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Extraction and Ranking Requirements in Design, Construction and Operation of LPG Storage Tanks with the Approach of Reduce Environmental Impact by Using Analytic) Hierarchy Process (AHP)

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Abstract: The petrochemical industry normally uses Liquefied Petroleum Gas (LPG) tanks which contain considerable volumes of flammable chemicals. Thus, the occurrence of a LPG tank accident is possible and usually leads to fire and explosions. During the fire, large amounts of CO_2, CH_4, CO and black carbon aerosols were injected into the atmosphere. Release of toxic chemicals by explosion or combustion of industrial facilities can similarly lead to large environmental problems (such as air pollution, increase of green house gas) and public health disasters. In last 50 years, trade organizations and engineering societies such as American Petroleum Institute (API), American Institute of Chemical Engineers (AIChE), American Society of Mechanical Engineers (ASME) and National Fire Protection Association (NFPA) have published strict engineering guidelines and standards for the construction, material selection, design and safe management of storage tanks and their accessories. Most companies follow those standards and guidelines in the design, construction and operation but tank accidents still occur. In this study, all requirements related to the four stages of design, construction pre-commissioning and operation of LPG tanks With a view to reducing the environmental impacts were extracted. Then by Analytical Hierarchical Process (AHP) the requirements were ranked and it became clear that the design phase is the most important role in reducing the environmental impact.

Key words: LPG storage, environment, requirement, Analytical Hierarchical Process (AHP), environmental

INTRODUCTION

In the last 40 years, intense industrialization in the developed countries and the constant economic growth have brought new technologies, new products, new opportunities, better conditions of life, fast transportation and modern communications. However, there are also some indirect disadvantages from these improvements, including industrial accidents. Every year hundreds of work accidents, some with human losses and high cost for the economy and the environment, take place in the world.

Petrochemical industries normally use Liquefied Petroleum Gas (LPG) tanks which contain large amounts of flammable chemicals. Hence, the occurrence of a tank accident is possible and it usually leads to fire and explosions. During the fire, large amounts of CO_2, CH_4, CO and black carbon aerosols were injected into the atmosphere. Experience has shown that the continuous dispersion of toxic pollutants from large tank fires such as smoke, SO_2 and CO is responsible for potential environmental and health problems.

In last 50 years, trade organizations and engineering societies such as American Petroleum Institute (API), American Institute of Chemical Engineers (AIChE), American Society of Mechanical Engineers (ASME) and National Fire Protection Association (NFPA) have published strict engineering guidelines and standards for the construction, material selection, design and safe management of storage tanks and their accessories. Most companies follow those standards and guidelines in the design, construction and operation but tank accidents still occur.

Also take a look at events in the world show that the slightest negligence in the design, construction, inspection and operation of LPG storage tanks can lead to accidents and will irrecoverable (Table 1).

The review of LPG tanks world events in the past few years show that an important part of this is related to poor design and operations activities. Other events are lack of sufficient attention to the instructions in the pre-commissioning and human error and maintenance during operation of LPG tanks.

LPG characterize: The most important chemical produced in the oil and petrochemical industry is Liquefied Petroleum Gas (LPG). The use of LPG in various industries including oil and gas and petrochemical industries and numerous applications to expand. Among

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Table 1: Major accident related to LPG tanks

Date	Location	Plant/unit/chemical	Death	References
1951	Port Newark, USA	LPG storage/propane	14	Chang and Lin (2006)
1954	Lake Port, USA	Storage unit/LPG	4	Lewis
1966	Feyzin, France	LPG tanks/propane	18	Chang and Lin (2006)
1972	Rio deJaneiro, Brazil	Refinery/storage area/LPG	37	Mhidas
1972	Duque de Caxias, Brazil	Storage tank/LPG	39	Lewis (1993)
1978	Texas, USA	LPG storage tanks/LPG	7	Mhidas
1984	Mexico City, Mexico	Storage tanks/LPG	650	Chang and Lin (2006)
1997	Visakhapatnam, India	Refinery/LPG	60	Mahoney (1990)
2009	Gazipur, Bangladesh	Blade making factory/LPG	3	Lewis

the properties that make it dangerous LPG screw is usually under pressure and at temperatures above the boiling point.

Due to its chemical nature and fast becoming the vapor phase in the vicinity of the ignition source is a potential fire and explosion. LPG is a general term that includes a combination of propane (C_3H_8), butane (C_4H_{10}) or a combination of the two is fluid. This compound is natural gas temperature and pressure but may be increased by reducing the temperature or become liquid phase.

LPG is colorless and odorless gas with flash point of -50°C and evaporates at room temperature 250 times its volume in air gives occupation. Most of the reasons flammable and explosion of LPG tanks is BLEVE (Boiling Liquid Expandin Vapor Explosion) phenomenon and LPG leakage can create VEC phenomenon (Khan and Abbasi, 1999b). Burning reaction can be considered as follows:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

$$LPG + O_2 \xrightarrow{\text{Combustion}} CO_2 + H_2O$$

Analytic Hierarchy Process (AHP): AHP is a decision-making tool that can help describe the general decision operation by decomposing a complex problem into a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives. Khan and Abbasi (1999a) applications of AHP have been reported in numerous fields such as conflict resolution, project selection,budget allocation, transportation, health care and manufacturing, environment challenges. More and more researchers are realizing that AHP is an important generic method and are applying it to various manufacturing areas (Andijani and Anwarul, 1997; Chan *et al*., 2000). In addition to the wide application of AHP in manufacturing areas, recent research and industrial activities of applying AHP on other selection problems are also quite active (Jiang and Wicks, 1999; Lin and Yang 1996; Tam and Tummala, 2001).

AHP's hierarchic structures reflect the natural tendency of human mind to sort elements of a system into different levels and to group like elements in each level. Khan and Abbasi (1999a). From a human factor point of view, AHP can be a very effective tool to assist human decision making. A study conducted by Lehner and Zirk (1987) show that when a human being and an intelligent machine cooperate to solve problems but where each employs different problem-solving procedures, the user must have an accurate model of how that machine operates. This is because when people deal with complex, interactive systems they usually build up their own conceptual mental model of the system. The model guides their actions and helps them interpret the system's behavior. Such a model when appropriate, can be very helpful or even necessary for dealing successfully with the system. However, if inappropriate or inadequate it can lead to serious misconceptions or errors (El-Wahed and Al-Hindi, 1998). Therefore, it is very important for decision makers to be able to underst and the decision-making model structure while AHP just provides such a simple, easily understood and flexible model structure. View of decision-making hierarchy that has three levels has been drawn in Fig. 1.

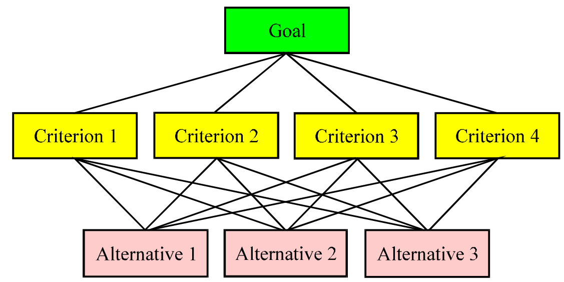

Fig. 1: Grossly simplifird structure of an exemplary AHP hierarchy

MATERIALS AND METHODS

Three steps of AHP methodology

Step 1 (structuring the hierarchy): Group related components and arrange them into a hierarchical order that reflects functional dependence of one component or a group of components on another. The approach of the

AHP involves the structuring of any complex problem into different hierarchy levels with a view to accomplishing the stated objective of a problem.

Step 2 (performing paired comparisons between elements/decision alternatives): Construct a matrix of pair wise comparisons of elements where the entries indicate the strengths with which one element dominates another using a method for scaling of weights of the elements in each of the hierarchy levels with respect to an element of the next higher level. Use these values to determine the priorities of the elements of the hierarchy reflecting the relative importance among entities at the lowest levels of the hierarchy that enables the accomplishment of the objective of the problem (Schniederjans and Garvin, 1997; Lehner and Zirk, 1987). The scale used for comparisons in AHP enables the decision maker to incorporate experience and knowledge intuitively (Young, 1981) and indicates how many times an element dominates another with respect to the criterion. The decision maker can express his preference between each pair of elements verbally as equally important, moderately more important, strongly more important, very strongly more important and extremely more important. These descriptive preferences would then be translated into numerical values 1, 3, 5, 7, 9, respectively with 2, 4, 6 and 8 as intermediate values for comparisons between two successive qualitative judgments. Reciprocals of these values are used for the corresponding transposed judgments.

Step 3 (synthesizing results): Synthesize these priorities to obtain the each alternative's overall priority. Select the alternative with the highest priority. The scale of paired comparison in AHP Method shows in Table 2.

Research methodology

LPG storage tanks requirements for the design, construction and operation: Regarding to review of several standards, the important elements can be effective in design, construction, pre-commissioning and operation tanks, especially LPG storage tanks can be classified as follows.

Design: Tank design is factor directly related to catastrophic tank failure. API and other organizations have standards and codes that address recommended practices for tank design. The requirements related to the design is presented.

Requirements related to the design:

- Attention to standards
- Attention to geographic and climatic conditions
- Dikes/tank bunds
- Foundation and supports
- Fire fighting systems
- Protection systems spill contamination
- Instruments

Construction: Construction and erection of storage tanks for two responses is important. First, the lack of attention to the requirements of this section at the time of commissioning and operation of reservoirs to incidents or related consequences will be severe. And also the lack of attention to the special environmental and safety requirements in during construction can be leading to accidents and environment pollutions. Therefore, the construction requirements include.

Construction requirements:

- Quality control and technical inspection
- Test (NDT/hydro test/…)
- Approval of design drawings
- Use of proper materials

Pre-commissioning: Pre-commissioning is to carry out all the activities necessary to complete the mechanical installation. In fact, pre-commissioning include of all activity such as inspections, tests and surveys in order to ensure that all the components in accordance with design specifications and schematics engineering, supply and installation are done. So, pre-commissioning is a checklist to prepare for the operation starting. Requirements related to pre-commissioning is presented.

Table 2: Scale of paired comparison in AHP Method

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another, its dominance demonstrated in practice
8	Very very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

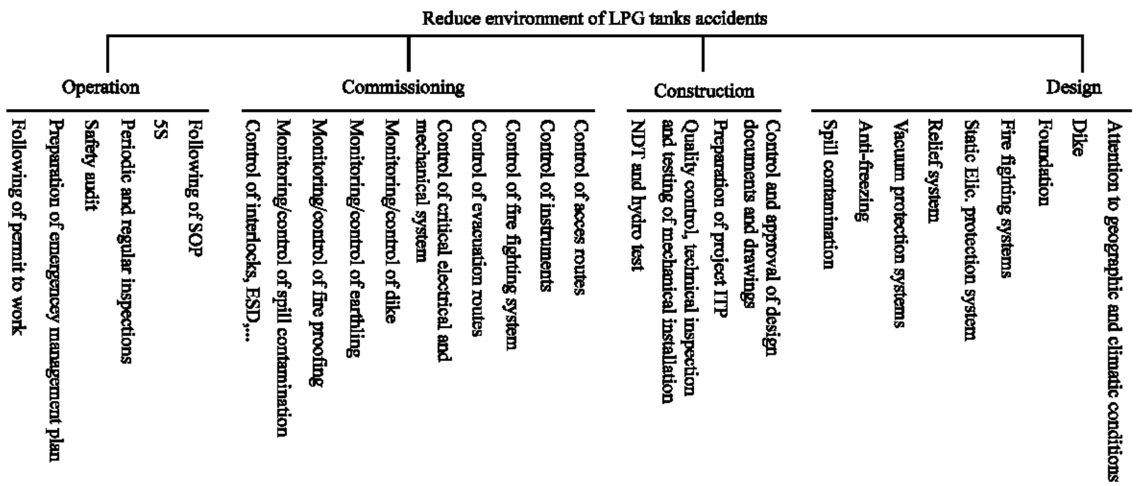

Fig. 2: Hierachical pattern study

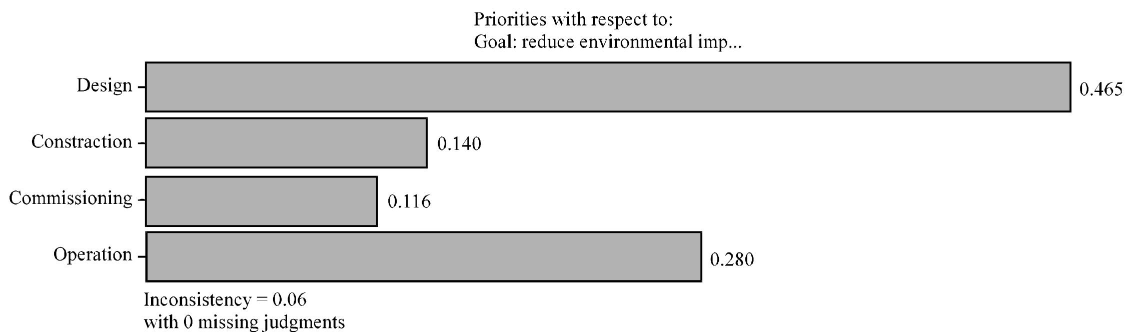

Fig. 3: The ranking of main criteria

Pre-commissioning requirements:

- Monitoring/control of spill contamination
- Pre Start up Safety Review (PSSR)
- Control of access and evacuation routes
- Control of instruments and critical systems
- Inspection/control of safety and fire requirements

Operation: The last phase in this study is the operation stage. This stage is the end of life cycle of any system and strict observance of operation requirements is very important. The requirements of this phase are presented.

Requirement for operation:

- Auditing
- Preparation of emergency management plan
- Following of permit to work
- Following of SOP
- Regular inspections and maintenance program

RESULTS AND DISCUSSION

Analytic hierarchy results: As a mention in previous discussed, aim of this study, ranking of effectiveness requirements in four steps of designing, construction and pre-commission and operation LPG storage tanks to reduce the environmental impacts in fire and explosion accident. In this study, LPG tanks requirements with environment approached by Analytic Hierarchy Process (AHP) is an objective and data analysis is performed using the software expert choice investigated.

According to the study phases of design, construction, commissioning and operation as the main criteria and requirements for each of these stages are defined as the following criteria. It was formed for the hierarchical model show in Fig. 2.

According to the hierarchical model created, the questionnaire developed for experts to collect and collected them. All questionnaires completed at the end of the study and were analyzed by using of expert choice software.

Among the four main phases of design, construction, pre-commissioning and operation, the design phase was awarded the highest rank with a score 0.465. After that, operation, construction and commission phases with 0.280, 0.140 and 0.116 scores, respectively in the second, third and fourth ranked (Fig. 3-6).

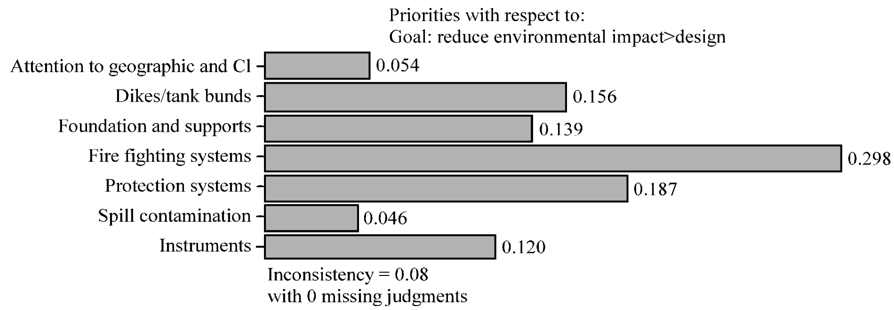

Fig. 4: The ranking of design sub criteria

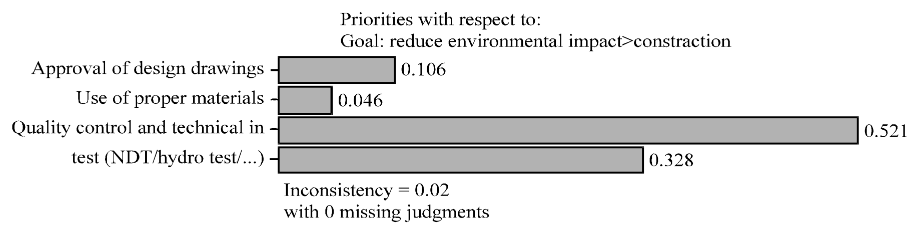

Fig. 5: The ranking of construction sub criteria

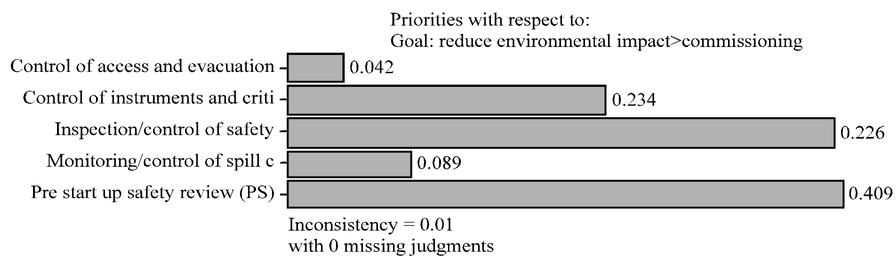

Fig. 6: The ranking of pre-commission sub-criteria

Fig. 7: LPG storage tank related standard

Similarly, the requirements for each phase based on environmental impact reducing were classified and ranked. The result of these analyses show in Fig. 4.

CONCLUSION

In this study, the requirements related to issues of safety, health and environment for phases of design, construction, commissioning and operation LPG storage tanks were identified and according to their importance with reducing the environmental impact were ranked.

It is clear from this ranking strict compliance requirements at the design stage are very important to reduce and prevent the environmental consequences of disasters.

Also reflecting to the particular requirements of each phase we fines that an attention to problems and requirements related to safety issues in order to achieve this study objective is very importance. This study led to consider of important following factors can effective to reduce impact environment in case of fire and explosion:

- Using the Dyke wall
- Use double or full tanks to prevent loss of material in time of internal rupture wall
- Consider pump and reserve tank to transfer the contents to another tank in emergency leakage
- Use close drain sump for tanks
- Use proper drainage to prevent transmission of fluids spilled into the sea
- Attention to the topography and physical geography
- Observe the maximum distance allowed of population centers/protected natural areas
- Considering the prevailing wind direction to prevent emissions of smoke and combustion
- Foundation proper tanks to prevent infiltration to groundwater
- The necessary measures to collect liquids spilled
- Attention to the dip tank at design time

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