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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 M10x1
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.

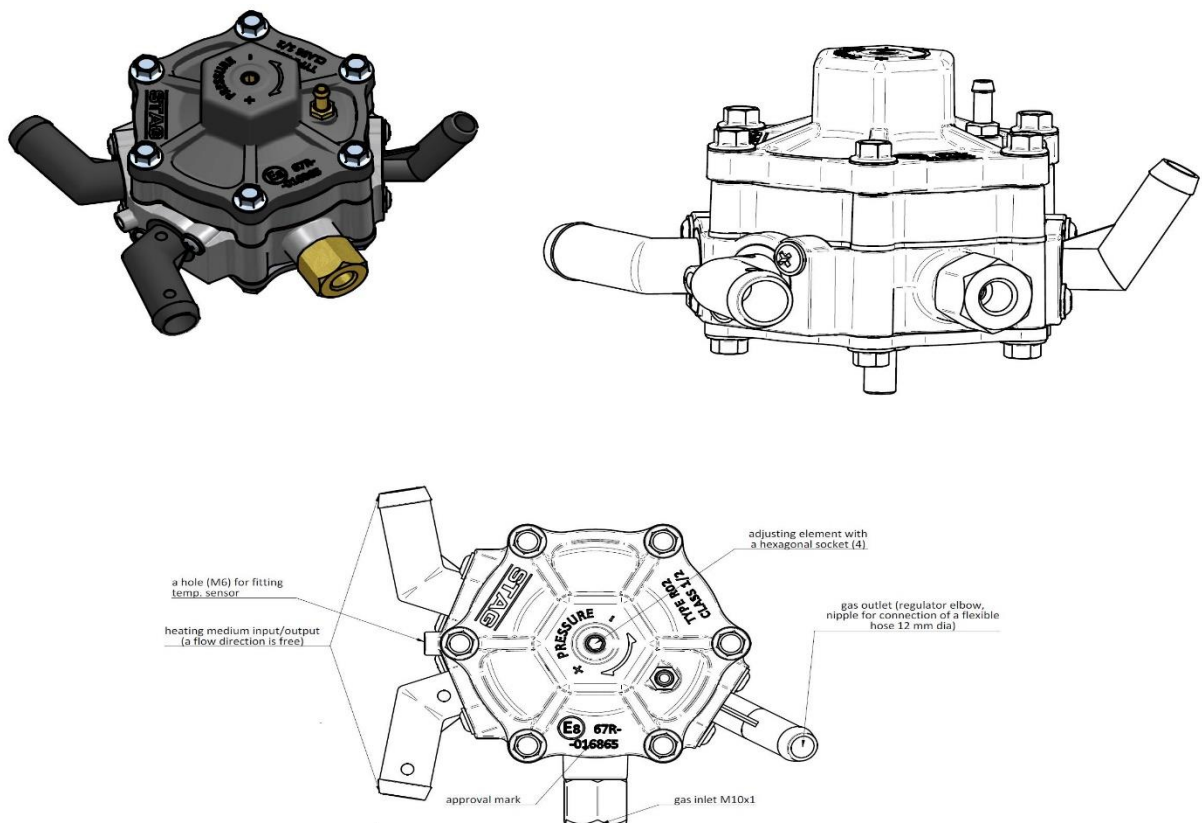


Fig. 1. The R02 reducer

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.

References

1. Beal R.E. 1999. "Methods and Equipment for Engine Coolant Testing". *Engine Coolant Testing* 4: 319-326. West Conshohocken, PA: ASTM International. ISBN 978-0-803-12610-7.

2. Čurčija D., I. Mamuzić, M. Buršak, J. Klüber. 2012. "Effects of cross-roughness on cold rolling process with greases". *Goriva i maziva* 51(2): 135-147.
3. GRAFEN. "EN AC-46000 AC-ALSI9CU3(Fe)". Available at: <http://info.grafen.ippt.pan.pl/bazy/bazy-materialowe/aluminium/aluminium-i-jego-stopoy/odlewnicze-stopoy-aluminium/itemlist/category/431-en-ac-46000-ac-alsi9cu3-fe.html?limitstart=0>.
4. Jacyna M., J. Merkisz. 2014. "Proecological approach to modelling traffic organization in national transport system". *Archives of Transport* 2(30): 43-56.
5. Jacyna-Golda I., M. Wasiak, M. Izdebski, K. Lewczuk, R. Jachimowski, D. Pyza. 2016. „The Evaluation of the Efficiency of Supply Chain Configuration”. In: *Proceedings of the 20th International Scientific Conference "Transport Means 2016"*. P.: 953-957. Juodkrante, Lithuania, Oct 05-07, 2016. ISSN: 1822-296X.
6. Luft S. 2007. *Dwupaliwowy silnik o zapłonie samoczynnym z wtryskiem ciekłego LPG do kolektora dolotowego*. [In Polish: *Dual-fuel, Self-ignition Engine with Liquid LPG Injection for Intake Manifold*.] Monograph No. 103. Printing Works of the Radom Polytechnic. ISSN 1642-5278.
7. Mikulski M., S. Wierzbicki, M. Smieja, J. Matijosius. 2015. „Effect of CNG in a fuel dose on the combustion process of a compression-ignition engine”. *Transport* 30(2): 162-171.
8. PN-EN 60068-2-11:2002. *Badania środowiskowe - Część 2-11: Próby. Próba Ka: Mgła solna*. [In Polish: PN-EN 60068-2-11:2002. *Environmental Research - Part 2-11: Trial. Ka's Attempt: Salt Spray*.] Warsaw: Polish Committee of Standardization.
9. PN-EN ISO 9227:2206. *Badania korozyjne w sztucznych atmosferach. Badania w rozpylonej solance*. [In Polish: PN-EN ISO 9227. *Corrosion Tests in Artificial Atmospheres. Research on Salt Spray*.] Warsaw: Polish Committee of Standardization.
10. PN-ISO 6957:1997. *Miedź i stopy miedzi - próba amoniakalna odporności na korozję naprężeniową stopów miedzi*. [In Polish: PN-ISO 6957:1997. *Copper Alloys - Ammonia Test for Stress Corrosion Resistance*.] Warsaw: Polish Committee of Standardization.
11. RAFFMETAL. "EN AB-46000". Available at: http://www.raffmetal.com/web_eng/prodotti.asp?q=1.
12. Romaniszyn K.M. 2007. *Alternatywne zasilanie samochodów benzyną oraz gazami LPG i CNG. Badania porównawcze dynamiki rozpędzania i emisji spalin*. [In Polish: *Alternative Fuel Supply for Cars with Gasoline and LPG and CNG Gases. Comparative Studies on Acceleration and Emission Dynamics*.] Warsaw: Scientific and Technical Publishers. ISBN 978-83-204-3308-1.
13. Schwartz S.A. 1999. "Silicate Stabilization Studies in Propylene Glycol". *Engine Coolant Testing* 4: 327-351. West Conshohocken, PA: ASTM International. ISSN 0066-0558.

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