Evaluation of Performance and Service Life of Low Pressure LPG Regulators for Home Use

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This paper presents the evaluation of LPG (Liquefied petroleum gas) regulators for home use. For the evaluation, several properties of the regulators were experimentally analyzed, such as the operation of safety device, the adjusting and lock-up pressure, the adjusting spring and the diaphragm, with respect to the used time of the regulators. Experimental results showed that the initial operation performances of regulators were degraded with increase of the service time and also showed that the degradation of the performance and material property could become serious after about six-year-use of the regulators.

Key Words : LPG Pressure Regulator

1. Introduction

LPG (Liquefied petroleum gas) has a large part of fuel for home use due to its clearness and convenience, and thus lots of gas appliances have been developed. Generally, the LPG is stored in a small size cylinder in a liquid state and is delivered to a home ; the LPG is vaporized in the cylinder to be supplied to a gas range through cylinder valves and pressure regulators. The pressure of gas in a LPG cylinder is up to 2~10 kg/cm^2, which is too high for the gas to be supplied directly to a gas range, thus pressure regulators are required to decompress the pressure of the LPG for safe combustion in a burner (KS B 6213, 2004 ; JIS B 8238, 1994 ; BS 3016, 1989 ; Korea Gas Safety Corporation, 2004).

A low pressure LPG regulator, which plays an important role in the supply of the LPG, is designed and manufactured to regulate the gas pressure properly for a gas range, regardless of the pressure variation in a LPG cylinder (Korea Gas Safety Corporation, 2004). However, as the using time of regulators increases, the aged regulators can have malfunctions : inappropriate pressure regulation that can lead to an instable combustion in a gas range ; too high pressure that increase a potential probability of gas accidents. Actually, gas accidents associated with the low pressure LPG regulator are being reported, even though not so many, every year. So, the reliability and the safety of the regulators are necessary for the safe use of the LPG.

In this paper, the performance characteristics and the service lives of low pressure LPG regulators were evaluated with respect to the age of the regulators.

2. Low Pressure LPG Regulator

A low pressure LPG regulator used to decompress the LP-gas pressure for the safe supply to a gas range consists of : the regulator body, the cap, the diaphragm, the adjusting spring, the spring retainer, the safety device and the valve body.

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High pressure LP-gas flows into the decompression room through the inlet of the regulator and flows out through the outlet after decompression by the lever and the valve body cooperating with the diaphragm and the diaphragm plate. The adjusting spring was installed on the upper side of the diaphragm plate to adjust the outlet pressure. The specification and the configuration of the low pressure LPG regulator analyzed in this study, which was manufactured by a aluminum die casting, are shown in Table 1 and Fig. 1.

The operation tests of the low pressure LPG regulators were carried out, as will be shown in Section 3, for the safety device, the adjusting and lock-up pressure, the adjusting spring and the diaphragm. For the tests, specimens were sampled in four areas of South Korea such as Gang-won, Chung-buk, Jeon-nam and Je-Ju ; the specimens included six unused regulators and 160 used regulators, whose ages were up to 1～10 years since the installation time for use.

Table 1 Specification of a low pressure LPG regulator

Inlet pressure (kg/cm^2)	Upper		15.6
	Lower		0.7
Out let pressure (mmH_2O)	Standard		280
	Adjusting pressure	Upper	330
		Lower	230
	Lock-up pressure		350
Operating pressure of safety device (mmH_2O)	Standard		700
	Opening		560～840
	Closing		504～840
Rated capacity (kg/hr)			4.0

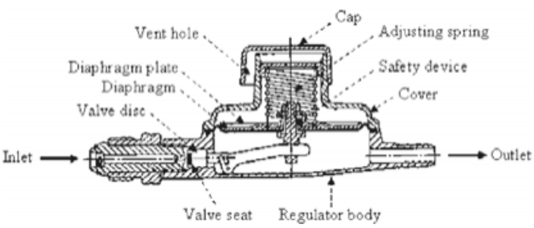

Fig. 1 Configuration of a low pressure LPG regulator

3. Experimental Results

3.1 Safety device

The operation tests of the low pressure LPG regulator's safety devices were carried out using a safety device tester ; the inlet of the regulator was closed, and opening pressure (the pressure when the safety device start to emit gas through a vent for decompression) and closing pressure (the pressure when the safety device start to re-close the vent) were measured with increasing the inner pressure pneumatically through the outlet.

In the safety device of a low pressure LPG regulator, a relief spring was installed to release the inner overpressure of the regulator, by the automatic ventilation of the regulating room, when the pressure of the regulating room exceeds the specific set pressure due to the increase of outlet pressure. For the low pressure LPG regulators tested in this study, the standard values of both the opening and closing pressures of the safety device were 840 mmH_2O, and lower limit of the opening and closing pressures were 560 mmH_2O and 504 mmH_2O respectively (Korea Gas Safety Corporation, 2004).

Figure 2 shows the result of the operation tests of the safety devices. In Fig. 2, the solid square (■) and the open circle (○) indicate the opening pressure and the closing pressure respectively. The dash-dot-dot-lines, which indicate the operating pressure range of unused regulators, were

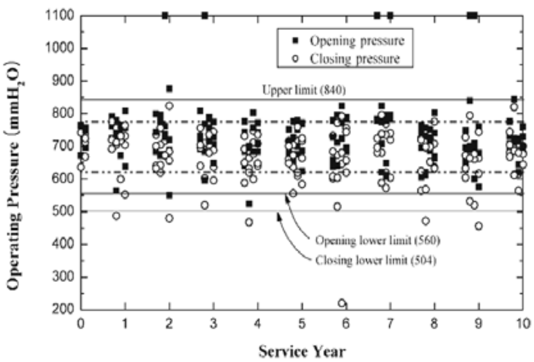

Fig. 2 Operating pressure distributions of the safety devices of low pressure LPG regulators at the inlet pressure of 10 kg/cm^2

drawn to compare easily the operating pressure range of the safety devices of used regulators with that of unused regulators. Experimental results showed that improper opening and closing operations of the safety devices appeared for the overall devices used for one year and over, and the results also showed that the operating pressure ranges of the used devices became wider than that of unused ones. The results imply that appropriate analysis and design are required for the safety device in that it is a very important one depressurizing unusual pressure increase that may occur in a regulator inside, a pipe line and a burner.

3.2 Adjusting and lock-up pressure

Adjusting pressure indicates the pressure of the gas flowing out through an outlet under given inlet pressure and outlet gas flow rate. The upper and lower limits of the adjusting pressure of low pressure LPG regulators were 330 mmH_2O and 230 mmH_2O respectively. The adjusting pressure must satisfy the lower and upper limit, regardless of the variation of inlet pressure (Korea Gas Safety Corporation, 2004).

Adjusting pressure was measured using a regulator performance tester; pressure values were measured for the inlet pressure of 0.7, 5.0, 10.0, and 15.6 kg/cm^2 with the outlet flow rate of 0, 5, 50 and 100% respectively. Figure 3 shows the result measured with 10 kg/cm^2 inlet pressure for 50% and 100% gas flow rate. In Fig. 3, the dash-dot-dot-lines, which were drawn to compare easily the values of used regulators with those of unused ones, indicate the adjusting pressure of unused regulators ranging from 282 mmH_2O to 295 mmH_2O.

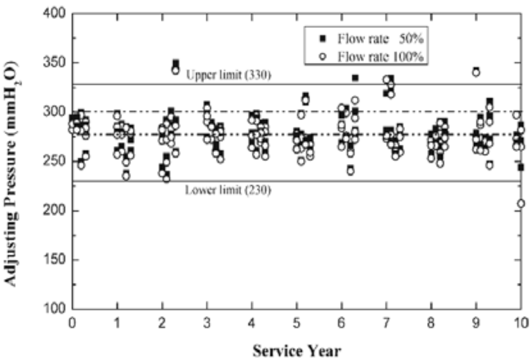

Fig. 3 Adjusting pressure distributions of low pressure LPG regulators at the inlet pressure of 10 kg/cm^2

The experimental result was highly consistent with general understanding that the adjusting pressure drops as the gas flow rate decreases. On the whole, the adjusting pressure ranges of the used regulators deviated from that of unused ones, and the pressure ranges of the regulators used for six years and over became wider than the ranges of the upper and lower limits. For the regulators used for seven years, the adjusting pressure values were not only over the upper limit but also widely distributed, which was contrary to the ideal adjusting pressure values expected to be densely distributed within the upper and lower limits. The results imply that a low pressure LPG regulator should be replaced with unused new one after use of about six years for the safety of the equipment as well as for LP-gas supply with optimum pressure level.

The lock-up pressure of a regulator is the inner pressure of the regulator when the outlet of the regulator was closed, and it actually means the inner pressure of regulating room after the gas line was shut off at a gas range or fuse-cocks in real time using. The lock-up pressure was not allowed to exceed the value of 350 mmH_2O for the low pressure LPG regulators analyzed in this study (Korea Gas Safety Corporation, 2004).

The lock-up pressure values were measured, similarly to the adjusting pressure measurement; the outlet was closed allowing no flux through it (0% flow rate), and the pressure values were measured with varying the inlet pressures of regulators such as 0.7, 5.0, 10.0, and 15.6 kg/cm^2. The results showed that the lock-up pressure became higher as the inlet pressure increased, as shown in Fig. 4. It was observed that the lock-up pressure of the regulators used for six years and over exceeded the maximal allowable pressure of 350 mmH_2O, excluding the regulators used for three years. Some of the regulators unsuccessfully manufactured were thought to be the reason of the exception of the three-year-used regulators.

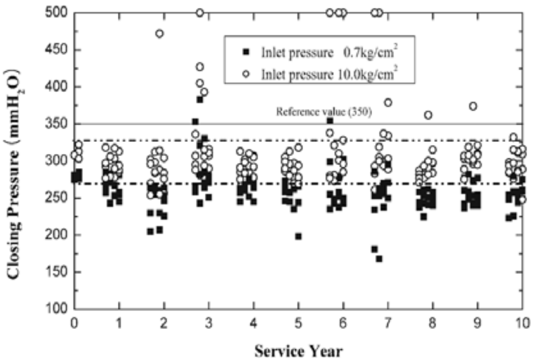

Fig. 4 Lock-up pressure distributions of low pressure LPG regulators

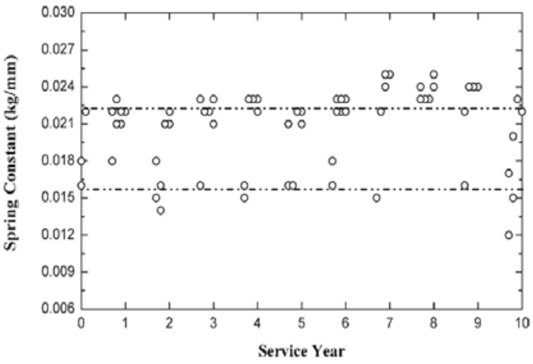

Fig. 5 Spring constant distributions of the adjusting springs of low pressure LPG regulators

The lock-up pressure range of the unused regulators was 275～322 mmH_2O as shown in Fig. 4, however, the lock-up pressure range of the regulators used for six and over years deviated from that of unused ones. Therefore, the proprieties of installation and maintenance should be considered for water or dirt not to flow into regulators and it is also required to develop and manufacture the diaphragm expected to have a high tolerance for the LPG.

It is concluded from the above results that the service time of the low pressure LPG regulators is about six years. It is recommended that the regulator should be replaced with unused new one before the six years to prevent the accidents originated from an improper operation.

3.3 Adjusting spring

Spring constants were measured using a spring tester for the adjusting springs of 80 used regulators and 4 unused regulators. To obtain tensile strength and elongation, tensile tests of the diaphragms extracted from the same specimen used in the spring constant measurement were carried out based on KS M 6518 (1994).

Figure 5 shows the measured spring constants of the adjusting springs and shows that the values of the spring constants became higher with the lapse of used time. Age hardening was thought to be the cause of the increase of the spring constants, and the age hardening was conspicuous for the regulators used for seven years. The spring constants showed a similar distribution for the regulators used under seven years but showed more wide distribution for the regulators used for seven years and over, when compared with that of unused ones.

Regulators should meet several requirements to regulate pressure properly : an adjusting spring should have proper spring constant and high degree of perpendicularity ; the adjusting spring must transmit and locate the load they received at the center of a diaphragm plate ; a valve seat must have a consistent contact with a valve disc. The cause of poor degree of perpendicularity is because warping and deflection appear after installation for a long time due to the too long free length of the spring or because the surface treatment of the spring end did not conducted in manufacturing processes. Hence, several studies on the adjusting spring need to be continued : the free length, the end surface treatment, the quality control and the durability improvement of the adjusting spring.

3.4 Diaphragm

The tensile strength of the diaphragm of regulators were measured and figured as shown in Fig. 6. The tensile strength of the diaphragm used for four years and under was relatively densely distributed, but that used for five years and over showed a considerably wide distribution. The tensile strength range of unused diaphragms was about 123.9～138.2 kg/cm^2. The change of the tensile strengths of the used diaphragms showed a somewhat different tendency depending on the

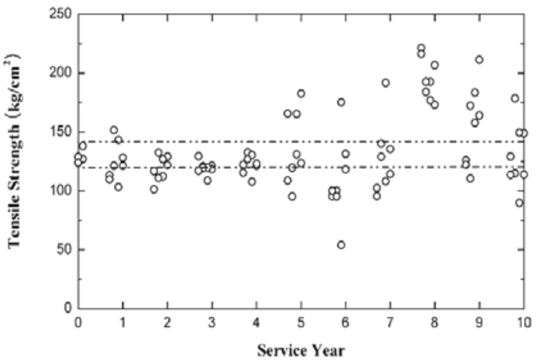

Fig. 6 Tensile strength distributions of the diaphragms of low pressure LPG regulators

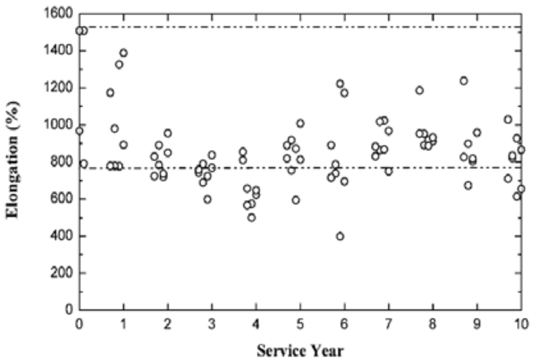

Fig. 7 Elongation distributions of the diaphragms of low pressure LPG regulators

used time : the tensile strengths of the diaphragms used for four years and under decreased a little compared with those of unused ones ; those used for five years and over, increased. The increased strength was thought to be caused by the age hardening, as similar to the case of the adjusting spring. Hence, it can be said that the diaphragms have a relatively stable material property, in consideration of only the tensile strength.

The results of the elongation measurements of the diaphragms showed, as shown in Fig. 7, a pretty similar distribution tendency to the tensile strength case ; the decrease and the increase of the elongation values were observed before and after 4-year-use. None of the elongation values of the used diaphragms exceeded the maximal elongation value, 1509.2%, of the unused diaphragms. To the contrary, for the diaphragms used for two years and over, some of the elongation values were under the minimal value, 789.9%, of the unused diaphragms, and the elongation values of the diaphragms used for six and over years were considerably widely distributed.

Considering the above results, the diaphragm is expected to maintain a proper performance to be used at least about six years. For the improvement of durability and reliability of the diaphragm, however, additional researches are required such as the effect of the plasticizer extracted from rubber material on the material properties of a diaphragm and the development of new rubber materials expected to improve the safety of the diaphragm.

4. Conclusions

In this paper, low pressure LPG regulators including new and used ones were experimentally analyzed, with respect to the used time of the regulators, to evaluate the performance and service life of the low pressure LPG regulator. The used regulators sampled for this study were 1～10 years in their used time.

Experimental results showed that the safety device of the regulators could not maintain its initial performance after one-year-use, and thus the opening and closing pressure ranges of the regulators used for one year and over deviated slightly from those of unused regulators. Similar results were observed for the adjusting and lock-up pressures to the opening and closing pressures. For the spring and the diaphragm of regulators, the degradation of the property caused by an age hardening was observed for the regulators used for six years and over. This remark implied that the spring and the diaphragm could be used with safety at least about six years.

From the whole results of the experiments, the service life of current low pressure LPG regulators in South Korea was evaluated as about six years. A regulator, however, is strongly recommended to be replaced with unused one for the prevention of accidents and for security.

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