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PRESSURE REGULATORS FOR HIGH PURITY APPLICATIONS

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REGULATOARE DE PRESIUNE FOLOSITE ÎN APLICAȚII DE MARE PURITATE

Funcția de bază a unui regulator de presiune este de a accepta un gaz de înaltă presiune dintr-un cilindru sau conductă, și de a reduce presiunea la un nivel sigur și potrivit pentru o anumită aplicație.

The basic function of a pressure regulator is to accept a high-pressure gas from a cylinder or pipe, and reduce the pressure to a safe level and suitable for a particular application.

Keywords: Regulators, high purity gases
Cuvinte cheie: Regulatori, gaze de înaltă puritate

1. Introduction

A pressure regulator is a control valve that uses no auxiliary source of power during operation. It controls pressure by varying flow as a function of the sensed difference between the actual and the desired value of pressure. Any unbalanced force, resulting from the pressure difference, moves a metering element, increasing or decreasing fluid flow to nullify the pressure error. In the space field, the term pressure regulator is generally accepted as meaning any device which maintains a predetermined upstream, downstream, or differential pressure by means of a pressure reducing control element. Since the primary component of any gas delivery system is the pressure regulator, it is appropriate to give serious attention to its selection. To properly design a regulator for high-purity service, it is first necessary to understand how a regulator functions, and how the various internal components can affect the gas purity.

2. Regulator function

The basic function of a pressure regulator is to accept a high-pressure gas from a cylinder or pipeline, and reduce its pressure to a safe level that is suitable for a specific application.

When selecting a regulator for high-purity service, the principal goal is to maintain the quality of the gas so that it has the same high level of purity when it leaves the regulator as it did when it entered. Selection criteria include the following: ● the gas must not be contaminated in any way by the materials with which it comes in contact. ● no air may leak into the gas scream. ● none of the gas may leak or be absorbed within the regulator.

While there are several differences between industrial and high-purity gas regulators, a brief review of their theory of operation, as well as a look at the common factors that influence their selection and application, should prove helpful in understanding how specialty gas regulators should be selected to achieve optimum performance.

A typical regulator is made up of two chambers: a body, which is exposed to high pressure, and a spring case or bonnet, which is exposed to atmospheric pressure. The diaphragm separates the two chambers.

The *body section* of a single-stage regulator contains a high-pressure inlet chamber, a low-pressure outlet chamber and a main valve assembly. The main valve separates the inlet and outlet chambers and controls the flow of gas between them.

The *spring case* contains the adjusting spring and hand knob. The spring case does not come in contract with the gas under normal conditions, and its material of construction will nor have a bearing on, maintaining gas purity. However, the spring case may contain important regulator features, such as panel mounting capability or captured venting, which may be required by the application.

3. Regulator operation

High-pressure gas enters the regulator through the inlet port beneath the main valve. A combination of forces, supplied by the marginal spring and the inlet pressure, acts on the main valve area (inlet force) to keep the main valve closed. As the adjusting knob is turned clockwise, the adjusting spring is compressed and a force is applied to the diaphragm. The diaphragm moves downward to open the main valve, and gas flows from the inlet chamber to the outlet chamber.

Gas pressure in the outlet chamber applies an upward force on the diaphragm. As the combined forces of the outlet pressure, marginal spring and inlet force equal the adjusting spring force, the diaphragm moves upward allowing the main valve to close. Gas flowing to the downstream system decreases the pressure beneath the diaphragm, and the cycle is repeated to maintain a constant pressure at the outlet of the regulator.

The outlet pressure will remain constant as long as the inlet pressure remains constant. However, during normal cylinder operation, the inlet pressure will decrease as the cylinder empties. The decrease in inlet pressure reduces the inlet force on the main valve, and there is a corresponding increase in outlet pressure. The rise in outlet pressure as inlet pressure decreases is known as the decaying inlet characteristic, which in most single-stage regulators is between five and seven psi. This means that the outlet pressure will rise approximately 70 to 100 kPa over the life of a cylinder if the pressure is not readjusted.

Dual-stage regulators minimize the effects of the decaying inlet characteristic. A dual-stage regulator is essentially two single-stage regulators in a single body. The first stage is preset at an intermediate pressure, normally 3500 kPa or below. This acts as the inlet pressure to the second stage. The second stage is adjustable and reduces the intermediate pressure to the desired working pressure. Since the second stage sees only minor variations in inlet pressure from the first stage, outlet pressure will remain constant throughout the life of a cylinder.

4. Regulator selection factors

Several factors influence regulator selection, including materials of construction, application and gas service. The body of the regulator has the largest surface area exposed to the gas. The four materials most commonly used for the body of a specialty gas regulator are forged brass, brass bar stock, aluminum bar stock and 316 stainless steel bar stock. For highly corrosive service, materials such as nickel-plated brass, Hastelloy or Monel may be used.

The next consideration when selecting a regulator for rare and specialty gas service is to ensure that all wetted materials are compatible with the intended gas service. Also, it is important to select regulators that keep to a minimum the number of wetted materials, particularly plastic or elastomeric materials.

5. Diaphragms

The most common material used as the diaphragm for a regulator is Neoprene or some other rubber materials. Rubber diaphragms are hydrocarbon based and will allow the outgassing of hydrocarbons into the gas stream. Rubber diaphragms are also permeable and will allow the entrance of atmospheric contamination (oxygen and moisture) into the gas stream. The preferred material for the diaphragm in a high-purity regulator is 316 stainless steel. Stainless steel diaphragms are non-permeable, and are also corrosion resistant.

The seal between the regulator body and the diaphragm is important in maintaining gas purity. A poor seal creates a leakage point through which contaminants may enter the system. A metal-to-metal seal (metal body-to-metal diaphragm) is the most reliable, leak-free type of seal. An elastomeric seal can degrade over time, compromising the integrity of the seal. Some regulator designs incorporate a stainless steel diaphragm that may be lined with Teflon. Although the diaphragm is stainless steel, the seal is created between the regulator body and the Teflon liner. It is not as reliable as a metal-to-metal seal.

6. Main valve

This is the most important part of any regulator, and it is the single component most likely to fail if the regulator is not designed properly. The seat of a regulator must be soft enough to seal leak tight, while strong enough to maintain integrity under the high forces generated by the inlet pressure.

In addition, the seat material must resist chemical attack from a wide variety of gases and chemicals without breaking down or absorbing any of the gas components. It has been found that Teflon is the ideal material for a regulator seat. Teflon is completely inert and provides a gas-tight positive seal in the regulator.

The primary cause of regulator failure is when particles get trapped between the seat and the nozzle of the main valve. This restricts proper closing, allowing high-pressure gas to creep through to the low-pressure side of the regulator. If this creep is permitted to continue, the result will be a failed diaphragm or outlet_pressure gauge. For this reason, proper filtration is necessary. There are two sources of particulate the gas steam and assembly of the regulator.

If the gas stream were the only source of particulate, a filter placed anyplace in the system would be adequate. However, since tightening the pipe when installing pressure gauges and inlet connections also generates particles, the filter must be placed directly before the main valve to preclude damage from all particulate sources. The 10-micron sintered filter in the capsule is in the ideal location to prevent seat damage.

7. Applications

Before a regulator can be specified, four applications-related parameters must be evaluated: - Gas service; - Inlet pressure; - Outlet pressure; - Flow rate.

7.1 Gas service

Rare and specialty gases may be separated into categories based on their properties. Each of the categories represents a different challenge to the regulator selection process.

7.1.1 Inert Gases

Inert gases are the simplest gases to categorize. They are non-corrosive and are compatible with most materials. As a result of this broad compatibility, regulators for inert gas service are often under-specified.

High-purity gas regulators (both machined bar stock and forged) are usually acceptable for inert gas service. Ultra-high gas service, however, requires that stainless steel regulators be specified.

7.1.2 Corrosive gases

Corrosive gases present special challenges in the selection of regulators. In corrosive gas service, it is not a question if a regulator will fail, but rather when it will fail. Most of the gases classified as corrosive (e.g., HCl, chlorine and H_2S) are corrosive only in the presence of moisture. Therefore, it is critical that the gases are kept dry and that moisture is excluded from the system. Even the small amount of moisture contained in the CGA fitting and the regulator inlet can promote rapid corrosion of the regulator and downstream equipment.

For this reason, it is highly recommended that a purge assembly be included between the cylinder and the regulator to remove corrosive gases before cylinders are changed, as well as to remove air and moisture from the system following cylinder change.

Where wet corrosive gases are handled, it may be necessary to specify a regulator made of the more exotic materials, such as Monel or Hastelloy.

7.1.3 Toxic gases

Toxic gases present a potential safety hazard in the workplace, and special care must be exercised -to prevent their release into the atmosphere. Thus, it is extremely important/that regulators selected for toxic gas service is equipped to capture any release.

Two safety features are important in toxic gas service. The first is captured-vent capability, and the second is a pipe-away relief valve. In the event of a diaphragm failure, a captured vent will capture any vented gases and allow them to be piped away to a safe location for cleanup or exhaust.

Normally, the relief valve is allowed to exhaust to the atmosphere, but where toxic gases are involved, this relief valve must be piped to a safe location.

7.2 Inlet pressure

The standard inlet pressure rating for regulators is 20000 kPa. There are, however, high-pressure cylinders with ratings of 25000; 40000 and 42000 kPa. Special consideration must be given to regulators for these cylinders to ensure safety. In addition, many specialty gases are liquefied or are stored at low pressure. Selecting a regulator with a low-pressure inlet pressure gage will enable the user to assess the condition of a cylinder's contents. However, care must be exercised to assure that the regulator never be placed onto a cylinder with a higher internal pressure than either the regulator inlet pressure gauge or the pressure rating of the regulator.

7.3 Outlet pressure

Regulators are designed with different adjustment springs in the spring case to achieve a specific outlet pressure range. The low-end range is normally zero to 100 kPa.

The upper limit in a diaphragm-type regulator is zero to 3500 kPa. Selection of the proper range for the application will ensure that the regulator will operate in its optimum design range. For outlet pressure ranges higher than 3500 kPa, a piston-sensed regulator is normally used. In a piston-sensed regulator, the diaphragm is replaced with a piston that can withstand the higher forces generated by the high outlet pressure of the gas.

7.4 Flow rate

Flow requirements of most rare and specialty gas applications will be fairly low, and are expressed in liters per minute (1/m).

All regulator manufacturers supply flow performance charts (see Figure 1) as part of their standard catalog information.

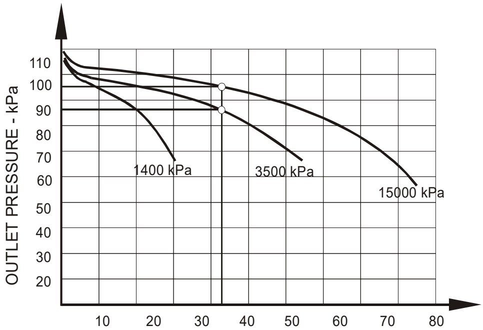

Fig. 1 Flow performance charts

7.4.1 Description of the proposed regulator

In figure 2 is presented a crossection of the piloted pressure regulator designed by the author for a hydrogen powered engine. This role of this regulator is to maintain constant pressure of oxygen supply for the engine. The main parts are presented below:

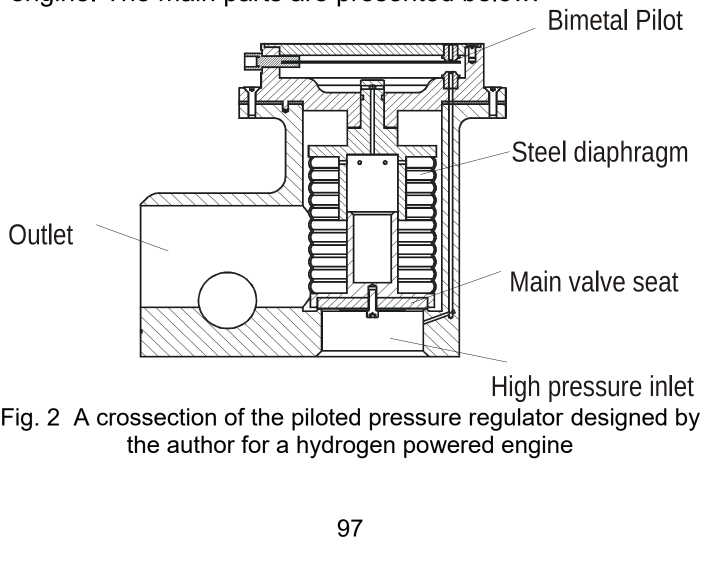

Fig. 2 A crossection of the piloted pressure regulator designed by the author for a hydrogen powered engine

More suggestive, the figure 3 presents an isometric projection of the proposed regulator.

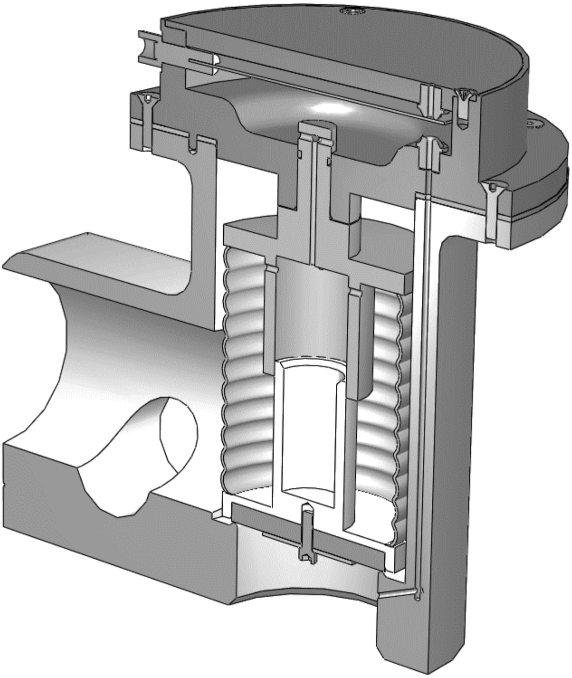

Fig. 3 Isometric projection of the proposed regulator

8. Conclusions

By paying attention to the factors that affect gas purity, proper selection of a regulator for high-purity applications becomes easy to design and produce.

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