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Corrosion Rate Assessment over LPG Transporting Pipelines in Korukupet & Manali Industrial Area

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Abstract: In a Crude oil refinery, Atmospheric Distillation Unit (ADU) is one the primary processing unit operation in which many Volatile Organic Compounds (VOCs), flammable liquids and gases would be separated. Most of these products contain alkane, alkene and alkyne hydrocarbon chemicals which is highly flammable in nature. The top distillate Liquefied Petroleum Gas (LPG) majorly composed of Propane and Butane popularly known as C3-C4 cuts is highly flammable in nature. LPG is one the primary domestic fuel as well as Industrial fuel used in furnaces and for other combustion activities. This LPG would be stored in Bullets which may be hemispherical or spherical. LPG is transported through Seamless Carbon Steel pipelines. As treated LPG is mostly transported either in refinery Unit or LPG Terminals, the likelihood for internal corrosion is very less. But the chances of localized atmospheric external corrosion would be more. The atmospheric pollutants & humidified air electrochemically reacts and forms corrosion over the pipelines. In this paper, LPG terminals which are existing in two most polluted regions in Chennai, Tamilnadu, India have selected. The ambient air quality has analyzed and corrosion simulation has studied.

Index Terms: ADU, VOCs, LPG, Pollutants

I. INTRODUCTION

The two LPG terminals have considered for ambient air quality analysis (i) Refinery I: Crude Oil refinery near Manali, Chennai (ii) Fuel Depot near Korukupet, Chennai. Refinery I has total refining capacity of 12 million metric tons per annum. It is a Government of India under taking organization. The top management has installed advanced control measures, modern technology reactors to improve its operation efficiency. The refinery has ties ups with Process Optimization experts/ consultants and it is continuously improving its production capacity. Top Management is strategically planning to balance production, profit maximization, workers safety and environmental protection. To show this commitment, management has achieved Integrated Management system Audit standards and absolutely complying with legal requirements. Crude Oil from harbor is pumped through pipelines and stored in Oil Movement & Storage Unit. The crude oil is pumped to De-Salter, Settler tanks to remove sands and other particulate sediments. Refinery I is getting different types of crudes, so blended crude oil would be the feedstock. This would be routed to Atmospheric distillation unit, in which fractional distillation process would be initiated. Different products like LPG, Naphtha, Kerosene, Diesel, Petrol, Raw Hexane, Heavy distillates would be separated. All the above products would be sent to purification and the Hydrogen Sulfide gas would be routed to Sulfur Recovery Unit to produce Sulfur. Raw Hexane routed to Extraction column to produce Food Grade Hexane. Petrol distillate would be send to reforming unit to increase the octane number. Diesel would be directed to Diesel Hydrodesulphurization unit to remove the sulfur contents. Appropriate purification, mainly removal of sulfur compounds would be done for all the fuels to ensure the eco friendliness. Heavy Distillates would be routed to vacuum distillation unit and Lube units to produce Lube Oil, Paraffin wax. The final residue would be used to produce Asphalt. In the Utility section, instrumental air would be produced which can be used to operate the Air to Open, Air to close valves. The waste gases are diverted to flare and complete combustion would be done to control the air pollution due to toxic gases. LPG has transported through pipelines from LPG treatment plant and stored in spherical bullets. Around Refinery I, many chemical factories like fuel additive manufacturing unit, Linear Alkyl Benzene Sulfonate (LABS), Methyl Ethyl Ketone unit, Polymer units are existing in which refinery I is acting as mother refinery. Due to these industrial emissions, hydrocarbon vapors the chances for atmospheric corrosion over LPG pipelines would be more. The Fuel depot Korukupet terminal is receiving LPG fuel from Manali refinery which is transported through 10 km over ground pipeline and exposed to atmosphere. It is also evident that few of the pipelines are traveling on the sides of traffic routes with safe distance and appropriate barricading. However, these pipelines are exposed directly to atmosphere and automobile emissions..

II. PROBLEM DEFINITION AND PROPOSED METHODOLOGY

The atmospheric corrosion damage over LPG transporting pipeline is unpredictable. The external corrosion monitoring is very challenging and it is difficult to calculate how much corrosion can happen. The site where the LPG Terminals / Crude oil refinery / transporting pipelines are running is an important factor contributing for corrosion. Before erecting LPG Terminals or pipeline

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grids, appropriate site selection and identifying safe pipeline run way may reduce the cost for corrosion prevention and control. But this corrosion less site selection involves lots of challenges and appropriate methods, analysis needs to be done. To overcome this challenge, two sites have selected. Site 1 is the crude oil refinery site which is located at Manali, Chennai and the produced LPG transported to Fuel storage terminal Site 2 which is located at Korukupet, Chennai. The ambient air quality analysis has done and the impact of atmospheric pollutant mainly Carbon dioxide corrosion has studied and the corrosion rate has determined using Multiphysics corrosion simulation software. This corrosion rate would be helpful to determine the level of corrosion in a particular site and appropriate control measure, safe design factors can be developed. The proposed methodology as follows:

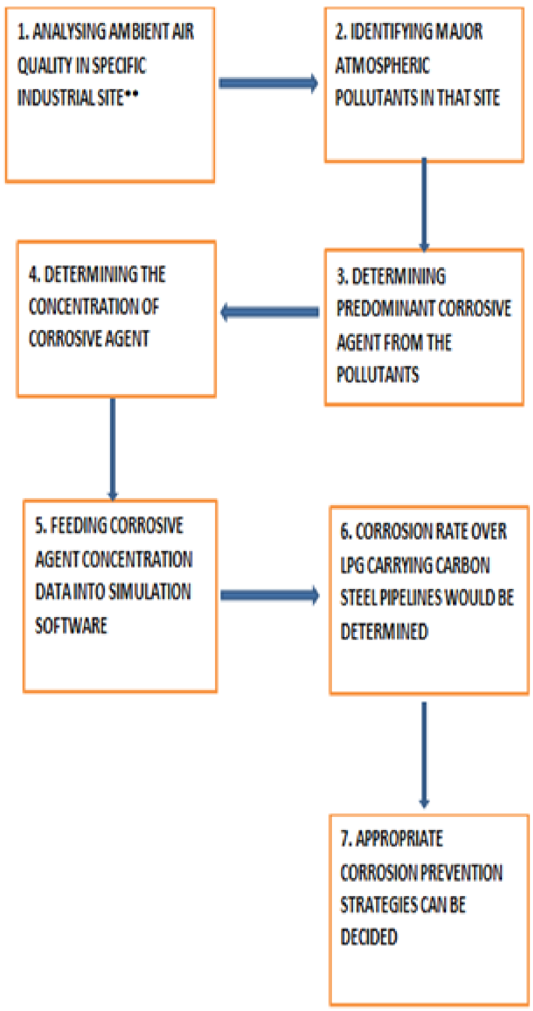

Fig. 1: Proposed Methodology

In this research**, Refinery near Manali and Fuel Depot near Korukupet sites near Chennai, Tamilnadu has selected.

III. AIR QUALITY ANALYSIS

The ambient air quality were gathered near Manali Industrial area and Korukupet area .Both this sites are located in North part of Chennai, Tamilnadu, India. This data were gathered through this web site (http://airpollutionapi.com) which is using the data source from Central Pollution Control Board. By analyzing the data, it is evident that Oxides of Carbon is the major pollutant in these two areas and tabulated below:

Table I: Manali Site – CO_2 Emission Level

Parameters	Day I -II : 25th April 2019 to 26th April 2019		
	Morning	**Evening**	**Average**
Ambience Temperature	34 °C	30 °C	32°C
Relative Humidity	53%	79%	66%
Oxides of Carbon (CO_x) $\mu g/m^3$	640	1090	865

Table II: Korukupet Site – CO_2 Emission Level

Parameters	Day I -II : 25th April 2019 to 26th April 2019		
	Morning	**Evening**	**Average**
Ambience Temperature	34 °C	30 °C	32°C
Relative Humidity	47%	79%	63%
Oxides of Carbon (Cox) $\mu g/m^3$	920	1090	1005

All the following calculations had executed for Manali location. Likewise, same procedures followed for Korukupet location. To convert Relative Humidity to g/kg appropriate *online LENNTECH* calculator has used and found that the amount of Water present in per Kg of air near Manali location is 20.39 g/kg. To convert g/kg to ppm *online ENDMEMO* calculator has applied and found that 20.39 g of water / Kg of air is equivalent to 20390 ppm. By using microgram/cubic meter to ppm *ENDMEMO* converter, pollutant (Carbon dioxide) concentration has found out in ppm and then using gm converter, pollutant concentration has found out in gm. As the concentration has specified per m3 of air, 1 ppm can be considered as equivalent to 1gm.

Table III: CO_2 & Moisture Ratio (in gm)

Parameters	**Manali Site** *(ppm per 1 m3 is equal to gm)*	**Korukupet Site** *(ppm per 1 m3 is equal to gm)*
Relative Humidity	20390 ppm/m^3 of air	19460 ppm/m^3 of air
Oxides of Carbon (COx)	0.865 gm	1.01 gm

The oxides of carbon by reacting with moisture which is present in air, carbonic acid would be formed. This carbonic acid would act as a corrosive agent and it cause corrosion impacts over the LPG pipelines which are exposed to atmosphere. By using stoichiometry calculator (http://www.thermobook.net/stoichiometry/).the amount of corrosive carbonic acid that can be formed near the site has found out and tabulated below

Table IV: CO_2 & Moisture Ratio (in gm)

Compounds	**Manali Site**	**Korukupet Site**
Oxides of Carbon (gm)	0.865	1.01
Moisture in Air (gm)	20390	19460
Carbonic Acid (gm)	1.22	1.42

Using Sensorex pH calculator the pH has calculated using weight method with the following input parameters for manali location, Weight of Carbonic Acid 1.22 gm and total volume of moisture in air 20.39 liters. The same method followed for Korukupet location

Table V: Carbonic Acid Concentration

Parameters	**Manali Site**	**Korukupet Site**
Carbonic Acid (pH)	4.7	4.65

Based on the ambient air quality analysis it is evident that the Carbonic acid concentration in both the sites ranges between 4 to 5. Korukupet site is slightly more acidic comparing with Manali Site As per pH scale, Carbonic acid can cause severe corrosive damage in both this sites. The Carbonic acid pH concentration between 4 to 5 would be considered for further corrosion simulation through Multiphysics Software.

IV. MULTIPHYSICS CORROSION SIMULATION

Atmospheric Corrosion is a multiphysics electrochemical reaction in which film of electrolyte formed by interaction of moisture present in the air and oxygen .Oxidation and reduction reaction would occur results in considerable material loss of metal. Carbon steel pipeline is mostly used to transport LPG. It is evident from the ambient air quality analysis that Carbon di oxide and Carbonic acid are the primary atmospheric pollutant acting as a corrosive agent in both sites. So, carbon di oxide (CO_2) corrosion simulation over carbon steel pipes has initiated for further progress. The following steps are tailed to progress with the simulation.

(i) Electrochemical corrosion reaction at the steel surface has identified:
(ii) The equilibrium reaction of electrolyte (humidified air (H_2O) and Carbon di oxide) to be recognized
(iii) To determine the corrosion potential at the steel surface, Electrode Surface boundary feature and bulk concentration of species (reactants) has applied
(iv) As corrosion is a mass transfer phenomenon, Diffusion co-efficient of species in (ii) to be found out
(v) As atmospheric corrosion has simulated, the following process parameters have considered. Atmospheric pressure is kept as constant. pH and ambient temperature variations has done to simulate the corrosions rate and appropriate graph would be generated
(vi) After completing the atmospheric corrosion of Carbon di oxide on Carbon steel pipes, Corrosion Rate graph has generated. This graph has plotted for different pH values of carbonic acid and ambient temperature. It is evident from the graph data that corrosion rate is proportional to the ambient temperature and inversely proportional to pH value.

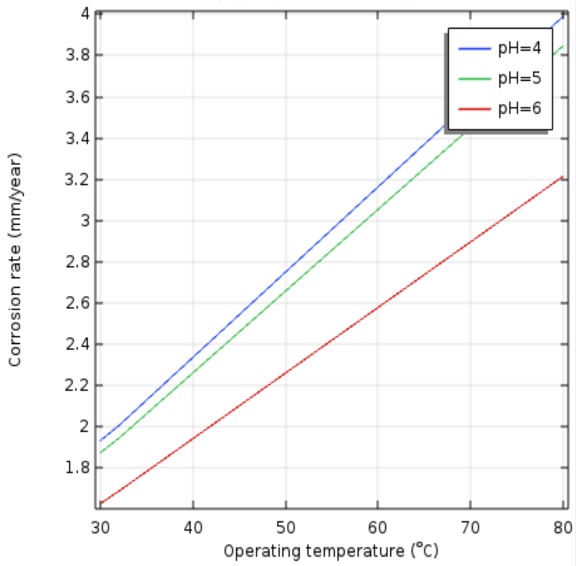

Fig. 2: Corrosion Rate Graph

As per ambient analysis of Manali & Korkupet site, average ambient temperature ranges between 30 to 40 °C and the pH of carbonic acid is 4.6 to 5.0. By coordinating these points in Corrosion rate graph it is evident that the corrosion rate over LPG carrying carbon steel pipe in both the site would be 2 mm/year.

V. RESULTS AND DISCUSSIONS

The atmospheric corrosion over LPG Pipeline grids is unavoidable. This chemical reaction would cause severe structural damage leads of leakage of LPG gas results in fire and explosion. There are so many active and reactive engineering techniques are available to control the corrosion. Apart from this, first ranking Hierarchy of Control measure *Eliminating the corrosion hazard* by appropriate site selection can be considered as most proactive control measure. Before erecting LPG terminals and deciding the pipeline pathways, that specific site can be analyzed and the level of corrosion intensity can be determined. Based on this data, appropriate corrosion safety measures can be taken and the fuel storage terminals can be erected at very safe place. To execute this analysis, two industrial sites namely Manali and Korukpet Industrial area has selected. In Manali LPG production, storage terminals are existing. In korukupet, LPG Terminal and pipeline grids is available. In both these sites, LPG pipelines are running OFFSITE and exposed to atmosphere. In this study, Carbon dioxide corrosion effect over LPG carrying carbon steel pipeline has analyzed. As a result of ambient air quality analysis, the corrosive causing carbonic acid in manali site found to be 4.7 and in korukupet 4.65. The average ambient temperature found to be 30 to 30 to 40 ℃. By feeding this data into corrosion simulation, corrosion rate found to be 2 mm/year. It is very evident from the above data, that both these sites are corrosive in nature and appropriate control measures are highly recommended. In future, it is better to avoid constructing very high flammable substances like LPG storage terminals and pipeline grid around these sites.

VI. CONCLUSION

LPG (Liquefied Petroleum Gas) is denser than air and transported through carbon steel pipeline grids either in ONSITE or OFFISTE services. These pipelines are exposed to atmosphere and external corrosion is unavoidable. If the pipelines are corroded, LPG may leak through the eroded pipeline surfaces and may form vapor cloud which may leads to explosions results in severe property damage. To avoid this proper corrosion monitoring and maintenance is mandatory. In this paper, an approach has attempted to eliminate the corrosion hazard at the source itself by selecting appropriate site for LPG terminal construction. By adopting this method, the corrosion rate for the specific site can be determined. Accordingly proper corrosion less site can be selected for LPG terminals construction. It is also helpful to decide the level of corrosion monitoring required with appropriate maintenance cycle for LPG carrying Carbon steel pipeline.

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