



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

The following guidance document was written by Steven Gourlay, Technical Support Officer, School of Engineering and has been converted into corporate guidance with his agreement. It has also been reviewed by Richard Fincham, Senior Engineer (Pressure Systems) Zurich Engineering.

This guidance note should be read in conjunction with the University Health and Safety Policy [Framework: Arrangements Section 15 on Pressure vessels](#).

### Introduction

1. Pressure vessels are widely used in research. Vessels that are made available commercially must comply with the Pressure Equipment Safety Regulations 2016 (PER), and have a declaration of conformity and CE/UKCA mark. This does not mean they are automatically safe to use, but shows that the manufacturer or supplier has satisfied certain essential safety requirements of the PER. Relevant British Standards or harmonised standards may also be quoted. Also for example, the supply of machinery (safety) regulations 2008 may also apply to some plant containing several different components, including a pressure vessel.

2. When in use, pressure vessels are subject to the Pressure Systems Safety Regulations 2000 (PSSR). <http://www.hse.gov.uk/pUbns/priced/l122.pdf>

They are also covered by the definition of 'work equipment', and so the Provision and Use of Work Equipment Regulations 1998 apply, <http://www.hse.gov.uk/pubns/indg291.pdf>

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 or UK regulations and relevant standards. This may be an onerous task and will 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 humans 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.

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 The University external consultants noted below.



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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 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, with the development of control features that provide continuing protection for all those potentially at risk. Design is an opportunity to address hazards before they manifest themselves during manufacture, testing or use, and is thus a critical tool for preventing failure of the vessel, with consequent serious injury or even death. Its importance 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 and how it may be constructed, used and maintained;
- 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, through HSE guidance, they are understood to mean a person or group of people who have the necessary combination of formal technical qualification(s), experience, aptitude, familiarity with good practice, understanding of hazard and risk, some knowledge of legal requirements, and an awareness of their own limitations. In terms of designing or adapting pressure vessels, this will be someone like a chartered mechanical engineer with experience in the field under investigation.

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). That person should assure themselves that others are competent to carry out the work allocated to them.

11. Any system using competent persons should be robust in that critical features of design are checked by others who are competent and preferably independent of the project in hand. For example, a colleague who is not involved in the research, an Engineer/surveyor from an inspection body, an external consultancy, 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. Having prepared and validated the design, 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 on the subject. This differentiates between

- a) Proof pressure test: this is carried out when the required thickness of all the pressure parts has not been accurately calculated or is in doubt. Its objective is to demonstrate the integrity of the pressure equipment. Proof pressure testing should only be carried out hydraulically and the pressure applied gradually until the specified test pressure is reached or until significant yielding of any part of the pressure equipment occurs. A method to determine significant yield is contained in British Standard 5500: 1997, amended 1998 Specification for unfired fusion-welded pressure vessels.
- b) Standard pressure test: this test is used when the required thickness of all pressure parts has been calculated. Its objective is to prove the quality of materials used and the construction of the pressure equipment before it enters or re-enters service. This test is carried out at a specified pressure above the design pressure, typically 1.25 to 1.5 times the design pressure.
- c) Leak test: this test may be carried out at a pressure not exceeding 10% of the design pressure on pressure equipment which has not been subjected to a standard pressure test. It may also be performed at a higher pressure, not exceeding 110% of the design pressure, on pressure equipment which has satisfactorily passed the standard pressure test.
- d) Functional test: this test is carried out using a suitable test medium at design pressure, or working pressure if this is lower, to check that the pressure equipment and its components function properly. It may include the actuation of moveable parts, such as the opening and closing of valves.

15. Any pressure system must have suitable protective devices (pressure relieving or pressure limiting devices, designed and installed so that the system cannot exceed 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 are not exposed to the released pressurised fluid.

16. A signed copy of the risk assessment must be included in the relevant lab passport and should be reviewed in the light of any changes made during the course



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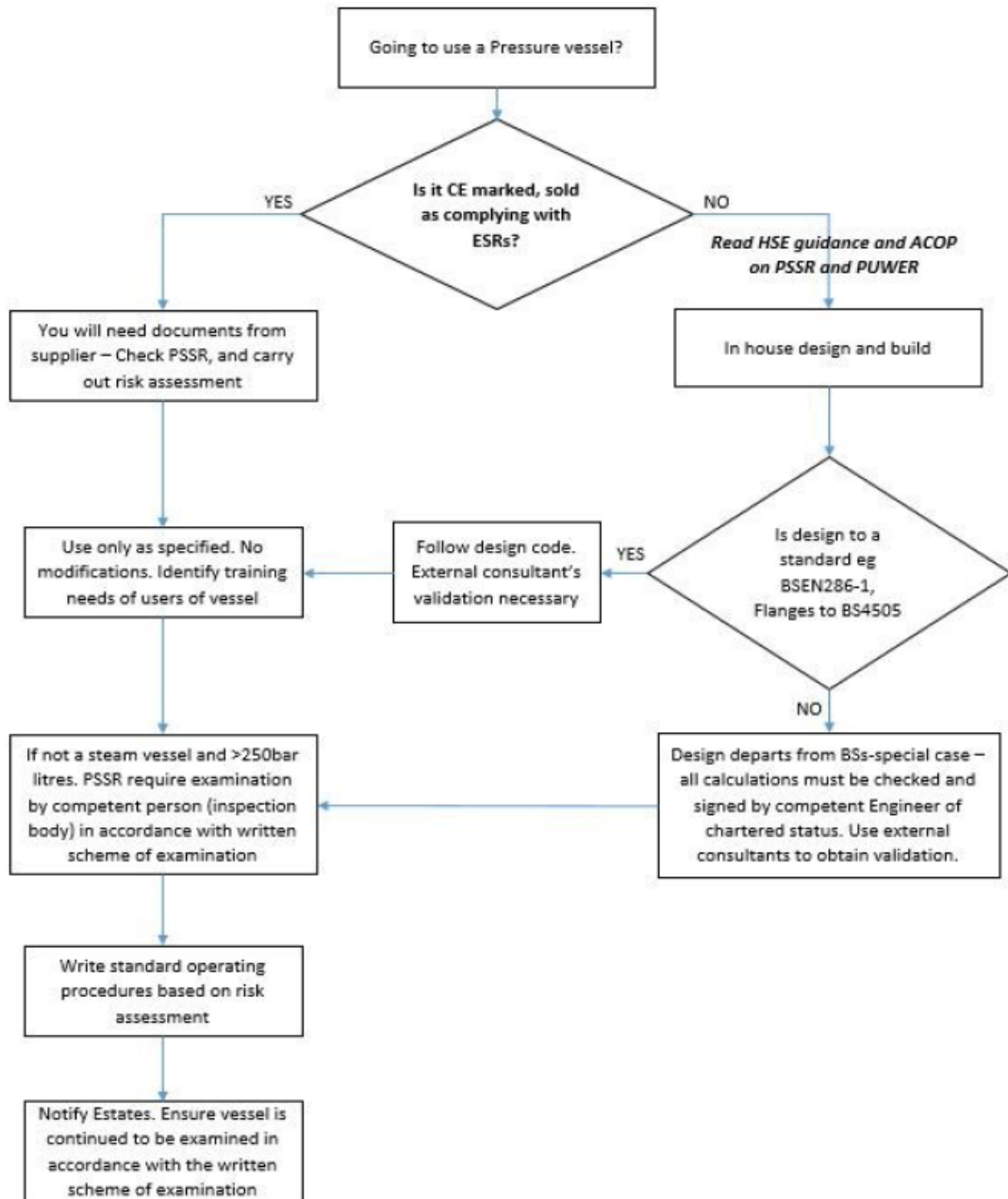
of the vessel's preparation and testing. Master copies of all relevant certification to be sent to the School pressure vessel advisor for central storage

Note: the School Safety Advisor /pressure vessel advisor is not responsible for the competency of the design or risk assessment.

17. Proposals for research funding may require 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 legal requirements.



The following flow chart may be of some assistance



\*Pressure Systems Safety Regulations 2000. If a pressure vessel (unless it contains steam) is <250 bar litres, the Regulations do not require a written scheme of examination, although other regulations of the PSSR apply.

\*\*ESRs are the 'essential safety requirements', as defined in the European Directives on product safety, in this case, the Pressure Equipment Directive.



## Use of pressure vessels

18. The person responsible for the safe use of any pressure system is the senior academic (PI) 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 as defined by the PSSR, 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.

### Definitions

A 'pressure system' means

(a) a system comprising one or more pressure vessels of rigid construction, any associated pipework and protective devices;

(b) the pipework with its protective devices to which a transportable pressure receptacle (gas cylinder) is, or is intended to be, connected; or

(c) A pipeline and its protective devices, which contains or is liable to contain a relevant fluid, but does not include a transportable pressure receptacle.

A 'relevant fluid' means

(a) steam;

(b) any fluid or mixture of fluids which is at a pressure greater than 0.5 bar above atmospheric pressure, and which fluid or mixture of fluids is

(i) a gas, or

(ii) a liquid which would have a vapour pressure greater than 0.5 bar above atmospheric pressure when in equilibrium with its vapour at either the actual temperature of the liquid or 17.5°C, or

(iii) 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.

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.hse.gov.uk/pUbns/priced/l122.pdf>

21. The Approved Code of Practice can be viewed Databases. 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 unintentional release of stored energy and the pressure system contents in their risk assessments.

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

25. The pressure system must be operated within its design parameters. If the research 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 and approved and validated by a person competent to do this, 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. These should cover the full range of operational variables.

### Purchase of pressure vessels

27. The Directive on Pressure Equipment (PED - 2014/68/EU) was adopted on 15 May 2014 and all of provisions entered into force on 19 July 2016, replacing the previous Directive 97/23/EC. The Directive was implemented into UK law by The Pressure Equipment (Safety) Regulations 2016 (SI 2016 No.1105) [http://www.legislation.gov.uk/ukxi/2016/1105/pdfs/ukxi\\_20161105\\_en.pdf](http://www.legislation.gov.uk/ukxi/2016/1105/pdfs/ukxi_20161105_en.pdf). With the advent of Brexit, the EU Directive on placing equipment on the market has been replaced with the 'The Product Safety and Metrology etc. (Amendment etc.) (EU Exit) Regulations 2019'.

All pressure equipment for sale 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 where required, satisfy appropriate conformity assessment procedures and carry the UKCA mark or CE mark if produced and put on the market in the EU and other information such as serial number, maximum allowable 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 recognised supplier / manufacturer in the UK, it must bear the UKCA mark and declaration of conformity. If purchased from within the EU after May 2002, it should come with the appropriate marking and a declaration of conformity. The purchaser should actively check that this is the case and ensure that the documentation is handed over. 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 they 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.

### A note on 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 – large vessels (more than 1 litre) will need a stout metal mesh cage, small vessels and wide bore tubing should be strapped with tape and sprayed with PVA. Use metal or PVC tubing where possible, in place of glass;
- the incorporation of flexible items where possible, eg bellows couplings;
- the effects of reagents;
- the need for routine maintenance and servicing of pumps, in accordance with the manufacturer's recommendations; and
- the need for suitable eye protection.

### Training requirements

32. The design and build of pressure systems requires competence and expertise, usually to degree 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.

### References

1. Pressure Equipment Regulations 1999 (SI 1999/No 2001) which implements the European Union Directive on Pressure Equipment 97/23/EC. Pressure Equipment safety Regulations 2016
2. Safety of pressure systems. Pressure Systems Safety Regulations 2000 Approved Code of Practice L122. HSE Books 2000 ISBN 9780717666447 Pressure Systems Safety Regulations 2000 which can be viewed at <http://www.legislation.hmsso.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 (4th edition)

#### 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](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>

## 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.



<p>Reg 5 : Provision on information and marking</p>	<p>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 PSSR.</p> <p>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).</p>
<p>Reg 6 : Installation</p>	<p>The system shall be safely installed, with no impairment of protective devices or inspection facility.</p>
<p>Reg 7 : safe operating limits</p>	<p>The user or owner shall not operate the system or allow it to be operated unless he has established the safety operating limits.</p>
<p>Reg 8 : written scheme of examination</p>	<p>The user or owner 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.</p> <p>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).</p>



Reg 9 : examination in accordance with the written scheme	The user or owner shall ensure that examinations take place in accordance with the written scheme of examination (reg 8), 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 authority, the user and where relevant owner, with details of the repairs, modifications or changes required to make it safe.
Reg 11: operation	The user or owner 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 or owner 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 or owner shall keep the last report of examination and other reports of 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 pursuant to Reg 5. These records must be passed on to new users or owners if the system changes hands.



<p>Reg 15 : precautions to prevent pressurisation in certain vessels</p>	<p>If a vessel has a permanent outlet to atmosphere, which if obstructed would become a pressure vessel, the user must ensure that the outlet is kept free from obstruction at all times the vessel is in use.</p>
<p>Schedule 1: Part 1 : Pressure systems excepted from all regulations</p>	<p>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 comply with the regulations as stipulated in the PSSR</p> <p>Current guidance in this area states that:-</p> <p>Where pressurised apparatus has been set up in a laboratory and is itself the subject of a research experiment, it may not be 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.</p> <p>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, contact your School Safety Adviser for advice.</p>

Note: the duties apply to users of installed systems, and owners of mobile systems (see flow chart).



## Appendix 2

### Decision tree: Do I need to comply with the PSSR2000?

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

