3. LPG Cylinder Testing

The chapter outlines various tests that are conducted on LPG cylinder in its life cycle. Although cylinder subjected to several tests and inspections during its life cycle, Acceptance test and hydrotests are having particular importance in LPG cylinder testing. They can be conducted only on random samples and that to only in manufacturer premises at the time of manufacturing a batch of cylinders as these tests are destructive in nature. Current research focuses on these two tests and hence in-depth details are given on these two tests in this chapter.

3.1 Introduction

LPG Cylinders are inspected and tested several times in their life cycle. Critical mandatory testing stages in a cylinder life cycle are [27]:

1. Raw material testing
2. Prototype testing for design approval
3. Testing and inspections of cylinders during manufacturing
4. Statutory testing for certification
5. Quality checks at customer premises
6. Requalification / Periodic testing of LPG cylinders
3.1.1 Raw Material Testing

Before starting production, raw material needs to be tested to confirm the material is meeting raw material requirements stated in the standard. The material should confirm to Indian standard IS 6240, which states the chemical composition and material physical properties required for a LPG Cylinder raw material. Table 1 (see chapter 2.4.1) gives the chemical composition requirements and Table 2 (see chapter 2.4.1) states material physical properties for cylinder raw material.

3.1.2 Design Approval

LPG cylinders are designed as per the chapter 2.4.2. Once the cylinder design is finalized, cylinder manufacturer need to produce few prototype cylinders as per the design specifications and the prototype cylinders needs to be tested as per IS 3196 Part1 and IS 3196 Part3. Once the prototype cylinders are meeting the requirements of IS 3196, the design is approved for production and a cylinder manufacturer can produce cylinders as per final design. The tests mentioned in IS 3196 ensure cylinder production methods adopted in a manufacturing plant can produce desired quality of cylinders. Further the following tests are conducted on cylinder to ensure the final product is exhibiting desired mechanical properties [25].

a) Acceptance tests;
b) Burst and volumetric expansion test;
c) Hydrostatic stretch test;
d) Hydrostatic test;
e) Pneumatic leakage test; and
f) Radiographic examination
3.1.3 Inspection and Testing During Manufacturing

LPG Cylinders can be produced in a manufacturing plant, after accepting prototype design testing. While producing cylinders several tests and inspections are to be carried out on cylinder at various stages during and after fabrication. These tests ensures cylinder are in line with the approved design and manufacturing standards and are [27]

- Raw material testing
- Welding inspection
- Agreed finished thickness test
- Cylinder circularity
- Surface defects examination of cylinder
- Profile regularity of cylinder
- Straightness of cylinder
- Verticality of cylinder
- Inspection of all individual components like bung, valve protection and foot ring
- Water capacity
- Radiography of welds, spot radiography
- Hydrostatic test
- Pneumatic test
- Cycle or fatigue test
- Inspection of certification markings

LPG cylinders are produced in batches. Once the batch starts producing the plant will not be stopped till completion of the batch. while producing batches, all the production parameters are kept uniform to all cylinders produced in that batch including heat treatment parameters
to relieve the stresses in cylinders. Few cylinders from each batch is drawn out randomly and tested for statutory tests for accepting the batch for market use.

### 3.1.4 Statutory Testing

LPG cylinders produced in a manufacturing location intended for Indian market are required to be certified by Bureau of Indian Standards (BIS) and BIS mark is affixed on every LPG cylinder. In addition to that Indian LPG cylinder design specification (code number) is also mention on cylinder for market reference. In order to get BIS certification few cylinders from each batch are to be tested for compliance [25]. In every manufacturing location, two cylinders picked randomly from a fresh manufacturing batch and are subjected to statutory testing. Among these two cylinders, one cylinder is subjected to acceptance test and the other is subjected to hydrotest. Few additional tests / inspections are carried out on these cylinders along with acceptance and Hydrotests and are water capacity test, thickness test, and pneumatic tests. Further, cyclic tests are to be carried out on few cylinders to check the acceptance of cylinder for cyclic tests. Thus the following are the critical tests for statutory approval [27].

**Acceptance tests**

The aim of the acceptance test is to verify the parent metal properties like yield strength, tensile strength and percentage elongation of cylinder parent metal. Also, acceptance test reveals weld tensile strength of cylinder weld joints. Standard IS 3196 part 3 specifies the sample lot size, sample preparation requirements, and sampling location on a cylinder. Also, the standard states minimum requirements for accepting a lot of cylinders [25].

**Burst and volumetric expansion test**

Volumetric expansion test reveals the volumetric expansion of cylinder under test pressure conditions. Standard allows permanent volumetric expansion of 1/20000 the total cylinder capacity. Once the volumetric expansion test is carried out the same cylinder may be
subjected for burst test to check he burst pressure of the cylinder. Based on the burst pressure nominal hoop stresses of a cylinder at burst pressure conditions are calculated. Standard states the sample size, minimum requirements of test parameters for verification purpose [25] & [27].

**Hydrostatic test**

All cylinders are subjected to hydrostatic test to check leaks if any, this is carried out at test pressure conditions and the pressure is applied for 30 seconds to check any pressure drop or leaks from body and weld joints [25] & [27].

**Pneumatic leakage test**

Once service valve is fitted on LPG Cylinder every cylinder has to undergo pneumatic leak test. Under this test, pneumatic pressure of 1180 kPa is applied to cylinder to verify any leaks from cylinder body or weld leaks [25] & [27].

**Radiographic examination**

Radiographic examination is intended to check weld quality and the weld defects in a cylinder during manufacturing process the examination is conducted on weld overlap to check weld defects [25] & [27].

**Fatigue test/cycle test**

Fatigue or cyclic test is a type test. This test is conducted under cyclic loads to check the fatigue strength of cylinder and cyclic pressures [25] & [27].

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### 3.1.5 Quality Checks at Customer Premises

Once the cylinders are manufactured and transported to customer premises, certain checks are conducted to ensure cylinders are meeting customer requirements. However at this stage only visual and body inspections can be carried out but not the material testing or non-destructive tests. Some of the tests conducted at this stage are; verification of cylinder dimensions, water capacity, tare weight check, paint thickness and primer thickness, visual marking on
cylinder, dents, body damages and visual defects. Indian oil companies are having a joint venture laboratory, where they can test material quality by destroying a cylinder. However, it is not mandatory or practical to send cylinders samples across all location in India for testing purpose to this laboratory. However, every bottling plant tries to send two cylinders per LPG cylinder manufacturer in a year from their annual new cylinders receipts. These cylinders are tested in all respects to ensure quality.

3.1.6 Requalification of LPG Cylinders

All LPG Cylinders are required to undergo periodic inspection at frequent intervals to serve their remaining life. For instance, in India, new cylinders are tested first after 10 years of their initial entry and subsequently they are subjected to requalification tests once in every 5 years [45] & [Indian Standard IS 8868: 1988]. During requalification test, cylinders are tested for hydrostatic stretch test and inspected against other requirements stated in standard. If the cylinders are meeting all stated requirements, the cylinders can serve another 5 years in the market [45]. At this stage, cylinders are also checked for body corrosion, internals inspection, bung thread inspection visual damages, dents, digs, scratches, fire marks etc. and segregated accordingly or discarded from service.

3.2 Testing of LPG Cylinder at Manufacturers Premises

Although cylinders are tested and inspected as per IS 3196 particular importance is given to acceptance test and hydrotest as these tests are destructive in nature. Rest of the inspections like water capacity test, dimensions verification can be repeated if necessary, whereas acceptance test and hydrotests actually destroy cylinder for obtaining critical parameters or test results. These tests are covered in subsequent sections in more detailed manner.
3.3 Acceptance Test

Acceptance tests are mandatory tests as per statutory authorities to certify a cylinder batch and to ensure cylinders are meeting regulatory compliance as per Indian standard. These tests are conducted on Liquefied Petroleum Gas (LPG) cylinders in manufacturing location when new cylinders are produced as per Indian standard, IS 3196. For every batch of 203 cylinders or less produced in a manufacturing location, one cylinder must undergo the acceptance test. As a part of this test, a sample cylinder is selected from a manufactured batch and two tensile samples are cut from the body of this cylinder; one in longitudinal direction and the other in transverse direction or circumferential direction for testing purpose. Figure 10 below shows the sampling location for a two piece cylinder [10] & [27].

![Test Specimen Sampling Location for Acceptance test](image)

Figure 10: Acceptance Sample location

Also Figure 11 below shows sample preparation method and Figure 12 refers sample dimensions for a tensile sample [3] & [27].

![Parent Metal Acceptance Test Sample (Tensile Sample) preparation methods](image)

Figure 11: Sample Preparation Methods
The tensile samples prepared as per Figure 12 [3][10][27] are tested on a universal testing machine to obtain physical properties of LPG Cylinder material. That is from this test; Longitudinal Tensile Strength (LTS), Longitudinal Yield Strength (LYS), Longitudinal Percentage Elongation (LPE), Circumferential Tensile Strength (CTS), Circumferential Yield Strength (CYS) and Circumferential Percentage Elongation (CPE) of cylinder material can be measured. See Figure 13 below [10].

Figure 13: Understanding Parent metal tensile test
These parameters are needed to be checked against standard requirements to pass a freshly manufactured cylinder batch in manufacturing location. LPG cylinders are produced from a definitely prescribed raw material and batch production methods are implemented for producing a specific batch. Hence it is expected that all cylinders in a batch are identical and having similar physical properties. These properties are revealed from a sample cylinder subjected to acceptance test and the values are attributed to all other cylinders in the batch.

### 3.4 Hydro-Test

#### 3.4.1. General

One cylinder for every manufactured lot of 403 cylinders and below is subjected to hydrotests [5][9]&[27]. Hydrotest on cylinder reveals cylinder water capacity, leaks, volumetric expansion, burst pressure and nominal hoop stress at which a cylinder bursts. Requirements of various hydrotests 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.

#### 3.4.2. Types of Hydro-tests

Table.3 shows the critical parameters of hydro-tests, their acceptable limits with cross reference to Indian Standard [9] & [25]. Manufacturers should conduct the following hydro-tests on every cylinders lot produced in their units. Volumetric expansion (VE), Burst pressure (BP) and Nominal Hoop Stresses (NHS) are considered as critical parameters in hydro-testing of LPG Cylinders.

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Parameter</th>
<th>Requirements as per Indian Standard, IS 3196 Part1: 2006</th>
<th>Clause / Cross Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro-test</td>
<td>Burst Pressure</td>
<td>Minimum 54.92 bar</td>
<td>Clause 9.1.2 of IS 3196 Part3: 2012</td>
</tr>
<tr>
<td></td>
<td>Nominal Hoop stress</td>
<td>Minimum 332.5 MPa</td>
<td>Clause 17.3.3 of IS 3196 Part1: 2006</td>
</tr>
<tr>
<td></td>
<td>Volumetric Expansion</td>
<td>≥ 20% (for Tensile strength ≤410 MPa)</td>
<td>Clause 17.3.3.e of IS 3196 Part1: 2006</td>
</tr>
</tbody>
</table>
**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 [25].

**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/cm² and retain the pressure up to 30 seconds to check any pressure drop. Once the cylinder surface is dried, they are checked for leaks and pressure drop. If there is any pressure drop or any visible external leaks on cylinder body or on welds, the cylinder is disqualified for usage [25].

**Hydrostatic stretch test**
One cylinder from every manufactured lot of 403 and below should undergo hydrostatic stretch test. 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. In the contrary, the cylinder is tested openly in a non-water jacket method. 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/cm² 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 is within 1/5000 of the original volume of the cylinder [27].

**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. 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 [27]

\[ fb = \frac{P_b \times D_i}{2t} \]

Where, \( fb \)-nominal hoop stress at which destruction occurs; \( P_b \)-Internal hydrostatic pressure at which cylinder bursts in MPa; \( D_i \)-Nominal original internal diameter of the cylinder in mm and \( t \)-minimum agreed finishing thickness of the cylinder in mm.

### 3.5 Scholar’s Publications Based On This Chapter


---End of Chapter 3---