Review Article

REVIEW ON LIQUEFIED PETROLEUM GAS CYLINDER DESIGN AND MANUFACTURING PROCESS AS PER INDIAN STANDARD, IS 3196 (PART1): 2006

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ABSTRACT:

Liquefied Petroleum Gas (LPG) Cylinders are manufactured and tested under stringent norms before they get certified by Bureau of Indian Standards (BIS) for market use. These LPG cylinders are designed and manufactured as per Indian standard. Normally, cylinders are produced in batches from raw material specified in Indian standards and tested before dispatching to market. As a part of design, cylinder thickness is calculated, that is based on the shape of the cylinder dome and cylindrical portion of the dome. Cylinders are then produced through various stages and tested before BIS Certifies a lot. An attempt has been made in this paper to explain the process behind manufacturing LPG Cylinder. The paper outlines the possible issues during cylinder manufacturing process and the deficiencies in the current Indian standard.

KEYWORDS: Liquefied Petroleum Gas Cylinders, Cylinder Design Specifications, LPG Cylinder testing, and LPG Cylinder Manufacturing.

INTRODUCTION

Liquefied Petroleum Gas (also known as LPG or LP Gas) Cylinders in India are produced as per Indian standard, *Welded low carbon steel cylinders exceeding 5 liter water capacity for low pressure liquefiable gases, IS 3196 (part 1):2006* [1]. India is the third largest LPG consumer of in domestic sector in the world [2]. Approximately 3 million LP Gas cylinders are delivered to Indian homes every day [2]. All these cylinders in India are manufactured, tested under stringent norms and certified by Bureau of Indian standards before they released for market use. An attempt has been made in this paper to review the cylinder manufacturing process from design stage to finished cylinder.

REVIEW OF CYLINDER MANUFACTURING PROCESS

General

LPG cylinders are manufactured either in two piece or three piece construction as shown in Fig.1. Body parts of a cylinder are explained in this figure [1]. In two piece construction, cylinders are fabricated by welding two domed ends directly together. A three piece cylinder is fabricated by joining two domed ends to a cylindrical body as shown in Fig.1. The domed ends can be tori-Spherical, Semi ellipsoidal or Hemi-spherical in shape as shown in Fig.2[1].

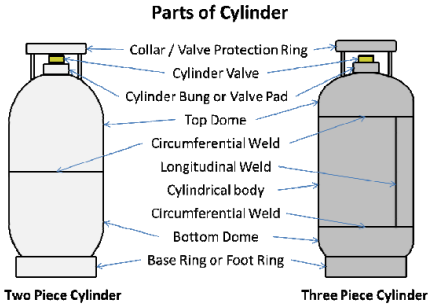

Fig.1 Parts of Cylinder

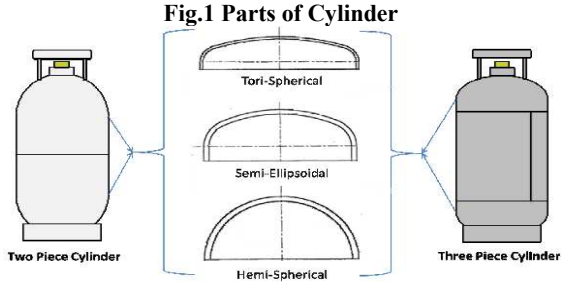

Fig.2 Types of dooms in two and three piece cylinders

Cylinder design

Wall thickness is primary factor to be arrived while designing a cylinder. Thickness depends on several factors such as cylinder test pressure, outer diameter of cylinder, shape of cylinder dome, yield strength of material, weld joint factor, ratio of domed end diameter to height, dishing radius, knuckle radius and length of straight flange. In order to design the thickness, a test pressure of 23.53 bar, and a minimum yield strength is 240 MPa [1] is considered as per Indian standard IS3196 part1. Further, weld joint factor to be considered as 1.0, 0.9 and 0.7 depends on type of radiographic examination adopted to check the welds during and after manufacturing[1]. Design calculations of any cylinder are based on cylinder dome shape. Figure 2 shows the shapes of cylinder domes in two and three piece cylinders and are, Tori spherical, Semi- Ellipsoidal and Hemi Spherical. Higher thickness among dome shapes and cylindrical portion of a cylinder is considered as a final thickness. Generally hemispherical domes are not used for two pieces [1].

The thickness of cylindrical portion is calculated using the following formulas and the highest thickness is considered as the cylindrical portion thickness [1].

$$t = \frac{PhDo}{200 \times 0.8\, J\, Re + Ph}$$

Or

$$t = \frac{PhDi}{200 \times 0.8\, J\, Re - Ph}$$

And

$$t = 0.136 \times \sqrt{Do}$$

Where

t = calculated minimum wall thickness, in mm
t_e = calculated wall thickness of doom, in mm
P_h = Test pressure, in Kgf/cm^2
D_i = inner diameter, in mm
D_o = outer diameter in mm
h_o = external height of domes end in mm
h_i = internal height of domed ends in mm
R_e = yield strength in MPa
J = weld joint factor
= 1.0 fully radio graphed welds
= 0.9 for two piece cylinder
= 0.9 where every 50 cylinders in batch are spot radio graphed as per standard
= 0.7 all other cases
K = ratio $D_o / h_o \geq 0.192$
R_i = dishing radius $\leq D_o$, in mm
r_i = knuckel radius $\geq D_o$
S_f = length of straight flange in mm
$\geq 0.3\sqrt{Dote}$

$$z = \frac{\frac{20ri}{Ri} + 3}{\frac{20ri}{20Ri} + 1}$$

Further, the thickness of a tori-Spherical cylinder dome is calculated from the following formula [1]$te = \frac{PhDo}{200 \times 0.8\ J\ Re + Ph} \times \frac{KZ}{5}$

and the thickness of a semi ellipsoidal cylinder dome is calculated with the following formula[1]

$$te = \frac{PhDo}{200 \times 0.8\ J\ Re + Ph} \times \frac{K(0.65 + 0.1K)}{4}$$

In addition to the above, the Indian Standard IS 3196 stipulates minimum cylinder thickness should be 2.4 mm [1] for cylinders up to and including 13 litre water capacity and 2.4 mm for cylinders above 13 litre water capacity. Once the design is finalized, a prototype cylinder to be produced and to be subjected to various tests to ensure deemed fit [1].

Raw material

Special grade steel complies with Indian standard IS 6240, *Hot rolled steel plate (up to 6 mm) sheet and strip for the manufacture of low pressure liquefiable gas cylinders* or equivalent is used for cylinder body[3]. Standard IS 3196 specifies critical parameters of material viz. yield strength, tensile strength, percentage elongation and the material composition[1]. The bung or valve pad should confirms to class 1A or Class2 of IS 1875, *carbon steel billets, blooms, slabs and bars for forging* or IS 2062, *Steel for general structural purposes* Valve protection ring, Foot ring should confirm to Grade 0 of IS 1079, *Hot rolled carbon steel sheets and strip* [7]or IS 2062 or IS 6240.

Manufacturing

Cylinders are generally manufactured in lots. Each cylinder lot consists of 202 cylinders or less[4].

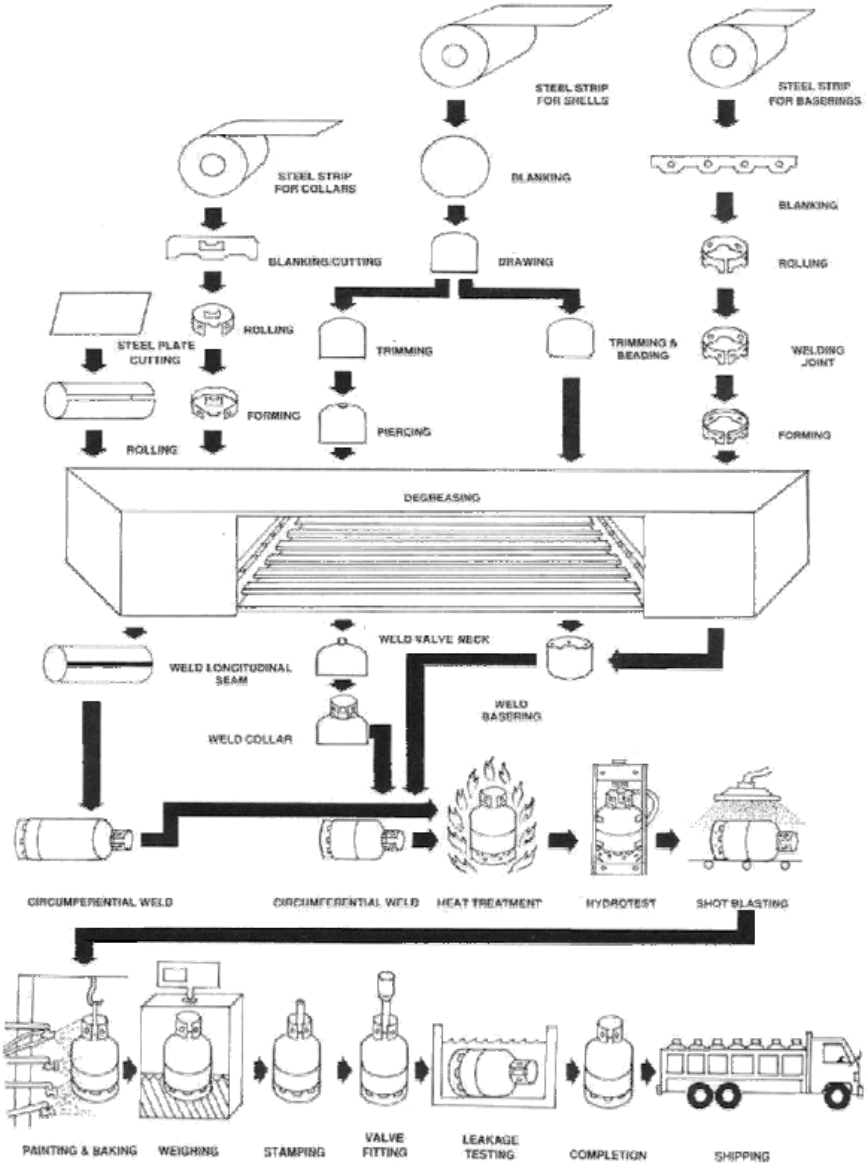

Fig.3: LPG Cylinder Manufacturing Process flow diagram

Fig.3 shows the cylinder manufacturing process from raw material to finished product for both two piece and three piece cylinders[5]. Raw material as per IS 6240 [3] or equivalent either in coil or sheet form may be used for producing cylinders. For a two piece cylinder, circular blanks are cut from sheet to produce top and bottom domes. Top dome further undergoes piercing operation to accommodate bung. Valve protection ring and foot rings are produced by blanking, rolling, joining and forming operations from raw material. For a three piece cylinder, cylindrical body piece is produced by rolling operation. All these components are degreased for efficient and defect free welding operation. Any fusion welding method can be used to join cylinder parts. However Welding procedure and the welder performance requirements should meet either IS 2825, *Code for unfired pressure vessels* [6] or IS 817, *code of practice for training and testing of metal arc*

welders for welding depends on full and partial radiographic examination.

The welding process starts with joining of valve pad, which is welded to top dome. Valve protection ring and foot rings are also welded to domes before they weld together, for a two piece cylinder. In case of a three piece cylinder, both these domes are welded to a cylindrical body to form a complete cylinder. The welding process can create heat affected zone on parent metal near the weld areas. This can cause internal stresses in the cylinder body. Such stresses are relieved in a heat treatment process during manufacturing. Depending on the raw material and the final cylinder material specifications the heat treatment can be either stress relieving or normalizing. Heat treatment time and temperature are maintained in such a way that the end product should meet the testing parameters mentioned in IS 3196 part3 [4].

All cylinders are subjected to hydro test after heat treatment to ensure that there are no leaks in the cylinders. The cylinders are then subjected to painting. The painting process includes short-basting powder coating and baking. The cylinders are then sent for markings. Cylinder unique serial number and test dates are marked on cylinder at this stage. Further, all cylinders are individually weighed and tare weight is stamped on stay plate. After this process, the valves are fitted to cylinders and tested for leaks in a leak test bath. This completes the cylinder manufacturing process.

Testing of cylinders

Normally one cylinder in a lot of 202 or less is subjected to acceptance test. Similarly out of 403 or less lot size one cylinder is subjected to hydrostatic test as per IS 3196 part3 [4]. In addition to that, cylinders are subjected to various non-destructive and destructive tests, to get Bureau of Indian certification for marketing. The following are the essential tests to be conducted on cylinders before they get certified by Bureau of Indian standards [4].

- Acceptance test
- Burst and volumetric expansion test
- Hydrostatic stretch test and burst test
- Hydrostatic test
- Pneumatic leak test
- Radiographic examination and
- Fatigue test/ Cycle test

Acceptance tests reveals yield, tensile strength and percentage elongation of parent metal and weld tensile strength. Further the acceptance test reveals weld quality through bend tests and macro examination of weld samples. Cylinder thickness is also measured in this test to verify the design compliance[4].

Hydrostatic stretch test reveals the permanent stretch retained in a cylinder under 80% of test pressure conditions to check whether the cylinder is meeting the required conditions or not. It may conducted wither water jacket method or non-jacket method. After this the cylinder is subjected to burst test to measure nominal hoop stresses in cylinder material [4].

Hydrostatic test is conducted to check the leaks in cylinders from pin holes, blow holes, undercuts in welding at test pressure conditions. This test is conducted on a cylinder with no valve attached to it. Once the valve is attached pneumatic test is conducted on cylinder to check for leaks, if any[4].

Radiographic examination is conducted on a cylinder to check weld penetration at weld overlaps and also to check the weld defects in cylinder [4].

Fatigue or cycle test is type test conducted on cylinders to check the behaviour of cylinder under cyclic loads. Cylinders are subjected to test pressure or two third of test pressures for a specified number of cycles and then subjected to burst pressure to check the burst test compliance [4].

The cylinders are also checked for circularity, surface defects, profile regularity, straightness and verticality during manufacturing, to ensure there are no manufacturing defects [1].

Various test methods and their requirements for LPG Cylinders are mentioned in a separately Indian Standard, welded low carbon steel cylinders exceeding 5 litre water capacity for low pressure liquefiable gases part3 Methods of test , IS 3196 Part3 [4]. On passing these requirements, the cylinders are certified by Bureau of Indian standards with a BIS mark for market use.

DISCUSSION

The stresses developed in parent metal due to welding of cylinders during manufacturing can be relieved only by heat treatment process. The heat treatment process parameter varies depending on the raw material composition. Typically the heat treatment for a domestic LPG cylinder of 33.3 water capacity is around 850^{O}Cto 900^{O}C for 10 to 15 minutes time. This process incurs huge cost to manufacturer for maintaining the furnace. On the other hand after completion of a lot of 403 cylinders only 3 cylinders undergoes testing as per IS 3196 part3. Based on the results of these three cylinders rest of the 400 cylinders are certified by Bureau of Indian standards for issuing BIS certification. It is almost impossible to any certifying agency like BIS to monitor the cylinder manufacturer on continues basis. In case, if manufacturer bypasses or adopt short cut methods for heat treatment process and manage to pass three cylinders in a batch, improperly heat-treated cylinders may enter into market. This type of scenario cannot be ruled out in India, keeping in view of consumer safety. In order to address this either, the sampling size of acceptance testing should be increased or there should be some provision to test all cylinders at manufacturing premises through non-destructive methods to ensure material quality compliance, which is not existence in the current Indian standard.

CONCLUSION

In this paper cylinder manufacturing process was described from design stage to finished cylinder. Cylinder design calculations are aimed to find thickness, which is calculated separately for cylindrical and domes portions and finalize whichever is greater. Once the design is finalized, cylinders are produced from a specified raw material through various processes. Internal stresses in cylinders are relieved in a heat treatment process. Cylinders are marked with unique serial numbers and tare weight. Various tests are conducted on cylinders to get certification from bureau of Indian standards for market circulation. Although LPG Cylinders are manufactured under stringent norms, with the

existing standard there is a possibility to enter non complied cylinder into market. This was explained briefly at the end of the paper.

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