

IPC Guidance Note

S2 3.03

Processes Subject to
Integrated Pollution Control

Manufacture of Glass Fibres,
Other Non-Asbestos Mineral
Fibres, Glass Frit, Enamel Frit
and Associated Processes



ENVIRONMENT
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IPC Guidance Notes

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Processes Subject to Integrated Pollution Control

IPC Guidance Note
Series 2 (S2)
Mineral Industry Sector

S2 3.03 Manufacture of Glass Fibres, Other Non-Asbestos Mineral Fibres, Glass Frit, Enamel Frit and Associated Processes

Prepared by the Environment Agency

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Executive Summary

This IPC Guidance Note supersedes Her Majesty's Inspectorate of Pollution's Chief Inspector's Guidance Notes IPR 3/4 and IPR 3/5 published by HMSO in 1992 and is issued by the Environment Agency as one of a series of guidance notes for processes prescribed for Integrated Pollution Control (IPC) in Regulations⁽¹⁾ made under Section 2 of the Environmental Protection Act 1990 (EPA90). It is a guide on techniques and standards relevant to the processes covered by the Note.

It will be used by Agency staff, in conjunction with other relevant guidance⁽²⁾, in assessing operators' proposals relating to their authorisations under EPA90. This Note should be used together with separate guidance on monitoring⁽³⁾, dispersion methodology⁽⁴⁾, and assessment principles for determining Best Available Techniques Not Entailing Excessive Cost (BATNEEC) and Best Practicable Environmental Option (BPEO)⁽⁵⁾ to provide a framework for a consistent approach to the regulation of this class of IPC process.

This Note covers processes for the manufacture of non-asbestos mineral fibres, glass frit or enamel frit described in Sections 3.3 and 3.5 Part A of the Regulations⁽¹⁾, and defined as follows:

- (a) The manufacture of
 - (i) glass fibres;
 - (ii) any fibre from any mineral other than asbestos.
- (b) The manufacture of glass frit or enamel frit and its use in any process where that process is related to its manufacture and the aggregate quantity of such substances manufactured in any 12 month period is likely to be 100 tonnes or more.

At the time of writing this Note, processes operating in England and Wales which are covered under the description in paragraph (a) above include the manufacture of:

continuous filament glass fibres;

- optical fibre;
- ceramic fibre;
- glass fibre wool;
- rock/slag fibre wool.

1 Introduction

Scope and status of Guidance Note

1.1 Scope and status of Guidance Note

This IPC Guidance Note supersedes Her Majesty's Inspectorate of Pollution's Chief Inspector's Guidance Notes IPR 3/4 and IPR 3/5 published by HMSO in 1992 and is issued by the Environment Agency as one of a series of guidance notes for processes prescribed for Integrated Pollution Control (IPC) in Regulations⁽¹⁾ made under Section 2 of the Environmental Protection Act 1990 (EPA90). It is a guide on techniques and standards relevant to the processes covered by the Note.

It will be used by Agency staff, in conjunction with other relevant guidance⁽²⁾, in assessing operators' proposals relating to their authorisations under EPA90. This Note should be used together with separate guidance on monitoring⁽³⁾, dispersion methodology⁽⁴⁾, and assessment principles for determining Best Available Techniques Not Entailing Excessive Cost (BATNEEC) and Best Practicable Environmental Option (BPEO)⁽⁵⁾ to provide a framework for a consistent approach to the regulation of this class of IPC process.

This Note represents the state of understanding at the time of writing, and includes:

- description(s) of the principal processes covered by the Note;
- the prescribed substances and other substances that can cause harm and are most likely to be released from the processes;
- guidance on appropriate techniques for the control of releases;
- benchmark release levels;
- other environmental standards relevant to the process; and
- information on economic implications of pollution control.

An operator should keep up to date with the best available techniques relevant to the process. This Note may not therefore be cited in an attempt to delay the introduction of improved, available techniques, and, except where specifically stated to the contrary, nothing contained herein should be considered prescriptive.

The concepts of BATNEEC and BPEO expressed in the EPA90 and associated Regulations are site-specific. This Note cannot take into account such site-specific considerations. Thus, while operators' proposals should be judged against the benchmark release levels given in this Note, the benchmarks

should not be applied as uniform release limits. They are indicative, but not prescriptive, for new processes which are expected to use modern techniques for the prevention, minimisation and abatement of releases.

Where less stringent release levels are proposed for a specific case, comparing them and the benchmark release levels will indicate the degree of technical and economic justification required to be provided by the operator. Conditions in authorisations which relate to permitted releases should ensure that all factors, including those which are site-specific, have been taken into account, and that the legal requirements to use BATNEEC and BPEO are fully satisfied.

Compliance with statutory environmental quality standards or objectives, and with agreed international obligations relating to permitted releases or environmental standards, remains mandatory. No discretion is permitted without formal policy approval.

Figures are included in this Note for the purposes of illustration and clarification. The appearance of any item of plant in a figure does not imply any recommendation – reference must be made to the text.

1.2 Existing processes

Existing processes should be upgraded taking into account the criteria included in Articles 4, 12 and 13 of the European Community Directive on the combating of air pollution from industrial plants known as the Air Framework Directive (84/360/EEC)⁽⁶⁾. Article 13 requires the following points to be taken into account:

- the plant's technical characteristics;
- its rate of utilisation and remaining life;
- the nature and volume of polluting emissions from it; and
- the desirability of not entailing excessive costs for the plant concerned, having regard in particular to the economic situation of undertakings belonging to the category in question.

Whilst it may be possible to make improvements to existing processes using techniques described in Section 2 of this Note, the state of design of some existing plant may prevent operators from achieving the release levels given in this Note, even with improvements.

Processes covered by this Note

Existing processes in this class have been authorised and site-specific improvement plans set where required. On reviewing an existing authorisation, or considering a variation, the above criteria should be applied to ensure the continuing application of BATNEEC/BPEO. This may require a timetable for improving or decommissioning the process. Improvement plans are a site-specific issue therefore no target dates are included in this Note.

- glass fibre wool;
- rock/slag fibre wool.

Where other prescribed processes are carried on in conjunction with the primary process, reference should be made to the relevant Chief Inspector's Guidance Notes or IPC Guidance Notes and, where appropriate, the Secretary of State's Guidance for Local Authority Air Pollution Control on the ancillary processes insofar as they have potential for releases to the environment.

1.3 Processes covered by this Note

This Note covers processes for the manufacture of non-asbestos mineral fibres, glass frit or enamel frit described in Sections 3.3 and 3.5 Part A of the Regulations⁽¹⁾, and defined as follows:

- (a) The manufacture of
 - (i) glass fibres;
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At the time of writing this Note, processes operating in England and Wales which are covered under the description in paragraph (a) above include the manufacture of:

- continuous filament glass fibres;
- optical fibre;
- ceramic fibre;

In the context of this Note 'process' is from receipt of raw materials via production of intermediates to dispatch of finished products.

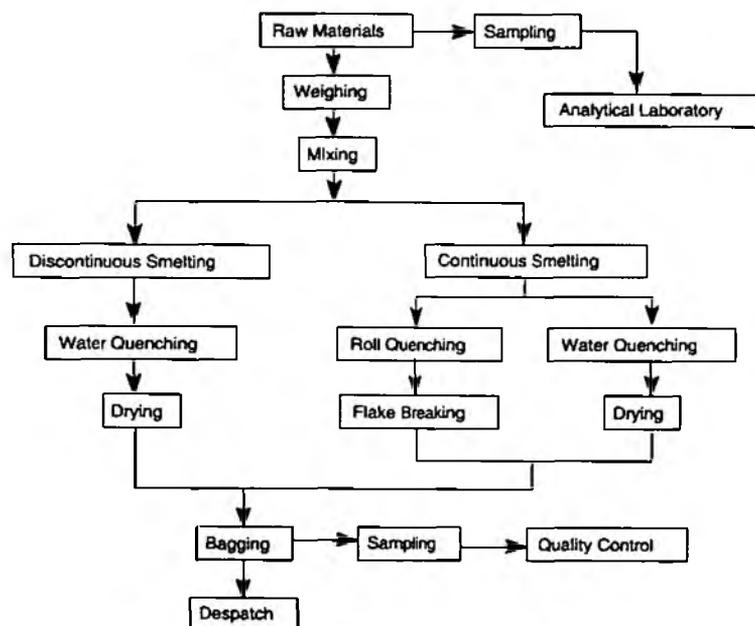
1.4 Processes

1.4.1 The manufacture of glass and enamel frits (See Figure 1)

Frit is prepared by fusing raw materials in a melter at high temperature. The molten material is then quenched causing the melt to solidify rapidly and shatter into friable particles termed frit. Glass frit is used as a raw material in the production of ceramic glaze. This is a vitreous coating applied to a ceramic body and fused by the application of heat. Similarly, enamel frit is a raw material used in the production of enamel. This is applied to metals for decorative and/or protective purposes. Glazes and enamels may be applied either dry or wet, the latter predominates and is usually in the form of a slip or slurry.

The process of fritting fuses water soluble raw materials into an insoluble glass, thereby making it

Figure 1: Schematic of the frit manufacturing process



easier to keep these materials uniformly distributed in the glaze or enamel suspension during subsequent processing. Furthermore, some of the raw materials used in the manufacture of glazes or enamels are both toxic and soluble. The conversion of these materials into an insoluble glass minimises the dissolution of toxic substances and therefore their potential for release to the environment.

The raw materials used in glass and enamel frit manufacture are essentially the same. They can be divided into four different groups – refractories, fluxes, opacifiers and colouring agents.

Refractories include materials such as clay, feldspar and quartz. They are generally acidic in character and provide body to the frit.

Fluxes are basic in character and react with the acidic refractories to form the glass. They include materials such as soda ash, potash, borax, cryolite and fluorspar.

Opacifiers provide the white opaque appearance which characterises many enamels. They can be insoluble such as titanium dioxide, tin oxide and zirconium oxide, or devitrification opacifiers such as cryolite or fluorspar. The latter may also act as fluxes rendering enamels more fusible. Opacifiers are not always included at the fritting stage but may instead be added during slip production.

Colouring agents may be oxides, elements or salts. Aside from their colouring properties they may act as either refractories or fluxes, and include materials such as cobalt oxide, chromium oxide and manganese oxide.

Raw materials may be stored in silos and conveyed to the weighing area pneumatically or mechanically. However, due to the relatively small size of UK manufacturers most materials are stored in bags and manually dosed to the weighing apparatus. The various raw materials are precisely weighed and mixed to produce a batch which is chemically and physically uniform before being charged to the furnace.

The frit industry utilises both continuous furnaces and discontinuous batch furnaces. The choice of furnace is dependent on the scale of production and the product formulation. The nature of the business is such that it is common for small batches to be produced for a wide range of frit formulations.

In continuous furnaces the raw materials are charged via a screw-feeder and form a pile at the charging point. Burners located along the sides provide temperature conditions of appropriate

stability to enable the face of the pile to melt continuously. As the materials melt, they form a shallow layer on the base of the furnace and flow to emerge at the opposite end. Production remains constant due to the continuous feeding of the raw material pile at the inlet.

The molten frit can be quenched directly in a water bath, or can be cooled between water cooled rollers to produce a flake product.

Batch furnaces are box shaped or cylindrical refractory lined vessels, mounted on bearings to allow a degree of rotation. To avoid contamination such furnaces are normally dedicated to similar types of formulation, though it is possible to purge furnaces between melts. Raw materials are charged through a port at the top of the furnace, and this can result in a short term high level of particulate matter emission. Direct water quenching is used almost exclusively in batch manufacture, and the quench water may become contaminated with particulate matter and any soluble components from the melt.

Temperatures in the furnace are typically in the range 1000°C to 1500°C, though lower temperatures are used for high lead frits. During the melting operation metal fume and other particulates may be generated. Residence time in the furnace is typically less than 4 hours.

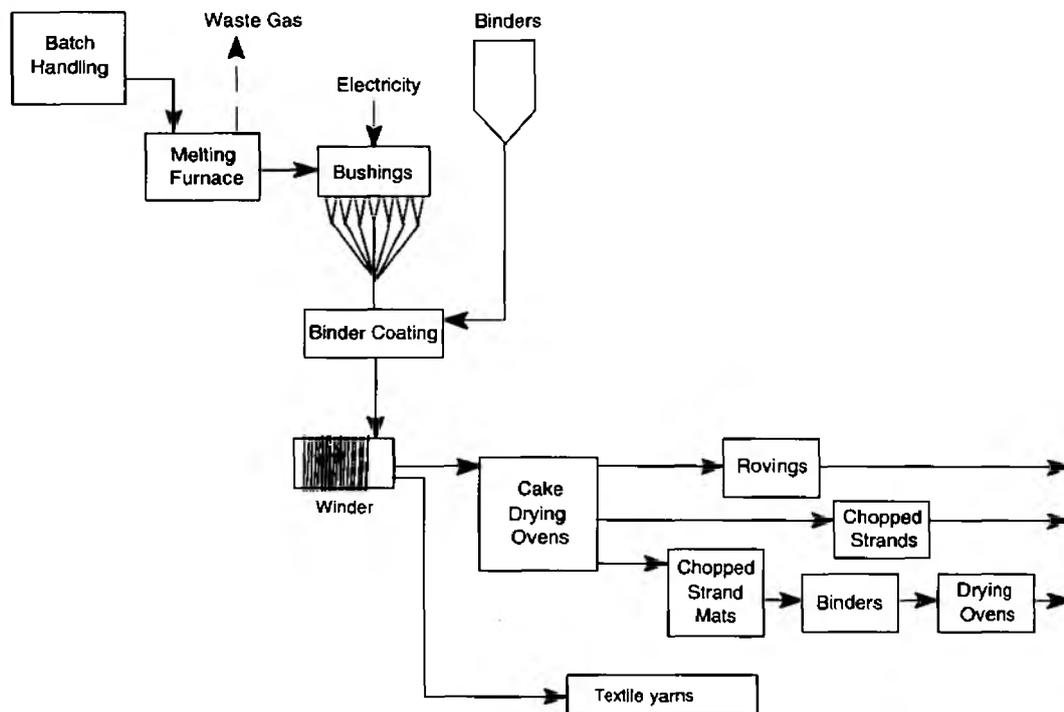
To produce a slip, the frit must first be finely ground. Grinding is generally carried out in ball mills utilising alumina balls or flint pebbles in water. Further constituents of the glaze or enamel, such as clays, colours, electrolytes and opacifiers, may be added at any desired stage in the grinding cycle. Mill cycle times may vary from 6 to 16 hours. On completion of the milling operation the blended slip is passed over a mesh screen and over a magnet to remove tramp iron. For dry products the resulting slip may be dried or a dry grinding process may be used.

Furnace fuels in frit manufacture are usually natural gas or oil. Most modern frit plants in Europe use pure oxygen or oxygen/air mixtures instead of air only for combustion. This is primarily due to:

- reduced fuel costs;
- a reduction in waste gas carryover;
- an increase in furnace efficiency and productivity; and
- reduced NO_x formation.

Processes

Figure 2: Generalised continuous glass filament manufacturing process



1.4.2 Continuous glass filament production (See Figure 2)

The raw materials for glass manufacture include: silica (sand); calcium carbonate (limestone); alumina silicate (china clay); calcium oxide (lime); calcium borate (colemanite); calcium fluoride (fluorspar); calcium sulphate (gypsum), sodium carbonate (soda ash) and sodium sulphate (salt cake). Processes will utilise a combination of these materials depending on the specific glass composition being produced. The raw materials are delivered by road tanker and are pneumatically conveyed into storage silos. Minor raw materials may be delivered in bags.

Raw materials are transferred to smaller "day bins" from where they are weighed out automatically to give a precisely formulated "batch". The batch is then mixed and conveyed to a storage silo in the furnace area.

The furnace consists of a large refractory box supported by a steel frame, and is heated by a series of gas burners along each side. The furnace is a continuous melter with an operational life of around ten to twelve years.

The blended batch materials are fed into the rear of the furnace onto the surface of the molten glass. Complex currents are induced in the molten glass by convection, the addition of air or nitrogen

bubbles and by drawing off molten glass from the front end of the furnace. The batch materials are progressively melted and undergo chemical reactions to produce the basic oxides which combine to form the glass structure. The circulation of the glass, the residence time in the furnace, and the temperature profile of the molten glass are critical to the quality of the final product. From the front end of the furnace the molten glass flows through a series of refractory lined, gas heated canals to the forehearths.

In the base of the forehearth are special refractory blocks each with an elongated hole. Below each hole there is a metal bushing plate, in which are many accurately dimensioned small tubes through which the glass flows to produce fibres. The bushings are electrically heated and temperature controlled. Glass filaments are rapidly attenuated to precise diameters through the tubes. The glass filaments are cooled by metal fins sited just below the bushings, and further cooling is applied by fine water sprays.

The filaments are drawn together and pass over a roller which applies an aqueous polymer solution to each filament. The coating material will vary depending on the end use of the product. Typical coatings are: film formers (eg polyvinyl acetate, starch, polyurethane, epoxy resins); coupling agents (eg organo-functional silanes); pH modifiers (eg acetic acid, hydrochloric acid, ammonium salts); and lubricants (eg mineral oils, silicones). The

coated filaments are gathered together into bundles called strands which are wound onto a rotating mandrel to form cakes up to about 18 kg in weight. The cakes are then labelled and passed forward for fabrication.

The cakes leaving forming are saturated with moisture and coating materials. For some applications the cakes can be processed wet, for others they have to pass through drying ovens. The ovens are heated by gas, steam, or by electricity. The main products are chopped strands, rovings and chopped strand mat.

Chopped strands are produced by unwinding the cakes and feeding the filaments into a machine with a rotating bladed cylinder. The chopped strands are conveyed into a variety of packages up to 1 tonne in weight. Rovings are produced by unwinding and combining the strands from multiple cakes, sufficient to achieve the desired weight of glass per unit length.

Chopped strand mat is produced by chopping the strands unwinding from the cakes in cylindrical choppers. The choppers are arranged so that chopped strands can be applied to a moving conveyor belt up to 3 m wide. The strands are sprayed with an aqueous solution of polyvinyl acetate which acts as a binder. The conveyor takes the now wet mat through a drying and curing oven and then through a pair of compaction rollers before winding the mat onto a mandrel. The mat can be made in various densities (wt/unit area) and widths and is packed into boxes with a typical weight of 50 kg.

1.4.3 Optical fibre manufacture (See Figure 3)

There are three major processes for optical fibre manufacturing. The processes Modified Chemical Vapour Deposition (MCVD), Outside Vapour Deposition (OVD) and Vapour Axial Deposition (VAD), all use silicon tetrachloride and small amounts of germanium tetrachloride to manufacture high purity glass with well controlled optical properties. The processes vary in the way in which the particles of glass are produced and collected.

In the MCVD process, the inside of a glass tube is cleaned by a chemical etching process. Freon gas and oxygen are passed down the tube, whilst the outside is heated with a flame burner which traverses along the length of the tube. The inside of the tube is coated with layers of cladding glass, by the vapour deposition of silicon dioxide. Silicon tetrachloride is passed down the glass tube, the outside of which is heated with a longitudinally moving flame burner. The silicon tetrachloride is

oxidised to silicon dioxide soot which is deposited on the inside of the tube and fused into a glass by the heat of the burner. Many layers of soot are deposited and fused into glass. Finally, the cylinder is collapsed to remove the centre hole and produce a glass preform.

In the OVD process, silicon tetrachloride is passed through a flame burner and oxidised to fine particles of silicon dioxide soot. The soot is deposited on the outside of a target rod which is passed back and forth through the flame. Many layers of soot are deposited on the rod to create a soot preform. This preform is later placed in a consolidation furnace where heat and process gases, chlorine and helium, are used to fuse the soot into glass, to close the hole left by removal of the target rod and to remove any water.

The VAD process is similar to the OVD process except that the soot particles are deposited on the end-face of the target rod instead of along its length. To make room for new growth, the target rod is moved away from the flame burner. The soot preform is consolidated in a manner similar to the description above. This glass preform is sometimes inserted into a glass tube, similar to that used as the starting tube for MCVD, to make the preform larger.

Any undeposited soot and reaction by-products (predominantly chlorine and hydrogen chloride) are extracted to pollution abatement equipment. Acidic gases from preform consolidation pass to the pollution abatement equipment as well. The final stage of the manufacturing process involves drawing the glass cylinder into a filament, coating the filament with an acrylic resin, curing the resin using ultraviolet light and winding the filament onto a reel. The reel of optical fibre is then tested for strength and optical properties before being wound onto a reel for storage and then sale.

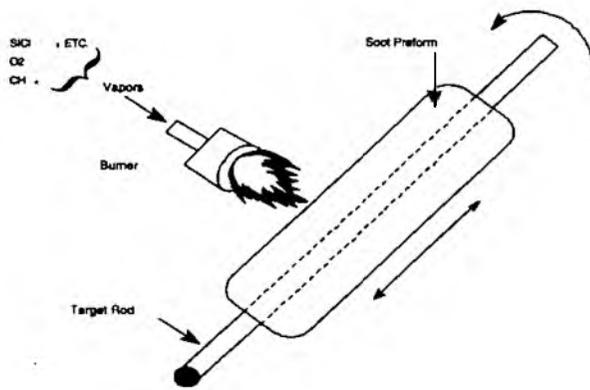
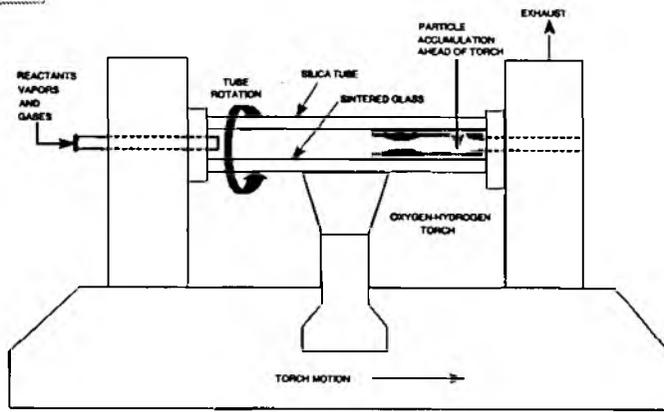
1.4.4 Ceramic fibre manufacture (See Figure 4)

If the fibre production is interrupted the molten stream is not stopped, it is quenched in water and where practicable reused in the process.

The fibres are drawn from the collecting chamber on a continuously moving belt to which a vacuum can be applied. As the resulting fleece comes off the lay-down belt it can be removed, baled and bagged, or allowed to continue down the production line to make blanket. This material can be baled as product or needlefelted to allow the fibres to knit together for additional strength. The needlefelted product can be passed through an oven to remove lubricant before being rolled up as blanket or cut into slabs.

Processes

Figure 3: Optical fibre manufacture



The OVD Soot Preform Process. (2)

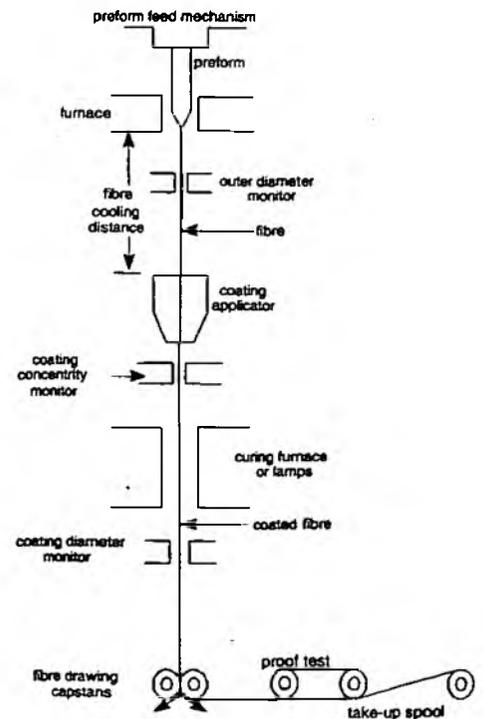
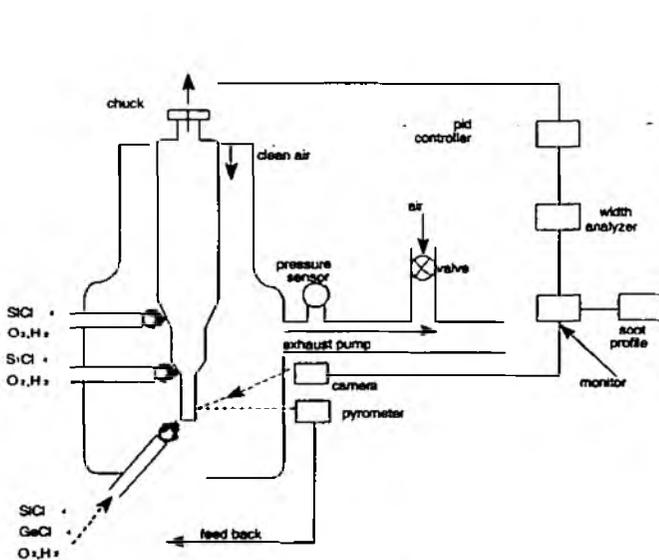
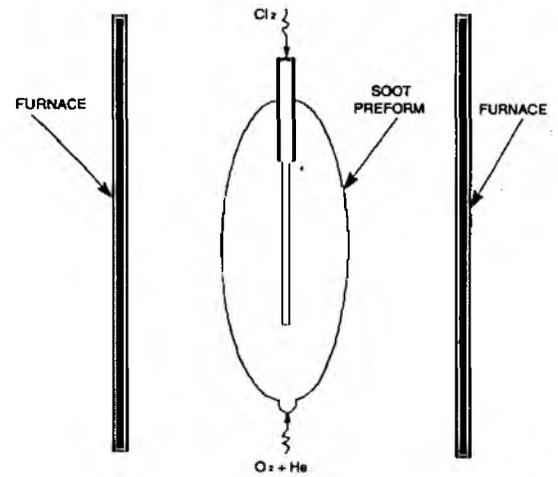
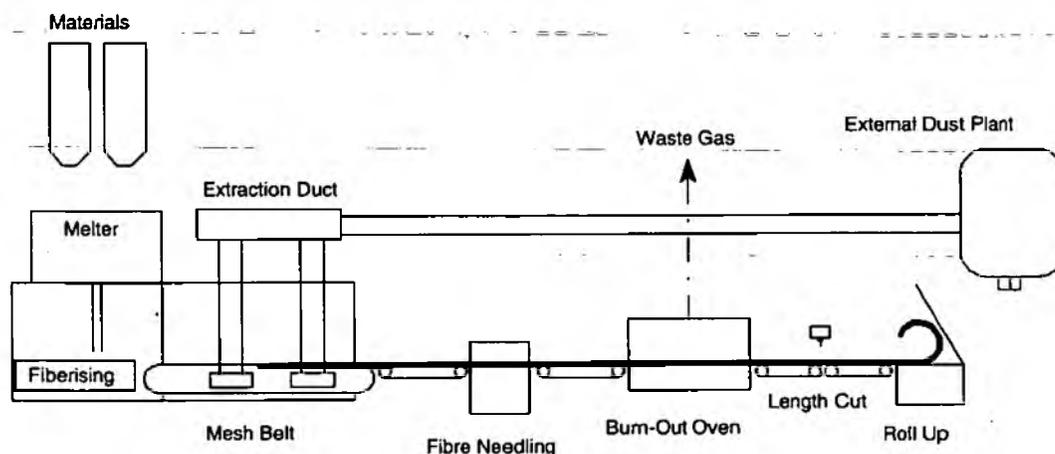


Figure 4: Generalised ceramic fibre process

Processes



The process can be divided into two parts, the production of the fibre and the conversion of the fibre into other components.

Oxides of aluminium, calcium, magnesium, silicon and zirconium are delivered in bulk road tankers and pneumatically transferred to bulk storage silos. Smaller volume raw materials, including organic additives, are received in, and dispensed from drums or sacks. The bulk raw materials are transferred from storage to the blending plant where they are mixed to give the required composition.

The blended material is transferred to the furnace, where it is melted by electrical resistive heating. The furnaces are about 1 metre deep and 2-3 metres in diameter, and have an open top which is covered in a layer of unmelted batch materials.

A molten stream of the alumino silicate melt flows from the furnace to fall either onto high speed rotating wheels, which throw off a spray of fibres into a collecting chamber, or

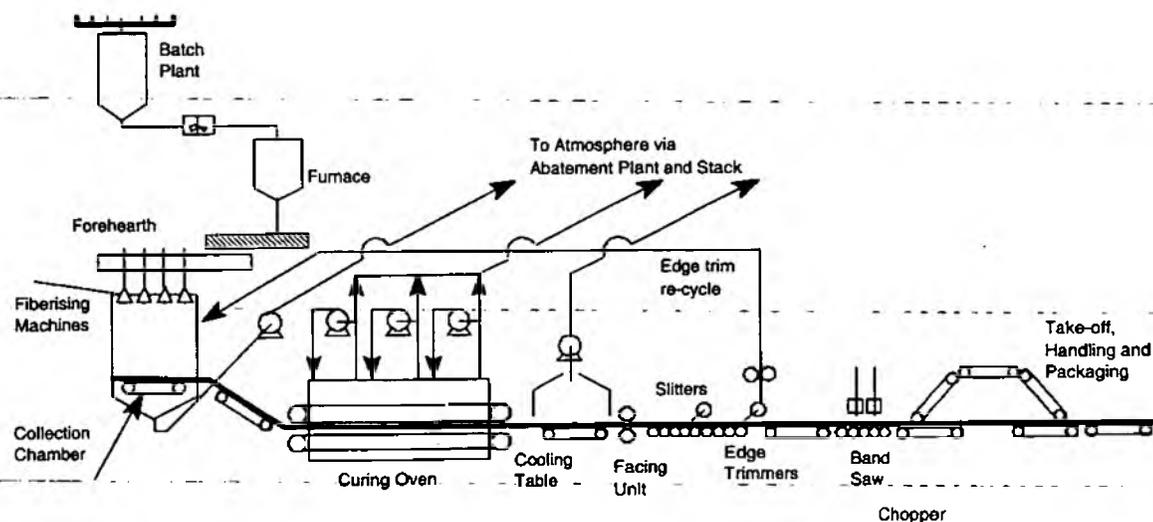
alternatively, in front of a high pressure jet which attenuates the molten material into fibres. In neither case are binders added to the fibres, but a small amount of lubricant is added which aids fiberisation.

Further downstream processing may also be carried out. The vacuum forming process consists of supplying a wet colloidal mixture of ceramic fibre and starch, latex, silica or clay to appropriately shaped moulds. The moulded shape is usually dried in a gas fired oven and may be buffed or trimmed and cut to size before packing and dispatch. Ceramic fibre papers, felts and boards may also be produced. This involves the laying down of an aqueous suspension of fibres onto a vacuum drum, followed by oven drying. A mixture of binders and additives may be added to the aqueous suspension.

1.4.5 The manufacture of glass fibre insulation (See Figure 5)

The raw materials for glass manufacture are delivered by road tanker and pneumatically

Figure 5: Generalised glass fibre insulation manufacture



Processes

conveyed into storage hoppers. Each process will use a range of raw materials and the precise formulation of the batch may vary considerably between processes. The basic materials for glass manufacture include sand, soda ash, dolomite, limestone, sodium sulphate, sodium nitrate, ulexite and granite.

Most processes also use process cullet as a raw material. This is shattered glass which has been produced by quenching the molten stream from the furnace in water, when the fiberising operation has been interrupted. Process cullet has the same precise formulation as the final product, and is readily recycled to the furnace. Other forms of waste glass, eg bottle cullet and plate glass cullet may also be used as a feedstock. This type of material is more difficult to recycle and its use will depend heavily on cost, composition, purity and consistency of supply.

These materials are automatically weighed out and blended to produce a precisely formulated batch. The blended batch is then transferred to an intermediate storage hopper before it is added to the furnace.

The furnace will be either an electrically heated furnace or a traditional refractory lined, gas fired recuperative furnace, similar to that described in Section 1.4.2 above. An electric furnace consists of a refractory lined box supported by a steel frame, with electrodes inserted either from the side or the bottom of the furnace. The energy for melting is provided by resistive heating as the current passes through the molten glass. The top of the molten glass is covered by a layer of batch material which gradually melts from the bottom upwards.

A stream of molten glass flows from the furnace along a refractory lined forehearth and pours through a number (usually one to ten) of single orifice bushings into specially designed rotary centrifugal spinners heads. Primary fiberising is by centrifugal action of the rotating spinner with further attenuation by hot flame gases from a circular burner. This forms a veil of fibres with a range of lengths and diameters randomly interlaced. The veil passes through a ring of binder sprays which spray a phenolic resin binder and mineral oil onto the fibres to provide integrity, resilience, durability and handling quality to the finished product.

The resin coated fibre is drawn under suction onto a moving conveyor to form a mattress of fibres. This mattress passes through a gas fired oven at approximately 250°C, which dries the product and cures the binder. The product is then air cooled and cut to size before packaging. Edge trims can be

granulated and blown back into the fibre veil, or they can be combined with surplus product to form a loose wool product.

Water is sprayed into much of the downstream process ducting, to prevent the build up of fibre and resinous material, which could cause fires or blockages, and to remove entrained material from the flue gas. Water is also used for cleaning the collection belt and other parts of the plant. The process water system is generally a closed loop; it is collected, filtered and reused for duct sprays, cleaning water and binder dilution.

A range of products can be produced from manufactured glass fibre. These include granulated insulation wool for blown installation in lofts and cavities, packaged uncured wool for supply to customers who would mould and cure secondary products and for on-line and secondary-process laminated or faced products. Pipe insulation is a significant secondary product usually manufactured by diverting uncured wool from the main process for press-moulding and curing. Alternatively, the wool may be wound onto retractable heated mandrels to form the bore and heat-processes to form the outer wall before transfer to an overall curing stage.

1.4.6 The manufacture of rock fibre insulation

Rock fibre is made by melting a combination of aluminosilicate rock (usually basalt), blast furnace slag, and limestone or dolomite in a hot blast cupola. The batch may also contain prepared, recycled, process/product waste. The cupola may be gas fired or more usually coke fired.

The inorganic materials and coke are charged to the top of the cupola in alternate layers. Oxygen enriched air is injected into the combustion zone of the cupola, about 1 to 2 metres from the bottom. This is the hottest part of the cupola at approximately 2000°C. The molten material gathers in the bottom of the furnace and flows out of a notch and along a short trough positioned above the spinning machine. Basalt and to a lesser extent blast furnace slag contain iron as Fe^{3+} and Fe^{2+} . In the reducing conditions of some areas of the cupola the ferric/ferrous iron is reduced to metallic iron. This collects in the bottom of the cupola, and would damage the expensive spinning machine if it was allowed to build up to the point where it flowed from the notch. To prevent this the iron is periodically drained, by piercing the lowest part in the curved base of the cupola. The melt falls onto the rapidly rotating wheels of the spinning machine, and is thrown off in a fine spray producing fibres. Air is blasted from behind the rotating wheels to attenuate the fibres and to direct

them onto the collection belt to form a mattress. An aqueous phenolic resin solution is applied to the fibres by a series of spray nozzles on the spinning machine.

The collection belt is under strong extraction – this performs three functions: it draws the fibre onto the belt, it removes the polluted air in the fiberising chamber, and it helps to distribute the phenolic binder across the mattress. The phenolic resin provides strength and shape to the product as in glass fibre insulation.

The mat passes through a gas fired oven at approximately 250°C, which dries the product and cures the binder. The product is then air cooled and cut to size before packaging.

Pipe insulation and some secondary products may be manufactured in the way described for the glass fibre process in Section 1.4.5.

Water is sprayed into ducting to prevent resin and fibre build-up, and to remove entrained material from the flue gas. It is also used for a variety of cleaning operations. As in the production of glass fibre insulation the process water is collected, filtered and reused.

1.5 Standards and obligations

1.5.1 Air quality standards

Statutory Instrument 1989 No.317, Clean Air, The Air Quality Standards Regulations 1989⁽⁷⁾ give limit values in air for the following substances:

- sulphur dioxide,
- suspended particulates,
- lead,
- nitrogen dioxide.

Inspectors are reminded that, at the time of writing, the Expert Panel on Air Quality Standards (EPAQS) have made recommendations with regard to possible implementation of air quality standards for five further substances, namely:

- benzene,
- 1,3-butadiene,
- carbon monoxide,
- ozone,
- suspended particulate matter less than 10 micrometre (PM₁₀'s).

EPAQS have also made a recommendation for a new short term air quality standard for sulphur dioxide. EPAQS will be carrying out similar studies for oxides of nitrogen in the near future.

Any emission from the process should not result in a breach of the appropriate air quality standard beyond the site boundary.

1.5.2 VOCs and ozone reduction

'Reducing emissions of VOCs and levels of ground-level ozone; a UK strategy'⁽⁸⁾ was published by the Department of the Environment in October 1993. It sets out how the Government expects to meet its obligation under the UNECE VOCs Protocol to reduce its total VOC emissions by 30% (based on 1988 levels) by 1999, including the reductions projected for the major industrial sectors. The methods of control described herein would be expected to ensure that the contribution of this sector to these reductions will be met.

1.5.3 Environmental quality standards

Statutory Instrument (1989) No. 2286⁽⁹⁾, The Surface Waters (Dangerous Substances Classification) Regulations gives the annual mean concentration limit values for certain substances including cadmium and mercury.

1.6 Release routes

Releases to the environment commonly associated with the processes described are listed in Tables 1, 2 and 3.

Release routes

Table 1: Potential release routes for prescribed substances and other substances which may cause harm from processes for the manufacture of glass and enamel frit

SOURCE RELEASES	Substances									
	Air	Water	Land	Particulate matter	Nitrogen oxides	Fluorides ⁽¹⁾	Cadmium ⁽²⁾	Lead	Other metals ⁽³⁾	Solid waste
To:										
Prescribed substances (defined in SI 472):	A	W	L							
Other substances which may cause harm:	a	w	l							
Raw materials handling				A			A ⁽⁴⁾	A ⁽⁴⁾	A ⁽⁴⁾	I
Charging				A			A ⁽⁴⁾	A ⁽⁴⁾	A ⁽⁴⁾	
Melting				A	A	A	A	A	A	I
Quenching				w			W	w ⁽⁵⁾	w ⁽⁵⁾	I
Drying				A	A		A ⁽⁴⁾	A ⁽⁴⁾	A ⁽⁴⁾	
Bagging				A						
Milling				A _{air}		w	W	A ⁽⁴⁾ ,w ⁽⁵⁾	A ⁽⁴⁾ ,w ⁽⁵⁾	
Abatement plant										L
Waste water				w			W	w ⁽⁵⁾	w ⁽⁵⁾	

Notes:

1. Generally only applicable to enamel frit plants.
2. Cadmium may be present if it is used in the batch materials. The operator should state in the application whether cadmium will be used in the process.
3. Other metals may include: antimony, arsenic, cobalt, copper, chromium, manganese, nickel, selenium, thallium, tin and vanadium. The presence of the metals will depend on the precise frit formulation being manufactured.
4. May be present in particulate matter.
5. Generally insoluble suspended solids.

Table 3: Potential release routes for prescribed substances and other substances which may cause harm from the manufacture of optical fibres

SOURCE RELEASES	Substances								
	Air	Water	Land	Particulate matter	Hydrogen fluorides	Hydrogen chloride	Chlorine	VOC	COD
To:									
Prescribed substances (defined in SI 472):	A	W	L						
Other substances which may cause harm:	a	w	l						
Vapour deposition				A	A	A	A		
Annealing						A	A		
Draining								A	
Waste water				w					w

Release routes

Table 2: Potential release routes for prescribed substances and other substances which may cause harm for the manufacture of glass filaments, ceramic fibres, glass fibre insulation, rock fibre insulation

SOURCE RELEASES	Substances																		
	To:	Air	Water	Land	Ceramic fibre	Particulate	Phenol	Formaldehyde	Ammonia	Amines	VOC (Note 1)	SO ₂	NO _x	Fluorides	Chlorides	Hydrogen sulphide	Carbon monoxide	Metals	COD
Prescribed substances (defined in SI 472):	A	W	L																
Other substances which may cause harm:	a	w	l																
Raw materials handling					A	A	A	A	A	A									W
Melting (cupola)					A							A	A	A	A	A	A	A	
Melting (gas fired)					A							A	A	A	A		A		
Melting (electric)					A							A	A	A					
Fiberising (continuous filament)																			W
Fiberising (ceramic)					A	A					A								
Fiberising (insulation)						A	A	A	A	A	A	A							
Curing (drying oven)						A	A	A	A		A	A		A					
Burnout oven (ceramic)					A	A					A								
Product cooling					A	A					A	A							
Trimming/packaging					A	A													
Pipe section production (insulation)						A	A	A	A	A	A	A							
Tail gas incineration											A	A	A						
Miscellaneous secondary processing					A	A					A								W
Waste water										W									W

Notes

1. The term "Volatile Organic Compounds" includes all organic compounds released to air in the gas phase.
2. This term is used to describe organic particulate matter and any binder droplets or mist which may be present in the waste stream.

2 Techniques for controlling releases

2.1 Introduction

The standard techniques for pollution abatement are outlined in various reference sources including:

- Separation Processes Service⁽¹⁰⁾, manuals and reports;
- Effluent Processing Club⁽¹¹⁾, manuals and reports;
- Air Pollution Advisory and Review Group⁽¹²⁾, reports;
- BAT Review Reports on Pollution Control; and
- HMIP/EA Technical Guidance Notes relating to IPC.

These techniques need to cover releases from raw materials reception/storage, internal transportation, processing, waste materials internal transport and storage pending disposal.

The process should be designed and operated in such a way that the substances released have the minimum impact on the environment. The operator's proposals should include a reasoned argument, in terms of the selected combination of primary process and abatement equipment, of why they represent BATNEEC to:

- prevent releases of prescribed substances or if not, to minimise them and render them harmless;
- render harmless releases of other potentially harmful substances; and
- provide the BPEO to minimise the environmental effect of operating the process.

This should then be confirmed by conditions in the authorisation. Since the priority is to prevent releases, emphasis should be placed on the avoidance of processes and abatement techniques which create wastes.

Prevention or minimisation by re-use, recovery and recycling procedures should be applied whenever possible, within the criteria for BATNEEC and BPEO.

In general, pollution control equipment should be kept running during start-up and shut-down for as long as is necessary to ensure compliance with release limits in authorisations.

All plant and equipment should be subject to regular preventative maintenance programmes, in line with operational requirements, to ensure continued optimum performance. There are certain difficulties specific to furnaces start-up, eg high waste gas volumes, which may make this difficult

to achieve. Where this is the case, techniques to minimise releases should be agreed with the site Inspector.

More details of the methods available for preventing or reducing releases are listed in BAT Review Report on Pollution Control for Fibre and Frit processes⁽¹³⁾. The most important techniques include, but are not restricted to, those given below.

2.2 Techniques for controlling releases to air

2.2.1 Materials handling

Fine materials should be stored in silos which are enclosed and vented to suitable arrestment plant such as fabric filters. Where practicable collected material should be recycled to the process. Where the amount of material used does not justify the use of silos, fine materials should be stored in enclosed containers or sealed bags.

Stockpiles of dusty materials should ideally be stored under cover with extraction to suitable arrestment equipment. Where dust is a particular problem, some sites may require the use of road cleaning vehicles and water damping techniques.

The transportation and handling of dusty materials should be carried out by methods which minimise emissions to air. External above ground conveyors for solid fuels and dry materials should be fitted with wind protection.

All areas of the process where dust is likely to be generated, eg bag opening, frit batch mixing, fabric filter dust disposal, etc should be provided with extraction which vents to suitable arrestment plant.

Volatile raw materials should be stored so as to minimise releases to air. In general bulk storage temperatures should be kept as low as practicable and temperature changes due to solar heating etc should be taken into account. For materials with a true vapour pressure (TVP) of 14 kPa or above at maximum run down temperature, or for odorous substances, specific techniques should be considered for reducing releases arising from tank breathing or from the displacement of vapour during liquid transfers.

Techniques for reducing losses from storage tanks at atmospheric pressure include the following:

- tank paint with low solar absorbency,
- temperature control,

- tank insulation,
- inventory management,
- floating roof tanks,
- vapour return transfer systems,
- bladder roof tanks,
- pressure/vacuum valves, where tanks are designed to withstand pressure fluctuations,
- specific release treatment eg adsorption, absorption, condensation,
- subsurface filling.

Bulk storage tanks should be sited above ground and should be impermeable to the tank's contents. All tanks should have adequate bunding with a capacity of 110% of the largest tank. Bulk storage tanks should be either fitted with protection against overfilling or procedures should be implemented to prevent overfilling. Vent pipes, valves, flanges, etc should be situated within the bunded area.

2.2.2 Frit manufacturing processes

Melting techniques

Gas fired furnaces are the accepted melting technique within the industry. There are three main types of gas fired furnaces; continuous, box and rotary. Each has its associated advantages and disadvantages which are discussed later in this Section.

The alternative to gas fired melting is electric melting. The technique is used widely in the glass industry, but it is thought that only one plant in the world utilises electric melting for commercial frit manufacture.

The principle of electric furnaces is that the conductive properties of molten glass increase as its temperature rises. Electrodes, constructed of materials such as molybdenum or tin oxide, are typically arranged laterally in the furnace, and raw materials are continuously fed on to the top of the melt by a screw conveyor. The geometry of the electrode arrangement in the melt can be used to control the heating effect.

Electric furnaces result in lower emissions than conventional gas fired furnaces. Fossil fuel combustion products are clearly eliminated, although releases will occur at the generation facility. More significantly the cold top layer of the melt results in a lack of turbulence at the surface and therefore minimal emissions of particulates and volatile components such as hydrogen fluoride. Other perceived advantages of electric melting include: potentially improved product quality due to greater circulation resulting in a more homogeneous melt; improved process control; overall reduction in energy consumption due to

lower radiant losses; higher output per square metre of furnace area; and lower capital costs due to a potential reduction in furnace size arising from the increased throughput.

However, electric melting has a number of drawbacks. The higher cost of electricity is unlikely to be compensated by the improved thermal efficiency, resulting in higher overall energy costs. Electrode replacement is costly and necessitates furnace stoppage resulting in lost production time. Electric melting is more suitable to continuous processes and the structure of the UK industry means that only a limited number of continuous furnaces can be operated economically.

Furthermore, there is very little operational experience of electric melting within the industry, and operators are extremely reluctant to take the risk of an essentially unproven technique, particularly for non-continuous furnaces. Releases from electric furnaces are still likely to require downstream abatement, although on a lesser scale than conventional furnaces. The rest of this Section is concerned with controlling releases from gas fired furnaces.

Specified pollutants

The principal environmental concerns associated with frit production are releases to air of particulate matter, fluorides, oxides of nitrogen and heavy metals including lead. These releases can be controlled by a range of processing methods and abatement techniques. Each substance is addressed separately, but where processing methods affect other substances reference to this is made.

Particulate matter

Particulate concentrations in untreated frit kiln flue gases are typically of the order of 200 mg/m³. The majority of particulates are generated during charging, but where the raw materials contain significant quantities of boron, volatile borates generated during melting will condense to form particulates on cooling.

Rotary and box furnaces are traditionally charged from a hopper above the furnace, resulting in substantial particulate carry over in the waste gases. Hopper systems should therefore be designed to minimise the height of charging. Side feeding using a screw feeder should be possible, but no working examples are known for box or rotary furnaces.

Continuous furnaces are charged with screw feeders and so do not experience the same problems. However, continuous furnaces can only be used where the economics of high volume production

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allow. The nature of the UK industry is such that many small batches are produced, and only a few continuous furnaces are operated in the UK.

Another method of reducing releases during charging is pelletisation of the batch. This technique is not currently used within the industry and will add additional costs to the manufacturing process. However, it may be cost effective in some circumstances, particularly where additional downstream abatement would otherwise be necessary.

In most processes downstream abatement of particulate matter will be necessary to meet acceptable release levels. The method accepted within the industry, and that likely to give the best results is physical filtration, and in particular reverse jet bag filters.

Where a bag filter system is employed to treat waste gases from the fritting kiln, gas cooling is often required. Waste gases leave the kiln at over 1000°C and the maximum operating temperature of a bag filter, using a stainless steel medium, is of the order of 500°C. Conventional fabric filters typically have a maximum operating temperature of 200–300°C, although the cost increases substantially above 200°C. Waste gases may be cooled by a number of methods: dilution, heat exchangers, or evaporative cooling. Dilution, in which fresh air is mixed with the waste gases in the ratio of approximately 2:1, is commonly practised in the UK.

Heat exchangers are not often employed due to corrosion and fouling problems. Boron, for example, which is a major constituent of borax frits, has a tendency to condense on the heat exchanger elements, requiring frequent cleaning. In principle, cooling by dilution should be considered a viable technique, provided that mass releases are not increased. Cooling by dilution increases the size of the bag filter unit required to achieve an equivalent level of particulate abatement. Dilution must not be used simply as a means to achieve a given release concentration.

Filtration media based on other materials, such as ceramics, may also be used to control particulates and avoid the need for dilution.

Alternative control techniques for particulate releases to air include inertial separators, ESPs and wet scrubbers/collectors. The removal efficiency of inertial separators, such as cyclones or settling chambers, falls off rapidly as particle size decreases. For a high efficiency cyclone, collection efficiency for particles with a diameter of 5 microns is in the region of 70%. In general, cyclones can remove

particles in the size range of 5 to 25 microns at up to 90% efficiency. Due to the formation of significant quantities of sub-micron fume from glass fritting processes, inertial separators are not considered satisfactory for particulate control of furnace emissions.

Manufacturers claim that ESPs can achieve the same removal efficiencies as the best bag filters, and theoretically there is no reason why an ESP could not be used on waste gases from fritting processes. ESPs are known to be employed at some plants but operation has been problematic and the technique has not achieved the levels experienced with bag filters.

Wet scrubbers and wet collectors are widely used to control releases of particulates and gaseous pollutants from a range of processes. The abatement efficiency of wet techniques for particulate removal does not, in general, match the performance of physical filtration devices or ESPs, and would not be expected to achieve the release levels identified in Section 3.

Oxides of nitrogen (NO_x)

NO_x is generated during the melting process from the thermal combination of oxygen and nitrogen in the air, and the decomposition of nitrogen compounds contained in raw materials. Releases therefore depend on the amount of nitrates in the raw materials, flame and kiln temperatures, and air ingress into the kiln. Enamel frit processes result in higher NO_x releases than glass frit processes, due to the use of more nitrate compounds in the raw materials and slightly higher melting temperatures.

After substantial development work, it has been concluded that at present, a significant reduction of nitrates in the enamel frit batch is not feasible. The reason for this is the need to maintain oxidising conditions in the furnace. This ensures that elements such as titanium in white enamels, and manganese in dark enamels remain in their correct oxidised state. The operators claim that excess air in the kiln during melting is not a substitute for nitrates and impairs the quality of the product. For example, the reflectance of white enamels is reduced and shades of dark coloured enamels are variable. Alternative oxidising agents, including sulphur from persulphates and chlorides from perchlorates have been tested, but these appear too unstable for practical use. Perborate has also been used as an alternative to nitrates, but is less effective and much more expensive.

The thermal generation of NO_x can be substantially reduced by the use of oxy-gas firing. The use of pure oxygen instead of air removes nitrogen from

Techniques for controlling releases to air

the combustion atmosphere. This technique is already widely used within the industry, and in the absence of electric melting, is likely to be the most appropriate NO_x control technique. The technique of oxy-gas firing is discussed further in the fossil fuels Section under glass melting. The advantages and disadvantages discussed have been proven to a greater degree in the frit industry than in the glass industry.

Air ingress can be a particular problem in continuous furnaces. Burners can be effectively sealed, but air can still enter via the open molten glass channels. This tendency can be reduced by minimising the space above the molten glass in the channels.

In batch furnaces creating a good seal can be problematic if the burners are removed during charging to prevent the depositing of dust on the burner nozzle. Whilst burners are removed the orifice should be covered to prevent the ingress of air. Alternative burners have been developed which create a constant flow of oxygen over the burner nozzle to prevent dust deposition, and do not need to be removed.

If NO_x levels cannot be controlled using firing techniques, other abatement options may have to be considered. These include: wet scrubbing, selective catalytic reduction, and non-selective catalytic reduction. These techniques can entail substantial costs and in most circumstances are unlikely to be appropriate to satisfy BATNEEC/BPEO obligations.

Fluorides

Emissions of fluorides are directly related to the use of fluoride compounds in the raw batch. Fluorides are predominantly used in the production of enamel frit, and are not present to any significant extent in the raw materials used for glass frit manufacture. Some glass frit producers may, periodically, manufacture small quantities of enamel frits in the glass frit kilns, giving rise to fluoride emissions, but this constitutes a very small proportion of the operator's overall production.

Emission of fluorides is the most significant environmental impact of enamel frit production. Fluorides provide unique properties to the frit, such as improved thermal and chemical resistance, and reduced risk of blistering of the enamel coating. They are added to the batch as fluorspar, fluorosilicate, cryolite or sodium fluorosilicate. Most producers now offer some fluoride free or low fluoride enamels, and the availability of these products is increasing. At present fluoride free products represent less than 10% of production,

with low fluoride products at about 30%. However, the reduction of fluoride in the batch will not be sufficient to achieve the release level specified in Section 3, and some form of abatement will be required for enamel frit processes.

Abatement techniques to control fluoride emissions are of two basic types, wet scrubbers and dry scrubbers. The principles of both of these techniques are described in HMIP publications^(14, 15), and in this Section they are described only in the context of their applicability to removing fluorides from frit process emissions.

Hydrogen fluoride is highly soluble in water, but the overall efficiency can be improved by the addition of an alkaline reagent, eg sodium hydroxide. Removal efficiencies of greater than 90% should be expected. The major drawback of wet scrubbers is the generation of a significant aqueous waste stream, which will require treatment and disposal.

An interesting modification to the use of wet scrubbers for the removal of hydrogen fluoride has been developed in Germany. This system involves reaction with a sodium hydroxide solution followed by a drying stage to produce sodium fluoride crystals, which are recycled as batch raw material. However, this system has been patented, but not yet marketed and therefore cannot be considered as currently available.

Dry scrubbing systems are commonly used to remove hydrogen fluoride from waste gases at frit plants throughout Europe. The technical characteristics of these systems are well known and are not reviewed in detail here. The conventional approach is to use lime or limestone as the reagent to react with the hydrogen fluoride to form calcium fluoride in the reaction:



The lime is injected into the gas stream after the kiln and the reacted particles are collected in the particulate removal devices, either a bag filter or an ESP. Most systems incorporate some form of recycling the unreacted lime back into the gas stream to ensure a high degree of conversion to CaF₂.

For most processes an efficient dry scrubbing system followed by an effective particulate removal system will be the most effective technique for fluoride removal from frit processes. A particulate removal system will be required regardless of the presence of fluoride, and the lower volumes resulting from the use of oxy-gas burners will considerably reduce the size of equipment needed.

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A potential problem with these techniques is the space required for installation. Where an Inspector is determining BATNEEC for a particular process, consideration of the costs of installation may be decisively important.

Lead

Attempts have been made to reduce lead in frits, particularly for tableware applications and some success has been achieved overseas, but because of the nature of the ceramic industry in the UK, lead is still an important constituent in the frit. In the UK, ceramic bodies are fired and then glazed in separate operations, with the glaze firing taking place at around 1060°C to 1150°C. At 1150°C low melting fluxes are needed, for which lead is ideally suited. On the continent, firing of the body and glaze is carried out in the same operation, at temperatures around 1400°C. PbO volatilises at 1150°C and hence its use is less important at these elevated temperatures.

The primary replacements for lead in borosilicate glass frits are bismuth and zinc, although barium alternatives are also being developed. Zinc based systems are an economical alternative to lead based frits, but are less resistant to strong chemicals. The bismuth system has good chemical and physical properties but is more expensive than the zinc option.

Material selection to eliminate the more toxic substances is hindered by the size of production runs. With the exception of continuously manufactured lead-based frits, customers generally place small orders, with very specific product quality requirements, which are met by the selection of tried and tested formulations.

Setting standards for material usage is problematic. Research continues to try and reduce the use of toxic compounds in frits, but in many cases frits are made to a customer's exacting specifications and there is limited opportunity for trying new formulations.

2.2.3 Optical fibre processes

The principal environmental concerns with optical fibre processes are the releases to air of particulate matter, acid gases (hydrogen fluoride and hydrogen chloride), and chlorine.

The particulate matter consists of silicon dioxide "soot", and has a high proportion of particles with diameters of less than 1 µm. For a gas stream containing this type of particulate matter the most effective abatement techniques are high efficiency bag filters or venturi scrubbers. Both of these

techniques are discussed in detail in HMIP guidance material^(14, 15). One problem associated with using a venturi scrubber would be the separation of the fine particulate material from the aqueous waste stream.

Hydrogen chloride, hydrogen fluoride and chlorine are readily treated using a wet scrubbing system, possibly enhanced by the addition of sodium hydroxide to the scrubber liquor.

Some VOC releases may be generated during the application of the coating material following the drawing process. These releases are generally of a very minor nature, and will rarely be of sufficient concentration to warrant specific control measures, beyond those proposed for the other materials.

The most effective technique for controlling releases to air from optical fibre processes is likely to consist of a high efficiency bag filter followed by a wet scrubbing system. Fabric filter systems should be fitted with failure detection devices, and if practicable continuous monitoring.

A venturi scrubber would have the advantage of efficient particulate arrestment in the event of bag failure. However, the venturi scrubber may not be as effective as a conventional packed bed scrubber for the removal of gaseous pollutants.

2.2.4 Ceramic fibre processes

The principal environmental concern with ceramic fibre processes is the release to atmosphere of particulate matter which may include ceramic fibres. In addition some secondary processing operations may give rise to VOC releases, especially during drying and curing operations.

Within the UK ceramic fibres are produced exclusively using electric melting technology, and this is currently considered to be the preferred environmental option. The furnace area should be served by an efficient extraction system which vents to a fabric filter system.

Particulate and fibre releases can be generated from a number of areas within the process, these include: fiberisation and collection, needling, lubricant burn off, slitting, trimming, cutting, packaging, and areas of secondary processing. All areas where particulate or fibre releases may be generated, should be served by an efficient extraction system which vents to a fabric filter system.

There are two approaches to the extraction and filtration of particulate laden air, namely:

- the provision of dedicated filter plants close to the source of the releases; and
- the extraction of air from a large number of sources to a common filter plant via a manifold system.

The most effective filtration system consists of a primary filter followed by a high efficiency secondary filter, fitted with a pressure drop monitor and continuous monitoring of the emission to air. High efficiency secondary filters result in lower releases and provide a safeguard in the event of the failure of the primary filter.

Where a number of sources are extracted to a common system, the installation of a secondary filter is likely to be excessively expensive. The resultant high airflows and the high resistance of the secondary filter would necessitate a large powerful fan with high energy requirements. A well designed and efficiently operated primary filtration system is capable of achieving the release levels identified in Section 3.

Where a process relies on primary filters some form of bag failure device should be used. Many plants are fitted with alarmed pressure drop monitors, but these should not be relied on exclusively. Where practicable all release points associated with ceramic fibres should be fitted with continuous particulate monitors which can be alarmed to detect bag failure. Written procedures which specify the actions to be taken in the event of an alarm should be agreed with the site Inspector. These procedures should specify the criteria requiring process shut-down and should cover the mechanism for safe shut-down.

Filter systems should be installed with the extraction fan on the clean side of the fabric filter – these are known as negative pressure systems. Positive pressure systems, with the fan on the dirty side, are potentially hazardous because any leaks in the system downstream of the fan will result in the release of material.

Cleaning cycles for fabric filters should be optimised to ensure maximum filtration efficiency. Modern systems usually use the reverse jet system, which results in lower peaks during cleaning than the shaker mechanism used on some older plants. However, in some applications, particularly those involving fibrous releases, shaker mechanisms can be more effective than reverse jet systems. The choice of material for the filter bag will depend upon the gas flow, the temperature of the gas and the properties of the material to be removed. The collected material should be handled and disposed of in a manner which prevents any release to atmosphere or to water. Where practicable

considerations should be given to recycling the collected material.

Organic releases can be generated during lubricant burn-off, or from curing or drying operations during secondary processing. Operational experience has shown that these releases tend to be very low. However, where the total release exceeds 100 g/hour, or where any of the release levels in Section 3 are exceeded, consideration should be given to either process modification or some form of abatement. Suitable abatement techniques such as incineration and absorption are described fully in HMIP guidance material⁽¹⁴⁾ and are not considered further in this Note.

2.2.5 Continuous glass filament, glass fibre insulation and rock fibre insulation processes

The control techniques for these processes are covered within the same Section in this Note because of similarities between the environmental problems of each process. However, there are inherent differences between the processes which may affect the selection of the most appropriate control technique.

The principal environmental concerns for continuous glass filament processes are the releases from the glass furnace, especially particulates, oxides of nitrogen and fluorides. Secondary processing of the fibre can give rise to VOC and particulate releases.

In glass fibre insulation processes there can be significant releases to air from the melting process, but the downstream releases are far higher than encountered in glass filament processes or ceramic fibre processes. This is principally due to the use of phenolic resin based binder systems within the process. Releases to air can include organic fume, particulate matter, phenol, formaldehyde and ammonia.

Rock fibre insulation processes generally utilise coke fired cupolas for melting the raw materials, and this gives rise to somewhat different environmental concerns than in glass processes. However, the downstream releases are essentially identical to those encountered in glass fibre insulation processes.

Glass melting

There are three principal techniques used for melting raw materials for glass production, namely:

- electric melting,
- fossil fuel (gas or oil) fired melting, and
- a combination of these techniques.

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Electric melting

Continuous glass filaments are generally produced with a glass formulation known as E Glass, which has a very low sodium content resulting in poor electrical conduction properties. E Glass and other low conductivity formulations cannot be melted economically using electrically heated furnaces, and the technique is not considered further in this Note for the production of continuous glass filaments.

100% electric melting has substantial environmental benefits over other technologies, but has a number of limitations that may restrict its use in some applications. The complete replacement of fossil fuels in the furnace eliminates the formation of combustion products, namely sulphur dioxide and thermally formed oxides of nitrogen. However, if a global view is taken these benefits must be considered against the releases generated at the power generation plant, and the efficiencies of power generation and distribution.

The absence of combustion in electric melting means that the waste gas volumes are extremely low, resulting in low particulate carry over and considerably reduced releases of the more volatile batch components. The molten glass in electric furnaces is completely covered by a blanket of unmelted batch material which absorbs some of the gaseous releases.

Electric furnaces may achieve the release levels specified in Section 3 without any abatement measures. However, depending on how the furnace is engineered some form of particulate abatement may be required.

Electric furnaces achieve higher melt rates per square metre of furnace. However, for a given throughput an electric furnace will have a significantly higher capital cost particularly when compared to a traditional air-gas fired furnace. The thermal efficiency of electric furnaces is two to three times higher than gas fired furnaces, but this is not sufficient to compensate for the higher costs of electricity. At the time of writing this Note, in the UK the cost of electricity is in the order of 10 times higher than natural gas per unit of energy.

A further complication with electric melting is the requirement to use sodium nitrate or potassium nitrate (niter) in the batch. The general view of the glass industry is that niter is required in cold-top electric furnaces to provide the necessary oxidising conditions for a stable, safe and efficient manufacturing process. The problem with niter is that as it breaks down in the melter, oxides of nitrogen are released which reduce some of the environmental benefits of electric melting.

Alternatives are available but generally create equivalent or worse environmental releases.

One company within the UK is operating a 100% electrically heated furnace without the addition of niter. However, other operators are unable to achieve the same result without significant operating disadvantages.

A significant problem facing the insulation industry is the disposal of process waste, particularly fibrous material. Process wastes tend to have a low mass to volume ratio, and are very expensive to dispose of in landfill sites. The decreasing availability of landfill and the consequent increase in disposal costs, provide substantial environmental and economic incentives to find alternative disposal routes. This is discussed further in later Sections of this Note, but one of the options available is the recycling of waste to the melter.

The majority of process wastes contain carbon, and this must be oxidised within the furnace, if material is to be recycled without causing serious problems with furnace operation or product quality. The general view within the industry is that to recycle process waste to an electric furnace, the niter content of the batch must be significantly increased along with a consequent increase in NO_x releases.

Fossil fuel (gas or oil) fired melting

These techniques apply to both glass fibre insulation and continuous glass filament processes.

All fossil fuel fired glass processes covered by this Note and operating in England and Wales use gas fired furnaces. Oil fired furnaces generally result in higher releases of particulate matter, oxides of nitrogen and particularly oxides of sulphur. It is unlikely that any new or modified processes could justify the use of oil as BATNEEC or BPEO.

Some existing processes operate on an interruptible gas supply. The use of low sulphur oil as a back up fuel is common, and this should not pose a problem if its use is limited to short periods. For new or modified processes, the options of an uninterrupted gas supply or a bottled gas back-up should be considered.

At the time of writing this Note, the most common melting technique within the industry is the direct firing furnace utilising air-gas burners. This is a very effective technique but has a number of associated environmental drawbacks namely: high levels of thermal NO_x generation, high waste gas volume, high particulate carry-over, and a high level of volatile component (fluoride, boron) loss.

An alternative to air-gas firing is oxy-gas firing. This involves the use of pure oxygen instead of air or oxygen enriched air in the gas burner. This technique is readily available and has been successfully used in a wide range of applications including some sectors of the glass industry. However, the application of the technique is still undergoing development in the glass fibre industry. The advantages and disadvantages that have been experienced in other industries vary from case to case, and may not apply directly to glass fibre processes in all instances. The potential advantages and disadvantages of oxy-gas firing are outlined below.

Advantages:

- Substantially reduced thermal NO_x generation, resulting from the reduction of atmospheric nitrogen in the combustion atmosphere.
- Reduced energy consumption. In an oxy-gas system, gas volumes are substantially reduced and therefore, less gas has to be heated and less energy is lost from the furnace. Reductions in excess of 50% have been observed in the frits sector.
- Oxy-gas combustion produces higher flame temperatures which may result in a reduced melting time, a further reduction in energy consumption per tonne of melt, and a higher throughput per square metre of furnace size.
- Lower releases of particulate matter and volatiles (fluoride/boron) due to the reduction in gas volume and turbulence.
- Reduced size, and therefore cost, of downstream abatement equipment, as a result of the reduced gas volume.
- Potentially better process control.
- More even burning resulting in less frequent replacement of furnace lining. This benefit may be offset by the higher flame temperatures and higher concentrations of corrosive volatile species.

Disadvantages:

- Oxy-gas fired furnaces have higher capital costs than air-gas fired furnaces. However, the capital cost is lower than for an electric furnace, and in some industries, the higher costs are greatly offset by the improved energy efficiency and other benefits, with some industry sectors experiencing payback periods of less than two years.
- The costs of installing and operating an oxygen system are substantial, but again these costs must be evaluated against the benefits.

- The higher flame temperatures result in a higher NO_x formation efficiency, and air ingress to the furnace must be minimised. Glass furnaces tend to operate at positive pressure and air ingress is likely to be less of a problem than in frit manufacture.
- If a global view is taken the environmental benefits arising from the use of oxy-gas firing must be considered against the environmental impact of oxygen production.

It is anticipated that oxy-gas burners could be installed in many processes without draining the furnace. However, in some cases it may be beneficial to delay installation until the next furnace rebuild to maximise potential benefits and to avoid any anticipated operating problems.

The addition of niter to the batch is not generally necessary with either air-gas or oxy-gas fired furnaces. Nor is niter expected to be required for the proposed levels of process waste recycling.

Combined fossil fuel and electric melting

There are two principal approaches to the use of this technique: predominantly fossil fuel firing with electric boost; or predominantly electrical heating with a fossil fuel support. Clearly the proportion of each type of heat input can be varied with each technique.

Whenever a fossil fuel is used, oxy-gas firing is likely to result in lower overall mass releases from the furnace. Where electrically heated furnaces use gas as a support fuel, it is often done to overcome some of the operational difficulties encountered with 100% electric melting.

The technique of using electric boost within a fossil fuel fired furnace is a well established technique that has been used for some time within the glass industry. Electric boost is traditionally used to increase the throughput of a fossil fuel fired furnace to meet periodic fluctuations in demand; without incurring the fixed costs of operating a larger furnace. Some modern furnaces have been designed with increased electric boost capacity to improve the environmental performance of the furnace, as well as its operational flexibility.

Furnaces fired principally on oxy-gas will usually require further abatement techniques to achieve the release levels identified in Section 3. Available techniques are considered below for specific substances produced during the melting operation.

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Particulate matter

The most appropriate techniques for controlling particulate releases from glass furnaces are likely to be high efficiency dry electrostatic precipitators or reverse jet bag filters. Both techniques will allow the collected material to be recycled to the furnace, and should be capable of achieving release levels in line with those identified in Section 3.

The hygroscopic nature of the fine particulate matter released from glass furnaces has led to a number of operational problems with bag filter systems. The most common difficulty experienced is frequent bag blinding: this is a particular problem in gas fired systems which generate a moist waste gas. A very high level of maintenance, based on extensive operational experience, is required to avoid frequent by passing of the equipment and the replacement of expensive bags.

These problems have led the industry to favour electrostatic precipitators for the control of furnace releases. Operational experience has shown that three stage precipitators can achieve releases of 50 mg/m³. More advanced systems could be expected to give lower concentrations, but the potential environmental benefits should be considered against the increased cost of the system.

Other techniques such as wet scrubbing may be appropriate in certain circumstances. Where other techniques are proposed, the generation of aqueous waste streams and the ability to recycle collected material, should be considered when determining the BPEO.

The furnace exit gas will be at high temperature and will require either a temperature resistant filtration medium or some form of cooling. Direct cooling, such as dilution or evaporative cooling is most commonly used. Indirect cooling using a heat exchanger would be preferable, but problems have been encountered with corrosion, and fouling caused by the condensation of borates.

Cooling is preferable to a high temperature filter because it ensures the condensation of volatile borates, before the gas reaches the filter or ESP.

One operator is doing extensive work on optimising furnace design and glass composition as an alternative approach to the fitting of abatement devices. If this proves successful in achieving the anticipated releases, in the order of 50 mg/m³, the further reductions achievable by installing downstream abatement may be disproportionate to the costs involved.

Fluorides

Fluorides are principally a problem associated with the continuous glass filament industry. Glass formulations currently used in the insulation industry do not contain significant fluoride levels.

There are two approaches to the control of fluoride releases: removal or substitution in the batch, and flue gas treatment.

Significant progress has been made in the reduction of fluoride in the raw materials, but a number of problems have been encountered particularly in the production of fine fibres. These problems include increased production costs, reduced process efficiency and difficulty in meeting product specification. It is unlikely that changes in process design and glass composition alone will be sufficient to achieve the release levels identified in Section 3. However, one operator has made extensive progress in this area and it is anticipated that releases in the region of 50 mg/m³ could be achieved without abatement. If these levels could be achieved, then as with particulate matter, a detailed study would be required to determine what constitutes BATNEEC/BPEO for that process. The precise details of the issues are considered as commercially confidential, and are not discussed further in this Note.

The progress made to date in fluoride reduction has not been sufficient to achieve the release levels identified in Section 3. Unless further progress is made, the achievement of these release levels would require flue gas treatment.

The various abatement techniques for fluoride releases are discussed in Section 2.2.2, and include dry and wet scrubbing. For continuous glass filament processes, dry scrubbing of processes gases with lime or limestone, followed by particulate removal using fabric filters or a dry ESP, is likely to be the most effective technique to achieve the release levels in Section 3.

The collected calcium fluoride and lime or limestone is chemically compatible with other raw materials and can theoretically be recycled to the furnace. However, the composition of the collected material may be very variable making it difficult to recycle directly. A further problem which may be encountered is metal contamination caused by the corrosive nature of the waste gases. In continuous filament processes metal contamination can cause fiberising difficulties.

The variability problem may be addressed by stockpiling and blending to produce a more consistent composition. Alternatively, the collected material can be recycled to the scrubber a number

of times, resulting in a material with a more consistent composition and a greatly reduced volume. Metal contamination may be addressed by the use of corrosion resistant materials in the scrubber and ducting.

As in the treatment of purely particulate releases some form of cooling will be necessary to condense out borates, and to condition the gas for the filter or ESP.

Oxides of nitrogen

Where neither electric melting nor oxy-gas firing is proposed some other form of NO_x control may be required. Other control techniques include:

- modified burner/furnace design,
- batch/cullet pre-heating,
- selective catalytic reduction,
- selective non catalytic reduction, and wet scrubbing.

These techniques are unlikely to represent the most cost effective methods of achieving the release levels in Section 3.

Glass melting conclusions

With the exception of E Glass and other low conductivity formulations, the most effective techniques for controlling releases to air are likely to consist of: 100% electric melting using zero or minimum levels of niter, followed by particulate abatement if levels exceed those specified in Section 3.

However, where it is proposed to recycle significant amounts of process waste to the furnace, or where for other reasons the process requires the use of significant amounts of niter, the most effective combination of techniques is likely to consist of: oxy-gas firing, or a combination of oxy-gas firing and electric melting, followed by particulate arrestment using fabric filters or an electrostatic precipitator.

Rock fibre melting

The consideration of what constitutes the BATNEEC for controlling releases to air from rock fibre processes is generally simpler than for glass processes. The only technique currently considered available in the UK is the coke fired hot blast cupola. Control techniques are restricted to raw material selection, good operating practice and waste gas abatement techniques.

The main environmental concerns from cupolas are particulates, oxides of nitrogen, sulphur dioxide,

hydrogen sulphide, heavy metals, and carbon monoxide.

The raw materials used for the process are generally a combination of basalt, blast furnace slag, limestone, and dolomite. The majority of the alumino silicate melt comes from the basalt and the slag. Dolomite and limestone operate as fluxes allowing the basalt to be melted and fiberised at lower temperatures. The slag also has flux properties.

The accepted control technique within the industry is a reverse jet bag filter (or similar) to remove particulate matter, followed by an oxidiser to convert hydrogen sulphide to sulphur dioxide and to oxidise any organic species present.

The main drawback with this system is the need to maintain the flue gas within the operating temperature range of the filter. If the temperature is too low condensation occurs and the filter becomes blinded. If the temperature is too high a conventional filter fabric will be damaged. The gas temperature is continuously monitored and when it moves outside the critical range the abatement system must be by-passed, resulting in unabated releases.

Clearly, a key factor in controlling emissions is reducing the required frequency of by-pass. One approach is to install a high temperature filter medium. However, although a definite improvement, this only solves part of the problem and the same result may be achievable using other process modifications. The precise methods for minimising by-pass frequency are likely to be confidential and should be agreed with the site Inspector.

A further concern is the level of sulphur dioxide release following the oxidation of hydrogen sulphide. There are two approaches to reducing releases of sulphur dioxide, the reduction of sulphur in the raw materials, and flue gas desulphurisation. However, there are problems with both of these approaches.

The main sources of sulphur in the raw materials are coke and blast furnace slag. Low sulphur alternatives command a considerable premium, and in the case of slag are not consistently available.

An obvious way of reducing the amount of sulphur in the raw materials would seem to be the production of fibre from just basalt and limestone/dolomite. When this option is examined more closely there are a number of drawbacks, which may mean the environmental benefits of slag removal are marginal. A detailed BPEO study will

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be required for each plant to determine the optimum slag levels for the particular circumstances of that process.

Problems with slag reduction include:

- Increased coke consumption, due to the decrease in thermal efficiency. This arises from the need to use more limestone flux which has a higher proportion of volatile species.
- Increased carbon dioxide release arising from the increased coke combustion, and the increased carbonate usage.
- Slag is thought to improve the melting and fiberising properties of the melt, which results in higher process efficiencies, less waste, and potentially reduced abatement equipment by-pass.
- Slag also contains less iron than basalt, and so its use results in reduced tap out frequency and a lower by-pass frequency.
- Slag is a waste material, if it were not utilised in the process it would have a higher likelihood of being disposed of to landfill.
- The use of slag in place of limestone or dolomite reduces the demand for quarried material.

Standard flue gas desulphurisation techniques can be applied to hot blast cupolas. The techniques include dry scrubbing to produce gypsum, and wet scrubbing to produce sulphuric acid. The techniques are described in more detail in HMIP guidance material⁽¹⁵⁾.

The use of flue gas desulphurisation combined with the other techniques described above, is currently considered to constitute the BAT for controlling releases from hot blast cupolas used in the manufacture of rock fibre insulation. However, in most circumstances flue gas desulphurisation would be likely to constitute excessive cost.

Thus given the current economic circumstances BATNEEC for controlling releases to air from these processes is likely to consist of: filtration followed by oxidation, and supported by the optimisation of slag usage and the continued development of techniques to reduce the frequency of abatement equipment by-pass.

Insulation fiberising (forming) area

In the fiberising area the glass/rock melt is fiberised and the binder is applied. The resin coated fibre is directed onto a collection belt which is under suction. Water is sprayed into the extraction ducting and into the fan. This performs two

functions, the prevention of resin build up on the ducting and the removal of some particulate and gaseous components from the gas stream.

The releases can be affected significantly by the fiberising process conditions, by the chemistry of the binder system, and by the method of binder application to the fibre. The optimisation of these parameters, in conjunction with in duct water sprays can significantly reduce process releases. However, it is unlikely that these measures alone will achieve the release levels identified in Section 3, except for some low density, low binder products. To meet these release levels consistently across the whole product range some form of abatement equipment is likely to be needed.

The forming area waste gas is likely to contain significant levels of particulate matter, phenol, formaldehyde and ammonia. The particulate matter consists of both organic and inorganic material, often with very small particle size. Lower levels of VOCs and amines may also be detected if they are included in the binder system. Due to the nature of the process the gas stream has a high volume and a high moisture content. These properties combined with the nature of the pollutants limit the number of abatement techniques that may be applied.

The incineration of forming area releases is likely to be prohibitively expensive, due to the high volume and high moisture content of the waste stream. The high moisture content and the presence of resinous material prevent the use of dry electrostatic precipitators or fabric filter systems.

Some rock-fibre processes use tower filters with rock wool as the filter medium. Operation can be on a wet or semi-dry basis. It is unlikely that this technique will achieve the levels identified in Section 3. However, this technique has the advantage that little or no aqueous waste is generated. Where disposal or treatment of an aqueous waste stream presents particular difficulties, this technique should be given consideration in the BATNEEC/BPEO assessment.

The remaining conventional abatement techniques that would be suitable for this type of waste stream are likely to be based on wet systems. Potential techniques would include:

- conventional wet scrubbing,
- wet inertial separators,
- wet electrostatic precipitators,
- ionising wet scrubbers, and
- multi-stage wet scrubbing.

Water is the most commonly used scrubber liquor and it has a number of advantages. In particular the potential to recycle a portion of the contaminated

water in the process water system. When the fiberising waste gas comes into contact with water in an efficient scrubbing system the following events will occur:

- a proportion of the entrained particulate matter, predominantly the larger particles and droplets will be held in suspension;
- a proportion of any soluble resinous material will be absorbed by the water, and
- the volatile substances will form an equilibrium between the gaseous and aqueous phases. The equilibrium will be dynamic and will be dependent on the concentration of volatiles in the gas stream, the available liquid surface area, species interaction, temperature, gas velocity, etc.

For the high gas volumes requiring treatment in this industry it is likely that a large, and therefore expensive, system would be required to ensure adequate contact time between the pollutant and the scrubber liquor. Another major problem with any wet system is maintaining sufficiently low concentrations of volatile materials in the scrubbing medium to facilitate efficient absorption of volatile materials, and to prevent their release back to the gas phase. The simplest solution to this problem is to use clean water with a sufficiently high purge to maintain efficient absorption. However, this generates a high volume of effluent which can be very expensive to dispose of, and may not constitute the BPEO. An alternative is chemically dosing the scrubber liquor with substances that would react with the volatile species, eg sulphuric acid to remove ammonia.

The addition of any chemicals is likely to make it very difficult for any of the scrubber liquor to be recycled to the process water system. The chemical reaction of the gaseous pollutant reduces the problem of vapour pressure equilibrium by binding the species. However, only phenol and formaldehyde, or ammonia will be able to be controlled in this way. The chemicals that would be required to remove all three species would react with each other, eg sulphuric acid and sodium hydroxide. The build-up of vapour pressure of the unreacted species, and the accumulation of particulate and resinous material, would necessitate a high level of fresh water input and contaminated liquor bleed off, still leaving the problem of disposing of a high volume high COD effluent.

The only techniques likely consistently to meet the release levels in Section 3 are enhanced wet scrubbing systems. This term is used to refer to the combination of two or more treatment stages or techniques. These techniques have not been proven within this industry, and their application would require substantial development work. The

following discussion seeks to identify potential control techniques which could be successfully applied to the industry.

A multi-stage scrubber would consist of two or three stages. The first stage would be a high volume water scrubber which would remove larger particulate matter, soluble substances and volatiles as described earlier. A portion of the scrubber liquor could be recycled to the process water system. The second stage would circulate a solution of sulphuric acid or phosphoric acid to remove ammonia. The same solution could be dosed with more acid and could be circulated for far longer than water alone, resulting in a much smaller volume and lower BOD effluent to dispose of. A third stage may be required to control phenol and formaldehyde releases. This would operate on the same principle as the second stage, but would use an alkaline solution such as sodium hydroxide.

For conventional wet systems, eg packed beds, the particulate collection efficiency falls off rapidly for particles with diameters below 3 μm to 4 μm . To achieve better collection efficiencies a higher pressure drop is required, which increases capital and operational costs substantially.

Wet electrostatic precipitators are very effective in removing fine particles, aerosols and fume. When combined with a single or multi-stage scrubber, as described above, very low release levels would be expected.

Ionising wet scrubbers have been used successfully in a number of applications around the world. They combine the benefits of wet electrostatic precipitators and wet scrubbers in one multi-stage unit.

Any of these enhanced wet scrubbing systems are likely to be very expensive. The costs are difficult to predict and could vary greatly depending on process size, the nature of the particular gas stream, and the configuration of any existing plant. Typical costs could be expected to be in the region of £1 million to £3 million.

Insulation curing oven

The wet mat enters the oven which is at approximately 250°C. The moisture is driven off along with any volatile material, and then the binder begins to cure. The temperature and residence time in the oven are critical. The binder must be adequately cross linked but not over cured or the product quality will suffer. The releases from the oven will consist of volatile binder materials, binder breakdown products and combustion products from the oven-burners.

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The oven is usually gas fired and under extraction. Water is sprayed into the extraction ducting to prevent the build up of condensable resinous material, and to prevent fires. The water sprays will remove some of the material entrained in the gas stream, but it is unlikely that they will achieve the release levels in Section 3.

The most effective way of controlling these releases is incineration of the waste gas. This is being carried out already in some processes and has proved extremely effective. Typical installation costs of incinerators would be in the region of £750,000.

The recirculation of the gases within the oven results in the partial combustion of some of the volatile materials. It may also be possible to use the oven waste gases as combustion air for the oven burners. Where incineration is not installed these techniques should be optimised.

Incineration may not constitute the most appropriate control technique in all circumstances. For example where an efficient treatment system is installed to control forming area releases, it may be cost effective to treat the much smaller volume of oven exhaust in the same system.

Insulation product cooling

A large quantity of air (typically 30,000 to 40,000 m³/hr) must be passed through the product to cool it to an acceptable temperature after leaving the oven. This gas is likely to contain glass fibre and low levels of organic material, and will usually require treatment before release. The gas should be passed through an efficient dust removal system, eg a bag filter, before release. Where significant levels of organic material are detected alternative techniques may be more appropriate.

Insulation product machining and packaging

Insulation processes involve a number of product trimming, cutting and slitting operations, which generate potential dust releases. Where all such operations are carried out efficient extraction should be provided. The extracted air should be passed through an efficient dust removal system, ideally a bag filter.

Packaging operations are also potential sources of dust releases and should be treated in the same way.

Insulation process resin and binder chemistry considerations

A substantial proportion of the releases from insulation processes arise from the application of phenolic resin based binder systems. Optimisation of the chemistry of the binder system and the efficiency of the method of application can have a substantial effect on the releases to the environment. The binder represents a high proportion of the cost of the final product, and developments in binder chemistry and application techniques are closely guarded by the process operators. This Section of the Note seeks to provide the Inspector with a basic understanding of binder chemistry and the factors affecting environmental release levels. Detailed discussions will need to be undertaken with each process operator to determine whether a particular system constitutes BATNEEC/BPEO for that process.

The binder is made up of water, phenolic resin, urea, ammonium sulphate, ammonia, silane, mineral oil, silicone oil and possibly other ingredients particular to the individual process.

The resin is essentially a phenolic resole consisting of a mixture of trimethylol phenol, dimethylol phenol, formaldehyde, minor reaction products of phenol and formaldehyde, and traces of phenol. The resin is water based and is typically 50% solids. An excess of formaldehyde is used in the reaction to achieve a low free phenol level.

Urea is reacted with the resin to extend the resin, to reduce free formaldehyde levels and it also has the effect of improving the fire resistance of the final product. The urea reacts with the free formaldehyde in the resin to form methylol ureas, which in turn will react with the active sites on the phenolic resin and take part in the cross linking mechanism during curing. The urea is acting as a substitute for phenol and results in a far cheaper binder. Therefore, there is an incentive for the operator to maximise the amount of urea in the resin, up to the point where product quality or processing parameters are adversely affected. Urea has two main drawbacks, it reduces the solubility of the resin, and it can breakdown in both the forming area and the curing oven to form ammonia. Environmentally the maximisation of urea usage is beneficial because it reduces formaldehyde releases, it replaces phenol, and the urea breakdown products are preferential to the phenolic derivatives and partial combustion products that would otherwise be produced.

Ammonia plays several important roles in the binder system and allows a degree of flexibility which is important in optimising the process as a whole. Ammonia improves the solubility of the

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binder enabling more urea to be added and allowing the binder to be stored for longer. It also helps to maintain the system pH in the correct range and reacts with any free formaldehyde. The nature of the process is such that higher than normal releases of ammonia may occur for short periods. Some processes, particularly older ones, may have difficulty in achieving the release levels specified in Section 3. The effects of reducing the ammonia levels in the process can be disproportionate to the effects on the rest of the process, and higher ammonia release levels may constitute the BPEO for a particular process.

Ammonium sulphate is added to control the curing of the resin. Silane provides a vital interface between the inorganic glass and the organic binder. Silane hydroxyl groups interact with the glass oxides and the organic functional group reacts with the resin to form a strong bond. Mineral and silicone oils are added to improve the product handling characteristics, to suppress dust formation, and to provide a degree of water repellency.

When the binder is applied to the hot glass in the forming area the volatile components (eg ammonia, formaldehyde, and phenol) will be vaporised and extracted to the release point. The level of volatile releases will be a function of the amount of unreacted volatile material in the binder, the dilution of the binder, the temperature in the forming hood and the temperature of the glass. The binder is applied as a fine spray and any droplets which are not retained on the mat will be released in the extracted air. The extent of binder retention on the product will depend on droplet size distribution, the mat thickness and the level of suction applied.

Continuous glass filament secondary processing

In these processes the temperature at which the fibre coating is applied is quite low, and no significant releases are experienced.

Secondary processes often involve drying ovens which can give rise to the release of organic species. The waste gas volumes are quite small and standard control techniques may be appropriate if significant releases are identified – these include:

- incineration,
- adsorption, and
- wet scrubbing.

Before any abatement techniques are installed the coating/binder formulation should be optimised to minimise releases.

2.3 Chimneys and vents

2.3.1 General

Operators should make an appropriate assessment of vent and chimney heights required to provide adequate dispersion of prescribed substances, and other substances which might cause harm, whose release cannot be prevented. This should include process failures. Some guidance is given in HMIP Technical Guidance Note D1⁽⁴⁾.

For many processes it will be necessary for dispersion modelling to be carried out which takes into account local meteorological data, local structures and topography, as well as other local releases. This will be particularly important for sites with any large volume emission, significant non-combustion sources or multiple release points and sites where there are sensitive receptors nearby. Operators should provide clear information on the parameters used and the assumptions made in their use of dispersion models. The assessment of background concentrations of pollutants will be particularly relevant. Statutory air quality standards⁽⁷⁾ and other recognised criteria should be taken into account.

The Agency may validate the assessment made by the operator using the appropriate calculations or dispersion models available.

2.3.2 Wet plumes

Wet plumes do not disperse well and tend to ground easily. Additionally there can be local visual amenity issues and, in severe cases, loss of light issues. Therefore the gas should be discharged at conditions of temperature and moisture content that avoid saturation under a wide range of weather conditions.

The normal option is to add heat, however, the use of energy should be balanced against the benefits gained. Plumes must be abated sufficiently to ensure good dispersion but a limited visible plume may be acceptable in cold damp conditions.

Alternatively moisture can be removed by cooling and condensation followed by reheat. However, where this is not an inherent part of a wet scrubbing process (where temperature is typically reduced to around 70°C for scrubbing purposes), the disadvantage would be the generation of a significant liquid effluent stream.

As a further option, to minimise expense and energy use, operators may wish to guarantee to reduce load under extreme weather conditions rather than to over design a plume abatement system.



2.4 Techniques for controlling releases into water

Process waters, site drainage waters, emergency fire water and chemically contaminated waters should, where appropriate, be contained and where necessary treated before release to controlled waters or sewer.

Areas where spillages are most likely, such as storage tanks and sampling points, should be bunded. Rainwater collected from bunds should not be disposed of via surface water drains or soakaways and the composition of any wastes collected should be checked prior to treatment or disposal. Bunds should:

- be impermeable;
- have no outlet;
- drain to a sump;
- be designed to catch leaks from any likely failure of the tank or its fittings;
- be hydraulically tested on initial construction and subsequently where there is any doubt about their integrity (noting the need for care in the disposal of any contaminated water);
- have a capacity at least 110% of the largest tank;
- where not frequently inspected, be fitted with a high level probe and an alarm as appropriate; and
- have the fill points within the bund where possible.

Releases to water may be direct, for example process effluent or cooling water, or indirect, for example, from plant surface water drains. In either case the water may contain relatively low concentrations of certain substances, but if large volumes of water are involved, the mass releases of those substances can be substantial. The following general principles should be applied in sequence to control releases to water:

- any use of water should be minimised, thereby minimising the amount of contaminated water to be dealt with.
- methods of avoiding or reducing contamination, or risk thereof, of process or surface water should be considered.
- water should be recycled within the process from which it issues, by treating it first if necessary. Where that is not practicable it should be recycled to another part of the process which has a lower water quality requirement.
- ultimately, surplus water is likely to need treatment to meet the requirement to prevent, or minimise and render harmless. Generally any physico-chemical treatment will be more efficient on the more concentrated individual or similar effluent streams than treating the whole

mixed effluent. However, the inherent properties of dissimilar waste streams can be usefully employed to avoid adding further chemicals, for example by balancing waste acid and alkaline streams to control the resultant pH. An exception to the preference for treating waste streams individually would be when biological treatment is proposed and treatment of the whole mixed effluent overcomes an inhibitory effect of any individual waste stream.

Further techniques can be found in reference 13.

2.4.1 Glass and enamel frit manufacture

Aqueous releases arise mainly from wet milling operations associated with glaze manufacture. The principal pollutant is suspended solids, although some of the more soluble batch materials, eg compounds of zinc, copper and lead may be present in small quantities. For each product formulation, fresh water must be used and the mill must be washed down, to prevent product contamination. Releases can be reduced by optimising production to maximise the campaign length for each product formulation, and thereby minimising wash down frequency.

The effluent can be treated using standard flocculation and settlement techniques.

The quenching process is a net user of water due to the amount of water vapour generated when the melt enters the bath. The bath needs to be emptied periodically due to the build up of solids and salts, or alternatively the bath should have a bleed off and top up system. Where milling operations are conducted on the same site, quenching bath water should be treated with the milling effluent. Where this is not the case the solids should be separated by decantation and disposed of as solid waste, or where practicable recycled to the process.

The quenching operation can be replaced by water cooled rollers. This produces a flake product which may require more milling than a standard frit, and therefore little environmental benefit is gained.

2.4.2 Optical fibre processes

There are no significant aqueous releases associated with the production of optical fibre. However, releases are generated by the wet scrubbers used to control chlorine and acid gas releases. Standard pH control techniques should be adequate to permit disposal with other site effluent.

2.4.3 Ceramic fibre processes

The principal sources of aqueous releases are secondary processing operations, particularly vacuum forming. Releases will contain organic material and suspended solids. Flocculation, filtration and settlement techniques should be used where appropriate.

2.4.4 Continuous glass filament processes

Releases arise from coating preparation and handling, throw off from winding, secondary processing and cleaning operations. Releases of organic material from secondary processes and coating preparation can be minimised by the careful handling of materials and the effective containment of any spillages. Flocculation and solids separation techniques should be used where appropriate.

2.4.5 Glass fibre and rock fibre insulation processes

The basic processes are net users of water, with large amounts of water vapour released from the forming area and curing oven. The process water system should be a closed loop with clean water top up. Precautions should be taken to ensure that clean water systems such as surface water and cullet quench water are not contaminated with process water. Small amounts of aqueous releases may arise from spillages or clean down operations. Releases from the binder preparation area should be minimised by the careful handling of materials and the effective containment of any spillages. Flocculation and solids separation techniques should be used where appropriate.

More specialised effluent treatment may be required where wet scrubbers are used for waste gas treatment.

2.5 Techniques for controlling releases to land

The aim for all processes covered by this Note should be to prevent the creation of waste containing substances prescribed for release to land or which could cause harm. Where this is not possible, releases should be minimised by attention to raw materials and process routes, and by recycling wastes arising within the process or re-using them elsewhere.

The key pollutants likely to be present in releases to land can be derived from a knowledge of the process, materials of construction, corrosion/erosion mechanisms and materials related to maintenance, validated as necessary by the appropriate analytical techniques. The presence of

substances created by abnormal operation should be identified, since process abnormalities can carry through substances into the solid waste that are not normally present.

Whether recycling is possible will depend on site-specific factors such as the particular fuels, raw materials, products and methods of operation.

Adequate facilities should be provided for the on-site storage, handling, loading and transportation of wastes prior to their removal from the area covered by IPC site authorisations.

Particulate matter collected from waste gas streams should be recycled to the process wherever practicable. In most melting operations, where dry collection systems are used, this will involve a simple adjustment of the batch formulation to allow for the composition of the collected material. Fine material cannot be recycled to a hot blast cupola without further treatment; this is discussed below.

Where dry scrubbing techniques are employed to remove fluoride, the collected material can only be recycled if it is compatible with the batch materials. The specific problems associated with dry scrubbing techniques in the continuous glass filament industry are discussed in Section 2.2. In frit processes it is unlikely that any collected material could be recycled to the furnace. Where this is the case techniques are available significantly to reduce the volume of material for disposal. The fluoride reaction occurs only on the surface of the lime dust, and so only a fraction of the mass of the collected material has actually reacted with the fluoride. The collected dust can be treated to remove the surface coating, with the remainder being recycled to the reaction section.

Insulation processes generate substantial amounts of solid waste, arising principally from out of specification product and material collected from the process water filtration system. Rock fibre processes also generate 'fiberising' waste sometimes known as 'shot'. This is the heavy non-fibrous and semi-fiberised material that is too heavy to reach the collection belt, and is collected below the spinning machine.

The waste produced by insulation processes has a high volume to mass ratio making it expensive to dispose of to landfill. Most of the companies in this sector are subsidiaries of large groups who are striving to reduce the overall environmental impact of their operations. Combined with ever increasing disposal costs and the desire to improve the efficiency of the process, this produces a strong

**Techniques
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land**

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incentive to reduce waste and maximise recycling opportunities.

Most of the developments in recycling are considered as commercially confidential, and only a brief summary of the techniques and issues is given below.

The fibrous nature of much of the waste makes it impracticable to recycle without further treatment. Glass furnace raw materials are charged as powders, and so waste material must be ground or pelletised before charging. This would usually be achieved by some form of milling operation. In hot blast cupolas any fibrous or dusty material would be carried out of the top of the cupola. The accepted solution to this problem is to mill the material and produce briquettes of comparable size to the other raw materials.

The waste product and the filtered waste contain significant levels of organic binder. In rock fibre processes this is not a problem; it is oxidised and adds a small amount of heat to the furnace. In a glass furnace the carbon content of the waste presents a number of problems including: reduced

heat transfer; foaming; destabilisation of melting conditions; and alteration of the furnace chemistry. These problems can be mitigated but there is a limit to the amount of waste that can be recycled to the furnace.

All operators are also actively pursuing markets for process wastes.

2.6 Odour and noise

2.6.1 Odour

Efforts should be made to identify substances present in emissions to air which may give rise to odours. BATNEEC must be used to prevent an offensive odour being noticeable outside the boundary of the site where the process is carried on.

2.6.2 Noise

Inspectors may be required to regulate noise emissions. Reference should be made to any separate guidance on techniques and standards which may be produced by the Agency.

3 Benchmark releases

Reference conditions

3.1 Reference conditions

The reference conditions of substances in releases to air from point sources are:

for combustion gases:

Dry, temperature 273 K (0°C), pressure 101.3 kPa (1 atmosphere), oxygen content 8% v/v, except where oxy-gas firing is used when no correction for oxygen content should be made.

For other gases including releases from drying or curing ovens without tail gas incineration:

Temperature 273 K (0°C), pressure 101.3 kPa (1 atmosphere), no correction for oxygen or water vapour content.

These reference conditions relate to the benchmark release levels given in this Note and care should always be taken to convert benchmark and proposed releases to the same reference conditions for comparison. The authorisation may employ different reference conditions if they are more suitable for the process in question.

To convert measured values to reference conditions see HMIP Technical Guidance Note M2⁽¹⁶⁾ for more information.

Releases may be expressed in terms of mg/m³, g/h, g/te(product) or g/MJ as appropriate. In particular with oxy-gas fired systems it may be appropriate to specify mass based limits, due to the inherently reduced exhaust gas volumes and consequently higher concentrations.

3.2 Benchmark release levels to air

3.2.1 General

Tables 4, 5 and 6 give benchmark release levels for key substances in the context of the processes concerned at the time of writing. They are not emission limits but are subject to consideration of site-specific BATNEEC and BPEO when framing conditions in an authorisation. Refer to Section 1.1 with regard to their use.

The following release levels are based on average figures and short term peak values of twice this level may be anticipated.

Substance	Benchmark release level (mg/m ³)
Particulate matter	20
Chlorine	10
Hydrogen chloride	10
Hydrogen fluoride	5
Total VOC ^(Note 1)	20

Notes

1. This release concentration should be aimed for where the release is greater than 100 g/hr.

Table 4:
Benchmark release levels to air for optical fibre processes

Substance	Benchmark release level (mg/m ³)
Particulate matter	20
Fluorides (expressed as hydrogen fluoride)	5
Oxides of nitrogen (expressed as nitrogen dioxide)	300 ^(Note 1)
Lead	5
Cadmium	0.2
Total lead and cadmium	5
Total arsenic, nickel, selenium, antimony, chromium and copper	1
Total manganese, vanadium and tin	5

Notes

1. This level is based on a furnace with no air ingress and a batch with no added nitrates. Where the raw materials necessarily contain substantial levels of nitrates, the authorisation limit should be calculated taking into account the NO_x released from the batch materials. The total elimination of air ingress to the furnace may not necessarily represent BATNEEC.

Table 5:
Benchmark releases to air for frit processes

Benchmark release levels to air

Table 6: Benchmark releases to air for ceramic fibre, glass fibre, rock fibre, and glass filament processes

Substance	Benchmark release level (mg/m ³)
Particulate matter ^(Note 1)	20 ^(Note 2)
Ceramic fibre ^(Note 3)	1
Fluorides (expressed as hydrogen fluoride)	5 ^(Note 4)
Chlorides (expressed as hydrogen chloride)	20
Oxides of sulphur ^(Note 5) (expressed as sulphur dioxide)	1750 ^(Note 6)
Oxides of nitrogen (expressed as nitrogen dioxide)	300 ^(Note 7)
Hydrogen sulphide	5
Phenol	10
Formaldehyde	5
Ammonia	50
Total amines	5
Total class A VOC ^(Note 8)	20
Total class B VOC ^(Note 8)	80

Notes

1. Particulate matter includes all inorganic and organic particulate matter. Where the waste gas may contain phenolic resin derivatives all material, including any condensed material, collected in the sampling train up to and including the filter shall be included in the total. Where appropriate inorganic and organic material should be reported separately and distinguished by differential weight loss, following drying to remove moisture and any material volatile below 120°C.

2. Particulate matter releases from these processes are inherently variable. Certain process releases (eg ceramic fibre processes, machining and packaging areas) will achieve this level comfortably and it may be appropriate to set authorisation limits below this level. In other instances the achievement of 20 mg/m³ is an onerous target, which may only be achievable using techniques which do not represent BATNEEC and BPEO. In particular, a release level of around 50 mg/m³ may be appropriate for the following cases: glass furnaces; hot blast cupolas; and glass and rock fibre insulation forming areas.

3. This applies only to ceramic fibre processes, a fibre in this context is defined as an object of length greater than 5 µm, breadth less than 3 µm and having a length/breadth ratio greater than 3:1.

4. Where raw materials necessarily contain substantial levels of fluorides, a benchmark release level of 15 mg/m³ should be used. This release level assumes waste gas treatment, and at the time of writing only continuous glass filament processes are recognised to fall within this category.

Table 6: Contd

- 5. This applies only to oil fired furnaces and to coke fired hot blast cupolas.
- 6. Where a process utilises substantial levels of blast furnace slag a higher release level may be appropriate. The authorisation limit should be based on a detailed sulphur balance, but it is unlikely that releases levels much above 3500 mg/m³ would be experienced.
- 7. For glass furnaces this release level is based on an oxy-gas fired system. Where a glass furnace is permitted to use an air-gas fired system a release level of around 1500 mg/m³ may be more appropriate. Where substantial levels of nitrates are necessarily added to the batch the authorisation limit should be calculated taking into account the NO_x released from the batch materials.
- 8. Wherever practicable, authorisations should set limits on individual VOCs.

The achievable release concentrations given in Table 6 for volatile organic compounds should be aimed for where the following mass release limits are exceeded:

Total Class A 100 g/hr
Total Class B (expressed as toluene) 2 kg/hr

Releases below these mass emission levels may not be trivial, and so may still require controls and the setting of appropriate release limits.

The use of a release concentration limit is not normally appropriate in the case of a release from an air-deficient saturated vapour space such as storage tanks for solvents or process vessels. An approach based on limiting total mass released or mass per unit of production is likely to be more effective.

VOCs may be categorised according to their environmental harmfulness. A method for categorisation of VOCs is provided in the research report entitled "The Categorisation of Volatile Organic Compounds" (DOE/HMIP/RR/95/009)⁽¹³⁾. The report provides information on the properties of some 500 VOCs and a summary table of resulting categorisations.

Substances such as benzene, vinyl chloride and 1,2 dichloroethane pose serious health risks to humans and are regarded as **highly harmful**. These substances should be specified individually in each authorisation and stringent release limits applied. The most likely highly harmful substance to be encountered in this industry sector is phenol. It is unlikely that processes in this sector will result in the release of any other substances in this category.

Some other VOCs carry a lesser but still significant health risk or may contribute substantially to ozone creation or destruction, or to global warming. These are regarded as of **medium harmfulness**, and may be referred to as Class A VOCs. They will include the substances listed in the Montreal Protocol, the phase out of which is covered by EC regulations 594/91, 3952/92, 2047/93 and

**Benchmark
release
levels to
water**

3093/94. VOCs within this categorisation which may be encountered in this industry sector would include formaldehyde.

Other VOCs, which may be referred to as Class B VOCs are of low harmfulness but are prescribed substances whose release must be prevented or minimised within the constraint of BATNEEC. VOCs within this categorisation which may be encountered in this industry sector include toluene, methanol, ethanol, etc.

Odorous VOCs may be offensive at extremely low concentrations and this property may indicate the need for very tight control of a substance which is otherwise of low harmfulness.

Where the term "expressed as" is used, then a correction should be carried out using the ratio of molecular weights of the substances as appropriate. The release level for a class B substance can be determined by multiplying the molecular weight of the pollutant by a factor of 0.87 to give the release level in mg/m³ expressed as toluene.

There is potential for the release of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans ("dioxins") from combustion processes. A benchmark release level of 1 ng/m³ ITEQ is appropriate.

All releases must be controlled and minimised to ensure that ambient air quality beyond the process boundary complies, as a minimum, with air quality standards⁽⁷⁾.

3.3 Benchmark release levels to water

3.3.1 General

Table 7 gives benchmark release levels for key substances in the context of the processes concerned at the time of writing. They are not emission limits but are subject to consideration of site-specific BATNEEC and BPEO when framing conditions in an authorisation. Refer to Section 1.1 with regard to their use.

The environmental impact of the aqueous releases from processes in this sector should be relatively low if the process is well designed and operated. With the potential exception of some frit processes

there should be no releases of any substances prescribed for release to water.

Where releases do occur the release levels given below are benchmark levels using the techniques referred to in Section 2. These levels may not be appropriate to releases arising from the use of wet collection devices, when specialised treatment techniques either on site or at the sewage treatment works may be necessary. Where releases are made to sewer the operator should demonstrate that the disposal of the effluent to sewer fulfils the statutory objectives for the operator to use BATNEEC, as described in Section 2.1.

3.4 Releases to land

Separate legislation⁽⁷⁾ deals with the disposal of controlled wastes to a licensed waste management facility, the consignment of special wastes and the duty of care on persons who produce, import, carry, keep, treat or dispose of controlled waste, and they should not be covered in the authorisation. Where controlled waste is finally disposed of by deposit to land, the operator must advise the Agency.

Substance	Benchmark release level
Suspended solids	50 mg/l
Chemical oxygen demand ^(Note 1)	See Note 1
Ammoniacal nitrogen	10 mg/l
Total metals ^(Note 2)	500 µg/l
Cadmium ^(Note 3)	50 µg/l

Notes

- Total COD load would be expected to be quite low, but may be in high concentration where volume is very low. The actual levels permitted for discharge will depend on the sewage treatment plant or the receiving water. The operator should be able to identify the main constituents of the COD and confirm the harmlessness of the effluent in the context of the receiving medium.*
- Total metals include: cadmium, thallium, antimony, arsenic, cobalt, copper, chromium, lead, manganese, nickel, selenium, tin and vanadium.*
- Applicable only to frit processes where cadmium is present in significant quantities in the raw materials.*

**Table 7:
Benchmark
releases to
water**

4 Financial implications and monitoring requirements

4.1 Financial implications

In determining a case the Agency must translate BATNEEC into conditions to be included in the authorisation. The BATNEEC criterion requires that a judgement be made, balancing cost against environmental damage. The operator should have constructed a BATNEEC case after examining the range of technically feasible process and/or abatement options. BATNEEC is not concerned with the financial health or resources of a particular operator. Excessive costs are viewed in the context of the process and the industry concerned, and costs of controlling releases should not be disproportionate to the environmental benefits delivered.

In the absence of scope for efficiency savings, there are two elements to the ability of a representative operator in any industry to bear extra abatement costs. One relates to the financial resources typically available for capital expenditure, whether from cash reserves or from external sources such as loans or equity. The other depends on the extent to which costs can be passed on to customers, passed back to suppliers, or absorbed by lower returns within the industry.

The different types of processes covered by this Note operate in very different markets and necessitate separate economic consideration.

4.1.1 The manufacture of glass and enamel frits

Although glass frit and enamel frit processes share many technical similarities, the products produced have significantly different applications and a clear distinction can be drawn between the markets for glass frits and enamel frits. The two industries are therefore addressed separately in this Note.

Glass frits

The UK glass frit manufacturing industry at present comprises two principal companies: Cookson Matthey Ceramics, with two plants in Stoke-on-Trent, one at Cresswell and the other at Meir, and James Kent with one plant, also located in Stoke-on-Trent. This concentrated industry structure has resulted from a recent period of consolidation during which a number of plants were taken over, scaled down or closed down.

The estimated production capacities for the principal companies are: Cookson Matthey

Ceramics Meir site, 10,000 tonnes per year; Cookson Matthey Ceramics Cresswell site, 2,000 tonnes per year; James Kent, 8,200 tonnes per year. In addition a small volume of frit, less than 50 tonnes per year, is produced by Emery Rheimbold & Strick in Stoke-on-Trent, a specialist manufacturer of glazes and glaze components.

The principal application of glass frit is in the manufacture of ceramic glazes. These glazes, when applied to the surface of ceramic bodies such as tiles and tableware, and then fired, provide an impervious, protective and decorative coating. Frits may be sold in the pure form to the ceramic ware manufacturers who create their own glazes, or the frit manufacturers may produce and supply the glazes themselves. Across the industry as a whole over half the frit manufactured in the UK is used internally in the production of glazes.

The demand for frit and fritted glaze in the UK is highly concentrated. The tableware manufacturing industry is dominated by two bone china producers, Royal Doulton and Wedgwood, which account for 80% of the bone china market. 90% of the UK's tile production is by two companies, Pilkington Tiles and H&R Johnson.

Cookson Matthey Ceramics (CMC) is a joint venture between the Cookson Group and Johnson Matthey. The Cookson Group and Johnson Matthey are both large, diversified materials supply companies. The joint venture merges Cookson's Supplies and Minerals businesses with the Colour and Print Divisions of Johnson Matthey. Sales of CMC in 1994 were £325m. CMC currently owns two large glass frit plants in Italy and Spain which supply local markets in these countries.

James Kent is an independent glass frit and glaze manufacturing company. James Kent acquired its independence in 1993 when it was bought by the management from the parent company, Bayer, the large German chemicals conglomerate.

The most significant competitive threats to the two UK frit manufacturers are from imports. Frits are generally high value, low volume products and transport costs generally comprise a relatively small proportion of the total product price. Worldwide consolidation in the industry is resulting in relatively fewer but larger plants serving wider international markets. Ferro's plant in Holland, for example, which produces 50,000 to 100,000 tonnes of frit a year, now serves as the company's

main European frit manufacturing centre, supplying the UK and other northern European states. Ferro is currently seen as the principal competitor to CMC and James Kent.

Imports may also come into the UK from Germany, Spain and Italy, where there are large established domestic frit industries. Owing to the size of these markets frit plants are much larger than in the UK, with production capacities of up to 100,000 tpa not uncommon. With higher production outputs these plants benefit from economies of scale and produce frits at lower cost than typical plants in the UK.

Imports from the Far East, although not at present a significant source of competition, could become a future threat to the industry, both in the market for frits and in the market for ceramic wares. The health of the UK frit industry closely follows the success of the ceramic sector as a whole, and if the latter declines as a result of imports, then the frit industry which serves it will also suffer. Exports comprise a minor share of UK glass frit production (5-10%), although new markets are being sought.

The production of glass frit is a well established industry and has served the ceramics sector for many years. Competition from raw glazes, which do not contain frit, is limited by their relatively poor leaching properties. Plastic coatings have been developed for table ware, but these suffer from the same leachability problems as raw glazes, particularly in the presence of organic acids, which are commonly found in food. It is not known to what extent plastic coatings may influence the market for fritted tile glazes.

Due to the absence of fluoride in most glass frit batches the costs of abatement are fairly modest. Oxyfuel fired systems are more expensive to install than air-fuel systems, and the cost of installing and operating an oxygen supply system can be considerable. However, in many applications the reduced fuel costs and the reduced size of abatement equipment lead to a payback of about two years for capital costs. Typical installation costs of a reverse jet bag filter system are around £500,000.

In the UK, glass frit production costs are typically of the order of £500 to £600 per tonne. Approximately 20% of these costs comprise fixed charges, such as capital depreciation, wages, fuel and insurance, with up to 50% attributable to raw materials. Cheaper imports have had a noticeable effect on UK frit prices, with some frits prices falling by 25%, from £540 per tonne to £400 per tonne in the last year. Other frits have decreased by

10% from an average price of £530 per tonne to £480 per tonne.

Throughout Europe and worldwide, frit and glaze markets are becoming increasingly price sensitive, benefiting the larger plants which are able to gain from economies of scale and sell frits at lower prices in wider geographical markets. Firms of a moderate size will find it harder to compete, although there are opportunities for flexible, niche suppliers, able to meet customers' specific requirements. Firms able to compete effectively in the international market will require a critical size which will enable them to make the necessary investments, of which environmental controls will form a necessary component. The niche market is relatively less threatened by international competition, and suppliers should be able to charge a moderate premium over the international price for their services. The additional costs of pollution control referred to above, therefore, should not be excessive in the context of this changing industry structure.

Enamel frit

The UK enamel frit industry currently consists of two companies: Vitreous Enamels Ltd and Escol Products. Escol Products is privately owned and has a production capacity of 8,800 tonnes per year. Vitreous Enamels Ltd is owned by an Italian company Merloni, and has a production capacity of 2,500 tonnes per year. The industry profitability has varied between 1% and 10% over the last 6 years.

Enamel frits are used in the manufacture of enamel glazes, the principal application of which is the coating of metal surfaces to provide a chemically and physically resistant covering. In 1994/95 the UK market for enamels was estimated at 5,700 tonnes. The principal market for enamels in the UK is in manufacture of cookers, for coating hobs, ovens, grills etc. Other applications for enamels include storage tanks, silos, baths, electronic components and signs.

Competition between the two UK frit producers is intense. Total market size has decreased in recent years, primarily due to the decline in cooker manufacture in the UK, although Ferro's closure of its frit manufacturing plant and Bayer's withdrawal from the UK enamel market, have allowed the remaining two companies some increase in market shares. Ferro continue to supply the UK market through its Dutch frit plant, although at a diminished level. And Bayer also supply a small quantity of frit to the UK from its plant in Belgium. The threat of such imports prevents any significant increase in prices in the UK market.

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The UK enamel frit market is generally considered as one of the most competitive in Europe, with some of the lowest frit prices. Nominal frit prices have remained roughly constant in the UK since 1989. It is generally recognised that there is excess enamel frit production capacity in the UK, and both companies are seeking to increase exports as a means of maintaining production volumes.

Threats to the industry from substitutes are small. Alternatives, such as paints, could potentially be used in similar applications, but they can not match the properties of enamels, in terms of heat, chemical and scratch resistance, and "cleanability".

Fluorine abatement is now widely installed in most European enamel frit plants. There are examples of such equipment in Holland, Germany and Spain. The capital cost of implementing the techniques is in the region of £300,000 to £500,000 with operating costs between £50,000 and £150,000 per year. A large proportion of the capital costs of fitting abatement equipment, such as a fluoride scrubbing system, are fixed and larger plants are able to spread these costs over more production units.

Raw materials represent roughly 50% of production costs, and due to the large number of small volume materials used it would be very difficult to pass any increased costs to raw material suppliers.

The enamel frit industry is becoming increasingly international and a typical plant should be described with reference to plants at the European scale rather than to those in a small, national industry. Markets are increasingly being driven by price and economies of scale are becoming more important.

A typical European plant may therefore be considered to produce between 5,000 and 15,000 tpa of enamel frit. Looking at the impact of pollution control costs on such plants illustrates the ability of a typical plant to afford pollution control equipment. Of the fluoride abatement systems actually installed at enamel frit plants, the impact is to increase costs of production by between approximately £9/tonne and £20/tonne of frit; currently the average frit price is around £1000 per tonne.

The European frit industry is undergoing rationalisation at present, with output being concentrated in the hands of fewer suppliers. The costs of transporting frits across international borders comprise a small proportion of the end selling price, and from single manufacturing centres, the major producers can supply a range of other European markets.

Plants capable of competing in this evolving European industry, should be able to afford the techniques recommended in this Note to control releases. At present emissions regulations affecting the European enamel frit industry, specifically the TA luft 5 mg/m³ fluoride limit, appear to be applied consistently throughout the continent, and most large plants have installed abatement equipment designed to meet these standards.

In the context of this changing industry structure, the costs of installing techniques capable of achieving the release levels identified in this Note at UK enamel frit plants should not be excessive.

4.1.2 The manufacture of continuous filament glass fibre

The UK industry is dominated by two companies PPG Industries (UK) Limited and Owens Corning Fibreglas (GB) Ltd. OCF operate one plant in Wrexham and are part of the Owens Corning Group based in the USA, which is the largest supplier of glass fibre and insulation products in the world. PPG operate one plant in Wigan and are part of the American PPG Group which has a range of interests in the mineral and chemical sectors. PPG also operate a glass fibre plant in Holland.

Worldwide, production of continuous filament glass fibres is highly concentrated. The industry is dominated by four groups, PPG, Owens Corning, Vetrotex (a subsidiary of St Gobain) and Asahi (Japan).

Continuous filament glass fibres are relatively high value products, they are readily transported and there is significant international trade in the industry. The two UK companies, for example, export between 60% and 80% of their output.

The principal use of continuous filament glass fibre is in the manufacture of composite materials. Continuous filament glass fibre plants only produce fibres, although producers may enter into agreements with resin suppliers to jointly develop composite materials. A continuous filament glass fibre plant typically produces fibres in four product forms: roving, mat, chopped strand and textile. A fifth type of product, milled fibre, may also be produced but its share of total output is small. These different product types reflect the various ways in which glass fibre composites are made and the range of end uses of the composite material.

The UK industry has been operating at or below break even point for the last few years, with only a slight improvement in profitability expected in the short term. Worldwide the industry is more buoyant and experiences respectable profitability.

Competition in the world market is at present strong. Owing to the relatively close proximity of producers in Europe, two in the UK and another in France, competition in the European and UK markets is perhaps even more intense. The state of competition has been amplified by the contraction in the main end user market for continuous filament glass fibres, the construction industry. Continuous filament glass fibre production is highly capital intensive and operators need to keep the plants running as close to full capacity as possible.

The installation of oxy-gas firing and waste gas treatment would represent a capital investment in the order of £5 million to £8 million, for a typical process with two production lines. Additional operating costs (excluding capital depreciation and any losses in process throughput) of approximately £1.5 million could be incurred. The implication of these costs is an increase in production costs of approximately £60 per tonne of fibre. This is equivalent to an increase of 5% in the selling price (based on an average selling price of £1.25 per kg).

The continuous filament glass fibre industry is characterised by high concentration, high capital intensity, cyclical demand and prices, and a high degree of international competition. Price competition has been very keen during the recession, but the market is now expanding at a rate of over 5% a year and operators are increasing output. The degree of international trade would make it very difficult for UK producers to command higher prices in the market. Therefore the costs would have to be either absorbed by lower returns within the industry or subsidised by parent companies.

Both UK operators are subsidiaries of major US companies which specialise in glass fibre production and together they account for over half the world's output. They both own a number of production facilities outside the UK, in Europe and throughout the world, and could potentially switch production away from the UK if the costs of production rose significantly. These plants represent substantial capital commitments and such decisions would not be taken lightly. These decisions are also influenced by considerations other than purely production costs. However, each operating company must survive on its own merits and must compete for available investment within the group.

The limited profitability of these companies combined with the difficulties described above make it difficult for the industry to meet the costs of some of the control measures described within this Note. Historically, uncontrolled releases from these processes have been higher than those authorised in many other industry sectors covered

under IPC. Emissions within the industry have been significantly reduced in recent years. However it is likely that further significant emission reduction programmes will be required.

Where such programmes are necessarily very capital intensive, careful consideration must be given to the timescale of their implementation, to ensure that the industry is not unnecessarily damaged. In particular the installation of waste gas treatment represents a massive capital commitment, which must be allowed to be discounted over a reasonable time period. These investments should be coordinated with the natural investment cycle of the industry, and sufficient planning should be allowed to ensure the maximum environmental benefit for the costs incurred.

4.1.3 The manufacture of optical fibres

Optical fibres are principally used in telecommunication applications as a replacement for conventional copper wires, and are used extensively throughout the communications industry. Typical applications range from short distance computer and video links through to international telecommunications links.

There are two main producers in the UK, Pirelli Cables and Optical Fibres. A third company BNR Europe is authorised but operates on a contract R & D basis. Pirelli Cables is owned by the Italian industrial group Pirelli and operates two plants in the UK, Harlow and Eastleigh. Optical Fibres is a joint venture partnership between US glass producer Corning Incorporated and BICC plc.

The producers supply optical fibre to cabling companies. Pirelli operate their own cable business and Optical Fibres sell a large portion of their fibre to BICC Cables. Independent companies are also significant customers. The main customers for fibre optic cables are the large telecommunication companies, such as BT, Mercury and, of particular significance at present, cable TV companies.

The market for optical fibres is very much transnational. Fibre optic cables are high value low volume products, and can be economically transported over relatively long distances. The industry is also highly concentrated with only a handful of world suppliers. The principal world players are: ATT (US), Corning (US), Alcatel (France), Siemens (Germany) and Phillips (Netherlands).

There is significant international competition in the optical fibre industry. However, the true extent of competition is somewhat mitigated by the preference of the main customers, which tend to

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be national telecommunication companies, to source from domestic suppliers.

Competition from substitutes is not a significant issue for the optical fibre industry. Optical fibres are a relatively new product, and they replace conventional copper telecommunication cables.

The most effective technique for treating waste gases from the forming area is likely to be a bag filter in combination with a wet scrubbing system. The costs of requiring all plants to achieve the standards identified in Section 3 are not likely to be excessive for each operator, nor for the industry as a whole. For plants which do not already achieve these standards the costs of up-grading or replacing the abatement systems are minimal in relation to the total manufacturing costs. Even so, the environmental benefits are likely to be small and the need for any additional further environmental expenditure would need to be carefully judged.

4.1.4 The manufacture of ceramic fibre

The UK ceramic fibre industry consists of two companies: Thermal Ceramics Ltd and The Carborundum Company Ltd. Thermal Ceramics operate one plant in Merseyside and two in France. The company is owned by the large industrial group Morgan Crucible, which has a range of interests in the ceramics industry. Carborundum operate one plant in St Helens and one in Germany. The company is owned by St Gobain, a large French company who are a major player in the European glass industry. St Gobain also own Kerlane who operate three plants in France. 95% of the European industry is shared roughly equally between Thermal Ceramics and St Gobain. The profitability of the industry has been fairly modest over the last few years but is thought to be improving.

The principal use of ceramic fibre products is in high temperature insulation applications. These include furnace and kiln linings, domestic and industrial heating appliances, metal processing, automotive uses, fire protection and more general industrial insulation applications. The main customers for these products are found in the heavy industries, such as aluminium, ceramics, forging, glass, hydrocarbon processing, steel, automotive, and fire protection.

Ceramic fibre can be sold to customers to be used in its raw form as "bulk fibre", or can be converted into down stream products, including blankets and felts, boards, paper, vacuum formed products and mixes and textiles. Bulk fibres, blankets and boards account for the majority of output. Most fibre producing plants carry out their own downstream

processing on the same site, although much bulk fibre is sold to specialist "converters". There are a large number of converters in Europe which buy from a much smaller number of fibre producers.

Competition between both UK suppliers is fierce. Production capacity in the UK exceeds domestic demand by about 50% and exports account for a substantial share of the industry's income. External trade figures, and company information, suggest that the UK exports around 30% to 40% of ceramic fibre products. Import penetration is weak, accounting for only about 5% of the UK market. This is largely due to the high costs of transporting bulk fibres, because of their low value to weight ratio, and the relatively low prices of ceramic fibres in the UK. The UK has some of the lowest fibre prices in Europe.

In the refractory lining market ceramic fibres compete directly with other refractory materials such as bricks. In other applications the main competition is from glass or rock wool, and a range of specialist silica and alumina fibres. Rock and glass wool products are substantially cheaper than those made from ceramic fibre, but less durable, whereas those produced from specialist fibres are considerably more expensive.

Owing to the unique thermal and physical properties of ceramic fibres the immediate competitive threat from substitutes is not considered significant.

Releases from ceramic fibre processes are quite low in comparison with other fibre industries, and emissions are already fairly well controlled. Where further control measures are deemed necessary typical costs are for secondary filtration, £225,000 per line capital costs with operating cost of around £30,000 per year and for a VOC incinerator, capital costs of £100,000 to £200,000 with 10% operating costs.

The costs of controlling releases from ceramic fibre processes to achieve the standards in this Note amount to an annual cost in the region of £10 to £15 per tonne. Assuming an average product price of £1,300 per tonne, these costs would represent around 1% to 2% of the average product price. Owing to the intensity of competition between the two UK operators, they have become relatively efficient, low cost producers, and consequently import penetration into the UK market is minimal. Both companies currently operating in the UK have made the necessary investment and are capable of meeting the release levels identified in Section 3. It is therefore unlikely that the costs of meeting these standards could be considered as excessive for any new or modified process.

4.1.5 The manufacture of glass and rock fibre insulation

The UK industry consists essentially of four companies: Owens Corning Building Products (UK) Ltd; Rockwool Ltd; Gyproc Insulation Ltd; and Supaglass Ltd. Armstrong World Industries Ltd produce a significant amount of rock fibre but it is used exclusively within the company to produce fibre ceiling tiles, and is not considered further in this Note.

Owens Corning Building Products operate three plants in the UK, two glass plants and one rock plant. The processes were operated by Pilkington Insulation Ltd until 1994 when the company was purchased by the American company Owens Corning. Owens Corning specialise in the production of glass fibres and are probably the world's largest producer. The three UK sites produce around 85,000 tonnes per year, over 40% of the industry's output.

Rockwool Ltd is owned by Rockwool International based in Denmark. The Rockwool Group specialises in the manufacture of insulation products from rock (or slag) wool. The company has some 15 production facilities worldwide, all but one of which are located in Europe. The UK plant in Wales accounts for around 8% of the group's total revenue. Rockwool Ltd produce around 70,000 tonnes per year, approximately 35% of the industry's output.

Gyproc is part of BPB Industries plc. BPB also owns British Gypsum through which it has interests in a range of mining and building product activities. BPB also owns a glass fibre plant in Ireland, Moy Insulation. Gyproc produce up to 20,000 tonnes per year.

Supaglass Ltd is an independent company based in Scotland and has an output of around 22,000 tonnes per year.

During the late eighties and early nineties the industry was affected very badly by the recession in the building industry and continues to be hampered by the poor performance of this sector. Profitability was very low during the early nineties but rose to around 6% in 1994. This upturn has proven to be short lived and profitability is expected to remain, at best, static for the foreseeable future.

The market for fibre insulation has become increasingly competitive over the last decade, with large investments being made in order to improve product quality and reduce operating costs. The business is inherently cyclical and seasonal, but overall demand for insulation products remains

essentially static. There is also considerable overcapacity in the market despite the closure of several operations. Mineral fibre manufacturing is a highly capital intensive process with low margins, and when demand falls, it becomes difficult for manufacturers to recover these large fixed costs. In spite of the technical expertise required to manufacture fibre insulation, it is essentially a commodity product. There is little opportunity for differentiation between products competing in the same markets, and competition is based principally on price. To improve its performance a company must either reduce its costs or gain market share, probably at the expense of a UK competitor.

The building products market accounts for between 60% and 70% of the industry's income, and due to a declining demand for these products, firms have reduced prices in order to maintain production levels. Nominal prices for rolls, for example, have decreased from around £1,200 per tonne in 1985 to £650 per tonne in 1995. Companies have survived in this climate by improving efficiency. Price competition is weaker in the "technical" product market, which requires higher value added products such as rigid pipe sections for high temperature and fire resistant applications. This sector has seen relatively good growth in the last few years.

Imports of European products account for approximately 25% of the domestic market. However, the UK exports an equal quantity to give an essentially equal balance of trade. In spite of the relatively low value to weight ratio of insulation fibre products, which limits the distance over which they can be economically transported, there is still significant international trade into and out of the UK. UK companies are therefore exposed to any significant variations in the cost of production between the UK and other countries. If the price of goods manufactured in the UK rises significantly above those in the UK's closest trading countries, in particular, France, Germany, Ireland and the Netherlands, import penetration into the UK market will increase. At the same time, exports would become less competitive.

Non-fibrous insulation products such as foams compete with fibre products in some applications, but are generally more expensive. Foams can achieve the equivalent insulation values to fibre products with less thickness, and are preferred to fibre in products where dimensions are important eg domestic appliances. Foam producers generally have a lower cost base and higher profitability than fibre producers. Increases in fibre insulation prices would inevitably result in stronger competition from alternative products which compete in the same markets.

Monitoring

The costs of achieving the release levels identified in Table 6 are difficult to predict and are likely to be significantly higher for existing processes than for new processes. For rock and glass fibre processes costs could be in the region of £60 per tonne and £110 per tonne respectively. However, processes may not require all the measures discussed in Section 2 to achieve these levels of releases. Assuming an average selling price of £900 per tonne these estimates represent an increase of 6%–12%. The average profit per tonne of product is in the region of £50.

For glass plants a large proportion of this cost is represented by the capital costs of electric melter installation. The installation of electric melting at the time of planned furnace replacement would mitigate the capital costs considerably, but operating costs can be significantly higher.

The release levels stated in Section 3 are some of the most stringent in Europe and the associated costs are substantial. Given the strength of international competition it is very unlikely that much of these additional costs could be passed onto customers, and the costs would have to be borne by reduced profits. With the low levels of profitability experienced within the industry any substantial increase in costs would be very damaging, and could put the industry back into a loss making position.

The wide variation of techniques currently employed in the six plants operating in the UK, will make it very difficult to ensure the equitable imposition of any substantial increase in production costs across the industry. The situation is further complicated by the fact that some processes have already invested heavily in environmental improvements, while others have invested comparatively little.

Clearly any increased costs imposed must be balanced against the ability of the industry as a whole to pay. An indication of this can be gained by a comparison of the increase in production costs per tonne of product and the profit per tonne of product for the industry. The BATNEEC/BPEO condition must be determined separately for each plant, taking into account the circumstances of each case and the likely environmental benefit to be gained. In an industry with very limited capital available for investment, it is important that any environmental expenditure represents the best value for money for the environment as a whole.

Environmental improvements in the insulation industry are likely to be capital intensive and where

practicable should be co-ordinated with the natural investment cycle of the industry. Where capital intensive improvements are required they should be allowed to be discounted over an appropriate timescale.

4.2 Monitoring

4.2.1 General

There is an expanding series of HMIP/Environment Agency Technical Guidance Notes on monitoring, containing information on theory and methodology, and providing technical information on monitoring techniques (see *Associated Publications* at the end of this Note).

Conditions in the authorisation should require the results of all monitoring to be reported in line with the IPC standard authorisation format.

The operator should provide a clear statement of the potential for release of all substances which might cause harm to the environment, and propose an unambiguous set of procedures for measuring or otherwise estimating releases of key pollutants.

Information should be provided on release routes, methods of relevant monitoring or sampling and analysis, and periods and frequency of assessment. Evidence should be provided that quality assurance procedures are in place to ensure all monitoring and test results are sufficiently accurate and reliable (for example by reference to British/international standards and accreditation with the UK Accreditation Service, UKAS – formerly the National Measurement Accreditation Service, NAMAS).

When setting standards of release in authorisations reference should be made to the application to ensure that such conditions are assessable by means described by the operator, and are properly enforceable.

The requirements and frequency of sampling, analysis and monitoring are site- and/or process-specific, influenced by consideration of the anticipated volume and composition of the waste streams, and the potential risk to the environment.

4.2.2 Records and reporting

Instructions on reporting and monitoring, and records and notifications relating to incidents, are given with the IPC standard authorisation format.

References

- 1 The Environmental Protection (Prescribed Processes and Substances) Regulations 1991
SI 1991 No 472, ISBN 0-11-013472-9 as amended by:
The Environmental Protection (Amendment of Regulations) Regulations 1991
SI 1991 No 836, ISBN 0-11-013836-8;
The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1992
SI 1992 No 614, ISBN 0-11-023614-9;
The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1993
SI 1993 No 1749, ISBN 0-11-034749-8;
The Environmental Protection (Prescribed Processes and Substances) (Amendment) (No 2) Regulations 1993
SI 1993 No 2405, ISBN 0-11-035405-2;
The Environmental Protection (Prescribed Processes and Substances, etc) (Amendment) Regulations 1994
SI 1994 No 1271, ISBN 0-11-044271-7;
The Environmental Protection (Prescribed Processes and Substances, etc) (Amendment) (No 2) Regulations 1994
SI 1994 No 1329, ISBN 0-11-044329-2; and
The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1995
SI 1995 No 3247, ISBN 0-11-053799-8.
- 2 Integrated Pollution Control: A Practical Guide (HMSO) April 1994, ISBN 0-11-752750-5; and Guidance Notes to Applicants for Authorisation – processes prescribed for regulation under IPC, available from the Environment Agency
- 3 HMIP Technical Guidance Notes, Monitoring Series (see Associated Publications on page 44)
- 4 Guidelines on Discharge Stack Heights for Polluting Emissions
HMIP Technical Guidance Note (Dispersion) D1 (HMSO) June 1993, ISBN 0-11-752794-7
- 5 Environmental, Economic and BPEO Assessment Principles for Integrated Pollution Control
Environment Agency Technical Guidance Note (Environmental) E1 (to be published 1996)
- 6 EC Directive on the Combating of Air Pollution from Industrial Plants (Framework) (84/360/EEC) (OJL 188, 16/7/84)
- 7 The Air Quality Standards Regulations 1989
SI 1989 No 317, ISBN 0-11-096317-2
- 8 Reducing Emissions of Volatile Organic Compounds (VOCs) and Levels of Ground Level Ozone: A UK Strategy
Department of the Environment, Romney House, 43 Marsham Street, London SW1P 3PY
- 9 The Surface Waters (Dangerous Substances Classification) Regulations 1989
SI 1989 No 2286
- 10 Separation Processes Service, Harwell Laboratory, Didcot, Oxfordshire OX11 0RA
- 11 Effluent Processing Club, Harwell Laboratory, Didcot, Oxfordshire OX11 0RA
- 12 Air Pollution Advisory & Review Group, Air and Environmental Quality Division, Department of the Environment, Romney House, 43 Marsham Street, London SW1P 3PY
- 13 Pollution Control at Large Glass Works Volume 1
Pollution Control at Glass and Enamel Frit Manufacturing Plants Volume 2
Department of the Environment Research Report No available from the Environment Agency's National Centre for Technical Guidance
- 14 Pollution Abatement Technology for the Reduction of Solvent Vapour Emissions
HMIP Technical Guidance Note (Abatement) A2 (HMSO) March 1994, ISBN 0-11-752925-7
- 15 Pollution Abatement Technology for Particulate and Trace Gas Removal
HMIP Technical Guidance Note (Abatement) A3 (HMSO) April 1994, ISBN 0-11-752983-4
- 16 Monitoring Emissions of Pollutants at Source
HMIP Technical Guidance Note (Monitoring) M2 (HMSO) January 1994, ISBN 0-11-752922-2
- 17 The Control of Pollution (Special Waste) Regulations 1980
SI 1980 No 1709, ISBN 0-11-007709-1;
The Controlled Waste Regulations 1992
SI 1992 No 588, ISBN 0-11-023588-6;
The Environmental Protection (Duty of Care) Regulations 1991
SI 1991 No 2839, ISBN 0-11-015839-5;
Waste Management, The Duty of Care, A Code of Practice (HMSO) ISBN 0-11-752557-X;
The Controlled Waste (Registration of Waste Carriers and Seizure of Vehicles) Regulations 1991
SI 1991 No 1624, ISBN 0-11-014624-7;

The Environmental Protection (Waste Management Licensing) Regulations 1994
SI 1994 No 1056, ISBN 0-11-044056-0;
The Environmental Protection Act 1990 Parts II and IV
The Controlled Waste Regulations 1992
DOE Circular 14/92, ISBN 0-11-752665-7;
and
Environmental Protection Act 1990 – Part 2: Waste Management Licensing;
The Framework Directive on Waste
DOE Circular 11/94, ISBN 0-11-752975-3 –
Annex 4, paragraphs 4.4 and 4.5.

Abbreviations and definitions

BATNEEC	Best Available Techniques Not Entailing Excessive Cost
BOD	Biochemical Oxygen Demand
BPEO	Best Practicable Environmental Option
COD	Chemical Oxygen Demand
EA	Environment Agency (for England and Wales)
EPA90	The Environmental Protection Act 1990
EPAQS	Expert Panel on Air Quality Standards
ESP	Electrostatic Precipitator
HMIP	Her Majesty's Inspectorate of Pollution
HSE	Health and Safety Executive
IPC	Integrated Pollution Control
ITEQ	International Toxicity Equivalents
NO _x	Oxides of Nitrogen
TOC	Total Organic Carbon
VOC	Volatile Organic Compound

Associated publications

The following are available from HMSO bookshops (see back cover), their accredited agents, and some larger bookshops.

Series 2

Chief Inspector's Guidance Notes (prepared by Her Majesty's Inspectorate of Pollution)

Fuel Production Processes, Combustion Processes (including Power Generation)

S2 1.01 Combustion processes: large boilers and furnaces
50MW(th) and over

November 1995, £9.95 ISBN 0-11-753206-1

Supersedes IPR 1/1

IPR 1/2 Combustion processes: gas turbines

September 1994, £4.00 ISBN 0-11-752954-0

S2 1.03 Combustion processes: compression ignition engines
50MW(th) and over

September 1995, £7.95 ISBN 0-11-753166-9

Supersedes IPR 1/3

S2 1.04 Combustion processes: waste and recovered oil burners
3MW(th) and over

September 1995, £7.95 ISBN 0-11-753167-7

Supersedes IPR 1/4

S2 1.05 Combustion processes: combustion of fuel
manufactured from or comprised of solid waste in appliances
3MW(th) and over

September 1995, £9.95 ISBN 0-11-753168-5

Supersedes IPR 1/5-1/8

S2 1.06 Carbonisation processes: coke manufacture

September 1995, £9.95 ISBN 0-11-753176-6

Supersedes IPR 1/9

S2 1.07 Carbonisation and associated processes: smokeless fuel,
activated carbon and carbon black manufacture

September 1995, £9.95 ISBN 0-11-753177-4

Supersedes IPR 1/10

S2 1.08 Gasification processes: gasification of solid and liquid
feedstocks

November 1995, £9.95 ISBN 0-11-753202-9

Supersedes IPR 1/11

S2 1.09 Gasification processes: refining of natural gas

November 1995, £9.95 ISBN 0-11-753202-7

Supersedes IPR 1/12 and 1/13

S2 1.10 Petroleum processes: oil refining and associated
processes

November 1995, £14.00 ISBN 0-11-753204-5

Supersedes IPR 1/14 and 1/15

S2 1.11 Petroleum processes: on-shore oil production

November 1995, £8.25 ISBN 0-11-753205-3

Supersedes IPR 1/16

S2 1.12 Combustion processes: reheat and heat treatment
furnaces 50MW(th) and over

September 1995, £8.50 ISBN 0-11-753178-2

Supersedes IPR 1/17

IPC Guidance Notes (prepared by the Environment Agency)

Mineral Industry Sector

S2 3.01 Cement manufacture, lime manufacture and associated
processes

September 1996, £21 ISBN 0-11-310120-1

Supersedes IPR 3/1 and IPR 3/2

S2 3.02 Asbestos processes

September 1996, £15 ISBN 0-11-310118-x

Supersedes IPR 3/3

S2 3.03 Manufacture of glass fibres, other non-asbestos mineral
fibres, glass frit, enamel frit and associated processes

September 1996, £21 ISBN 0-11-310121-x

Supersedes IPR 3/4 and IPR 3/5

S2 3.04 Ceramic processes

September 1996, £17 ISBN 0-11-310119-8

Supersedes IPR 3/6

Waste Disposal and Recycling Sector

S2 5.01 Waste incineration

October 1996

Supersedes IPR 5/1, 5/2, 5/3, 5/4, 5/5 and 5/11

S2 5.02 Making solid fuel from waste

July 1996, £15.00 ISBN 0-11-310114-7

Supersedes IPR 5/6

S2 5.03 Cleaning and regeneration of carbon

July 1996, £13.00 ISBN 0-11-310115-5

Supersedes IPR 5/7

S2 5.04 Recovery of organic solvents and oil by distillation

July 1996, £12.50 ISBN 0-11-310116-3

Supersedes IPR 5/8 and IPR 5/10

Series 1**Chief Inspector's Guidance Notes (prepared by Her Majesty's Inspectorate of Pollution)****Metals Production and Processing**

IPR2/1 Iron and steel making processes: integrated iron and steel works

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M1 Sampling facility requirements for the monitoring of particulates in gaseous releases to atmosphere
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January 1994, £10.00 ISBN 0-11-752922-2

M3 Standards for IPC Monitoring Part 1: Standards, organisations and the measurement infrastructure
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M4 Standards for IPC Monitoring Part 2 : Standards in support of IPC Monitoring
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A3 Pollution abatement technology for particulate and trace gas removal
April 1994, £15.00 ISBN 0-11-752983-4

Environmental

E1 Environmental, economic and BPEO assessment principles of Integrated Pollution Control
(To be published 1996)

Relevant DOE publications

A review of "The potential effects of release of krypton-85"
£4.95, DOE Publications Sales Unit, Block 3, Spur 2,
Room 1/2, Government Buildings, Lime Grove,
Eastcote, HA4 8SE

Integrated Pollution Control: a practical guide
(HMSO) £5.00 ISBN 0-11-752750-5

Secretary of State's Process Guidance Notes

Processes Prescribed for Air Pollution Control by Local Authorities

A list of these notes is available from:

Department of the Environment
Air and Environmental Quality Division
Romney House
43 Marsham Street
London SW1P 3PY

Tel: 0171 276 8322

MANAGEMENT AND CONTACTS:

The Environment Agency delivers a service to its customers, with the emphasis on authority and accountability at the most local level possible. It aims to be cost-effective and efficient and to offer the best service and value for money.

Head Office is responsible for overall policy and relationships with national bodies including Government.

Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol BS12 4UD
Tel: 01454 624 400 Fax: 01454 624 409

The Agency's National Centre for Technical Guidance gives guidance on techniques and standards in support of Integrated Pollution Control (IPC): Government Buildings, Burghill Road, Westbury-on-Trym, Bristol BS10 6EZ
Tel: 0117 987 3400 Fax: 0117 987 3272

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For general enquiries please call your local Environment Agency office. If you are unsure who to contact, or which is your local office, please call our general enquiry line.

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