航空技術學院學報　第十四卷　第一期　第 83－88 頁（民國一〇四年）
Journal of Air Force Institute of Technology, Vol. 14, No. 1, pp. 83-88, 2015

The Automatic Measuring and Calculation System For Water Heater Gas Consumption Inspection

Ming-Sen Hu[1], Chia-Rei Tao[2]
胡明森[1]、陶家瑞[2]
[1,2]Department of Military Meteorology, Air Force Institute of Technology
軍事氣象系副教授[1] 軍事氣象系講師[2] 空軍航空技術學院

Abstract

The gas consumption inspection is an important examination of gas water heaters before the products import or export from the factory. These tests are currently relied on manual operations to implement. It not only wastes a lot of manpower, but also takes a lengthy inspection time. For solving these problems, we developed an automatic measurement and calculation system for gas consumption inspection of gas water heaters. This system can calculate the gas consumption and consumption error of water heaters by measuring the temperature, pressure and flow of the gas and the water automatically, then determine whether or not the inspection is qualified and generate an output report finally.

Keywords: commodity inspection, gas consumption, automatic measurement

1. Introduction

According to the regulations of "Commodity Inspection Law"[1], products imported or domestic should complete and are qualified for the inspection procedures, in order to meet the safety, health and environmental requirements and consumer protection. Before each item is imported or sold, it should be attached a “commodity inspection logo”. The “products should be inspected” means that the announcement of the enforced inspection from the BSMI of Ministry of Economic Affairs[2] by assessing the safety of the use of these products. These “products should be inspected” announced currently including five categories i.e. electronics, electrical appliances, machinery, chemicals and toys, a total of 614 products [1].

The gas water heaters are products should be inspected in mechanical category. The gas water heaters can be divided into two types: instantaneous water heaters and storage water heaters[3]. These water heaters may be burned by liquefied petroleum gas (LPG) or natural gas. Base on the regulation of CNS 13605[5], gas water heaters must pass various examinations first, such as the gas consumption test, tightness test, gas thermal efficiency test, without ventilation combustion state test, noise test, ... etc., then they are allowed to sell on the market.

This research concerned with the gas

consumption inspection of gas water heaters. Such inspection currently rely on manual operations implemented by the inspection personnel to operate test equipments, and control the pressure and flow of gas and water into the water heater, and then record all of the pressure, flow and temperature values by operator, then the operator must complete the inspection report according to the recorded parameters and calculated gas consumptions. Such inspection wastes a lot of labor costs and takes longer time. There is even more artificial shortage of imprecise records. To solve these problems above, we applied the technology of automatic measurement [6,7] to develop an automatic measurement and calculation system for gas consumption inspection of gas water heaters. This system can simultaneously measure the temperatures, pressures and flows of both the gas and the water. The gas consumptions and consumption errors, automatically calculated based on these measurements, the results are used to determine the heater qualified or not, finally an original record report is generated as well.

2. The Automatic Measurement System Design

The instantaneous gas water heater has a cold water control switch. It is linked to the gas valve to opening or closing. When the cold water pass through the thermal exchanger of gas water heater, the cold water is heated up[3]. For the inspection of gas consumption, both the gas valve and water valve must be open first, and then regulate their pressures to activate the burning of water heater until the gas flow go steady. After that, the system start to measure various parameters, such as, the temperature, pressure and flow of the gas, the inlet temperature, pressure, flow and outlet temperature of the water. All of these acquired parameters would be used to calculate the gas consumption and consumption error for qualification judgment, and make an original inspection record report.

The system structure of the automatic measurement system is shown in Figure 1.

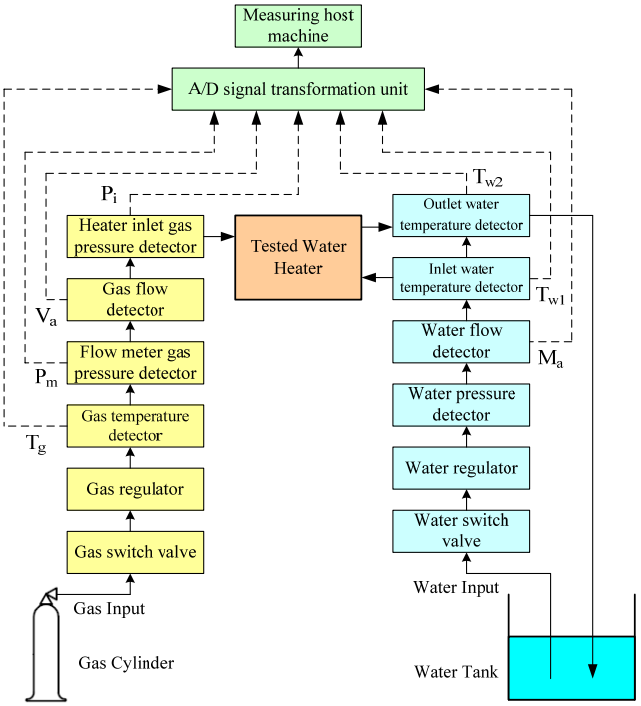

Figure 1. The automatic measurement system structure

The function of each constituent unit is as follows:

(1) Tested burner: gas water heater to be tested.

(2) Switch valves: to control the gas or water open or close.

(3) Regulator: to adjust the gas or water

pressure.

(4) Gas temperature detector: to detect the gas temperature (T_g).

(5) Gas pressure detector: to detect the gas pressure (P_m) through the flow meter.

(6) Gas flow meter: for gas flow (V_a) detection.

(7) Burner inlet pressure sensor: to detect the gas pressure (P_i) into burner after the pressure drop through flow meter.

(8) Water pressure detector: for the detection of cold water pressure into the burner.

(9) Water flow detector: water flow (M_a) detection of the cold water.

(10) Inlet temperature detector: to detect the cold water temperature (T_{w1}) before into the burner.

(11) Outlet water temperature detector: to detect the hot water temperature (T_{w2}) after it leave the burner.

(12) A/D signal transformer: Advantech USB-4711A data acquisition card, used to transform all analog signals from the flow, pressure and temperature detectors to digital data, then transfer the data to the monitoring host.

(13) Monitoring host: a personal computer (Notebook) with an automatic monitoring program, it can perform the two-stage measurement and calculation process in accordance with a predefined way.

The hardware design P&ID (piping and instrumentation diagram) of the measurement system is shown in Figure 2. Wherein SV is the switching valve and PV represents the pressure regulating valve. The detected parameters by PT-01 (detection of P_m), PT-02 (detection of P_i), TT-01 (detection of T_g), FT-02 (detection of M_a), TT-02 (detection of T_{w1}), TT-03 (detection of T_{w2}) and FT-01 (detection of V_a) are all connected to the analog inputs (AI1 ~ AI7) of USB-4711A acquisition card, served as the integrated interface of hardware and software. The internal configuration of the developed gas consumption measurement system entity is shown in Figure 3. Figure 4 shows the external view of the system entity.

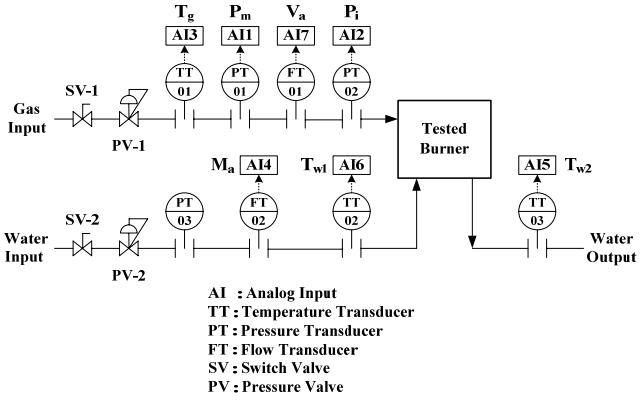

Figure 2. The measurement system P&ID diagram

Figure 3. The internal configuration of the gas consumption measurement system entity

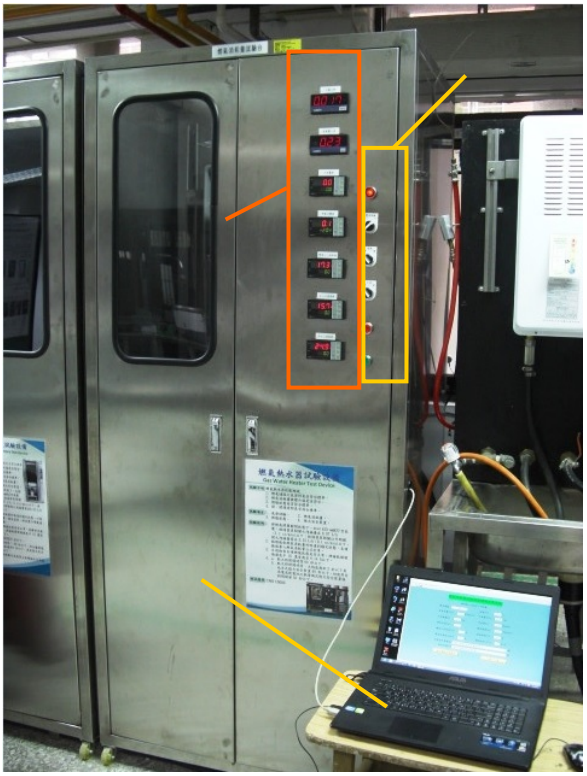

Figure 4. The external view of the gas consumption measurement system entity

3. The Measuring and Calculation Process

In this study, the designed system is based on the operational requirements of gas consumption inspection for water heaters, The flowchart is shown in Figure 5. The operator should set related inspection parameters first；then start the process of measuring and calculation. In initial stage, the system will check the gas flow has reached a stable state. After the gas flow reach stable, the system start a two-stage test of gas consumption inspection, the test time of each stage is T_1(minutes), the interval between the two stages is a pause time T_2(minutes). After the completion of each stage, the system will calculate the gas consumption and consumption error automatically based on the setting parameters and the measured values of temperature, pressure and flow. Finally, the consumption errors of the two stages are used to determine the products qualified or not (both two errors are less than 10%) and an original record report is generated as well.

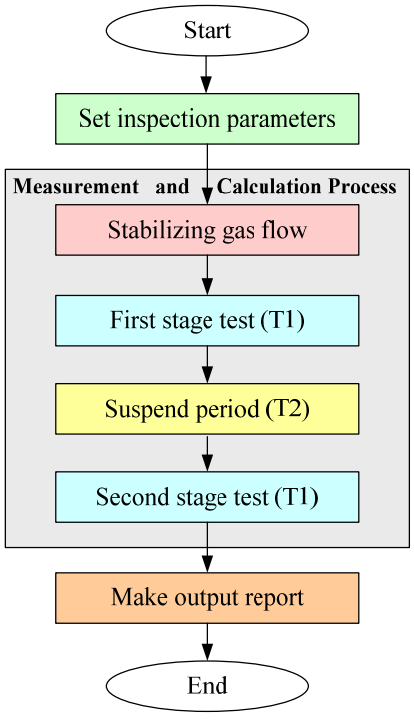

Figure 5. The system flowchart

The parameter-setting screenshot of the system is shown in Figure 6. This screen allows users to set the gas type, Wobei index(WI_s), room temperature, atmospheric pressure(B), testing gas standard pressure (P_s), specific heat of water(C), gas proportion(d_a), gas calorific value(Q), test time(T_1), pause time(T_2), maximum tolerance error(E_t), sampling rate(ΔT) (sec/time), and report file storage path.

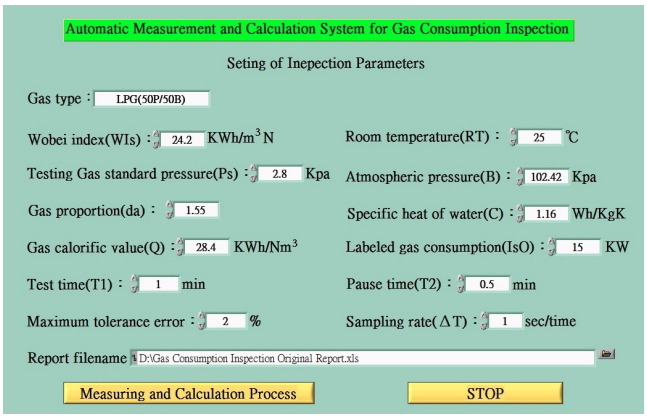

Figure 6. The screenshot of the setting of inspection parameters

The measurement and calculation screen of the system is shown in Figure 7, the left side of the screen displays all inspection parameters have been set, in the middle part shows the pressure chart, the temperature chart, the flow chart. These charts display the changes of various curves during test. The flow chart displays the curves of M_a and V_a, the pressure chart displays the curves of P_s, P_m and P_i, and the temperature chart displays the curves of T_g, T_{w1} and T_{w2}. By CNS 13603 standards, the output water temperature of the gas consumption test must be higher than the input water temperature 40 (± 5) ℃, i.e. T_{w2} - T_{w1} = 40 ± 5℃.

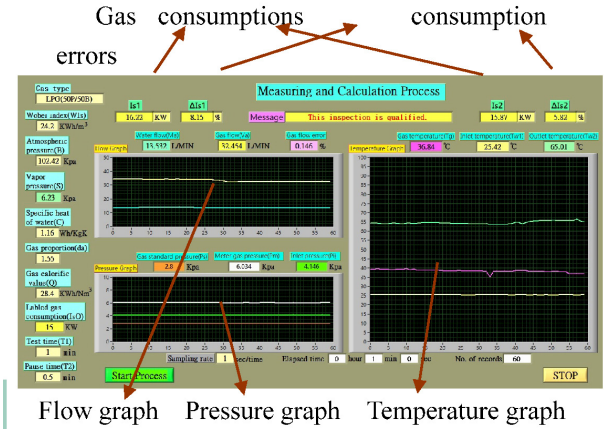

Figure 7. The screenshot of measurement process

After the completion of each stage of the test, the system will automatically calculate the gas consumption I_s and the consumption error ΔI_s, the I_s is calculated by the following formula:

$$I_s = 1/3.6 \times \sqrt{da} \times Va \times \frac{273}{293} \times \frac{101.3 + Ps}{101.3} \times \frac{B + Pm}{B + Pi} \times \sqrt{\frac{293}{273 + Tg}} \times \frac{B + Pm - \left(1 - \frac{0.622}{da}\right) S}{101.3 + Ps}$$

Wherein S represents the water vapor pressure, its value can be determined by the gas temperature(T_g) as following:

$$S = 10^{\alpha} \quad \text{and} \quad \alpha = 7.203 - \frac{1735.74}{Tg + 234}$$

The gas consumption error ΔI_s is computed by the following formula:

$$\Delta I_s = \frac{I_s - I_sO}{I_sO} \times 100$$

Wherein I_sO is the labeled gas consumption when exported from factory, if ΔI_s less than 10%, which means the heater pass the test, and if ΔI_s greater than 10%, which means the heater test failed. When these two-stage tests passed, this gas consumption inspection is qualified.

Figure 7 shows the two-stage test process

completed, the top left of the screen displays the calculated gas consumption I_{s1}(16.22) and the consumption error ΔI_{s1}(8.15%) of the first stage test, the upper right of the screen displays the gas consumption I_{s2}(15.87) and the consumption error ΔI_{s2}(5.82%) of the second stage test, both the consumption errors of the two-stage tests are less than 10%, which means that the gas consumption inspection of the tested gas heater is qualified. In addition to the calculations of I_s and ΔI_s and the judgment of qualified whether or not, the original inspection record report can also be generated automatically after completion of the two-stage test process (as shown in attachment table), for the follow-up use.

5. Conclusion

The developed automatic measurement and calculation system can measure the pressures, flows and temperatures of both the gas and the water simultaneously. Then the gas consumptions and consumption errors are calculated automatically, which used to determine the inspection is qualified or not. Finally an original inspection record report is created for certification use. With the help of this system, we will save effectively to inspection manpower costs, and shorten the inspection time and promoted inspection accuracy. In the future research, we will expand the system function to the gas thermal efficiency inspection[3] of gas water heaters, and in the other aspect is to provide the inspection capabilities of gas thermal efficiency and gas consumption for household gas cooking stove appliances[4].

6. Reference

[1] Commodity Inspection Law (2007), amended and announced at 11 July 2007.

[2] Bureau of Standards, Metrology & Inspection (BSMI) of Ministry of Economic Affairs, www.**bsmi**.gov.tw/wSite/index.jsp.

[3] CNS 13603, S1235(2012), Gas burning water heater for domestic use, amended and announced at 10 Feb. 2012.

[4] CNS 13604, S1236(2011), Gas burning cooking appliances, amended and announced at 25 Mar. 2011.

[5] CNS 13605, S2154(2011), Method of test for gas burning appliances of domestic use, amended and announced at 25 Mar. 2011.

[6] K. Sakai and S. Tanaka(2007), The automatic Hydrogen Gas Measurement Apparatus Developed in Sakai Group since 1993, http://www.scc.kyushu-u.ac.jp/Sakutai/manuals/GC.pdf.

[7] K. C. Yao, J. S. Lai and J. S. Fang (2013), Automatic Measurement Technology, Chuan Hwa Book Publishing.

Attachment: The original inspection record table

The Original Record of Gas Consumption Inspection for Heat Water

Inspect Item：Test of gas consumption　　Proposal No.：
Factory：　　Type：　　Test Date：2014/3/29
Labeled gas consumption：15KW　　Gas Type：LPG
1. Pre-Heatup：
A.Time：From Hour Min ~ Hour Min
B.Gas Pressurwe：280 mmH$_2$O
C.Water Pressure：1 kg/cm^2
2. Gas Consumption Inspection：

Test Content		Unit	Code	Values	
Test Conditions	Type of test gas	/	LPG(50P/50B)		
	Wobei Index	KWh/m^{3}N	Wi	24.2	24.2
	Room temperature	℃	/	25	25
	Water pressure	Kgf/cm^2	/	1	1
	Atmospheric pressure	Kpa	B	102.42	102.42
	Gas temperature	℃	Tg	39.4	38.4
	Vapor pressure	Kpa	S	6.23	6.23
	Gas pressure in meter	Kpa	Pm	6.02	6.05
	Inlet gas pressure	Kpa	Pi	4.14	4.12
	Gas proportion	/	da	1.55	1.55
Test time		Sec	Tt	60	60
Total gas consumption		m^3	V	0.03	0.03
Measured gas consumption		m^3/hr	Va	2.05	2
Gas consumption		KW	Is	16.22	15.87

Remarks：
1. Formula of LPG gas consumption：

$$Is(Kw) = \frac{1}{3.6}\times Wi_{st}\times\sqrt{da_{st}}\times V_{st}\times\frac{273}{293}\times\frac{1013+Ps}{1013}\times\frac{B+Pm_{st}}{B+Pi}\times\sqrt{\frac{293}{273+t}\times\frac{B+Pm_{st}\left(1-\frac{0.622}{da_{st}}S\right)}{1013+Ps}}$$

2. LPG is the liquefied petroleum gas composed of Propane 50% and Butane 50%
3. The inspection spec references session 5 of CNS 13605 and session 5.2 of CNS 13603.
4. 1 mmHg = 0.1338Kpa, 1 mmAq = 0.0098Kpa

Tester：