Health & Safety
Executive

Specification Number

VAC007(HSE)

SPECIFICATION
FOR ULTRA HIGH VACUUM WELDED STAINLESS STEEL SPHERICAL TRANSPORTABLE PRESSURE RECEPTACLES WITH A MAXIMUM CAPACITY OF 30 LITRES.

ISSUE 1 : DECEMBER 2002

GENERAL

VW007 (HSE) Stainless Steel Receptacles were developed to meet the requirements defined by consumers and producers of very high purity chemicals and gases.
These clean receptacles are used for the transport and storage of high purity gas or chemicals whilst under pressure, for industries such as Semiconductor and Microelectronics, they can also be used to store and transport air samples for environmental studies to monitor air pollution etc.
By virtue of their design, stainless steel receptacles have a number of specific user advantages, such as corrosion resistance, material properties and accurate surface treatment.
Vacuum Baking is a crucial part of the final test procedure, with the aid of an RGA (Residual Gas Analysis) trace it can be shown that the receptacle is clean.

1. SCOPE

Welded Stainless Steel Spherical Receptacles used for any chemical or gas which is non – corrosive to 316L Stainless Steel, having a maximum filling pressure of 43 Barg at 15 deg C, a maximum nominal water capacity of 30 Litres and a design temperature range of minus 40 degrees C to plus 50 degrees C.
Final tests shall include a vacuum bake with a Residual Gas Analysis (RGA) to prove leak tightness under vacuum conditions and the final cleanliness of the receptacle.

2. CERTIFICATE OF COMPLIANCE

A nominated Approved Inspection Body (AIB) or a Notified Body (NB) to the Transportable Pressure Equipment Directive shall certify that manufacture, inspection and testing of each receptacle was carried out in compliance with this specification.

3. DEFINITIONS

The following definitions shall apply for the purpose of this standard:

3.1 Yield Stress

Value corresponding to the 0.2% proof stress (Rp0,2) or, for austenitic steels in the solution annealed condition, 1% proof stress (Rp1,0)

3.2 Solution Annealing

Softening heat treatment for austenitic steels in which a receptacle is heated to a uniform temperature above the upper critical point (AC3, as defined in EN 10052) of the steel followed by rapid cooling

3.3 Cold Working

Plastic deformation treatment given to sheet material at ambient temperature, with the aim of permanently increasing the material strength

3.4 Cold Forming

Final deformation treatment at ambient temperature given to the prefabricated receptacle, known as the preform, which results in a permanent increase in material strength.

3.5 Batch

Batch testing shall be carried out on finished receptacles of the same design, size and material specification.
Testing shall be carried out for each batch of 50 receptacles, manufactured from the same batch of material.

Note: This definition allows different suppliers to be used for the different pressure parts within a batch, eg one supplier for heads, another for bases

3.6 Design Stress Factor (F)

Ratio equivalent wall stress at test pressure (Ph) to a guaranteed yield stress (Re)

4. SYMBOLS

The following symbols shall apply for the purpose of this standard:

a - Calculated minimum thickness, in millimetres, of the receptacle shell

D – Outside diameter, in millimetres, of the receptacle

Df – Diameter of former in millimetres

F – Design stress factor

n – Ratio of diameter of bend test former (Df) to the thickness of the test piece (t)

Ph – Hydraulic test pressure, in bar, above atmospheric pressure

py – Observed yield pressure, in bar, above atmospheric pressure

Re – Yield stress, in N/mm^2, used for design calculation

Rea – Value of the actual yield stress, in N/mm^2, determined by the tensile test

Rp0.2 – Minimum value of 0.2% proof stress, in N/mm^2, guaranteed by the receptacle manufacturer for the finished receptacle, in accordance with EN 10002-1

Rp1.0 – Minimum value of 1.0% proof stress, in N/mm^2, guaranteed by the receptacle manufacturer for the finished receptacle, in accordance with EN 10002-1

Rg – Minimum value of tensile strength, in N/mm^2, guaranteed by the receptacle manufacturer for the finished receptacle

Rm – Actual value of tensile strength, in N/mm^2, determined by tensile test

t – Actual thickness of the test specimen, in millimetres

5. STANDARD REFERENCES

EURONORM 6-55, bend test for steel

EN287-1, Approval testing of welders – Fusion Welding – Part 1: Steels

EN288-3, Specification and approval of welding procedures for metallic materials – Part 3: Welding procedure tests for the arc welding of steels

EN473, Non destructive testing – Qualification and certification of NDT personnel – general principles

EN970, Non-destruction examination of fusion welds – Visual examination

EN1435, Non destructive examination of welds – Radiographic examination of welded joints.

EN1803, Transportable gas cylinders. Periodic inspection and testing of welded carbon steel gas cylinders.

EN10002-1, Metallic materials – Tensile testing – Part 1: Method of test (at ambient temperature)

EN10003-1, Metallic materials _ Brinell hardness test – Part 1: Test method

EN10045-1, Metallic materials – Charpy impact test – Part1: Test Method

EN10088-2, Stainless steels – Part 1: List of stainless steels

EN10028-7, Stainless steel for pressure receptacles

EN12517, Non-destructive examination of welds – Radiographic examination of welded joints – Acceptance levels

EN25817, Arc welded joints in steel: guidance on quality levels for imperfections (ISO 5817)

ENISO11114-1, Transportable gas receptacles – Compatibilty of receptacle and valve materials with gas contents – Part 1: Metallic materials (ISO 11114-1: 1997)

EN ISO 3651-2, Determination of resistance to interangular corrosion of stainless steels – Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels – Corrosion test in media containing sulphuric acid (ISO 3651-2)

ADR, European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), UN9 EC 90E01, ECE/TRANS/80(vol.1).

6. MATERIAL OF CONSTRUCTION

The stainless steel receptacles shall be designed and manufactured in accordance with the requirements stated herein.
For stainless steel pressure receptacles, the purely austenitic chromium nickel steel 316L to BSEN10088-2 and 10028-7, shall be used

6.1 Chemical Composition

The chemical composition and allowable deviations shall be in accordance with table 1.

Table 1 – 316L

Chemical Composition In Max %, Max or Range

C	Si	Mn	P	S	N	Cr	Mo	Ni
0.030	**0.75**	**2.00**	**0.045**	**0.030**	**0.10**	**16.00/ 18.00**	**2.00 / 3.00**	**10.00 / 14.00**

6.2 Traceability

Certificates of the ladle analysis of the steel supplied for the construction of the pressure retaining parts of the receptacle and for the welding consumables shall be obtained and provided by the manufacturer of the receptacle.

Welding consumables shall be such that they are capable of giving consistent welds with minimum tensile strengths at least equal to that specified for the parent materials in the finished receptacle.

6.3 Properties of corrosion chemistry

When required material and welds shall be tested regarding inter-granular corrosion, the specification ISO3651 part 1/2 shall apply.

6.4 Mechanical properties

All parts of the finished receptacle shall have a tensile strength in the range 520 to 680 N/mm2,
Yield Strength – Rp0.2 in the range 220/240 N/mm^2
Rp1.0 in the range 260/270 N/mm^2
Elongation minimum of 40%.

6.5 Material shall be supplied in a heat treatment condition

The tube and shell parts must be supplied in the solution-annealed condition, the following requirements shall apply:

Solution-annealing temperature for tubes and shell parts: 1020 - 1080°C

Quench in water or rapid cool by other means.

6.6 Test Requirements

6.6.1 Testing shall be carried out for each new design of receptacle

A receptacle shall be deemed as a new design when:
a - It is manufactured in a different factory

b - If there is a radical change in an existing process, ie, heat treatment, a steel with a different chemical composition, change in base profile or different welding process

c - Change in the minimum guaranteed yield stress and/or tensile strength

d - The nominal outside diameter increases

e - The guaranteed minimum wall thickness decreases

f – The hydraulic test pressure changes (if the receptacle is used for a lower pressure service than that for which it was approved, it shall not be deemed a new design)

6.6.2 Design drawings, calculations, material details, welding, manufacturing, heat treatment processes and a technical specification shall be attached to the design test certificate by the manufacturer.

6.6.3 The manufacturer shall guarantee a minimum of 50 receptacles, to be representative of a new design, these shall be made available for design testing. If the total production is less than 50, enough receptacles shall be made to complete the tests, in addition to the production quantity.

7. DESIGN

7.1 Minimum wall thickness

The following formula shall apply when calculating the wall thickness of the spherical shell subject to internal pressure:

$$a = \frac{D}{2}\left[1 - \sqrt{\frac{10.F.1.\mathrm{Re} - \sqrt{3.Ph}}{10.F.\mathrm{Re}}}\right]$$

Design Stress Factor (F) shall be defined by the formula shown below

$$F = \text{The lesser of } \frac{0.65}{(\mathrm{Re}/Rg)} \text{ or } 0.77$$

Re/Rg shall not exceed 0.85

The minimum wall thickness, a, shall be 2.0mm after forming.

7.2 Design of openings

All openings shall be restricted to the ends of the receptacle, and shall be separated from circumferential joints at a distance not less than 3a.
The opening shall be securely attached by welding, of adequate strength and to result in no harmful stress concentrations. This shall be confirmed by design calculations using area replacement methods and a pressure cycling test.`

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7.3 Non Pressure Attachments

These parts must be manufactured from steel compatible with that of the receptacle, such parts being handles, valve protection rings and foot rings. Each attachment must be clear of the circumferential weld at a distance not less than 3a, must not trap water, must be designed to allow inspection of the attachment weld.
A footring or other support shall be fitted to the receptacle to provide stability. Permanently attached footrings shall be drained and the space enclosed by the

footring shall be ventilated.

7.4 Valve Protection

A protective shroud shall be fitted around the valve. It shall be constructed to give the valve sufficient protection against dropping from a height or from impact from a sideways direction.

8. CONSTRUCTION

8.1 Welded pressure joints

All welds shall be of full penetration. All welders shall be qualified to BSEN 287-1, and all welding procedures to BSEN 288-1 and BSEN 288-3.

Records of qualifications shall be kept on file by the manufacturer.

8.2 Welds

Circumferential welds shall be checked for full penetration, have a smooth finish and merge into parent metal and meet the requirements of EN 25817 level C.
Radiographic examination of welds shall conform to the techniques in EN 1435.
Radiographs shall show complete weld penetration. Any part of the weld which is not full penetration shall be deemed as an unacceptable defect and shall be treated as a reject.
Acceptance criteria to EN 25817 level C or level 2 in EN 12517.
The test equipment shall be operated by personnel certified at least to EN 473 level1 and supervised by personnel certified to at least EN 473 level 2.
Radiographs shall be assessed on the original films in accordance with the practice recommended in clause 6 of ISO 2504.

8.3 Unacceptable Defects

Before any machining or welding of the two hemispheres they shall be checked for unacceptable defects, such as deep scoring or gouges in the material surface, edges are free from splits or cracks and a mechanical inspection of wall thickness shall be under taken to ensure that at no point it falls below the minimum required thickness.

8.4 Roundness

The out of roundness of the shell will be limited so that the difference between the maximum and minimum outside diameter in the same cross section is not more than 2% of the mean of these diameters.

8.5 Leak Test

After the welding has cooled down to ambient temperature, the receptacle shall be leak checked on a helium sensitive mass spectrometer.
The leak rate shall be less than 1×10^{-9} Torr Litres per Second.

8.6 Pneumatic test

Every receptacle shall be pneumatically pressure tested using clean filtered Nitrogen, tested to their test pressure and held for a period of 15 minutes, if a loss of pressure is observed an investigation shall be made to find the point at which the pressure loss occurs, if it shows a leak on the receptacle, the receptacle shall be deemed as a reject from the batch.

It must be pointed out that pneumatic testing is far more dangerous than hydrostatic testing, all necessary safety precautions must be taken as stated in Annex C

8.7 Vacuum bake

Every receptacle shall be Vacuum Baked to show a vacuum pressure less than 1×10^{-9} Torr Litres, no peaks other than air and nitrogen shall be present.

8.8 Stamping

The following markings shall be engraved on the foot ring of each receptacle.

- Maximum fill pressure in Barg at 15 deg C
- Test Pressure in Barg
- Maximum working temperature in degrees C
- Minimum working temperature in degrees C
- Name of manufacturer
- Year of manufacture
- Water capacity in Litres
- Serial number
- Tare weight of receptacle
- Approval mark for specification VW007 (HSE)
- Type liquids or gases for which the receptacle is to be used
- Mark of the AIB or NB
- π mark if to the TPED

9. PROTOTYPE TESTING

9.1 Material Tests

Tests shall be carried out on two receptacles, as shown on Figure 1

a: Tensile Test

This test on parent material will be carried out on a test sample taken from a finished receptacle, in accordance with the requirements of EN 10002-1. The two faces of the test pieces shall not be machined, the ends may be flattened for gripping in the test machine.
Test samples to be taken, one from either end, and one longitudinal sample from a finished receptacle, and shall be taken from positions shown on figure 1.
A tensile test is also required from the circumferential weld area, the test piece to be 25mm wide over a length of 15mm beyond the edge of the weld.
The tests shall show all joints are at least as strong as the parent material.

b: Bend Test

Bend testing will be carried out in accordance with EURONORM 6-55.
This test will be one root and one face bend from the circumferential weld, the test piece will not crack when bent inwards around a former until the inside edges are not further apart than the diameter of the former.
The diameter shall be value n x t (the thickness of the material being tested), as shown in table 2

Test results shall show no cracking of the test piece

Table 2 – Bend test requirements.

Actual tensile strength Rm in N/mm^2	**Value of n**
$520 < Rm \leq 600$	**4**
$600 < Rm \leq 700$	**5**

c: Macroscopic examination of weld cross-sections

A macroscopic weld examination for each type of welding procedure shall be performed. It shall show complete fusion and shall be free from any assembly

faults or unacceptable defects. Acceptance criteria shall be as specified to level C in EN 25817 or level 2 in EN 12517.

9.2 Radiographic Examination

100% of the weld joining the two hemispheres shall be tested by means of a radiographic test, as specified in section 8.2.
This test can be carried out on one of the receptacles to be used for Tensile/Bend test.

9.3 Hydrostatic Burst Test

This test shall be carried out on two receptacles which shall bear all the markings required for a completed receptacle.
The test shall be carried out on equipment which enables the pressure to be increased at a controlled rate until the receptacle bursts. This pressure shall be recorded.
The receptacles in this specification shall burst at least 9/4 times the test pressure.
The observed yield pressure (Py) shall be equal to or greater than the value calculated by the following formula: $Py \geq Ph/F$, 1% proof stress (Rp1,0) for austenitic steels in the solution annealed condition.
The burst test should not cause the receptacle to fragment, with the main fracture not showing any brittleness
If the configuration of the fracture does not conform to the requirements, the receptacle shall be submitted to a further examination to enable a decision to be reached as to the acceptance or the rejection of the batch.

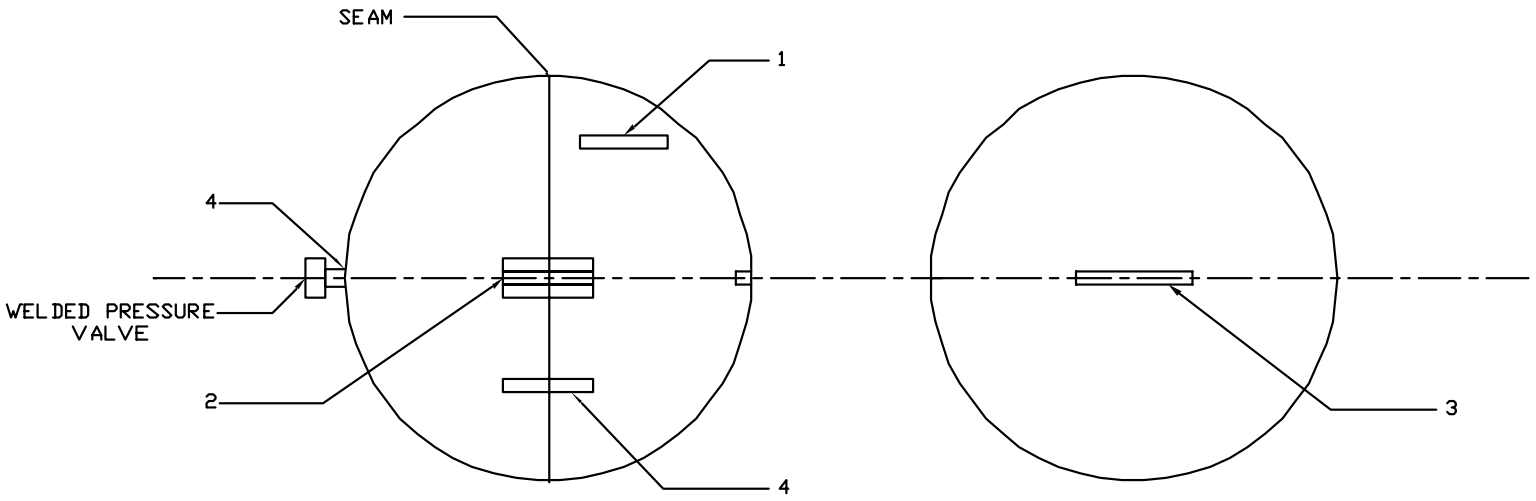
9.4 Pressure Cycling Test

This test shall be carried out on one receptacle bearing all the markings required for a completed receptacle.
A non-corrosive liquid shall be used for the test. The test will subject the receptacle to successive reversals of upper pressure, which is equal to the hydraulic test pressure, and lower pressure, which is equal to a value no higher than 10% of the upper pressure.
The pressure reversals shall not exceed 15 cycles per minute for a period of 12000 cycles, no leakage or failure should be evident
After the test the receptacle is to be sectioned in order to measure the thickness, the thickness shall be no higher than 15% above the minimum thickness prescribed in the design. The thickness shall be recorded on the design test certificate.

9.5 Drop Test

This test shall be carried out on a finished receptacle, filled full of water, and dropped from a height of 3metres onto a concrete base, directly onto the valve shroud. The valve and receptacle shall show no signs of leakage.

The receptacle shall then be subjected to1000 pressure cycles, with no signs of leakage, and then shall be subjected to a hydrostatic burst test as defined in section 9.4.



1 1 tensile test piece
2 1 tensile test piece, 1 root bend test piece, 1 face bend test piece
3 1 tensile test piece – Required only if insufficient spherical length available
4 2 macro test pieces

Figure 1 – Location of test pieces taken from two part receptacles

10. BATCH TESTING

Batch testing shall be carried out on one receptacle for material tests and radiographic examination, as defined in sections 9.1 and 9.2, and one receptacle for hydrostatic burst test as defined in section 9.3.

11. TESTS ON EVERY RECEPTACLE

11.1 Cleaning

This shall be to Ultra High Vacuum standard, no surface grease, dirt or weld burn shall be present on the receptacle surfaces

11.2 Welding Tests

Welds shall be visually checked externally and internally with the use of an endoscope to EN 25817 level C.

11.3 Leak Test

As specified in section 8.5

11.4 Pneumatic Pressure Test

As specified in section 8.6

11.5 Vacuum Bake

As specified in section 8.7

11.6 Receptacle Markings

As specified in section 8.8

11.7 Final Checks

The following shall be verified by the Approved Inspection Body/Notified Body

- Prototype test certification as per Annexe A
- Batch test certificate as per Annexe B
- All material certification
- Receptacle markings

- Receptacle dimensions
- Tare weight
- Reports of Non-Destructive tests
- Final documentation shall include:

  a) Leak test certificate
  b) Pressure test certificate
  c) Vacuum Bake certificate
  d) Certificate of Conformity

All original certificates shall be kept by the receptacle manufacturer.

12.0 Periodic Examination

12.1 Receptacles made to this specification shall be periodically examined in accordance with the requirements of table P200 of the latest edition of ADR using the latest edition of BSEN1803 for guidance.

ANNEX A

Prototype Test Certificate

Certificate No: ……..

Issued By: ……..

Date: ……..

The prototype testing on two receptacles met the requirement of the approved design specification VW007 (HSE)

Type of receptacle: ……

Drawing Number: …….

Name of Manufacturer: ……..

Address of Manufacturer: ……

……

Name of AIB/NB: ……..

Address of AIB/NB: ……

……

Date: ……..

Place: …….

Signature: ……..

A technical specification of each receptacle shall be attached to the prototype Test Certificate.

The specification shall include:

- **Design drawings**
- **Material details**
- **Welding qualifications**
- **Design calculations**
- **Radiographic test results**
- **Mechanical destruction test results**

ANNEX B

Batch Test Certificate

Specification: VW007 (HSE)

Date: …….

Design Certificate Number: …….

Name of Manufacturer: ……...

Address of Manufacturer: ……

…….

Description of receptacle: ……..

Drawing Number: ……

Batch Numbers to be tested: …….. to ……

Table B.1 – Batch – Sample Receptacle Measurements.

Test No	Serial No's of batch samples: ..……to……..	Water capacity in Litres	Mass when empty in kg	Minimum measured thickness of hemisphere in mm

A copy of test certificates shall be attached to Batch Test Certificate.
Test Certificates to include:

- **Material**
- **Burst Test**
- **Tensile Test**
- **Bend Test**
- **Macroscopic**
- **Radiographic Test**
- **Visual examinations**

All tests shall be carried out at an UKAS approved test house and shall be verified by the AIB/NB.

I, the undersigned hereby declare that I have checked that the verification operations, tests and checks prescribed in VW007 (HSE) have been carried out successfully.

Special remarks: ……

…….

…….

General remarks: …….

…….

…….

Address: …….

…….

Signature: …….

Date: …….

Stamp of AIB/NB:

ANNEX C

Guidance notes for 'Safety in Pressure Testing'.

These guidance notes are written to point out the dangers of pressure testing and for the protection of the personnel carrying out the testing.

Standard pressure test.

This test is used when the required thickness of all pressure parts has been calculated. The objective of this test is to prove the quality of the materials used and the construction before it enters into service. This test is carried out at a specified pressure above the design pressure, typically 1.25 to 1.5 times above the design pressure.

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 correctly. It may include the actuation of moveable parts such as the opening and closing of valves.

Hydraulic and Pneumatic testing.

Hydraulic testing is carried out using a liquid as the pressurising medium, although this is a far safer method of testing, it is not without risks, and should be used wherever practicable. Pneumatic testing uses air, steam or gas as the pressurising medium, and is potentially more dangerous due to the higher energy levels involved, for example the energy released during a total failure of pressure equipment containing compressed air is 200 times higher than released by the same volume of water compressed to the same pressure.
Pneumatic testing should only be carried out when hydraulic testing is practicable, for instance where the interior of the pressure equipment will be contaminated by the hydraulic test medium.

Risk assessment.

A risk assessment must be carried out before any form of pressure testing is performed. This assessment guides the employer as to the measures he needs to take to carry out their legal obligations.
It will point out all of the relevant hazards and dangers, and consists of an estimation of the risks arising from them with a view to their control or avoidance. It will indicate the extent and content of the safe system of work that needs to be in place before any pressure testing is carried out. A safe system of work is necessary to ensure the safety of the testing personnel and other people in the vicinity.
As this specification requires pneumatic testing, the assessment shall state that all equipment being tested shall be placed behind a protective barrier.

Hazards

The main hazard when pressure testing is the unintentional release of stored energy. In the case of pneumatic testing this can lead to a blast wave and missiles.

Stored energy

The release of stored energy can be due to:

a: rupture of pressure equipment due to brittle fracture.

b: rupture of pressure equipment due to ductile fracture.

c: detachment or removal of blanking plates and their clamps/attachment bolts, screwed plugs, isolation valves etc.

d: detachment of temporary welds on plugs, at pipe ends and nozzles.

Brittle fracture

The risk of rupture of the pressure equipment due to brittle fracture under test conditions should be assessed at the design stage.

Safe system of work

A risk assessment should indicate the extent and content of the safe system of work that needs to be in place before any pressure testing is carried out, it should include:

1: Permit-work-system
This should include a recorded positive verification by a competent person that safe working conditions are in place before each pressure test commences.
Recorded authorisation by a competent person that the pressure equipment is isolated from pressure sources, fully de-pressurised and vented before dismantling of the pressure equipment, its components or any remedial work takes place.

2: Training
All personnel involved with pressure testing are adequately and properly trained.

3: Written testing instructions and procedures
Written testing instructions should be available which include procedures for pressurising, de-pressurisation and venting.

These instructions shall define:

a: the test pressure, test duration and test medium to be used.
b: where the test medium supply line is to be attached to the pressure equipment.
c: the position and specification of safety valves and pressure gauges.
d: the position of isolation valves.
e: the sequence for opening vent valves when more than one venting position is to be used.

If the system being checked is complex, an up-to-date drawing will be required to show positions of isolation valves, safety valves, non return valves etc.
The safe system of work should also indicate that only trained personnel can carry out the pressure test, in a room designated for pressure testing only, this room to be clearly marked pressure test bay and whilst a test is in progress marked 'Danger, pressure test in progress'.

4: Venting

There should be sufficient venting positions to prevent the testing medium being trapped behind non return valves, in dead legs or between isolation valves.
Before venting the pressure testing medium supply line to be disconnected. Venting should allow the test medium to flow away in a safe manner away from the testing personnel.

5: Clamps and bolts

Clamps or bolts on bolted flanges must not be loosened or tightened while the pressure equipment is under pressure.

6: Test equipment

Pressure gauges should be fitted at or near each venting and pressurising medium supply point where they can easily be seen by the operator.
All gauges used for pressure testing shall be compared regularly against a calibrated gauge, these records of comparison should be kept. Any gauges used for pressure testing should have a current certificate of calibration.

General precautions for pressure test

Pressure equipment should not be subject to any form of shock loading whilst under pressure.
To avoid brittle fracture the temperature of the medium entering the pressure equipment should not be lower than the test temperature stated in the testing procedure.
The pressure equipment to be tested shall be evaluated and inspected before it is tested. The evaluation should include consideration of the design criteria, material specification and construction methods, as specified within this specification VW007 (HSE).
Personal protection during pressure testing should be provided including eye protection, pneumatic testing shall be carried out behind a protective screen.
The testing medium shall be controlled by reducing valves and flow control valves.

It is recommended 'Safety in pressure testing' guidance notes GS4 (HSE) are read in conjunction with this specification.