Chapter-4

4. Literature Review

The chapter discusses existing literature available in LPG cylinder specifications and allied areas. Literature was reviewed under broad relevant heads and the inferences are recorded briefly under each category. It is evident from the literature that there is a chance to entry of non-complied cylinders into market due to gaps in national and international standards on cylinder sampling and test methods. Also, literature provides a basis for various cylinder parameters that can be studies for developing relations among several parameters. The chapter ends highlighting gaps in existing standards systems and procedures.

4.1 General

Literature review carried out under the following broad categories. Summary of inferences, gaps from literature review is given under each category.

Table 4: Summary of literature survey

<table>
<thead>
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<th>Main theme</th>
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### 4.2 Cylinder Marketing

The following documents reviewed under the category of cylinder marketing

- LPG As a cooking fuels option for India[13]&[14]
- Management of Supply Chain in Petroleum Corporations in India [15]
- Understanding the political economy and key drivers of energy access in addressing national energy access priorities and policies [49]
- Scenario analysis of household energy use in India [16]
- Residential market for LPG [100]

It is understood that the 17.5 % of Indian homes are equipped with LPG as a cooking fuel and it is equivalent to 33.6 million numbers. This is a huge number. The supply chain of LPG Cylinder management is critical for the operating firms particularly the initiatives taken towards green supply chain, where in emphasis is on optimize the entire supply chain. Although the potential exists, infrastructure needs to strengthen in terms of reliability for increasing the access of energy

### 4.3 Cylinder Incidents

The following documents reviewed under this category

- Identification Of Technological Disaster Prone Areas In Province Punjab, Pakistan [1]
- Modelling The Performance Of Coated LPG Tanks Engulfed In Fires[42]&[43]
Increase use of LPG enhances the risk of boiling liquid expansion vapor explosion (BLEVE). In simple terms, BLEVE is an intense explosion due to sudden and rapid expansion of LPG. It is evident from the studies that the BLEVE triggered secondary fires due to flying hot objects due to explosion. Although there is no direct study on material safety vs. BLEVE, improper heat-treat on LPG Cylinder can cause cylinder to burst with fragments in burst test of LPG Cylinder. These fragments are the main reason for secondary fires associated with BLEVE.

4.4 Cylinder Design

The following documents reviewed under this category

- Pressure-Temperature Diagram Analysis Of Liquefied Petroleum Gas And Inspection Of Retrograde Phenomenon [72]
- A New End-Closure Design For DOT-4BA Propane Cylinders [105]
- Burst Tests And Volume Expansions Of Vehicle Toroidal LPG Fuel Tanks [106]
- Determination Of Burst Pressure And Location Of The DOT-39 Refrigerant Cylinders [101]
- Determination Of Stress And Deformations Analysis On LPG Steel Cylinder [90]
• Determination Of Stresses Of LPG Gas Cylinder By Finite Element Method [78]
• Effects Of Weld Zone Properties On Burst Pressures And Failure Locations [104]
• Finite Element Analysis Of LPG Gas Cylinder [66]
• Minimum Material Design For Propane Cylinder End Closures [102]
• Stress Analysis Of LPG Cylinder Using Ansys Software [67]
• Design and analysis of LPG cylinder using ANSYS software [33]
• Design and finite element analysis of FRP LPG cylinder [71]

From the literature, Cylinder thickness is the critical factor in designing. If the thickness is increased the cylinder safety increases in conventional design. However the weight of the cylinder increases proportional to thickness. The cylinder specifications states, the thickness is based on yield strength and test pressure, weld joint factor and the diameter of cylinder. Among these parameters the yield strength can be obtained only with tensile testing of cylinder material.

While analysis stresses and deformation studies on cylinders, critical factors are identifies such as tensile strength, yield strength, percentage elongation, burst pressure and volumetric expansion. Limits for these parameters are given in Indian Standards for further reference. From studies, it is evident that the burst test and volumetric expansion can be estimated using mathematical models for LPG fuel tanks that are large capacity cylinders that are not intended for domestic consumption. In small cylinder segment like refrigerated cylinders, the burst pressure and its location can be predicted with mathematical models. Softwares like FEA, ANSYS, Pro-E WILDFIRE can be used for estimation of stress in cylinders. However,
this software cannot be used for routine laboratory tests as these are expensive, cannot be operative in shop floor and are not possible to integrate with online field equipment, where instantaneous response is solicited.

4.5 Cylinder Material Properties

The following documents reviewed under this category

- Comparison Of Hardness, Tensile Stress And Yield Stress, Depending On Temperature And Annealing Time Of Degradation Of P91 Steel [37]
- Correlation Between Hardness And Tensile Properties In Ultra-High Strength Dual Phase Steels – Short Communication [68]
- Effect Of Cooling Rate On Hardness And Microstructure Of Aisi 1020, Aisi 1040 And Aisi 1060 Steels [2]
- Effect Of Soaking Time On The Mechanical Properties Of Annealed Cold-Drawn Low Carbon Steel [76]
- Experimental And Analytical Investigation Of Thermal Coating Effectiveness For 3m3 LPG Tanks Engulfed By Fire [43]
- Fuzzy Regression Analysis: An Application On Tensile Strength Of Materials And Hardness Scales [95]
- Influence Of Degree Of Cold-Drawing On The Mechanical Properties Of Low Carbon Steel [74]
- Estimation Of Yield Strength From Hardness Measurement [84]

Form the literature; it is evident that correlations relationship is possible among hardness, tensile strength and yield strength. It is also evident that the heat treatment process on low carbon steel there is a relation between of steel effects its mechanical properties such as hardness, yield strength, tensile strength and ductility in other words percentage elongation.
This depends on soaking temperatures and time. The Indian standards on LPG Cylinder states repeated heat treatment on LPG cylinders till they pass the acceptance test instead of discarding a failed batch during the production process. This scenario affects mechanical properties, based on the literature study. Also the few studies revealed linear relation between yield strength and hardness on low carbon steel. Cylinder domes are manufactured with deep drawn domes. The cold drawing process can influence mechanical properties especially, tensile strength and hardness. Yield strength, tensile strength and ductility reduces with increased cold drawing operation on a steel sample.

4.6 Cylinder Manufacturing

The following literature reviewed under this category

- Effective LPG Cylinder Distribution To Shun Black-Marketing Of Gas Cylinders [65]
- Production As A Service: An Analysis Of Theory Of Constraints (TOC) Methods [81]
- The Increase Of Sustainability In Cylinder Manufacturing [79]
- Theoretical And Practical Evaluation Of Plastic Deformation And Straining Throughout Cupping The Shells Of Domestic LPG Cylinders [17]
- Code of practice for visual inspection of newly manufactured low pressure welded steel gas cylinders during manufacturing [53]

Cylinder manufacturing process, activity based costing of individual process in cylinder manufacturing process is reviewed. It is evident from the literature that the heat treatment is a critical operation in cylinder manufacturing to relieve the stress produced due to welding operation. The heat treatment is the most expensive operation in cylinder manufacturing process.
4.7 Guidelines and Standards

The following guidelines and standards are reviewed under this category:

- Comparisons of DOT ISO BS Standards on LPG Cylinder Specifications [83]
- Indian LPG Cylinder Specifications IS3196 part1 2006 A1 to A5 [25]
- Indian LPG cylinder test methods IS 3196 Part3:2012 [27]
- BS 5045 - British Standard for Transportable Gas Containers[21]
- BS EN 1442-2006 British Standard for Transportable Cylinder Specifications[19]
- BS EN 10002-1 Metallic materials - tensile testing [22]
- BS EN 12807-2009 [23]
- US standards, DOT Cylinder Specifications 4BA [40]
- DOT Specifications for periodic testing and inspection of Cylinders [75]
- EN 10002-5 Metallic testing at elevated temperatures - tensile test [32]
- Gas cylinder Rule 2004 [70]
- Gulf standards for LPG Cylinders, GSO-ISO-22991-2008-E [99]
- Guide to Gas Cylinders - Newzeland standards on Gas Cylinders [39]
- Guidelines for Good Safety Practices in the LP Gas Industry [94]
- Hazardous Materials Requirements for DOT Cylinder specifications [40]
- Cylinder raw material standard, IS6240 2008 [26]
- ANSI standard on LIQUID PROPANE GAS (LPG) FUEL CYLINDERS [12]
- Gas cylinder standard ISO 4706-1 Standard [63]
- ISO Standard for LPG Cylinders, ISO 22991 Standard [99]
- LP Gas Serviceman’s manual [77]
- Periodic testing and inspection of used LPG Cylinders Tender specifications [97]
- Steel - Conversion of elongation values part1 carbon and low alloy steels  ISO 2566-1 1984 [50]
- Welding guidelines for a metallic material grouping system [30]
- Steel sheet and strip for welded gas cylinders [20]
- Rules for rounding off numerical values while calculating percentage elongation [24]
- Guidelines for liquefied petroleum gas cylinders [46]
- Code for unfired pressure vessels [52]
- Inspection and conditioning of used LPG cylinders [56]
- Oman LPG Standard 120 [93]

From various guidelines and standards, it is understood that Indian standard is similar to European standards in terms of test methods and sampling procedures. However, the American standard is slightly different in test methods. Cylinders than can meet European standards can also meet American standards. Whereas cylinders are compiled to American standards require additional tests to meet European standards. Reviewed raw material specifications, welding process parameters, inspection methods, test methods at various stages of LPG Cylinder life cycles studies in this section.

Only 1 cylinder out of 203 cylinders is tested for acceptance test as per Indian standard and one cylinder out of 403 is tested for hydro test to ensure material properties. The sample size is very small and is not fit into any of the statistical sampling methods. American standard requires only circumferential sample testing whereas Indian and European standards requires both circumferential and longitudinal sample testing for acceptance test. There is no clause for rejection criteria in Indian standard if the sample is not qualified in acceptance test. The standard is lenient and allows re-heat treatment of cylinder batch till the batch gets passed in the test.
4.8 Policy Development and Analysis

The following literature reviewed under this category

- Bureau of Indian Standards List of License holders for LPG Cylinder manufacturing [31]
- Bharat petroleum Tender specifications for New cylinders – Non complied cylinders and suspension clause [18]
- Bureau of Indian standard consolidated suspension list for a year [28]
- De-regulation of LPG and diesel prices: a look at an alternative policy [41]

There are more than 125 cylinder manufacturers in LPG Cylinder manufacturing to cater the needs of LPG Cylinder market in India. Oil companies witnesses LPG Cylinder failures in market and they include the inspection clauses in their tender documents on cylinder manufacturer suspension procedures, if they are not meeting the standards. It means there is possibility to present a non-complied cylinder in market, which is perfectly certified by BIS and marked with BIS logo on it. Interestingly from a BIS site, one can access the number of cylinder manufacturers’ suspension details in a particular year. However, the consolidated list of suspensions of cylinder manufacturers shows no records, which is contradictory. In simple terms, even though BIS certifies LPG Cylinders, non-compliant cylinders can exist in market.

This is recognized by Indian oil companies. There is no clear policy in the existing system to curb the entry of non-compliant to consumer. There are few cases on Cylinder manufacturers that show business practices adopted in this segment is not so transparent, due to demand and high competition [35]. There is no clear policy to control in the existing scenario.

4.9 Miscellaneous documents related to the field of study

The following literature reviewed under this category

- A handbook of the petroleum industry [38]
• Oil and gas production handbook [47]
• Code of practice for training and testing of metal arc welders [51]
• Glossary of terms used in gas cylinder technology [54].
• Steel - conversion of elongation values: part 1 carbon and low alloy steels [55]
• Carbon steel billets, blooms, slabs and bars for forgings [57]
• Hot rolled carbon steel sheets and strips [58]
• Steel for general structural purposes [59]
• Metallic materials - tensile testing at ambient temperature [61]
• Energy Access [92]

This is a general category in which the areas broadly covered are LPG cylinder testing, tensile testing, raw material, welding processes to support main research domain.

4.10 Summary

It is evident from literature, existence of non-complied cylinders in market is possible and there is no policy / method to curb this scenario. Lack of sufficient samples for the destructive test, no clarity on defective cylinders in market, vast LPG Cylinder population / market requires a system to control such occurrences. It is only possible with the verification of all cylinders produced in manufacturing with a fail-safe system. Literature provides the basis for the research by showing the gaps and the linkages for addressing the gaps. Although direct literature is not available on LPG material similar to cylinder parent metal is available for study. Based on the literature, a strong base can be established that clear relations can be established among various parameters of cylinder material. Also literature can provide various other aspects to be considered while establishing relations. From the literature base, it is possible to establish relations and estimate all critical parameters using hardness, tensile strength and percentage elongation.

---End of Chapter 4---