Market Surveillance: Compliance assessment of portable air compressors with Simple Pressure Vessels Regulations and designated standards

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Market Surveillance: Compliance assessment of portable air compressors with Simple Pressure Vessels Regulations and designated standards

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Abbreviations and Acronyms

BDC – Bottom Dead Centre

CE – Conformité Européene

ESR – Essential Safety Requirement (as specified in SPVD)

GB – Great Britain

NDT – Non Destructive Testing

OES – Optical Emission Spectography

PED – Pressure Equipment Directive

PER – Pressure Equipment (Safety) Regulations

PSSR – Pressure Systems Safety Regulations

PRV – Pressure Relief Valve

PUWER – Provision and Use of Work Equipment Regulations

SEP – Sound Engineering Practice

SPVD – Simple Pressure Vessels (Safety) Directive

SPVR – Simple Pressure Vessels Regulations

UKCA – United Kingdom Conformity Assessed

WSE – Written Scheme of Examination

Key Messages

The overarching objective of the Simple Pressure Vessels (Safety) Regulations (SPVR) and its designated standards is to ensure that pressurised work equipment is manufactured to a standard that ensures it is fit for purpose and safe to use. This objective is supported by the incorporation within the regulations of the requirement for periodic market surveillance to be undertaken by the relevant enforcement authority.

Sixteen different compressor models from eleven different manufacturers were evaluated for this project. The compressors ranged in size from small volume compressors that might be found in dentist's surgeries or laboratory settings, to larger volume compressors that would more typically be found in a workshop or garage setting. The acceptance criteria selected for this project were limited to: manufacturer's documentation, functionality testing, material quality, weld quality and UKCA and/or CE marking.

All of the compressors examined during this project were found to have a standard of welding that did not meet the requirements of the relevant standard. One of the compressors was non-compliant with the certification and paperwork requirements of SPVR. Three compressors failed the essential safety requirement in SPVR that the maximum allowable pressure could not be exceeded by more than 10% and were therefore non-compliant. These were vessels 8 (14%), 11 (25%) and 14 (11%). In two cases the amount by which the requirement was exceeded was small.

Ten of the sixteen compressors were subjected to destructive burst testing, with particular attention being paid to compressors which exhibited the worst quality welding and fabrication. The lowest burst pressure recorded was 61 barg with the mean burst pressure being greater than 75 barg.

Considering that the average maximum working pressure for compressors was 10 barg, the lowest burst pressure provides a factor of safety of 6. As the compressors would be unlikely to generate outlet pressures of 60 bar or over, testing did not provide any evidence that these compressors represented an immediate safety hazard (despite not being fully compliant).

However, only one of each type of compressor was tested. Without undertaking testing of a statistically significant sample size it is impossible to conclude that these tests were representative of each type of compressor and did not just represent outlying results.

Those compressors with poorly located drain valves and/or non-functioning inspection ports could represent a safety hazard over time due to an inability to fully drain condensate from the vessel and/or carry out internal inspections. Both of these circumstances could lead to increased and/or unchecked rates of corrosion and subsequent reduction in material thickness and, ultimately, compromise the mechanical integrity of the vessel.

Executive Summary

Background

It is a requirement of the Great Britain Regulation on Accredited Market Surveillance (GB RAMS) that the relevant enforcing authority conducts periodic market research to assess levels of compliance with the appropriate supply regulations. Simple pressure vessels are manufactured to the requirements of the Simple Pressure Vessels (Safety) Regulations (SPVR). This report describes market research undertaken by the Health & Safety Executive to assess levels of compliance for the simple pressure vessels supplied into the UK marketplace specifically for use with portable air compressors.

The definition of a pressure vessel as per SPVR is a simple pressure vessel manufactured in series with the following characteristics;

- The vessel is welded, intended to be subject to an internal gauge pressure greater than 0.5 bar, contain air or nitrogen, and is not to be fired

- The parts and assemblies contributing to the strength of the vessel under pressure are made of non-alloy steel, of non-alloy aluminium, or of non-age hardening aluminium alloys.

The maximum operating pressure for a pressure vessel claiming compliance with SPVR is 30 barg, with a pressure volume product (the operating pressure in bar multiplied by the internal volume of the vessel in litres) not exceeding 10,000 bar litres. Vessels are further categorised as follows:

(a) Category A vessel, the pressure volume product of which exceeds 50 bar litres

(i) Category A.1 vessel; the pressure volume product of which exceeds 3000 bar litres

(ii) Category A.2 vessel; the pressure volume product of which exceeds 200 bar litres but is less than 3000 bar litres

(iii) Category A.3 vessel; the pressure volume product of which exceeds 50 bar litres but is less than 200 bar litres

(b) Category B vessel, the pressure volume product of which is 50 bar litres or less.

Other pressure vessels which are outside the scope of the SPVR are covered by the Pressure Equipment (Safety) Regulations (PE(S)R) (2016).

The majority of the vessels selected for this work were Category A.2 type vessels unless otherwise indicated.

In addition to the above, HSE guidance leaflet; “Buying new machinery: A short guide to the law and your responsibilities when supplying machinery for use at work” describes the various duties placed on manufacturers, suppliers and users when buying new machinery. While the advice in the leaflet is not specific to pressure equipment, the general principals are. For example, when buying new equipment (including machinery), users are required by PUWER to check it complies with all relevant supply laws. This means checking that it is:

- marked with either the UKCA or CE conformity marking
- supplied with a Declaration of Conformity and user instructions in English
- free from any obvious defect (such as missing or damaged guards)

Users also have other duties under PUWER, such as maintaining and inspecting the equipment to ensure it remains safe.

Findings

Six criteria were selected as representative indicators of compliance for the compressors examined for this work with the requirements of SPVR and designated standards. This doesn’t include compliance with other standards relating to the subsequent use of the pressure vessel in other pieces of equipment[1]. Each criteria was assigned an identifier, as follows;

Table 1 Showing sample compliance criteria

Identifier	Criteria
A	Declaration of Conformity present
B	Instructions present
C	Operational tests (including safety devices)
D	Material specification
E	Weld quality
F	CE or UKCA Marked

Using the sample criteria shown in Table 1, each compressor was designated as compliant or not compliant, as shown in Table 2.

[1] *For example the use of a pressure relief valve that did not meet the requirements of BS EN ISO 4126 would not mean non-compliance with SPVR which only covers the pressure vessel.*

Table 2 Showing compliance status for all compressors against the sample criteria

Compressor No.	A	B	C	D	E	F	Overall compliance.
1	C	C	C	C	NC	C	NC
2	C	C	C	C	NC	C	NC
3	C	C	C	C	NC	C	NC
4	C	C	C	C	NC	C	NC
5	C	C	C	C	NC	C	NC
6	C	C	C	C	NC	C	NC
7	C	C	C	C	NC	C	NC
8	C	C	NC	C	NC	C	NC
9	C	C	C	C	NC	C	NC
10	C	C	C	C	NC	C	NC
11	C	C	NC	NC	NC	C	NC
12	C	C	C	C	NC	C	NC
13	C	C	C	C	NC	C	NC
14	C	C	NC	C	NC	C	NC
15	NC	C	NC	C	NC	NC	NC
16	C	C	C	C	NC	C	NC

Note: “C” indicates compliance in a specific category whereas “NC” indicates non-compliance. If a compressor was compliant in all categories it was designated ”FC” or fully compliant. A compressor that was non-compliant in any category will be “NC” or non-compliant overall.

Of the sixteen compressors examined for this work, all of them were found to have a non-compliance of some type. Poor quality welding (Category E) was the most common non-compliance, occurring in every compressor.

Destructive pressure tests were focussed on the vessels that exhibited the most significant manufacturing defects and/or welding defects in an effort to understand what impact such defects might have on end user safety. The destructive testing demonstrated that vessels with minimal material thickness and/or poor quality welding had a burst pressure significantly in excess of what the compressor pump would be likely to be able to deliver.

Contents

1 Introduction

Portable air compressors typically utilise thin walled, non-alloy steel pressure vessels for the storage of compressed air. These pressure vessels must meet the essential safety requirements described in the Simple Pressure Vessels (Safety) Regulations (SPVR) (HSE, 2016) in order to be placed on the market as pressure equipment in the United Kingdom. The SPVR enacts the requirements of the Simple Pressure Vessels Directive (SPVD) (European Commission, 2014) in UK law.

More complicated pressure vessels outside the scope of SPVR are covered by the Pressure Equipment (Safety) Regulations (PER) (which enacts the requirements of the Pressure Equipment Directive (PED) (European Commission, 2014)).

The primary objective of these Regulations is to ensure that pressure vessels are designed, fabricated and assembled in such a way that they are safe to use. The Regulations refer to a number of designated standards prescribing the requirements for other aspects of portable air receivers such as provision of instructions, marking and information, and safety devices.

This report describes market surveillance work undertaken by HSE scientists and engineers to assess levels of compliance of portable air compressors against the requirements of the SPVR and its designated standards. In addition, this report also acknowledges potential difficulties posed by non-compliant pressure equipment for duty holders in complying with workplace regulations such as the Provision and Use of Work Equipment Regulations (PUWER) (HSE, 1998) and the Pressure Systems Safety Regulations (PSSR) (HSE, 2000).

The definition of a pressure vessel as per the SPVR is a simple pressure vessel manufactured in series with the following characteristics:

- the vessel is welded, intended to be subject to an internal gauge pressure greater than 0.5 bar and to contain air or nitrogen, and is not to be fired.

- the parts and assemblies contributing to the strength of the vessel under pressure are made of non-alloy steel, of non-alloy aluminium or of non-age-hardening aluminium alloys.

The maximum operating pressure for a pressure vessel claiming compliance with SPVR is 30 barg with a pressure volume product (the operating pressure in bar multiplied by the internal volume of the vessel in litres) not exceeding 10,000 bar litres. Vessels are further categorised as follows:

(a) Category A vessel, the pressure volume product of which exceeds 50 bar litres

(i) Category A.1 vessel; the pressure volume product of which exceeds 3000 bar litres

(ii) Category A.2 vessel; the pressure volume product of which exceeds 200 bar litres but is less than 3000 bar litres

(iii) Category A.3 vessel; the pressure volume product of which exceeds 50 bar litres but is less than 200 bar litres

(b) Category B vessel, the pressure volume product of which is 50 bar litres or less.

Other pressure vessels which are outside the scope of the SPVR are likely to be covered by the Pressure Equipment (Safety) Regulations (PE(S)R) (2016).

The majority of the vessels selected for this work were Category A.2 type vessels.

When buying new equipment (including machinery), users are also required by PUWER to check it complies with all relevant supply laws. This means checking it is:

- marked with either the UKCA conformity marking or CE marking
- supplied with a Declaration of Conformity and user instructions in English
- free from any obvious defect (such as missing or damaged guards).

Users also have other duties under PUWER, such as maintaining and inspecting the equipment to ensure it remains safe.

1.1 Research Aim

The aim of this research is to assess levels of compliance for portable air receivers against the requirements of the SPVR (HSE, 2016) and to produce data which can be fed back to manufacturers and/or suppliers so improvements can be made where necessary. The research also seeks to quantify the level of risk associated with non-compliant pressure vessels through practical testing of vessels and the provision of burst pressure data.

1.2 Methods

A general visual inspection and functionality test of each compressor was carried out to establish if each product had been manufactured in accordance with sound engineering practice (SEP). Safety and pressure indicating devices were removed and tested in isolation for functionality and accuracy. Documentation and vessel data plates were also examined for compliance with the requirements of the standard.

Radiographic analysis of complete vessels was carried out along with metallurgical analysis and material samples removed from vessels.

In addition to the above, destructive pressure testing was conducted on complete pressure vessels to establish the significance of the identifiable manufacturing defects on burst pressure.

2 Product Selection

2.1 Selection Procurement Criteria

The criteria for product selection was intentionally broad so as not to exclude or favour any particular supplier or manufacturer, with the exception of the requirement that any integral pressure vessel should be within the scope of SPVR (HSE, 2016)

Initial internet searches were made from various search engines using simple search queries such as “portable air compressor”, “50 litre air compressors” and “single phase air compressor”.

Particular searches were made for vessels with a pressure volume product of greater than 250 bar litres as this is the point at which a pressure system would require a written scheme of examination (WSE) under the requirements of the Pressure Systems Safety Regulations (PSSR) (HSE, 2000). Compressors that would require a WSE are identified in Table 3.

In addition to the above, particular searches were made for silent run and low noise compressors in order to obtain equipment which utilises electric motors or refrigeration type compressors motors as prime movers.

2.2 Supplier and Compressors Purchased

The compressors examined were either bought from UK tool suppliers or, where there were special requirements, purchased direct from manufacturer’s websites. In some cases different versions of the same compressor were purchased with different capacity air receivers.

In accordance with HSE report guidelines manufacturer and supplier information has been anonymised. Supplier, manufacturer and model were given alphabetic designations to differentiate between different suppliers and manufacturers and to identify which compressors had similar origins. An anonymised list of compressors is given in Table 3.

The three principal suppliers were all large UK tool and equipment suppliers with multiple “bricks and mortar” outlets and a strong online presence. Supplier A supplied compressors from manufacturers a, b and g. Supplier B supplied compressors from manufacturers c, e and k. Supplier C supplied compressors from manufacturers a, d and j. Manufacturer a was available from more than one supplier.

To allow the inclusion of silent run compressors, compressors were purchased directly from manufacturers f, h and l.

Table 3 Compressor models purchased and their supplier

	Supplier	Manufacturer	Model	Capacity	Max Supply Pressure (PS)	Pressure Volume Product	PSSR WSE Required?
1	A	a	i	100L	11 bar	1100 bar L	Yes
2	A	a	i	50L	11 bar	550 bar L	Yes
3	A	b	ii	100L	10 bar	1000 bar L	Yes
4	B	c	iii	50L	10 bar	500 bar L	Yes
5	C	d	iv	50L	10 bar	500 bar L	Yes
6	C	a	i	10L	10 bar	100 bar L	No
7	B	e	v	50L	10 bar	500 bar L	Yes
8	Direct from Manufacturer	f	vi	50L	7 bar	350 bar L	Yes
9	A	g	vii	50L	10 bar	500 bar L	Yes
10	A	b	ii	50L	10 bar	500 bar L	Yes
11	Direct from Manufacturer	h	viii	50L	8 bar	400 bar L	Yes
12	C	j	ix	50L	10 bar	500 bar L	Yes
13	C	a	x	24L	10 bar	240 bar L	No
14	B	k	xi	33L	9 bar	297 bar L	Yes
15	Direct from Manufacturer	l	xii	50L	8 bar	400 bar L	Yes
16	A	g	vii	100L	10 bar	1000 bar L	Yes

2.3 Standard Compliance Indicated on Manufacturers' Documentation

Table 4 lists the individual compressors and the claimed standards compliance as indicated in the manufacturers' documentation.

All of the compressors except 11 and 15 claimed compliance with either SPVR or PER. Compressor 15 was not supplied with appropriate documentation or certification.

Table 4 Compliance with standards indicated on manufacturers' documentation

	Simple Pressure Vessels Directive 2014/29/EU	Pressure Equipment Directive 2014/68/EU	Machinery Directive 2006/42/EC	Electromagnetic Compatibility Directive 2014/30/EC	Low Voltage Directive 2014/35/EU	Noise Emission s Directive 2000/14/EU	RoHS 2011/65/EC	Noise Emission Directive 2005/88/EU	SPVD (repealed) 2009/105/EC
1	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
2	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
3	No	Yes	No	No	No	No	No	No	No
4	Yes	Yes	No	Yes	Yes	No	Yes	No	No
5	Yes	Yes	Yes	Yes	No	No	No	Yes	No
6	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
7	Yes	No	Yes	Yes	No	Yes	Yes	No	No
8	Yes	No	Yes	Yes	Yes	No	No	No	No
9	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
10	No	Yes	No	No	No	No	No	No	No
11	No	No	No	No	No	No	No	No	No
12	No	Yes	Yes	Yes	No	Yes	No	Yes	No
13	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	No	No	No	No	No	No	No	No	No
16	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No

3 Compliance Assessment – General

Each compressor was subjected to a general mechanical inspection and functionality testing of various attributes and components required by SPVR (HSE, 2016), designated standards and other relevant regulations, guidance and specifications. The regulatory and supply requirements which were the basis of this assessment are outlined below, where text is included in italics this is quoted directly from the Regulation or Standard:

Scope of Supply (A1)
This section covers the type of equipment and its intended use as well as details of documentation and certificates provided with the equipment.

A1.1 Equipment Type
This criteria is included to identify the application of the pressure vessel.

A1.2 Provision of a UK plug
Included for information only.

A1.3 Provision of User Instructions
This criteria assess whether documents were provided and whether they were broadly understandable. Where instructions were provided for the equipment that there was suitable reference to safety information relating to the vessel.

Regulation 12 of SPVR states that "*When placing a vessel on the market, a manufacturer must ensure that a vessel is accompanied by instructions and safety information that are clear, legible and in easily understandable English".*

A negative response to this question would mean that the compressor would be non-compliant with SPVR.

A1.4 Provision of Maintenance Instructions
This criteria assess whether documents were provided and whether they were broadly understandable. Where instructions were provided for the equipment that there was suitable reference to safety information relating to the vessel.

Regulation 12 of SPVR states that "*When placing a vessel on the market, a manufacturer must ensure that a vessel is accompanied by instructions and safety information that are clear, legible and in easily understandable English".*

A negative response to this question would mean that the compressor would be non-compliant with SPVR.

A1.5 Provision of a Certificate of Conformity

This criteria assess whether a Declaration of Conformity was provided and whether an appropriate data-plate carrying the required information was affixed to the vessel.

Regulation 6 of SPVR states that *"Where the conformity of a category A vessel with the essential safety requirements has been demonstrated by a relevant conformity assessment procedure, before placing that vessel on the market, a manufacturer must—*

(a)draw up declaration of conformity in accordance with regulation 43; and
(b)affix the information set out in paragraph (1B[2]) to—

(i)the vessel;
(ii)its data plate; or
(iii)where paragraph (1A) applies—

(aa)to a label affixed to the vessel; or

(bb)in a document accompanying the vessel;"

A negative response to this question would mean that the compressor would be non-compliant with SPVR.

Compressor Equipment (A2)

This section covers hardware details of relating to the vessel and the compressor system in which the pressure vessel is incorporated.

A2.1 Provision of a Condensate Drain

Indicates the presence of a condensate drain. Compression of ambient air at uncontrolled humidity can lead to the generation of quantities of moisture within the vessel. Over time this can result in corrosion and a resulting deterioration in mechanical properties.

[2] *(1A) This paragraph applies to a vessel that is placed on the market within a period of seven years beginning with IP completion day.*
(1B) The information referred to in paragraph (1)(b) is— (a)the UK marking; (b)the last two digits of the year in which the UK marking is affixed;(c)the inscriptions.

Requirement 12 of Schedule 1 of SPVR (Part B – Vessel Design) states that "*A manufacturer must also take account of the following provisions—*

(a)it must be possible to inspect the inside of vessels;
(b)it must be possible to drain the vessels;
(c)the mechanical qualities must be maintained throughout the period of use of the vessel for the intended purpose;
(d)the vessels must, bearing in mind their prescribed use, be adequately protected against corrosion."

During the initial visual assessment, the presence of a suitable port was confirmed or otherwise. Where it was considered significant, the position of ports was noted (e.g. a drain port that was not located at the bottom dead centre (BDC) of the vessel will require the vessel to be lifted and tipped for effective drainage to occur). Functionality was confirmed as part of stage A3.

A2.2 Provision of a Vessel Inspection Port
Indicates the presence of a vessel inspection port. Compression of ambient air at uncontrolled humidity can lead to the generation of quantities of moisture within the vessel. Over time this can result in corrosion and a resulting deterioration in mechanical properties.

The regulatory requirements relating to vessel inspection ports are outlined in Section A2.1. SPVR is not prescriptive regarding the number, size or position of ports. It is therefore acceptable to combine the functions of a condensate drain and those of a vessel inspection port within a single port.

During the initial visual assessment, the presence of a suitable port was confirmed or otherwise. Functionality was confirmed as part of stage A3.

A negative response to both A2.1 and A2.2 would mean that the compressor would be non-compliant with SPVR. However, a negative response to either of these questions may not mean non-compliance if the other port could be used to perform both functions.

A2.3 Provision of Pressure Indication
Indicates the presence of one or more pressure gauges or other means of monitoring pressure.

Pressure indication is present as part of the compressor equipment rather than the pressure vessel. BS EN 1012 -1, the European standard for compressors and vacuum pumps states that "*A suitable pressure indicator shall be provided either on the compressor unit or remotely to display the pressure:*

- *existing at the final outlet of a compressor;*
- *in each separate stage of diaphragm compressors with a maximum allowable pressure exceeding 3 bar; BS EN 1012-1:2010 EN 1012-1:2010 (E) 21*
- *on the pressure side of each separate stage of positive displacement compressors having a shaft input power of more than 20 kW;*
- *of lubricant systems equipped with oil pumps on compressors having an input power of more than 75 kW;*
- *at the inlet of a compressor having inlet pressure above atmospheric."*

A negative response to this questions would mean that the compressor would be non-compliant with BS EN 1012-1. However, as BS EN 1012-1 is not a designated standard this would not represent non-compliance with SPVR.

A2.4 Provision of Pressure Relief
Indicates the presence of a pressure relief valve (PRV) to prevent over-pressurisation of the vessel.

BS EN 1012 -1 states that:

"A pressure relief device or devices shall protect pressure-containing parts if their maximum allowable pressure can be exceeded."

A separate pressure relief valve is not required in those cases where the maximum allowable pressure in a separate compartment can only be exceeded due to external pressure supplies. Where a pressure relief valve is not supplied then the provisions of 7.2.1.4 i) shall apply."

And:

“Devices to prevent the maximum allowable pressure from being exceeded shall be:
“

a) pressure relief valves; or
b) bursting discs and buckling pins; or
c) pressure sensing devices, whose performance level is determined with reference to 4.5 of EN ISO 13849-1:2008. Such devices shall employ 'redundancy' in accordance with 4.12.3 of EN ISO 12100-2:2003. There shall be at least two of them and they shall be protected against unauthorized adjustment. These devices may provide any one of the following actions:
    1) stopping of the prime mover;
    2) isolating the pressure system from its supply by shut-off devices;
    3) opening of a control valve to exhaust the excess pressure.”

“Where a pressure relief valve is intended as a safety function device designed to protect pressure equipment against the allowable limits being exceeded, it shall be in accordance with EN ISO 4126-1.

The absence of a PRV is not necessarily evidence of non-compliance. However schedule 1 of SPVR includes an Essential Safety requirement (ESR) restricting the potential of over-pressuring the vessel. If that cannot be met then this constitutes a non-compliance under SPVR.

A2.5 Provision of Stop/Start Switch
Indicates the presence of a pressure Stop / Start switch for activating the equipment.

BS EN 1012 -1 states that “*The requirements for a start and restart shall be in accordance with 5.2.3 of EN ISO 13849-1:2008*”. Clause 5.2.3 of BS EN ISO 13849-1, which covers machinery control systems, prohibits restarting in instances where hazards may exist and considers instances where equipment may be activated remotely, which is not relevant here.

The absence of a Stop / Start switch is not indicative of non-compliance.

A2.6 Provision on an Emergency Stop
Indicates the presence of an “Emergency Stop” mechanism for isolating the equipment.

BS EN 1012 -1 states that “*The need for and provision of an emergency stop shall be in accordance with 5.5.2 of EN ISO 12100-2:2003.”* BS EN ISO 12100-2 directs that the requirement for an emergency stop should be based upon a risk assessment of the equipment.

The absence of an Emergency Stop switch is not indicative of non-compliance.

Functionality Test (A3)
Where a functionality assessment of a device or component was required, the results were described in a free form text box in the report using a common nomenclature.

A3.1 Functionality of Condensate Drain
The requirements to drain the vessel are laid out in Clause 12 of Schedule 1 of SPVR (Part B – Vessel Design) (see A2.1 and A2.2). This examination confirmed that the drain provided a clear route to the vessel, i.e. that ports were not blocked or obstructed and that there was no reason to suspect that their function was impeded. Condensate drains were not tested for flow.

A negative response to both A3.1 and A3.2 would mean that the compressor would be non-compliant with SPVR. A negative response to either of these questions may not mean non-compliance if the other port could be used to perform dual functions.

A3.2 Functionality of Inspection Port
The requirements to inspect the vessel are laid out in Requirement 12 of Schedule 1 of SPVR (Part 2 – Vessel Design) (see A2.1 and A2.2). This examination confirmed that the supplied port provided a clear route to the vessel, i.e. that ports were not blocked or obstructed and that there was no reason to suspect that their function was impeded. Inspection ports were used to undertake a preliminary assessment of internal condition using a borescope, prior to subsequent sectioning of vessels.

A negative response to both A3.1 and A3.2 would mean that the compressor would be non-compliant with SPVR. A negative response to either of these questions may not mean non-compliance if the other port could be used to perform dual functions.

A3.3 Functionality of Pressure Indication
The pressure indicator was compared against a calibrated pressure gauge. BS EN 1012-1 requires pressure indication but does not include any requirements on accuracy. BS EN 837 does include accuracy requirements based on the size and type of gauge. The widest acceptable accuracy band is $^{+}/_{-}$ 4%, in this instance a pressure indicator was considered to be functional if it was within this range.

A negative response to this question would not indicate non-compliance with BS EN 1012-1 but would indicate that the gauge was non-compliant with BS EN 837. Neither of these standards are designated under SPVR.

A3.4 Functionality of Pressure Relief

The lifting pressure of the pressure relief valve was recorded and compared with the maximum allowable pressure of the compressor and the tolerances specified within BS EN ISO 4126-1, the standard for pressure relief valves. The valve was then tested using a pneumatic test rig to determine lifting and reseating (blowdown) pressure. Tests were repeated three times. Other requirements including flow characteristics were not assessed.

Schedule I of SPVR outline Essential Safety Requirements (ESR) and states that "*A manufacturer must take account of the fact that under the conditions of use envisaged—*

> *(a)the vessels must not be subjected to stress likely to impair their safety in use;*
> *(b)internal pressure must not permanently exceed the maximum working pressure PS. However, it may momentarily do so by up to 10%."*

BS EN 1012 -1 states that: *"It shall be determined that, under all foreseeable conditions, the design shall not result in maximum allowable pressure of any compressor compartment being exceeded. Where the maximum allowable pressure is exceeded then this shall not be by more than 10 % and only as a momentary transition. Selection of the pressure relief device shall take into account the operational requirements of pressure and flow rate during the 10 % momentary transition phase."*

BS EN ISO 4126-1, states allowable tolerances of $^{+}/_{-}$ 4%, of set pressure or $^{+}/_{-}$ 0.1 bar (whichever is greater) on the lifting pressure for PRVs.

A negative response to this question would indicate non-compliance with BS EN ISO 4126-1 (PRVs) or more seriously BS EN 1012-1. BS EN ISO 4126-1 is not a designated standard. Non-compliance with BS EN ISO 4126-1 would not necessarily indicate that the vessel was at a heightened risk of over-pressurisation. The SPVR and BS EN 1012-1 requirements are in agreement, a failure to meet those requirements would mean a non-compliance with SPVR.

A3.5 Functionality of Stop/Start Switch

The stop / start switch was assessed for its function. The lack of a functional of a Stop / Start switch is not indicative of non-compliance.

A3.6 Functionality of an Emergency Stop

The emergency stop was assessed on the following requirements from BS EN ISO 12100-2:

- *“the actuators shall be clearly identifiable, clearly visible and readily accessible.”*
- *“the hazardous process shall be stopped as quickly as possible without creating additional hazards”.*
- *“Once active operation of the emergency stop device has ceased following an emergency stop command, the effect of this command shall be sustained until it is reset. This reset shall be possible only at that location where the emergency stop command has been initiated. The reset of the device shall not restart the machinery, but only permit restarting*.”

The absence of a functional Emergency Stop switch is not indicative of non-compliance.

Additional Comments (A4)

This section records any additional information generated during the assessments above.

A4.1 Inspection with Borescope

As part of A3.2 the function of the inspection port was assessed. Where the port was functional, each vessel had an internal inspection with a borescope to evaluate the efficacy of simple borescope inspections for identifying manufacturing defects and deterioration in service. This section records a preliminary comment on the internal condition of the vessel with respect to weld quality (A4.1.1) and corrosion (A4.1.2).

This was undertaken to both assess the effectiveness of inspection ports and give early indications of the condition of the vessel. Assessment of non-compliance were not made until a full inspection had taken place

A simple tabulated report was produced for each vessel recording the results of compliance assessment, pressure testing and metallurgical examination items. These are included as Appendix A and summarised in Table 5.

Key findings from this table are:

- One compressor (15) was supplied without the required documentation (categories A1.4 and 1.5).
- Two vessels (14, 15) had no inspection ports (A2.2) and a further two (6, 8) had inspection ports which could not be opened (A3.2). All of these vessels had functional condensate drains (A2.1) which may provide access for inspection, meaning that these vessels are not necessarily non-compliant with SPVR.
- Six vessels (1, 3, 7, 10, 12, 15 (external welds)) had indications of poor weld quality (A4.1.1). Vessels were sectioned and a more detailed examination of welds was undertaken as part of Section 5.
- Six vessels (3, 9, 10, 11, 13 and 16) had indications of internal corrosion (A4.1.2). In all instances this was deemed to be localised or minor and therefore not significant (at this point of the examination). Vessels were sectioned and a more detailed examination of the vessel interior was undertaken as part of Section 5.
- The PRV on compressor 15 did not activate reliably (A3.4).
- Three compressors failed the requirement in BS EN 1012-1 that the maximum allowable pressure could not be exceeded by more than 10% (A3.4). These were vessels 8 (14%), 11 (25%) and 14 (11%). Vessels 8 and 14 were close to the 10% limit and may be within the limits of accuracy of measurement.
- Additionally, four PRVs (4, 11, 12 and 13) failed the BS EN ISO 4126-1 requirements (A3.4). Despite not meeting the accuracy requirements for PRVs, with the exclusion of compressor 11 (see above), there was no evidence that this would lead to over-pressurisation of the vessel.
- Vessel manufacturer VM3 manufactured the vessels used in compressors 3, 9, 10 and 16 manufactured by manufacturers b and g. All of these vessels had indications of internal corrosion (A4.2) identified by borescope inspection. Two (3, 10) additionally exhibited potentially poor-quality welding (A4.1).
- Loose material within the vessel of compressor 15 is significant as it may potentially form a projectile in the event of a premature failure.

Table 5 Summary of assessment against Scope of Supply (A1) Requirements

	A1.3 User instructions (SPVR)	A1.4 Maintenance instructions (SPVR)	A1.5 Certificate of Conformity (SPVR)	A2.1 Condensate rain present (SPVR)	A2.2 Inspection port present (SPVR)	A2.3 Pressure indication present (BS EN 1012-1)	A2.4 Pressure relief present (BS EN 1012-1)	A2.5 Stop/Start switch present (BS EN 1012-1)	A2.6 Emergency stop present (BS EN 1012-1)	A3.1 Condensate rain function (SPVR)	A3.2 Inspection port function (SPVR)	A3.3 Pressure indication function (BS EN 837)	A3.4 Pressure relief function (SPVR)	A3.5 Stop/Start switch functiom	A3.6 E- stop function (BS EN ISO 12100-2)	A4.1.1 No indication of welding issues	A4.1.2 No Indication of Corrosion Issues
1	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓	✓	✓	✓	✓	N/A	**No**	✓
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓	**No**	✓	✓	✓	N/A	N/A	N/A
7	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓	✓	✓	✓	✓	N/A	**No**	✓
8	✓	✓	✓	✓	✓	✓	✓	**No**	✓	✓	**No**	✓	**No**	N/A	✓	N/A	N/A
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓
11	✓	✓	✓	✓	✓	✓	✓	**No**	✓	✓	✓	✓	**No**	N/A	✓	✓	✓
12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓
13	✓	✓	✓	✓	✓	✓	✓	✓	**No**	✓	✓	✓	✓	✓	N/A	✓	✓
14	✓	✓	✓	✓	**No**	✓	✓	✓	**No**	✓	N/A	✓	**No**	✓	N/A	N/A	N/A
15	✓	**No**	**No**	✓	**No**	✓	✓	✓	✓	✓	N/A	✓	**No**	✓	✓	**No**	N/A
16	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

4 Qualitative Safety Assessment – Burst Pressure Test

In addition to functionality testing and conformity assessment, a number of the pressure vessels, were selected for a pressure test to destruction (burst) test based upon the results of visual and borescope examination. The results of the burst tests are shown below in Table 6.

Table 6 Pressure vessels subjected to burst testing

Sample no	Manufacturer compressor	Manufacturer vessel	Max Working Pressure (PS) (Barg)	Burst pressure (Barg)	Ratio
1	a	VM1.	11	70	6.4
2	a	VM2	11	Not tested	
3	b	VM3	10	69	6.9
4	c	VM4.	10	79	7.9
5	d	VM5	10	69	6.9
6	a	VM1.	10	Not tested	
7	e	VM6	10	89	8.9
8	f	VM7	7	Not tested	
9	g	VM3	10-	84	8.4
10	b	VM3	10	69	6.9
11	h	VM8.	8	88	11
12	j	VM9.	10	Not tested	
13	a	VM10	10	Not tested	
14	k	VM11	9	Not tested	
15	l	Not supplied	8	78	9.75
16	g	VM3	10	61	6.1

Destructive pressure tests were focussed on the vessels that had exhibited potentially poor weld quality during initial examination, in an attempt to understand what impact such defects might have on end user safety.

These tests were conducted hydraulically (using water as a pressurising medium) to minimise the amount of energy released at the point of failure. The burst pressure measured in a hydraulic test will be the same as that measured in a pneumatic test (using air or compressed gases).

Vessels were removed from the compressor and all vents and drains were blanked (to prevent safety devices relieving pressure). Vessels were pressurised using a high pressure water pump.

Failure pressure ranged from 61 to 89 barg. This is significantly above the maximum working pressure for these compressors which ranged from 7 to 11 barg. The ratio of maximum working pressure ranged from 6.1 to 11, therefore the lowest burst pressure provides a factor of safety of 6.

As all of the compressors were fitted with safety devices and pumps that would be unlikely to generate outlet pressures of 60 bar or over, and in all cases, the PRV were set at a level well below the burst pressure Testing identified that all PRV were functional and would have vented before burst occurred.

This may suggest that the compressors examined for this project, while not being fully compliant, did not represent an immediate safety hazard as new products. However, only a single model of each type of compressor was tested, without undertaking testing of a statistically significant sample size it is impossible to conclude that these tests were representative of each type of compressor and did not represent outlying results.

Additionally, those compressors with poorly located drain valves and/or non-functioning inspection ports could represent a safety hazard over time due to an inability to fully drain condensate from the vessel and/or carry out internal inspections. Both of these circumstances could lead to increased and/or unchecked rates of corrosion and subsequent reduction in material thickness and, ultimately, compromise the mechanical integrity of the vessel.

5 Materials Characterisation of Vessel Shells

5.1 Introduction

A range of tests were carried out to examine the pressure vessels selected for this project. The tests were as follows:

- Radiography examination of approximately 100% of the welds on each vessel was carried out. Acceptance criteria was for the welds were stated in BS EN ISO 5817 (BSI, 2023) Level B. The design and fabrication of simple pressure vessels such as those used in the air compressors in this project, should be produced in accordance with BS EN 286-1:1998+A2:2005, this standard states that radiographic assessment of the welds “shall comply with class B of EN1435” and “The imperfections found shall be compared with the level of acceptable imperfections given in EN25817”.

- Optical Emission Spectroscopy (OES) of samples taken from each of the pressure vessel shells was carried out to establish if the material used was consistent with the steel grades given in BS EN 10207:2017 (BSI, 2017). BS EN 10207 is a designated standard under SPVR.

- Tensile testing of samples taken from each of the pressure vessel shells was carried out to establish if the material used was consistent with the steel grades given in BS EN 10207:2017.

A simple tabulated report was produced for each vessel recording the results of compliance assessment and the above. These are included as Appendix A.

5.2 Radiography

Radiography examination of approximately 100% of the welds on each vessel was carried out by Morgan Ward NDT on behalf of HSE. A wide range of weld defects were identified in the pressure vessel welds such as:

- Lack of fusion

- Lack of penetration

- Crack

- Inclusions
- Porosity

Examples of the radiographs produced are given in Figure 1 to Figure 5 illustrating the types of weld defect that can result in a weld being rejected for failing to meet the acceptance criteria for the welds as stated in BS EN 5817 (BSI, 2023) Level B.

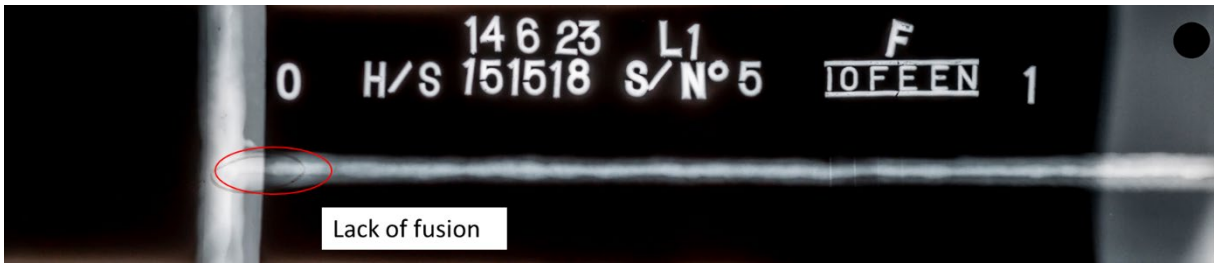

Figure 1 Radiograph of longitudinal weld in a pressure vessel. Lack of fusion in the weld is highlighted in red.

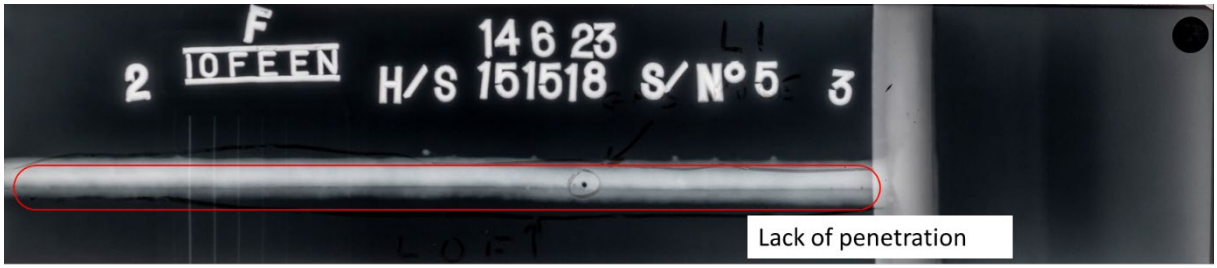

Figure 2 Radiograph of longitudinal weld in a pressure vessel. Lack of penetration in the weld is highlighted in red.

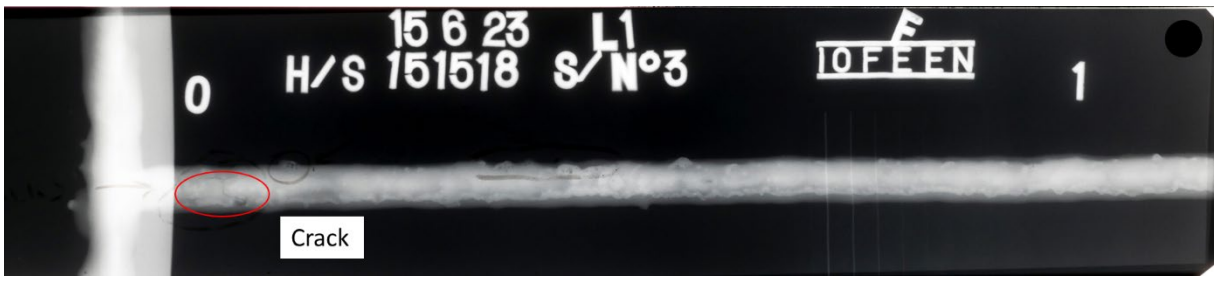

Figure 3 Radiograph of longitudinal weld in a pressure vessel. A crack in the weld is highlighted in red.

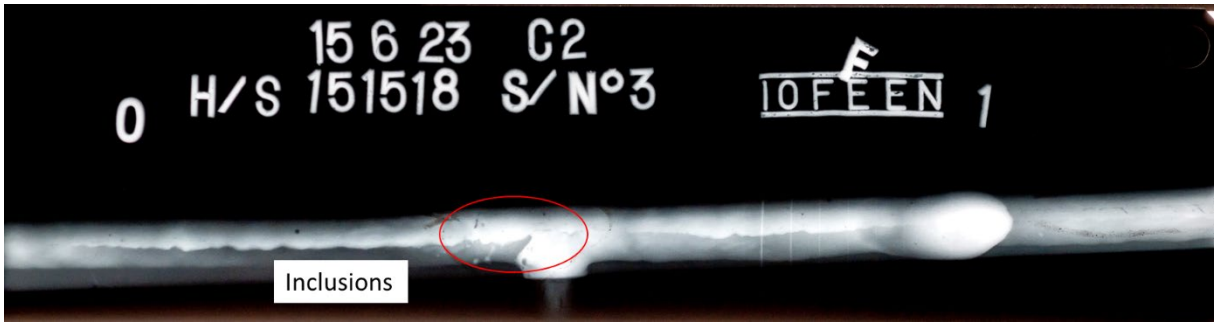

Figure 4 Radiograph of circumferential weld in a pressure vessel. Inclusions in the weld are highlighted in red.

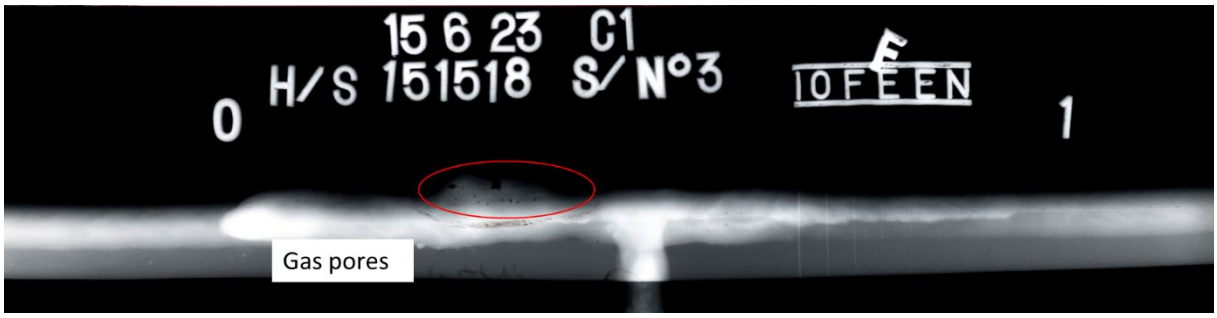

Figure 5 Radiograph of circumferential weld in a pressure vessel. Porosity in the weld is highlighted in red.

The acceptance criteria for the welds as stated in BS EN 5817 Level B were used to determine if the pressure vessel welds were of acceptable quality. The results of the radiographic analysis are summarised in Table 7.

Table 7 Summary of radiography results

Vessel ID	Weld	Defects					Accept Weld	Vessel
		Lack of fusion	Lack of penetration	Crack	Inclusions	Porosity		
1	Cir 1					X	Reject	Fail
	Cir 2		X				Reject	
	Long					X	Reject	
2	Cir 1				X	X	Reject	Fail
	Cir 2				X	X	Reject	
	Long			X	X	X	Reject	

Vessel ID	Weld	Defects					Accept Weld	Vessel
		Lack of fusion	Lack of penetration	Crack	Inclusions	Porosity		
3	Cir 1			X	X	X	Reject	Fail
	Cir 2		X		X		Reject	
	Long			X	X	X	Reject	
4	Cir 1			X		X	Reject	Fail
	Cir 2			X	X		Reject	
	Long			X	X	X	Reject	
5	Cir 1					X	Reject	Fail
	Cir 2	X					Reject	
	Long	X				X	Reject	
6	Cir 1		X				Reject	Fail
	Cir 2					X	Reject	
	Long		X			X	Reject	
7	Cir 1	X					Reject	Fail
	Cir 2	X				X	Reject	
	Long					X	Reject	
8	Cir 1	X				X	Reject	Fail
	Cir 2	X				X	Reject	
	Long	X				X	Reject	
9	Cir 1	X				X	Reject	Fail
	Cir 2		X			X	Reject	
	Long	X				X	Reject	
10	Cir 1	X					Reject	Fail
	Cir 2	X					Reject	

Vessel ID	Weld	Defects					Accept Weld	Vessel
		Lack of fusion	Lack of penetration	Crack	Inclusions	Porosity		
	Long		X				Reject	
11	Cir 1	X					Reject	Fail
	Cir 2	X			X		Reject	
	Long	X		X	X		Reject	
12	Cir 1	X			X		Reject	Fail
	Cir 2	X					Reject	
	Long				X	X	Reject	
13	Cir 1		X		X		Reject	Fail
	Cir 2	X					Reject	
	Long	X				X	Reject	
14	Cir 1	X					Reject	Fail
	Cir 2	X			X		Reject	
	Long	X				X	Reject	
15	Cir 1					X	Reject	Fail
	Cir 2			X		X	Reject	
	Long			X	X	X	Reject	
16	Cir 1			X		X	Reject	Fail
	Cir 2					X	Reject	
	Long	X			X		Reject	

Overall, from the radiography results, all the welds in the vessels examined would fail to meet the acceptance criteria laid out in BS EN 5817, consequently all 16 of the vessels would be rejected for failing to conform to BS EN 5817.

5.3 Visual Inspection

All sixteen pressure vessel shells were sectioned to remove the two circumferential welds and the linear weld. The welds were then visually inspected.

Visual inspection of the welds showed that there was a large variation in visual appearance. An example of a weld that appears to be of reasonable quality is shown in Figure 6.

Figure 6 Photograph illustrating one of the best quality welds observed in the pressure vessels used in the study. The colour change observed around the weld shows the extent of the heat affected zone

The weld shown in Figure 6 was neat and continuous, with no signs of weld spatter of corrosion. There was a visible colour change of the shell material either side the weld. This observation was not unexpected. Heat from the welding process is well known to change the chemistry in the material surrounding the weld, in this case the chemical changes have resulted in heat tinting of the shell material.

Several of the welds showed gaps where the weld passes appeared to have stopped and started. Examples of welds with stop / start regions are shown in Figure 7 and Figure 8.

Figure 7 Photograph showing an example of a stop / start a weld

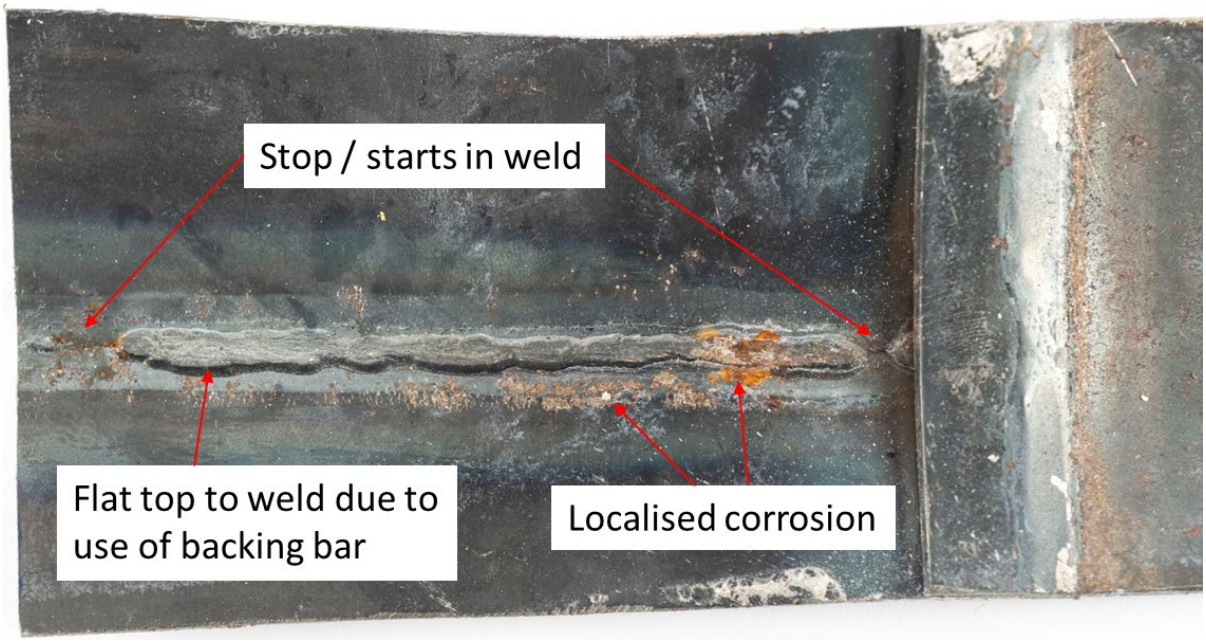

Figure 8 Photograph shows another example of a weld with stop / start regions

From a purely visual inspection these stop regions suggested that there may be regions where the weld material had not fully penetrated the joint and there may be a lack of fusion in the weld.

Several of the welds were observed to have a flat weld root, examples of which are shown in Figure 8 and Figure 9. This type of flattening of the weld root is consistent with a back bar being used during the welding process.

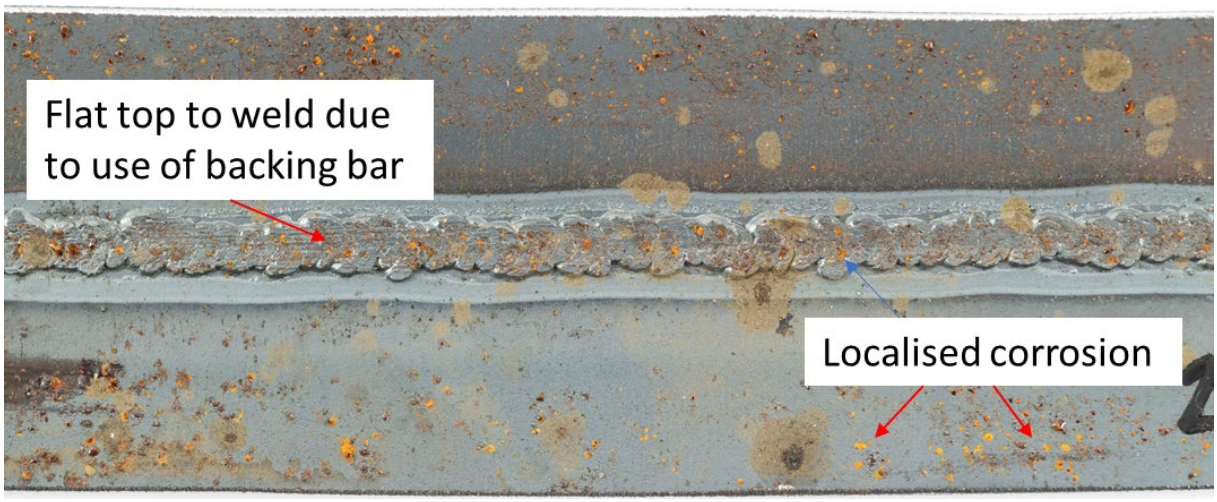

Figure 9 Photograph showing an example of a weld with a flat top and localised corrosion

The welds in several vessels had a rusted appearance, the level of rust observed varied from vessel to vessel. In some cases the rust occurred in isolated spots, see Figure 9, in others the corrosion was much more widespread and covered the majority of the heat effected zone, see Figure 10 and Figure 11.

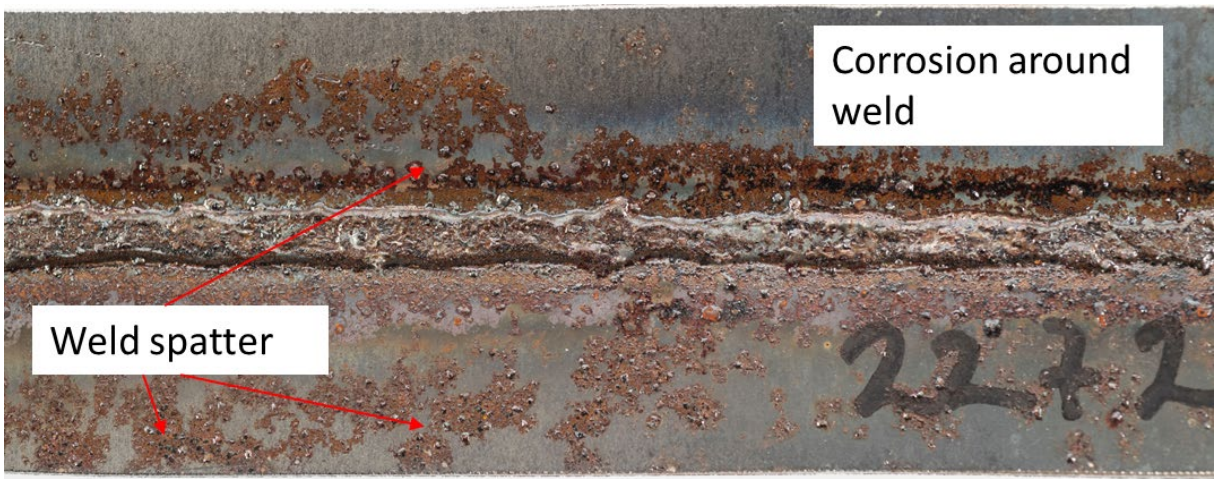

Figure 10 Photograph showing widespread corrosion around the weld and heat affected zone

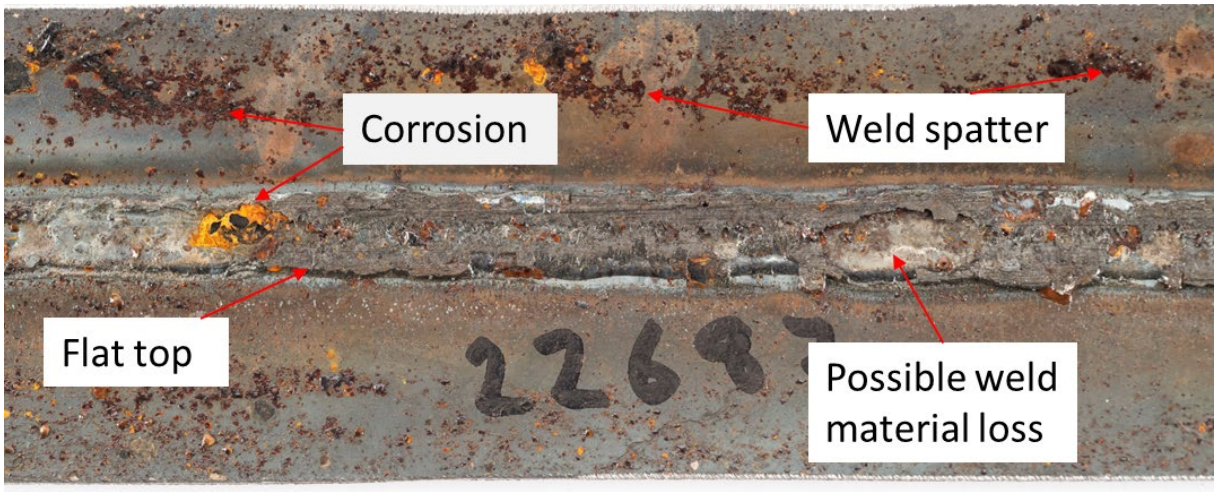

Figure 11 Photograph showing poor quality weld widespread corrosion and multiple weld defects

The rust generally appeared to be localised to the welds and the associated heat affected zone, the surrounding parent material of the vessel shell was not affected by corrosion to the same extent.

This observation was not unexpected. Heat from the welding process can result in changes in chemistry in the weld, and the surrounding area, which can reduce the corrosion resistance.

Overall, there was wide variation in the overall appearance of the pressure vessel welds, some had a much neater regular appearance, while others had a lumpy inconsistent appearance. A comparison of a weld that appears to be of reasonable quality and one that appears to be of poor quality is shown in Figure 12.

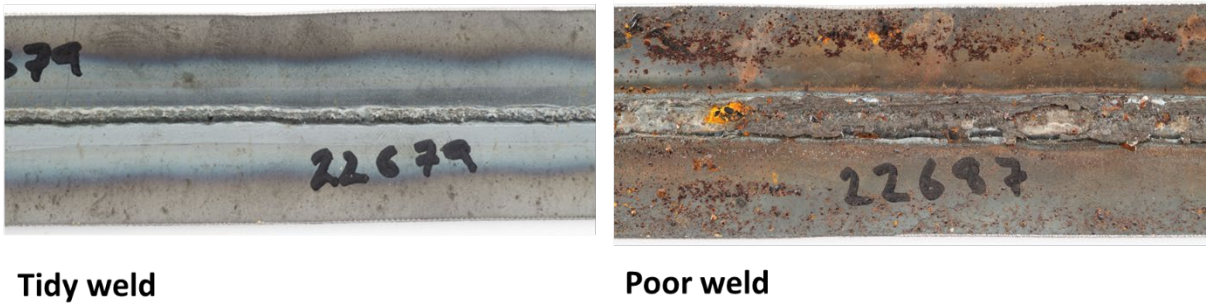

Figure 12 Photographs comparing the appearance of a good quality weld and a poor quality weld

The radiography results showed that all the welds in the vessels examined in the study failed to meet the weld quality requirements given in BS EN 5817 (BSI, 2023) Level B. The appearance of the welds could not be used as a predictor of the quality of the welds as all the welds failed the radiography inspection. i.e. the welds that had a neat, tidy and consistent appearance failed the radiography examination as frequently as welds that had an untidy irregular appearance.

In summary the visual inspections showed that:

- Several of the welds showed stop / starts and the welds were not uniform in appearance
- The roots of several of the welds had a flat appearance which indicated that a back bar had been used during the welding process
- Some welds had a rounded root to the weld beads and indicated that backing bars were not used during the production of those welds
- Some welds showed significant corrosion and rusting while others showed no signs of corrosion
- The visual appearance of the weld could not be used as a indicator of whether or not the weld would met the radiography weld quality requirements. Even welds that visually appeared to be of reasonable quality, still failed the radiography inspection.

The presence of significant corrosion on and around the welds in some of the vessels examined was unexpected. There are large number of variables and that could affect the rate of corrosion development inside the vessels at the welds, such as:

- The grade of steel used.
- The welding procedure used.
- How the vessels were treated after welding.
- Where and how the vessels were stored.
- How long ago the vessels were manufactured.

Understanding how these variables may have affected the development of internal corrosion at the welds is outside the scope of the current work which was focused on assessing the small pressure vessels in their as-received condition.

5.4 Metallurgical Inspection

Several of the welds showed gaps where the weld appeared to have stopped and started. From a purely visual inspection this suggested that that there may be areas where the weld material had not fully penetrated the joint and there was a lack of fusion in the weld.

One of the largest “stop/start” regions was sectioned, mounted and polished for a more detailed metallurgical inspection of the weld. Photographs showing a cross-section through the weld are shown in Figure 13.

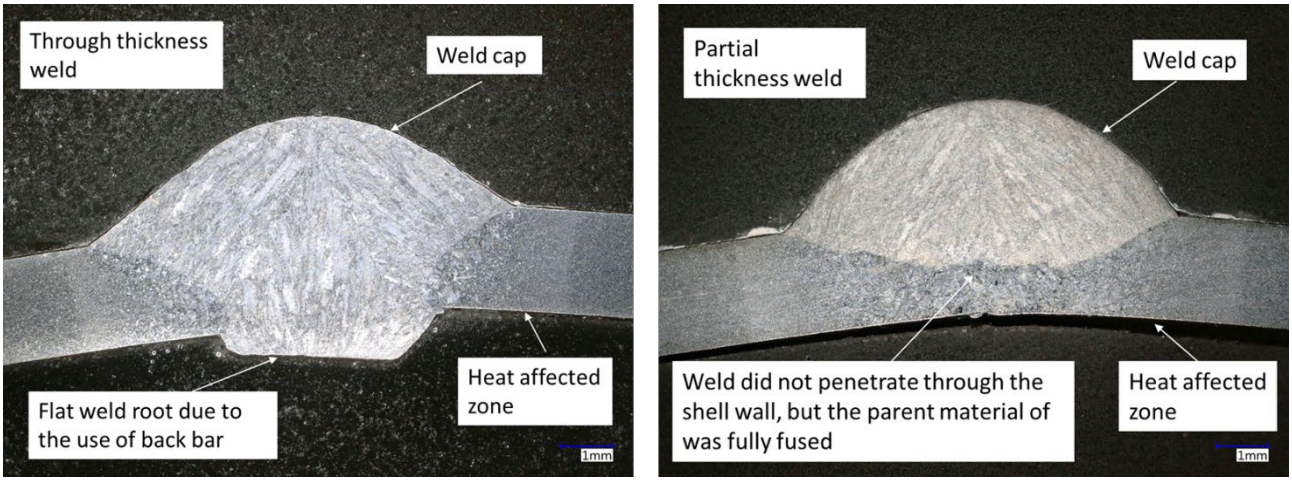

Figure 13 Light microscope images showing cross-sections comparing through thickness and partial thickness welds

It can be seen from the light microscope image, that the weld has fully fused the pressure vessel walls, despite the visual appearance suggesting a lack of fusion and penetration. This finding confirmed the finding that the visual appearance of the welds is not a good predictor for the weld quality and whether or not the weld would meet the radiography requirements for weld quality.

5.5 Chemical Analysis - Optical Emission Spectroscopy (OES)

Coupons of material were cut from all sixteen pressure vessel shells These coupons were taken to Element Materials Technology, Sheffield, for chemical analysis. The results of the OES tests are summarised in Table .

Table 8 Summary of OES chemical analysis results for the pressure vessel shell materials

Sample No	Vessel No	C	Cr	Cu	Fe[1]	Mn	Ni	P	S	Si	Meets Standard
22675	1A	0.12	0.02	0.01	99.3	0.21	0.01	0.017	<0.005	0.2	Yes
22684	2A	0.15	0.02	0.04	99.2	0.37	0.02	0.014	0.017	0.08	Yes
22692	3A	0.17	0.04	0.01	99.1	0.42	0.02	0.02	0.007	0.11	Yes
22700	4A	0.15	0.01	0.01	99.2	0.49	0.01	0.019	0.11	0.02	Yes
22708	5A	0.18	0.02	0.04	99.3	0.2	0.02	0.011	<0.005	0.15	Yes
22716	6A	0.16	0.03	0.01	99.1	0.37	0.01	0.023	0.012	0.17	Yes
22725	7A	0.21	0.03	0.02	99.4	0.15	0.02	0.012	<0.005	0.05	Yes
22733	8A	0.18	0.05	0.01	99.4	0.19	0.01	0.033	0.005	0.03	Yes
22741	9A	0.2	0.03	0.01	99.4	0.15	0.02	0.039	<0.005	0.03	Yes
22749	10A	0.06	0.02	0.01	99.2	0.49	0.01	0.021	0.008	0.14	Yes
22757	11A	0.19	0.02	0.01	99.4	0.19	0.01	0.023	<0.005	0.06	Yes
22765	12A	0.19	0.02	0.01	99.5	0.16	0.01	0.018	<0.005	0.05	Yes
22773	13A	0.07	0.06	0.01	99.1	0.45	0.02	0.21	0.014	0.22	Yes
22781	14A	0.17	0.03	0.01	99.2	0.35	0.02	0.023	0.009	0.13	Yes
22789	15A	0.06	0.02	<0.01	99.3	0.5	0.01	0.017	0.005	0.01	Yes
22797	16A	0.08	0.02	0.01	99.2	0.4	0.01	0.023	0.018	0.19	Yes

[1] Fe content is calculated

Overall, the chemical analysis of the coupons taken from the 16 pressure vessel shells showed that the chemical composition of the material used to fabricate the vessels was consistent with one or more of the steel grades recommended for use in BS EN 10207:2017 (BSI, 2017).

5.6 Tensile Testing

Coupons of material were cut from all sixteen pressure vessel shells for tensile testing. The tensile test coupons were taken to Element Materials Technology, Sheffield. Four blanks were supplied from each pressure vessel to produce tensile test specimens. Three tensile tests were carried out on each of the pressure vessels used in the study.

An example of a failed tensile test specimen is shown in Figure 14. It can be seen that the steel either side the fracture had necked slightly, i.e. the width of the gauge section has been slightly reduced.

Figure 14 Studio photographs of failed tensile test specimen

Overall, the tensile test samples did not exhibit significant large scale plastic deformation before failure. This showed that the steel grades used to produce the pressure vessel shells had limited ductility. The limited ductility of the shell materials suggest that during operation the pressure vessel shells may not show significate signs of deformation prior to bursting.

The tensile test results for the yield strength and the ultimate tensile strength (UTS) for the shell materials are summarised in Table 9. Overall, the tensile test results obtained for all 16 small pressure vessels showed that the yield strength and UTS of the shell materials were consistent with the steel grades recommended for use in BS EN 10207:2017 (BSI, 2017).

Table 9 Summary of tensile test results for the pressure vessel shell materials

Vessel No	Yield Stress (MPa)	Average (MPa)	Ultimate Tensile Strength (MPa)	Average (MPa)	Consistent with standard
1A	378 379 379	379	445 447 443	445	Yes
2A	287 288 292	289	421 422 433	425	Yes
3A	300 302 308	303	441 445 447	444	Yes
4A	333 333 325	330	438 442 438	439	Yes
5A	320 320 323	321	452 451 455	453	Yes
6A	323 324 323	323	452 452 454	453	Yes
7A	335 354 352	347	470 491 479	483	Yes
8A	360 364 366	363	477 477 483	479	Yes

Vessel No	Yield Stress (MPa)	Average (MPa)	Ultimate Tensile Strength (MPa)	Average (MPa)	Consistent with standard
9A	328 334 334	332	474 473 476	474	Yes
10A	283 282 282	282	391 386 386	388	Yes
11A	359 355 360	358	491 489 490	490	Yes
12A	367 357 356	360	477 480 478	478	Yes
13A	302 300 299	300	408 407 406	407	Yes
14A	325 324 327	326	461 456 463	460	Yes
15A	251 243 238	244	351 340 340	344	Yes
16A	283 283 280	282	398 398 395	397	Yes

6 Assessment

6.1 Compliance

One compressor (15) was supplied without the required documentation. This was a silent run compressor purchased directly from its manufacturer rather than one of the trade equipment suppliers. Additionally, this compressor had numerous other faults including:

- No inspection port.
- Poor weld quality on external welds.
- Unreliable pressure relief.
- Quantity of entrapped material within the vessel.

The presence of this compressor within the UK market was a potential cause for concern.

SPVR includes requirements that vessels can be both inspected internally and drained. The inspection ports were either absent or ineffective on 25% of the vessels (6, 8, 14, 15). However, as all of these vessels had effective condensate drains which may have provided access for inspection, meaning that these vessels were not considered non-compliant with SPVR. The effectiveness of undertaking an internal inspection using condensate drains was not assessed.

The necessity of internal inspections was highlighted by the indications of internal corrosion on half the vessels which were inspected (3, 9, 10, 11, 13 and 16). While this was deemed to be localised or minor and therefore not significant, it was present on vessels supplied as new and there would be inevitable deterioration while the compressors were in use. Four of these vessels (3, 9, 10 and 16) were all manufactured by a single vessel manufacturer (VM3).

Three compressors failed the essential safety requirement in SPVR that the maximum allowable pressure could not be exceeded by more than 10% and were therefore non-compliant. These were vessels 8 (14%), 11 (25%) and 14 (11%). In two cases the amount by which the requirement was exceeded was small. Additionally, four PRVs (4, 11, 12 and 13) failed the BS EN ISO requirements. Despite not meeting the accuracy requirements for PRVs, with the exclusion of compressor 11, there was no evidence that this would lead to over-pressurisation of the vessel.

Half of the vessels that could be inspected (1, 3, 7, 10, 12, 15) gave indications of poor weld quality (including 2 that also had early indications of corrosion).

Borescope examination gave early indications of potential issues on ten of the twelve vessels where inspection was undertaken. These were subsequently confirmed during more detailed examination. This confirms the usefulness of this as an inspection technique and reinforces the need for functioning inspection ports.

6.2 Burst Pressure

Failure pressure ranged from 61 to 89 barg. This is significantly above the maximum working pressure for these compressors which ranged from 7 to 11 barg. The ratio of maximum working pressure to burst pressure ranged from 6.1 to 11, therefore the lowest burst pressure provides a factor of safety of 6.

Burst testing provided no evidence that any of these compressors presented a heightened risk of premature failure. However, given that only a single model of each type of compressor was tested, it is impossible to conclude that these tests were representative of each type of compressor and did not represent outlying results. To fully demonstrate that these compressors were safe would require testing of a statistically significant sample size

It should be noted that these compressors were tested “as new”, these compressors will deteriorate in service. This may be more significant for those compressors with poorly located drain valves and/or non-functioning inspection ports (due to an inability to fully drain condensate from the vessel and/or carry out internal inspections). The ESR’s of SPVR includes requirements that “*the mechanical qualities must be maintained throughout the period of use of the vessel for the intended purpose*” and “*the vessels must, bearing in mind their prescribed use, be adequately protected against corrosion*”. Increased and/or unchecked rates of corrosion could result in reduction in vessel wall thickness and, ultimately, compromise the mechanical integrity of the vessel.

6.3 Materials Characterisation

The chemical testing showed that that the shell material of all sixteen pressure vessels that the composition of the shell materials were consistent with the steel grades recommended for use in BS EN 10207:2017 (BSI, 2017).

Additionally, tensile testing showed that the yield strength and UTS of the shell materials for all sixteen vessels were consistent with the expected mechanical properties of the steel grades recommended for use in BS EN 10207:2017 (BSI, 2017).

Borescope examination identified potential welding issues on six of the twelve vessels where inspection was possible. Sectioning the vessels and examining further revealed that each vessel contained multiple examples of different types of fault (lack of fusion, lack of penetration, inclusions, cracking and porosity).

All of the welding on the sixteen pressure vessel shells failed to meet the pass criteria for BS EN 5817 Level B, and therefore failed to meet the requirements of BS EN 10207:2017.

It was not possible to establish any meaningful trends in the different vessels manufactured by the same manufacturer.

7 Conclusions

1. One compressor was supplied with multiple defects and without the required documentation. This was a silent run compressor purchased directly from its manufacturer rather than one of the trade equipment suppliers.

2. Three compressors failed the essential safety requirement in SPVR that the maximum allowable pressure must not be able to be exceeded by more than 10% and were therefore non-compliant. Although the possibility of over-pressurising the vessel is serious, it should be noted that in two cases the amount by which the requirement was exceeded was small.

3. SPVR includes requirements that vessels can be both inspected internally and drained. The inspection ports were either absent or ineffective on 25% of the vessels. Functioning condensate drains may provide alternative access for inspection, meaning that these vessels, were compliant with SPVR.

4. Internal inspection identified defects on ten of twelve vessels inspected, indicating the effectiveness of borescope inspection.

5. Burst testing provided no evidence that any of these compressors presented a heightened risk of premature failure.

6. The potential for compressors to deteriorate in service making the presence of defects more significant should be acknowledged.

7. All of the vessels were found to comply with the material requirements of BS EN 10207:2017 (BSI, 2017).

8. All of the welding on the 16 pressure vessel shells failed to meet the pass criteria for BS EN 5817 Level B.

9. It was not possible to establish any meaningful trends in the different vessels manufactured by the same manufacturer.

8 References

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9 Appendix A: Individual Summary Reports

For each of the vessels a summary report, including all information, was produced. It was intended that this summary report could be shared with equipment manufacturers to identify how their equipment had performed. Anonymised versions of these reports are included in this Appendix.

9.1 Summary Report Vessel 1

General Compliance Assessment

	Equip Manufacturer	**a**	
	Model	i. Vertical –	100 litre
	Vessel Manufacturer	VM1	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not Bottom Dead Centre (BDC)
A2.2	Vessel inspection port	Present	
A2.3	Pressure indication	Present	2 Pressure gauges
A2.4	Pressure relief	Present	PRV was CE marked
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	None	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<12.1 bar*** *and BS EN ISO 4126-1* ***7.97 to 8.63 bar***	Satisfactory	PRV marked as set at 8.3 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	N/A	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appeared poorly executed. External welds appear poorly executed on visual inspection.
A4.1.2	Corrosion		Clean interior with no rust evident.

Metallurgical Assessment

Equip Manufacturer	**a**	
Model	i. Vertical –	100 litre
Vessel Manufacturer	VM2	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.12	Yes
Cr	0.02	Yes
Cu	0.01	Yes
Fe	99.3	Yes
Mn	0.21	Yes
Ni	0.01	Yes
P	0.017	Yes
S	<0.005	Yes
Si	0.02	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	379	Yes
Ultimate Tensile Strength	445	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
11	**70**	**6.4**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1					X	Reject	**Fail**
Cir 2		X				Reject	
Long					X	Reject	

9.2 Summary Report Vessel 2

General Compliance Assessment

	Equip Manufacturer	**a**	
	Model	i. Vertical –	50 litre
	Vessel Manufacturer	VM2	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	
A2.3	Pressure indication	Present	2 Pressure gauges
A2.4	Pressure relief	Present	PRV was CE marked
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<12.1 bar*** *and BS EN ISO 4126-1* ***7.97 to 8.63 bar***	Satisfactory	PRV marked as set at 8.3 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appears good where seen.
A4.1.2	Corrosion		Clean interior with no rust evident.

Metallurgical Assessment

Equip Manufacturer	**a**	
Model	i. Vertical –	50 litre
Vessel Manufacturer	VM2	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.15	Yes
Cr	0.02	Yes
Cu	0.04	Yes
Fe	99.2	Yes
Mn	0.37	Yes
Ni	0.02	Yes
P	0.014	Yes
S	0.017	Yes
Si	0.08	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	289	Yes
Ultimate Tensile Strength	425	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
11	Not tested	

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1				X	X	Reject	**Fail**
Cir 2				X	X	Reject	
Long			X	X	X	Reject	

9.3 Summary Report Vessel 3

General Compliance Assessment

	Equip Manufacturer	**b**	
	Model	ii.	100 litre
	Vessel Manufacturer	VM3	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports
A2.3	Pressure indication	Present	2 Pressure gauges
A2.4	Pressure relief	Present	And over temperature cut out
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Satisfactory	PRV marked as set at 8 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Appearance of longitudinal weld is poor. Possible stop / start marks apparent.
A4.1.2	Corrosion		Minor surface rust evident.

Metallurgical Assessment

Equip Manufacturer	**b**	
Model	ii.	100 litre
Vessel Manufacturer	VM3	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.17	Yes
Cr	0.04	Yes
Cu	0.01	Yes
Fe	99.1	Yes
Mn	0.42	Yes
Ni	0.02	Yes
P	0.02	Yes
S	0.007	Yes
Si	0.11	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	303	Yes
Ultimate Tensile Strength	444	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**69**	**6.9**

Radiography

Weld	***Defect***						
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1			X	X	X	Reject	**Fail**
Cir 2		X		X		Reject	
Long			X	X	X	Reject	

9.4 Summary Report Vessel 4

General Compliance Assessment

	Equip Manufacturer	**c**	
	Model	iii.	50 litre
	Vessel Manufacturer	VM4	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	BDC
A2.2	Vessel inspection port	Present	2 Inspection ports
A2.3	Pressure indication	Present	2 Pressure gauges
A2.4	Pressure relief	Present	And over temperature cut out
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***9.6 to 10.4 bar***	Exceeds ISO 4126 upper limit.	PRV marked as set at 10 bar. Initial lift at 11 bar with reseat at 10 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appears good where seen.
A4.1.2	Corrosion		Clean interior with no rust evident.

Metallurgical Assessment

Equip Manufacturer	**c**	
Model	iii	50 litre
Vessel Manufacturer	VM4	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.15	Yes
Cr	0.01	Yes
Cu	0.01	Yes
Fe	99.2	Yes
Mn	0.49	Yes
Ni	0.01	Yes
P	0.019	Yes
S	0.011	Yes
Si	0.02	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	330	Yes
Ultimate Tensile Strength	439	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**79**	**7.9**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1			X		X	Reject	**Fail**
Cir 2			X	X		Reject	
Long			X	X	X	Reject	

9.5 Summary Report Vessel 5

General Compliance Assessment

	Equip Manufacturer	**d**	
	Model	iv.	50 litre
	Vessel Manufacturer	VM5	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports
A2.3	Pressure indication	Present	2 Pressure gauges
A2.4	Pressure relief	Present	And over temperature cut out
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Satisfactory	PRV marked as set at 8 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appears good where seen.
A4.1.2	Corrosion		Clean interior with no rust evident.

Metallurgical Assessment

Equip Manufacturer	**d**	
Model	iv.	50 litre
Vessel Manufacturer	VM5	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.18	Yes
Cr	0.02	Yes
Cu	0.04	Yes
Fe	99.3	Yes
Mn	0.2	Yes
Ni	0.02	Yes
P	0.011	Yes
S	<0.005	Yes
Si	0.15	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	321	Yes
Ultimate Tensile Strength	453	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**69**	**6.9**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1					X	Reject	**Fail**
Cir 2	X					Reject	
Long	X				X	Reject	

9.6 Summary Report Vessel 6

General Compliance Assessment

	Equip Manufacturer	**a**	
	Model	i	. 10 litre
	Vessel Manufacturer	VM1	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports
A2.3	Pressure indication	Present	2 Pressure gauges
A2.4	Pressure relief	Present	And over temperature cut out
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	None	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Fail	Inspection bungs could not be removed.
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***9.6 to10.4 bar***	Satisfactory	PRV marked as set at 10 bar. Initial lift at 10 bar with reseat at 8 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	N/A	
A4	**Additional Comments**		
A4.1	Borescope Examination	Fail	
A4.1.1	Weld quality	N/A	
A4.1.2	Corrosion	N/A	

Metallurgical Assessment

Equip Manufacturer	**a**	
Model	i.	. 10 litre
Vessel Manufacturer	VM1	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.16	Yes
Cr	0.03	Yes
Cu	0.01	Yes
Fe	99.1	Yes
Mn	0.37	Yes
Ni	0.01	Yes
P	0.023	Yes
S	0.012	Yes
Si	0.17	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	323	Yes
Ultimate Tensile Strength	453	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	Not tested	

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1		X				Reject	**Fail**
Cir 2					X	Reject	
Long		X			X	Reject	

9.7 Summary Report Vessel 7

General Compliance Assessment

	Equip Manufacturer	**e**	
	Model	v.	50 litre
	Vessel Manufacturer	VM6	

	Inspection	***Result***	***Comment***
	Scope of Supply		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	No	Adaptor supplied.
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	
A2.3	Pressure indication	Present	
A2.4	Pressure relief	Present	And over temperature cut out
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	None	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	Outlet pressure only.
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***9.6 to10.4 bar***	Satisfactory	PRV marked as set at 10 bar. Initial lift at 10 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	N/A	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appears poorly executed – spatter and inclusions.
A4.1.2	Corrosion		Interior surface clean with no evidence of rust.

Metallurgical Assessment

Equip Manufacturer	**e**	
Model	v	50 litre
Vessel Manufacturer	VM6	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.21	Yes
Cr	0.03	Yes
Cu	0.02	Yes
Fe	99.4	Yes
Mn	0.15	Yes
Ni	0.02	Yes
P	0.012	Yes
S	<0.005	Yes
Si	0.05	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	347	Yes
Ultimate Tensile Strength	483	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**89**	**8.9**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X					Reject	**Fail**
Cir 2	X				X	Reject	
Long					X	Reject	

9.8 Summary Report Vessel 8

General Compliance Assessment

	Equip Manufacturer	**f**	
	Model	vi. 50 litre	
	Vessel Manufacturer	VM7	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports.
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	
A2.5	Stop/start switch	None	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Fail	Inspection ports could be opened even using significant force.
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<7.7 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Exceeds EN 1012-1 upper limit	PRV marked as set at 8 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	N/A	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Fail	
A4.1.1	Weld quality	N/A	
A4.1.2	Corrosion	N/A	

Metallurgical Assessment

Equip Manufacturer	**f**	
Model	vi. 50 litre	
Vessel Manufacturer	VM7	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.18	Yes
Cr	0.05	Yes
Cu	0.01	Yes
Fe	99.4	Yes
Mn	0.19	Yes
Ni	0.01	Yes
P	0.033	Yes
S	0.005	Yes
Si	0.03	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	363	Yes
Ultimate Tensile Strength	479	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
7	Not tested	

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X				X	Reject	**Fail**
Cir 2	X				X	Reject	
Long	X				X	Reject	

9.9 Summary Report Vessel 9

General Compliance Assessment

	Equip Manufacturer	**g**	
	Model	vii.	50 litre
	Vessel Manufacturer	VM3	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports.
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	And over temperature cut off.
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Satisfactory	PRV marked as set at 8 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Weld quality appeared satisfactory.
A4.1.2	Corrosion		Narrow strip of corrosion adjacent to longitudinal weld

Metallurgical Assessment

Equip Manufacturer	g	
Model	vii.	50 litre
Vessel Manufacturer	VM3	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.2	Yes
Cr	0.03	Yes
Cu	0.01	Yes
Fe	99.4	Yes
Mn	0.15	Yes
Ni	0.02	Yes
P	0.039	Yes
S	<0.005	Yes
Si	0.03	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	332	Yes
Ultimate Tensile Strength	474	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**84**	**8.4**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X				X	Reject	**Fail**
Cir 2		X			X	Reject	
Long	X				X	Reject	

9.10 Summary Report Vessel 10

General Compliance Assessment

	Equip Manufacturer	**b**	
	Model	ii.	50 litre
	Vessel Manufacturer	VM3	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports.
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	And over temperature cut off.
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Satisfactory	PRV marked as set at 8 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Appearance of longitudinal weld is poor. Possible stop / start marks apparent.
A4.1.2	Corrosion		Minor surface rust evident.

Metallurgical Assessment

Equip Manufacturer	b	
Model	ii.	50 litre
Vessel Manufacturer	VM3	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.6	Yes
Cr	0.02	Yes
Cu	0.01	Yes
Fe	99.2	Yes
Mn	0.49	Yes
Ni	0.01	Yes
P	0.021	Yes
S	0.008	Yes
Si	0.14	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	282	Yes
Ultimate Tensile Strength	388	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**84**	**8.4**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X					Reject	**Fail**
Cir 2	X					Reject	
Long		X				Reject	

9.11 Summary Report Vessel 11

General Compliance Assessment

	Equip Manufacturer	**h**	
	Model	viii	50 litre
	Vessel Manufacturer	VM8	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports.
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	
A2.5	Stop/start switch	None	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<8.8 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Exceeds EN 1012-1 and ISO 4126 upper limits.	PRV marked as set at 8 bar. Initial lift at 9 bar with reseat at 8 bar.
A3.5	Stop/start switch	N/A	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Weld quality appeared satisfactory.
A4.1.2	Corrosion		Minor surface rust evident.

Metallurgical Assessment

Equip Manufacturer	h	
Model	viii	50 litre
Vessel Manufacturer	VM8	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.19	Yes
Cr	0.02	Yes
Cu	0.01	Yes
Fe	99.4	Yes
Mn	0.19	Yes
Ni	0.01	Yes
P	0.023	Yes
S	<0.005	Yes
Si	0.06	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	358	Yes
Ultimate Tensile Strength	490	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
8	**88**	**11**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X					Reject	**Fail**
Cir 2	X			X		Reject	
Long	X		X	X		Reject	

9.12 Summary Report Vessel 12

General Compliance Assessment

	Equip Manufacturer	**j**	
	Model	ix.	50 litre
	Vessel Manufacturer	VM9	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	And over temperature cut out.
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Exceeds ISO 4126 upper limit.	PRV marked as set at 8 bar. Initial lift at 9 bar with reseat at 8 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appeared poorly executed. External circumferential welds appeared poorly executed.
A4.1.2	Corrosion		Clean interior with no rust evident.

Metallurgical Assessment

Equip Manufacturer	j	
Model	ix.	50 litre
Vessel Manufacturer	VM9	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.19	Yes
Cr	0.02	Yes
Cu	0.01	Yes
Fe	99.5	Yes
Mn	0.16	Yes
Ni	0.01	Yes
P	0.018	Yes
S	<0.005	Yes
Si	0.05	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	360	Yes
Ultimate Tensile Strength	478	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	Not tested	

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X			X		Reject	**Fail**
Cir 2	X					Reject	
Long				X	X	Reject	

9.13 Summary Report Vessel 13

General Compliance Assessment

	Equip Manufacturer	**a**	
	Model	x.	24 litre
	Vessel Manufacturer	VM10	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present	2 Inspection ports.
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	CE Marked.
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	None	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Exceeds ISO 4126 upper limit.	PRV marked as set at 8.3 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	N/A	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Longitudinal weld appears good where seen.
A4.1.2	Corrosion		Clean interior, some superficial rust spots.

Metallurgical Assessment

Equip Manufacturer	**a**	
Model	x.	24 litre
Vessel Manufacturer	VM10	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.07	Yes
Cr	0.06	Yes
Cu	0.01	Yes
Fe	99.1	Yes
Mn	0.45	Yes
Ni	0.02	Yes
P	0.021	Yes
S	0.014	Yes
Si	0.22	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	300	Yes
Ultimate Tensile Strength	406	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	Not tested	

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1		X		X		Reject	**Fail**
Cir 2	X					Reject	
Long	X				X	Reject	

9.14 Summary Report Vessel 14

General Compliance Assessment

	Equip Manufacturer	**k**	
	Model	xi.	33 litre
	Vessel Manufacturer	VM11	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	Satisfactory	
A1.5	Certificate of conformity	Supplied	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	None	
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	And over temperature cut out.
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	None	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	N/A	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<9.9 bar*** *and BS EN ISO 4126-1* ***9.6 to 10.4 bar***	Exceeds EN 1012-1 upper limit.	PRV marked as set at 10 bar. Initial lift at 10 bar with reseat at 8 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	N/A	
A4	**Additional Comments**		
A4.1	Borescope Examination	Fail	
A4.1.1	Weld quality	N/A	
A4.1.2	Corrosion	N/A	

Metallurgical Assessment

Equip Manufacturer	**k**	
Model	xi.	33 litre
Vessel Manufacturer	VM11	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.17	Yes
Cr	0.03	Yes
Cu	0.01	Yes
Fe	99.2	Yes
Mn	0.35	Yes
Ni	0.02	Yes
P	0.023	Yes
S	0.009	Yes
Si	0.13	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	326	Yes
Ultimate Tensile Strength	460	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
9	Not tested	

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1	X					Reject	**Fail**
Cir 2	X			X		Reject	
Long	X				X	Reject	

9.15 Summary Report Vessel 15

General Compliance Assessment

	Equip Manufacturer	**I**	
	Model	xi.	50 litre
	Vessel Manufacturer	Not supplied	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	None	
A1.5	Certificate of conformity	None	No dataplate present
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	None	
A2.3	Pressure indication	Present	1 Pressure gauge marked in BarA. This means the gauge will indicate atmospheric pressure even when the vessel is empty.
A2.4	Pressure relief	Present	Not CE marked.
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	A substantial amount of loose steel peening material was recovered from the inside of the vessel
A3.2	Vessel inspection port	N/A	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<8.8 bar*** *and BS EN ISO 4126-1* ***7.97 to 8.63 bar***	Fail	PRV function variable.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	

A4	Additional Comments		
A4.1	Borescope Examination	Fail	
A4.1.1	Weld quality	N/A	External welds were poor quality with visible stop / start marks. Possibly manually welded.
A4.1.2	Corrosion	N/A	

Metallurgical Assessment

Equip Manufacturer	**I**	
Model	xi.	50 litre
Vessel Manufacturer	Not supplied	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.06	Yes
Cr	0.02	Yes
Cu	<0.01	Yes
Fe	99.3	Yes
Mn	0.5	Yes
Ni	0.01	Yes
P	0.017	Yes
S	0.005	Yes
Si	0.01	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	244	Yes
Ultimate Tensile Strength	344	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
8	**78**	**9.75**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1					X	Reject	**Fail**
Cir 2			X		X	Reject	
Long			X	X	X	Reject	

9.16 Summary Report Vessel 16

General Compliance Assessment

	Equip Manufacturer	**g**	
	Model	vii.	100 litre
	Vessel Manufacturer	VM3	

	Inspection	***Result***	***Comment***
A1	**Scope of Supply**		
A1.1	Type of Equipment	Compressor	
A1.2	UK plug	Yes	
A1.3	User instructions	Satisfactory	
A1.4	Maintenance instructions	None	
A1.5	Certificate of conformity	None	
A2	**Compressor Equipment**		
A2.1	Condensate drain	Present	Not BDC
A2.2	Vessel inspection port	Present6	2 Inspection ports.
A2.3	Pressure indication	Present	2 Pressure gauges.
A2.4	Pressure relief	Present	And over temperature cut out
A2.5	Stop/start switch	Present	
A2.6	Emergency stop	Present	
A3	**Functionality test**		
A3.1	Condensate drain	Functional	
A3.2	Vessel inspection port	Functional	
A3.3	Pressure indication	Satisfactory	
A3.4	Pressure relief *Requirements from BS EN 1012-1* ***<11 bar*** *and BS EN ISO 4126-1* ***7.68 to 8.32 bar***	Satisfactory	PRV marked as set at 8 bar. Initial lift at 8 bar with reseat at 6 bar.
A3.5	Stop/start switch	Functional	
A3.6	Emergency stop	Functional	
A4	**Additional Comments**		
A4.1	Borescope Examination	Successful	
A4.1.1	Weld quality		Weld quality appears satisfactory.
A4.1.2	Corrosion		Minor surface rust spots.

Metallurgical Assessment

Equip Manufacturer	**g**	
Model	vii.	100 litre
Vessel Manufacturer	VM3	

Chemical Analysis		
Element	***Wt %***	***Meets standard***
C	0.08	Yes
Cr	0.02	Yes
Cu	0.01	Yes
Fe	99.2	Yes
Mn	0.4	Yes
Ni	0.01	Yes
P	0.023	Yes
S	0.018	Yes
Si	0.19	Yes
Meets Standard Overall		**Yes**

Mechanical Properties		
Tensile Results	***MPa***	***Meets Spec for steel***
Yield Strength	282	Yes
Ultimate Tensile Strength	397	Yes
Meets Specification Overall		**Yes**

Max. Supply Pressure (PS) (barg)	***Burst Pressure (barg)***	***Ratio***
10	**61**	**6.1**

Radiography

Weld Defect							
	Lack of fusion	***Lack of penetration***	***Crack***	***Inclusions***	***Porosity***	***Accept Weld***	***Pass/Fail***
Cir 1			X		X	Reject	**Fail**
Cir 2					X	Reject	
Long	X			X		Reject	

HSE is required under the Regulations on Accredited Market Surveillance (GB RAMS) to undertake periodic market research to assess the levels of compliance of work equipment with product supply legislation.

This compliance assessment reports on the findings of sixteen air compressors subjected to documentary and physical checks against the requirements of the Simple Pressure Vessels Safety Regulations 2016.

The catastrophic failure of compressors such as these has the potential for significant injury and substantial property damage, so ensuring they are safe is a key requirement.

These types of compressors are commonly found in a wide range of workplaces and are used as an energy source for powering pneumatic machinery, tools, inflating tyres, cleaning, painting, medical applications and for many more purposes.

For the purposes of this work, smaller, cheaper compressors were purposefully chosen to test. All compressors were identified via open-search methods and purchased from online retailers.

Every compressor tested was found to have a failure of some description, ranging from the absence, or non-compliance of accompanying documentation, to physical defects such as poorly placed drain valves, non-functional inspection ports and defects in the welding quality.

The results of the testing and the findings of the report will be passed to HSE's product safety and market surveillance unit to contact the manufacturers, importers and suppliers of the equipment.

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