Scientific Paper / Artículo Científico

UNIVERSIDAD POLITÉCNICA SALESIANA ECUADOR
INGENIUS
Revista de Ciencia y Tecnología
https://doi.org/10.17163/ings.n19.2018.05
pISSN: 1390-650X / eISSN: 1390-860X

Factors for selecting Petroleum Liquefied Gas conduction pipes in Ecuador

Factores para seleccionar tuberías de conducción de gas licuado de petróleo en el Ecuador

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Abstract

In order to build residential, commercial and industrial installations of Liquefied Petroleum Gas (LPG) in Ecuador, the INEN 2260: 2010 Ecuadorian Technical Regulation establishes the minimum safety guidelines that must be taken into account in this type of installations. To conduct this hydrocarbon, the Standard accepts several materials of pipes, methods of union with accessories, forms of installation, which makes the responsible for the sizing and planning of this type of systems have several options to choose from when directing a determined project. This paper shows some factors that affect the selection of the most suitable pipeline for LPG systems, complying with the mandatory Technical Standard in Ecuador. The mechanical strength, hardness and weight are compared as properties of the accepted materials; the execution times of pipes and fittings and, finally, the costs associated with materials, labor and maintenance that must be given to these systems are compared.

Keywords: Recommended materials, Technical Standard, pipes, best application, properties.

Resumen

Para realizar instalaciones residenciales, comerciales e industriales de gas licuado de petróleo (GLP) en el Ecuador, rige la norma técnica ecuatoriana INEN 2260:2010, la cual establece los lineamientos mínimos de seguridad que se deben tener en cuenta en este tipo de instalaciones. Para conducir este hidrocarburo, la norma acepta varios materiales de tuberías, métodos de unión con accesorios, formas de instalación, lo que hace que el responsable del dimensionamiento y planeación de este tipo de sistemas tenga varias opciones para escoger al momento de encaminar un proyecto determinado. El presente trabajo muestra algunos factores que inciden en la selección de la tubería más adecuada para sistemas de GLP, cumpliendo con la norma técnica obligatoria en el Ecuador. Se compara la resistencia a la tracción, dureza y peso como propiedades de los materiales aceptados; tiempos de ejecución de uniones entre tuberías y accesorios y, finalmente, se comparan los costos asociados a los materiales, mano de obra y mantenimiento que debe darse a estos sistemas.

Palabras clave: materiales recomendados, norma técnica, tuberías, mejor aplicación, propiedades.

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Received: 27-06-2017, accepted after review: 12-08-2017

Suggested citation: Venegas, D.; Ayabaca, C.; Celi, S.; Rocha, J. and Mena, E. (2018). «Factors for selecting Petroleum Liquefied Gas conduction pipes in Ecuador». Ingenius. N.°19, (january-june). pp. 51-59. doi: https://doi.org/10.17163/ings.n19.2018.05.

1. Introduction

Liquefied Petroleum Gas (LPG) is a fuel used for residential, commercial and industrial applications [1, 2]. In Ecuador, use of this hydrocarbon is very frequent, and, as such, the National Government has foreseen a subsidized price for the residential sector [3, 4], since it offers several advantages, among which we can mention [5–8]:

El gas licuado de petróleo (GLP) es un combustible utilizado para aplicaciones residenciales, comerciales e industriales [1, 2], y en el Ecuador el consumo de este hidrocarburo es muy frecuente, por lo que para el sector residencial el Gobierno nacional ha previsto un precio subsidiado [3, 4], ya que brinda varias ventajas entre las que se pueden mencionar [5–8]:

- High calorific power compared to other energy sources.
- Clean in terms of emissions of polluting gases.
- It satisfies several energy needs.

As it is a very explosive and flammable fuel [9], much caution is required when planning, sizing and selecting storage systems (containers), transport (pipes), consumer equipment, and protection and safe-ty elements [10].

The risk in a LPG system is always present and can not be eliminated [11], but it can be minimized if the systems that contain it are conceived technically [12, 13], in accordance with the guidelines established in technical standards [14] where the minimum safety requirements are indicated at the time of installation.

In Ecuador, the INEN 2260: 2010 standard is in force: «Fuel gas installations for residential, commercial and industrial use. Requirements» [15], which establishes the minimum mandatory safety parameters in the national territory, and covers all the necessary components in an installation, from storage tanks, pipes, regulation and control systems, prevention sys-tems, maintenance, among others.

In nature, LPG is in a gaseous state, but to facilitate its storage in containers it is converted to a liquid state by increasing its pressure and lowering its temperature [16]. Inside these containers, a phenomenon of natural vaporization of the liquid occurs as a result of heat exchange between it and the environment [17], and it is in this state that it is transported through pipes for consumption.

These pipelines must at minimum comply with the following [18, 19]:

- Manufacturing materials must be compatible with the fuel they are transporting.
- Their dimension must be adequate to drive the flow that is required in the operation of consumer equipment.
- They must withstand pressure tests and the ser-vice pressure to which they will be subjected.
- They must withstand the physical conditions of the environment in which they will be in-stalled.

The types of pipe materials that the technical standard accepts for the installation of LPG systems are shown in Table 1.

Table 1. Load estimation of a cooling unit, Chiller 2 – West-inghouse – 460 V

Pipeline	Manufacturing standard
Carbon steel	ASTM A 53 [20] ISO 65 (serie Heavy) [21]
Stainless steel	ANSI/AGALC1 [22] ASTM A 240 [23]
Copper	ISO 1640 [24] ASTM B88 [25]
Polyethylene	ISO 4437 [26] ASTM D2513 [27]
P-Al-P*	AS-4176 [28] ISO 17484-1 [29]

* P-Al-P Polyethylene aluminum polyethylene.

The table shows that accepted materials can be metal-lic or plastic, and there is a procedure or method of joining pipes with their accessories for each of them. Table 2 shows the most commonly used procedures for joining pipes with their accessories.

Table 2. Methods for joining pipes with accessories [30]

Pipeline	Union procedure
Carbon steel	SMAW o threaded
Stainless steel	Pressing fit
Copper	Oxyacetylenic
Polyethylene	Thermofusion or electrofusion
P-Al-P	Thermofusion or electrofusion

For ease of inspection, maintenance and repair in case of leaks, it is recommended that the pipes that conduct LPG be installed in plain sight. However, users prefer that they are hidden for aesthetic reasons.

The technical standard accepts that pipes for conducting LPG can be hidden if they are installed:

- inside ducts,
- jacketed in a pipe of greater mechanical strength,
- embedded in walls and floors, provided they are covered with an easily removable material,
- buried if they are given adequate protection against physical damage or corrosion.

Table 3. Ways to install pipes [31]

Way to instalation	Stainless	Steel steel	Copper	Polyethylene	P-Al-P
View	Yes	Yes	Yes	No	No
Embedeed	Yes	Yes	Yes	No	Yes
In pipeline	Yes	Yes	Yes	No	Yes
Buried	Yes	Yes	Yes	Yes	Yes
Recessed*	No	No	No	No	No

*Recessed: That pipe that is fused in the building becomes a structural part of it.

Table 3 shows the accepted forms of pipe installation according to the materials used.

With these options of pipe materials, joining procedures with accessories and ways to install them, there are several additional factors that can affect the proper selection for an LPG installation in Ecuador. This paper presents several of these influencing factors to obtain a selection that is more in line with the characteristics of each user, and the particular conditions that surround them.

2. Materials and methods

2.1. Properties of the material

The following physical and mechanical properties of the materials indicated in Table 1 were compared: ten-sile strength, hardness and weight per meter of pipe.

- To measure the mechanical strength, a Tinius Ol-sen universal testing machine model Super L-20, series 80700-1 was used. The criteria for the measurement is based on ASTM E-8M [32].
- The Rockwell durometer used to measure the hardness is a Mitutoyo, Durotwin model, BG000062 series, diamond penetrator for ADC scales, 1/16” steel ball penetrator for FBG scales, with analog reading. To validate the hardness measurement procedure, the ASTM E18 03 Standard method for Rockwell hardness by in-dentation [33] and ASTM D785 Standard test method for Rockwell hardness of plastics and electrical insulating materials [34] were used.
- To measure the weight of pipes, the Shimadzu Unibloc balance was used. Cap 220 g.

2.2. Installation times

Each of the procedures described in Table 2 has its particularities, its form of execution, its complexity and therefore, its installation time.

Joints were made for 1” pipe and under the procedures established in Table 2, all of them by qualified personnel with vast experience in the assembly of LPG systems.

- The first procedure consisted of making a joint and measuring the time between the start and the end, from the time the tool is operated until the joint is finished.
- For the second procedure, the necessary connections were made to obtain a pipe section of 60 m, with a joint at each end that could then be joined to another accessory. The total time required was recorded.

In both procedures, a Steren chronometer model CLK-150 was used. It should be noted that the external conditions (ambient temperature, atmospheric pressure) for the two procedures were similar.

2.3. Cost ratio

A fundamental aspect that a user of this type of system takes into account is the installation cost, which depends directly on:

- Prices of materials (Table 1) and compatible ac-cessories, plus consumables, according to the joining procedures (Table 2). These prices have been requested from 3 local suppliers and the lowest value quote has been chosen.
- Qualified workforce carries out the assemblies and installations (in welding procedures, the personnel must be qualified by a certifying body). These costs have been obtained with the help of installation companies with several years of experience in LPG systems.
- Preventive maintenance of an installation must be carried out every 5 years [35]. These maintenance values have been estimated in installations of similar size for each of the materials (Table 1) and installed forms of pipe (Table 3).

The cost relationship expresses a value taken as a unit, and from this value and according to the expressed criterion, it is compared as many times as con-tains the unit for the following values.

3. Results and discussion

3.1. Properties of the material

Each material displays certain characteristics, physical and chemical properties, which make them more ad-vantageous than others for a given application.

a) Tensile strength

With this value it is possible to determine what load each one of them can bear before exceeding their elastic limit and deforming without losing their initial properties. Figure 1 shows the tensile strength of the various materials suitable for transporting LPG.

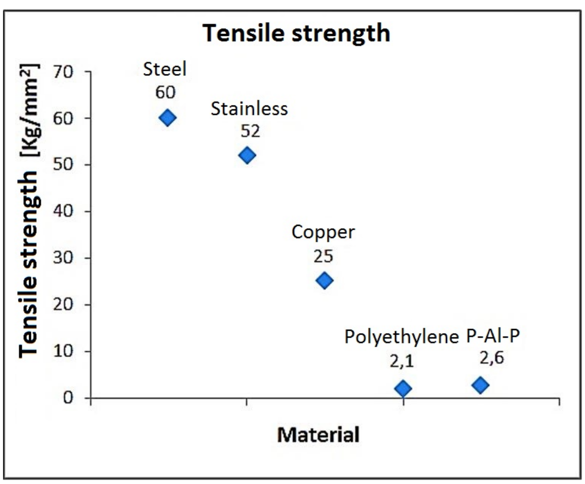

Figure 1. Comparison of tensile strength

The material with the highest tensile strength is steel with 60 kg/mm^2, followed by stainless steel with 52 kg/mm^2, then copper with 25 kg/mm^2, P-Al-P with 2.6 kg/mm^2 and, finally, polyethylene with 2.1 kg/mm^2.

b) Hardness

Hardness is the property of resistance of the materials to scratches and perforations, and as a pipe for conduction of LPG is exposed to scratches and blows by external agents, this property is shown in Table 4.

With the results of a) and b), steel pipe is the most recommended to be installed in areas of high shock risk. Due to its low resistance and its degradation when exposed to sunlight, it is recommended that polyeth-ylene pipe is buried when installed.

Table 4. Hardness of materials

Pipeline	Hardness	Scale
Carbon steel	99	Rockwell B
Stainless steel	92	Rockwell B
Copper	37	Rockwell B
Polyethylene	68	Rockwell C
P-Al-P	11*	Rockwell B

* Aluminum hardness

c) Weight

The weight per length unit of pipe for a diameter of 1” determines which type will perform better when ele-vated installations are required, or for long trips that are manageable for crews of installers.

Regarding weight, the polyethylene pipe is lightest (0.146 kg/m), which makes it very versatile when installed in long stretches (Figure 2), and as it comes in rolls, installation is very simple. A similar thing occurs with P-Al-P pipe, with a weight of 0.293 kg/m. It is very versatile for long sections, and this pipe can be embedded in walls and floors, through ducts and jacketing.

Figure 2. Polyethylene pipe ready to be installed.

Next is the stainless-steel pipe with 0.675 kg/m, then the copper pipe with 0.997 kg/m and, finally, the steel pipe, whose weight is 2.478 kg/m, which means that for long stretches it is necessary to install intermediate joining accessories such as flanges or universals. This also makes it difficult to handle in large diameters to perform work in the workshop, which means that the joints for these pipes can only be worked on in situ.

Figure 3 shows the comparison of values of the weights per meter of pipes for LPG conduction.

Table 5 shows the connection times of pipes with fittings, taken for the procedures described in 2.2 (a single connection of pipe with accessory and union of 60 lineal m continuous pipes).

Table 5. Average times to make joints or links in LPG pipes

Time	Steel	Stainless Steel	Copper	Polyethylene	P-Al-P
Connection time for a joint	18 min	15 s	1 min	1 min	1 min
Coonection time for 60m of pipe	4,5 h	3 min	30 min	2,5 min	2,5 min

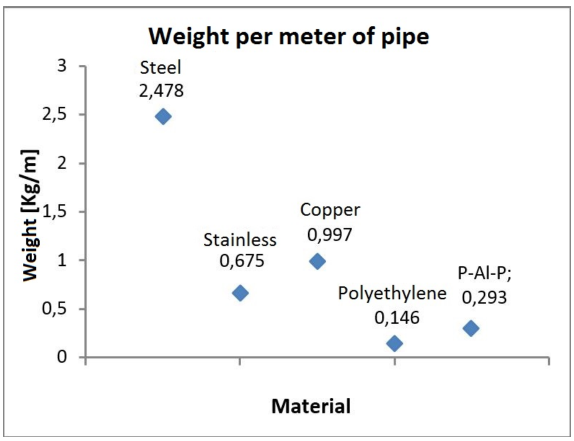

Figure 3. Comparison of pipe weights for conducting LPG

The first measured procedure corresponds to a single joint for a 1" pipe with one joint. The quickest joint to make is the pressing fit. Its value of 15s corre-sponds to the switching on of the tool, closing of the tongs, and subsequent pass—not pass check with the gauges. It is a very fast and clean process. The follow-ing methods have the same joint time of 1 min: poly-ethylene, P-Al-P and copper. The method includes heating the plate for thermofusion, the pipe reaching the required temperature, and joining it with the acces-sory. For copper, the connection time of the pipe with the accessory by oxyacetylene is taken into account, using a 5% silver alloy rod which is then melted, and the liquid formed is poured between the pipe and the fitting to achieve fusion. The longest method is the SMAW for steel pipe (18 min.). The time required for 4 steps is taken into account, from the root, to the final finish, including the cleaning of slag.

For the second procedure, the times taken are those necessary to join 60 meters of pipe. The fastest methods are polyethylene and P-Al-P (2.5 min), since only two joints are needed because these pipes are continuous and come in rolls. It is followed by the joining method for stainless steel with pressing fit (3 min), then the capillarity method for copper tubing with 30 min and, finally, the SMAW method for steel pipe with 4.5 h.

3.2. Cost ratio

Figure 4 shows the costs associated with the pipes. The measures involved are materials, maintenance and labor. This analysis considers relative costs, taking as a unit lower costs (in materials and labor). Meanwhile, regarding maintenance, 1 is taken as the lowest cost for visible pipe, considering that plastic pipes (polyethylene and P-Al-P) can only be installed hidden and requires almost no maintenance.

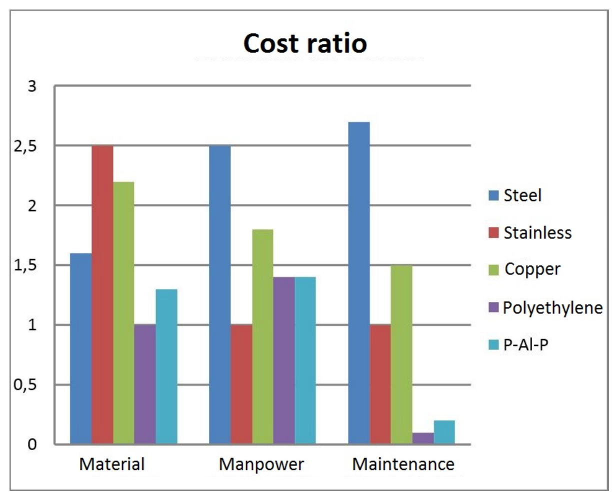

Figure 4. Ratio of pipe costs for LPG services.

The results of the costs presented in Figure 4 can be interpreted as follows:

a) Material

Polyethylene pipe has a value of 1; the P-Al-P pipe is 1.3 times more expensive; steel is 1.6 times more ex-pensive; copper is 2,2; and stainless steel is 2.5 times more expensive.

b) Workforce

The smallest item corresponds to the union of stainless steel pipes by means of pressing fit, since this joining method «only» involves operating a device for closing clamps, the installer does not require more skill or training, therefore, its cost is the lowest of all.

It is followed by polyethylene pipes and P-Al-P with 1.4 since the hot melt, although it is not a very complicated procedure to execute, needs greater skill on the part of the installer than in the case of stainless steel. Copper pipes follow with a value of 1.8. This method requires more skill on the part of the installer, who must be qualified and certified according to the technical standard [15].

Finally, the highest labor cost (2.5) corresponds to the steel pipe that requires the electric arc method (SMAW) for joining, whose installer is a person with great skill, experience, qualified and certified.

c) Maintenance

The unit value (for pipes that can be installed in plain sight) corresponds to the stainless-steel pipe, its maintenance is minimal, since it does not corrode and is aesthetically pleasing to the eye. With 1.5 follows the copper pipe, which requires greater care and protection for sections at plain sight.

Finally, the carbon steel pipe stands at 2.7, since its maintenance requires future repainting of sections that have been installed in highly corrosive atmospheres, or even total repainting.

When buried, polyethylene pipe has the lowest value (0.1), since it does not require maintenance; a value of 0.2 is assigned to P-Al-P pipe considering minimum cleaning maintenance in sections installed in ducts.

3.3. Other selection factors

The fact that a certain material has better mechanical properties (resistance) over another can become an indirect selection factor in LPG pipes, for example:

- Due to their greater mechanical resistance, metal pipes (steel, stainless steel and copper) are better resistant to rodent bites than plastic pipes, and this is of the utmost importance, especially in in-stallations located in open areas or ducts, where the presence of these animals is highly probable [31].
- When a pipe is installed in plain sight, it must be marked according to the respective regulations and painted with the respective color [36], yellow ocher for LPG conduction in vapor phase and white for LPG conduction in liquid phase (Figure 5), in order to alert someone out-side the installation of the danger associated with the fuel.
- Similarly, it is important to protect and signal hidden pipes, as well as the elements that are lo-cated as protections. In this way, and in the case of work in the surrounding area, the protections will be found before the pipes.
- From an aesthetic point of view, stainless steel pipes have a better rating than those made of carbon steel.
- The bacterial growth resistance of stainless steel pipes is superior to the rest [31], which makes them ideal in installations where neatness and asepsis are required.
- There are external factors that affect the selection of a given material in a facility, such as availability of all materials and accessories by the suppliers when required, availability of qualified personnel to carry out the installations, among others.
- Additionally, an indirect cost of installation is that of the equipment and tools necessary to make the pipe joints with accessories. This cost, however, has not been taken into account for this analysis, since the allocation of this value to a given project will depend on the projection that the installation company has for work to be done in a certain period of time. In addition, each project has a different execution times, which makes the depreciation of both machin-ery and tools difficult to determine.

Figure 5. Signaling of LPG pipes (yellow LPG vapor, white LPG liquid).

4. Conclusions

Each project has a different reality because of its location, pipe placement, availability of materials in the market, availability of the right personnel to carry out the work. This makes the selection of the appropriate pipeline specific to each project.

It cannot be said that a material is perfect for an in-stallation, since there are many factors that make its selection feasible. However, and depending on the particular conditions of each installation, there is one that will have several advantages over others.

It is important to indicate that the user that requires an installation of LPG, and when dealing with a fuel where safety criteria must be taken into account, the personnel that must carry out said installation must be qualified and certified by the competent authority.

The installer of an LPG pipe system is the one who must guarantee technical consistency by using materials, joining procedures, and correct ways to install pipes according to the conditions of each project, and it is the one who must evaluate the best alternatives according to the case.

Joining the criteria of mechanical strength and hardness will allow us to better evaluate applications of pipes near areas of vehicular flow, transport of goods, which at a certain time can directly affect and cause damage to said pipes. All the comparisons made correspond to the instal-lation of pipes and fittings by qualified personnel and under the minimum criteria established in the technical standard.

A LPG pipe must be leak-proof and leak tight, so performing the bonding procedure correctly will re-duce the risks associated with transporting the fuel through the pipes.

It is recommended that polyethylene pipes are always «buried» when installed, they can never be left in plain sight.

5. Recommendations

It is essential to perform a vacuum seal test on the pipe at a pressure greater than normal working pressure prior to determining the supply of fuel in a new instal-lation, the material used, the joint method used and the type of installation.

P-Al-P pipes can be installed in ducts, embedded or buried, that is, hidden. They can in no way be installed in plain sight as they are affected by solar rays (crys-tallization) which makes them fragile, leading to breakage and leaks.

If a metallic pipe is buried, an effective mechanism to protect it must be provided against the corrosion to which it may be exposed.

Regardless of the pipe material, if it is hidden when installed, it must be protected by some mechanism whose mechanical resistance is superior to that of said pipeline, with the aim that if any person involuntarily performs some activity in the vicinity, they find this mechanism first and avoid damage to the pipe.

If a user who needs this type of installation has several commercial proposals, he should seek quali-fied external advice to help them choose the best op-tion.

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