

ENVIRONMENT AND HERITAGE SERVICE

**GUIDANCE FOR PROCESSES PRESCRIBED FOR
AIR POLLUTION CONTROL
BY THE CHIEF INDUSTRIAL POLLUTION INSPECTOR**

**CHIEF INSPECTOR'S GUIDANCE
TO INSPECTORS
(PART B PROCESSES)**

**PROCESSES FOR THE MANUFACTURE
OF FIBRE REINFORCED PLASTICS**

B PROCESS GUIDANCE NOTE - GNB 4/2 VERSION 1

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CONTENTS

1. INTRODUCTION.
2. PROCESS DEFINITION.
3. GENERAL REQUIREMENTS
4. RELEASES INTO AIR
5. RELEASE ROUTES
6. TECHNIQUES FOR RELEASE MINIMISATION.
7. COMPLIANCE MONITORING PROGRAMME.

1. INTRODUCTION

This Note is issued by the Chief Industrial Pollution Inspector as one of a series providing guidance for processes prescribed for Air Pollution Control (APC) by the Chief Inspector in Regulations made under the Industrial Pollution Control (Northern Ireland) Order 1997.

A further series of Notes is produced by the Department of the Environment (NI) for those processes prescribed for air pollution control and subject to regulation by the District Councils.

This Note provides a guide on standards and techniques to Inspectors in their assessment of an application for, or variation of, an APC authorisation under the Order.

This Note will also be of interest to operators of such processes, however it should be understood that whether an authorisation is granted, and on what conditions, will depend on the particular circumstances of each application. Parameters such as individual process characteristics and site location may influence the nature of the conditions that are included in an authorisation.

A key objective of the legislation is to ensure that, in carrying on a prescribed process, the best available techniques not entailing excessive cost (BATNEEC) will be used -

- (i) for preventing the release of prescribed substances into the air or, where that is not practicable by means, for reducing the release of such substances to a minimum and for rendering harmless any such substances which are so released; and

- (ii) for rendering harmless any other substances which might cause harm if released into the air.

This Note comprises guidance in relation to new and existing processes and is based on an assessment of best available techniques as qualified by the requirement not to entail excessive cost. (The definition and meaning of BATNEEC is contained in the Industrial Pollution Control Part A and B processes “A Practical Guide”.)

The guidance contained in this Note is based on the current stage of knowledge and understanding of these processes, their potential impact on the environment, and the available control techniques at the time of publication. The guidance will be updated regularly, (as a minimum the Note will be reviewed at not more than four yearly intervals from the date of publication), to reflect changes in knowledge and understanding. It will not always be possible to revise the Notes quickly enough to keep in absolute step with rapid changes. It is therefore recommended that operators and their advisors check with the Inspectorate as to whether there have been any changes before relying on this Note for the purpose of making an application or taking other significant action under the Order.

2. **PROCESS DEFINITION**

- 2.1 This Note applies to processes manufacturing fibre reinforced plastics which are likely to involve the use of 100 tonnes or more of styrene or any other unsaturated hydrocarbons in any 12 month period as described in Schedule 1 - Section 4.2, Part B of the Industrial Pollution Control Order (Prescribed Processes and Substances) Regulations (Northern Ireland) 1998.
- 2.2 Fibre reinforced plastics consist of bundles of fibres bonded together in a resin matrix to produce a material which has much better mechanical properties than either the fibres or the cured resin would have if used separately. By far the most important fibre reinforcement used is glass fibre which can be supplied in a number

of forms including continuous rovings, woven rovings, cloths and random chopped fibre mats. In recent years, however, carbon fibres and polyaramid fibres have been used to an increasing extent, particularly in the manufacture of lightweight structural components.

- 2.3 The most frequently used resins in the manufacture of fibre reinforced plastics are unsaturated polyester resins. These are syrups consisting of polymer chains dissolved in a reactive organic diluent. The most commonly used diluent is monomeric styrene, (sometimes referred to as vinyl benzene), although alternatives such as methyl methacrylate and vinyl toluene may be used. Resins generally also contain fillers and additives which improve aspects of their performance. These may include pigments, fire retardents and thixotropic agents which aid handling.
- 2.4 Polyester resins are cured using a free radical co-polymerisation reaction, (typically initiated by an organic peroxide “catalyst”), which is generally added to the resin immediately before curing is required. The “catalyst” is normally broken down in the presence of an accelerator, such as cobalt octoate or a tertiary amine, to form highly reactive free radicals which react with the styrene to form further free radicals. The styrene free radicals then react with the double bond in the polyester chain. Thus, a solid, three-dimensional structure is built up, consisting of polyester chains cross-linked with styrene molecules. Alternatively, the reaction may be initiated by radiation, for example heat or UV light. Further details of a range of manufacturing techniques are given in Appendix 1.
- 2.5 For the purposes of this Note, the definitions in Appendix 2 apply.
- 2.6 In the context of this Note “process” comprises the whole process including the treating, handling and storage of any materials used in the process as well as products and wastes produced by the process.

3. **GENERAL REQUIREMENTS**

- 3.1 New processes must comply with the standards contained in this Note immediately.
- 3.2 It should be the aim to bring processes up to current standards whenever the opportunity arises. Account should be taken of the plant's technical characteristics; its rate of utilisation and the length of its remaining life; the nature and amount of polluting emissions from it and the desirability of not entailing excessive costs for the plant concerned.
- 3.3 As part of the first application for authorisation of existing processes, those areas of the process that require upgrading to achieve the standards of this Note should be identified and the possible techniques which are to be employed indicated. Under normal circumstances, a detailed programme for upgrading, including timetable, should be submitted with the application.

4. **RELEASES INTO AIR**

4.1 **Reference Conditions**

All pollutant concentrations should be expressed at reference conditions of temperature 273K (0°C) and pressure 101.3 kPa (1 atmosphere) without correction for water vapour content. These reference conditions do not apply to the mass emissions of styrene, which does not require adjustment for temperature or pressure.

4.2 **Emission Targets**

- 4.2.1 The total emission of styrene from any process for the manufacture of fibre reinforced plastics should not exceed the mass quoted in the table below per tonne of resin used in the process.

Process	Maximum emission of styrene (kg/tonne of resin used)*
Application of gel coat	200
Contact moulding, filament winding and centrifugal casting	60
Continuous sheet moulding and pultrusion	40
Resin transfer moulding and hot press and cold press injection moulding	20

Note * Refer to Appendix 3 for monitoring emissions.

4.2.2 Where arrestment equipment is necessary to meet the standards of either par. 4.2.1 or 4.2.6 the following emission concentration standards should be applied to contained releases (expressed as 30-minute mean concentrations):

<u>Emissions</u>	<u>Concentration (mg/m³)</u>
Carbon Monoxide (from incinerators)	100
Oxides of Nitrogen measured as nitrogen dioxide (from incinerators)	100
Volatile Organic Compounds (expressed as total carbon excluding particulate matter)	50

4.2.3 Although the emission standard for Volatile Organic Compounds (VOCs), where arrestment equipment is required, is 50 mg/m³, there may be some circumstances in which it will be difficult to maintain compliance with this standard (for example, where the input styrene concentration to the incinerator is extremely high, typically above 15 g/m³). In these circumstances it may be necessary to assess what emission standard is achievable in accordance with BATNEEC and to specify a standard

which can be achieved using the quoted arrestment efficiency of the proposed incinerator. It is not envisaged that this would result in a significant derogation from the emission standard for VOCs in par. 4.2.2.

In the case of condensation arrestment equipment the efficiency should be at least 96% recovery when the arrestment equipment is operating at its maximum design styrene input, (provided this is appropriate to the process in question). Recovery efficiency should not be less than 90% when operating below maximum design styrene input.

In the case of absorption arrestment equipment, emissions during absorption bed reconditioning should be discounted when calculating the time-weighted average VOC emissions, except if styrene laden air is passed in to the bed at the time of reconditioning.

- 4.2.4 The concentration of particulate emissions from spray-up processes should not exceed 20 mg/m³.
- 4.2.5 All releases, other than steam or condensed water vapour, should be free from persistent mist or fume and free from droplets.
- 4.2.6 The aim should be that all releases are free from offensive odour outside the process site boundary, as perceived by the Inspectorate.
- 4.2.7 The introduction of dilution air to achieve the emission standards in this Note should not be permitted. If emission concentration standards are already being met or do not apply, dilution air should be permitted if necessary to render harmless a coloured or odorous emission.

5. **RELEASE ROUTES**

The principal release routes are as detailed below:

<u>Pollutant</u>	<u>Source</u>
Styrene plus other VOCs	Receipt, storage and handling operations especially bulk storage tank venting and local storage vessels. Process operations especially mould injection and spraying procedures. Process equipment cleaning. VOC abatement plant exhaust.
Particulate (dust)	Receipt, storage and handling of raw materials; finishing operations and solid waste storage.
Oxides of Nitrogen)
Oxides of Carbon)
Oxides of Sulphur) Thermal oxidation unit exhaust
Mixed trace Organics)

6. **TECHNIQUES FOR RELEASE MINIMISATION**

6.1 **Introduction**

The techniques selected need to cover releases from raw materials reception/storage, internal transportation, and from processing.

The process should be designed and operated in such a way that the substances released have the minimum impact on the environment. As a general principle the Inspectorate should be looking for evidence of the prevention, minimisation and rendering harmless of all releases of prescribed substances, and the rendering harmless of all other releases in the application, and requiring this in the authorisation.

Releases from the process may require a combination of several abatement techniques and the careful control of the process route taken in order to deal with the

releases. The applicant should review all the options that are available and demonstrate that the combination of primary process and selected abatement equipment demonstrates BATNEEC.

6.2 **Techniques**

6.2.1 **Materials Handling**

6.2.1.1 The receipt, handling and storage of polyester resins and other potentially odorous or harmful substances should be carried out in such a way that emissions are prevented, or where not practicable due to process characteristics, minimised and rendered harmless.

6.2.1.2 Resins and amine accelerators should preferably be stored in fixed tanks. Static bulk resin storage tanks should be fitted with pressure vacuum relief valves on vents where the composite vapour pressure of the solvent exceeds 0.4 kPa at 293K. Operators should be aware that the sizing, siting, safety features and maintenance arrangements associated with fitting pressure vacuum relief valves may be subject to health and safety legislation. Additionally, level indication using hydrostatic or pressure methods may be affected. Pressure vacuum relief valves should be visually checked at least once every six months for contamination, seating and corrosion and the results of the check recorded. Emissions should be vented to suitable arrestment equipment if necessary to meet the terms of par. 4.2.6.

6.2.1.3 All waste materials, such as dust from finishing operations, should be stored in enclosed containers to prevent entrainment of particulate matter into the air.

6.2.1.4 Bulk chemical storage tanks should be completely contained by bunding which is sealed and resistant to the chemicals in storage and capable of holding 110% of the capacity of the largest storage tank.

- 6.2.1.5 To prevent overfilling, all bulk storage tanks should be fitted with suitable audible and visual alarms which will operate when any tank is in danger of becoming overfull. Where practicable, (for example, where raw material delivery pumps are not mounted on delivery vehicles), an interlock to the tank filling system should be provided. Alternative tank filling procedures may be followed, subject to the agreement of the Inspectorate.
- 6.2.1.6 Where storage of resins in portable containers is unavoidable for operational reasons, such as use of only small quantities, all reasonable efforts should be made to minimise the amount of residual styrene-bearing materials left in drums and other containers after use. The location of open-air storage areas for such drums and containers should be carefully selected to meet the requirements of par. 4.2.6 of this Note. Used and partly-used containers should be securely lidded.
- 6.2.1.7 Where spillages of liquid resin occur, they should be immediately cleaned up and contaminated material should be held in a closed bin. Sufficient supplies of decontaminant and a suitable absorbent material should be kept at all times.
- 6.2.1.8 The pumping of resin in enclosed pipework from storage to the point of use will minimise emissions. Where operational considerations allow, this practice should be adopted.
- 6.2.2 **Processing**
- 6.2.2.1 Wherever practicable, other than in the case of continuous processes, filament winding or centrifugal casting, resin should be introduced into a closed mould which is not opened until curing has taken place. Where a closed mould system is used which has been designed with the intention that resin will be introduced into the mould when open, the mould should be closed or covered as soon as possible after lay-up. The use of closed mould techniques may not be practicable in circumstances where large mouldings are being manufactured.

- 6.2.2.2 Resins which give rise to low styrene emissions should be used wherever possible and in particular where open moulding takes place. Where they are not employed for open moulding the process operator should provide justification for this decision to the Inspectorate. Reasons for not using styrene-suppressed resins containing waxes might include the need for a non-slip surface or a requirement for a high degree of structural integrity.
- 6.2.2.3 The time during which gelation of resin occurs should be minimised, in order to reduce emissions from this stage of the process.
- 6.2.2.4 Certain resin application techniques will give rise to lower levels of styrene emission. For example, rolling, brushing and flow coating tend to emit less styrene than spraying. The applicability of these techniques will be very process dependent, but there are likely to be cases where they can reasonably be used.
- 6.2.2.5 Where resin is sprayed into moulds, air assisted airless, centrifugal or high volume low pressure (HVLP), where the atomisation pressure is less than 69 kPa (10 psi), sprayguns should be used in order to achieve efficient transfer and reduce styrene emissions to atmosphere. Other spray techniques should be permitted if it has been demonstrated to the satisfaction of the Inspectorate that at least the equivalent transfer efficiency and styrene can be achieved. Care should be taken to minimise overspray.
- 6.2.2.6 Where resin is applied by means of fibres passing through a resin bath, excess resin should be removed from the fibres, (for example, nip rollers or a “doctor” blade).
- 6.2.2.7 As a disproportionate amount of styrene is emitted from the top layer of a laminate, as many layers as possible should be built up at any one time, having regard to the design performance required. This is known as “wet-on-wet lay-up”.
- 6.2.2.8 Where the holding of resin in buckets and other small holding containers is unavoidable, the containers should be lidded at all times when resin is not being

poured or used for lay-up. In no circumstances should containers be left open for more than 8 hours.

6.2.2.9 Emissions from activities likely to give rise to airborne particulate matter, (for example the chopping of glass fibre rovings and the cutting and finishing of products), should be collected and extracted, where necessary, to suitable abatement equipment. Alternative procedures, such as wet cutting, may be employed if the operator can demonstrate their effectiveness to the satisfaction of the Inspectorate.

6.2.3 **Spray Booths**

6.2.3.1 Where proprietary booths are provided, all spray-up operations should be carried on in the booth to prevent fugitive emissions of odour and particulate matter. Booths should be fitted with a means of preventing spraying operations from continuing in the event of positive pressure within the booth, (for example the loss of draft from the local exhaust ventilation system or a plugged filter).

6.2.3.2 Where spray-up is carried out in a totally enclosed proprietary type spray booth, the booth should be designed to meet the standards for VOC and particulate emissions specified in par. 4.2.2 and 4.2.4. The Inspectorate should be provided with a guarantee from the spray booth manufacturer that a newly-installed booth will meet these emission standards, and the guarantee should be supported by emission test data for the spray booth type that the guarantee relates to. Where an existing spray booth is upgraded to achieve the emissions standards specified in par. 4.2.2 and 4.2.4, a guarantee should be obtained either from the spray booth manufacturer, or the company who carries out the upgrading, that the upgraded booth will meet the emission standard. The guarantee should be supported by emission test data for the spray booth.

6.2.3.3 Where no such guarantee is obtainable, either for a new booth or for an existing booth which has been upgraded, or where the operator feels that upgrading of the existing booth is unnecessary, emission testing from that specific booth should be

required to demonstrate compliance with the emission standards specified in par. 4.2.2 and 4.2.4. Additionally, where the problems of particulate emissions are perceived, a particulate emission monitoring exercise should be required, even if a manufacturers' guarantee is available for the booth.

6.2.3.4 Where a proprietary type spray booth is not available, all spraying should be carried out in a totally enclosed area, and the spraying area should not be under positive pressure throughout spraying and curing operations, to prevent fugitive emissions of odour and particulate. The requirements of par. 6.2.3.1 in respect of positive pressure interlocks should also be met. Emissions from such spraying facilities should be measured at least once every 12 months to demonstrate compliance with the emission standards specified in par. 4.2.2 and 4.2.4.

6.2.4 **Equipment Cleaning**

6.2.4.1 Emissions of volatile organic compounds, including styrene, from cleaning operations should be minimised in accordance with par. 6.2.4.2 to 6.2.4.5.

6.2.4.2 Operators should be encouraged to make arrangements to despatch, (for recycling or reuse), all dirty solvents which have been used, (for example cleaning equipment), and all other liquid wastes which contain volatile organic compounds.

6.2.4.3 Cleaning operations should be reviewed to identify any cleaning steps which can be eliminated.

6.2.4.4 Alternative cleaning techniques should be used where practicable, (for example using water (with or without mechanical, chemical or thermal enhancements) or organic solvents which are significantly less volatile).

6.2.4.5 Where manual cleaning is unavoidable;

- (i) cleaning solvents should be kept in enclosed containers whilst not in active use;
- (ii) wiping cloths or brushes should be impregnated with cleaning solvent in a controlled manner, using a dispenser or similar device; and
- (iii) used wiping cloths or brushes should be stored in enclosed containers pending recovery or disposal.

6.2.5 **Fugitive Emissions**

6.2.5.1 The potential for fugitive releases should be considered in the design of the equipment, in the plant layout and in operating practices with the objective of eliminating the release of untreated emissions.

6.2.6 **General Operations**

6.2.6.1 Effective control of emissions requires the maintenance and proper use of equipment, as well as prudent supervision of process operations. Effective preventive maintenance should be employed on all plant and the equipment concerned with the control of emissions to the air. Essential spares and consumables should be held or available at short notice.

6.2.6.2 Any malfunction or breakdown leading to abnormal emissions should be dealt with promptly and process operations adjusted until normal operations can be restored. The inspector should be informed without delay. All such malfunctions should be recorded in a log book retained by the operator for a minimum of 4 years and available for examination by the Inspectorate.

6.2.6.3 Staff at all levels should receive the necessary formal training and instruction in their duties relating to control of the process and emissions to air. Particular emphasis should be given to training for start-up, shut down and abnormal conditions.

6.2.6.4 A high standard of housekeeping should be maintained.

6.2.7 **Dispersion**

6.2.7.1 The applicants will need to satisfy the Inspector that an appropriate assessment of vent and chimney heights has been made to provide adequate dispersion of prescribed substances, and other substances that might cause harm, which cannot be prevented and may be released. Some guidance is given in Technical Guidance Note D1 (ISBN 0-11-752794-7).

6.2.7.2 It may 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, (for example sites with any large volume emission, significant non-combustion sources or multiple release points and sites where there are sensitive receptors nearby).

6.2.7.3 Applicants should provide clear information on the parameters used and the assumptions made in their assessment, especially when using dispersion models. The assessment of background concentrations of pollutants will be particularly relevant. Statutory air quality standards and other recognised criteria should be taken into account.

6.2.7.4 Process upsets or equipment failure giving rise to abnormally high release levels over short periods should be assessed. Even if a very low probability of occurrence can be demonstrated by the applicant, a value for the chimney or vent height should nevertheless be set to avoid any serious damage to health in such circumstances.

6.2.7.5 The Operator should have procedures in place to reduce load or shut-down plant in the event of inadequate dispersion conditions.

6.2.7.6 Chimneys or process vents should be designed to provide efflux velocities that meet the requirements for stack aerodynamic downwash as described in Technical

Guidance Note D1. Care should be taken to avoid generating positive pressure zones within the chimney unless the chimney wall is impervious or lined. Where a wet method of arrestment is used, the linear velocity within the arrestment equipment should not exceed 9 m/sec, to avoid entrainment of droplets.

6.2.7.7 Chimney flues, process vents and all ductwork should be leakproof. Chimney flues and ductwork leading to the chimney should be adequately insulated to minimise the cooling of waste gases and prevent liquid condensation on internal surfaces. Chimney flues and ductwork should be regularly cleaned to prevent accumulation of material.

6.2.7.8 Chimney or process vents should not be fitted with any restriction at the final opening, (for example, a plate, cap or cowl), where it is necessary to achieve dispersion of the residual pollutants except for a cone to meet the efflux velocity requirements of par. 6.2.7.6. The discharge should be vertically upwards.

7. COMPLIANCE MONITORING PROGRAMME

7.1 General

Conditions in the authorisation should require the results of all monitoring to be recorded. It should further distinguish between:

- compliance records;
- measurement or records for which regular formal returns to the Inspectorate are not normally required; and
- operational records made by the operator during the normal course of operating the process.

7.2 **Monitoring Requirements**

- 7.2.1 Compliance with the mass emission standard specified in par. 4.2.1 should be demonstrated by a survey of styrene emissions from the process which should be carried out at least once every twelve months. Further guidance on the methodology to be used can be found in Appendix 3.
- 7.2.2 Where styrene arrestment plant is necessary, emissions from arrestment plant should be continuously monitored for volatile organic compounds (VOCs) expressed as total carbon excluding particulate matter. Continuous emission charts and records should be retained by the operator for a minimum of 4 years and available for examination by the Inspectorate. Where the arrestment plant includes an incinerator and the requirements of par. 7.2.3 and 7.2.4 are met, it should not be necessary to continuously monitor VOC emissions. In these circumstances it should be sufficient to demonstrate compliance with commissioning profiles for adequate VOC destruction, its correlation with incinerator temperature and in the case of catalytic incinerators its correlation with carbon monoxide emissions. Where the VOC emission standard is met without the use of arrestment equipment, VOC emissions should be tested at least once a year.
- 7.2.3 Emissions from thermal incinerators should be tested for VOCs, carbon monoxide and oxides of nitrogen (as nitrogen dioxide) at least once a year. The Inspectorate should agree a minimum incineration temperature for the process to achieve adequate destruction of VOCs, and this should be continuously monitored.
- 7.2.4 Emissions from catalytic incinerators should be continuously monitored for carbon monoxide and the incineration temperature, (which should be agreed as per par. 7.2.3), and tested at least once a year for emissions of VOCs and oxides of nitrogen.
- 7.2.5 Subject to par. 6.2.3.2 emissions from spray booths, where spray-up is carried out, should be tested at least once a year for total particulate emissions. Where spray booths are vented to arrestment plant for VOCs, (for example, an incinerator),

particulate emission testing should be undertaken at the exhaust from the arrestment plant. However, where the operator can demonstrate that a number of processes carry out similar operations which lead to emissions of the same nature and volume, the Inspectorate may approve a sampling programme. In any case, each emission should be tested at least once every 4 years, and at least 25% of all emission points should be tested each year. Emissions from arrestment plant should be tested at least once a year.

- 7.2.6 All continuous monitoring instruments should be checked for correct functioning and calibrated in accordance with the manufacturer's instructions. The results from all continuous monitoring instruments should be continuously recorded.
- 7.2.7 The frequency of testing should be increased as part of the commissioning of new or substantially changed processes or where there is a justifiable complaint situation.
- 7.2.8 The results of all periodic monitoring and inspections should be recorded in a log book, retained by the operator for a minimum of 4 years and available for examination by the Inspectorate. Adverse results should be investigated immediately and in all cases should be recorded in the log book. The operator should ensure that the cause of such adverse results has been identified and corrective action taken, and this action recorded in the log book.

The log book may be in electronic form, provided that a printout verified by a responsible person is provided on request.

- 7.2.9 A summary of any continuous monitoring results should be forwarded to the Inspectorate at least once every 6 months. Where applicable this information should include a list of daily mean VOC emission concentrations and a list of 30-minute mean VOC emission concentrations which exceed twice the emission standard and the times and dates to which these refer in a format enabling the Inspectorate to determine compliance with par. 4.2.2. In the case of incineration arrestment plant the information should include a time and date referenced list of occasions when the

incinerator temperature fell below, (and for catalytic incinerators the carbon monoxide concentration rose above), the level consistent with adequate destruction of VOCs.

- 7.2.10 The Inspectorate should be advised at least 7 days in advance of any periodic monitoring exercise to determine compliance with emission standards, as well as the provisional time and date of monitoring, pollutants to be tested and the methods to be used. The results of all non-continuous emission monitoring should be forwarded to the Inspectorate as soon as possible but no later than 8 weeks after the completion of the sampling.
- 7.2.11 The sampling positions for all monitoring instruments should be agreed with the Inspectorate. Care is needed in the design and location of sampling systems in order to obtain representative samples.
- 7.2.12 The reference test method for particulate emissions in chimneys or ducts is that of British Standard BS 3405: 1983. Alternative methods of testing may be acceptable by agreement with the Inspectorate provided that it can be shown that comparable results are obtained.
- 7.2.13 The onus is on the operator, that the appropriate equipment, laboratory facilities, expertise and quality control procedures are provided to ensure accurate results.
- 7.2.14 The measurement of the concentration of other pollutants should be with test methods agreed with the Inspectorate.
- 7.2.15 **Resin Inventory**

An inventory of resin usage and styrene consumption should be kept and forwarded to the Inspectorate at least every 12 months.

7.2.16 **Environmental Monitoring**

The impact of the process on the environment will be affected by the size of the releases and the site's location. The need for environmental monitoring should be addressed in the application, where necessary, to demonstrate that the releases have been adequately rendered harmless by the application of BATNEEC.

APPENDIX 1

DESCRIPTIONS OF TYPICAL PROCESSES

Open mould processes *Hand lamination* - resin is typically mixed by hand in a bucket and applied to the mould using a brush or roller. Normally a neat resin layer, referred to as a gel coat, is applied first and allowed to cure. Alternative layers of resin and reinforcement are then applied to the mould. A ribbed metal roller is used to consolidate the laminate and fully impregnate the reinforcement whilst air remaining in the laminate is forced out.

Saturation - this process is similar to hand lamination. However, rather than the resin and being mixed by hand and applied by brush or roller, mixing is mechanical and the resin sprayed on to the mould.

Spray-up - in this process, resin and fibre are sprayed on to the mould together. Strands of continuous reinforcement are cut up and ejected by an air driven chopper unit mounted on the spray gun. Spray-up can be automated to improve control over the distribution of fibres and resin.

Filament winding - this technique is particularly suitable for the manufacture of hollow shapes, such as pressure vessels. The component is moulded on a male former, mounted on a rotating shaft. Continuous fibre strands are fed through a resin bath and a comb, both mounted on a traverse, before being wrapped around the rotating former.

Centrifugal casting - this is another process which may be used to produce hollow articles although in this case the moulded surface is

on the outside. Resin and reinforcement are placed inside a cylindrical mould which is rotated at high speed. For the production of simple mouldings, a traversing spray-up gun can be used to apply resin and reinforcement together.

Closed mould process

Vacuum bag moulding - this is the simplest form of closed mould process. Following hand lay-up, a release film is laid over the laminate, followed by a rubber bag which is clamped to the edge of the mould. The space between the bag and the mould is evacuated so that atmospheric pressure is applied over the surface of the laminate to effect consolidation.

Pressure bag moulding - this technique is similar to vacuum bag moulding but higher pressures are achieved by the injection of compressed air into a void between the rubber bag and a lid which is clamped over the mould. A similar technique can be used within an autoclave where high product quality is essential.

Matched mould techniques - these allow the production of a moulding with two moulded faces. The simplest form of matched mould process, known as leaky moulding, commences with hand lay-up in a female mould. A male mould is then clamped over the laminate. A better quality moulding can be produced by the use of a hydraulic press. The rate of production can be increased significantly by applying heat to the mould surface to accelerate curing. Hot press moulding is often carried out using pre-impregnated reinforcement (prepreg) or moulding compounds.

Resin injection - as with matched moulding, the reinforcement pack is made up and loaded in the mould. In this process, however, the mould is closed on to the dry pack before the resin is introduced. Resin is mixed mechanically and dispersed into the mould through

one or more injection points. Larger, stronger mouldings can be produced using vacuum assisted resin injection techniques. A seal is formed around the edge of the mould and a partial vacuum formed within the mould cavity. A flexible FRP upper mould or flexible film is used which deforms under injection pressure but allows the resin to pass across and through the reinforcement pack.

Injection moulding - this technique is suitable for high volume components. A dough is mixed containing resin and reinforcement which is then loaded into a hopper from where it is forced into the mould by a screw or piston.

Continuous process

Continuous lamination - in this process, reinforcement and resin are combined and contained between two layers of release film which act as carriers transporting the laminate on a conveyor through a curing oven. On emerging from the oven, the release film is peeled off and the cured laminate cut to length. The process can be used to make flat sheet or, by using formers, a corrugated profile.

Pultrusion - the reinforcement is impregnated with resin and pulled through a heated die from which it emerges fully cured. Resin impregnation can be submerging the reinforcement in a bath or by injection directly into the die.

Continuous filament winding - filament wound pipe can be produced continuously using this technique. A winding head containing several "cheeses" of continuous yarn reinforcement rotates around the mandrel, wrapping on yarn as it does so. The pipe emerges at a constant rate from a curing oven whilst the mandrel continuously collapses onto itself and then reforms into a cylinder at the start of the process.

APPENDIX 2

DEFINITIONS OF TERMS USED IN THE GUIDANCE

The following definitions are largely taken from ISO 472:1988 Plastics - Vocabulary.

accelerator: A substance used in small proportion to increase the reaction rate of a chemical system (reactants plus other additives).

composite: A solid product consisting of two or more distinct phases including a binding material (matrix) and a particulate or fibrous material.

Note - Example: moulding material containing reinforcing fibres, particulate fillers or hollow spheres.

crosslinking: The process of multiple intermolecular covalent or ionic bonding between polymer chains.

gel coat: An outer layer of resin, sometimes containing a colorant, on a reinforced plastic part to improve surface properties.

laminate: Material composed of successive bonded layers of resin and fibre or other reinforcing substance.

monomer: A compound consisting of molecules each of which can provide one or more constitutional units.

prepreg: An admixture of resins (with or without fillers), additives and reinforcements in woven or filamentous form, ready for moulding.

reinforced plastic: A plastic with high strength fibres embedded in the composition, resulting in some strength properties greatly superior to those of the base resin.

reinforcement: Strong, inert material, usually fibres, strongly bonded into the resin to achieve enhanced strength, stiffness and impact resistance.

Note - Reinforcement fibres are commonly available in the following forms:

- chopped strand mat, formed of strands cut to a short length, randomly distributed, without intentional orientation, and held together by a binder;
- continuous mat, formed of strands, randomly distributed, without intentional orientation, and held together by a binder that is not soluble in styrene;
- roving, which is a collection of parallel strands (multistrand roving) or parallel filaments (multifilament roving) assembled without intentional twist;
- woven roving, which is a fabric woven from roving;
- multidirectional crossply roving, which is a fabric of crossply rovings in two or more directions;
- unidirectional roving, which is a fabric of rovings arranged in one direction; and
- cloth, which is a fabric woven from yarn.

resin: Reactive synthetic that in its initial stage is a liquid, but during cure is transformed into a solid.

Note - Resins are used in different formulations:

- as gelcoat for the mould side of the laminate, giving a smooth, flexible and water resistant surface;
- as a matrix material for the reinforcing fibres of the laminate;
- as a topcoat for the non gelcoated surface to achieve a flexible, water resistant and tack free surface; and
- as a matrix material for fillers and putties.

spray-up: The simultaneous spraying of prepolymer, catalyst and chopped fibres on to the mould or mandrel.

unsaturated polyester: A polyester characterised by carbon-carbon unsaturation in the polymer chain, which permits subsequent crosslinking with an unsaturated monomer or prepolymer.

APPENDIX 3

MONITORING STYRENE EMISSIONS FOR THE PURPOSE OF COMPARISON WITH THE MASS EMISSION TARGETS IN PAR. 4.2.1

Wherever possible, emissions of styrene from FRP manufacturing processes should be measured by monitoring the concentration of styrene and the airflow in the exhaust stacks. In this way, a mass emission over a period of time, preferable eight hours but at least a complete process cycle, may be calculated. This can then be compared with the mass of resin which has been used over the same period. Sampling points should be situated at least five stack diameters downstream from any bends or obstructions in the stack.

Difficulties may arise in situations where there are no extraction points close to the processing area and fugitive emissions represent a significant proportion of the total releases. In these circumstances, measured stack emissions should be supplemented with mass balance calculations in which resin consumption is compared with the mass of parts produced, allowing for contamination of drapes, filters, tools, etc.

Three methods which are appropriate for the determination of styrene emissions are described below:

*Flame ionisation
detection (FID)*

FID based analysers utilise the principle of hydrogen flame ionisation for detection and measurement of organic vapours. The carbon-containing ions that are generated are driven to a collecting electrode and the resulting ionisation current is measured. Instruments are calibrated by the manufacturer against hydrocarbon standards, generally methane or propane. Regular recalibration is required. Correlation to styrene concentrations is achieved using pre-determined response factors. FID does respond to other volatile organic compounds, such as cleaning solvents, and the use of these should therefore be avoided during the sampling period. If this is not feasible, the coupling of the FID with a gas chromatograph

should be considered, in order that differentiation of the organics present can take place.

*Photo ionisation
detection (PID)*

PID shares the same basic principles as FID, but ionisation is achieved by means of an ultra-violet light source rather than a hydrogen flame.

*Infra-red vapour
analysis*

Organic compounds absorb infra-red radiation at characteristic wavelengths. Infra-red analysers are factory calibrated for a particular compound. This specificity means that these analysers are particularly suitable for measuring styrene in the presence of other volatiles which may be present in the resin or other materials such as cleaning compounds.