melted with increasing temperature, silicate formation reactions is being completed, and mutual dissolution of silicates takes place. Excess quartz is dissolved in silicate melt – this process is the essence of the stage, which results in forming transparent, inhomogeneous metal (melt), including many bubbles. The stage is completed at 1200-1250^{O}C;

3) Refining (degassing) to remove visible gas inclusions – bubbles (completed commonly at 1500-1600^{O}C);

4) Homogenization (averaging), with averaging chemical composition of the melt to reach its uniformity (simultaneously with refining in the same temperature range);

5) Cooling, with preparing glass melt for forming, for which temperature is regularly decreased to 300-400^{O}C to provide required glass viscosity.

This glass melting process subdividing into 5 stage is rather conditional – in industry there is superposition of the stages. Only the 1st and the 5th stages are separated in furnaces in time and space, whereas the 1st and the 2nd stages begin simultaneously and are completed before finishing glass formation, and than the 3rd and the 4th stages go on simultaneously.

Forming

Together with glass melting, glass forming process compose core of modern glass production.

The forming process includes two main stages, determining its course: deforming of glass melt and it gradual solidification, which goes on during the whole forming process.

The first stage goes on in temperature-viscosity range of glass melt, when in is capable yet for flow and plastic deformation: in viscosity range of 10^2 to $4 \cdot 10^7$ Pa·s that corresponds approximately to temperature range of 1200-800^{O}C. At the stage required shape of final product is reached by special techniques and devices.

The second stage – fixing the shape – corresponds to field of active solidification of glass in the course of its cooling, i.e. viscosity range of 10^8 to 10^{12} Pa·s in temperature range of 900-500^{O}C.

The glass forming methods and subdivided, first of all, by shape of final products required (that determines procedure of action on glass melt and devices used).

Technology of treatment and annealing of glass

After forming, glass is subjected to various kinds of treatment, which can be classified into 3 main groups:

1) mechanical treatment;
2) heat treatment;
3) chemical treatment.

Mechanical treatment of glass consists in cold glass products treatment by grinding and polishing. The former process provides reaching required shape of item; rough grinding and smoothing are distinguished, with rough grinding followed by smoothing.

Glass grinding is conducted by rotating grinding tools, which is forced to glass surface at preset pressure by special devices. The grinding is conducted with the use of abrasives (diamond, boron carbide, electrocorundum), which are feed as powder or pulp (free grinding) or strictly fixed in base material (fixed-abrasive grinding).

Polishing glass is to remove its surface unevenness to size below wave length of visible light (0.4-0.7 microns) to provide smooth and mirror glass surface, which does not dissipate light. Polishing is conducted by rotating tools with polishing powders.

Heat treatment of glass (annealing and tempering)

Stress-relief annealing of glass. In the process of forming glass products, in the course of rather fast cooling, irregularly-distributed stresses originate in a glass, worsening its mechanical properties. Additional thermal treatment of glass - stress-relief annealing is designated for improving glass mechanical strength, being a required part of glass products manufacture process.

The stress-relief annealing includes 4 main stages:

1) heating (or cooling) to the annealing temperature;
2) aging at the annealing temperature until complete stress relief;
3) slow cooling to bottom temperature of annealing to prevent glass from stress origination;
4) quick cooling of glass to room temperature.

Temperature range of annealing between top and bottom temperatures is 50-150^{O}C depending on glass composition. The top limit corresponds to viscosity 10^{12} Pa·s, at which 95%-stress relief is reached for 3 minutes, and the bottom limit corresponds to viscosity of $10^{13.5}$ Pa·s, at which 5%-stress relief is reached for 3 minutes.

The annealing regime depend on properties of glass, shape and size of glass products, technology of their manufacture and design features of lehrs.

Glass Tempering. Glass which has been heated to a temperature near its softening point and forced to cool rapidly under carefully controlled conditions is described as "heat-treated glass" or tempered glass. The heat treating process produces highly desirable conditions of induced stress (described below) which result in additional strength, resistance to thermal stress, and impact resistance.

Heat-treated glasses are classified as either fully tempered or heat strengthened. According to Federal Specification DD-G-1403B, fully tempered glass must have a surface compression of 10,000 psi or more or an edge compression of 9,700 psi or more. Heat-strength glass must have a surface compression between 3,500 and 10,000 psi, or an edge compression between 5,500 and 9,700 psi. The fracture characteristics of heat- strengthened glass vary widely from very much like annealed glass near the 3,500 psi level to similar to fully tempered glass at the 10,000 psi level.

Glass can fracture when its surfaces or edges are placed into tension. Under these conditions inherent surface or edge fissures may propagate into visible cracks.

The basic principle employed in the heat treating process is to create an initial condition of surface and edge compression. This condition is achieved by first heating the glass, then cooling the surfaces rapidly. This leaves the center glass thickness relatively hot compared to the surfaces. As the center thickness then cools, it forces the surfaces and edges into compression. Wind pressure, missile impact, thermal stresses or other applied loads must first overcome this compression before there is any possibility of fracture.

Chemical treatment of glass

Chemical strengthening is a process in which glass is fortified using an ion-exchange method. This process is used when an increased strength of glass is required. As a result this process offers an increased surface compression that strengthens the glass without creating distortions, and the glass surface is rendered harder and more resistant to scratching.

Chemically strengthened glass is typically six to eight times the strength of annealed glass.

The glass is chemically strengthened by submerging the glass in a bath containing a potassium salt (typically potassium nitrate) at 400-450 °C. This causes sodium ions in the glass surface to be replaced by potassium ions from the bath solution.

These potassium ions are larger than the sodium ions and therefore wedge into the gaps left by the smaller sodium ions when they migrate to the potassium nitrate solution. This replacement of ions causes the surface of the glass to be in a state of compression and the core in compensating tension. The surface compression of chemically strengthened glass may reach up to 690 MPa.

There also exists a more advanced two-stage process for making chemically strengthened glass, in which the glass article is first immersed in a sodium nitrate bath at 450 °C, which enriches the surface with sodium ions. This leaves more sodium ions on the glass for the immersion in potassium nitrate to replace with potassium ions. In this way, the use of a sodium nitrate bath increases the potential for surface compression in the finished article.

Chemical strengthening results in a strengthening similar to toughened (fully tempered) glass, however the process does not use extreme variations of temperature and therefore chemically strengthened glass has little or no bow or warp, optical distortion or strain pattern. This differs from toughened glass, in which slender pieces can often be significantly bowed.

Also unlike toughened glass, chemically strengthened glass may be cut after strengthening, but loses its added strength within the region of approximately 20 mm of the cut. Similarly, when the surface of chemically strengthened glass is deeply scratched, this area loses its additional strength.

The above-described process, which is also called as “low-temperature ion-exchange strengthening”, can also be based on replacing sodium ions with rubidium and caesium ions.

Besides, for glass surface strengthening, so-called “high-temperature ion-exchange method” is applied, consisting in replacing ions of sodium and/or potassium with lithium cation, arriving from liquid or gaseous reagent at 500-700^{O}C. Length of the glass aging depends on kind of glass and reagent and ranges 20 to 240 minutes. The process provides for 2-2.5 times increasing of glass strength and 1.5-2 times raising its heat resistance, with increasing chemical resistance of the glass surface to acids and raising its electric resistance.

Process of chemical etching of glass is based on ability of hydrogen fluoride (hydrofluoric acid HF) to react with glass components (Na_2O, K_2O CaO, MgO, PbO, as well as SiO_2, forming structural framework of most of inorganic glasses) to break the framework of glass with its fast decomposing – etching. This process of etching is applied for polishing, matting (frosting), decoration of glass surface, as well as for glass strengthening.

Forming film coatings on glass (oxide-metal, polymer ordganic and organosilicon) is conducted for protecting glass surface, its strengthening, hydrophobization and changing optic properties. On the whole, the coating processes are conducted under elevated temperatures and consist in combination of hydrolysis, precipitation and chemical reactions with active centers on the surface.

The coated glass obtains new, preset properties independently on its chemistry and thickness.