A4. USE OF BORATES IN GLASS AND GLASS FIBRE

A4.1 Background to Use of Borates

As discussed in Section 3, one of the largest uses of borates in Europe is in insulation and textile fibreglass. In both insulation and textile fibre glass, borates act as a powerful flux and lower glass batch melting temperatures. They also control the relationship between temperature, viscosity and surface tension to create optimal glass fiberisation (IMA, 2008). Borates may also be used as fire retardants in woven textiles.

In addition to glass fibres, borates are used in a range of glass and glass products where they increase the mechanical strength of glass, as well as their resistance to thermal shock, chemicals and water (IMA, 2008). Information received from several companies indicates that during production of borosilicate glass, the borates (added as fluxes and glass stabilisers which modify the properties of the resulting glass) become irreversibly integrated into the vitreous glass network. Borosilicate glass is highly resistant to corrosion with a high hydrolytic resistance to water, acids and alkaline liquids. Such glass also has a high resistance to thermal shock, low thermal expansion properties and low electrical conductivity.

Information provided by several companies and industry associations indicate that borosilicate glass is used to produce:

- heat resistant glass cookware;
- laboratory equipment, including pharmaceutical equipment;
- pharmaceutical packaging material;
- glass fibre insulation material;
- light bulbs (and other electrical lighting);
- textile glass fibre composites (fibre glass);
- enamel frit and other enamelling products;
- glass for liquid crystal display screens (LCDs);
- radiation shielding for the nuclear industry and hospital x-ray equipment;
- solar panels;
- ophthalmic lenses, especially for high prescription eyesight correction; and
- heat resistant glass panels (e.g. in cookers).

A4.2 Market Profile and Consultation Findings

Information on the use of borates in glass and glass fibre production was received from:

- the European Insulation Manufacturers Association (EURIMA) which represents all major mineral wool producers throughout Europe;
- the European Glass Fibre Producers Association (APFE) which represents nine companies located in the EU (and submitted a consolidated response on behalf of its members);

- the European Special Glass Association (ESGA)/Standing Committee of the European Class Industries (CPIV) which forwarded nine anonymised responses; and

- six responses directly from companies.

Information provided by APFE (based on responses provided by 75% of its members) suggests that over 84,000 tonnes of borates are used by its members to manufacture glass products. Each company has around two or three suppliers and the continuous filaments glass fibres are sold to industrial engineered plastics companies (compounders, transformers, etc) and distributed down the supply chain of reinforced plastics materials and articles. The range of end uses is quite broad and includes automotive, marine, construction, infrastructure and renewable energy applications. APFE estimates the total EU volume for glass fibre production at around one million tonnes of fibre glass and all products are sold to industrial applications (APFE, 2008). The above estimate is comparable to the estimated glass fibre production of nearly 800,000 t/year by CPIV - which at 5-10% B_2O_3 suggests a B_2O_3 usage of around 50,000 t/year.

The typical glass fibre industry in the EU shows a growth rate of around 3 to 4% annually. In terms of market trends, the boron in glass is a fixed part of the end-product and volumes used depend on (and are directly proportional to) the production level of fibres. The recent trend is to use purer forms of borates and to reduce their level of usage due to their relatively high cost against other glass making materials (APFE, 2008).

EURIMA estimates that based on figures for 2005, around 80,000 tonnes of borates are used in the manufacture of around 3.6 million tonnes of end-product. Most of the man-made vitreous fibres produced worldwide are used as insulation. Over the last decade, glass wool, rock (stone) wool and slag wool have together met just over half of the world demand for insulation. Around 75% of the world's insulation material is produced and used in North America and Europe. Approximately 88% of glass wool and 80% of rock (stone) and slag wool are used in the construction of residential and commercial buildings; 12% of glass wool and 20% of rock (stone) and slag wool are used in industrial applications, including heating, ventilation and air conditioning, household appliances and transportation (EURIMA, 2008).

According to EURIMA, there has been an increased demand for glass mineral wool insulation products due to improved building standards, increased environmental awareness by customers, energy reduction commitments, increased energy costs and CO_2 reduction targets within Europe. These have resulted in increased plant output and additional manufacturing capacity leading to an increased requirement for disodium tetraborate pentahydrate in the manufacturing process (EURIMA, 2008).

Information provided by individual companies is provided in Table A4.1.

Table A4.1: Summary of Market Data Provided by Glass Producers							
	Source of Borates		**Quantity of Product (2007)**		**Percentage Sales to:**		
Company	**EU**	**Other**	**Used (tonnes)**	**Sold in EU (tonnes)**	**Consumers**	**Professional Users**	**Industrial Users**
1	Yes		2,860	23,991	15%	0%	85%
2			3,030	25,512	15%	0%	85%
3			138		100%	0%	0%
4			55,000		80%	15%	5%
5		Yes	5,500	19,000	0%	0%	100%
6	Yes	Yes	27,800	50,000	30%	60%	10%
7			11,000		10%	10%	80%
8		Yes	5,515		50%	10%	40%
9			55,000		80%	15%	5%
10			15,700	50,000	70%	0%	30%
11		Yes	480	13,700	70%	30%	0%
12			1,000		100%	0%	0%
13			994	982	0%	75%	25%
14			359				
15			1,900	5,000	20%	0%	80%
16			15,500	30,000	30%	60%	10%
Total			**202,000**				

A4.3 Concentrations and Types of Borates Used

Information provided by EURIMA indicates that only borax pentahydrate is used by their members and glass fibres used for insulation applications typically contain between 1.5% and 3.6% boron (w/w) (EURIMA, 2008).

On the other hand, APFE indicates that boric acid and borax pentahydrate are primarily used by their members, based on average figures for 2004 to 2007. The borosilicate glass produced by APFE members contains <5% boron (w/w) as diboron trioxide (B_2O_3) APFE, 2008).

Although these values are consistent with the general view (as presented in Section 3.2 of he main text) that, in recent years, the boron content has gradually been reduced from 8-10% B_2O_3 (or 2.5-3% boron) by weight to around 5% (1.5% boron), the concentrations are much higher in some specialised applications.

A list of borate compounds used for making glass as well as the amounts used by the companies that provided data are displayed in Table A4.2.

Table A4.2: The Amounts of Different Borates Used to Produce Glass			
Type of Borate	**CAS Number**	**Amount Used (tonnes/year)**	**% of Total Borate Used**
Boric Acid	10043-35-3	75,621	56%
Diboron Trioxide; Boric Oxide	1303-86-2	110	0.08%
Disodium Tetraborate, Anhydrous; Boric Acid, Disodium Salt	1330-43-4	420	0.31%

Table A4.2: The Amounts of Different Borates Used to Produce Glass

Type of Borate	**CAS Number**	**Amount Used (tonnes/year)**	**% of Total Borate Used**
Disodium Tetraborate Decahydrate; Borax Decahydrate	1303-96-4	95	0.07%
Disodium Tetraborate Pentahydrate; Borax Pentahydrate	12179-04-3	46,695	35%
Lithium Tetraborate	12007-60-2	0	0%
Boron Orthophosphate	13308-51-5	0	0%
Potassium Tetrafluoro Borate	14075-51-5	0	0%
Colemanite	Not specified	11,000	8.2%
Total		**133,941**	**100%**

Not all the 16 responding companies indicated the specific borate compound being used; hence the total amount of borates used displayed in Table A4.2 is only 66% of that displayed in Table A4.1.

A4.4 Criticality of Borates

Information was received from several glass manufacturers and industry associations on how critical borates are to glass operations. They explain that the main component for glass making is silica which forms a SiO_2 network. A 100% SiO_2 glass (known as 'quartz glass') has very high melting temperatures of up to 2,000°C. To lower the melting and forming temperature of the glass, additives are added. Alkali-components are relatively cheap additives but these components also increase the electric conductivity of the glass. Most continuous fibre glass is formed from E-glass, were the 'E' stands for the low electric conductivity of the glass. To maintain this property, the prescribed amount of alkali for E-glass is low. However, borate additives also lower the melting and forming temperature of SiO_2 glass but without raising the electrical conductivity. The boron added to the glass forms covalent bonds with oxygen atoms in the silica network. The majority of E-glass produced in Europe contains < 5% by weight of boron as di-boron tri-oxide (B_2O_3) (APFE, 2008).

A strong relationship exists between boron content of glass, the fibre forming temperature and crystallisation temperature. The interval between these two temperatures (•T) is critical for forming the continuous fibres at an efficient conversion level. Lowering boron content means decreasing •T and increasing the temperatures (and associated energy consumption and emissions). If •T becomes too small, crystallization will appear during the forming of the filaments, thus causing the filaments to break. Therefore, the production of continuous fibre glass with low or zero boron contents requires special technology. However, such technology is not freely available on the market due to patent restrictions. In addition, the very high temperatures involved and critical •T demands special infrastructural design that most plants cannot incorporate (APFE, 2008).

Information provided by glass manufacturers indicates that, in addition to the effects described above, the addition of borates also:

- increases chemical resistance to water, acids and alkaline liquids;
- increases resistance to thermal shock (three times that of soda-lime glass);

- improves resistance to stress;
- improves radiation shielding properties;
- increases in strength (over twice as strong as soda-lime glass)
- lowers thermal expansion (coefficient one third that of soda-lime glass); and
- lowers electrical conductivity.

As such, the combination of properties produced, through the addition of borates to glass, are unique. These properties together make borosilicate glass uniquely suited to the production of laboratory equipment. The resistance of such glass to thermal shock also makes it suitable for heat resistant cookware.

A4.5 Potential Substitution of Borates

According to information provided by glass producers and their trade associations, there are no known viable alternatives to the use of borates in the manufacture of borosilicate glass or indeed, mineral wool insulation products.

One company stated that there are a number of low cost 'alkali-components' that may be used as glass additives; however, such alkali-components also raise the electrical conductivity of the glass, making it unsuitable as an alternative for borosilicate glass for many applications. One company is also known to have developed a proprietary glass formulation, which contrary to other E-glass containing boron, advertises its product as 'boron-free'[1].

There are no alternatives to the use of borates for the production of glass suitable for the production of: heat resistant cookware; heat resistant glass panels (e.g. in cookers); laboratory ware; LCD screens; solar panels; optical glass, for specific high prescription applications; and radiation shielding glass.

A4.6 Impact of Potential Restrictions

According to APFE (2008), since borates are an integral component for glass fibre manufacturing and boron oxide in the network assures their flexibility and dielectric properties, restrictions on borates would mean that fibre glass products could no longer be manufactured by almost all of their current member companies.

EURIMA (2008) also notes that, in the absence of any technically or economically viable alternative to the use of borates in the manufacture of bio-soluble borosilicate glass, the manufacture of mineral wool insulation products would cease with the closure of all

1 Boron-free glass fibres include those for both general purposes (such as *Advantex*) and special purposes (see, for example, Wallenberger *et al*, 2001 and APFE, 2003). In these boron-free glass fibres, it appears to be the case that rather than the boron being replaced with another additive, the boron-free glass is produced from a different mix of oxides under different heat conditions.

manufacturing plants and ensuing loss of employment. It would also remove from the EU market a practical, viable and safe solution to meeting EU energy reduction and CO_2 reduction targets.

Information provided by glass producers, APFE (2008) and EURIMA (2008) indicates that restrictions on borates would reduce the revenue of many companies by at least half their current levels and the majority of companies have stated that they would have to cease trading entirely. Few companies provide quantitative estimates of the costs of a ban on the use of borates to their business; however, where such data are provided, they are summarised in Table A4.3.

Table A4.3: Quantitative Cost Estimates of a Ban on the Use of Borates to Glass Producers

Factor	One-off costs (€)	Annual cost (€)	No of Staff Lost
Company 1	€32 million	€7 million	400
Company 2	€30 million	€7.5 million	220
Company 8	€150 million		13,000
Company 9			5000
Company 10		€100 million	800
Company 11			2,000

From the data provided in Table A4.3 it can be seen that the one-off costs and annual costs to European industry from a ban on the use of borates in glass would be in the order of hundreds of millions of Euros. In addition, tens of thousands of jobs could be lost in the EU. Moving further down the supply chain, companies that require the products listed above would be forced to adapt their products or remove them from the market; the cost to such industries in lost revenue and jobs is uncertain. Several glass producers highlight that a ban on the use of borates in glass production would result in the products which cannot be produced without boron being unavailable to industry and consumers

The cost of boron-free glass fibre is estimated by one company to be 0.3 €/Kg higher than the boron containing equivalent. Should borosilicate glass not be available, it is not clear whether or not the EU capacity to produce boron-free glass fibre would be sufficient to meet demand. It is also not clear whether or not the higher cost of boron-free glass fibre would result in the production of an economically competitive insulation material. Several companies state that without boron, glass may need to be heated to higher temperatures to soften it for fibre production. Its production would therefore require more energy, raising costs and potentially increasing the amount of carbon dioxide released into the atmosphere.