EIGA Safety Information

Prepared by WG-2 Safety Info 21/19

Cylinder Valves - Design Considerations

EIGA companies have historically encountered safety issues with the use of cylinder valves. The introduction of standards, such as EN ISO 10297, *Gas cylinders -- Cylinder valves -- Specification and type testing*, has made significant improvements to mitigate the risk of in-service issues.

Historically, some basic design defects have occurred amongst valves from various manufacturers. These defects are not necessarily limited to valves that have been recently introduced into the market, but also those that have been long established.

These valves could have already passed type approval testing in accordance with the relevant standards; however, these standards may not highlight all potential defects. This Safety Information identifies additional failure modes and items that should be considered when selecting new valve designs and can also apply to other accessories including pressure regulator or filling connectors.

1. Overstressing

Components that are exposed to high stresses due to gas pressure, including the valve body, gland nut and lower spindle are at risk of deformation or cracking. In addition, repetitive torque stresses / mechanical fatigue, for example, of the lower spindle and upper spindle, or high assembly stresses, (valve stem threads) are also at risk of deformation or cracking. For components potentially subject to stress corrosion, see Sections 3 and 4.

A typical instance of this effect is the failure of the lower spindle soft seal retention skirt, as illustrated in Figure 1.

Individual components except the valve inlet, that is the threads that connect the valve to the cylinder, should be designed to operate at a combined stress level due to pressure and assembly torque with a safety factor of at least 4. Particular care needs to be taken to prevent stress concentration areas in the design such as sharp internal corners. Whatever the safety factor, the assembly should comply to fail safe requirement as described in Section 5.

Additionally, threads that connect the valve to the cylinder (both taper and parallel types) should be tested during type approval to prove there is no visible (external) deformation or cracking when assembled to a torque of 1.5 times the maximum recommended in EN ISO 13341, *Gas cylinders -- Fitting of valves to gas cylinders*.

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Figure 1: broken lower spindle seal retention skirt

2. Stress corrosion cracking

Tensile stress in brass, especially in non-stress relieved, thin-section components, and in the presence of moisture, can lead to failure by stress corrosion cracking. Typical examples of this effect are residual pressure valve (RPV) back plugs, See Figures 2 and 3.

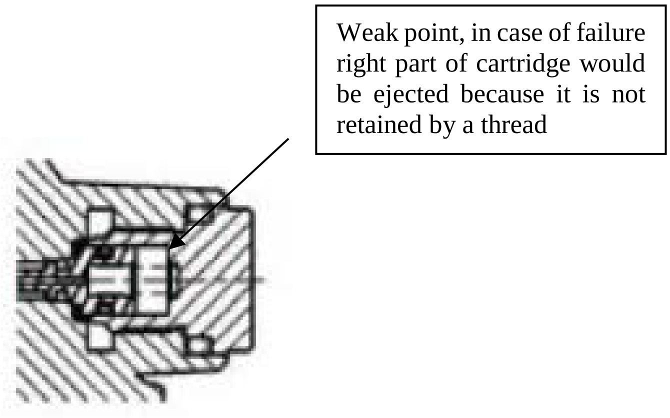

Figure 2: Inadequate design of residual pressure valve back plug

Figure 3: defective residual pressure valve plug

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Stress corrosion cracking can be avoided by:

- suitable material selection, for example stainless steel, if compatible with the gas service;
- reduction in stress level, by:
  - o improving geometry;
  - o reducing stress related to assembly torque; and
  - o performing stress relief treatment
- change of stress from tensile to compressive, by improving configuration of design, see Figure 5,
- elimination of residual corrodent in the highly stressed components, for example, after cleaning or leak testing.

For further information see Section 5.

3. Incorrect choice of materials

It is strongly recommended that the guidance of ISO 11114 *Gas cylinders -- Compatibility of cylinder and valve materials with gas contents*, Parts 1 and 2 is followed for material selection, especially for gas wetted materials.

Metallic components used in the gas wetted area during use including the safety device in activated and non-activated positions, including the springs for residual pressure valves and valve with integrated pressure regulators (VIPR), shall be of a suitable material, for example, copper beryllium springs for oxygen service, and of a suitable design.

Correct selection of gas wetted non-metallic materials is also of great importance. Problems can arise in oxygen and corrosive gas service, but compatibility issues of carbon dioxide and other gases also need specific attention.

Brass alloys containing more than 3.5% of lead and high stress brass should be avoided due to sensitivity to stress corrosion. Brass used shall meet the requirements of the appropriate standards. Test data on chemical composition and mechanical properties including tensile data and impact values should be requested and retained by the valve manufacturer as part of their quality assurance system.

4. Poor mechanical design

The following are specific examples of poor mechanical design that have historically caused incidents in service.

- For some valve designs with a rotating lower spindle, inadvertent unscrewing of the valve operating mechanism can occur in service. It can be prevented by having a finer pitch thread on the gland nut (1) than is used on the lower spindle. If this is implemented, even if the gland nut becomes loosened in service it will not be ejected.

- A lower spindle with bleed hole to the gland nut chamber prevents trapping of liquefied gases, such as carbon dioxide in the gland chamber after filling. Extremely high pressures can be generated in the gland nut area, causing gland nut threads to stretch if trapped liquids are not allowed to escape. Stretching of the thread would then allow the gland nut to be loosened.

- Valve designs which have the outer spindle thread running in the gland nut (1) which is itself threaded into the valve body (2) have a history of loosening the gland nut following opening and closing of the valve. High levels of gland nut torque alone are not sufficient to prevent this happening in long-term service. These designs could need the gland nut to have separate mechanical locking, for example by a cover nut (3) retained by a thread of opposite direction to the gland nut thread, see Figure 4.

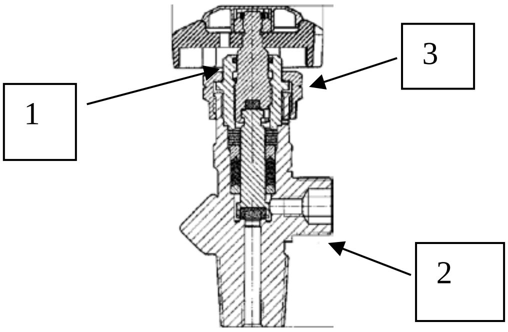

Figure 4: Valve with cover nut

- Pressure relief devices, which have a retaining cap-nut (1a) in tensile stress can lead to cracking due to stress corrosion cracking or over-stressing due to over torque during assembly, see Figures 5 and 6.

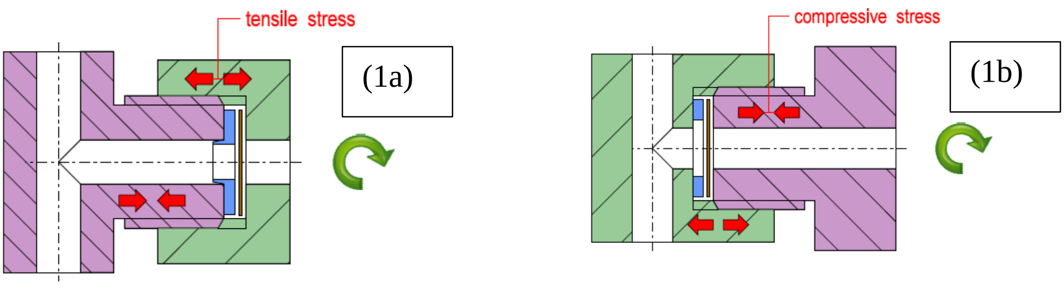

Figure 5: change bad tensile stress (left) to Figure 6 good compressive stress (right)

A change of design to use a retaining plug-nut (1b) in compressive stress will overcome this problem, as long as stress is not higher than allowed for the material (see Section 1).

- For cylinder valves other than VIPR, the use of filters for oxygen and oxidizing gases service is not recommended. The flow of gas through a cylinder valve is bi directional. A filter, which accumulates debris in one direction, will discharge it in the other, thus leading to a risk of ignition through adiabatic compression in one direction and particle impact in the other.

For VIPR valves, filters are used to protect sensitive areas of the valve, for example, the regulator. In these cases, an analysis of the design should be undertaken on a case-by-case basis to decide where a filter should be positioned, if at all. However, bi-directional flow through a filter in a VIPR should be avoided.

In all cases where a filter is installed for oxygen and oxidizing gases bi-directional flow is not recommended, due to collected particles can be ejected from the filter when the flow direction is reversed.

5. Fail safe design

5.1 New valves

Valve designs shall be examined to identify the likely modes of failure. The failure can be the result of a combination of different design and/or operational problems previously described, for example, overstress plus stress corrosion cracking plus incompatible material.

For this reason, EIGA strongly recommends fail-safe design in cylinder valves.

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Then, if a failure were to occur, the design can ensure that the valve will still function at a basic level (i.e. it can open and close safely) and no unsafe gas release or ejection of parts under pressure can take place. In this case, the severity of any incident is significantly reduced, for example, the residual pressure device plug thread configuration, see Figure 7.

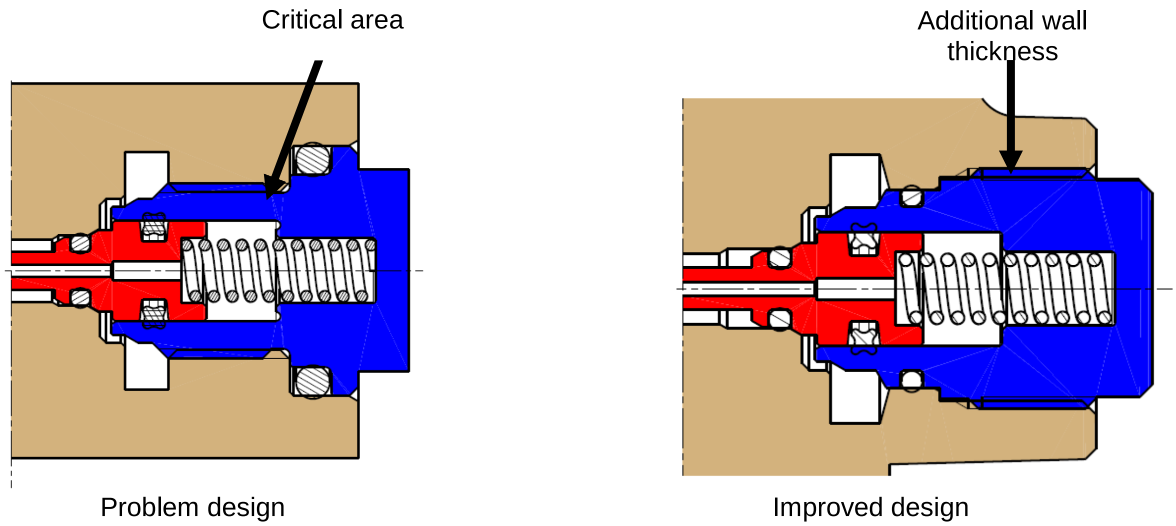

Figure 7: Improved valve design

5.2 Existing valves

For valves on the market which are not in line with best practice, the following possibilities exist:

- Removing the valve from service.
- Continuing in service but with conditions:
  - Perform a risk assessment to demonstrate there is no risk of hazardous ejection, *e.g.* valve guard acting as a shield.
  - Modification where parts are replaced with a new design to solve the specific root cause.
  - Addition of extra components to avoid hazardous ejection and permit a safe release of gas, if the primary components fail. Some examples of this approach are shown in Figure 8.
- Reducing the severity of service conditions, such as pressure.

Figure 8 Examples of revised designs

5. Tamper proof design

Historically, there have been incidents with unauthorised manipulation of valves. This can be due to many reasons, for example:

- Unauthorised filling, by removing residual pressure device;
- Removal of residual pressure device by the customer in order to empty the cylinder below the predefined residual pressure;
- Removal of high value metallic components for scrap sale; and
- Other improper use of a valve.

A valve that has been manipulated can often lead to an unexpected severe incident, for example, ejection of components under high pressure.

Whenever possible, it is recommended that external metallic components to the valve, particularly high pressure retaining, are designed to hinder manipulation or to make the manipulation easily visible, examples include tamper evident seal or the geometry of the residual pressure valve back plug fixing, see Figure 9. For existing valves, not following the above recommendation, a relevant inspection procedure prior to filling should be implemented.

Figure 9 Examples of tamper evident system and fixing geometry

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