High temperature textile dyeing machines

Guidance Note PM4

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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.

Contents

Introduction

1 Each year there are accidents and dangerous occurrences causing serious and sometimes fatal injuries to operators of high temperature dyeing machines, as well as damage to plant.

2 For the purposes of this guidance note a high temperature dyeing machine is one that operates at temperatures above 100°C and pressures above atmospheric.

3 Dye vessels containing steam or hot water above 0.5 barg pressure (ie over 110°C) will be subject to the Pressure Systems and Transportable Gas Containers Regulations 1989 (PSR).[1-5] The Regulations are designed to reduce the risk of serious injury caused by the unintentional release of stored energy within a pressure vessel and to reduce the risk of scalding from steam.

4 This guidance note is issued by the Health and Safety Executive (HSE) and aimed at suppliers, operators, and those concerned with maintenance and thorough examination of high temperature dyeing machines. It draws attention to various hazards and describes ways in which those hazards can be reduced or eliminated.

Dangers

5 The majority of accidents at dyeing machines are caused by explosions or scalding. For example:

(a) Pressure vessels or components such as opening covers have failed while under pressure, due to mechanical failure or faulty closing.
(b) Vessels have failed during bleaching operations using hydrogen peroxide (H_2O_2). Decomposition of H_2O_2 has led to the rapid evolution of oxygen which has been beyond the capacity of the relief devices, causing the vessel to fail catastrophically.
(c) Operators may be engulfed with steam, boiling liquid, or hot water, when:
    (i) the temperature of dyeing liquor is above or about 100°C and a lid or sample chamber is opened, allowing liquor to flash violently into steam and erupt from the vessel;
    (ii) doors are opened and hot liquor allowed to spill out, eg from horizontal vessels not completely drained or vertical vessels filled above cover-flange level;
    (iii) one of a bank of machines is inadvertently pressurised from an adjacent machine, via a common blow-down or drain line.

Design safeguards

Integrity of the vessel

6 Designers, manufacturers, importers and suppliers of high temperature dyeing machines have a duty under the PSR to prevent danger by ensuring that every pressure vessel is properly designed and constructed to provide an adequate margin of safety for the duty it has to perform. The use of appropriate standards such as British Standard BS 5500: 1994 *Specification for unfired fusion welded pressure vessels*[6] is recommended. The vessel should:

(a) be properly constructed from suitable material;
(b) permit access to conduct examinations for preventing danger (eg non-destructive testing of welds);
(c) have marked on it the safe working pressure and corresponding temperature;
(d) have a correct pressure gauge;
(e) have a suitable safety device (safety valve and or bursting disc) having such capacity and being so adjusted as to prevent the vessel from being over-pressurised. (A safety device fitted to a vessel designed for dyeing may not have sufficient capacity for bleaching with hydrogen peroxide - see paragraphs 36 to 38.);
(f) have its supply pipe fitted with a suitable reducing valve, or other suitable automatic device, to prevent the safe working pressure being exceeded if pressure is supplied from an outside source, eg steam or air at pressure greater than the safe working pressure of the vessel.

Multi-bolted doors

7 An operator is unlikely to release all bolts on a multi-bolted door under full pressure without being warned of danger by a gradual leakage of steam or liquid during the slackening of the bolts. However, when the vessel is under slight or residual pressure, there is a danger of doors sticking after all the bolts have been removed and the door then being violently blown open when freed. To facilitate the safe release of any residual pressure, the door should be fitted with a device to either break the seal or to restrain the door from opening more than 3 mm. Typically, a swing bolt may be fitted opposite the hinge in which its trapped nut is restrained by the door housing until the seal is broken and the door is cracked opened by 3 mm.

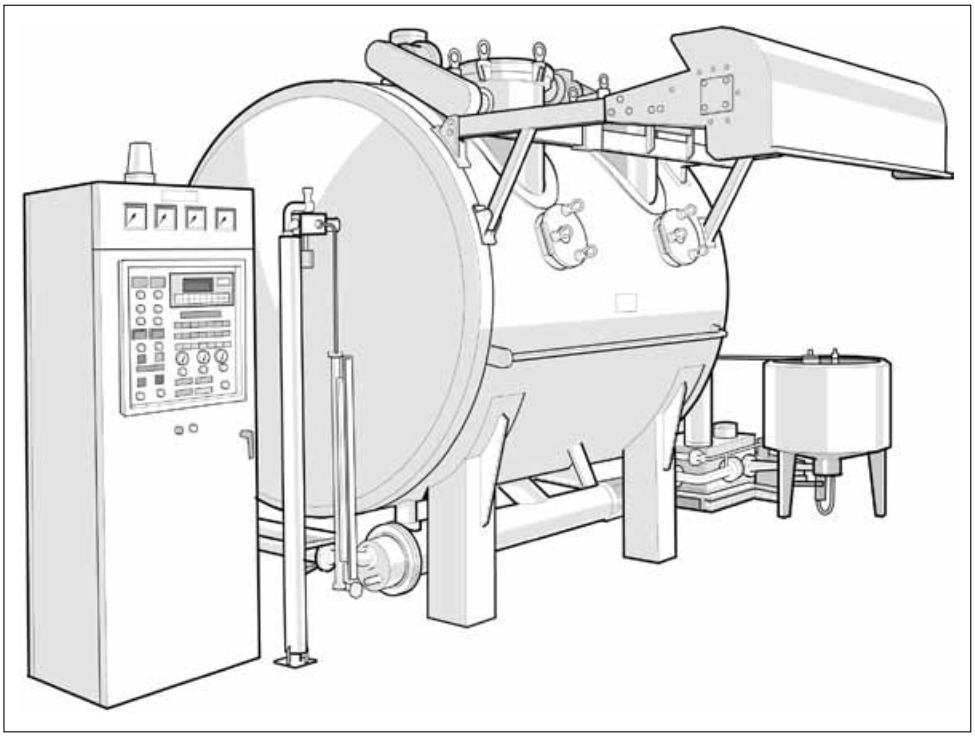

Figure 1 High temperature dyer for fabric with multi-bolted doors

Quick-opening doors (other than multi-bolted doors)

8 Pressure vessel doors of the quick-opening type should be fitted with the following devices.

(a) An interlock between the door-locking mechanism and the pressurising system, eg

(i) If pressure is applied by steam, liquid, air or other gases, the inlet valve should be interlocked with the door-locking mechanism in such a manner as to prevent the valve being opened to pressurise the vessel until the door is fully closed and locked.
(ii) If the pressure is applied by boiling the liquor until steam is formed, then there should be an interlock which prevents heat being applied until the door is fully closed and locked. The interlock should also ensure that the source of heat is turned off before the door can be unlocked.
(iii) If the vessel is pressurised by an external pump then there should be an interlock which prevents the pump from applying pressure until the door is fully closed and locked. The interlock should also ensure that the pump is switched off before the door can be unlocked.

(b) An interlock between the door-locking mechanism and the main vent, arranged so that the vent must be open before the door can be unlocked (but it can be closed once the door is clear of the seal). Note: It is sometimes necessary to carry out non-pressurised or low temperature dyeing with the door of the vessel open but it should not be possible to commence a high temperature dyeing cycle with the door partially closed.
(c) A test-cock, unless the main vent outlet is clearly visible to the operative at the vessel door. The test-cock should be situated at a level below the vessel door and so interlocked that it has to be opened before the door can be unlocked. The test-cock should give audible or visual indication as to whether the vessel is still pressurised or has hot liquid above the door level. The bore of the test-cock should be large enough to avoid blockage, typically at least 12 mm.

(d) A restraint, to hold the door after it has been unlocked and to prevent it opening violently by any residual pressure remaining in the vessel not indicated either by the test-cock or pressure gauge, eg a catch which has to be opened independently after the door has been unlocked and which may not be released until the door has been unlocked and cracked open. Alternatively, a hydraulic or pneumatic damper or ram, designed to act as an effective restraint to the door movement, may be used.

(e) A temperature sensitive interlock, to prevent the door being opened while the temperature of the liquor inside the vessel exceeds 80°C. The temperature sensing probe of such an interlock should be located in a position so that it normally registers the highest temperature in the system. The device should fail-safe, ie if the interlock is not in place, then the temperature may not exceed 80°C. Where the normal flow of liquor is disrupted or distorted, eg by failure of pump or motor, or by jamming of valves or entanglement of fabric, then extreme care is necessary to ensure that the whole of the machine and its contents are cooled to a safe temperature before the vessel is opened.

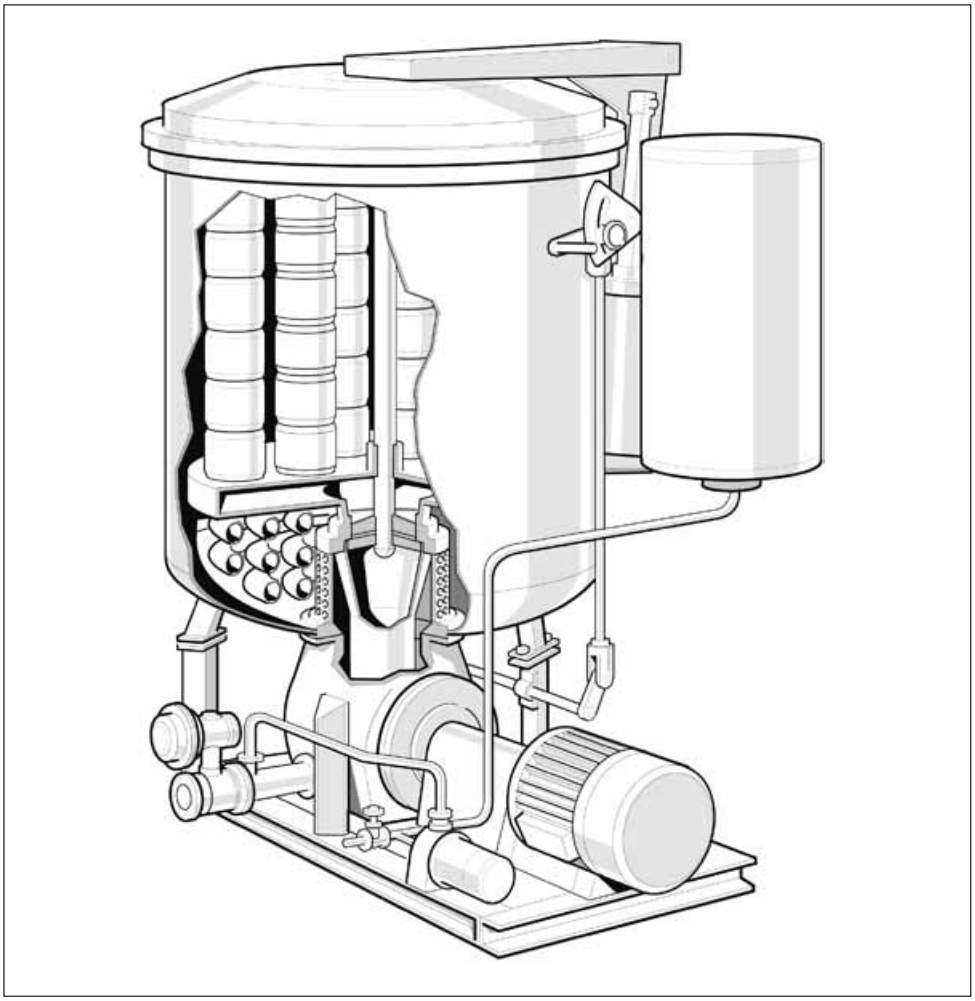

Figure 2 Vertical cylindrical high temperature dyeing machine for yarn packages, with quick opening door

Interlocks

9 While it is preferable for interlocking systems on dyeing machines to be simple and mechanical in operation, it is sometimes impracticable to achieve this. An interlocking key system is often appropriate, eg on sampling devices.

10 All interlocking systems, whether mechanically, electrically, pneumatically or hydraulically operated, should fail-safe in their mode of operation.

11 When safety depends upon electrical systems, and no other back-up safety devices are provided, integrity can be improved by fitting two limit switches designed to operate in opposite modes. Where electrical interlocks are used for safety purposes the circuit should be completely independent of any other system. Advice on the application of electrical limit switches is given in BS EN 1088:1996[7] and BS 5304:1988.[8] Limit switches mounted on a high temperature dyeing machine operate in an adverse environment of heat and moisture. To prevent moisture getting in, it is recommended that switches fitted have enclosures that achieve a minimum rating of IP 55 as defined in BS EN 60529: 1992 *Specification for degrees of protection provided by enclosures*.[9]

Sampling device

12 Numerous accidents have occurred while operators have been taking samples from pressurised dyeing machines. There are several different methods of sampling but any sampling device should be interlocked to ensure that the sampling pot or device is depressurised (open to drain) before it can be opened to remove the sample. It is important that designers carefully consider the sampling mechanism to prevent foreseeable mistaken actions by operators taking samples.

13 Over recent years programmable controllers have been fitted to high temperature dyeing machines to reduce costs and ensure consistent quality. With many dye-houses aiming to achieve a one stop dye process, new machines fitted with programmable controllers are often supplied without a sampling device and the machine must be stopped in mid-cycle and the main lid opened. In such situations the door interlocks (see paragraphs 7-11) should ensure that the liquor is cooled and any pressure within the vessel is relieved prior to sampling.

Installation and modification

14 Installers should ensure that the method of installation does not give rise to danger. Hot work, such as cutting or welding, which may affect mechanical integrity should not be carried out without the agreement of a competent person. It is good practice to ensure that pipework and fittings do not obscure pressure gauges and manufacturer's markings or obstruct parts of the dyeing machine where access is required for examination.

15 When machines are interconnected via a common drain or blow-down line, it is recommended that a non-return valve and an isolating valve are fitted in each line. This is to prevent the possibility of steam and hot water being transferred from one dyeing machine to another in which personnel may be working, for example during maintenance. Useful advice is given in HSE Guidance Note PM 60 *Steam boiler blow-down systems*.[10]

16 A competent person should be consulted before work begins on any modifications or repairs that may affect the vessel integrity or the operation of any protective devices.

Information provided by the supplier

17 Suppliers have a duty to provide sufficient written information to enable the user to operate the equipment safely. Typically, this information would include the maximum permissible working pressure and temperature.

18 Suppliers also have a duty to provide sufficient information concerning the design, construction, examination, operation, and maintenance of the plant to

assist the user to prepare a written scheme of examination under PSR. It is helpful for the manufacturer to provide a sample written scheme of examination as they will know how the equipment is designed to operate, its anticipated life, and the initial frequency of examination.

Operations

19 In addition to structural failures, it is important to remember that human failures can lead to accidents. So often and frequently after long association with a process, even the best trained operators can become complacent and prone to error. It is therefore essential that all operators are adequately trained and supervised. The PSR require users to establish the safe operating limits, and to ensure that the equipment is operated within them. The manufacturer's instructions or advice on operation should be made readily available to operators and should be followed strictly.

20 Operating personnel should be sure that vessels are completely vented before attempts are made to open lids or doors, and they should be made aware of the dangers of bypassing safety devices and of using extensions to handles of door-opening mechanisms. They should also be familiar with the functions and operations of various controls and safety devices used with the unit and should report at once any malfunction or damaged components. Management are advised to keep records of reported malfunctions so that they can identify trends and take appropriate remedial action.

21 At jet dyeing machines in particular, attempts at unblocking tangled fabric may release pockets of liquor which can be at a higher temperature than is measured by the temperature sensing probe and this may flash into steam when released. It is therefore vital that correct procedures are followed and these should be set out in a safe system of work, which may include the use of suitable protective clothing and face shields.

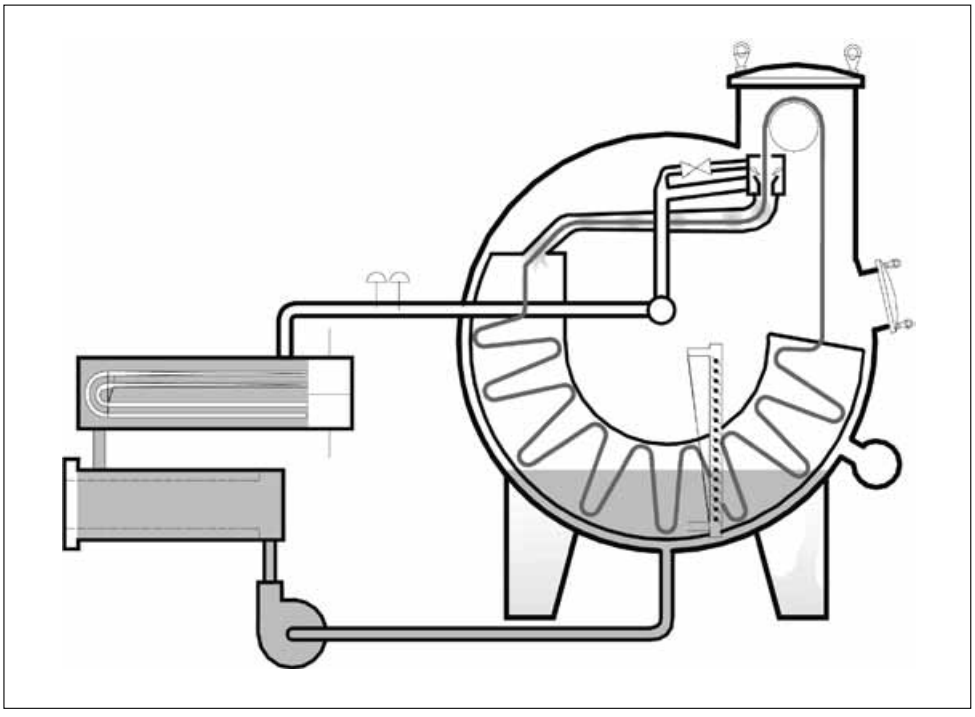

Figure 3 Schematic of high temperature dyer for fabric

Maintenance

Lids and doors

22 It is recommended that a preventative maintenance scheme be employed to make sure there are no faults or missing parts on the door mechanisms and that the various controls or safety devices are functioning correctly. Where limit switches are used in the door opening interlock circuits it is important that the mechanical operation of the switches is regularly tested in addition to any electrical test carried out during routine maintenance. Accidents have occurred due to switches coming loose on their mountings, through wear on the rollers and cams, and incorrect positioning so that the switch contacts open after the door has been cracked open. Any faults or defects should be reported to a responsible person and remedied before the vessel is re-used.

23 It is recommended that the bearing surfaces of the door locking devices be regularly checked. If cracks or other defects are suspected in the vessel or door operating mechanism, the vessel should be taken out of use and a competent person consulted immediately to determine whether the integrity of the vessel has been compromised. Repairs should be carried out in accordance with paragraph 16.

24 When a door-locking mechanism is designed to permit release in two stages, it is most important for the gap between the cover and the seal to be sufficiently wide to ensure pressure equilibrium (generally at least 3 mm). This gap should not be reduced by the use of new seals. The correct joint size should, therefore, be established and only replacement seals recommended by the manufacturer used. Two stage doors should never be modified to give single stage opening.

Operating procedure

25 Before every dye cycle, it is good practice to check the door-locking mechanism in both the open and closed positions to ensure that engagement of the locking device is even and complete over the entire circumference, and that the door locates correctly each time it is closed.

26 After loading the vessel and before it is closed, all dirt and spillage should be cleaned from the locking parts of the door and the joint examined to confirm it is properly seated in the groove.

27 The door safety devices should never be forced into position. Any resistance to closing or locking should be investigated immediately, and rectified before the machine is put into use. Care should be taken that the locking rings of doors do not bind during rotation, otherwise the point of friction can become a fulcrum leading to high stresses which can cause failure.

Vents and pressure relief devices

28 It is important that vent devices are designed so that proof of clearway can be established before covers are opened. It is preferable that discharge outlets are visible to operating personnel, and are led to a safe place.

29 An effective maintenance regime will ensure that the safety valves are in good order and that they operate at the set pressure. Where loose stock is dyed, fibres may accumulate in the relief valve or its associated pipework which would impede

efficient venting. Users are advised to check, and where necessary clean, the safety valve at regular intervals. The examination and setting of the safety valve should be included in the written scheme of examination. It is important to test pressure gauges regularly.

Common drain and blow-down lines

30 If a blow-down pit or muffler system is installed it is important that it is inspected frequently to verify that the drain system is not blocked due to deterioration and/or sludge.

31 Maintenance staff have been injured when adjacent machines have vented into a common pit. Venting can occur during the normal dye cycle or if a drain valve is unintentionally opened. It is recommended a safe system of work is employed that includes the isolation of the machine being worked on.

Thorough examination

32 The PSR require the user of a high temperature dyeing machine to ensure that a written scheme of examination is drawn up, certified as suitable by a competent person, and that the vessel is examined in accordance with the written scheme. The written scheme of examination should specify the nature and frequency of the examinations necessary to prevent danger and should take account of known failure mechanisms such as corrosion, erosion, and fatigue. It should be reviewed over time to reflect changes in operating conditions and any deterioration detected on previous examinations. Advice on the preparation of a written scheme of examination can be sought from the manufacturer or supplier (see paragraphs 17 and 18).

33 Users have a duty under the PSR to keep records of previous reports of examination and any documents that will assist the competent person to assess whether the vessel is fit for further operation. It is recommended that records be kept of all maintenance and remedial work carried out. Records for each individual dyeing vessel should be kept, together with entries countersigned by a responsible person.

34 Regulation 12 (protection against specified hazards) of the Provision and Use of Work Equipment Regulations 1992[11] (PUWER) concerns the requirement to prevent the unintended or premature discharge of any gas, liquid or vapour stored in work equipment such as a high temperature dyeing machine. As the correct operation of the door interlocks is crucial to preventing danger, the integrity of door interlocks should be examined periodically. Where users do not possess the necessary in-house expertise, competent specialists should be consulted.

35 A high temperature dyeing machine will not be subject to the PSR if it does not employ steam and cannot be operated above 110°C. However, to comply with their duties under PUWER, employers are advised to ensure that such vessels are examined at regular intervals by a competent person. The period between examinations should reflect the risk of injury from stored energy and scalding. Any faults revealed during the examination should be reported to a responsible person and remedied before the pressure vessel is re-used.

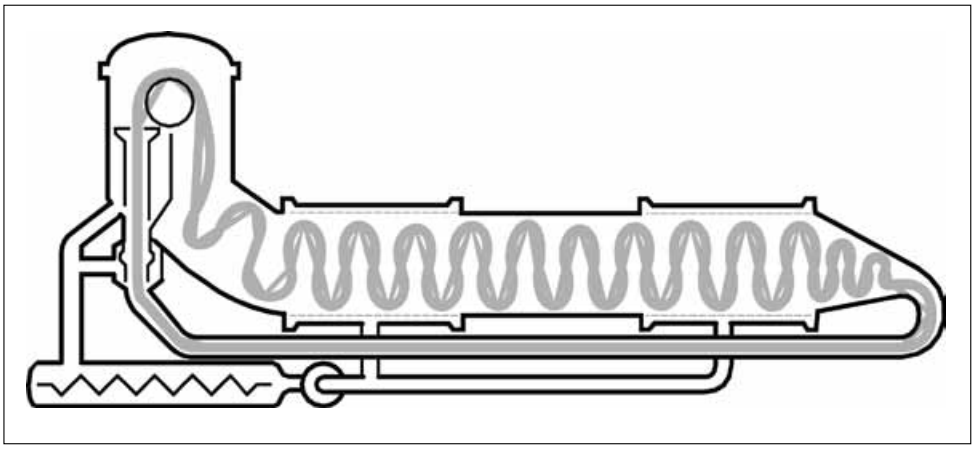

Figure 4 High temperature jet dyeing machine for fabric

Use of hydrogen peroxide (H_2O_2)

36 Hydrogen peroxide is sometimes used as a bleaching agent in textile finishing processes. If the chemical reaction during peroxide bleaching is not strictly controlled there can be a rapid evolution of oxygen caused by the decomposition of the H_2O_2. The rapidity of the reaction and the volume of oxygen produced may be beyond the capacity of the relief devices and the vessel may fail catastrophically. The vessel could also fail due to stress corrosion cracking if it was not designed or constructed for peroxide bleaching using an appropriate grade of austenitic stainless steel or other suitable material resistant to attack. Further advice on the explosion risks at pressure vessels used for bleaching with hydrogen peroxide is given in HSE Information Document HSE 764/3.[12]

Design

37 To reduce the risk of explosion, it is recommended that the concentration of the bleaching liquor, normally expressed in millilitres/litre (ml/l) or grammes/litre (g/l) does not exceed 14 ml of 35% H_2O_2 per litre of liquor (16 g/l). At that concentration the pressure vessel heating system should limit the rate of temperature rise to a maximum of 6°C/min. If a higher concentration is required a separate assessment should be carried out as to the stability of the peroxide and the capacity of the pressure relief system. It is strongly recommended that the user seek advice from the peroxide supplier.

38 The relief devices should be properly sized for a discharge capacity based on the maximum foreseeable concentration of peroxide, and they should ensure that the design pressure cannot be exceeded by more than 10%. The relief devices should also be sized for two phase flow conditions, and vent to a safe place.

Operations

39 Users are advised to implement procedures to define the various recipes and conditions under which bleaching takes place to ensure that the maximum concentration of the dosing solution is not exceeded.

40 Peroxide bleaching solution must always be diluted before it is transferred to the vessel. A temperature interlock should be provided so that the bleaching solution cannot be transferred to the pressure vessel if the temperature of the solution exceeds 45°C.

41 A safe method of controlling the concentration of hydrogen peroxide is to install a volumetric tank before the additions tank of the dyeing machine. The volumetric tank should be sized at the maximum safe volume of hydrogen peroxide that the vessel can accept and be fitted with an overflow pipe. Before the line connecting the additions tank to the vessel can be opened, the feed to the additions tank has to be isolated to prevent further peroxide flow.

42 Operators should be aware of the hazards of peroxide bleaching and be properly trained to carry out the process in safety.

Maintenance

43 When using hydrogen peroxide it is vital to have an effective maintenance system for checking and cleaning of the pressure relief systems (see paragraph 29)

Thorough examination

44 The written scheme of examination should refer to the intended use of the vessel and the suitability of the vessel and its protective devices for use with hydrogen peroxide. Reports of examinations under the written scheme should also refer to the vessel's use and whether or not it is fit for the purpose.

References

1 *The Pressure Systems and Transportable Gas Containers Regulations 1989* Statutory Instrument 1989 No 2169 HMSO ISBN 0 11 098169 3

2 *Safety of pressure systems. Pressure Systems and Transportable Gas Containers Regulations 1989. Approved Code of Practice* COP 37 HSE Books 1990 ISBN 0 11 885514 X

3 *A guide to the Pressure Systems and Transportable Gas Containers Regulations 1989* HS(R)30 HSE Books 1990 ISBN 0 7176 0489 6

4 *Introducing competent persons: Pressure Systems and Transportable Gas Containers Regulations 1989* HSE leaflet IND(S)29 HSE Books. Available in priced packs ISBN 0 7176 0820 4

5 *Written schemes of examination: pressure systems* HSE leaflet IND(G)178 HSE Books

6 British Standard BS 5500: 1994 *Specification for unfired fusion welded pressure vessels*

7 British Standard BS EN 1088: 1996 *Safety of machinery - interlocking devices associated with guards. Principles for design and selection*

8 British Standard BS 5304: 1988 *Code of practice for safety of machinery*

9 British Standard BS EN 60529: 1992 *Specification for degrees of protection provided by enclosures*

10 HSE Guidance Note PM60 *Steam boiler blow-down systems* HSE Books 1987 ISBN 0 11 883949 7

11 *The Provision and Use of Work Equipment Regulations 1992* Statutory Instrument 1992 No 2932 HMSO ISBN 0 11 025849 5

12 *Explosion risk at pressure vessels used for bleaching textile materials with hydrogen peroxide* HSE Information Document HSE 764/3

13 British Standard BS EN ISO 11111: 1995 *Safety requirements for textile machinery*

The future availability and accuracy of the references listed in this publication cannot be guaranteed.

Further information

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