Abstract

This chapter deals with the general introduction (need for high strength steel line pipe X-120M) which comprises of brief description of line pipe and different manufacturing techniques of line pipe, brief history of line pipe, research objective, experimental setup and the scope of present study.
1.0 Introduction

The energy demand is increasing day by day, in the coming years the demand will increase in many folds as of today. The energy is the basic requirement for the economic growth as well as to fulfill the daily activities whether it is at home, office or industry. There are different types of energy sources which are used directly or indirectly like petrol/diesel, coal, natural gas etc. and these sources are depleting day by days and not economic due to the limited availability. The availability of the natural gas is of plenty in the remote locations. The natural gas can be used as the alternative energy source economically if we can explore the possibility for economical transportation from the remote locations or economic long distance transportation. The major gas producing companies are investing heavily in technological developments to reduce the cost of energy delivery [1]. These competing technologies include new design methods, materials, welding and construction practices for large diameter pipe line, lower cost LNG (liquefied natural gas) transportation, conversion of gas to liquids, generation of high DC (Direct Current) voltage electricity for long distance transportation. Over the next decade, operators will be considering onshore development that will be involving installation of tens of billions of dollar of pipeline infrastructure. In several cases, the cost of exporting the product will determine the viability of the upstream production facilities so that some projects may only progress if the cost of getting the gas to the market can be substantially reduced. The predicted [2, 3] growth in energy consumption in the coming years requires sever efforts for transporting large amount of natural gas to end users and crude oil to the refineries. Large diameter pipelines serve the economic and safest mode of transportation. The tremendous pressure on the price of natural gas and oil, forces pipeline operators to explore all the possibilities to reduce the cost of the pipeline projects in future to lower down the cost of the gas and oil to end users. The use of X-80M has already shown the result in substantial cost savings. Furthermore cost can be saved as enhancing the properties of the weld and steel. There are large gas reservoirs [4, 5] around the world that could help to close the supply gap, but many of those reservoirs are leveled static because the industry lacks an efficient and economic ways to deliver the gas to the end users. The impact of this inability to deliver the gas to market is a global slowing of economic growth. Therefore economic transport of gas from remote sources of supply is an important consideration in today’s global economic environment. With the development of X-120M line pipe, economic benefits can now be realized that will make commercialization of remote gas resources practical. The application of high-strength steel line pipe can reduce the total cost of long distance pipelines on the order of 5-15% and in some cases might be enabling technology. Replacing lower strength line pipe with thinner wall X-120M line pipe reduces steel tonnage and cost, but optimal application of X-120M line pipe occurs at higher pipeline operating pressures. The ability to design higher pressure, smaller diameter, and thinner wall pipelines using X-120M steel provides opportunities to reduce material, construction and compression costs thus giving the lowest cost of supply to deliver gas to market.
The material also makes dense phase pipeline operations economically attractive and offers the potential to further reduce the overall cost of gas development projects by allowing additional optimization of process facilities based on the capability of the pipeline system. In view of the ever-increasing length of pipeline networks and ever-increasing operating pressure, it is very essential to develop high strength steel for manufacturing line pipes. The governing parameters of any pipeline project are project cost, operating cost and operating life. The variables affecting the project cost are mainly the tonnage of steel and the welding consumables. The development of high strength low alloy steel makes a significant contribution to pipeline project cost reduction. Recent experiments show that X-100M steel could give investment cost savings of about 7% with respect to X-80M and by using X-100M instead of X-70M, the cost saving can be higher. When we use X-120M steel the cost saving may be much higher over X-70M material. Natural gas [6] is an increasingly alternative energy source but major reservoirs are normally remotely located from the end users. High operating pressure and/or thin walled line pipes are the means to reduce the cost, but conventional steels typically lacking sufficient strength to utilize those cost saving measures. To solve these challenges, a high strength grades, small and large diameter Line pipe, X120M J-C-O-E Line pipe has to be developed. Therefore, a large step in Linepipe manufacturing technology was required to develop X-120M from the exiting technological base. The development of steel making technology [7] and new installations in the plate mills in combination with deeper knowledge in austenite processing allow the introduction of modern pipe line grades with lower ‘C’ levels. These steels show a better strength/toughness ratio and weldability, taking into account other prerequisites they allow also resistance against Hydrogen Induced Cracking (HIC). Several efforts have been noticed to reduce the cost by alternative alloy design. Recent progress in high strength and low alloy steel plates by Thermomechanical Controlled Processing (TMCP) manufacturing technology has called for new developments in welding consumables to produce weld metal deposit with strength and toughness essentially equivalent to the base metal. The welding and pipe forming procedures of manufacturing the line pipe for critical applications is need to be developed. The steel for API-5L Grade X-120M steel line pipe is readily available but the weldability and formability of this material is at an embryonic stage. Advancement in welding and materials science technology has resulted in greater improvements in the reliability of the weld.

1.1 Line Pipe

Line Pipe [8] is nothing but a long, hollow cylinder, usually steel, through which fluids are transported and is used for transportation of gas, oil or water generally in a pipeline or utility distribution system. The line pipe is suitable for use in conveying gas, water, and oil in both the oil and natural gas industries. Line pipe can be of seamless and welded. It includes plain-end, threaded-end, and beveled end pipe, as well as through-the-flow line (TFL) pipe and pipe with ends prepared
for use with special couplings. Although the plain-end line pipe meeting API 5L is primarily intended for field makeup by circumferential welding as the manufacturer will not assume responsibility for field welding.

1.2 Description of Line Pipe

Line pipes [8] are generally used to make pipelines for the transportation of Oil, Gas, Slurry and Water which includes compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon and structural applications as well. Line pipes fabricated from the steel plate or steel coil with longitudinal or helical but weld seam are called as welded line pipe. The welding may be done by a shielded metal-arc welding (SMAW), submerged arc welding (SAW), gas tungsten-arc welding (GTAW), gas metal-arc welding (GMAW), flux-cored arc welding (FCAW), and Electric resistance welding (ERW) processes or by a combination of these processes using a manual, semiautomatic or automatic welding techniques or a combination of these techniques. Line pipes which are fabricated from steel billets by a hot forming process and followed by cold sizing and cold finishing and are known as seamless line pipe.

1.3 Classification of Line Pipe

Line pipes are generally manufactured as per API 5L specification [8] and classified as per product specification level depending on the service conditions. The first category ‘PSL-1’ provides a standard quality level for line pipe and second category ‘PSL-2’ has additional mandatory requirements for chemical composition, notch toughness and strength properties and additional non-destructive testing requirements. Depending upon the environmental condition ‘PSL-2’ category is again divided into two groups namely “Sour Service” and “Offshore Service”. Offshore services line pipe are intended for exploration, drilling, production, processing or storage of hydrocarbons or other related activities/fluids and sour service line pipe is applicable at corrosive atmosphere or transporting fluid which corrosive in nature.

1.4 Line Pipe Manufacturing Techniques

Line pipe can be manufactured in many way like submerged arc weld (SAW), electrical resistance weld (ERW), continues weld (CW) and seamless process. Line pipe can be manufactured from the plates, coils, and billets depending on the manufacturing processes.

1.4.1 Double Submerged Arc Welded (DASW) Line Pipe

The line pipe welded by combination of GMAW and SAW welding processes is known as SAW line pipe. In this technique, the SAW line pipe can be manufactured from steel plate or steel coil and depending on the method of line pipe forming, it is designated in two categories i.e. longitudinal
double submerged arc welded pipe (LDSAW) and helical double submerged arc welded pipe (HDSAW).

1.4.1.1 Longitudinal Double Submerge Arc Welded (LDSAW) Line pipe
LDSAW line pipe having a one Longitudinal seam, produced by the combination of the gas metal arc welding and submerged arc welding processes in which gas metal arc welding is used to do the continuous tacking to maintain the alignment of the abutting edges. The LDSAW line pipes are again can be formed by three different processes i.e. Three Roll Bending, UOE and JCOE techniques.

1.4.1.1.1 Three Roll Bending Process
In this line pipe forming process the plate is formed / rolled in three roll bending unit to make the shell. After three roll bending shell is post formed along the longitudinal edges to match the curvature of the edges with the body of the shell. After completing the forming operation the longitudinal edges are continuous tack welded by GMAW welding and final welding by automatic submerge arc weld on both inside and outside of the line pipe. Finally the line pipe is mechanically expanded and followed by end beveling, hydrostatic testing, non-destructive testing (NDT) and other essential testing/inspection to confirm the compliance with the applicable specification.

1.4.1.1.2 U-O-E process
In this line pipe forming process, edges of the plate is crimp formed along the length, converted into U-shape by a single stroke U-pressing die and then pressed in O-shaped die which is in two half. After completing the forming operation, the longitudinal edges are continuous tack welded by GMAW welding and final welding by automatic submerge arc weld on both inside and outside of the line pipe. Finally the line pipe is mechanically expanded and followed by end beveling, hydrostatic testing, non-destructive testing (NDT) and other essential testing/inspection to confirm the compliance with the applicable specification.

1.4.1.1.3 J-C-O-E Process
In this line pipe forming process, edges of the plate is crimp formed along the length, after crimping, the plate is then press formed into a J-shape, C-shape and then O-shape by incremental progressive pressing along the length. After completing the forming operation the longitudinal edges are continuous tack welded by GMAW welding and final welding by automatic submerge arc weld on both inside and outside of the line pipe. Finally the line pipe is mechanically expanded and followed by end beveling, hydrostatic testing, non-destructive testing (NDT) and other essential testing/inspection to confirm the compliance with the applicable specification.
1.4.1.2 Helical Double Submerge Arc Welded (HDSAW) Line Pipe
In the forming process, strip from hot rolled coil continuously feed to the press forming station at an angle and the edges of the strip comes out with together in helical form. The edges of the strip are continuously tack weld at the forming stage itself and after having the sufficient length required the formed line pipe is cut. After cutting the final welding carried out by automatic submerge arc weld on both inside and outside of the line pipe. Finally the line pipe is end beveled followed by hydrostatic testing, non-destructive testing (NDT) and other essential testing/inspection to confirm the compliance with the applicable specification.

1.4.2 Electrical Resistance Welded Line Pipe (ERW)
In the forming process, strip from hot rolled coil continuously feed to the press forming (series of forming rolls with decreasing radii) and longitudinal abutting edges are welded together by electrical resistance welding (edges to be welded are mechanically pressed together and the heat for welding is generated by the resistance to flow of electric current applied by induction). After welding the line pipe is hydrostatic tested followed by the NDT and other essential testing/inspection to confirm the compliance with the applicable specification.

1.4.3 Seamless Line pipe
Seamless pipe is fabricated without a weld seam, produced by a hot piercing process of billet, which can be followed by cold sizing or cold finishing producing the desired shape, dimensions and properties. After line pipe end beveled followed by hydrostatic testing, non-destructive testing (NDT) and other essential testing/inspection to confirm the compliance with the applicable specification.

1.5 History of line pipe
Perhaps the first use was by ancient agriculturalists that diverted water from streams and rivers into their fields [9]. Archeological evidences suggest that the Chinese used reed pipe for transporting water to desired locations as early as 2000 BC. Clay tubes that were used by other ancient civilizations have been discovered. During the first century AD, the first lead pipes were constructed in Europe. In tropical countries, bamboo tubes were used to transport water. Colonial Americans used wood for a similar purpose. In 1652, the first waterworks was made in Boston using hollow logs. Development of the modern day welded steel pipe can be traced back to the early 1800s. In 1815, William Murdock invented a coal burning lamp system. To fit the entire city of London with these lights, William Murdock joined together the barrels from discarded muskets. He used this continuous pipeline to transport the coal gas. When his lighting system proved successful, a greater demand was created for long metal tubes [9]. To produce enough tubes to meet this demand, a variety of inventors set to work on developing new pipe making processes. An early notable method
for producing metal tubes quickly and inexpensively was patented by James Russell in 1824. In his method, tubes were created by joining together opposite edges of a flat iron strip. The metal was first heated until it was malleable. Using a drop hammer, the edges folded together and welded. The pipe was finished by passing it through a groove and rolling mill. Russell's method was not used long because after that year, Comelius Whitehouse developed a better method for making metal tubes. This process was called the butt-weld process and is the basis for our current pipe-making procedures. In this method, thin sheets of iron were heated and drawn through a cone-shaped opening. As the metal went through the opening, its edges curled up and created a pipe shape. The two ends were welded together to finish the pipe. The first manufacturing plant to use this process in the United States was opened in the year 1832 in Philadelphia. Gradually, improvements were made in the Whitehouse method. One of the most important innovations was introduced by John Moon in 1911 [9]. He suggested the continuous process method in which a manufacturing plant could produce pipe in an unending stream. He built machinery for this specific purpose and many pipe manufacturing facilities adopted it. While the welded tube processes were being developed, a need for seamless metal pipes arose. Seamless pipes are those which do not have a welded seam. They were first made by drilling a hole through the center of a solid cylinder. This method was developed during the late 1800s. These types of pipes were perfect for bicycle frames because they have thin walls, light weight and strong. In 1895, the first plant to produce seamless tubes was built. As bicycle manufacturing gave way to auto manufacturing, seamless tubes were still needed for gasoline and oil lines. This demand was made even greater as larger oil deposits were found. As early as 1840, iron workers could already produce seamless tubes. In one method, a hole was drilled through a solid metal, round billet. The billet was then heated and drawn through a series of dies which elongated it to form a pipe. This method was inefficient because it was difficult to drill the hole in the center. This resulted in an uneven pipe with one side being thicker than the other. In 1888, an improved method was awarded a patent. In this process the solid billet was cast around a fireproof brick core. When it was cooled, the brick was removed leaving a hole in the middle. Since then, the new roller techniques have replaced these methods. There are two types of steel pipe, one is seamless and another has a single welded seam along its length. Both have different uses. Seamless tubes are typically more light weight, and have thinner walls [9]. They are used for bicycles and transporting liquids. Seamed tubes are heavier and more rigid. They have a better consistency and are typically straighter. They are used for things such as gas transportation, electrical conduit and plumbing. Typically, they are used in instances when the pipe is not put under a high degree of stress. The diameter can range from tiny pipes used to make hypodermic needles, to large pipes used to transport gas throughout a city. The wall thickness of the pipe can also be controlled. Often the type of steel will also have an impact on pipe's the strength and flexibility. The primary raw material in pipe production is steel. Steel is made up of primarily iron and other metals that may be present in the
alloy include aluminum, manganese, titanium, tungsten, vanadium, and zirconium. Steel pipes are made by two different processes. The overall production method for both processes involves three steps. First, raw steel is converted into a more workable form. Next, the pipe is formed on a continuous or semi-continuous production line. Finally, the pipe is cut and modified to meet the customer's needs. Both skelp and billets are used to make pipes. Skelp is made into welded pipe. It is first placed on an unwinding machine. As the spool of steel is unwound, it is heated. The steel is then passed through a series of grooved rollers. As it passes by, the rollers cause the edges of the skelp to curl together. This forms an unwelded pipe. The steel next passes by welding electrodes. These devices seal the two ends of the pipe together. The welded seam is then passed through a high pressure roller which helps to create a sound weld. The pipe is then cut to a desired length and stacked for further processing. Welded steel pipe is a continuous process and depending on the size of the pipe. When seamless pipe is needed, square billets are used for production. They are heated and molded to form a cylinder shape, also called a round. The round is then put in a furnace where it is heated white-hot. The heated round is then rolled with great pressure. This high pressure rolling causes the billet to stretch out and a hole to form in the center [9]. Since this hole is irregularly shaped, a bullet shaped piercer point is pushed through the middle of the billet as it is being rolled. After the piercing stage, the pipe may still be of irregular thickness and shape. To correct this, it is passed through another series of rolling mills. After either type of pipe is made, they may be put through a straightening machine. Pipes are also inspected for defects at the end of the process. One method of testing a pipe is by using a special machine. This machine fills the pipe with water and then increases the pressure to see if it holds. Defective pipes are returned for scrap.

The Egyptians made the first metal pipe of copper in 3000 BC until cast iron became relatively cheap in the 18th century [10]. Welded steel pipe is made by bending strips of steel into the form of a tube and welding the longitudinal seam either by electric resistance, by fusion welding, or by heating the tube and pressing the edges together. Steel pipe, introduced in the early 20th century, is widely used for conducting substances at extremely high pressures and temperatures. Cast-iron pipes, which came into common use in the 1840s, resist corrosion better than steel pipes and are therefore frequently used underground. During World War II, manufacturers developed plastic pipe to replace metals that were in short supply [10]. The first natural-gas and petroleum pipelines in the United States were built during the 19th century. Today in many parts of the world pipelines are an extremely important means of transporting diverse fluids. The Trans-Arabian Pipeline, which carries oil from the Persian Gulf to the Mediterranean, is over 1,600 km long [10]. Pipelines continue to play a major role in the petroleum industry, providing safe, reliable and economically transportation [11]. As the need for more energy increases and population growth continues away from supply centers, pipelines are needed to continue to bring energy to you. From the early days of wooden trenches and wooden barrels, the pipeline industry has grown and employed the latest technology in pipeline
operations and maintenance. Today the industry uses sophisticated controls and computers systems, advanced line pipe materials and corrosion prevention techniques. In the 1860's as the pipeline business grew, quality control of pipe manufacture became a reality and the quality and type of metal for line pipes improved from wrought iron to steel. Technology continues to make better line pipes of better steel. At the same time pipeline safety regulations become more driven by better understanding of materials available and better techniques to operate and maintain pipelines [11].

Now a days, the steel line pipe manufacturing is a technology driven whether it is basic steel making or slab casting or steel plate rolling for line pipe steel plates or the line pipe manufacturing (forming, welding, finishing and the testing of line pipes for the compliance to the specific specification) itself. The specification for the above processes has been developed and established to produce the quality product at every stage of manufacturing for monitoring and controlling the quality of the product.

1.6 Research Objective

In view of the ever-increasing demand for energy and ever increasing operating pressure of line pipe, it is very essential to develop high strength steel and production technology for manufacturing the line pipes of high strength of level to X-120M. Recent experiments show that X-100M steel line pipe could give investment cost savings of about 7% with respect to X-80M and by using X-100M instead of X-70M, the cost saving can be higher. If we use X-120M steel line pipe, cost saving is 5-15% over X-70M material as discussed in the introduction of this chapter. Therefore, economic transport of gas from remote sources is an important consideration in today's global economic environment. To solve these challenges, a high strength grades, large diameter line pipe of X-120M strength level through J-C-O-E technique has to be developed. Therefore, a large step in line pipe manufacturing technology was required to develop X-120M line pipe from the exiting technological base. Recent progress in high strength and low alloy steel plates manufacturing technology has called for new developments in forming, welding and finishing of the line pipe to required properties and dimensions. The manufacturing of X-120M line pipe is required to be developed through J-C-O-E technique as manufacturing of API-5L Grade X-120M steel line pipe is at an embryonic stage. Advancement in welding and materials science technology has resulted in greater improvements in the reliability of the steel and weld. To achieve the above, the plate material and welding consumables, welding process control, pipe forming procedure (as the spring back is very high at this level of strength) and expansion percentage should be selected in such a way that exceeds the targeted values in terms of strength and toughness of X-120M line pipes. To achieve the strength and toughness level of X-120M, tool is to control and development of the microstructure in the base (Plate) material, weld as well as in the heat affected zone (HAZ) of line pipe with lower transformation products like lower bainite, martensite, to achieve the strength and toughness.
In present study materials science concept (Structure-property relationship) was used to develop a weldable high strength line pipe (X-120M) for transportation of gas through J-C-O-E technique of manufacturing. The manufacturing X-120M line pipe, the target properties is for load-based design of size 18” diameter and 14.3 mm wall thickness with reference to API-5L as shown in the Table #1.01.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Base Pipe</th>
<th>Seam</th>
</tr>
</thead>
<tbody>
<tr>
<td>YS</td>
<td>&gt; 830 MPa</td>
<td>≥ 830 MPa</td>
</tr>
<tr>
<td>UTS</td>
<td>≥ 915 MPa</td>
<td>≥ 915 MPa</td>
</tr>
<tr>
<td>CVN @ -30 °C</td>
<td>≥ 231 J</td>
<td>≥ 84 J</td>
</tr>
<tr>
<td>CTOD @ -20 °C</td>
<td>≥ 0.14 mm</td>
<td>≥ 0.08 mm</td>
</tr>
<tr>
<td>DWTT</td>
<td>&lt; -20 °C</td>
<td>---</td>
</tr>
<tr>
<td>DWTT (SA%) @ -20 °C</td>
<td>≥ 85%</td>
<td>---</td>
</tr>
<tr>
<td>YS/UTS Ratio</td>
<td>&lt; 0.99</td>
<td>---</td>
</tr>
</tbody>
</table>

Table #1.01 Target Properties for X-120M Line pipe

1.7 Experimental setup

For API-5L, X-120M line pipe manufacturing material/tool required can be classified in three categories which are required to design/select with respect to the size, grade and thickness of the line pipe. The first category is steel plates has to be design or select very-very carefully as these ultimately effect the final properties of the line pipe. The plates for line pipes are the basic raw material which is specifically design to meet the mechanical properties of the base and HAZ (Heat Affected Zone) of the line pipe. To meet the mentioned properties the microstructure of the plate is the deciding factor, accordingly the chemistry and TMCP and accelerated cooling cycle has been fixed. Secondly the weld is the integral part of the line pipe so the chemistry of the SAW welding wire and type of SAW flux has to be decided to produce the desired microstructure in as-weld condition to meet the strength and toughness criteria of the line pipe. As submerged arc weld is high heat input weld, the welding parameter (Heat Input) has been design to produce the sound weld and strength toughness criteria in the heat affected zone (HAZ) as good as base metal. The welding consumables and heat input has been designed/optimized to obtain the strength in the weld more than that of base metal. The plate edge milling and end beveling insert can be selected according to the size required for making the weld joint geometry on plates and the end bevel of the line pipe. The third is the tooling which required forming/shaping of the plate into line pipe. The important part of the tooling is the design (length, width and radius) and the material to have sufficient strength and hardness to withstand the forming load to form/shape the high strength plate formation. Before proceeding for line pipe manufacturing, the line pipe manufacturing procedure has to be established, this includes the following activities.
1. Steel plates manufacturing specification to meet the strength and toughness requirement of X-120M line pipe base metal.
2. Establishment of the heat affected zone (HAZ) of weld which can meet toughness requirement of X-120M line pipe.
3. Establishment of the welding consumables for submerged arc welding for X-120M line pipe.
4. Establishment of the forming and mechanical expansion tooling for X-120M line pipe.

The experimental set up to manufacture the line pipe requires the following manufacturing and testing equipments.

1. **Tab Joining** (Run-in and run-out tabs for submerged arc welding).
2. **Plate Ultrasonic Testing Setup** (Scanning of full plate for any laminar defects).
3. **Edge Milling Setup** (Joint geometry for SAW weld and fixing of the width of the plate).
4. **Crimping Press Setup** (Crimping of plate edges along the length to required curvature).
5. **JCO Forming Setup** (Forming the plate into line pipe of required diameter).
6. **Continuous Tack Welding Setup** (Carry out the root welding operation with GMAW).
7. **Multi Wire SAW Setup** (Carry out the final welding operations on line pipe).
8. **Real time X-ray Setup** (Inspection of the line pipe weld for any internal defect)
9. **Mechanical Expander** (Achieving the desired dimensions in the line pipe)
10. **End Chamfering Setup** (End joint geometry of line pipe).
11. **Hydrostatic testing setup** (Testing of line pipe for any leak)
12. **Automatic Ultrasonic multi channel Setup** (Testing of the weld for any defect).
13. **Tensile Testing Setup** (Verification of the strength).
14. **CVN Setup** (Toughness verification).
15. **CTOD Setup** (Ductile fracture propagation resistance verification).
16. **Hardness tester** (Hardness verification)
17. **DWTT Setup** (Verification of ductile/brittle fracture in the base metal)
18. **Light and Electron Microscopes**. (Verification of microstructures)

1.8 Scope

Scope of the present study is to establish the manufacturing of API-5L, X-120M grade line pipe by utilizing the existing facility through JCOE technique. A large step required to manufacture the X-120M line pipe as the line pipe mill is installed to produce the line pipe up to the grade X-80M. The manufacturing processes/stages which required development/optimization of line pipe forming, mechanical expansion and long seam welding. The forming and expansion of ultra high strength TMCP and accelerated cooled steel line pipe required the special tooling that has to be designed and the process parameters required to optimize for desired formation. As for as long seam welding is concerned the welding procedure has to be established for optimum heat input level to get the desired
strength and toughness in the heat affected zone of the long seam weld and development of welding consumables for long seam weld of strength level equal or greater than the strength level of X-120M and the toughness level down to -20°C. Finally after establishing the forming, mechanical expansion and welding operations, the line pipe of API-5L, X-120M grade to be manufactured which should meets the requirement of objective of the present study and line pipe specification API-5L.

1.9 References

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