ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 1, July 2013

Study on Hydro Testing of LPG Cylinders

Akula Ramakrishna[a]*, Nihal A Siddiqui[b], P Sojan Lal[c]
[a] Research Scholar, University of Petroleum and Energy Studies, Dehradun, India
[b] Professor, University of Petroleum and Energy Studies, Dehradun, India
[c] Professor, Mar Baselios Institute of Technology and Science, Kothamangalam, Kerala, India

Abstract*— Liquefied petroleum Gas (LPG) cylinders are designed and manufactured in India as per Indian standard IS 3196 part 1. Several tests mentioned in IS 3196 part 3 need to be conducted on LPG Cylinders for introducing them to market. Among these tests, acceptance and hydro-tests are major tests to be conducted on LPG Cylinders to get Bureau of Indian certification. Hydro-tests on LPG cylinders reveals permanent volumetric expansion of cylinder, nominal hoop stresses at the time of destruction and the internal pressure at which a cylinder bursts. These values are important to ensure that the design and construction of cylinders are safe and compiled to standards. These hydro-test results depend on cylinder raw material selection, manufacturing processes and the heat treatment process parameters adopted during manufacturing process. An attempt has been made in this paper to study experimental test data of 40 Domestic LPG cylinders Hydro test results to understand correlations among these parameters.

***Index Terms*— Hydrostatic testing of LPG Cylinder, Burst testing of LPG Cylinder, Volumetric expansion tests of LPG Cylinders, Hydro-testing of LPG Cylinders.**

I. INTRODUCTION

LPG Cylinders are manufactured in India as per Indian standard IS 3196[2][3][4]. Cylinder manufacturers design, manufacture and test these cylinders as per this standard and get certified by Bureau of Indian Standards (BIS) for marketing. It is mandatory to get certification for every cylinder released from manufacturing location to market. Two cylinders from each manufactured lot are subjected to destructive test for verification of cylinder material properties, as a part of certification process [3]. For every manufactured lot of 203 and below one cylinder is tested for acceptance test [3]. Parent metal physical properties like yield strength, tensile strength, percentage elongation of parent metal, weld tensile strength, weld joint strength etc. are revealed in acceptance test [2]. Similarly for every manufactured lot of 403 cylinders and below one cylinder is subjected to various hydro-tests [3]. Hydro-test on cylinder reveals cylinder water capacity, leaks, volumetric expansion, burst pressure and nominal hoop stress at which a cylinder bursts [3]. Requirements of various hydro-tests for LPG cylinders are mentioned in Indian standard IS 3196 part 1 and various test methods are described in Indian Standard, IS 3196 part 3. There are few factors that can influence these results during manufacturing process and are cylinder raw material selection, cylinder manufacturing process, heat treatment process parameters [5][11][12]. An attempt has been made in this paper to study permanent volumetric expansion, burst pressure and nominal hoop stresses by analyzing 40 domestic LPG cylinders burst test results. These results are correlated and analyzed using Minitab 16, a Microsoft windows based statistical software.

II. MATERIALS AND METHODS

A. General

Burst test results of domestic LPG cylinders of 33.3 liter capacity are selected for this study. These cylinders are most common type of cylinders used in Indian houses and are designed and manufactured as per IS 3196 and certified by Bureau of Indian Standard for market use [2]. In addition to this certification, Indian government oil companies verify cylinder quality in their own independent laboratory for quality compliance.

B. Material

Forty domestic LPG cylinders of 33.3 liters capacity received from various locations across India are tested in Bureau of Indian Standards approved lab for analysis. All these domestic cylinders are produced from raw material meeting IS 6240 standard [1]. Physical properties and hydro-test requirements of these cylinders are meeting the Table.1 [1][2][3].

Table.1 Requirement of LPG cylinder parent metal physical properties

Type of Test	Parameter	Requirements as per Indian Standard, IS 3196 Part1: 2006	Clause / Cross Reference
Acceptance Test	Tensile Strength (TS)	350MPa to 450 MPa	Clause 4.1 of IS 3196 Part1: 2006 and Table 3 of IS6240:2008
	Yield Strength (YS)	240 Mpa	Clause 4.1 of IS 3196 Part1: 2006 Table 3 of IS6240:2008
	Percentage Elongation (PE)	25%	Clause 4.1.1 of IS 3196 Part1: 2006 Table 3 of IS6240:2008

Type of Test	Parameter	Requirements as per Indian Standard, IS 3196 Part1: 2006	Clause / Cross Reference
Hydro-test	Burst Pressure	Minimum 54.92 bar	Clause 9.1.2 of IS 3196 Part3: 2012
	Nominal Hoop stress	Minimum 332.5 MPa	Clause 17.3.3 of IS 3196 Part1: 2006
	Volumetric Expansion	≥ 20% (for Tensile strength ≤410 MPa)	Clause 17.3.3.e of IS 3196 Part1: 2006

C. Types of Hydro-tests on LPG Cylinders

General

Table.1 shows the critical parameters of hydro-tests and their acceptable limits with cross reference to Indian standard. Manufacturers should conduct the following hydro-tests on every cylinders lot produced in their units. These hydro-tests reveal Volumetric Expansion (VE), Burst Pressure (BP) and Nominal Hoop Stresses (NHS). These VE, BP and NHS values are considered as critical parameters in hydro-testing of LPG Cylinders [6][7][8]. These values can be correlated

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 1, July 2013

with tensile strength and yield strength of material [10].

Water capacity test

In a water capacity test, cylinder water capacity is measured and checked whether they are within acceptable limits are not. Domestic LPG Cylinders in India are of 33.3 liter water capacity and its acceptable limit is within 33.30 liters to 33.95 liters as per Indian standard, IS 3196 part 1[2] [3].

Hydrostatic test

Every cylinder produced in a manufacturing location should undergo hydrostatic test. In this test, cylinders are subjected to hydrostatic test pressure of 25 kgf/cm^2 and retain this pressure up to 30 seconds to check any pressure drop [2] [3]. Once the cylinder external surface is dried, they are checked for visual external leaks and pressure drop. If there is any pressure drop or any visible external leaks observed on cylinder body or on welds, the cylinder is considered as failed cylinder for usage [2] & [3].

Hydrostatic stretch test

One cylinder from every manufactured lot of 403 and below should undergo hydrostatic stretch test [3]. This test can be performed either with water jacket method or non-water jacket method described in IS 3196 part 3. The test cylinder is submerged in a water bath for conducting the test, in a water jacket method [3]. In the other hand, the cylinder is tested openly in a non-water jacket method [3]. In both cases there is a provision to control and measure the water pumped to cylinder. Initially a cylinder is filled with measured quantity of water say, C1. This filled cylinder is gradually pressurized with water till it reaches hydrostatic test pressure of 25 kgf/cm^2 through an apparatus that can measure the pumped water quantity in a precise manner. Once the pressure reaches, the test pressure, the pressure is retained for not less than 60 sec and measures the water contained in the cylinder as C2. The water capacity of cylinder is measured once again after releasing the test pressure and recorded as C3. Based on the records, the volumetric expansion is calculated as; the difference between C1 and C2 represents the total volumetric expansion and the difference between C1 and C3 represents the permanent expansion. This value should be within 1/5000 of the original volume of the cylinder [3] to pass the test.

Burst test and nominal hoop stresses

One cylinder from every manufactured lot of 403 and below should test for measuring burst pressure and nominal hoop stresses [2] & [3]. Generally the cylinder tested for volumetric expansion test can be used for this purpose. In this test, cylinders are subjected to continuous hydrostatic internal pressure till it bursts. The internal pressure of cylinder at which it bursts is noted and recorded as burst pressure. Based on this burst pressure nominal hoop stresses are calculated using below formula

$$fb=(Pb \times Di)/2t$$

Where, *fb*-nominal hoop stress at which destruction occurs; *Pb*-Internal hydrostatic pressure at which cylinder bursts in MPa; *Di* -Nominal original internal diameter of the cylinder in mm and *t*-minimum agreed finishing thickness of the cylinder in mm [3].

III. EXPERIMENTAL DATA VALIDATION AND ANALYSIS

Forty domestic LPG cylinders results of volumetric expansion (VE), burst pressure (BP), and nominal hoop stress (NHS) are collected and checked the relation among these parameters by correlation analysis. 40 observations of cylinders are shown in control charts of volumetric expansion (VE), burst pressure (BP) and normal hoop stresses (NHS) in Fig. 1, 2 and 3 respectively. Person correlation constants were calculated among the possible pairs of VE, BP and NHS. The correlation pairs, constants and the trends are tabulated in Table 2.

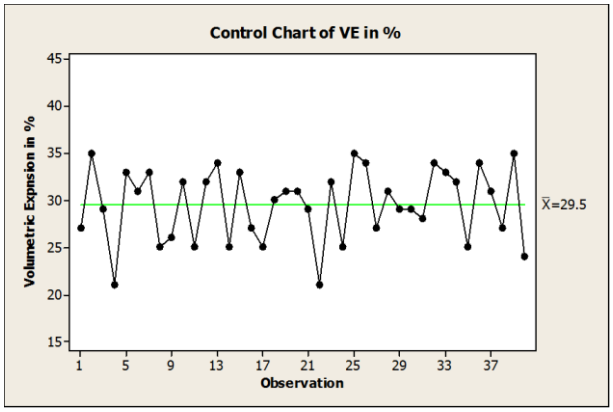

Fig.1 Control Chart for Volumetric Expansion (VE)

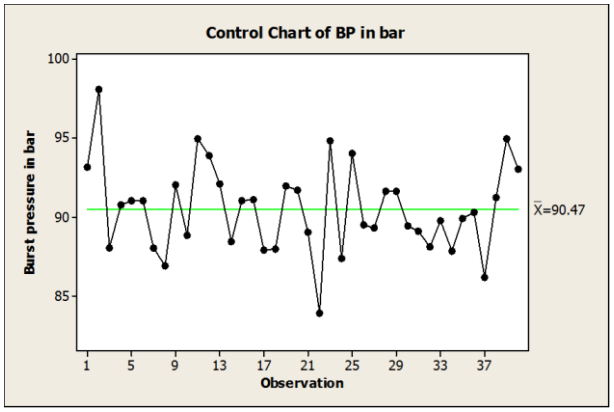

Fig.2 Control Chart for Burst Pressure (BP)

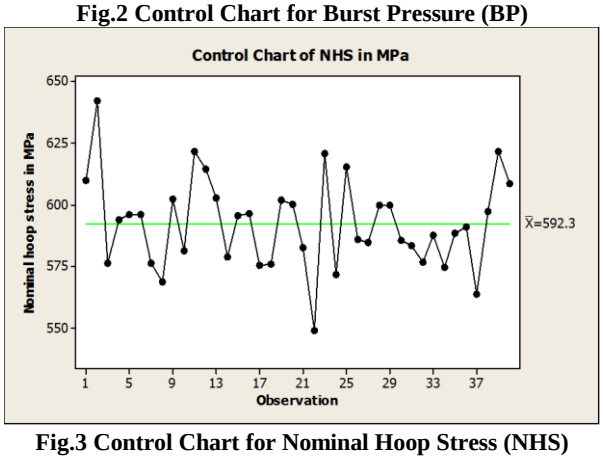

Fig.3 Control Chart for Nominal Hoop Stress (NHS)

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 1, July 2013

Table.2 Hydro-Test Parameters Relations, Pearson Correlation Coefficients and Trends

Correlation Study among variables			
Parameter	VE	BP	NHS
VE			
BP	BP Vs. VE		
NHS	NHS Vs. VE	NHS Vs, BP	

Pearson Correlation Constants			
Parameter	VE	BP	NHS
VE			
BP	0.334		
NHS	0.334	1	

Trend Analysis			
Parameter	VE	BP	NHS
VE			
BP	Positive		
NHS	Positive	Positive	

IV. DISCUSSION

Referring to the Table.1 and control harts of VE, BP and NHS (Fig. 1, 2 and 3), the test results are validated as per Indian standard, IS 3196. It is evident from Pearson correlation constants mentioned in Table.2, relations can be established among BP vs. VE, NHS vs. VE and BP vs. NHS. The relationship among BP vs. VE and NHS vs. VE shows positive trend. That means, if the volumetric expansion of LPG cylinder is observed relatively more, the burst pressure and nominal hoop stresses will also report relatively high. Similarly if the volumetric expansion is low, the burst pressure and the nominal hoop stress reports relatively low values. The relation among BPVs NHS is showing a strong positive relation of one because the NHS is derived from BP with the formula given above. Although the correlation exists strongly among these variables, it is not fully evident through Pearson correlation studies. This is mainly because of few parameters like raw material selection, manufacturing process parameters and testing conditions can change the end results [11][12]. This can be justified as under. In the current study, samples are taken from different manufacturing locations across [9] India and are compiled to IS 6240 [1]. Although raw material is compiled to Indian standards, it is sources from various steel manufacturers in India. Standard stipulates only minimum specification for the raw material (see Table.1) not the best quality or highest possible specifications. Suppose, if a manufacturer is left with no option but to use high quality in terms of logistics or transportation cost or high demand for the product at the time of production, they may use raw material having quality mentioned beyond minimum specification for cylinder manufacturing, which can affect hydro-test results. All cylinders while manufacturing need to pass heat treatment process to get desired physical properties of finished cylinder and to relieve internal pressures generated due to welding process. The Indian standard once again stipulates minimum requirements of material physical properties (see Table1). The manufacturer can even go beyond the stated specifications due to lack of options mentioned above such as logistics, timelines and to meet the demand requirements. Further, the heat treatment process parameters like soaking time in furnace and cooling times after heat treatment are set based on raw material mill certificate and furnace manufacturer's recommendation [5]. Although the end products are meeting the minimum specifications, these parameters can slightly vary in commercial environments and thus the end product quality can meet and go beyond the stated requirement. Further, the welding process and weld methods are can also influence the burst test results and volumetric expansion [7] as these weld methods, welding procedures; weld electrodes are different from one cylinder manufacturer to another. Thus varying heat treatment process parameters and welding methods have a definite impact on Hydro-test results of LPG Cylinders. The testing conditions can also influence hydro-test results. Manufacturing locations are commercial establishments and are predominantly work in commercial framework. These establishments are different from testing laboratories or research and development institutes. Standard provides flexibility in testing through various options like water jacket method and non-water jacket method etc. to accommodate different manufacturing setups. Also they do not suggest a specific test setup for a specific test. Chances always exist to vary test results within acceptable limits when they are subjected to two different test methods and setups. This will affect the repeatability of the test results within acceptable limits. Also, individual equipment used in test setup can some time leads inadvertent mistakes. For example, while subjecting a cylinder for burst test, the pressure can be increased with a positive displacement pump (Piston pump). The output from positive displacement pump is pulsating. The gauges attached to such test setup should take care of such fluctuations while reading the dial gauge with appropriate dampening medium. Otherwise there could be an error in reading accurate pressure especially while reading burst pressure. Such phenomenon can affect the hydro-test results.

V. CONCLUSION

In this work, forty domestic LPG Cylinders hydro test data was analyzed to establish correlations among volumetric expansion, burst pressure, and nominal hoop stresses. It is evident from the correlation study that a relation can be established among these variables. Although, it is clearly evident that there is a relation exists among various parameters, few factors like raw material, heat treatment process parameters, welding processes, test setups can affect test results in typical commercial environments.

REFERENCES

[1] Indian Standard (1999). IS 6240: 1999. HOT ROLLED STEEL PLATE (UP TO 6 Mm) SHEET AND ASTRIP FOR THE MANUFACTURE OF LOW PRESSURE LIQUEFIABLE GAS CYLINDERS. New Delhi: Bureau Of Indian Standard.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 1, July 2013

[2] Indian Standard (2006). IS 3196 (Part 1): 2006. WELDED LOW CARBON STEEL CYLINDERS EXCEEDING 5 LITRE WATER CAPACITY FOR LOW PRESSURE LIQUEFIABLE GASES PART 1 CYLINDER FOR LIQUEFIED PETROLEUM GASES (LPG) - SPECIFICATION. New Delhi: Bureau Of Indian Standard.

[3] Indian Standard (2012). IS 3196 (Part 3): 2012. WELDED LOW CARBON STEEL CYLINDERS EXCEEDING 5 LITRE WATER CAPACITY FOR LOW PRESSURE LIQUEFIABLE GASES PART 3 METHODS OF TEST. New Delhi: Bureau of Indian Standard.

[4] Ministry of Commerce and Industry (2004). Part II Section 3 Sub Section (i). GAS CYLINDER RULES, 2004. New Delhi: The Gazette of India.

[5] Nurudeen Adekunle Raji and Oluleke Olugbemiga Oluwole (2012). EFFECT OF SOAKING TIME ON THE MECHANICAL PROPERTIES OF ANNEALED COLD-DRAWN LOW CARBON STEEL. Materials Sciences and Applications. 2012, 3, pp.513-518.

[6] Y. Kisioglu, J. R. Brevick and G. L. Kinzel (2001). DETERMINATION OF BURST PRESSURE AND LOCATION OF THE DOT-39 REFRIGERANT CYLINDERS. Transactions of the ASME. Vol. 123, MAY 2001, pp.240-247.

[7] Yasin Kisioglu (2003). EFFECTS OF WELD ZONE PROPERTIES ON BURST PRESSURES AND FAILURE LOCATIONS. Turkish J. Eng. Env. Sci.. 29 (2005), pp.21-28.

[8] Yasin Kisioglu (2009). BURST TESTS AND VOLUME EXPANSIONS OF VEHICLE TOROIDAL LPG FUEL TANKS. Turkish J. Eng. Env. Sci.. 33(2009), pp.117-125.

[9] BUREAU OF INDIAN STANDARDS (2013). List of Licenses [online]. Available from: &lthttp://nicdc.nic.in/CMMS/InternetRep/InternetReportView.aspx?strstate=>. [Accessed 22 July 2013].

[10] George Ellwood Dieter (1976). Mechanical metallurgy. 1988. ed. Singapore: McGraw-Hill.

[11] Nihal A Siddiqui, Akula Ramakrishna and P Sojan Lal (2013). REVIEW ON LIQUEFIED PETROLEUM GAS CYLINDER DESIGN AND MANUFACTURING PROCESS AS PER INDIAN STANDARD, IS 3196 (PART1): 2006. International Journal of Advanced Engineering Technology. IV Issue II, pp.124-127.

[12] Nihal A Siddiqui, Akula Ramakrishna and P Sojan Lal (2013). REVIEW ON LIQUEFIED PETROLEUM GAS (LPG) CYLINDER LIFE CYCLE. International Journal of Advanced Engineering Technology. IV Issue III, pp.37-41.

AUTHOR'S PROFILE

Ramakrishna Akula is research Scholar from University of petroleum and Energy Studies, Dehradun, India. He is having more than 13 years of LPG industry experience. He completed his bachelor degree in mechanical technology from NIT Warangal. He won several national level awards from prestigious institutes like IIT Bombay on student design projects and presented several technical papers at various student conferences and published so far 5 research papers in academic journals. He started his professional career with Hindustan Petroleum Corporation limited as a management trainee and exhibited his excellency through handling unique R&D projects related LPG equipment. He was deputed as a mechanical lab in charge in LPG Equipment Research Centre (LERC), Bangalore in 2003. He led several R&D projects in LERC and successfully completed those projects during 2003-2007. He investigated several equipment failure and accident investigations related to LPG equipment during his tenure. He can be reached at akula.ramakrishna@gmail.com

Dr Nihal Anwar siddiqui is a dynamic and distinguished HSE academician having 17+ years of combined experience in academic, research and industrial domains. He is currently working as a professor and head- Department of health safety fire and environment in university of petroleum and energy studies, Dehradun. Dr. Siddiqui is an eminent member in several renowned professional bodies such as IOSH, Energy institute, London and National safety council etc. He was trained in several HSE and Fire safety specializations and became certified professional on topics like managing safety, construction safety, OHSAS lead auditor etc. He attended several national and international conferences as a speaker. Dr. Siddiqui is an author for more than 40 + research publications, published in prominent national and international journals. So far, He guided 50+ M.Tech dissertations and supervised 3 PhD's. He undertook several sponsored R& projects in HSE field from both government and private sectors. His patent on odor pollution monitoring kit is pending. He was exclusively selected for international academic service and working as an assistant professor for Ethiopian medical college. His first book on natural resources and environment management was published from Kannan publications. Dr. Siddiqui is available at nsiddiqui57@gmail.com.

Dr. P. Sojan Lal, Professor, In charge of Academic Research received his BE in Mechanical Engineering from Bangalore University, Karnataka, in 1985, M.Tech in Computer Science from National Institute of Technology (NIT), Warangal, AP in 1993 and Ph.D degree from Cochin University of Science and Technology, Cochin, Kerala, India in 2002. He is also a Research Guide with School of Computer Science, Mahatma Gandhi University, Kottayam, Kerala. Dr Sojan, who has 25 years of experience, has published 33 technical papers and one textbook in Computer Programming and Numerical Methods. He has also obtained MBA from Strathclyde Business School, Scotland, UK and is a Fellow of The Institution of Engineers (FIE-India) since 2004. He is a member of ISTE, ASME, IEEE, CSI and Engineering Council (UK).