"...and justice for all."

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RE: DOCKET # FD 36065 PETITION FOR DECLATORY ORDER PLAINS ALL AMERICA/RANCHO LPG

CYNTHIA BROWN, CHIEF SECTION OF ADMINISTRATION
OFFICE OF PROCEEDINGS
SURFACE TRANSPORTATION BOARD
395 "E" Street SW
Washington, DC 20423

Dear Ms. Brown

Attached are 10 copies of the Response to Ron Conrow, Western District Manager, Plains/Rancho LPG, letter dated November 11, 2016 to Honorable Janice Hahn, Member of Congress, 44th District, California, Washington, DC Office.

Respectfully submitted,

Anthony G. Patchett
Attorney for San Pedro Peninsula Homeowner's United Inc.
John Tommy Rosas, Tongva Ancestral Territorial Tribal Nation

"...and justice for all."

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December 1, 2016

Mr. Ron Conrow
Western District Manager
Plains/Rancho LPG
19430 Beech Avenue
Shafter, California 93263

Dear Mr. Conrow,

We recently were provided a copy of the letter sent by you to Congresswoman Hahn regarding her support letter on our community's behalf regarding our request for Declaratory Order from the Surface Transportation Board.

You made several statements in that letter that we are compelled to respond to in order to adequately describe the reasons why Congresswoman Hahn, and our community itself, find your facility's presence unacceptable.

In paragraph 2 of your letter, you describe liquefied petroleum gas as simply a "by-product" of the refining process, implying that it is a "benign" commodity. Certainly, not so. Liquefied Petroleum Gas is highly explosive and flammable gas singled out from other petroleum products by the US Coast Guard as a "commodity of particular hazard". You reference that many other refineries store this product on premise and that the Congresswoman should not "single out Rancho". This point underscores Plains/Rancho's continued efforts to spin the reality. There is, in fact, every reason to single your facility out as it is very different from the operations of a refinery.

Refineries are held to a much higher regulatory standard than mere "storage facilities". The "volume" of LPG held at the Plains/Rancho LPG storage facility far exceeds the local refineries onsite LPG storage. And, as read in your paragraph 3 regarding "worst case EPA reporting", the Phillips refinery, abutting your Rancho LPG facility, reports ***their largest* 5-million-gallon butane tank** as having a blast radius of 2 miles. By contrast, **your** Plains/Rancho LPG facility reports a worst-case blast radius from your **12.5-million-gallon butane tank at ½ mile!** This severely reduced reported blast radius gives even the most infantile mind pause for grave concern! There is a defective allowance in place with the EPA which affords the ability to report a reduced a blast radius "if" a safety mitigation measure has been applied to a hazardous facility. In the case of the Plains/Rancho LPG facility, you have offered a "non-responsive" impound basin as a means to capture the "liquid" butane gas that would leak from a tank rupture. However, this premise is patently false as liquefied butane held in a "refrigerated" tank (to keep it in liquid form) will rapidly vaporize, expanding over 200 times its volume as a liquid, as it meets warmer ambient air temperature from a tank rupture. This means that the "heavier than air gas" would overflow any catch basin. So, that this notion of capture is false and misleading as a safety mitigation measure. The EPA has been contacted over the years to explain their rationale for allowing this erroneous reporting. See attached letter from Earthjustice that the EPA has refused to respond to. This link below takes you to a study performed by Martin County, Florida Fire Rescue, defining the blast radius and impacts from 20,000 railcars of several hazardous commodities including propane.
https://www.martin.fl.us/sites/default/files/meta_page_files/ADM_AAF_Railcar_Plume_Modeling_May_2015_0.pdf

The Study's blast radius from a 20,000-gallon rail car of LPG is estimated at .58 mile! So, again we are somehow expected to "believe" that Rancho's estimate of a ½ mile blast radius from their **12.5 MILLION GALLONS of LPG** is less than that of one of their 30,000 gallon railcars?! Obviously, there is a serious problem with the Plains/Rancho LPG's estimate!

Congresswoman Hahn is exactly on point in her letter recommending that both the Valero and Tesoro refineries store their excess butane on their own property. While these refineries have complained that they do not have the "footprint" to allow for this additional storage, we see that Tesoro is now in the EIR process for a very large expansion of their refinery. So, it appears that the only thing that Tesoro doesn't have room for is the storage of their *most hazardous commodity*, LPG!

Certainly, the Valero refinery could also accommodate the storage of this LPG as well by simply removing some of their less volatile products in tankage onsite. It is important to remember that refinery regulations are far more stringent for tanks storing explosive LPG, and respectful of their distance to other flammables on premise. These updated safety conditions are completely ignored at the antiquated Plains/Rancho LPG site which was also *exempted* from an assortment of regulations upon introduction in 1973, and located within a mere 1,000 feet of pre-existing homes and schools. The substandard and flagrantly dangerous factors in play here offer great credibility to the *necessity* of these two refineries to accept their individual responsibilities to protect public safety. By locating the highly explosive liquefied petroleum gas storage offsite, both refineries can reduce their insurance costs by a significant amount. Yet, huge liability is being assumed by the Port and City of LA and unnecessary high risk endured by the public.

On page two, you reference the authorization of PHL to transport hazardous commodities from your Rancho LPG site. We continue to disagree with that statement. Plains/Rancho LPG is not identified as a hazardous rail operation in the PHL contract. Again, the rail activity of the Plains/Rancho LPG facility is not included in the Port's own Risk Management Plan, and your rail permit continues (after 40 years) to be conducted under a temporary, month to month "roll over" status, offering it the ability to circumvent the required EIR and risk analysis for a long-term contract. In other words, the true hazard of your operation continues to deprive the community the right to know their own jeopardy.

At the end of page two, you state that Rancho has had "no major incidents, releases or accidents". We know that over the years there have been several releases and instances of violation, and that there was a railcar derailment on Memorial Day of 2005 at Channel and Gaffey. We also remind you of the accident of March 8, 2012 (photo included) when a semi-truck stuck a propane gas rail car at the intersection of Westmont Dr. and Gaffey Street just as Taper Avenue elementary students were being released from school. Both the derailment and the 2012 accident narrowly escaped a rupture of the tank that would have been devastating. So, basically, what you are saying is that we all have been "profoundly" lucky! We don't disagree with that. However, "luck" does not last forever. And, the greater point here is that only "one" major incident or accident at your facility has the potential to completely "decimate" the entire Harbor area. We will do everything that we can to prevent that.

Congresswoman Hahn will now move into the County Supervisor role and that position will continue to have a major stake in public safety as it applies to your facility. The land directly abutting your Plains/Rancho LPG facility to the south is an LA County Flood Zone. That zone incorporates a storm drain that leads into the community to the west, and runs parallel to Gaffey St. on the south emptying into the waters of the LA harbor.

Released butane gas from a tank rupture at the Plains All American Pipeline / Rancho LPG property will flow out seeking the lowest levels. The lowest level immediately below your butane tanks is the storm drain located on LA County property. That drain would move the explosive gas directly into LA Harbor and through the community. Your highly explosive butane gas can be ignited with as little as an electric "spark". Within only a few feet of your tanks is one of the busiest traffic corridors in San Pedro.

In closing, the words of California Earth Corps. President, Don May resonate clearly a warning of the hazard of this facility made back in 2005;

"The LPG/Butane facility in the Port of LA is directly over the button hook of the Palos Verdes Fault (predicted for rupture within the 10-50 yr. time frame.) A geology firm up in Montrose, Ca who are the acknowledged experts on that fault structure, and a group from Cal Tech who are the experts in predicting the vertical accelerations to be expected from the predicted events, and an engineering group who could evaluate the ability of the tanks to withstand the shear forces generated explained: 2G's of vertical shear force would cut through those LPG tanks like a hot knife through butter, yet the expected rip force would be far greater.

The event would empty both LPG tanks, which are surrounded by a multitude of ignition sources, resulting in an inextinguishable column of fire up to the inversion layer thousands of feet high, raising the temperature above the ignition point of most flammables within a mile or two, causing a Dresden like firestorm through San Pedro and into the port. The pool of fire itself would burn for days."

Sincerely,

Anthony G. Patchett, Esq.
Law Offices of Anthony G. Patchett
Attorney for
San Pedro Peninsula Homeowner's United Inc. & John Tommy Rosas, Tongva Ancestral Territorial Tribal Nation

Cc: Congresswoman Janice Hahn
Congresswoman Elect, Nanette Barrigan
Congressman Ted Lieu
Mayor Eric Garcetti
Councilman Joe Buscaino
State Controller, Betty Yee/ Ann Baker
Gene Seroka, Port of LA
Ed Renwick, Port of LA Commissioner
Jennifer Luchessi, State Lands Commission
Professor Bob Bea, UC Berkeley
Daniel Meer, EPA Region 9
Noel Weiss, Atty at Law
Adrian Martinez, Earthjustice
Ethan Bruckner, Standearth
David Petit, NRDC
Morgan Wyenn, NRDC
Thomas W. Wilcox, GHK Law
Justin Houterman, Deputy City Attorney, Port of Los Angeles
Rose-Michele Nardi, Transport counsel, PC
Cynthia Brown, Chief Section of Administration, Surface Transportation Board (STB)
Katherine Bourdon, STB

VERIFICATION

I, Anthony G. Patchett, verify under penalty of perjury that the factual statements made in the foregoing Reply to letter of Ron Conrow, Western District Manager, Plains/Rancho LPG, dated November 11. 2016 to the Honorable Janice Hahn, Member of Congress, 44th District, California are true and correct to the best of my knowledge, information and belief.

Further, I certify that I am qualified and authorized to file this Verification.

Executed on December 3, 2016 at Glendale, California

Anthony G. Patchett, Esq.
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EXHIBIT LIST

REPLY TO RON CONROW'S LETTER TO HONORABLE JANICE HAHN

Exhibit D	Letter of Ron Conrow to Honorable Janice Hahn, Member of Congress, 44th District, California, dated November 11, 2016	3 pages
Exhibit E	Photo of Rancho's LPG train accident with truck at Gaffey Street March 12, 2012	
Exhibit F	Phillips 66/Tesoro refinery 5 million gallon butane tank blast radius of 2 miles	4 pages
Exhibit G	A Study of Storage Accidents by James I Chang, Cheng-Chung Lin May 2005	9 pages

EXHIBIT D

RANCHO
LPG Holdings LLC

November 11, 2016

Honorable Janice Hahn
Member of Congress
44th District, California
Washington, DC Office
404 Cannon House Office Building
Washington, DC 20515

Dear Congresswoman Hahn,

We are deeply disappointed by the attached letter you wrote on October 10, 2016 to the Surface Transportation Board (STB) in support of a Declaratory Order introduced by the San Pedro Peninsula Homeowners United (SPPHU) regarding the liquefied petroleum gas (LPG) storage facility owned by Rancho LPG Holdings LLC in San Pedro, California. Consistent with past correspondence from your office, this letter contains flagrant mischaracterizations and inaccuracies regarding the facility. Below are some specific areas of inaccuracies and/or mischaracterizations from your letter:

- **Storage of liquefied petroleum gases (LPG).** It is true that the Rancho facility stores LPG which is simply is a bi-product produced by the refining process. Consequently, all complex refineries do in fact process, store, and transport LPG as well. If your primary concern about LPG is safety, then we suggest you take a holistic review of all facilities in the harbor area that handle LPG instead of singling out Rancho. A cursory review of this matter may prove enlightening for you as LPG (such as butane) is not toxic, but flammable. If your office wanted to focus on materials that were a direct threat to the public, then *toxic*, rather than *flammable*, materials should be the focus of your efforts.

  The "worst case" scenario as contained in our RMP on file at LAFD/CUPA for public review is 0.5 miles. The EPA has vetted the "worst case" and declared, "It meets the letter of the law". While it is not our intention to marginalize any offsite impacts especially to schools, the "worst case" scenario for the Rancho LPG facility per EPA regulation does not result in a cataclysmic event and has less potential for damage than the worst-case scenarios of other facilities in the immediate vicinity.

- **Close Rancho and have fuel (LPG) stored at the refineries.** During your tenure as Councilwoman for CD 15, you co-sponsored a Motion (CF 04-16-45 Hahn/Cardenas) to have the Amerigas (Rancho) facility relocated. As a result, on September 15, 2005, a stakeholder meeting was held in San Pedro involving of representatives from Amerigas, Valero Wilmington Refinery, BP Carson Refinery, the Port of Los Angeles, PCAC, and three San Pedro Neighborhood Councils.

  Public records from that meeting indicate that executives from both the Valero and BP refineries explicitly confirmed that neither refinery had the footprint required to fully replace the LPG capacity stored at the Amerigas facility. Additionally, a letter from the LA City Attorney declared; "there appears to be no legal basis at this time to compel Amerigas to relocate the subject facility".

- **Current rail contract do not permit the transportation of hazardous materials.** This statement is blatantly inaccurate. Pages 12 & 13 attached from the LA City Attorney to the STB declare; "In fact both permits POLA RP 10-05 and PHL 1989 by their terms allow for the transportation of hazardous cargo as required by both federal law regarding common carrier track serviced by a common carrier and the STB approved terms of the City's acquisition of the line".

  Additionally, "It is the City's understanding that PHL's common carrier obligations include the duty to transport hazardous materials (such as those handled by Rancho) and that PHL cannot refuse to provide this permitted service. The City understands of PHL's common carrier obligations are reflected in Permit No. 1989 section 15.3". Therefore, your claim that the rail permit is being improperly used by Rancho is inaccurate.

In a prior letter dated January 18, 2016, you were provided with the attached Parcel Profile Report from the LADBS website for the Rancho facility job addresses located at 2110 and 2240 North Gaffey Street. The Parcel Report clearly shows the facility site is located in M2/M3 zones which are classified as light industrial and heavy industrial respectively...not residential. Therefore, your continued inference that the Rancho facility is inappropriately located is untrue.

Research indicates that immediately prior and during your term as CD 15 Councilwoman, several major building projects were undertaken such as; the Field of Dreams Soccer park, Home Depot, Target, and Port Distribution Center. As a former LA Council member you should know that the City of Los Angeles requires developments such as these to conduct an Environmental Impact Report (EIR) which includes a risk assessment prior to approval of the project. The EIR addresses not only impacts of the project itself related to public health and safety, but also evaluates the potential impacts to the project from adjacent hazardous material upsets, releases, or spills from facilities like Rancho or refineries. Therefore, if Rancho is the risk to the community and schools you describe, then how did these projects obtain city approval?

Please know that Rancho performs one vital task for the local refiners of gasoline in our area and for the Southern California market. That task is to store butane (which is both a bi-product and component of gasoline) during the warmer spring and summer months when it cannot be blended into the gasoline supply due to strict California Air Resources Board (CARB) regulations. During the cooler autumn and winter months, butane can once again be added to our fuel (to increase combustion performance). Hence, Rancho's primary role is as an *environmental compliance service provider* to the refiners of our gasoline supply. Without Rancho, refiners would have to flare the butane into the atmosphere, transport it out of our area by more trains or trucks or decrease production of gasoline which would have an adverse effect on prices, our local economy and the average Southern California consumer. *Just as, if not more important, because of Rancho, our local refineries can comply with our strict air standards making our air better to breathe.*

Rancho LPG and its International Longshore and Warehouse Union Local 26 workforce take pride in its safety record. The facility has experienced no major incidents, releases or accidents in the facility's 42-year operating history. Rancho LPG maintains a robust program of mechanical integrity and inspection to ensure all vessels, tanks, piping and infrastructure is maintained in accordance with applicable regulations. The facility has been audited approximately 62-times since the beginning of 2010 by City, and continues to perform well in these audits.

We trust these facts highlight the inaccuracies from your October 10, 2016 letter. In order to obtain accurate information about the facility, we encourage you and your staff to come to us with any questions or to request a tour of the Rancho LPG facility instead of relying on inaccurate information provided by local misguided self-serving activists.

Finally, we offer our congratulations on your recent election as 4th District LA County Supervisor. It is our sincere wish that we can forge a closer working relationship with you in this capacity.

Regards,

Ron Conrow

Ron Conrow
Western District Manager
Plains/Rancho LPG

cc:
CD 15 Councilman Joe Buscaino
Los Angeles Mayor Eric Garcetti
CD 33 Congressman Ted Lieu

EXHIBIT E

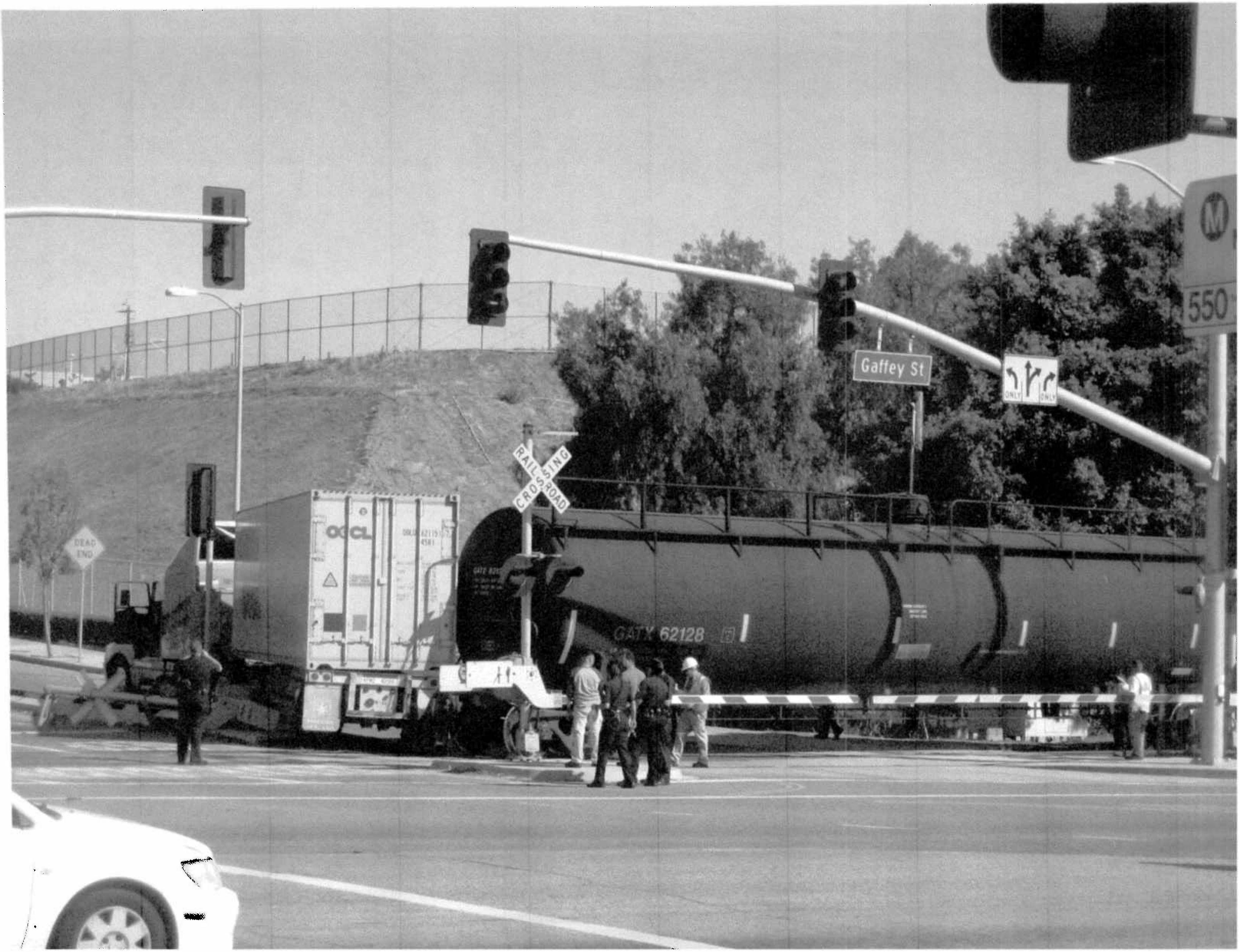

Gaffey St
RAILROAD CROSSING
DEAD END
GATX 62128
OOCL
ONLY
ONLY
550

EXHIBIT F

LIVING SAFELY WITH CHEMICALS

UNDERSTANDING CHEMICAL RISK MANAGEMENT

CAER COMMUNITY

Butane

Tosco Refining Company
Tosco Los Angeles Refinery
1660 W. Anaheim Street
Wilmington, CA 90744

TOSCO

WHAT IS RMP?

The main focus of the Federal Environmental Protection Agency (EPA) **Risk Management Plan** (RMP) Rule is the prevention of chemical releases that could affect the surrounding community or environment. The RMP Rule is also intended to assist in improving plant safety and protecting the public by collecting information to encourage community discussions in three main areas:

- **Hazard Assessment**
- **Prevention Program**
- **Emergency Response Program**

BASIC INFORMATION

At Tosco's Los Angeles Refinery, the petroleum gases in use are butane, methane, ethane, propane and pentane. Petroleum gases are invisible and have a very slight sweet, oil-like odor. They are very flammable. Petroleum gases are naturally occurring. They are produced from decaying plant material in swamps and can be found from underground sources. Some of the common uses of liquefied petroleum gases include:

- Sources of heat
- Cooking, barbeques
- Heating homes, farms and businesses
- "Clean-burning" fuel for cars
- Cigarette lighters

Small concentrations of liquefied petroleum gases can be mildly irritating to the nose, eyes, and throat and may cause headaches. High concentrations could cause more serious problems, such as convulsive coughing, difficult and painful breathing, nausea and vomiting, and require medical attention. Frostbite will occur only if there is direct contact with liquefied gas.

FOR MORE INFORMATION:

This brochure is only a summary of what has been provided to the Federal and State agencies. If you would like more information, please contact Tosco Los Angeles Refinery Public Affairs at (310) 952-6035 or (310)952-6038.

6/99

FIVE-YEAR ACCIDENT HISTORY

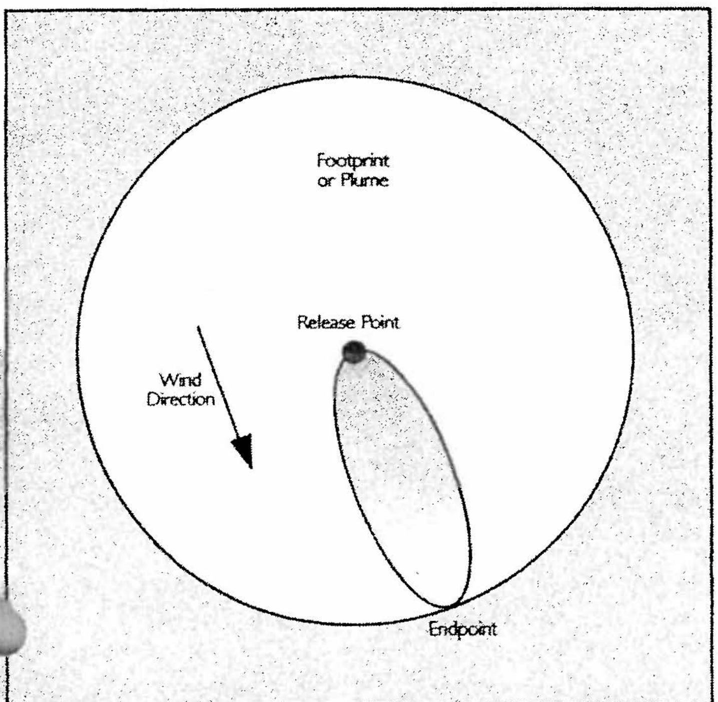
The Federal Environmental Protection Agency (EPA) requires companies to report releases that have resulted in an injury, illness or a significant impact on the community or the environment. In the past five years at Tosco's Los Angeles Refinery, we have had no releases of butane that were significant enough to be reported under the Risk Management Plan (RMP).

ACCIDENTAL RELEASE SCENARIOS

The Risk Management Plan requires companies to identify "worst case" and "alternate release" scenarios as defined by EPA. In determining the worst case scenario, no safety measures (such as automatic shutdown systems) or emergency response actions can be considered. For the alternate release scenario, existing safety systems and typical emergency response actions can be considered. For *toxics*, both the worst case scenario and the alternate release scenario would create a vapor cloud near the ground that travels away from the facility in the direction of the wind. As the cloud travels away from the facility it will spread out, becoming less concentrated and less harmful. For *flammables*, the release could affect the "full circle", but will be over very quickly. **It is important to remember that these scenarios are not predictors of events but rather are intended to be used as emergency response planning tools.**

HOW TO READ A SCENARIO MAP

The maps on the next page show the worst case and alternate release scenarios for butane at Tosco's Los Angeles Refinery.

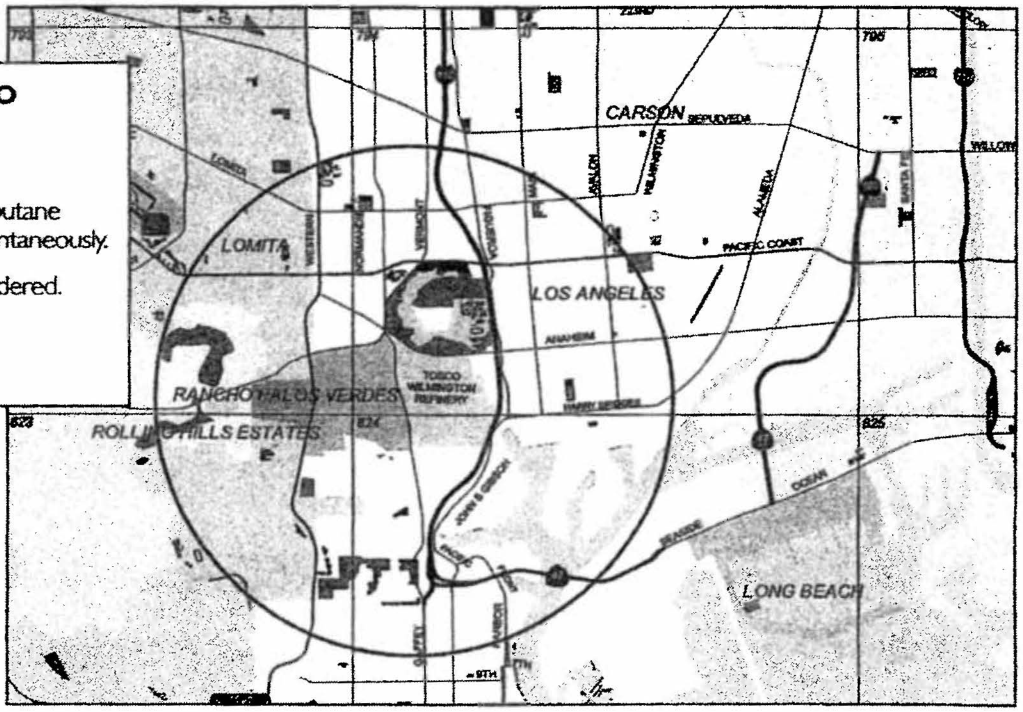


Scenario Circle
A circle extending from the release point to the endpoint distance. Used by local officials for emergency planning.

Endpoint
For *toxics*, the endpoint is the distance at which a person can be exposed for up to an hour without serious health effects. For *flammables*, the endpoint is the distance at which a fire or explosion should no longer damage buildings or hurt people.

Footprint or Plume
Assumptions are used to establish an area that could be affected by an accidental release. Toxic releases generally go in the direction of the wind and may travel many miles over several hours. The greater the distance from the release, the more time there is to take protective action. The effects of flammable releases are limited to areas much closer to the release point and could affect the "full circle", but are over very quickly.

WORST CASE SCENARIO



WORST CASE SCENARIO ASSUMPTIONS FOR BUTANE:

- Everything in a refrigerated butane storage tank is released instantaneously.
- Safety controls are not considered.
- Butane completely vaporizes and explodes.

DISTANCE OF POTENTIAL IMPACT:

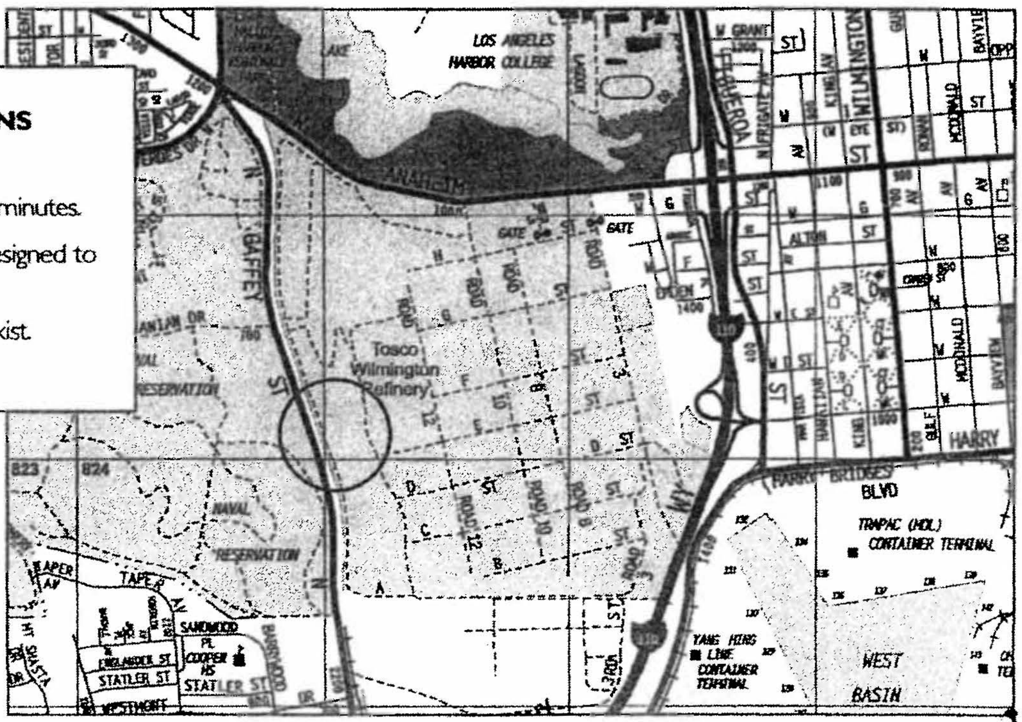
2.3 MILES

PUTTING IT INTO PERSPECTIVE

Worst Case Scenario Amount Released .... 5,092,000 Gallons

Alternate Release Scenario Amount Released .... 6,160 Gallons

ALTERNATE RELEASE SCENARIO



ALTERNATE RELEASE SCENARIO ASSUMPTIONS FOR BUTANE:

- Release of 30,000 lbs. in 15 minutes.
- Safety controls operate as designed to minimize release.
- Typical weather conditions exist.

DISTANCE OF POTENTIAL IMPACT:

0.11 MILES

WHAT WE DO TO PREVENT ACCIDENTAL RELEASES

At Tosco's Los Angeles Refinery, safety is our number one priority and we take it seriously. We use a variety of safety equipment and follow strict procedures to prevent releases and to reduce the impact of releases. Some examples are:

- Safety controls, such as leak detectors, warning alarms and automatic shutdowns
- Regular equipment inspections and maintenance to ensure proper operation
- Investigation of all incidents to improve our procedures and prevent reoccurence
- Routine audits of processes both by Tosco's Los Angeles Refinery and outside agencies

WHAT TO DO IN A CHEMICAL EMERGENCY

Although the chance of a significant chemical accident is small, the possible health effects could be serious. Therefore, it is important for you to know what to do. These accidental releases can occur quickly. For the first few minutes of any emergency, you will be on your own and you will need to rely on your senses.

If you are outdoors and you smell a strong chemical odor, protect yourself by immediately going inside the nearest building, home or vehicle.

This is called **Shelter in Place** and is the best way to protect yourself and your family in the event of an accidental chemical release. This works because the outside air does not mix quickly with the air in these spaces when they are closed or sealed. Shelter in Place protects you from the most toxic vapors as the cloud passes.

1. Go indoors immediately.

2. Close doors and windows.

3. Shut off heaters & air conditioners. Close fireplace dampers.

4. Other precautions to consider: cover nose & mouth with wet cloth, seal windows.

5. Listen to KNX 1070AM, KFWB 980AM or local television station.

6. Wait for additional instructions. Following an "all clear" message, air out your home.

PREPARING FOR EMERGENCIES

Tosco's Los Angeles Refinery and other nearby facilities have formed a relationship with the local authorities in order to ensure your safety during a chemical emergency. Emergency plans are reviewed by local emergency responders, such as city and county fire departments. Tosco's Los Angeles Refinery conducts emergency response drills to prepare for accidents such as those described in this brochure.

For more information, please contact Jeff Callender at (310)952-6035 or Agnes Sibal at (310)952-6038 or Los Angeles City Fire Department at (213) 485-8080.

EXHIBIT G

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Journal of Loss Prevention in the Process Industries 19 (2006) 51–59
Journal of Loss Prevention in the process industries
www.elsevier.com/locate/jlp

A study of storage tank accidents

James I. Chang[a,*], Cheng-Chung Lin[b]

[a]Department of safety, Health and Environmental Engineering, National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan, ROC
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Received 5 December 2004; received in revised form 19 May 2005; accepted 26 May 2005

Abstract

This paper reviews 242 accidents of storage tanks that occurred in industrial facilities over last 40 years. Fishbone Diagram is applied to analyze the causes that lead to accidents. Corrective actions are also provided to help operating engineers handling similar situations in the future. The results show that 74% of accidents occurred in petroleum refineries, oil terminals or storage. Fire and explosion account for 85% of the accidents. There were 80 accidents (33%) caused by lightning and 72 (30%) caused by human errors including poor operations and maintenance. Other causes were equipment failure, sabotage, crack and rupture, leak and line rupture, static electricity, open flames etc. Most of those accidents would have been avoided if good engineering have been practiced.

Keywords: Fishbone Diagram; Accident statistics, fire and explosion

1. Introduction

Storage tanks in refineries and chemical plants contain large volumes of flammable and hazardous chemicals. A small accident may lead to million-dollar property loss and a few days of production interruption. A large accident results in lawsuits, stock devaluation, or company bankruptcy. 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 (AIChE, 1988; 1993; API, 1988; 1990; ASME, 2004; NFPA, 1992; UL, 1986; 1987). Most companies follow those standards and guidelines in the design, construction and operation, but tank accidents still occur. Learning from the past history is definitely important for the future safe operation of storage tanks.

The purpose of this paper is to categorize the causes that lead to 242 tank accidents occurred in last 40 years. The fishbone diagram (The cause and effect diagram) invented by Dr Kaoru Ishikawa (Ishikawa and Lu, 1985) is used to summarize the effects and the causes that create or contribute to those effects. We hope that this work will be beneficial to tank operators and engineers.

2. Overall statistics

The information of 242 tank accidents reviewed in this work was collected from published reports (March and Mclennan, 1990; 1997; 2002; Persson and Lonnermark, 2004), books (CPC, 1983; 2002; Pekalski, 1997; Lees, 1996), CSB incident news (USCSB, 2000–2003) and databases (UQ, 2001; USCHSIB, 2004; IChemE, 2002; PAJ, 2004; USNOAO, 1999). There were 114 occurred in North America, 72 in Asia and 38 in Europe (Table 1). USA had 105 accidents reviewed because of the easy accessibility to accident information. As indicated in Table 2, accidents occurred more frequently at petroleum refineries with 116 cases (47.9%). The second most frequently involved place was terminals and pumping stations (64 cases, 26.4%). Only 25.7% of accidents occurred in petrochemical plants (12.8%), oil fields (2.5%), and other types of industrial facilities (10.3%) such as power plants, gas plants, pipelines, fertilizer plants,

* Corresponding author. Tel.: +886 916143783; fax: +886 7 6011061.
E-mail address: envjames@ccms.nkfust.edu.tw (J.I. Chang).

0950-4230/$ - see front matter
doi:10.1016/j.jlp.2005.05.015

Table 1
Continents where accidents occurred

Year	North America[a]	Asia and Australia[b]	Europe[c]	South America	Africa[d]	Total
1960–1969	3	7	6	1	0	17
1970–1979	18	9	6	1	2	36
1980–1989	26	9	9	5	4	53
1990–1999	36	33	12	2	2	85
2000–2003	31	14	5	0	1	51
Total	114	72	38	9	9	242

[a] South Africa:5.
[b] USA:105, Mexico:6, Canada:3.
[c] Taiwan:19, Japan:10, China:6.
[d] UK:6, Italy:4.

Table 2
Type of complex where accidents occurred

Year	Refinery	Terminal/Storage	Chemical Plant[a]	Oil Field	Misc.[b]	Total
1960–1969	10	5	1	0	1	17
1970–1979	22	11	0	0	3	36
1980–1989	25	17	5	2	4	53
1990–1999	41	22	16	1	5	85
2000–2003	18	9	9	3	12	51
Subtotal	116	64	31	6	25	242

[a] Petrochemical plants included.
[b] Other industrial facilities such as power, gas, pipeline, fertilizer, and plating plants.

Table 3
Type of tank contents

Year	Crude oil	Oil products[a]	Gasoline /Naphtha	Petro-chemicals	LPG[b]	Waste oil water	Ammonia	Hydrochloric acid	Caustic soda	Molten sulfur	Total
1960–1969	6	3	0	3	3	2	0				17
1970–1979	8	7	13	3	3	2	0				36
1980–1989	17	14	17	4	1	0	0				53
1990–1999	23	19	21	11	5	4	0	1		1	85
2000–2003	12	16	6	6	1	1	3	2	3	1	51
Subtotal	66	59	55	27	15	9	3	3	3	2	242

[a] Fuel oil, diesel, kerosene, lubricants.
[b] Propane and butane included.

etc. Crude oil, gasoline and oil products such as fuel oil, diesel, etc. were major contents (Table 3). The atmospheric external floating roof tank was the most frequent type and the atmospheric cone top tank was the second most frequent type. Both types were used extensively for the storage of crude oil, gasoline, and diesel oil (Table 4).

Fire was the most frequent type of loss with 145 cases and explosion was the second most frequent type of loss

Table 4
Type of tanks and contents

Content	External floating top	Cone top	Sphere	Cone roof internal floating top	Refrigerated tank	Wooden top	Fiber glass	Total
Crude Oil	23	5	0	2	0	2	0	32
Oil products	3	10	0	1	0	0	0	14
Gasoline	20	3	0	3	0	0	0	26
LPG	0	0	11	0	0	0	0	11
Propane	0	0	0	0	1	0	1	2
Hydrochloric acid	0	0	0	0	0	0	2	2
Methyl cyanate	0	0	0	0	1	0	0	1
Subtotal	46	18	11	6	2	0	3	88

Table 5
Type of accidents

Year	Fire	Explosion	Spill	Toxic gas Release	Misc.	Subtotal
1960–1969	8	8	0	0	1[a]	17
1970–1979	26	5	5	0		36
1980–1989	31	16	3	2	1[a]	53
1990–1999	59	22	2	1	1[b]	85
2000–2003	21	10	8	10	2[c]	51
Subtotal	145	61	18	13	5	242

[a] Tank body distortion.
[b] Personal fall.
[c] 1 Person fell and 1 person was electrified to death.

with 61 cases as indicated in Table 5. Fire and explosion together accounted for 85% of total cases. Oil spill and toxic gas/liquid release were the third and the fourth most frequent, respectively. The tank body distortion and the worker's falling only occurred a few times. Property losses were rarely reported and the information was difficult to find. The average property loss of the 10 largest storage tank damage losses listed in Table 6 is 114 million in January 2002 dollars.

3. Causes of accidents

As indicated in Table 7, lightning was the most frequent cause of accident and the maintenance error was the second most frequent cause. The rest were operational error, equipment failure, sabotage, crack and rupture, leak and line rupture, static electricity, open flames etc. To illustrate causes and effects, a fishbone diagram as shown in Fig. 1 was developed. A fishbone diagram as shown in Fig. 2 was also developed for the prevention of accidents.

3.1. Lightning

There are two major causes of lightning related fires. The first one is a direct strike and the second is the secondary effects such as the bound charge, the electromagnetic pulse, the electrostatic pulse and the earth currents (Carpenter, 1996). A direct lightning strike zone has a radius between 10 and 10 m. When a storage tank is in the direct strike zone,

Table 6
Ten largest tank accidents between 1963 and 2002

Item	Date	Location	Loss[a]	Description
1	2/24/86	Thessaloniki Greece[b]	330	Sparks from a flame cutting torch ignited fuel from a tank spill in a dike of a fuel tank. The fire spread to other areas resulting in destruction of 10 out of 12 cruel oil tanks.
2	4/3/77′	UMM said Qatar	179	A 260,000-barrel tank containing 236,000 barrels of refrigerated propane at -45°F failure massively. An adjoining refrigerated butane tank and most of the process area were also destroyed by fire.
3	1/20/68	Pernis Nether-lands	141	Frothing occurred when hot oil and water emulsion in a slop tank reacted with volatile slop, causing a violent vapor release an boil-over. The fire destroyed 3 hydrocarbon, a sulfur plant, and 80 storage tanks.
4	9/1/79′	Deer Park, Texas, USA	138	Nearly simultaneous explosions aboard a 70,000 DWT tanker off-loading and in an 80,000-barrel ethanol at a refinery occurred during a electric storm.
5	5/30/78′	Texas City Texas, USA	120	An unidentified failure led to the release of light hydrocarbons which spread to an ignition source. 11 tanks in this alkylation unit were destroyed.
6	8/20/81	Kuwait	73	Fire destroyed 8 tanks and damaged several others. The cause of the fire has not been disclosed.
7	″ 9/14/97	Vishakhapatnam, India	64	LPG ignited during tank loading from a ship. A thick blanket of smoke spreading panic among the residents resulted in 37 people died and 100 injured. 15 storage tanks burned for two days.
8	12/21/85'	Naples, Italy	60	Twenty four of the 32 tanks at a marine petroleum products terminal destroyed by fire that began with a tank overfill. Explosion caused complete destruction of the terminal buildings and nearby industrial and residential structures.
9	1/7/83′	Newark, New jersey, USA	52	A overfilling of a floating roof tank spilled 1300 barrels of gasoline into the tank dike. The vapor cloud carried by wind to a nearby incinerator and was ignited. The resulting explosion destroyed two adjacent tanks and the terminal.
10	5/26/83′	Prodhoe, Bay, Alaska, USA	47	A low-pressure NGL feed drum ruptured in a crude oil station, resulting in fire damage to one third of the module and exterior of surrounding structure within 100 ft.
Avg.			114	

[a] In million January 2002 US dollars.
[b] The loss quoted in Fewtrell and Hirst (1998) was converted into 2002 US dollars.

Table 7
Cause of tank accidents

Year	1960–1969	1970–1979	1980–1989	1990–1999	2000–2003	Total
Lightning	4	10	19	37	10	80
Maintenance/hot work	1	5	9	12	5	32
Operational error	1	5	6	8	9	29
Equipment failure	3	1	5	7	3	19
Sabotage	2	5	2	6	3	18
Crack/rupture	0	3	3	3	8	17
Leaks and line rupture	0	3	2	5	5	15
Static electricity	2	1	2	2	5	12
Open flame	1	0	4	2	1	8
Nature disaster	1	2	1	1	2	7
Runaway reaction	2	1	0	2	0	5
Total	17	36	53	85	51	242

flammable vapors exposed to the heating effect or the stroke channel may be ignited. Among the 80 lightning accidents, a dozen tanks were hit directly resulting in roof blowing off and massive destruction. A lighting strike to a floating roof tank containing naphtha on October 24, 1995 in Gilacap, Indonesia resulted in fires and property damages of 38 million dollars in January, 2002 dollars (March and Mclennan, 1997). Because of this incident, the refinery operated at approximately 70% of capacity as of July 1995, and was not expected to operate at full capacity until March 1997.

A storm cell induces a charge on the surface of the earth and structures projecting from the surface under the cell. The charged area varies in size from 15 to 150 sq km, which is much larger than a direct strike zone. The risk of secondary effects related fire is far higher than the risk of a direct strike. After the nearby strike, a well-grounded tank will still take on the storm cell induced charge, but it releases the charge faster.

The rim seal of a floating roof tank is the most likely place to be ignited in a thunderstorm. Most rim seal fires were extinguished in a few hours, but a 1989 lightning strike in Dar Es Salaam, Tanzania led to a 360 ° rim seal fire around an 80,000 barrels external floating roof storage tank containing crude oil that lasted for five days (Persson and Lonnermark, 2004). A rim fire on a Singapore storage tank in 1991 escalated to a full surface and bund fire. Tight sealing to prevent the escape of liquids or vapors is definitely necessary for storage safety. Vent valve is also a likely place to be ignited. Flame arrestor should be installed.

The existing lightning protection standards for the petroleum industry provide little help. The conventional radioactive lightning protection installed on a Nigerian 670,000-barrel crude oil tank did not prevent the tank from

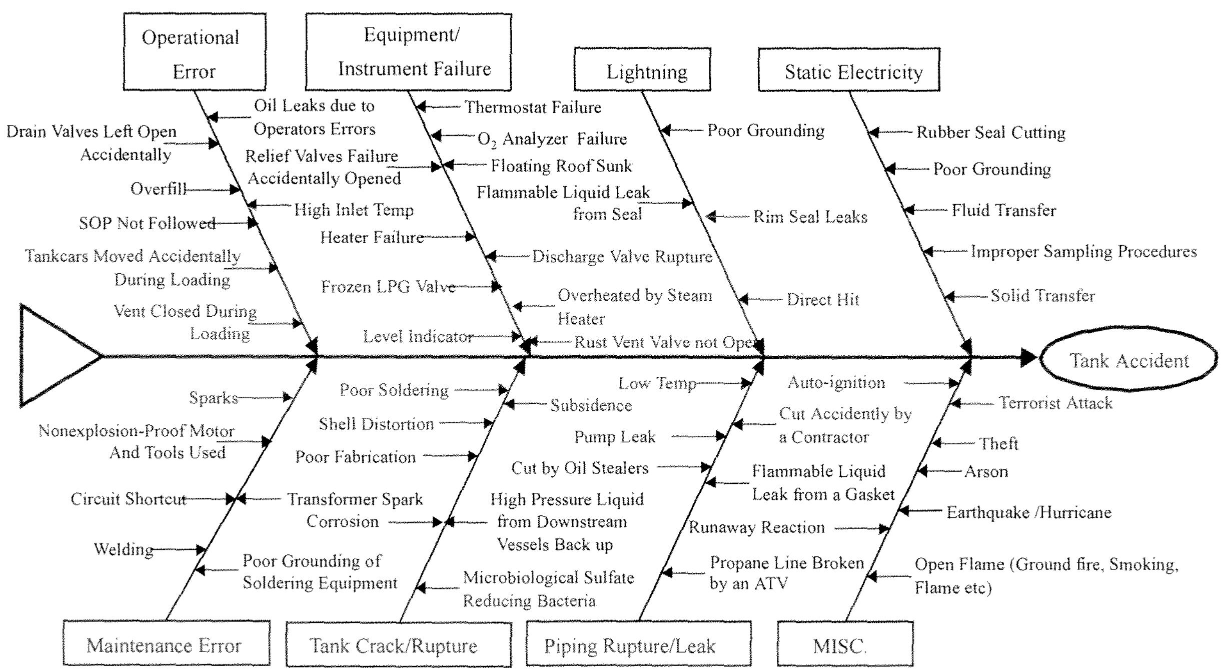

Fig. 1. Fishbone diagram of accident causes.

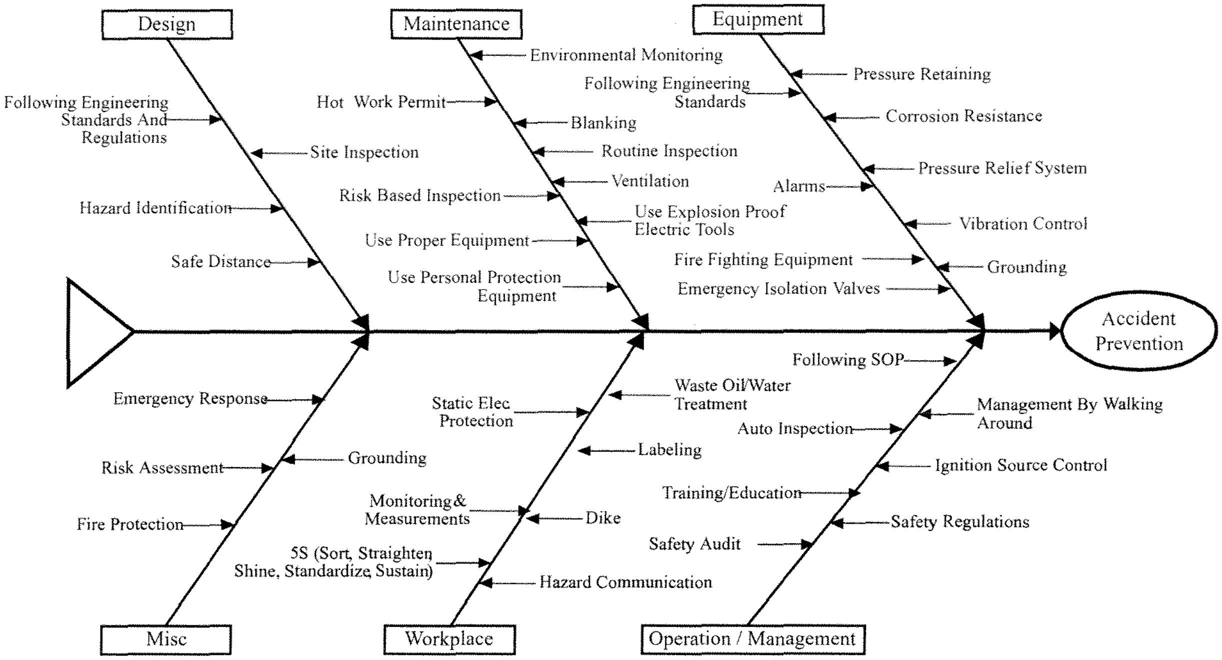

Fig. 2. Fishbone diagram of accident prevention.

the lightning strike in 1990 (Carpenter, 1996). The National Fire Protection Publication on lightning protection, NFPA-78/780, describes the problem and industrial standard policies, but provides no positive protection solutions.

3.2. Maintenance error

Welding is responsible for 18 accidents. Catastrophic failures of aboveground atmospheric storage tanks can occur when flammable vapors in the tank explode. In a 1995 accident, during a welding operation on the outside of a tank, combustible vapors inside two large, 30-ft. diameter by 30-ft. high, storage tanks exploded (USEPA, 1997). In a 1986 accident in Thessaloniki, Greece, sparks from a flame of a cutting torch ignited flammable vapors resulting in a fire spreading to other areas (Fewtrell and Hirst, 1998). The fire extended for seven days resulting in the destruction of 10 out of 12 crude oil storage tanks and five deaths. Both OSHA's regulations concerning hot work and NFPA's standards on welding should be reviewed. Hazard reduction measures include proper hot-work procedures such as obtaining a hot work permit, having a fire watch and fire extinguishing equipment present, and proper testing for explosivity; covering and sealing all drains, vents, man-ways, open flanges and all sewers (USEPA, 1997).

Mechanical frictions also generate sparks that ignite flammable vapors. A 1988 accident in Memphis, Tennessee and a 1989 accident in Sandwich, Massachusetts, USA occurred during insulation installation. On October 28, 1999, a spark from a man lift with two employees in Ponca City, Oklahoma, USA ignited vapors (Persson & Lonnermark, 2004). The ignition tore the insulated cone roof into several pieces resulting a full surface fire. A fire destroyed an almost empty refinery gasoline tank during a 2002 tank inspection in Superior, Wisconsin (Persson & Lonnermark, 2004). In 1983, three Crinto, Nicaragua workers were killed in an explosion while repairing a purification duct on top of an oil storage tank. In a 1994 accident, during a grinding operation on a tank holding petroleum based sludge, the tank was propelled upward, injuring 17 workers and spilling its contents over a containment beam into a river (USEPA, 1997). In a 2000 incident, naphtha trapped in the seal ignited during a cleaning operation of a naphtha storage tank at an Anchorage, Alaska petroleum tank farm, (Persson & Lonnermark, 2004). In 1973, 40 workers at a Staten Island, New York City gas plant were killed in an explosion while cleaning an empty LNG tank (Juckett, 2002). The explosion was caused by the ignition of cleaning chemicals.

Electric sparks and shocks also ignite flammable vapors or liquids resulting in fire or explosion also. A 1984 accident at a Kaohsiung, Taiwan refinery and a 2002 accident at a Lanjou, China refinery were caused by the electric sparks generated by electric motors (CPC, 2002). A 1996 accident at a Chaiyi chemical plant was caused by sparks from an electric soldering machine (CPC, 2002). To reduce the electric hazard, each room, section, or area must be considered individually in determining its classification defined in National Electrical Code, NFPA 70, Article 500, Hazardous (Classified) Locations (AIChE, 1993). Engineers must pay attention to the safe application of electric apparatus also.

3.3. Operational error

Overfilling is the most frequent cause in this category. Among the 15 overfilling cases, nine of those were from gasoline tanks, two from crude oil tanks, two from oil products tanks, one from a phenol tank, one from a benzene tank. When a tank containing flammable liquid overfills, fire or explosion is usually unavoidable. Any spark nearby may ignite flammable vapors released from the tank. 13 out of 15 overfilling cases led to fire and explosion. In a 1975 incident, vapors from an overfilled internal floating crude oil tank travelled to a boiler stack where they were ignited (Persson and Lonnermark, 2004). In 1983, the wind carried the vapor cloud released from a Newark, New Jersey gasoline tank to a 1000-ft away incinerator (March and Mclennan, 1997). Vapors released from the tank overfilling were ignited by electric switches in a 1980 incident in Hawaii, USA and a 1999 incident in Yunnan, China. Vapors released from an overfilled Jacksonville, Florida gasoline tank in 1993 and a Louisiana gasoline tank in 1980 were ignited by automobile engines (Persson & Lonnermark, 2004). Incorrect manual setting of the transfer system caused a Wrexam, UK tank overflow in 2001 and resulted in 14 tonnes of toxic phenol released into a bund area (UKHSE, 2001). In 2001, 46 children and 2 villagers were hospitalized, after 50 kilograms of benzene leaked from an over-pressurized storage tank at a chemical plant in Wuyi, Zhejiang, China sent (USCSB, 2001–2003).

Overpressure from the pressure of the pipeline supplying the plant was the probable cause of the rupture of an 8-inch line between a sphere and a series of cylinders in a Mexico City, Mexico LPG facility on November 11, 1984 (Paullin & Santman, 1985). A drop in pressure was noticed in the control room and also at a pipeline pumping station, but the operators could not identify the cause of the pressure drop. The release of LPG continued for 5–10 min when the vapor cloud drifted to a flare stack and ignited. The explosion led to a number of ground fires and explosions that destroyed the facility and killed 500 people. The installation of a more effective gas detection and emergency isolation system could have averted the accident.

Four out of five accidents occurred during LPG and propane loading was caused by operational error. In a 1964 accident in Japan and a 1998 accident in Kaohsiung, Taiwan, the drivers moved the tankers inadvertently resulting in hose disconnecting, vapor release, fire and explosion. In a 1979 accident in Ypsilanti, Michigan, USA, the hose failed during tank loading (Lenoir and Davenport, 1993). In 1972, a drain valve at the bottom of a LPG sphere in a Brazil refinery was left open by an operator resulting in the destruction of 21 storage tanks and an office building (March & Mclennan, 1990). In 1990, the outlet valve on a butane sphere in Korea was inadvertently opened resulting in a tank explosion (CPC, 2002).

Toxic fumes or liquids may also be released if operators make mistakes. On September 10, 2001, a large quantity of toxic gas was released into the atmosphere from a British factory, when 300 l of sodium hypochlorite was accidentally released into a tank containing 6000 l of hydrochloric acid (USCSB, 2001–2003). About 170 workers were evacuated. 2000 gal of hydrochloric acid spilled from a waste holding tank at a Phoenix, Arizona plating plant on Monday, January 15, 2001 and reached storm drains in a western Phoenix industrial park. No injuries were reported and those who worked in the industrial park were evacuated. Operational errors led to an asphalt tank overheating, a fire and an explosion at a Portland, Oregon plant in 2003 and at a Richland, USA roof company in 1997 (USCSB, 2001–2003).

3.4. Sabotage

Sabotage is the fourth frequent cause. There were 15 cases of terrorist attacks or military operations, 1 case of arson, and 3 cases of theft. During Iraqi occupation of Kuwait in 1991, several tank farm facilities were set on fire. Only a few fires were fought while others were allowed to burn out due to war situation. Anhydrous ammonia theft has been a growing problem in the United States in recent years. A 2002 Ammonia leak at a Snohomish county, Washington state food processing plant as well as a 2002 leak at a Bonita, Louisiana storage was also blamed on thieves (USCSB, 2001–2003).

3.5. Equipment failure

There were 11 cases of sunken-roof, 4 cases of valve failure, 2-heater malfunctions, 1 analyzer failure, and 1 thermostat failure. A typical external floating roof tank consists of an open-topped cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. A seal system, which is attached to the roof perimeter and contacts the tank wall, reduces evaporative loss of the stored liquid. The seal system slides against the tank wall as the roof is raised and lowered with the liquid level in the tank. The floating roof may not function normally, if the rooftop is out of balance or the tank body distorts. The roofs of several floating roof tanks sank after a heavy storm as a result of a low capacity of roof drain. Flammable vapors were ignited by lightning or static charge.

In 1962, the body of a Japanese cone roof tank in naphtha service shrunk as a result of vent valve failure. A discharge valve on a LPG sphere at a Feyzin, France refinery froze and unable to close as a result of LPG vaporization after samples were taken. A large quantity of LPG vapors released resulting in a big fire that killed 19 people and the destruction of 5 tanks (March and Mclennan, 1990). In 1994, a safety valve on a molten sulfur tank at a Kaohsiung, Taiwan refinery did not open when the tank was overheated resulting in a gas explosion (Lin, 2003). In 2000, a valve on an Ammonia tanker in Jiande city, Zhejiang, China burst, spilling the ammonia and injuring 13 people, and exposing 12 construction workers (USCSB, 2001–2003). Routine checkup and maintenance to ensure the integrity of all valves on a storage tank is necessary.

In 1990, an oxygen analyzer used to regulate the nitrogen sweep rate of a wastewater storage tank at a Channelview, Texas petrochemical plant malfunctioned and allowed oxygen to accumulate in the tank (March and Mclennan, 1997). The explosion and fire resulted in significant equipment damage.

Heavy oil is usually heated to increase its fluidity. When the heater is malfunctioned or the thermostat fails, the oil may be overheated resulting in flammable vapors release. A 1990 fire that destroyed a 60,000-barrel gas oil tank in Lemont, Illinois, USA (Persson and Lonnermark, 2004) and a 1969 explosion that destroyed a fuel oil tank at a Kaohsiung, Taiwan sugar mill were caused by the heater malfunction. A 1983 fire that destroyed a fuel oil tank at a Venezuela power plant was caused by the failure of a thermostat (CPC, 1983).

3.6. Crack and rupture

There were 13 tank cracks, 2 body ruptures one roof hole and one flange crack resulting in 13 spillages including oils, hydrochloric acid, sulfuric acid, molten sulfur, and sodium cyanide solution, 3 fires and explosions, and the falling of one operator. Most storage tank damage is attributable to age deterioration, corrosion and seismic motions. Cracks usually occur at the bottom or the welding edges. A 1970 crack at the bottom of a crude oil storage tank at a Kaohsiung, Taiwan refinery was attributed to the slow subsidence of the foundation (Lin, 2003). Both crude oil spills from storage tanks into bunds at a Kaohsiung, Taiwan refinery in 2002 and at a Fawley, Hampshire, UK refinery were caused by the corrosion of tank bottom (UKHSE, 2000). The corrosion of a defective weld was attributed to a 1999 spillage of 12 tonnes of sodium cyanide solution from a Cleveland, UK storage tank into the ground and river tees (UKHSE, 2000). The 1977 incident at an Umm Said, Qatar gas processing plant was caused by a weld failure of a 260,000-barrel tank containing refrigerated propane at −45 degree Fahrenheit. The weld failure was attributed to three possibilities, including microbiological sulfate reducing bacteria from hydrotesting the tank with seawater (March and Mclennan, 1997). The crack of a flange on the south side of an oil tank at a Houston, Texas oil and chemical company in 2003 let the oil out and led a small fire (USCSB, 2000–2003). The failure of the bottom portion of a newly fabricated tank containing hydrochloric acid at an Illinois lighting plant in 2001 was probably due to malfabrication (USCSB, 2000–2003). The rupture of a tank containing sulfuric acid at a mothballed dye plant in Guangdong, China in 2001 and a collapse of a fiberglass tank containing hydrochloric acid in Pennsylvania, USA were attributed to lack of maintenance (USCSB, 2000–2003).

Most of the spills were restricted to areas around the tanks or within protective bunds, but those located at seashores or riverbanks released a large quantity of tank contents into the water. A crack of a storage tank at a Floreffe, Pennsylvania terminal in 1988 released 92,400 barrels of diesel oil into the river (March & Mclennan, 1997) and a 1974 crack at the bottom plate of a tank at a Mizushima port, Japan refinery released 7500 kl of heavy oil into the sea (PAJ, 2004). The tidal wave carried thousands barrels of crude oil into the river, after 4 storage tanks ruptured at a Lima, Ohio refinery in December 1983 (Persson and Lonnermark, 2004). The Umm Said, Qatar incident that resulted in an 8-day fire and property damage over 100,000,000 dollars is the largest property damage loss caused by the crack (Fewtrell and Hirst, 1998). In 1993, an operator at a Kaohsiung, Taiwan refinery fell off from a rust hole on the roof into the tank (Lin, 2003).

3.7. Static electricity

12 tank accidents were caused by static electricity. 6 occurred during the sampling of storage tanks containing flammable liquids at the open access ports. The operators in a 1965 accident and a 1972 accident in Japan (Takagi Nobuo, 1994), and a 2002 incident in Kaohsiung, Taiwan (Lin, 2003) used metal devices or container connected with nonconductive threads. To reduce the sampling hazard, avoid operations at the open access port. If the operation at the open access port is unavoidable, use sampling beakers and sampling gauges made of nonconductive material. Do not use any device made of metal. Fluid flow in the connecting line and turbulence in the pump can also lead to charge of the liquid and of the pipe. Sparking is possible between metal parts especially when the pump is inserted or removed (ESCIS, 1988). A 1996 incident at a Kaohsiung, Taiwan plastics plant (CESH, 2003a) and a 2003b incident at a Glennpool, Oklahoma tank farm (Persson & Lonnermark, 2004) were caused by the discharge of static electricity generated during fluid transferring. The containers should be bonded to each other, and the one being dispensed from should be ground during fluid transferring. A 1997 accident at a chemical plant in Kaohsiung, Taiwan was blamed on the ignition of plastic dusts by the discharge of static electricity generated during pneumatically conveying of plastic pellets.

3.8. Leak and line rupture

In 1997, LPG leaked for several hours without being detected after a tanker ship pumped it on shore at a Vishakhapatnam, India storage facility. A thick blanket of smoke engulfed the port city resulting in 37 deaths, 100 injuries, and a property loss of 64 million in 2002 dollars (March & Mclennan, 2002). In 1990, an initial fuel leak at an operating fuel pump in the valve pit was ignited by the electric motor for the pump resulting in a big fire that damaged 7 storage tanks in the fuel tank farm adjacent to the

Denver international airport. The 2002 fire of a tank containing 30,000 barrels of residual fuel oil at a Houston, Texas terminal was caused by the rupture of an expansion joint on a transfer line (USCSB, 2000–2003). The propane tank explosions at a Tewksbury, Massachusetts gas plant in 1972 (Kearns, 1972) and in Albert, Iowa in 1998 (USCSB, 1998) were caused by line snapping of automobiles. A 2003 tank explosion at a Midland, Texas tank farm was caused the ignition of oil leak from a 'lack unit' measuring how much oil moved through the tank (USCSB, 2000–2003). The failure of a rupture disk on the fire protection line of a hydrocarbon storage tank near Red Deer, Canada caused the hydrocarbon leak in the year of 2000 (USCSB, 2000–2003). Four people died in a huge blast at a key oil-producing area in the north of Kuwait on January 31, 2002 (USCSB, 2000–2003). Officials say the explosion was caused by a leak from a pipeline that spread to a power substation. The fire occurred after an explosion rocked the Raudhatain oil field setting ablaze about half of an oil gathering center, a gas booster station and a power substation near the Iraqi border. Officials reported that the fire was a result of a technical fault, not terrorism or sabotage.

3.9. Open flames

Open flames such as ground fires, cigarette smoking, and hot particles also ignite flammable vapors around storage tanks. Four accidents including a 1981 accident at a Kuwait refinery (March & Mclennan, 1997), and a 1989 incident at a Baton Rouge, Louisiana refinery was caused by the ground fires or explosion close by (Persson & Lonnermark, 2004). Both a 1997 and a 1999 accident during tank cleanings at a Kaohsiung, Taiwan refinery were blamed on cigarette smoking. A 1983 accident at a Milford Heaven UK refinery were caused by incandescent carbon particles discharged from the top of a 250-foor-high flare stack (March & Mclennan, 1990). In 2001, a Tonganoxide, Kansas, USA worker struck a match while checking the oil level of a storage tank at night (Persson & Lonnermark, 2004). The flame ignited flammable vapors and resulted in an explosion.

3.10. Natural disasters

The damage to an oil storage tank in an earthquake is a complex phenomenon involving the characteristics of seismic motions, the tank structure, the characteristics of the ground, the physical properties of a substance contained, etc. all interacting with each. Fortunately, only 4 earthquakes in the past resulted catastrophic oil spills or fires. Among the 4 accidents, 3 occurred in Japan and one in Turkey. The big fire at a Niigata, Japan refinery in 1964 was caused by the ignition of hydrocarbon vapors with sparks generated during an earthquake (Watanabe, 1966). A 1978 earthquake resulted in the cracks of two heavy oil storage tanks and one light oil storage tank at a Shiogama, Japan refinery (PAJ, 2004). A large quantity of oils released into the sea. The August 17,1999 earthquake in Turkey killed thousands people and triggered a fire at a refinery resulting in the destruction of 3 naphtha tanks (Persson and Lonnermark, 2004). A September 26, 2003 earthquake damaged 29 tanks and ignited one tank at a Hokkaido, Japan refinery (Persson & Lonnermark, 2004). The 1995 Hyogo-ken Nanbu (Kobe) earthquake damaged many small-scale above ground tanks, but did not cause serious fire, explosion or spillage of hazardous materials (NRIFD, 2003).

Hurricanes are quite often in Bahamas, Gulf of Mexico and Southeast Asia, but only three that caused significant damages to storage tanks. A fire in a tank of jet oil at a Cabras Island, Puerto Rico storage tank farm during super hurricane Pongsona in 2003 lasted for 5 days due to limited water supply (USCSB, 2000–2003). The 1989 hurricane Hugo struck St Croix, Virgin Islands and destroyed fourteen storage tanks in the tank farm area (March & Mclennan, 2002). Hurricane Celia in 1970 with a wind speed of 150 mile/h struck Corpus Christi, Texas and damaged 30 storage tanks (March & Mclennan, 1990).

3.11. Runaway reactions

Exothermic runaway reactions may occur when impurities or foreign materials are present in the storage tanks. A 1993 explosion that blew off the lid of a fixed roof tank at a Knell, Australia refinery was caused by the pyrolytic action of caustic soda used for cleaning of pipelines and the diesel oil (Persson & Lonnermark, 2004). In 1979, pyrophoric action started a fire in a slop tank at a Joliet, Illinois, USA refinery resulting in the loss of three tanks (Persson & Lonnermark, 2004). In 1962, a small quantity of ammonia gas was mistakenly introduced into a 6500-gal ethylene oxide tank in a Brandenburg, Kentucky ethanolamine plant triggered an exothermic polymerization and an explosion (March & Mclennan, 1990). In a 1968 accident at a Pernis, Netherlands refinery, hot oil and water emulsion reacted and resulted in frothing, vapor release and boil-over. The fire engulfed 30 acres, destroyed 2 wax crackers, a naphtha cracker, a sulfur plant and 80 tanks (March & Mclennan, 1997). The 1984 release of methyl isocyanate vapor from a storage tank at a Bhopal, India chemical plant was caused by the exothermic reaction of liquid methyl isocyanate with water (March & Mclennan, 1990).

4. Conclusion

The information of 242 tank accidents occurred in industrial facilities in last 40 years was reviewed. The causes and the contributing failures that led to accidents were expressed with a fishbone diagram in a systematic way. Most of those tank accidents would have been avoided if good engineering in design, construction, maintenance and operation has been practiced and safety management program has been implemented and executed.

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I hereby certify that the foregoing Reply to Ron Conrow, Western District Manager, Plains/Rancho LPG, letter to Honorable Janice Hahn, Member of Congress, 44th District, California dated November 11, 2016, was served on the 3rd day of December, 2016 by first class mail prepaid on the foregoing parties:

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