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HOMOLOGATION TESTS OF SINGLE-STAGE R02 REDUCER

Summary. This article presents the results of homologation tests of an LPG reducer. Due to the material requirements of the LPG reducer in this case, the R02 reducer, designed by the joint-stock company AC Spółka Akcyjna, is used. Test procedures, which must be carried out, are also presented and generally explained with specified conditions for conducting the processes. The advantages of using the R02 are also presented. The properties of aluminium alloy 226, which is the body of the reducer, are characterized and are divided into four groups: technological features/qualitative indications, physical properties, mechanical features and chemical composition. The whole article is summarized with appropriate conclusions.

Keywords: LPG reducer; aluminium alloy 226; test procedures; R02 reducer

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1. INTRODUCTION

Rising oil prices and the instability of oil supplies have directed the attention of vehicle manufacturers and users towards substitute fuels. This term should be understood as fuels other than the previously used classical options, e.g., petrol and diesel. The justifications for such actions arise from the following premises [2,4,5,6,7,12]:

- Economic - searching for cheaper fuels and reducing car operations
- Ecological - searching for solutions in the field of environmental protection

The mentioned factors contribute to the increased interest in fuelling cars with LPG gas. In accordance with Polish law, certain rules are in force to ensure an adequate level of safety in the use of cars, including those equipped with gas supply systems.

Strict requirements for the use of an LPG reducer as a widespread product for everyday use match those set by the competent standardization committee, but also provide the highest quality of service. Test procedures help to determinate the utility of the equipment and also provide information about safe usage. The texture of a reducer must also meet appropriate technical requirements.

2. R02 REDUCER

The R02 single-stage reducer (Figure 1) is designed by AC Spółka Akcyjna for car sequential injection systems. The device is responsible for converting the LPG state from its liquid phase into a gaseous one (vaporization), reducing tension in the LPG vapour to the required value and keeping the pressure level in the regulator output in a strictly determined range [13].

Figure 1 presents the LPG reducer in three ways: a three-dimensional model in colour, a side view in black and white and the view from the top, also in black and white.

It is equipped with a thermal insulation system, a pressure stabilizing system and a universal mounting system.

The technical data for the R02 (Table 1) emphasize the advantages of using it, which include:

- small dimensions
- excellent thermal efficiency
- resistance to LPG contamination
- stable feeding, independent of gas cylinder inlet pressure
- low pressure drops at high loads
- stable adjustments
- elbow connector system
- mounting with a single, centrally located bolt

Table 1

Technical data on the R02

| | |
|----------------------------------|--|
| Material | Two aluminium castings and a cover made of hard and resistant plastic material |
| Weight | Reducer - 850 g Complete kit – 1,156 g |
| Dimensions [mm] | 125x122x89 |
| Maximum inlet pressure | 3 MPa |
| Outlet pressure | Adjustable, 0.9-1.5 bar |
| Voltage electrovalve | 12 VDC |
| Coil power | 11 W |
| Electrovalve connector | Amp Superseal socket |
| Gas inlet diameter [mm] | Ø 6.0 MI0x1 |
| Gas outlet diameter [mm] | Ø12 |
| Water connector diameter [mm] | Ø16 |
| Maximum engine power | 100 kW/136 km |
| Type approval number | E8-67R-01 6865 |
| Compensation pressure input [mm] | Ø4 |

3. TEST PROCEDURES FOR THE LPG REDUCER

The LPG reducer, as an appliance in everyday use, is susceptible to wear. To verify whether it is efficient, test procedures are conducted according to standards established by the competent standardization committee [8,9,10].

Test procedures are executed in the two different parts of the reducer, which are referred to as ‘classes’:

- Class 1 - a part of the regulator being in contact with the liquid LPG
- Class 2 - a part of the regulator contained the vaporized LPG

Table 2 presents the actual test procedures conducted at the lab, which apply both to Class 1 and Class 2.

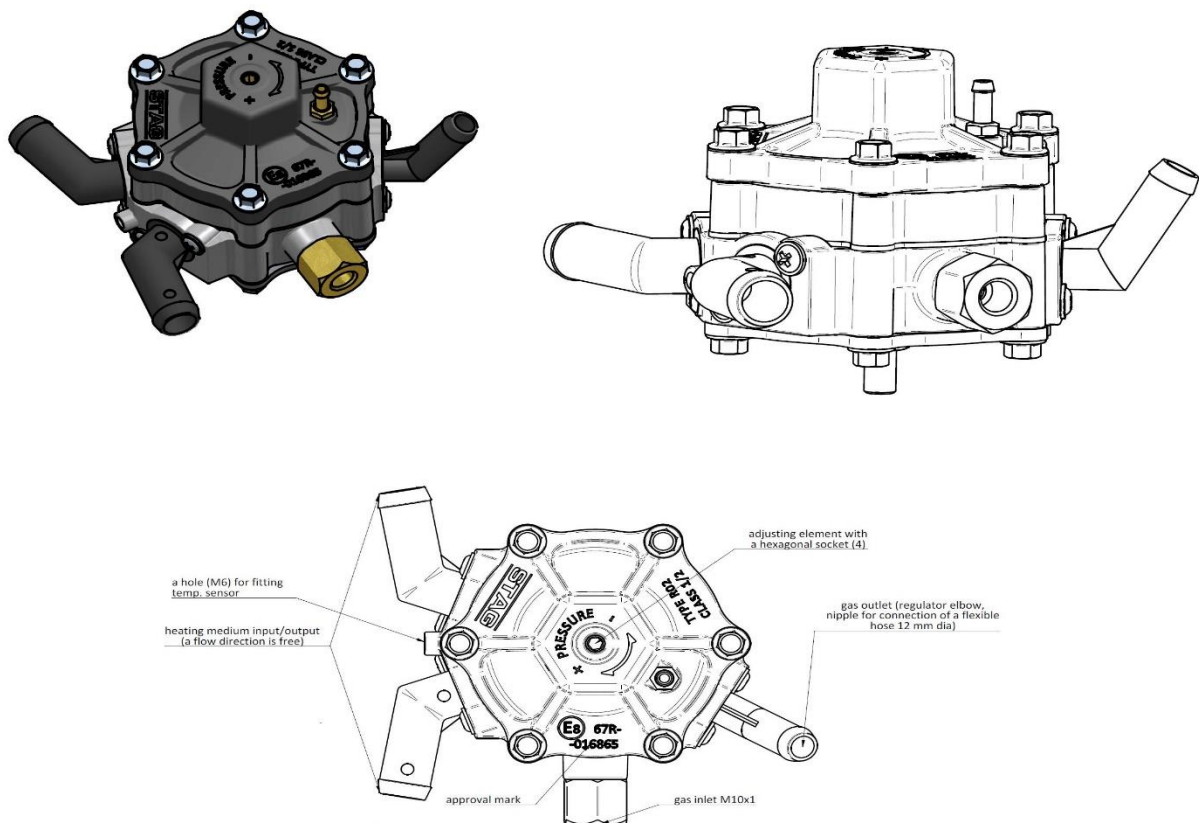


Fig. 1. The R02 reducer

Table 2

Test procedures for the LPG reducer

| | Test pressure/time (Class 1) | Comments | Test pressure/time (Class 2) | Comments |
|--|------------------------------|---|------------------------------|---|
| Overpressure test under hydraulic conditions | 6,750 kPa /min | Rupture and permanent distortion are tested | 1,015 kPa /min | Rupture and permanent distortion are tested |
| External leakage test | 0 to 4,500 kPa/min | - | 0 to 675 kPa /min | - |
| High temperature test | 4,500 kPa /min | 8 h of tempering | 675 kPa /min | 8 h of tempering |
| Low temperature test | 4,500 kPa /min | 8 h of tempering | 675 kPa /min | 8 hours of tempering |
| Endurance | - | - | - | - |

| | | | | |
|--|---|---|---|---|
| LPG compatibility test for synthetic materials | - | Maximum change in volume and change in mass, after air tempering, are tested | - | Maximum change in volume and change in mass, after air tempering, are tested |
| Resistance to dry heat | - | Allowable change in tensile strength and allowable change in ultimate elongation are tested | - | Allowable change in tensile strength and allowable change in ultimate elongation are tested |
| Ozone ageing | - | Cracking of test piece is tested | - | Cracking of test piece is tested |
| Corrosion resistance | - | - | - | - |
| Compatibility with heat exchange fluid | - | Maximum change in volume, change of mass after air tempering, allowable change in tensile strength and allowable change in ultimate elongation are tested | - | Maximum change in volume, change of mass after air tempering, allowable change in tensile strength and allowable change in ultimate elongation are tested |

It is required that the leakage cannot be greater than 15 cm³/h.

3.1. External leakage test

The external leakage test is conducted at:

- Room temperature (+20°C)
- Low temperature (-20°C)
- High temperature (+120°C)

3.2. Endurance test

The endurance test (Table 3) is conducted at a rate of six cycles/min. The total number of cycles during the test is 50,000. The testing medium is air [1]. Subsequently, the external leakage test is conducted after every endurance test.

Table 3

Endurance test parameters

| | Number of cycles | Test pressure | External leakage test pressure |
|--|------------------|-------------------------|--------------------------------|
| Room temperature cycling - part 1 (+20°C) | 47,500 | 700 kPa | 0 to 700 kPa over 1 min |
| Room temperature cycling - part 2 (+20°C) | 500 | From 700 kPa to 350 kPa | 0 to 700 kPa over 1 min |
| High temperature cycling - part 1 (+120°C) | 500 | 700 kPa | 0 to 700 kPa over 1 min |
| High temperature cycling - part 2 (+120°C) | 500 | From 700 kPa to 350 kPa | 0 to 700 kPa over 1 min |
| Low temperature cycling - part 1 (-20°C) | 500 | 350 kPa | 0 to 350 kPa over 1 min |
| Low temperature cycling - part 2 (-20°C) | 500 | From 350 kPa to 175 kPa | 0 to 350 kPa over 1 min |

It is required that the leakage cannot be greater than 15 cm³/h.

- The general external leakage test is conducted again after the endurance test is finished.

3.3. LPG compatibility test for synthetic materials

The following is required:

- Maximum change in volume of a sample: 20%
- The change in mass after air tempering must be greater than -5%

3.4. Resistance to dry heat

The following is required:

- Allowable change in tensile strength cannot be greater than 25%
- Allowable change in ultimate elongation from -30% to +10%.

3.5. Corrosion resistance

One sample is tested according to ISO 9227 over 144 h under salt spray. The second is tested according to ISO 6957 by immersion in ammonia for 24 h.

After the corrosion resistance test, the previous tests are carried out again, namely:

- Overpressure hydrostatic test
- External leakage test
- High temperature test
- Low temperature test

3.6. Compatibility with heat exchange fluid

The following is required:

- Maximum change in volume of a sample: 20%
- Change in mass after air tempering must be greater than -5%
- Allowable change in tensile strength cannot be greater than 25%
- Allowable change in ultimate elongation: from -30% to +10%

4. MATERIAL USED AS A REDUCER BODY: ALUMINIUM ALLOY (DIN 226)

The material used as reducer body must provide excellent thermal insulation and resistance to LPG contamination [3,11].

Table 4 presents the properties of aluminium alloy 226, which are divided into four groups (technological features/qualitative indications, physical properties, mechanical features and chemical composition) as shown below.

Table 4

Properties of aluminium alloy 226

| | | | |
|--|---|--------------------|---------------------|
| Technological features/qualitative indications | Strength at elevated temperature (to 200°C) | GOOD | |
| | General resistance to corrosion | LOW | |
| | Machinability | GOOD | |
| | Castability | GOOD | |
| | Polishing | MEDIUM | |
| | Resistance to hot tearing | GOOD | |
| | Pressure tightness | MEDIUM | |
| | Weldability | NOT RECOMMENDED | |
| | Decorative anodizing | INSUFFICIENT | |
| | Shock resistance | LOW | |
| Physical properties | Density | kg/dm ³ | 2.76 |
| | Specific heat | J/g*K | 0.88 |
| | Linear shrinkage at high pressure | % | 0.4-0.6 |
| | Electric conductivity | MS/m | 13-17 |
| | Modulus of elasticity | kg/mm ² | 7,500 |
| | Thermal conductivity at 20°C | W/m*K | 110-120 |
| | Linear thermal expansion from 20°C to 100°C | 1/K | 21x10 ⁻⁶ |
| | Suggested casting temperature in pressure die | °C | 630-710 |

| | | | |
|----------------------|-----------------------|-------------------|-----------|
| Mechanical features | Tensile strength | N/mm ² | 240-310 |
| | Yield strength | N/mm ² | 140-240 |
| | Elongation | % | 0.5-3 |
| | Brinell hardness | HB | 80-120 |
| Chemical composition | Si | % | 8.0-11.0 |
| | Fe | | Max. 1.0 |
| | Cu | | 2.00-3.50 |
| | Mn | | 0.10-0.5 |
| | Mg | | 0.10-0.50 |
| | Cr | | Max. 0.10 |
| | Ni | | Max. 0.30 |
| | Zn | | Max. 1.20 |
| | Pb | | Max. 0.20 |
| | Sn | | Max. 0.10 |
| | Ti | | Max. 0.15 |
| | Individual impurities | | Max. 0.05 |
| | Global impurities | | Max. 0.25 |

5. CONCLUSIONS

Based on the analysis of the test results, the following final conclusions can be formulated:

1. The LPG reducer is subject to high technical requirements.
2. Elements of the gas installation must be highly durable and safe.
3. The reducer should be resistant to large temperature fluctuations when operational.
4. The reducer retains its performance and strength properties in the temperature range from -20 °C to + 120 °C.
5. The installation should be tight and the maximum leak should not exceed 15 cm³/h.
6. The material used for the production of the reducer body has natural anti-corrosion properties.
7. The aluminium body provides excellent thermal insulation and resistance to LPG contamination. Good thermal conductivity means that lower temperatures have a positive effect on the internal parts of the reducer and provide greater durability.
8. The material used to cast the reducer body was selected in such a way that the highest endurance parameters were obtained at the lowest cost.

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