Glass reinforced plastic vessels and tanks

Advice to users

This is a web-friendly version of leaflet PM75 (Third edition)

Guidance Note PM75 (Third edition)

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Guidance Notes are published under five subject headings:

Medical
Environmental Hygiene
Chemical Safety
Plant and Machinery
General

Scope

1 HSE has produced this good practice guidance note in consultation with industry. It outlines essential requirements to safeguard against the failure of glass reinforced plastic (GRP) tanks, vessels and scrubbers in service.

2 This document gives guidance on the specification, design, manufacture, transportation, installation, operation and inspection of GRP vessels and tanks, both with and without thermoplastic liners. It is for all who specify, install or use GRP tanks and vessels. If you follow this advice then the likelihood of an incident will be reduced.

3 This guidance does not preclude the use of alternative strategies and arrangements which provide equivalent or higher standards of safety.

4 The document does not extend to the precautions to be adopted by the manufacturer during the production of vessels and tanks, scrubbers, pipework and other items, nor is it intended to apply to road tankers or tank containers.

Introduction

5 GRP tanks and vessels have a variety of applications and are very common in the chemical and food and drink industries for storing a wide range of materials, some of which are classified as hazardous.

6 Many GRP vessels and tanks are produced annually and the vast majority perform satisfactorily. However, a number have failed in service, with a proportion of these failures being catastrophic. Even in situations where the substances contained are not themselves hazardous, the consequences of a catastrophic failure may be serious. To reduce the risk of such failures, you should be aware of what can go wrong and – more importantly – how to avoid it.

7 There has been a commonly held misconception that GRP storage tanks can be ‘fitted and forgotten’ as they are frequently portrayed as having good chemical resistance and no need for maintenance or examination up to their design life. You should be aware that this is not the case and take suitable measures to make sure GRP tanks are correctly specified, examined and maintained throughout their service life.

8 Investigation into tank and vessel failures has shown that designers and manufacturers are not always made fully aware of the exact operating conditions which need to be withstood. This lack of information is one of the commonest causes of in-service problems. This latest edition clarifies the advice on maximum operating temperatures (see paragraphs 14 and 16).

9 The Pressure Equipment Regulations 1999 (PER)[1] place duties on manufacturers/suppliers of defined pressure equipment (including vessels) to request relevant information from the client. For non-pressure equipment, a similar exchange of information to specify the required tank duty early in the procurement process is an important measure to help make sure the purchased item will be fit for service.

10 There are a number of codes, standards and guidance documents in widespread use for the design and manufacture of non-metallic storage tanks, including BS 4994[2] which remains current alongside other BS EN standards referenced in this guidance.

11 The requirements for underground GRP storage tanks are given in BS EN 976-1,[3] BS EN 976-2,[4] BS EN 977[5] and BS EN 978.[6]

12 Units which have been correctly specified, designed and manufactured for the required duty can be further safeguarded if users make sure they are installed, operated, examined and maintained in accordance with relevant standards and manufacturers' recommendations.

13 In accordance with good practice, you should keep records for each tank or vessel, including the original user specification, the manufacturer's documentation and calculations, the design life (number of fill/empty cycles), installation documentation, and records of all examinations.

GRP

Material selection

14 Improvements in resin technology over the last decade have resulted in a range of case histories of the successful use of GRP in hostile environments. Manufacturers of GRP tanks and vessels have access to published data to inform the choice of resin for a particular duty and they may also discuss resin selection directly with the resin supplier. Resin systems can achieve different maximum operating temperatures, so with careful selection of liner and resin system, GRP can offer excellent corrosion resistance to a wide range of fluids and gases at ambient temperatures and at higher temperatures, subject to documented service experience or testing (typically up to a maximum of 50°C, but beyond that in certain circumstances).

15 Problems can occur because some chemicals, particularly oxidising acids, alkalis and organic solvents, have adverse effects on GRP. Once the liner and resin system have been selected to suit the particular operating environment, the unit should perform satisfactorily. However, if the original design duty is subsequently changed or exceeded then new degradation mechanisms may occur.

16 It is a requirement of the design standards that there is an adequate margin between the maximum operating temperature the vessel will experience (the design temperature), and the temperature at which the strength of the resin deteriorates beyond acceptable limits (the heat deflection or distortion temperature). Depending on the design standard and temperature, this margin is at least 20°C and can be as much as 40°C. Correct selection of resin should ensure that the unit performs satisfactorily at the specified temperature. However, if the operating temperature is elevated above the resin design limit, eg due to a process upset, materials which are themselves innocuous may have adverse effects on GRP.

17 Resins used for the external surfaces of the unit should also be carefully selected to ensure that the satisfactory performance of the unit is not compromised. For example, overflow of contents may damage the unit externally. You must also ensure that the full range of duties to which the item may be exposed are carefully considered. For example, steam or other fluids used for cleaning may expose the item to temperatures/fluids outside the normal intended duty. These parameters should be taken into account at the design stage.

General selection considerations

18 GRP has two positive factors to be considered when determining the overall cost of a plant item. First, because GRP has a high degree of environmental resistance externally, in many cases it requires less maintenance than conventional

vessels and tanks, offering reduced running costs over the life of the item. Second, GRP is lightweight when compared to other materials. This tends to reduce the installation costs and the cost of supporting structures.

19 GRP is a thermal insulator that reduces the need to insulate tanks and pipes for heat retention or to protect people.

20 With the use of certain additives, GRP may be made suitable for use on a wider range of applications. For example, fire-retardant additives may be used to improve the suitability of GRP where improved performance is required in the event of a fire.

21 Many GRP tanks and vessels are self-coloured during manufacture which provides protection against ultraviolet degradation. It should be noted that unpigmented GRP laminates will degrade more quickly when exposed to sunlight and will allow light to penetrate. This may promote the growth of microbiological organisms and algae in some substances. Where this is a possibility, the dutyholder may wish to specify self-coloured GRP as a preventive measure.

22 GRP is naturally an electrical insulator. Static build-up should be considered at the design stage as this may create a potential source of ignition. This is particularly important in certain situations, eg when tanks or vessels are designed for the storage of flammable liquids, or are to be located in areas where ignition sources are controlled.

23 Care must be taken to prevent mechanical damage during installation, maintenance, examination and vessel entry because GRP has relatively poor impact resistance. Possible undetected damage to the inside surface might occur by mishandling or lifting, or by dropping items on the tank or vessel floor. Tanks or vessels installed in areas where vehicles operate may need to be protected by crash barriers or other means to reduce the risk of impact.

Manufacture/design considerations

24 Vessels built after 1987 should have been constructed to British Standard BS 4994:1987, or to an equivalent standard. Requirements to safeguard against tank or vessel failure can be found in the design standards listed in the References.

25 Manufacturers should work to an appropriate standard which simplifies quality control. Prospective purchasers should seek advice from the manufacturer regarding a suitable standard for the design and construction of new tanks and vessels.

26 In the case of existing vessels or tanks not manufactured in accordance with a recognised standard, it is recommended that such items be assessed against a relevant standard applicable at the date of manufacture, by the manufacturer or competent person to verify fitness for purpose.

27 BS 4994 enables designers to calculate strain levels for GRP units. If these strain levels are exceeded then environmental stress cracking becomes a possible failure mechanism in acidic environments. You should take steps to ensure the tank/vessel and associated pipework and fixings are adequately supported to avoid exposing GRP equipment to undue stresses.

28 GRP is constructed by blending layers of resin and reinforcement that results in the layers not necessarily having the same mechanical properties in every direction (ie they are anisotropic). This can be extreme when the laminate is formed by the filament winding process. It is important that this is considered at the design stage. Design standards cover this requirement to ensure proper loading in the correct direction.

29 GRP is a relatively brittle material which does not yield. It is a softer material than steel and can be more easily cut, crushed or worn away. In addition, the expansion coefficient of GRP can be more than three times that of steel. None of these characteristics should cause a problem providing they are all taken into account at the design stage.

30 Appendix 1 is taken from BS 4994:1987. This outlines information the user should supply to the manufacturer. In addition, the manufacturer should provide full details of the design to the user. Independent verification of design and construction should be sought for items on hazardous duties to provide a degree of assurance regarding initial integrity.

Legal requirements

31 This section highlights regulations of particular relevance to tank integrity management. Additional sources of guidance and information that may help dutyholders understand the legal duties arising through the life cycle of a tank/vessel from design and installation – through maintenance, inspection, possible repair and eventual retirement of the item – are given in the References.

Health and Safety at Work etc Act 1974[7]

32 The general duties in sections 2 to 4 and 6 to 8 of the Health and Safety at Work etc Act 1974 apply to all work activities which are the subject of this guidance. These duties include requirements on employers to, so far as is reasonably practicable, provide and maintain safe systems of work, ensure the health and safety of their employees, and conduct their undertakings in such a way as to ensure that anybody else who could be affected by the work activity is not exposed to risks to their health or safety. This includes ensuring that risks arising from the potential failure of a GRP tank or vessel are properly assessed and controlled.

Provision and Use of Work Equipment Regulations 1998 (PUWER)

33 Operators of GRP tanks or vessels have a duty to maintain the integrity of these items to prevent harm to people as a result of a loss of containment. Guidance on these Regulations is available in the Approved Code of Practice, L22.[8] Duties include a requirement to ensure the tank/vessel is suitable for the intended use, is maintained in a safe condition and is inspected to ensure it is, and continues to be, safe for use. Inspections must be carried out by a competent person (which could be an employee with the necessary skills and expertise to perform the inspection) and an inspection record must be kept until the next inspection. This requires the adoption of a suitable inspection regime to verify the continued fitness for service of the tank/vessel throughout its life.

Pressure Systems Safety Regulations 2000 (PSSR)

34 PSSR 2000 will apply to GRP vessels containing a relevant fluid. Guidance on these Regulations is available in the Approved Code of Practice, L122.[9] Duties include producing a suitable written scheme of examination (WSE) for the purposes of preventing danger from those parts of the pressure system included in the scheme, such as an uncontrolled release of stored energy. A competent person, as defined in the Regulations, must write or certify the WSE as suitable for this purpose.

35 The Regulations set out the content of the WSE, which includes specification of the scope of the examination (the vessel plus any associated pipework, valves etc, as deemed necessary), the nature of the examination (in-service and out-of-service requirements, inspection methods, testing etc) and the frequency of examinations, allowing for the setting of limits after which the vessel cannot be operated without a further examination.

36 PSSR 2000 may also cover design and construction issues where the Pressure Equipment Regulations[1] do not apply. Users can seek advice from their supplier in this regard. See the References for details of further guidance covering these aspects.

Control of Major Accident Hazards Regulations 1999 (COMAH)[10]

37 Operators of establishments where there are GRP tanks or vessels containing hazardous materials will, where the establishment is subject to the COMAH Regulations, have a duty under regulation 4 of COMAH to take all measures necessary to prevent a major accident.

38 Compliance with COMAH regulation 4 will go in hand with compliance with relevant PSSR and/or PUWER Regulations. This includes taking steps to ensure the tank or vessel is correctly specified, designed to an appropriate standard, manufactured, installed and operated correctly, and that integrity is maintained throughout the service life to prevent a loss of containment (and/or an uncontrolled release of stored energy) which could give rise to a major incident. Taking 'all measures necessary' includes establishing a suitable inspection regime based on a documented scheme of examination, which takes account of all relevant degradation mechanisms.

Dangerous Substances and Explosive Atmospheres Regulations 2002

39 A number of Approved Codes of Practice (ACOPs) have been published under DSEAR. The most relevant of these for users of GRP tanks is L135 *Storage of dangerous substances*,[11] which contains further information on the design, installation and use of tanks for the storage of flammable liquids.

Installation

40 Many GRP storage tank failures have been due to installation problems, eg a small item left under the base can lead to failure of the tank.

41 The berthing site should be inspected before installation to identify any defects or debris, and take corrective action, if necessary, before the unit is berthed.

42 GRP tanks and vessels should be installed in accordance with the relevant standard. Reference should also be made to the manufacturer's recommendations, and installation instructions should be followed.

43 Entry into tanks and vessels by people, eg during maintenance and inspection, is covered by the Confined Spaces Regulations 1997. Further guidance on these Regulations may be found in the Approved Code of Practice, L101.[12]

44 Lifting and loading a GRP tank or vessel should be in accordance with the relevant standard, with the manufacturer's instructions for handling and lifting the vessel or tank, and in compliance with the Lifting Operations and Lifting Equipment

Regulations 1998 (LOLER). Guidance on LOLER is available in the Approved Code of Practice, L113.[13] Slinging should be done using purpose-made equipment. Chain and wire rope slings should not be used as these are likely to cause mechanical damage. Fibre slings or ropes, as detailed in the relevant standards, may be used and the unit should be carefully handled at all times to avoid impact damage. Use should be made of the manufacturer's lifting lugs where possible. Fittings such as nozzles, branches or accessories should not be used. The lifting appliance should have sufficient capacity to lift the vessel or tank without the need for dragging the vessel or tank along the ground.

45 Connecting pipework should be supported so that the total loads local to the branches do not exceed the design values of the tank or vessel. Similarly, install any fixing bolts in accordance with manufacturer's recommendations to avoid stressing the unit. The use of levers to finely position the unit on its support should be prohibited.

46 Where temporary storage is required, take care to store on a flat surface, clear of any debris, protected from the risk of impact and in its correct orientation. The unit should be anchored to prevent any movement, eg due to wind.

47 Tanks or vessels installed near to roadways or other areas where vehicles operate should be provided with suitable impact barriers.

48 Tanks and vessels should be anchored. Take care to choose materials for hold-down brackets, bolts and earth connections that are compatible with the particular duty. Where located in a secondary containment area, anchorage will prevent floating when empty in the event that the area fills with liquid. The base of the vessel must also be designed to withstand the upward thrust. Alternatively, the plinth may be higher than the secondary containment wall. Careful consideration should be given to siting GRP tanks within a multiple tank secondary containment area where materials not compatible with GRP may be stored.

49 Underground tanks should be installed in excavations which are large enough to allow them to be installed without an increased risk of damage to the tank due to limited space. They should be installed in ground which is well drained and be supported on a firm foundation. Underground tanks should also be securely anchored or weighted to prevent flotation from floodwater or a high water table. Tanks likely to be subject to loadings from above ground (eg from traffic) should be protected by a reinforced concrete slab or other adequate cover. Alternatively, the area around the tank may be fenced off with the tank perimeter clearly marked.

50 Special considerations apply to the installation of underground tanks used for the storage of petroleum spirit – BS EN 976-1 and BS EN 976-2 should be consulted.

51 Appendix 2 sets out instructions from BS EN 13121-4:2005 which establish minimum inspection and test requirements following installation, and as required in the operating instructions given by the manufacturer.

Operation and maintenance

52 In-service integrity of tanks and vessels is maintained by correct operation and suitable maintenance, including periodic examination.

Operation

53 GRP tanks and vessels should be operated within defined safe operating limits, based on the original design or a revised duty verified by a competent person.

54 Where a tank or vessel is subjected to conditions outside the allowable operating limits, eg during a process upset, which may raise the temperature above the maximum allowable limit, this should trigger a review of the possible effects arising from the deviation to verify the continuing integrity of the item.

Examination

General requirements

55 After installation and before use, a competent person should inspect the unit. The relevant standards give detailed guidance on inspection and testing procedures to be adopted after completion of fabrication and before tanks or vessels enter service. Underground tanks should be examined before installation and tested for soundness by a competent person after lowering into the excavation but before infilling takes place.

56 A pre-commissioning examination provides a record of the as-new condition. This sets a baseline against which deterioration can be judged when assessing the results of future examinations. It also confirms that no damage has been caused to the unit before first use.

57 Subsequent internal and external inspections should be undertaken at appropriate intervals as determined by the user and competent person. The first internal inspection is particularly important to verify the design, construction and correct installation of the unit.

58 The scope, nature and frequency of inspections should be informed by a range of factors, which include the design and construction standards, operational experience, experience with similar vessels and contents elsewhere, foreseeable modes of failure and the consequences of failure. Inspection requirements should be documented in a scheme of examination.

59 Tanks that have a thermoplastic liner should be examined to detect any seepage of content that has passed the liner. The liner integrity should be checked by looking for signs of discolouration, cracking, bubbling, construction defects or any indication of surface environmental attack.

60 Following an accident, an impact, an excursion beyond allowable operating limits or a change in operating conditions, it will usually be necessary to subject the unit to a further examination outside the normal periodic examination schedule to verify ongoing integrity.

61 Routine (eg daily, weekly, monthly) visual external checks of GRP tanks and vessels, their secondary containment area and scrubbers represent good practice. Check records should also be kept, at least on a monthly basis and possibly more frequently, particularly for items with high failure consequences. Such checks may be carried out by operating staff trained to identify early indicators of integrity problems. Routine checks enable contents to be removed or, for non-hazardous contents, the operating level to be lowered to reduce the risk and consequences of a catastrophic failure if a weep, leak or other sign of degradation is observed. This is an important safeguard as many failures experienced to date have been ‘leak before burst’.

62 GRP tanks should have a finite design life stated when new (number of fill/empty cycles). This will identify the time at which an 'extension of life' inspection and assessment should be carried out by a competent person, or the tank taken out of service.

63 If it is concluded that a tank or vessel may remain in service beyond the original design life, the competent person should review and update the inspection regime taking account of all relevant factors including any potential age-related degradation mechanisms.

External examination

64 External examination requirements should be specified in the documented scheme. The tank/vessel inspector should decide whether the external examination is sufficient or if further examination, including internal examination, is necessary to ensure the continued safe operation of the vessel.

65 Signs of degradation that can be detected during a visual external examination include:

- change of surface condition;
- softening of the surface of the material;
- star cracks;
- delamination (separation of the layers);
- fibre prominence;
- local swelling;
- discolouration;
- white or coloured spots;
- liquid droplets permeating the surface; and/or
- cracks and fissures.

66 If signs of degradation are noted during routine checks, a competent person should assess the item for continued fitness for service. If a tank, vessel or scrubber is found to be leaking in service or if telltale signs of imminent failure (such as the appearance of liquid droplets permeating the surface) are noted, then where failure may cause harm or pose a risk to the environment, it should be taken out of use immediately and the cause investigated by a competent person.

67 The inspection should pay particular attention to the following areas:

- shell base junction;
- branch and man way attachments;
- support of piping and valves; and
- vessel support points.

68 The competent person's inspection should extend to the venting or pressure relief arrangements, the overflow system and also to the foundations and holding down arrangements where appropriate.

69 Vessels or tanks with internal liner protection, which have experienced an overspill, should be carefully examined for possible external damage to the shell, base or foundations at the earliest practicable opportunity. Similar examinations should be made of the hold-down arrangements and supports or foundations.

Internal examination

70 Internal examinations are particularly important in the case of tanks and vessels with acidic contents, as in certain conditions environmental attack can give rise to progressive strain cracking of GRP laminates.

71 Internal examinations should be undertaken initially within two years from commissioning and then at appropriate intervals, taking into account inspection history and operational experience. Technical justifications influenced by experience of the same specification tanks in comparable service elsewhere need to be carefully considered to ensure conclusions are soundly based.

72 When making internal examinations of GRP tanks and vessels, great care should be taken to work safely. Entry into any confined space should be carefully planned and supervised and should be subject to a strict procedure. Precautions set out in *Safe work in confined spaces*[12] should be rigorously followed. See also *Guidance on permit-to-work systems*,[14] *Safe use of lifting equipment*,[13] and *Safe use of work equipment*.[8]

73 Take care during internal examinations to avoid damage to the vessel or tank. A means of access should be provided which does not impose unacceptable loadings on the vessel or tank or their connections. All activity within the tank or vessel (eg personnel, use of scaffolds, tools etc) should be carefully controlled and performed to prevent danger to people or damage to equipment.

74 The examination report should indicate continued fitness for purpose of the vessel or tank until the next examination date, which should be stated or alternatively indicate any remedial work necessary for continued safe use. A record of the examination findings should be kept for comparison with future findings.

High-consequence equipment

75 Users of GRP tanks with hazardous contents should adopt good practice, using an inspection regime based on a documented scheme of examination which specifies internal and external examination requirements and inspection intervals. Items should not be operated beyond their next inspection due date without further inspection in accordance with the scheme of examination, or formal deferral by the competent person. Inspection records should be kept for comparison following inspection to monitor equipment condition over time.

76 An outline scheme of examination should be provided by the manufacturer with further details drawn up between the owner and the competent person, as appropriate. The scheme will establish the nature, scope and frequency of the examination and the inspection techniques to be used.

77 Users should be aware that an inspection regime developed to address PSSR requirements may not be sufficient where equipment is also subject to the COMAH Regulations. The inspection regime must take account of all failure modes, including loss-of-containment scenarios that may not involve an uncontrolled loss of stored energy.

78 For vessels and tanks on hazardous duties it is good practice to undertake annual external inspection by a trained and competent person, with the first internal inspection within two years of commissioning. The nature and frequency of subsequent internal inspections should be determined by a competent person, influenced by inspection findings and other relevant factors.

79 All inspections should be recorded and the competent person should issue an examination report indicating continued fitness-for-purpose until the date of next examination (which should be stated) or alternatively indicating remedial work necessary before continued use. Inspection results should be compared with previous results to enable identification and monitoring of any active degradation mechanisms.

80 The frequency of routine visual external checks to monitor for early warning signs of degradation and associated recording requirements will need to be

determined on a case-by-case basis for items with high failure consequences. As a minimum, monthly checks should be carried out with results recorded in line with general good practice.

81 For underground GRP tanks and vessels on hazardous duties, consider alternative methods for routine monitoring, eg via boreholes around the tank to monitor for possible ground contamination as a result of leakage.

Inspection techniques

82 Inspection techniques may vary for different tanks and vessels and should take account of the contents, operating conditions, construction materials, design code, and foreseeable failure modes. Visual examination may need to be supplemented by other non-destructive examination (NDE) techniques.

83 NDE techniques are not as fully developed for GRP as for steel but appropriate methods may help when performed by suitably qualified and experienced people. You should ensure that NDE operatives are suitably qualified, use properly calibrated equipment and follow an appropriate written procedure.

Repairs and modifications

84 GRP is often difficult to modify because its strength depends largely on the continuity of fibres throughout the matrix. It is important that the appropriate surface preparation and materials are used – extensive grinding back followed by rebuilding is always needed. The common practice of bonding polyester composites with polyester resin may not always be appropriate.

85 Repairs or modifications affecting the integrity of the vessel or tank should be carefully considered and the procedures to be followed agreed by the user and competent person. The work should comply with relevant design standards. On completion, the competent person should carry out a design verification of the repair and certify the vessel or tank as fit-for-purpose for continued use within specified safe operating conditions. This would normally involve a hydrostatic test as part of the verification process. The implications of the repair or modification for the future scheme of examination should also be considered.

86 Full documentation of all modifications should be retained with the records for the tank or vessel, including full technical details of the materials, techniques, drawings, test certificates and details of the person who approved the repair/ modification method.

Change of use/second-hand tanks

Change of use

87 During the life of a tank or vessel, the user may wish to hold substances outside the original specified duty. The type of liner or grade of resin dictates the corrosion resistance and, if the use of the vessel is changed in any way, then the user and competent person must be satisfied that the construction material and design are suitable for the new duty.

88 Any change of use should be properly managed. You should consider factors such as the compatibility of any new substance, or a new concentration of an existing substance, with the GRP and any liner. Calculations may also be needed to verify the fill level, making allowance for any increase in the weight of the contents.

89 If the original content permeates into the liner material, it could create a compatibility issue and may adversely affect corrosion resistance to the new substance. The manufacturer's literature should be checked and/or the designer or manufacturer contacted to ensure suitability for the new substances.

90 Any departure from original design conditions must be preceded by an examination by the competent person. The competent person must confirm with the manufacturer and the operator that the unit is safe to use under the new conditions.

Second-hand tanks

91 All second-hand (and pre-used) GRP vessels and tanks will be in a changed mechanical state from their as-new condition as a result of prior use. It is not possible to verify how the stresses and strains of transportation may affect the item, in particular if transported in an orientation other than that in which it had been previously operated.

92 Second-hand GRP tanks and vessels should not be purchased (or pre-used tanks relocated) for use on pressurised duty or for the storage of hazardous fluids, as it is not possible to verify the integrity of such items in the proposed new environment.

93 Users who wish to purchase second-hand tanks or vessels (or relocate and reuse existing tanks or vessels) for use on non-hazardous duties should satisfy themselves that the consequences of failure are taken into account when deciding whether to use such items. The dutyholder must ensure that measures are taken to manage the potentially high risk of catastrophic failure, to prevent harm to people or the environment. This would include verification of fitness-for-purpose in principle, based on design data, equipment history, compatibility assessment etc, and having suitable measures in place to ensure that consequences are mitigated in the event of a catastrophic failure.

Appendix 1 Extract from BS 4994:1987

Information to be supplied by the purchaser

The following information shall be supplied by the purchaser and shall be fully documented. Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with this standard can be made.

Process conditions

1 Materials to be handled (names, concentrations, and relative densities) including likely impurities or contaminants
2 Design pressure (or vacuum) including test requirements and design temperature
3 Operating pressure (or vacuum) and temperature
4 Mode of operation, eg process cycling conditions
5 Any abrasion or erosion problems which may be encountered

Site conditions

1 Nature of ambient atmosphere including any extremes of temperature
2 Superimposed loads, eg wind, snow and associated pipework
3 Loads imposed by personnel during erection and operation
4 In the case of buried vessels and tanks, soil conditions and expected loading, eg traffic
5 Seismic loading

Special conditions

1 Boiling out
2 Vibration due to adjacent plant
3 Agitation details
4 Danger of mechanical impact and damage
5 Loads imposed during transport
6 Finish, eg if fire-resisting

Requirements to be agreed and documented

The following items to be agreed between the purchaser, or the Inspecting Authority, where appropriate, and the manufacturer shall be fully documented. Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with this standard can be made and verified.

(a) Resin system to be used

(b) Use of reinforcing material other than those complying with BS 3396, BS 3496, BS 3691 or BS 3749 as appropriate

(c) Mechanical properties of materials

(d) Type of chemical barrier to be used

(e) Where a thermoset lining is used on tanks and vessels which are constructed in accordance with categories I and II, whether it is permissible to reduce the backing layer

(f) Design details
   1 Essential dimensions, including tolerances, preferably on a drawing
   2 Design calculations with references
   3 Nominal thickness, including tolerance, of corrosion-resisting lining (gel coat or thermoplastics) which does not contribute to strength
   4 Form(s) of reinforcement including type, number and arrangement of individual layers
   5 Form(s) of local stiffening, where used
   6 Details of welds in thermoplastic linings
   7 Bolting and flange materials and details
   8 Gasket materials and details
   9 Details of external finish, including steelwork
   10 Requirements for access and inspection openings

(g) Where the design incorporates reinforcement with directional properties, the orientation of the fibres

(h) Lining and laminate system to be employed

(i) Supports

(j) Any modification to the approved design

(k) Where site fabrication is employed, the special procedures to be adopted

(l) Repair of laminate defects and methods of repair

(m) Whether hot plate welding is to be used

(n) Circumferential tolerance

Cylindrical shells

Diameter	Tolerance
<600 mm	5 mm
>600 mm	0.25%

(o) Arrangements for access to the manufacturer's premises

(p) The provision of special test laminates and the extent of mechanical testing to be carried out either on cut-outs or prepared laminates

(q) If the prototype tests are not to be witnessed by the purchaser, and the Inspecting Authority, where applicable

(r) The nature of prototype tests, the hydraulic test pressure if it is higher than the design pressure and the limits of cyclic variations to determine fatigue strength

Appendix 2 Inspection and tests

(BS EN 13121-4:2005 p7)

After completion of installation, the tank or vessel shall be inspected and tested, as required in the operating instructions given by the manufacturer of tank or vessel, and shall include as a minimum:

(a) Visual inspections, shall indicate the general state of the tank or vessel, the state of the wall material, nozzles, connections and joints. Subject of inspections shall be the outer surfaces, and, for reasons of impact damage or abrasion, the inner surfaces. Visual inspections shall be performed before and after hydraulic or pressure test.

(b) Hydrostatic or pressure tests, tests on safety or on operational devices and spark testing of lining seams.

Conditions and results of inspections and tests shall be recorded.

References

1 *Pressure Equipment Regulations 1999* SI 1999/2001 The Stationery Office 1999 ISBN 978 0 11 082790 2

2 BS 4994:1987 *Specification for design and construction of vessels and tanks in reinforced plastic* British Standards Institution

3 BS EN 976-1:1997 *Underground storage tanks of glass-reinforced plastics (GRP). Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels. Requirements and test methods for single wall tanks* British Standards Institution

4 BS EN 976-2:1997 *Underground tanks of glass-reinforced plastics (GRP). Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels. Transport, handling, storage and installation of single wall tanks* British Standards Institution

5 BS EN 977:1998 *Underground tanks of glass-reinforced plastics (GRP). Method for one side exposure to fluid* British Standards Institution

6 BS EN 978:1997 *Underground tanks of glass-reinforced plastics (GRP). Determination of factor* α *and factor* β British Standards Institution

7 *Health and Safety at Work etc Act 1974 (c.37)* The Stationery Office 1974 ISBN 978 0 10 543774 1

8 *Safe use of work equipment. Provision and Use of Work Equipment Regulations 1998. Approved Code of Practice and guidance* L22 (Third edition) HSE Books 2008 ISBN 978 0 7176 6295 1

9 *Safety of pressure systems. Pressure Systems Safety Regulations 2000. Approved Code of Practice* L122 HSE Books 2000 ISBN 978 0 7176 1767 8

10 *A guide to the Control of Major Accident Hazards Regulations 1999 (as amended). Guidance on Regulations* L111 HSE Books 2006 ISBN 978 0 7176 6175 6
(Operators must take all measures necessary to prevent a loss of containment that could lead to a major accident hazard.)

11 *Storage of dangerous substances. Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice* and guidance L135 HSE Books 2003 ISBN 978 0 7176 2200 9

12 *Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice, Regulations and guidance* L101 HSE Books 2009 ISBN 978 0 7176 6233 3
(Of relevance to inspection, maintenance and repair activities.)

13 *Safe use of lifting equipment. Lifting Operations and Lifting Equipment Regulations 1998. Approved Code of Practice and guidance* L113 HSE Books 1998 ISBN 978 0 7176 1628 2
(Of relevance to all activities involving lifting equipment, eg during installation, inspection involving confined entry, maintenance and repair work.)

14 *Guidance on permit-to-work systems: A guide for the petroleum, chemical and allied industries* HSG250 HSE Books 2005 ISBN 978 0 7176 2943 5

Other relevant design standards

BS EN 13923:2005 *Filament-wound FRP pressure vessels. Materials, design, manufacturing and testing* British Standards Institution

BS EN 13121-3:2008 *GRP tanks and vessels for use above ground. Design and workmanship* British Standards Institution

BS EN 13121-1:2003 *GRP tanks and vessels for use above ground. Raw materials. Specification conditions and acceptance conditions* British Standards Institution

BS EN 13121-2:2003 *GRP tanks and vessels for use above ground. Composite materials. Chemical resistance* British Standards Institution

BS EN 13121-4:2005 *GRP tanks and vessels for use above ground. Delivery, installation and maintenance* British Standards Institution

Further reading

HSE website www.hse.gov.uk/comah

Approved Codes of Practice

Management of health and safety at work. Management of Health and Safety at Work Regulations 1999. Approved Code of Practice and guidance L21 (Second edition) HSE Books 2000 ISBN 978 0 7176 2488 1
(Work activities associated with integrity management where a risk assessment would be required include tank/vessel installation, maintenance, operation, inspection and repair activities. Risk assessment enables hazards to be identified and appropriate preventive and protective measures introduced.)

Unloading petrol from road tankers. Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance L133 HSE Books 2003 ISBN 978 0 7176 2197 2

Design of plant, equipment and workplaces. Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance L134 HSE Books 2003 ISBN 978 0 7176 2199 6
(Offers advice on meeting the requirements of regulations 5 and 6 to assess the risks from places where dangerous substances are stored and required control and mitigation measures.)

Managing health and safety in construction. Construction (Design and Management) Regulations 2007. Approved Code of Practice L144 HSE Books 2007 ISBN 978 0 7176 6223 4
(Applicable during the early stages of the life cycle from design through to installation and commissioning.)

Free leaflets

Pressure systems: Safety and you Leaflet INDG261(rev1) HSE Books 2001 (single copy free or priced packs of 15 ISBN 978 0 7176 1562 9) www.hse.gov.uk/pubns/indg261.pdf

Leadership for the major hazard industries Leaflet INDG277(rev1) HSE Books 2004 (single copy free or priced packs of 15 ISBN 978 0 7176 2905 3) www.hse.gov.uk/pubns/indg277.pdf

Integrity of atmospheric storage tanks SPC/Tech/Gen/35 HSE www.hse.gov.uk/foi/internalops/hid/spc/spctg35.htm

Glossary

Common terms used in this document are as follows:

Competent person a person having such theoretical and practical knowledge and actual experience of inspection that would enable them to detect defects or weaknesses, and to assess their importance in relation to the design of a GRP vessel, tank or scrubber.

Flammable liquid a liquid with a flashpoint of 55°C or below. This does not include liquids which, when tested at 55°C in the manner described in Schedule 2 of the Highly Flammable Liquids and Liquified Petroleum Gases Regulations 1972, do not support combustion and which have a flashpoint of ≥21°C and ≤55°C.

Glass reinforced plastic (GRP) a laminate consisting of a synthetic resin system – usually polyester, epoxy, furane, vinyl ester – reinforced with glass fibres or other fibres. GRP is used interchangeably with the more generic FRP (fibre reinforced plastic) term. GRP can be manufactured by:

- the wet lay up process, ie by applying laminates in position on a former prior to cure;
- machine controlled filament winding for cylindrical forms; or
- spray application of chopped glass and resin.

Liner non-structural component – usually thermoplastic material – in contact with the process liquid.

Maximum allowable pressure the maximum pressure for which the equipment is designed, as specified by the manufacturer.

Notified body 'notified bodies' are appointed by EU member states either in the approval and monitoring of the manufacturer's quality system or in direct product inspection. Notified bodies are only required for equipment manufactured in accordance with Category II, III and IV of the Pressure Equipment Regulations 1999.

Pipework pipe fittings up to the first isolation valve.

Relevant fluid as defined within the Pressure Systems Safety Regulations 2000: steam at any pressure; or any fluid or mixture of fluids at a pressure greater than 0.5 bar above atmospheric pressure, **and** which is a gas or liquid with a vapour pressure greater than 0.5 bar above atmospheric pressure when in equilibrium with its vapour at the actual temperature of the liquid or 17°C; or a gas dissolved under pressure in a solvent contained in a porous substance at ambient temperature and which could be released from the solvent without the application of heat.

Scrubber a fume cleaning apparatus normally with liquid reservoir at the base.

Tank a container for the storage of liquids subject only to its own hydrostatic head and freely vented to atmosphere.

Vessel a closed container subject to applied pressure or vacuum, with or without hydrostatic head.

Written scheme of examination (WSE) where PSSR 2000 applies the content of the WSE is defined in regulation 8 and in the associated ACOP (L122). In circumstances where PSSR 2000 does not apply, the required documented scheme of examination should meet this benchmark standard.

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Further information

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This document is available at: www.hse.gov.uk/pubns/guidance/pm75.pdf.