



WHITEPAPER Status: 14.12.2020

MATERIAL TRUST

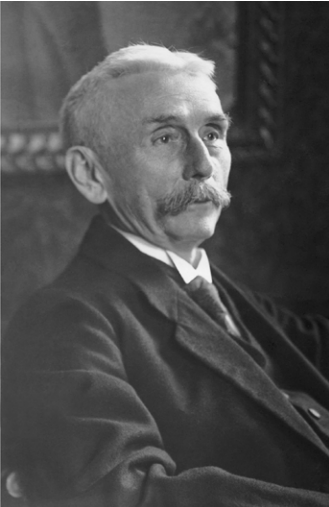
The role of **DURAN®** borosilicate glass 3.3 in laboratory applications



DWK LIFE SCIENCES
DURAN WHEATON KIMBLE

MATERIAL TRUST

The role of **DURAN®** borosilicate glass 3.3 in laboratory applications



When Otto Schott invented borosilicate glass in 1887, he had an ambitious goal: to manufacture a glass that in contrast to soda-lime glass or lead glass would reliably withstand high temperatures and temperature changes, while also proving resistant to acids and alkalis. Schott was successful in creating the foundation for modern laboratory and industrial glass thanks to one specific formulation that became known as “borosilicate glass 3.3”. The formulation was later registered under the DURAN® brand name in 1938.

This whitepaper highlights the applications for which borosilicate glass 3.3 is suited and the properties that have continued to characterize it right up to the present day. A closer look at its production will reveal the requirements that raw materials and manufacturing processes must meet to produce the formulation and how as a result DURAN® glass delivers the highest quality standards.

Consistent global glass demand

As a material, glass is an integral part of our everyday lives and is essential for the hygienic handling of a range of substances. There is enormous demand for resistant glasses in professional environments such as medical laboratories and the chemical industry. For many decades, DURAN® borosilicate glass 3.3 has been regarded as the material of choice, offering high chemical resistance, and thermal durability. The market for borosilicate glass has also remained consistently strong.¹ New applications are emerging, for example, in the field of medical and health technology, where there is demand for borosilicate glass for implantable devices. There are also a wide range of pharmaceutical applications, such as vials and ampoules, that require high quality, durable glass. Furthermore, a growing global population and increasing urbanization – linked with rising purchasing power – have increased sales of consumer and household appliances. Borosilicate glass is benefiting from this as a result of its use in coffee and tea pots, glasses, vases, and numerous other consumer products.

The market remains strong because the alternatives to such a heat, pressure, and corrosion resistant material are few and far between.² However, there is increasing competitive pressure from thermoplastic materials that also offer a high level of chemical and thermal resistance. Although glass has been replaced by plastic in many industrial sectors, in medical, pharmaceutical, and chemical environments there are still large numbers of applications where only glass will suffice.³ DURAN® borosilicate glass 3.3 in particular can be optimally cleaned and then reused many times without any reduction in quality. That is why it remains the material of choice, ahead of plastics, in many laboratories.

¹ > Future Market Insights: Borosilicate Glass Market. Global Industry Analysis 2013 – 2017 and Opportunity Assessment; 2018 – 2028.

² > Frost & Sullivan: Innovations in Borosilicate Glass, 2017

³ > The Lab Professionals: Market Data 2016



Safety and Quality under the spotlight

The pharmaceutical, food, and chemical industries are highly regulated sectors. Any materials used must be subject to the highest safety and quality standards. An important point of reference is the designation of DURAN® borosilicate glass 3.3 as a food contact material "Generally Recognized As Safe" (GRAS) by the US Federal Food and Drug Administration (FDA). GRAS status is determined in a safety review conducted by qualified experts. It ensures that a substance is safe in its intended use and harmless when used with food.

DURAN® glass is also classified as neutral borosilicate glass 3.3 according to the international ISO 3585:1998 standard. On the basis of its hydrolytic durability, it is a Type 1 Glass in accordance with DIN ISO 719 – in other words, it is a neutral glass whose durability arises out of its precisely defined chemical composition.⁴ It therefore meets the quality requirements for pharmaceutical use, as prescribed, for example, in the European Pharmacopoeia (EP) under Paragraph 3.2.1 ("Glass Containers for Pharmaceutical Use"), the United States Pharmacopeia (USP), and the Japanese Pharmacopoeia (JP). The glass's resistance permits the safe handling of highly toxic active ingredients in manufacturing facilities and laboratories.

Based on its proven non-cytotoxicity (ISO 10993-5 and USP 87), DURAN® borosilicate glass 3.3 can also be safely used in sensitive and more cutting-edge areas of research and development, such as in bioreactors, in stem-cell research or cell culture applications. Furthermore, as a physiologically inert material, Type 1 Glass is also optimally suited for the storage and transport of foods as well as parenteral nutrition products.

⁴ > Class A Type 1 Glass: Borosilicate glass with low expansion according to laboratory glass specification ASTM-E438-1992



Properties you can trust

High proportions of silicon dioxide (SiO_2) and boron trioxide (B_2O_3) are characteristic glass-forming constituents of borosilicate glass. It is above all the boric oxide content of roughly 13% and the silica proportion of over 80% in the glass matrix that leads to its high resistance to water, chemicals, and drug substances. Borosilicate glasses as a general group are subdivided into three groups: non-alkaline-earth, alkaline-earth-containing, and high borate borosilicate glasses. Borosilicate glass 3.3 is the most commercially manufactured non-alkaline-earth borosilicate glass.

DURAN® borosilicate glass 3.3 has the following chemical composition (percent weight by weight):

Silicon dioxide (SiO_2):	81%
Boron trioxide (B_2O_3):	13%
Sodium oxide (Na_2O) and potassium oxide (K_2O):	4%
Aluminum oxide (Al_2O_3):	2%

Variations in borosilicate glass 3.3

Borosilicate glass 3.3 only designates the material from which a lot of laboratory glassware is manufactured. To be classified as such, it is sufficient that the material meets the requirements listed in DIN ISO 3585 standard. In other words, the designation "borosilicate glass 3.3" documents the fact that a gob of glass satisfies the standardized parameters when it leaves the melting tank. However, this designation does not say anything about the quality of the raw materials or the properties of the finished glass product when the forming process is completed. Differences in quality between glasses from different manufacturers can therefore occur, especially after repeated use, even if the chemical composition is the same. The main reasons for these variations are the quality and purity of the raw materials, the use of advanced melting technology, forming process parameters, and the stringency of the quality control (see "Precise Production" for more information).

One example of where significant variation can occur is the wall thickness of laboratory glassware. The ISO standard permits wide differences in glass thickness, as shown by the example of an Erlenmeyer flask below:

	DIN ISO	DURAN® specification
Height [mm]	140 ± 3	140 ± 2
Wall thickness [mm]	min. 0.9	2 + 0.8 / -0.6

In this case, significantly thicker glass – compared to the standard – provides greater mechanical stability. Furthermore, the maximum variation in DURAN® glass wall thickness was 14%, while the variation for comparable products amounted to 36% (in-house comparative measurements). This difference has a direct impact on durability because the more irregular the wall thicknesses are, the higher the transient tensions become in the glass after heating or cooling in the laboratory, and the more stress is placed on the material.

The most important properties of DURAN® borosilicate glass 3.3 are described in greater detail on the next pages.

Chemical resistance

The composition of DURAN® borosilicate glass 3.3 makes it extremely resistant to water, neutral and strong acids, and acid mixtures, as well as chlorine, bromine, iodine, and organic substances. Even in the event of longer exposure times and temperatures over 100°C, the glass surpasses most metals and other materials in terms of chemical resistance. Only hot concentrated phosphoric acid, hydrofluoric acid, and strong alkalis can remove the surface of DURAN® glass.

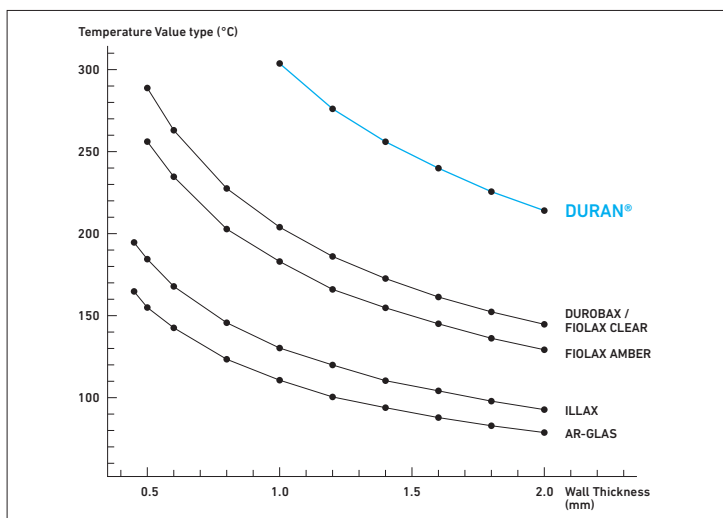
The acid resistance of borosilicate glass 3.3 corresponds to Class 1 of the glass categories defined in the DIN 12 116 standard. DURAN® is classified as highly acid resistant borosilicate glass because the amount of surface removal after being boiled in hydrochloric acid for six hours is less than 0.7 mg/100 cm². The amount of alkali oxides dissolved in accordance with DIN ISO 1776 is less than 100 µg Na₂O/100 cm².

Its alkali resistance is categorized as Class 2, the intermediate of the three classes defined in DIN ISO 695. After being boiled in a solution of sodium hydroxide and sodium carbonate for three hours, the weight loss is only around 134 mg/100 cm².

In addition to this, borosilicate glass 3.3 is an almost inert material. No significant interactions occur between medium and glass – for example, there is only a low-level ion exchange, which occurs with other materials. This effectively rules out any disruptive influence on laboratory experiments.

Heat and thermal shock resistance

In addition to its exceptional chemical resistance, DURAN® borosilicate glass 3.3 has the lowest thermal expansion of any industrially produced glass: $3.3 \times 10^{-6}/\text{K}$. That corresponds to roughly one third of the value for typical window glass. It was also the low expansion coefficient that led to the designation “3.3”. This results in a high thermal shock resistance of $\Delta T = 100 \text{ K}$. The coefficient is so low that hardly any stresses occur in the material. For example, the glass cannot shatter when boiling water is poured onto it. It is also suitable for use in a microwave oven.



The diagram on the left shows the resistance to thermal shock of different neutral glasses in relation to the respective wall thickness.

Source: http://www.vidrasa.com/eng/products/duran/duran_pf.html

Thanks to the high level of heat and thermal shock resistance, the properties of the glass remain practically unchanged over the entire temperature range. The maximum permitted temperature for the short-term use of borosilicate glass 3.3 is 500°C. The glass reaches its transition temperature at 525°C; at 860°C it becomes liquid. In the other direction, the glass can be cooled down to the maximum possible negative temperature and is therefore suitable for use in liquid nitrogen at roughly -196°C. It is important to note that the maximum temperature difference during thawing is 100 K. In practice, incremental cooling or heating is recommended.

Mechanical strength

Another strong argument for using DURAN® borosilicate glass 3.3 is its high mechanical resilience. It has a significantly higher compressive and tensile strength than other materials, which is why it is suitable for use in pressure vessels. Furthermore, mechanical loss of glass is exceptionally low. Considering a safety factor for brittle materials that has been established in practice, the following strength values apply:

Tensile and flexural strength value:	7 N/mm²
Compressive strength value:	100 N/mm²
Elastic modulus (Young's modulus):	64,000 N/mm²
Poisson's ratio for calculating lateral strain:	0.2

One quality factor that should not be underestimated is the even distribution of wall thickness throughout the whole of the glass product (also see "variations in borosilicate glass 3.3" for more information). This increases stability and resistance to temperature changes. Monitoring of wall thickness is a standard procedure during the production of DURAN® glass.

Despite its high stability, borosilicate glass 3.3 is a comparatively light glass. With a density of 2.23 g/cm³ at 25°C, its weight is roughly 10% lower than that of window glass. It is therefore not only suitable for laboratory and industrial applications, but also ideal for use in private households as a non-breakable and easy-to-handle glass.

Optical properties

DURAN® borosilicate glass 3.3 is very transparent and therefore enables the constant visual monitoring of ongoing processes. Absorption is negligibly small in the spectral range from 310 to 2,200 nm. Larger layer thicknesses – for example, in the axial view of tubes – appear slightly yellowish to greenish. Due to the transmittance in the UV range, photochemical reactions such as chlorination and sulfochlorination can also be carried out. Amber colored borosilicate glass is suitable for working with light-sensitive substances. The transmission of amber glass is less than 10% in the range of wavelengths between 300 and 500 nm. As a result, amber DURAN® glass meets the requirements of the pharmacopeias EP 3.2.1 and USP <671> for protection against UV light.



Precise Production

The outstanding quality of DURAN® glass derives from its high-purity raw materials; a fully automated weighing, mixing, melting, and forming process and the continuous monitoring of every step of the production process. These factors lead to consistent and precise glass properties of the highest standard.

Only raw materials from certified and regularly inspected long-term suppliers are used in the production of DURAN® glass. This includes quartz sand and feldspar, which together provide the silica that is the main glass network former. Both materials meet the requirements for GRAS status. Raw materials for the alkali metal oxides Na_2O and K_2O are added to reduce the high melting point of silica to approximately $1,700^\circ\text{C}$. The addition of aluminum oxide increases the chemical resistance of the glass. The boron trioxide that gives the glass its name is added to reduce the thermal expansion coefficient and to slightly increase the chemical resistance of the final glass.

The mixture is melted at $1,550^\circ\text{C}$ using high-quality melting furnaces as shown above. A precise arrangement of tanks ensures good mixing, high glass homogeneity, and efficient tank degassing. Melting agents, such as arsenic, tin or antimony, are not used for environmental protection reasons. They also have a detrimental effect on the chemical properties of a glass, despite reducing production costs, so are avoided during a production process that focuses on quality. Primary melting is followed by the fining process to completely remove remaining bubbles. Potential impurities rise to the surface and are removed from the molten glass. The melting process is fully automated and runs continuously (24/7) to maintain consistently high product quality.

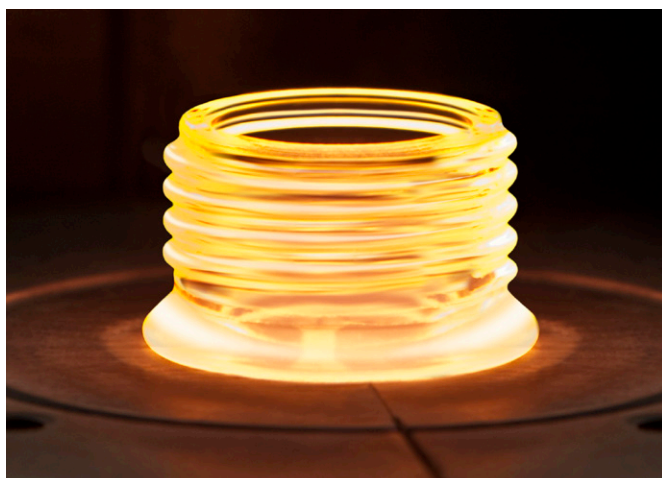
Attention needs to be paid to many parameters during the subsequent forming process: mold design and materials, blowing pressure, rotation speed, the timing of mold closing, mold changing, and much more. Several material and process checks are carried out by qualified personnel to continuously maintain optimum process parameters. Since uneven cooling can cause stress and weakness in the glass, a separate tempering process follows. A cooling furnace heats the products again and then cools them down under controlled conditions over a period of between 20 minutes and 3 hours depending on the thickness of the glass.



In the case of amber colored glass, a special diffusion color is applied to the external surface of the glass using a process that results in a uniform application of the coloring agent. During the subsequent firing process the color diffuses into the surface of the glass, which protects it against chemical attack. The proven properties of borosilicate glass 3.3 remain unaffected inside the bottle. Continuous process and quality checks are also carried out during this stage.

The reproducibility and traceability of products plays an essential role in a transparent and reliable production process. The reproducibility of DURAN® glass is guaranteed by the fully automated production plant used by DWK Life Sciences in Mainz, Germany. The first time laboratory glass was produced anywhere in the world using an automated process was in Mainz in 1955. The traceability of the finished glass products is made possible by a Retrace Code. This service enables users to obtain a batch certificate for all coded laboratory glass bottles, beakers, Erlenmeyer flasks, baffled flasks and reagent bottles.

The production process for DURAN® glass is the responsibility of DURAN Produktions GmbH & Co. KG, whose quality management has been certified in accordance with the ISO 9001:2015 standard. The company's quality management is tailored to the requirements of the international pharmaceutical industry. These special quality standards, which relate to raw materials and their processing, guarantee a consistently high standard of material in keeping with the expectations of "German quality products".



A Future Shaped by Passion, Creativity and Innovation

Since it was first invented by Otto Schott, borosilicate glass has proved itself an invaluable resource. Thanks to its properties and controlled production, DURAN® borosilicate glass 3.3. has become a highly valued material not only in laboratories and highly regulated industries but in domestic households too.

The exceptional durability of DURAN® glass was confirmed by a recent competition that aimed to find the oldest item of laboratory glassware still in regular use. Some of the submitted entries were for items that dated back to the early 1940s, such as those shown here.⁵

While the composition and production of DURAN® glass has hardly changed over the decades, numerous innovations have been introduced to create even more application-oriented designs and user-friendly ergonomics. For example, DURAN®'s classic laboratory glass bottles have been refreshed and improved for contemporary users with the launch of the DURAN® YOUTILITY bottle system.⁶ The wider DURAN® range of closely coordinated systems also offers countless options and extensive accessories, including appropriate caps, pouring rings and more. It has been possible to optimize laboratory beakers, Erlenmeyer flasks and other glass products through increased wall thickness and reinforced upper rims for example, making the products even more resilient. As a result of close consultation with users and a passion for creativity, innovation and excellence, DURAN® borosilicate glass 3.3 is set to remain as important in the future as it has been for the last one hundred years.

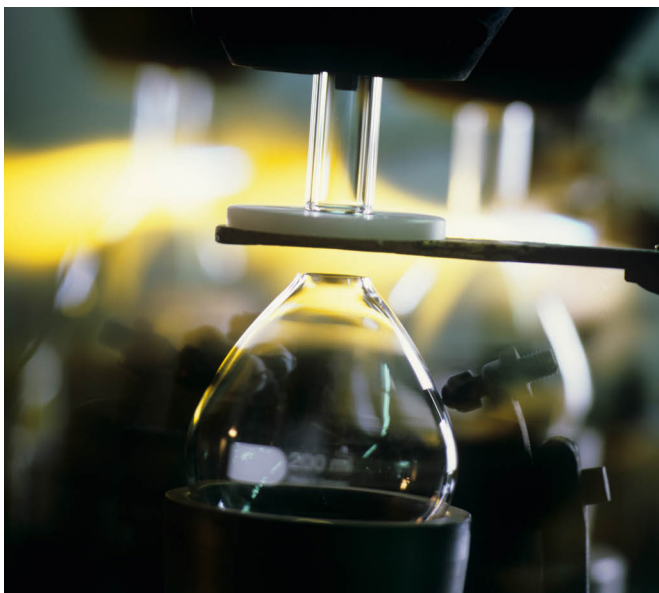
⁵ > Source: <https://www.laborpraxis.vogel.de/suche-nach-aeltestem-laborglas-endet-erfolgreich-a-417008/>

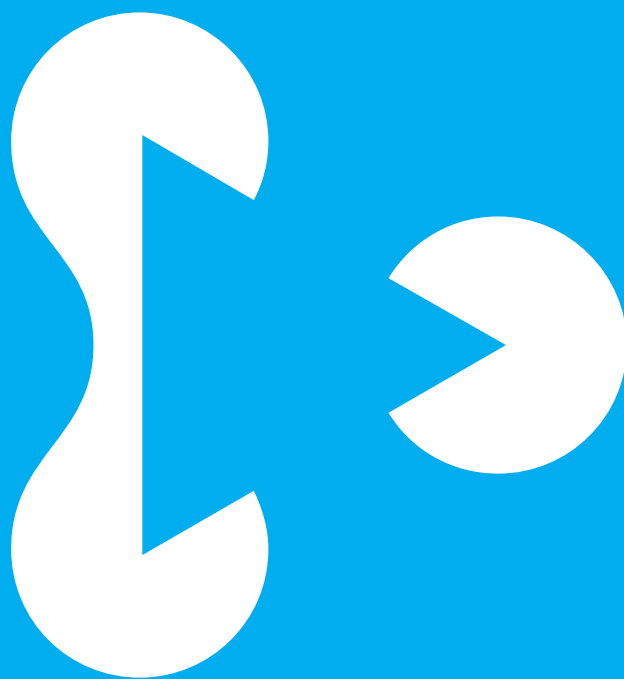
⁶ > Simpler and safer handling is provided, for example, by the award-winning laboratory bottle DURAN® YOUTILITY GL 45.



Overview of physical data for **DURAN®** borosilicate glass 3.3

Mean coefficient of thermal linear expansion α (20°C; 300°C) according to DIN ISO 7991	$3.3 \times 10^{-6} \text{ K}^{-1}$
Transition temperature T_g	525°C
Temperature of the glass at viscosity η in dPa x s: 10^{13} (annealing point)	560°C
$10^{7.6}$ (softening point)	825°C
10^4 (working point)	1260°C
Maximum short-time working temperature	500°C
Density ρ at 25°C	2.23 g x cm^{-3}
Elastic modulus (Young's modulus)	$64 \times 10^3 \text{ N x mm}^{-2}$
Poisson's ratio μ	0.20
Thermal conductivity λ_w at 90°C	$1.2 \text{ W x m}^{-1} \text{ x K}^{-1}$
Temperature for the specific electrical resistance of $10^8 \Omega \text{ x cm}$ (DIN 52 326) t_k 100	250°C
Logarithm of the electric volume resistance ($\Omega \text{ x cm}$)	at 250°C 8/ at 350°C 6.5
Dielectric properties (1MHz, 25°C) Dielectric figure ϵ	4.6
Dielectric loss factor $\tan \delta$	37×10^{-4}
Refractive index ($\lambda = 587.6 \text{ nm}$) n_d	1.473
Stress-optical constant (DIN 52 314) K	$4.0 \times 10^{-6} \text{ mm}^2 \text{ x N}^{-1}$





Excellence in your hands

Contact us at [DWK.com](https://www.dwk.com)

© 2022 DWK Life Sciences • The trademarks used are owned by DWK Life Sciences GmbH, DWK Life Sciences LLC or DWK Life Sciences Ltd.