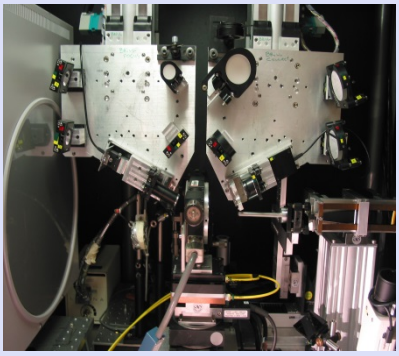

Guidance on the design, manufacture, testing and use of Pressure Vessels and Systems in Research

Key word(s):	Pressure vessels, Vacuum systems, Research, Pressure Systems Safety Regulations, safe design, competence, Responsible Person
Target audience:	Heads of Schools, Principal Investigators, Researchers, Safety Advisors

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Introduction

1. Pressure vessels are widely used in research. Vessels that are made available commercially must comply with the Pressure Equipment Regulations 1999, and have a certificate of conformity (CE kite mark). This does not mean they are automatically safe to use for any purpose, but it is an indication that the manufacturer or supplier has a technical file that satisfies certain essential safety requirements of the Supply of Machinery (Safety) Regulations 1992 and the Pressure Equipment Regulations 1999. Relevant British Standards or harmonised standards may also be quoted.

2. When in use, pressure vessels are subject to the Pressure Systems Safety Regulations 2000. They are also covered by the definition of 'work equipment', and so the Provision and Use of Work Equipment Regulations 1998 apply. Vessels that are designed or adapted 'in house' are subject to the same requirements.– before they can be brought into use at work, the designer / manufacturer (in this case, the research team) must prepare a technical file to demonstrate that the equipment complies with EU regulations and essential safety requirements. This may be an onerous task and may well require external validation. In-house design of pressure vessels, or adaptations of commercially available models, is therefore, not to be undertaken lightly.

3. This document is intended as an aide for those using and designing pressure vessels. It is not a technical document, but focuses mainly on the managerial processes that must be considered / undertaken. When working with vessels that have the potential to cause significant damage to persons and property, there is no substitute for a competent practitioner. This will usually be a chartered engineer, or someone of similar qualification, who is experienced in the type of vessel being worked on. The Department for Business, Energy & Industrial Strategy issues a list of organisations which have been appointed to be conformity assessment bodies for the purposes of the Pressure Equipment Regulations 1999.

4. Where researchers propose work for which they themselves do not have the technical expertise or experience (for example, in interdisciplinary work), great care must be exercised by them to ensure that people with the necessary skills are either brought into the research team from within the University, or that additional expertise is acquired through the use of external consultants or other means. Research proposals of this type will need to anticipate and plan for the costs of obtaining the necessary expertise.

Responsibilities

5. Head of School must ensure that all staff/students using or designing pressure systems have regard to this guidance, and in particular, that there is access to competent advice and expertise.

General principles of design and testing

6. The key to safe design is a proactive approach to accident (failure) prevention through competent risk assessment, and with the development of control features that provide continuing protection for all those potentially at risk. The design process is an opportunity to address hazards before they manifest themselves during manufacture, testing or use, and is therefore a critical tool for preventing failure of the vessel, potentially resulting in serious injury or even death. The importance of safe design therefore cannot be over-emphasised.

7. It may be helpful to work through the following steps:

   - Identify the significant health and safety hazards likely to be associated with the design, construction, use and maintenance.
   - Consider the risk from those hazards.
   - Where possible, alter the design to avoid or eliminate the hazard altogether, or where this is not reasonably practicable, reduce it at source. If the hazard cannot be reduced at source, look at other ways to control the risk, e.g. mitigating the effects of the hazard.

8. It follows therefore that design must be carried out by those who are 'competent' i.e. those who can envisage and assess modes of failure, including those arising from human behaviour, in a comprehensive manner. The design will be assessed in accordance with a defined formal method of risk quantification, so that steps can be taken, through amending the design, to eliminate or at least adequately control the risks of failure.

9. There is no formal definition of the terms 'competence' or 'competent person' in health and safety legislation. Nevertheless, the HSE guidance defines a competent person as: a person or group of people who have the necessary combination of formal technical qualification(s), experience, aptitude, familiarity and skill, with good practice, an understanding of hazard and risk, some knowledge of legal requirements, and an awareness of their own limitations.

   For designing or adapting pressure vessels, a chartered mechanical engineer with experience in the relevant field under investigation could provide advice and support.

10. The management structure of the designer or design team must be clearly stated and understood by all those involved. The Responsible Person will usually be the academic in charge (Principal Investigator) and they must be able to assure themselves any delegated persons are also competent to carry out the work allocated to them.

11. Any system which must be operated or inspected by competent should be robust in that critical features of design are checked by others who are competent and preferably independent of the activity. For example, a colleague who is not directly involved in the research or teaching activity, an Insurance Assessor, an External Consultancy, or a full member of the Institution of Mechanical Engineers, etc.

12. The design should take into account the properties of the substance(s) likely to be in contact with the system, and their predicted effects on all components. The full range of operating conditions of temperature and pressure should also be considered.

13. Following design and validation, the responsible person should ensure that a written risk assessment is prepared for all aspects of work under the control of the University, including the vessel's fabrication, assembly and testing.

14. Pressure testing should be carried out in accordance with HSE guidance, which differentiates between:

    - Proof pressure testing: a test of the vessel and system integrity, carried out hydraulically. Pressure is increased gradually and strains monitored until the specified test pressure is reached and held, or until there are any indications of yielding or failure. Adequate shielding may be required to protect operators. The test pressure may exceed the design safe working pressure, e.g. by up to 10%.
    - Leak testing: is a test normally carried out at low pressure (e.g. not exceeding 10% of the design pressure, unless the assembly has been subject to integrity tests). HSE guidance strongly advocates the use of hydraulic testing wherever practicable. If pneumatic testing is carried out, other means of reducing the stored energy should be considered e.g. reducing the internal volume, isolating sections and testing separately, followed by re-assembly and leak testing.

15. Any pressure system must have suitable protective devices (pressure relieving or pressure limiting devices, designed and installed so that the system cannot develop more than the safe operating limit.

Where these vent the contents of the vessel or system, the design must allow for this to be done safely, i.e. to a place where people will not be exposed to the released pressurised fluid.

16. A signed copy of the risk assessment must be sent to the relevant School Safety Advisor for their records. The risk assessment must be reviewed in the light of any changes made during the preparation and testing of the vessel.

    Note: the School Safety Advisor is not responsible for the competency of the design or risk assessment, but will check that those preparing the documents and involved in the fabrication have appropriate qualifications and experience, and where possible, that the appropriate British Standards or other guidance have been selected and used.

17. Proposals for research funding must proceed with a signed statement from the Head of School that a preliminary risk assessment has been completed. The purpose of this requirement in the context of pressure vessels is to identify any capital funds required to acquire or design and build a suitable vessel and associated systems in accordance with the legal requirements.

Use of pressure vessels

18. The person responsible for the safe use of any pressure system is the senior academic in charge of the research project who may delegate day-to-day arrangements to others who are competent to carry out those tasks, but will still retain overall responsibility.

19. The use of any pressure system, including pressure vessels, must comply with the Pressure System Safety Regulations 2000. Even where there are specific exemptions from certain regulations, the principles usually have to be complied with as far as it is reasonable to do so in the circumstances. The HSE have published an Approved Code of Practice and guidance on these regulations which provide authoritative information on how to comply with the regulations.

20. These Regulations contain a set of duties on employers and people who design, manufacture, import, supply and use pressure systems. The Regulations can be viewed at http://www.legislation.gov.uk/uksi/2000/128/contents/made

21. The Approved Code of Practice can be viewed via OHSIS in the Library's Electronic Databases or HSE website. See Appendix 1 for a summary of the requirements – note that this summary is an aide memoire, and no substitute for the detail of the regulations and ACOP.

22. Appendix 2 includes a flow diagram to help users understand which regulations apply to their own systems.

23. All users of any pressure system will need to include the risk of uncontrolled release of pressure and the pressure system contents in their risk assessments. The Regulations are concerned with reasonably foreseeable danger to people from the unintentional release of stored energy. In addition, they deal with the scalding effects of steam which is classed as a relevant fluid at any pressure.

24. Where substances contained in the pressure system are considered to be hazardous to health, explosive or flammable, users will need to complete COSHH and/or DSEAR risk assessments.

25. The pressure system must be operated within its design parameters. If the activity calls for operating conditions beyond the design parameters, the risk assessment must be completely revised by a competent person, taking into account the changed operating requirements, any alterations or adaptations to the system, and all other relevant factors. All adaptations or alterations must be completed and tested, before the system is used for the different operating conditions.

26. Standard operating procedures must be drawn up and made known to all those using the equipment and should cover the full range of operational variables.

Purchase of pressure vessels

27. The Pressure Equipment Directive (PED) 97/23/EC was implemented in the UK by the Pressure Equipment Regulations 1991. These Regulations came into force in November 1999 with a transitional period up to 29 May 2002. During the transitional period, manufacturers of pressure equipment could use existing national standards. From May 2002 all pressure equipment for sale above that operates above 0.5 Bar must comply with the Regulations (with some exceptions). This means that the vessels must be safe, meet essential safety requirements covering design, manufacturing and testing, satisfy appropriate conformity assessment procedures and carry the CE mark and other information such as serial number, maximum working pressure etc. This duty lies with the manufacturer/supplier and will, in most cases, require the involvement of a ‘Notified Body’ with obvious cost implications.

28. If a pressure vessel is purchased from a recognized supplier/manufacturer within the EU after May 2002, it should come with the appropriate marking and a Certificate of Conformity. The purchaser should actively check that this is the case and ensure that the relevant documentation is received. Compliance should never be assumed.

29. Occasionally, a researcher may need to import pressure equipment from outside the EU, e.g. the United States.

    In this case, the researcher should make suitable enquires about compliance prior to ordering it. Legally, the purchaser will become the supplier as s/he will be the first point of contact within the EU. As the supplier, you will be responsible for ensuring that the equipment is tested in accordance with the Directive and Regulations, preparing the safety file and submitting all the technical data for verification by a notified body which can give permission for the CE mark to be fixed. The legal requirements are fairly complex, and this exercise could be expensive and time consuming. If the purchase can be made through an EU based agent, then they would be the supplier and the responsibility would rest with them.

Vacuum systems

30. Vacuum systems are not covered by the Pressure Systems Safety Regulations. Nevertheless, the danger of implosion depends on the absolute pressure difference between the inside and outside of the system.

    Vacuum systems should be designed using the same management principles outlined above for pressure systems, i.e. a competent person must confirm the design calculations and details before any new system is first brought into use.

31. There should be a risk assessment for the use of any vacuum system taking into account all relevant factors, including:

    - The guarding of equipment;
    - the incorporation of flexible items where possible, e.g. bellows couplings;
    - the need for routine maintenance and servicing of pumps, in accordance with the manufacturer's recommendations; and
    - the requirement for suitable eye protection.

Training requirements

32. The design and build of pressure systems requires competence and expertise, usually to degree level equivalent, or higher standard.

    Most people will be members of bodies such as the Institute of Chemical Engineers, Institute of Mechanical Engineering, or will be working under supervision from such a person.

33. The Staff Learning and Development Unit can provide assistance for training courses and awareness sessions covering the legal requirements.

References

1. Pressure Equipment Regulations 1999 (SI 1999/No 2001) which implements the European Union Directive on Pressure Equipment 97/23/EC.

2. Safety of pressure systems. Pressure Systems Safety Regulations 2000 Approved Code of Practice L122. HSE Books 2000 ISBN 0 7176 1767 X Pressure Systems Safety Regulations 2000 which can be viewed at http://www.legislation.hmso.gov.uk/si/si2000/20000128.htm

3. Provision and Use of Work Equipment Regulations 1998, SI 1998/2306, Stationary Office.

4. Advanced accident investigation and risk assessment techniques include: Management Oversight & Risk Tree (MORT), Technique of Operations Review (TOR), Events & Causal Factors Analysis (ECFA), Hazard and Operability studies (HAZOP), Failure Modes and Effects Analysis (FMEA), Event Tree Analysis (ETA) and Fault Tree Analysis (FTA). A reasonable summary of these techniques is in Health & Safety: Risk Management, T Boyle, IOSH Services, 2000, ISBN 0 9013 5727 3.

5. Health & Safety Executive Research Report No 121, on Benchmarking the competent person in manufacturing and engineering sectors, at http://www.hse.gov.uk/research\rrpdf\rr121.pdf

   Note: Details of chartered engineers will be available from bodies such as the professional engineering institutes, Engineering Council, Hazards Forum etc.

6. Safety in pressure testing GS4 (3rd edition), HSE Books 1998 ISBN 0 7176 1629 0.

Other useful publications

- An Engineer's Responsibility for Safety – Safety by Design, The Hazards Forum, 1996, ISBN 0 9525103 1 6.
- Safe use of work equipment. Provision and Use of Work Equipment Regulations 1998. Approved Code of Practice and Guidance L22 (2nd edition). HSE Books 1998 ISBN 0 7176 1626 6.
- Safe under pressure, BOC Guidelines for all who use BOC gases in cylinders, G2314/rev/CSD/12.90/BB/15M.

Additional sources of information

- G Saville et al, Pressure test safety, CRR168, HSE Books 1998 ISBN 0 7176 1542 1, which can be viewed at http://www.hse.gov.uk/research/crr_pdf/1998/CRR98168.pdf
- HSE leaflet on written schemes of examination at http://www.hse.gov.uk/pubns/indg178.pdf
- HSE leaflet on pressure systems – safety and you, at http://www.hse.gov.uk/pubns/indg261.pdf
- Numerous British Standards and other documents are available on-line through the University of Manchester Library's Electronic Databases

Document control box	
Title	Guidance on the design, manufacturer, testing and use of Pressure Vessels and Systems in Research
Link to Policy or Chapter	
Date issued:	June 2005
Issued by:	Safety Services
Implementation date:	v1.2 April 2017 v1.1 January 2009 v1.0 June 2005
Version:	v1.2
Next review date:	Upon significant change
Owner of this document:	Head of Safety Services, Dr Patrick Seechurn
Lead contact:	Robert Derbyshire, University Safety Coordinator

Appendix 1 Summary of Pressure Systems Safety Regulations 2000

Regulation	Summary of requirements
Reg 4: design and construction	Any person involved in the design, manufacture, import or supply of a pressure system must ensure that it is properly designed and properly constructed from suitable material, so that all necessary examinations can be carried out and that access can be gained without danger. The pressure vessel must be provided with protective devices necessary to prevent danger, which enable safe release of contents.
Reg 5: Provision on information and marking	The designer / supplier must provide written information about the design, construction, examination, operation and maintenance of the system to enable users to comply with the PSS Regs. Anyone who modifies a pressure system must also provide such information. Specified information must be indelibly marked on the vessel (including manufacturer's details, a serial no, date, standard to which it is built, maximum allowable pressure, design temperature).
Reg 6: Installation	The system shall be safely installed, with no impairment of protective devices or inspection facility.
Reg 7: safe operating limits	The user shall not operate the system or allow it to be operated unless he has established the safety operating limits.
Reg 8: written scheme of examination	The user shall not operate the system or allow it to be operated unless he has a written scheme for the periodic examination, by a competent person, of the protective devices, pressure vessel and / or pipeline, any part of the pipework in which a defect may give rise to danger. The user must ensure that the scheme is reviewed and modified in the light of recommendations from the competent person. **Note:** Schedule1, part II of the PSS Regs exempt vessels of less than 250 bar litres from Regs 8-10, unless the relevant fluid is steam (in which case there is no size exemption).
Reg 9: examination in accordance with the written scheme	The user shall ensure that examinations take place in accordance with the Reg 8 scheme of examination, and prepare the system for examination. The competent person carrying out the examination shall make a written report, which is signed and dated. The regulation specifies items to be covered in the report. The user shall carry out any specified repairs, etc. within agreed timescales.
Reg 10: action in case of immediate danger	The competent person carrying out the examination shall report cases where in his opinion there is imminent danger to the enforcing authorities, and to the user, with details of the work

Regulation	Summary of requirements
	required to make it safe.
Reg 11: operation	The user shall provide any person operating the system with adequate and suitable instructions for safe operation and action to be taken in an emergency. The user shall ensure that the system is not operated except in accordance with those instructions.
Reg 12 : maintenance	The user shall ensure that the system is properly maintained in good repair, so as to prevent danger.
Reg 13: modification and repair.	The employer of anyone who modifies or repair a system shall ensure that nothing about the way in which the repair or modification is carried out gives rise to danger, or impairs the operation of the protective devices or inspection facility.
Reg 14 : keeping of records	The user shall keep records of the last examination and other examinations where this could assist in determining whether the system is safe to operate, or whether repairs or modifications can be carried out safely, and information provided under Reg 5. These records must be passed on to new users if the system changes hands.
Reg 15: precautions to prevent pressurisation in certain vessels	If a vessel has a permanent outlet to atmosphere, which if obstructed could lead to pressurisation of a vessel, the user must ensure that the outlet is kept free from obstruction at all times the vessel is in use.
Schedule 1: Part 1 : Pressure systems excepted from all regulations	Exemption 6 applies to pressure systems which are the subject of a research experiment or comprises temporary apparatus being used in a research experiment, **BUT** only if it is not reasonably practicable to do this. Current guidance in this area states that:- Where pressurised apparatus has been set up in a laboratory and is itself the subject of a research experiment, it is not always reasonably practicable to apply most of the regulations to the equipment. In the case of other research projects, the individual circumstances and duration of the project will dictate whether it is reasonably practicable to comply with the regulations. Anyone relying on this exception should be able to justify their reasons for non-compliance and any failure to take the basic precautions required under the regulations to prevent risk of injury from system failure. In practice, this exemption will not apply to most research rigs. If researchers feel the exemption might apply to their system. Full, written justification will be required.

Appendix 2 Decision tree: Do I need to comply with the PSSR 2000?

(Adapted from the HSE's ACOP on the Pressure Systems Safety Regulations 2000)