

Glass industry and research in Brazil

Brazil is the fifth largest country in the world, with a total area of 8,547,404 km². Its 170,000,000 inhabitants (IBGE² -2000) represent an average population density of about 200 inhabitants/km². By Ana C M Rodrigues and Edgar Dutra Zanotto.

This population is unevenly distributed, the density varying from 1 inhabitant/km² in some of the northern states to 140 inhabitants/km² in the state of São Paulo. Intersected by both the Equator and the tropic of Capricorn, Brazil is located between the +5 and -33 latitudes and has equatorial, tropical, sub-tropical and temperate climatic zones.

Considering recent GNP levels, Brazil ranks as the world's eighth largest economy. This country, the largest in South America, responded quickly and decisively to the Asian financial crisis in October 1997, which brought strong pressure to bear on the domestic currency. These actions included a near doubling of interest rates, maintenance of an exchange rate policy in the face of large capital outflows, and Congressional approval of a fiscal package aimed at saving US\$18 billion in 1998, 2.5% of GDP. Financial markets responded positively to these measures, and capital inflows - including direct investment - increased strongly. By March 1998, international reserves had recovered to their pre-crisis level of US\$62 billion. Imports to Brazil are increasing in response to lower tariffs and generally freer markets, and are now composed of a wide variety of industrial, agricultural and consumer goods. Trade deficit for the four month period January-April 1998 stood at US\$2 billion.

This recent economic stabilization and growth has attracted foreign investments, and several manufacturers have opened new plants. These include car manufacturers such as the Japanese Company Honda, the

French companies Peugeot and Renault and Matra, and the German manufacturer Volkswagen. All these companies certainly require the participation of the glass industry. The construction industry is also growing considerably and the production and sales of flat glass are booming.

Historical Overview

The glass industry started in Brazil in the 19th century. In 1822, several small companies began the "manufacturing of lead crystal glass, large and small bottles and flasks at the same prices as those practiced at the Court of London"³. Some of these companies closed and later reopened under different names. On the occasion of the 1861 exhibition, there were factories operating in Rio de Janeiro, São Paulo and Bahia. However, the glass industry in Brazil was only consolidated in 1895, with the foundation of the Prado & Jordão company, which was the embryo of the Santa Marina plate glass manufacturer, founded in the following year. Santa Marina became a corporation in 1903, when it was renamed Vidraria Santa Marina (now Saint Gobain).



After Santa Marina, other companies were founded, such as the Industrial Company São Paulo and Rio (Cisper) in 1916, and Nadir Figueiredo in 1935. The Brazilian glass industry today comprises 74 companies, which can be divided into three groups: handmade glass manufacturers (43), automatic glass manufacturers (19) and transformation glass manufacturers (12). The products of these companies include plate glass, containers, table and house ware, fiberglass, technical glass and lead crystal glass. The most recent addition to the glass industry in Brazil, was the installation of the american Guardian, a float glass manufacturer, in the state of Rio de Janeiro in 1998. It has also recently been announced that Brazil will house the first aeronautical glass factory in Latin America, built specifically to equip Embraer aircraft⁴. Fig 1 shows the current geographical

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▲ Heavy investments have taken place.

distribution of Brazil's glass manufacturers. This distribution is marked by a concentration of these companies in Brazil's southeast, which houses 81,2% of the country's glass manufacturers, followed by the northeast with 12,5% and the south with 6,3%.

Analysis of the glass sector in Brazil's industry

A remarkable growth in Brazil's glass industry has occurred in recent years. All four segments of the industry, ie, container glass, plate glass, tableware and technical glass, have participated in this development.

The French group Saint Gobain, leads this industrial segment, producing tableware and container glass as well as plate and glass fibre at its different units, particularly at its Santa Marina plant.

The second largest producer – Cisper Indústria e Comércio, produces containers and tableware and belongs to the North American group Owens-Illinois. Ranking in third and fourth place are CIViv, in Brazil's northeast, and Nadir Figueiredo in the state of São Paulo, which also produce containers and tableware. Nadir Figueiredo is the largest Brazilian company in the glass sector.

The glass container manufacturers constitute the largest part of the glass sector, with a capacity of approximately 1,521,000 tons/year (2000). Most of these companies are either large or medium sized and use automated production processes. However, small companies of the sector producing lower quality products often use semiautomatic or manual processes.

The automated container glass manufacturers are located in the

states of Pernambuco, Bahia, Rio de Janeiro, Rio Grande do Sul and São Paulo, although 58% of the national production is concentrated in the state of São Paulo.

Cisper and Santa Marina represent almost 50% of the container glass market. These two major manufacturers also control the third largest company, Rimisa, through a joint venture. Cisper, the largest in terms of installed capacity, holds 24,4% of the market share, followed by Santa Marina with 22,6%, Rimisa with 13,4%, CIV with 10,7% and Wheaton with 8,8%.

The main sectors that consume glass containers are that of beverages, representing 39% of units consumed, followed by food (25%) and non-foods (36%). The latter segment includes personal hygiene, beauty and pharmaceutical products, among others. The market demand for glass containers in 1999 represented 15% of the total market demand for packaging, which amounted to 5,456 million tons.

The plate glass sector uses exclusively automated processes. In 1997, Cebrace (Brazilian Crystal Company) was the only plate-glass manufacturer employing floating processes. This company operates two manufacturing units and is controlled by a joint-venture between Saint Gobain and Pilkington. After the installation of Guardian, the installed capacity of this segment grew from 500,000 (1997) to 800,000 tons/year (2000).

Santa Marina stopped producing flat plate glass, although it still produces printed plate glass at its industrial unit in São Vicente. Another company, União Brasileira de Vidros, located in São Paulo, also produces printed plate glass.

According to the sector's estimates, the construction industry, which uses 55% of the country's total production (particularly of tempered glass), is the largest consumer of flat plate glass, followed by the automotive industry (laminated) – 25% and mirror manufacturers – 13%, with the remaining 7% distributed among the other sectors. Printed glass, which falls within the market segment of raw materials for the construction industry, is used for specific purposes such as the production of window glass with an opaque side.

The household glass segment, which involves the manufacture of decorative objects and household utensils such as tableware, glassware, jugs, etc, is divided into two large markets: housewares and lead crystal glass.

Most of Brazil's small manufacturers operate in the tableware segment, using almost exclusively manual processes. Some medium sized companies also use such processes.

The automated tableware manufacturers have an installed capacity of approximately 327,000 tons/year (2000) and are concentrated in the states of Rio de Janeiro and São Paulo, with 74% of the production capacity owned by the latter.

Although some of the companies in this sector include the term "crystal" in their names or use it to describe their products to differentiate them from "common glass", this terminology does not always correspond to the definition given in the international technical norms for lead crystal glass.

The production of glass fibre began in the 70's with Fiberglas Fibras, a subsidiary of the Owens-

▼ Table I. Installed capacity of Brazil's glass industry (1000 tons) and (% of total)*.

Segment	1996	1997	1998	1999	2000	Growth over the period (%)
Container	1048 (49.5%)	1048 (49.5%)	1497 (53.9%)	1497 (52.7%)	1521 (52.8%)	45.1
Plate	550 (26.0%)	550 (26.0%)	800 (28.3%)	800 (28.2%)	45.5 (27.7%)	45.5
Tableware	305 (14.4%)	305 (14.4%)	305 (10.8%)	318 (11.2%)	327 (11.3%)	7.2
Technical	215 (10.1%)	215 (10.1%)	221 (7.8%)	225 (7.9%)	235 (8.2%)	9.3
Total	2118	2118	2823	2840	2883	36.1

Corning group. This industrial segment is made up of four automated companies, (Fiberglas, Santa Marina, Eucatex and Vitrotex), all located in the state of São Paulo. Glass fibre today is considered "technical glass" and its production is included in the statistics on special glasses.

The technical glass segment involves the glass fabrication production of special compositions, including glass for TV screens, electric bulbs glass fibre and drinking glasses. This segment also includes the production of optical fibers, ophthalmic glasses, insulating glass blocks for civil construction and others.

Brazil's (nominal) production capacity of around 235,000 tons/year (2000) of several types of technical glass is insufficient to supply the domestic market. Regardless of a company's size, technical glass is usually produced by automatic processes. Manual processes only in low production volumes that do not justify investments in costly equipment. The manufacturers of technical glass are located mostly in Pernambuco, Rio de Janeiro, Minas Gerais and São Paulo, with 43.4% of the installed capacity concentrated in the state of São Paulo.

Abividro

Founded in April 1962, the Automated Glass Manufacturers' Technical Association (ABIVIDRO) is an organization of 29 automated manufacturers from the segments of plate glass, plate glass transformation, tableware, glass containers, technical and glass fibre, whose purpose is to foment the ongoing improvement of this industrial activity and to represent the common interests of its members.

During the period of 1996 to 2000, Abividro recorded a 15.6% growth of the gross revenue of the glass sector. The production volume showed a 25.0% increase over the same period, although the industry's full production capacity has not yet been reached. Heavy investments were made in the flat glass segment in 1997 with the establishment of the Guardian plant, and the glass containers segment has also received substantial investments in recent years.

Segment	1996	1997	1998	1999	2000	Growth over the period (%)
Container	690 (33.5%)	670 (31.9%)	613 (30.0%)	691 (31.1%)	771 (32.4%)	11.7
Plate	530 (25.7%)	550 (26.2%)	518 (25.3%)	554 (25.0%)	600 (25.2%)	13.2
Tableware	353 (17.1%)	355 (16.9%)	359 (17.5%)	368 (16.5%)	389 (16.3%)	10.2
Technical	489 (23.7%)	524 (25.0%)	556 (27.2%)	610 (27.4%)	618 (26.0%)	26.4
Total	2062	2099	2046	2223	2378	15.3

▲ Table II. Gross sales for the sector (in R\$ millions)^a.

This volume of investments is a strong indication of the sector's concern regarding the implementation of new technologies and the need for improvements of its products to increase their competitiveness in international markets. In the glass container segment, these investments reveal the efforts that are being made to meet the growing demand for lighter and more resistant glass containers. The tableware segment seeks to modernize its product lines to align them with the market's new technological levels.

Foreign trade: imports/exports

Another positive factor in Brazil's trade balance, is that, since 1999, the glass sector has experienced a significant growth in volume of glass exports and a drop in the volume of imported glass. Hence, in the last three years, Brazil has exported more glass than it imports. This fact is reflected both in the volume of exports in tons and the mix of devices/goods exported. The main countries to which Brazil exports glass are Argentina, the USA and Spain.

A calculation of the apparent consumption of glass (total production - exports + imports) divided by the number of inhabitants reveals that Brazil's per capita consumption in 2000 was 3.8kg /per capita, which is low compared to that of European countries (30-50kg /per capita) or to the world's largest glass consumer - France, with 65.4kg /per capita.

Glass research and development in Brazil

The exact place and date is uncertain, but glass research in Brazil is believed to have begun at the

Institute of Physics of the Campinas State University (UNICAMP) and at the University of São Paulo (USP) in São Carlos in the early seventies. The research group of the Vitreous Materials Laboratory (LaMaV) at the Federal University of São Carlos (UFSCar), to which the authors of this document article are associated, was formed in January 1977.

There are now several groups focusing on scientific or technological research on glass in Brazil. These groups are still concentrated at federal and state universities and at a few research institutes. The research areas cover a wide range from domestic products for containers to special glasses, such as bio-glasses and optical fibers.

Data for 2001 are not available, but there are other glass research groups, for instance, at the Universidade Federal do Ceará, Universidade Estadual de Maringá, Universidade Federal do Paraná, CEFET, etc.

The research infrastructure of most of these groups is generally quite good. In general, since they are part of physics, chemistry or materials engineering departments that have laboratories for the sample preparation and structural characterization of samples, microstructural characterization (optical microscopy, etc.) and property analyses (DTA, DSC, dilatometry, viscosity, mechanical properties, etc). An important facility is the Sincrotron National Laboratory (LNLS) inaugurated in 1997, which has facilities for DRXRD, EXAFS, SAXS, UV Spectroscopy, High Resolution Electron Microscopy.

The impact of the scientific research of these groups in reaching

new discoveries at a worldwide level is illustrated by the fact that, between January 1995 and July December 2001, the Brazilian groups were responsible for approximately 14.34% of all the papers published in the "Journal of Non-Crystalline Solids" and for 2.0% of the papers published in "Physics and Chemistry of Glasses", two of the most prestigious scientific periodicals on glasses. Compared to this figure, for example, we can state that Brazil's overall scientific research is responsible for only 1.3% of the worldwide publications listed by the ISI (Institute of Scientific Information).

The situation is even worse at a higher technological level, i.e. these glass research groups have filed fewer than a dozen patents in the last twenty years. Their interaction with industries has been modest and has focused almost exclusively on analytical services and technical reports.

There are already more than 22 PhDs and several MScs specialized in glass in Brazil. This number is inconceivable if one includes several faculty members and post-docs who graduated from foreign universities. It should be noted that approximately 30 PhDs and 20 MSc's level students were working on their theses and dissertations in December 1995.

The regrettable fact is that, although a few of these professionals have been hired by universities and research institutes and others continue doing post-doctoral work, none of them has been hired by the industry! To reinforce this thesis, a recent survey (Dec. 1998) revealed that, of the 98 MScs who received their degrees from UFSCar in the area of ceramic materials engineering, only 2 were hired by the industry after receiving their degree. Moreover, of the 250 materials engineers specializing in ceramics who graduated from UFSCar between 1974 and 1997, only 45 are currently working in the glass industry.

An analysis of this information raises the following question: Why should universities produce glass specialists? Our current proposal is to train engineers and researchers with a wide scientific base, who can later specialize in glasses (or in any other area) through updating or refresher courses, or even at a MSc

or PhD level, only after they are recruited by some glass manufacturer. Their theses or dissertations could be designed to meet the interests of their employers without, of course, neglecting the educational aspects.

The Vitreous Materials Laboratory (LaMaV) of the Department of Materials Engineering (DEMa), Federal University of São Carlos (UFSCar) was founded in 1977, headed by its current co-ordinator (Professor E D Zanotto). At the time this article was written (January 2002), the group was composed of the following researchers:

3 Lecturers? Faculty, PhD, 2 Post-Doctoral dDoctoral researchers, 6 5 Ph.D. students, 1 2 M.Sc. Students, 4 5 undergraduate Engineering Students Trainees, 1 Technician. The construction of a new 530m² building containing up-to-date facilities for glass melting, preparation and characterization is underway.

Most of the research concentrates on crystallization, in which the group has an international reputation, although it also encompasses the study of mechanical, electrical, biological and rheological properties. The work method of LaMaV members is to melt and prepare their own samples (whenever possible), characterizing them with their own specialized technical equipment (eg, viscosity, DSC, dilatometry, refractive index, and optical microscopy, etc) and completing the characterization using either the equipment available at DEMa (DRXXRD, IR, UVV, NMR, ESCA / Auger, HAS, WITHOUT, DTA, chemical, electrical & DSC, dilatometry, mechanical properties, etc.) or the Sincrotron Light National Laboratory (LNLS), which has facilities for DRXXRD,, EXAFS, SAXS and other X-ray techniques.

Conclusions

The volume of glass production in Brazil is significant, with a large number of industrial plants showing annual gross sales of over US\$1.5 billion. The number of groups devoted to glass research is also notable. However, there is hardly any interaction between universities and glass industry's research centres in the glass sector in Brazil. The

analogous sectors of ceramics, metallurgy and polymers, for instance, that comprise mostly Brazilian manufacturers, interact much more closely with the local universities. Thus, the development of a truly national glass technology is still far from adequate.

Most of the glass companies operate with foreign capital and maintain research centers in their countries of origin. That is probably the reason for the lukewarm interaction between companies and university research groups in Brazil.

Despite the fact that most of the academic research groups began their activities less than ten years ago, their productivity, which is evaluated by the number of Ph.D. theses, Master's dissertations and publications produced, has been growing considerably. Today, these groups are responsible for 4.3 1.5-2.0% of all the scientific articles published in the most renowned international journals.



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