Sudan University of Science and Technology

College of Petroleum Engineering and Technology

Department of Transportation and Refining

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Evaluation and Control of Evaporation Losses fromGasoline Internal Floating Roof Tanks

التقييم والتحكم في فواقد التبخر من خزاناتالجازولين ذات السقوف العائمة الداخلية

Submitted in partial fulfillment of the requirement of for the B.Sc. Degree in Transportation and Refining Engineering

Prepared by:

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Supervised by:

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(Sep. 2014)

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(Sep. 2014)

الإستهلال

قال تعالى:

(اللَّهُ لَا إِلَٰهَ إِلَّا هُوَ الْحَيُّ الْقَيُّومُ لَا تَأْخُذُهُ سِنَةٌ وَلَا نَوْمٌ لَهُ مَا
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مِنْ عِلْمِهِ إِلَّا بِمَا شَاءَ وَسِعَ كُرْسِيُّهُ السَّمَاوَاتِ وَالْأَرْضَ وَلَا
يَئُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ)

آية الكرسى (البقرة255)

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DEDICATION

To our parents, brothers, sisters

Our Teachers

Our friends

And all we knew and we will

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Abstract

Gasoline is a Volatile Organic Compounds (VOCs) with different boiling point range of (30-200) ºC. The lightcompounds that have boiling point of less than 40 ºC constitute about 10V %.

The objective of this study is to evaluate the amount of evaporation loss of gasoline frominternal floating roof storage tank. The case study is based on U.S Environmental Protection Agency Data (USEPA) the evaporation loss calculation is accomplished by company (A).

By comparing the different rim seal system liquid it was found that liquid mounted seal with rim mounted secondary has minimum evaporation loss (4068.19 Ib/yr) ,which equals toless than (50%) of vapor mounted seal primary only (8679 Ib/yr),so it is most suitable for internal floating roof tanks.

Reduction of evaporation loss of gasoline will give attractive economic returns aswell as reducing air pollution and hazards. This reduction could be achieved byplantation of the depots and increase the shadow area around tanks, and reducethe wind speed which would be considered as metrological conditions control action. in addition to the future tank design consideration and mechanicalupgrades for the existing one.

Key word:

Internal floating roof tanks ,gasoline ,evaporation loss ,rim seal loss ,withdrawal ,deck fitting loss, deck seam loss.

تجريد

الجازولين من المنتجات البتروليه الهيدروكربونية المتطايرة (VOCS)والتي لها درجة غليان تتراوح ما بين(30-200) درجة مئوية، وتمثل المركبات ذات درجة الغليان الاقل من 40 درجة مئوية تمثل 10% من حجم البنزين المنتج

وتهدف هذه الدراسة لتقدير الكمية المفقودة بواسطة التبخر من البنزين داخل الخزانات ذات الاسقف الداخلية العائمة ، وقد اعتمدت هذه الدراسه على المعلومات المأخوذة من الوكالة الامريكية لحماية البيئة((USEPA

بمقارنة الانظمة المختلفة للحشوات المستعملة بين جدار الخزان والسقف العائم وجد ان إضافة حشوة إضافية يؤدي الى تقليل فاقد البخر الى اقل من النصف اي بنسبة أكثر من (% 50)، حيث تبلغ كمية فاقد البخر حوالي (8679 رطل /السنة)عند استخدام نظام الحشوة الأولية بينما يبلغ (4068.19 رطل/السنة) عند إضافة حشوة ثانوية .

تخفيض نسبة البخر من البنزين له الأثر الافتصادي والبيئي الملحوظ ومن اهم الاجراءات المتبعة لتقليل نسبة البخر هي: خفض درجات الحرارة وسرعة الرياح في المنطقة المحيطة بالخزانات عن طريق التشجير وزيادة مساحة الظل حولها وهو مايعرف بالتحكم في العوامل المناخية ، ويمكن التحكم في تقليل البخر من البنزين بأخذ الاعتبارات التصميمية للخزانات المستقبلية وادخال التحسينات الهندسيه على الخزانات الموجودة حاليا.

List of Abbreviation

API	American petroleum Institute
US EPA	Unite State Environmental Protection Agency
VOCs	Volatile Organic Compounds
V	Volume
L_T	Total loss, lb/yr
L_{WD}	Withdrawal loss, lb/yr;
L_F	Deck fitting loss, lb/yr;
L_D	Deck seam loss (internal floating roof tanks only), lb/yr;
L_R	Rim Seal loss, lb/yr
K_{Ra}	Zero wind speed Rim Seal loss factor, lb-mole/ft.yr;
K_{Rb}	Wind speed dependent Rim Seal loss factor, lb-mole/(mph) ft/year;
v	Average ambient wind speed at tank site, mph;
n	Seal-related wind speed exponent, dimensionless;
P^*	Vapor pressure function, dimensionless;
D	Tank diameter, ft
M_V	Average vapor molecular weight, lb/lb-mole.
K_C	Product factor;
K_C	0.4 for crude oils;
K_C	1 for all other organic liquids.

P_{VA}	Vapor pressure at daily average liquid surface temperature, psia
V_V	Vapor space volume, ft3,
M_V	Stock vapor density, lb/ft3
K_E	Vapor space expansion factor, dimensionless
K_S	Vented vapor saturation factor, dimensionless
Q	Annual throughput (tank capacity [bbl] times annual turnover rate), bbl/yr
C_S	Shell clingage factor, bbl/1,000 ft2;
W_L	Average organic liquid density, lb/gal;
N_C	Number of fixed roof support columns, dimensionless
F_C	Effective column diameter, ft (column perimeter [ft]/π)
H_{VO}	Vapor space outage, ft,
H_S	Tank shell height, ft
H_L	Liquid height, ft
H_{RO}	Roof outage, ft.
H_V	height of the vapor space under the floating roof, ft
T_{LA}	Daily average liquid surface temperature, °R.
M_V	Vapor molecular weight, lb/lb-mole
L_{TL}	Total losses during roof landing, lb per landing episode
L_{SL}	Standing idle losses during roof landing, lb per landing episode
L_{FL}	Filling losses during roof landing, lb per landing episode
T_{AX}	Daily maximum ambient temperature, °R
T_{AN}	Daily minimum ambient temperature, °R
F_F	The total deck fitting loss factor, lb-mole/yr
N_{Fi}	Number of fittings of a particular type dimensionless
K_{Fi}	Deck fitting loss factor for a particular type of fitting, lb-mole/yr.ft number of different types of fittings, dimensionless

Chapter 1

Introduction

1.1 Sudanese Petroleum:

Sudanese petroleum is classified as light petroleum with high API, high Reid vapor pressure (RVP) and volatile organic components (VOCs) according to American Petroleum Institute. so their products need more careful in transportation and storage.

There are four refineries in Sudan, Khartoum refinery which is designed to received (100,000bbl/d), Port Sudan refinery is designed to treatment the imported petroleum now it is closed. Alobeid refinery which is smaller than Khartoum refinery with operation capacity (15,000bbl/d) and Abugabrah refinery with operation capacity (2,000bbl/d).

Tables (1.1) showthe petroleum products in Sudan (2008___2012).

Table (1.1) show the hydrocarbons products in $sudan$[9]

1.1Year	Gasoil(ton)	Gasoline(ton)	Jet(ton)	Furnace(ton)	Kerosene(ton)
2008	2346385	588086	247106	505808	6721
2009	2359291	675056	218607	497991	4212
2010	2199928	761507	235344	555290	3012
2011	2163850	791039	289476	531991	3496
2012	2337910	834893	253008	348063	3118

1.2 Sudan Environment:

Sudan environment is high temperature compare with other countries, It characterized with an average of 10 hrs of sun Shine and solar of (3.05-7.62)KW/m^2/daythe temperature about (32-45), so we need to keep the hydrocarbon products safety in transport and storage to control the total evaporation losses and minimize it.

1.3 Storage Tanks:

Storage tanks had been widely used in many industrial established particularly in the processing plant such as oil refinery and petrochemical industry. They are used to store a multitude of different products.

They are many different sizes from small to larger vessel, product stored range from raw material to finished products, from gases to liquids, solid and mixture. There are a wide variety of storage tanks, they can be constructed above ground, in ground and below ground. In shape they can be in vertical cylindrical, horizontal cylindrical, spherical or rectangular form, but vertical cylindrical are the most usual used. In a vertical cylindrical storage tank, it is further broken down into various types, including the open top tank, fixed roof tank, external floating roof and internal floating roof tank. The type of storage tank used for specified product is principally determined by safety and environmental requirement. Operation cost and cost effectiveness are the main factors in selecting the type of storage tank.

Design and safety concern has come to a great concern as reported case of fires andexplosion for the storage tank has been increasing over the years and these accident cause injuries and fatalities. Spills and tank fires not only causing environment pollution, they would also be severe financial consequences and significant impact on the future business due to the industry reputation. Figure (1.1) shows the accident of the tanks that caught on fire and exploded. Lots of these accidents had occurred and they are likely to continue unless the lessons from the past are correctly learn.

Figure (1.1) Fire and explosion incidents in the tanks[13]

1.4Evaporation Losses:

Evaporation loss is a natural process in which part of liquid is turning to vapor and vanishing into the atmosphereCrude oil compound from the several hydrocarbons in which some of them evaporate and could be released into the atmosphere at ambient temperature and pressure. This process causes to pollute the environment and has effects on crude oil quality.

Any reduction in the loss will also have financial benefit. This makes the phenomena, crude oil evaporation loss an important issue, which should be carefully investigated and effects of various parameters be studied.

1.5Aims of project:

This Research Aims to:

- Understand the design effect in evaporation losses control
- Understand the standard for evaporation losses estimation
- How to reduce the evaporation losses from internal floating roof tank
- Environmentaland Economical impact of evaporation losses control

Chapter 2

Literature Review

Literature review is conducted to study the basic design and requirement of the floating roof storage tank in the storage tank design code (API 650 – Welded Steel Tanks for oil storage tank) and method of evaporation losses estimation according to U.S Environmental Protection Agency (USEPE).

2.1Tank Configuration:

The placement of storage tanks is above ground or underground, depending on the requirements. The wall construction of the storage tank usually dictates its suitability for a particular application. Single shell storage tanks are common for various applications. Double shell storage tanks are used in applications low temperature storage or higher pressure considerations are necessary, and the storage tank can be vertical or horizontal.

2.2Materials of storage tanks:

Materials for storage tank construction include galvanized steel, stainless steel, Nickel steel and steel

- Steel is a ferrous-based metal having a variety of physical properties depending on composition. Steel used in storage tank applications is typically rolled steel plate.
- Stainless Steel is a type of metal that resists corrosion.
- Nickel Steel is used for tanks designed to obtain sufficient ductility and structural integrity at extreme subzero temperatures (e g. -196ºC).
- Galvanized Steel is cold rolled steel that has been surface treated with a layer of zinc.
- Industries and applications that use storage tanks include:

  1. Chemical processing
  2. Food and beverage processing
  3. Oil and fuel processing
  4. Paper and pulp processing
  5. Pharmaceutical processing
  6. Plastic processing
  7. Water applications.

2.3 Main parts of tanks:

1. Tank Shell
2. Bottom plate
3. Annular Plate
4. Backing strip
5. Anchor chairs and Anchor bolt arrangements
6. Draw of sump
7. Cleanout catch
8. Nozzles
9. Shell man way
10. Roof man way
11. Fire safety
12. Primary & Secondary Wind girder
13. Curb angle or compressing ring
14. Roof plate
15. Crown plate
16. Vent Nozzles
17. Overflow pipes
18. Roof Structures and support structures
19. Internal pipe supports
20. Internal man way rungs and internal ladder with support clips
21. External cage Ladder and spiral Staircase ladders and platforms with support clips
22. Roof handrails

2.4 Tank Appurtenances:

Tanks may include a variety of appurtenances depending on the storage application, owner requirements, and applicable design codes. In addition to normal product fill and withdrawal connections, access man-ways and various instrument or gauging connections, a tank can include shell-mounted mixers, internal heaters, platforms, ladders, and pressure/vacuum relief vents.

Floating-roof tanks require special attention to details because it very affect safe operation of the floating roof. In external floating-roof tanks, be sure that the rim seals, rolling ladder, and roof drain(s) are designed to minimize any unbalanced loads in the floating roof structure. Each floating roof should include a single ant rotation device designed to limit the rotation of the floating roof while it is free to move up or down within the tank shell.

Some features are required for safe operation of the floating roof while others may be optional based on specific storage requirements. Many of these features affect the low operating levelsofthe floating roof. Optional details are available to address many of these interference issues, enabling a qualified designer to minimize the product heel while maximizing the working capacity of a floating-roof tank.

2.5Hydrocarbons Storage Tanks:

Storage tanks containing organic liquids can be found in many industries, including

- Petroleum producing and refining
- petrochemical and chemical manufacturing
- bulk storage and transfer operations
- Other industries consuming or producing organic liquids

Organic liquid in the petroleum in industry usually called petroleum liquids, generally are mixtures of hydrocarbons having dissimilar true vapor pressures (for example,gasoline and crude oil) Organic liquids in the chemical industry, usually called volatile organic liquids, are composed of pure chemicals or mixtures of chemicals with similar true vapor pressures (for example, benzene or a mixture of isopropyl and butyl alcohols)

Six basic tank designs are used for organic liquid storage vessels: fixed roof (vertical and horizontal), external floating roof, domed external (or covered) floating roof, internal floating roof, variable vapor space, and pressure (low and high).

2.5.1 Fixed Roof Tank:

Vertical fixed roof tank is shown in Figure 2.1 This type of tanks consists of a cylindrical steel shell with affixed roof, which may vary in design from cone or dome shaped to flat. losses from fixed roof tanks are caused by changes in temperature, pressure, and liquid level.

Fixed roof tanks are free vented or equipped with a pressure/vacuum vent. The latter allows the tanks to operate at a slight internal pressure or vacuum to prevent the release of vapors during very small changes in temperature, pressure, or liquid level.

Of current tank designs, the fixed roof tank is the least expensive to construct and is generally considered the minimum acceptable equipment for storing organic liquids.

Horizontal fixed roof tanks are constructed for both aboveground and underground service and are usually constructed of steel, steel with a fiberglass overlay, or fiberglass-reinforced polyester. Horizontal tanks are generally small storage tanks with capacities of less than 40,000 gallons.

Horizontal tanks are constructed such that the length of the tank is not greater than six times the diameter to ensure structural integrity.

Horizontal tanks are usually equipped with pressure-vacuum vents, gauge hatches and sample wells, and manholes to provide access to these tanks.

The potential emission sources for above-ground horizontal tanks are the same as those for vertical fixed roof tanks. Emissions from underground Storage tanks are associated mainly with changes in the liquid level in the tank.

Losses due to change in temperature or barometric pressure are minimal for underground tanks because the surrounding earth limits the diurnal temperature change and change in barometric pressure result in only small losses.

Fixed Roof Tanks can be divided into cone roof and dome roof types. They can be self-supported or rafter supported depending on the size.

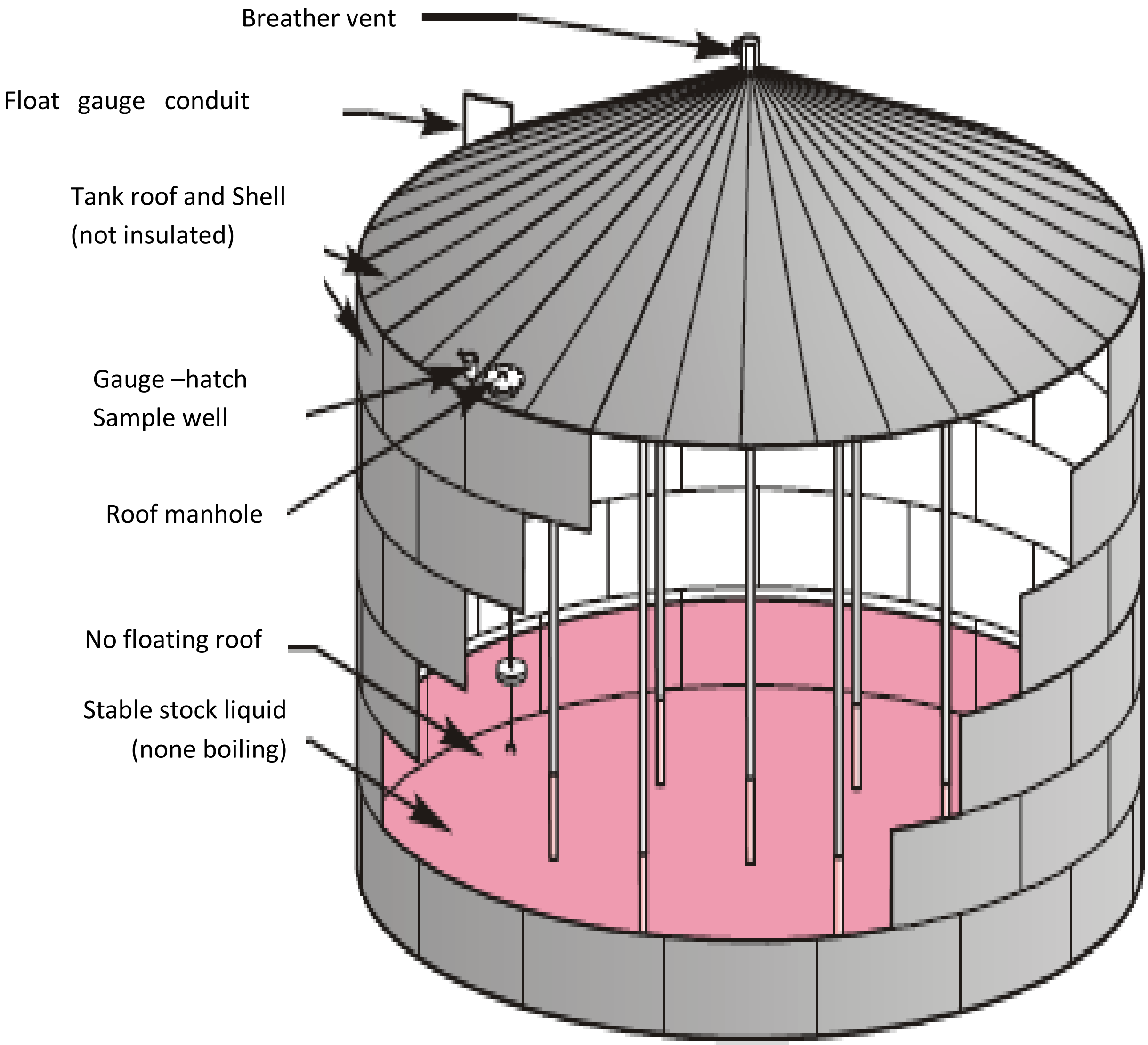

Figure (2.1) Typical fixed roof tank[3]

Fixed roof are designed as:

- Atmospheric tank (free vent)
- Low pressure tanks (approx. 20 mbar of internal pressure)
- High pressure tanks (approx. 56 mbar of internal pressure

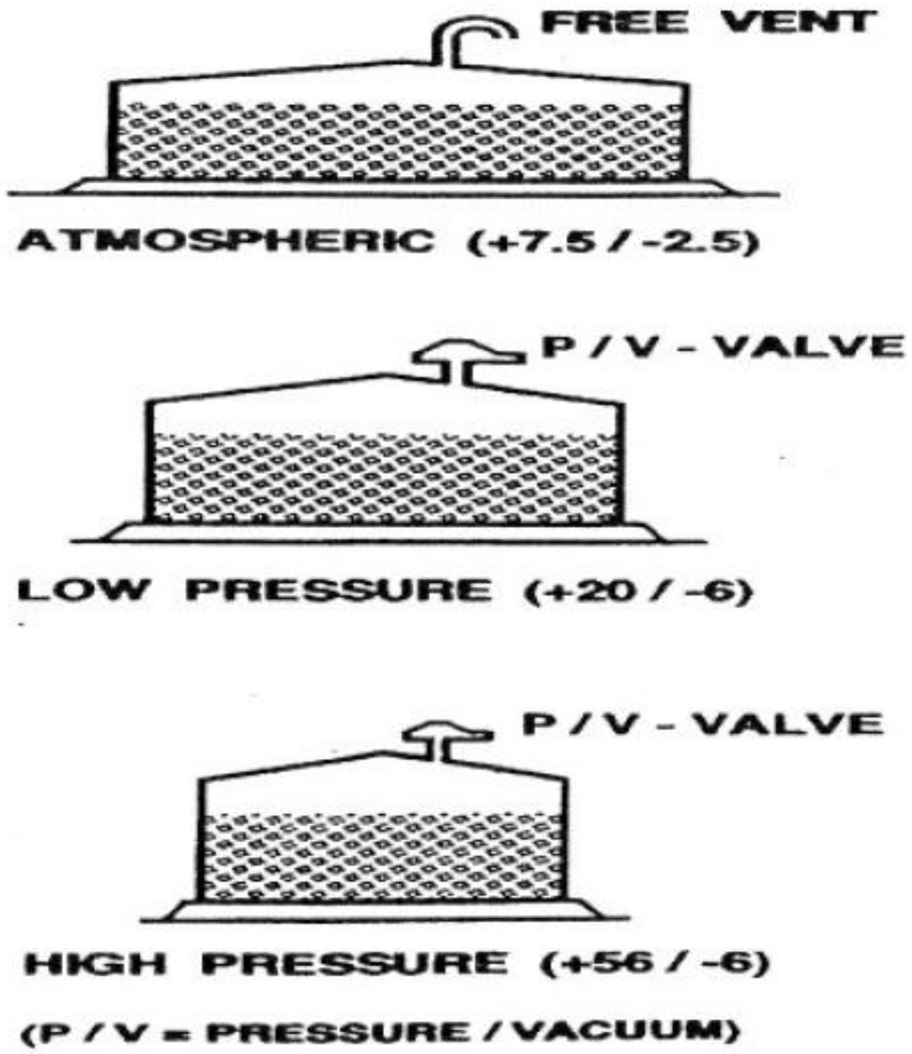

Figure (2:2) shows the three types of Fired Roof Tank[3]

2.5.2 External Floating Roof Tank:

A typical external floating roof tank (EFRT) consists of an open topped cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. The floating roof consists of a deck, fittings, and Rim Seal system.

Floating decks that are currently in use are constructed of welded steel plate and are of two general types: pontoon or double-deck.

Pontoon type and double-deck-type external floating roof tanks are shown in Figures(2.3)and (3.4).

With all types of external floating roof tanks, the roof rises and falls with the liquid level in the tank. External floating decks are equipped with a Rim Seal system, which is attached to the deck perimeter and contacts the tank wall.

The purpose of the floating roof and Rim Seal system is to reduce evaporative loss of the stored liquid.

Some annular space remains between the rim seal system and the tank wall. The rim seal system slides against the tank wall as the roof is raised and lowered. The floating deck is also equipped with fittings that penetrate the deck and serve operational functions.

The external floating roof design is such that evaporative losses from the stored liquid are limited to losses from the Rim Seal system and deck fittings (standing storage loss) and any exposed liquid on the tank walls (withdrawal loss).

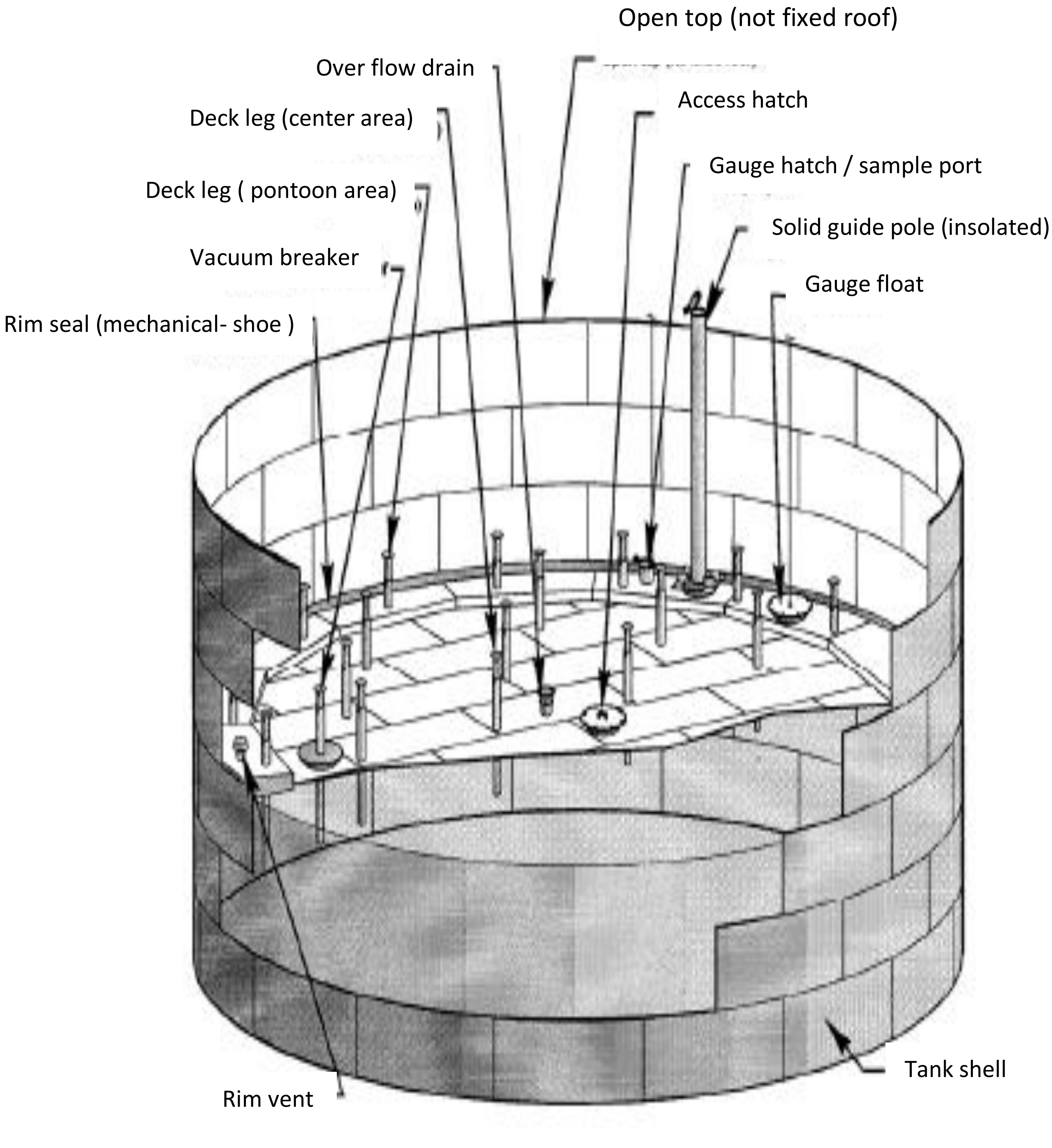

Figure (2:3) External floating roof tank (pontoon type)[3]

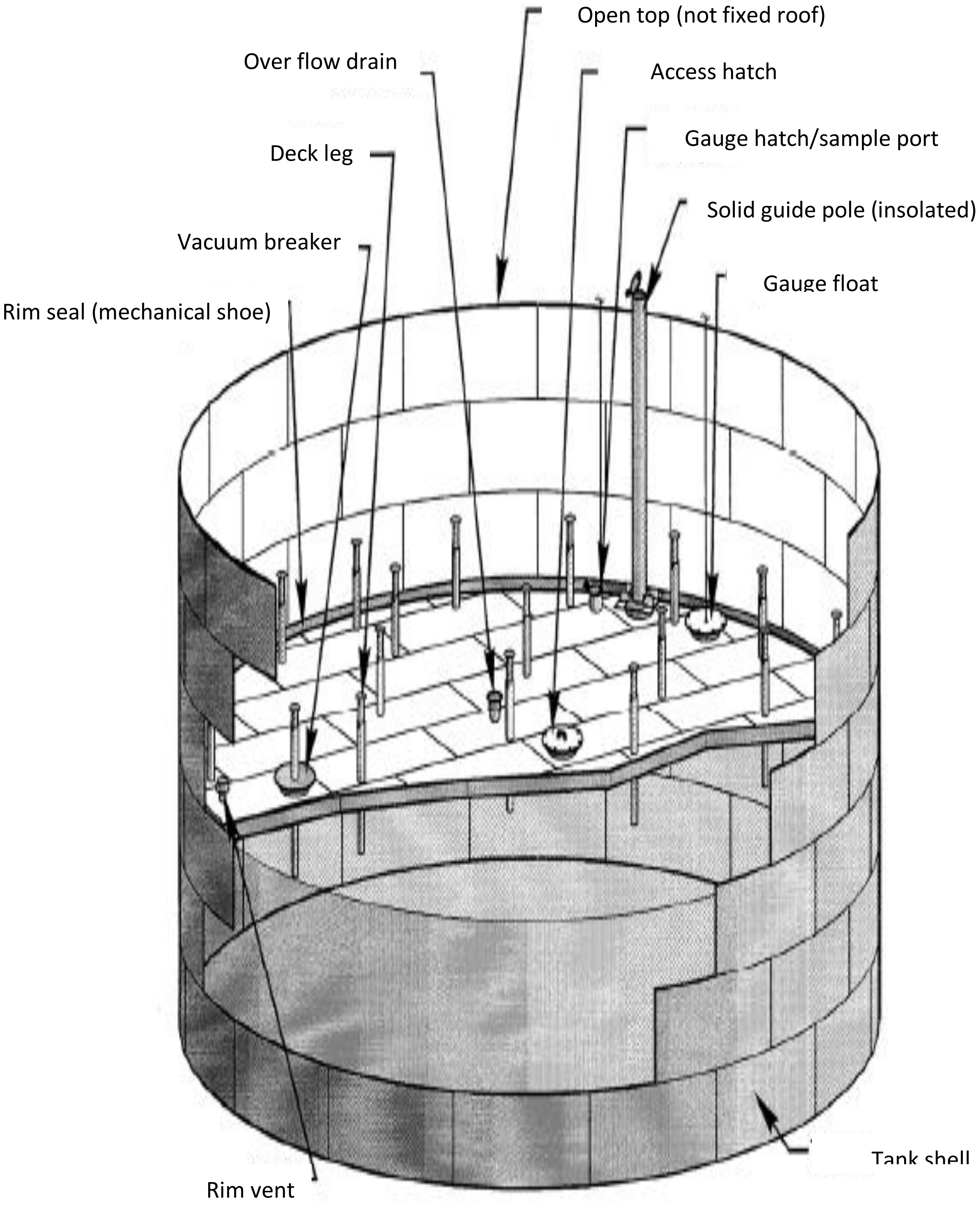

Figure (2.4) External floating roof tank (double deck)[3]

2.5.3 Internal Floating Roof Tank:

An internal floating roof tank (IFRT) has both a fixed roof and a floating roof inside. There are two basic types of internal floating roof tanks:

I. Tanks in which the fixed roof is supported by vertical columns within the tank

II. Tanks with a self supporting fixed roof and no internal support columns.

Fixed roof tanks that have been retrofitted to use a floating roof are typically of the first type.

External floating roof tanks that have been converted to internal floating roof tanks typically have a self supporting roof.

Newly constructed internal floating roof tanks may be of either type. The deck in internal floating roof tanks rises and falls with the liquid level and either floats directly on the liquid surface (contact deck) or rests on pontoons several inches above the liquid surface (noncontact deck).

The majority of aluminum internal floating roofs currently in service have noncontact decks. A typical internal floating roof tank is shown in Figure(2.4)

Installing a floating roof minimizes evaporative losses of the stored liquid.

Both contact and noncontact decks incorporate Rim Seals and deck fittings
for the same purposes previously described for external floating roof tanks.

Evaporative losses from floating roofs may come from deck fittings, non welded deck seams, and the annular space between the deck and tank wall.

In addition, these tanks are freely vented by circulation vents at the top of thefixed roof

Vents minimize the possibility of organic vapor accumulation in the tank vapor space in concentrations approaching the flammable range. An internal floating roof tank not freely vented is considered a pressure tank.

Advantages of internal floating roof tank:

The internal floating roof tank (IFRT) was developed in the mid 1950s to provide protection of the floating roof from the elements, including lightning strikes to the floating roof. The tank vapor space located above the floating roof and below the fixed-roof includes circulation vents to allow natural ventilation of the vapor space reducing the accumulation of product vapors and possible formation of a combustible mixture.

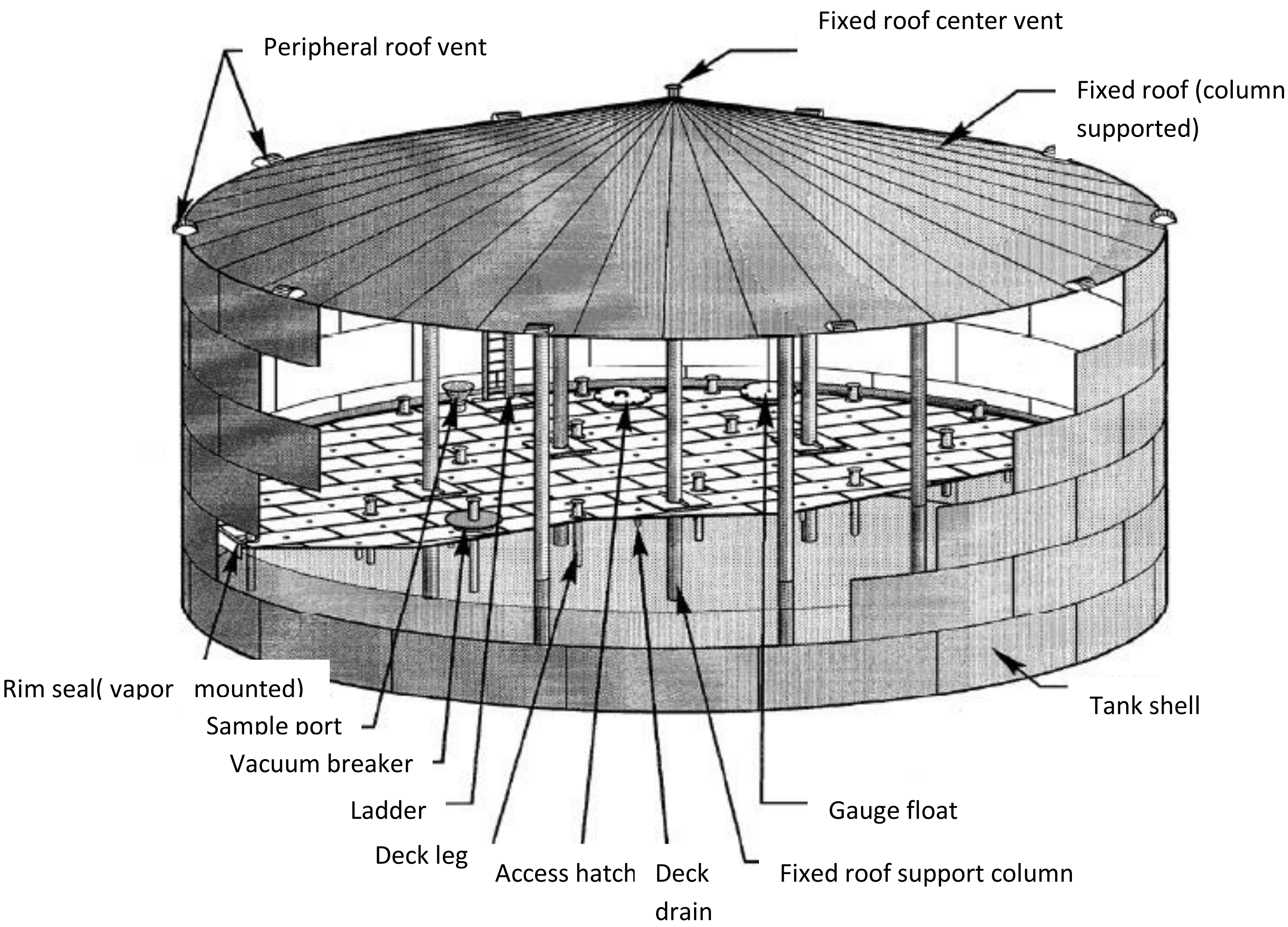

Figure (2.5)internal floating roof tank[3]

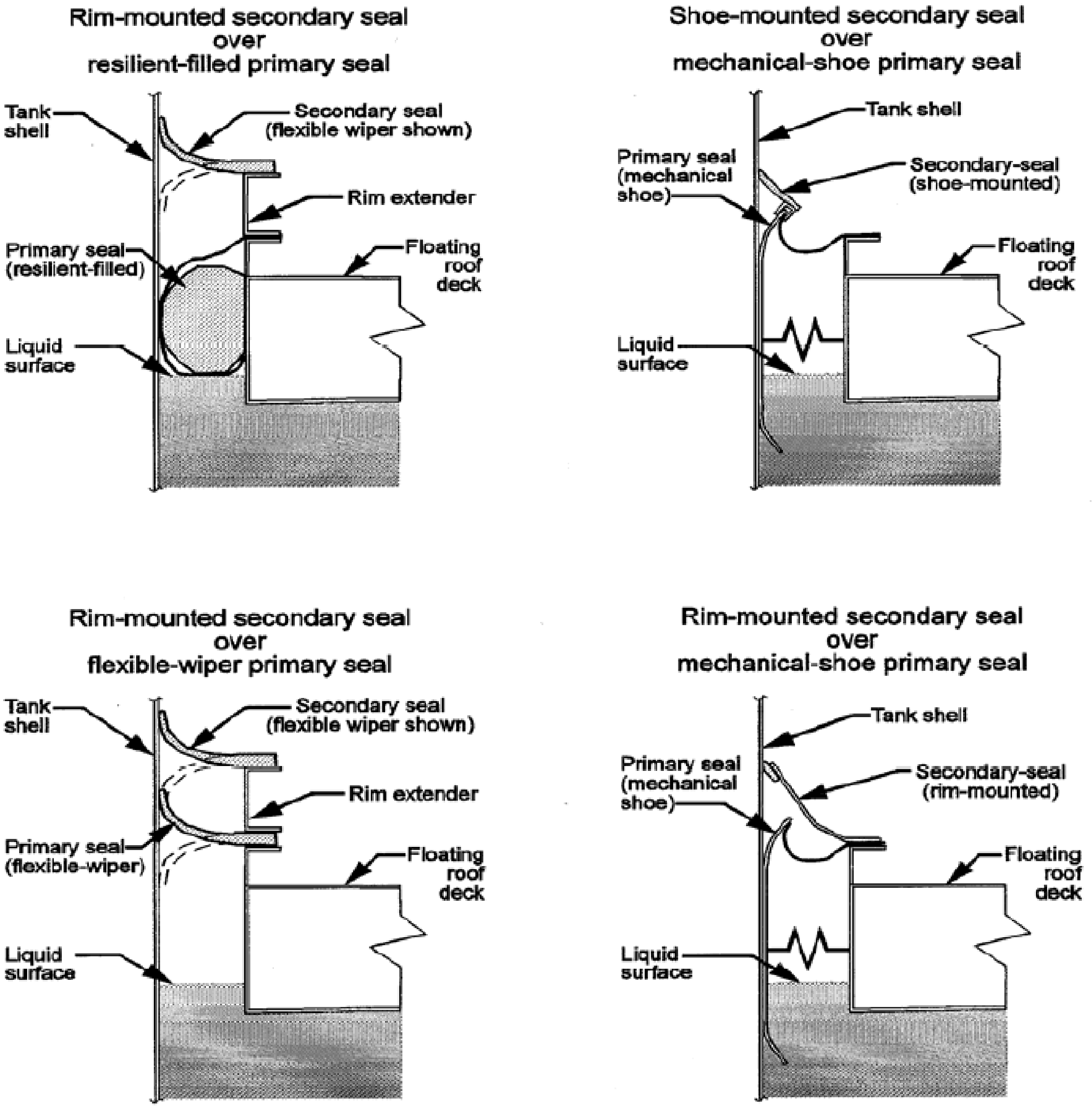

Figure (2.6) Secondary rim seals[3]

2.6 Applications ofinternal floating roof tanks:

When product vapor pressure is greater than 0.5 psia but less than 11.1 pisa, the U.S. Environmental Protection Agency permits the use of a floating-roof as the primary means of vapor control from the storage tank.

Floating roof tanks are not intended for all products. In general, they are not suitable for applications in which the products have not been stabilized (vapors removed). The goal with all floating-roof tanks is to provide safe, efficient storage of volatile products with minimum vapor loss to the environment.

2.7 Design of tanks:

Design requirements for external floating roofs are provided in Appendix C of the API Standard 650. The external floating roof floats on the surface of the liquid product and rises or falls as product is added or withdrawn from the tank.

2.8 Design Codes and Standards:

The design and construction of the storage tanks are regulated by various codes and standards. List a few here:

- American Standards API 650 (Welded Steel Tanks for Oil Storage)
- British Standards BS 2654 (Manufacture of Vertical Storage Tanks with Butt welded Shells for the Petroleum Industry)
- The European Standards
    - German Code Din 4119 – Part 1 and 2 (Above Ground Cylindrical Flat Bottomed Storage Tanks of Metallic Materials)
    - French Code, Codes – (Code Français de construction des réservoirs Cylindraiqu’EvertCau en acier U.C.S.I.P. et S.N.C.T.)
- The EEMUA Standards (The Engineering Equipments and Materials Users Association)
- Company standards such as shell (DEP) and Petronas (PTS)

2.8.1 API Standard:

The API 650 standard is designed to provide the petroleum industry with tanks of adequate safety and reasonable economy for use in the storage of petroleum, petroleum products, and other liquid products commonly handled and stored by the various branches of the industry. This standard does not present or establish a fixed series of allowable tank sizes; instead, it is intended to permit the purchaser to select whatever size tank may best meet his needs.

This standard is intended to help purchasers and manufacturers in ordering, fabricating, and erecting tanks; it is not intended to prohibit purchasers and manufacturers from purchasing or fabricating tanks that meet specifications other than those contained in this standard.

This standard has requirements given in two alternate systems of units. The requirements are similar but not identical. These minor differences are due to issues such as numerical rounding and material supply. When applying the requirements of this standard to a given tank, the manufacturer shall either comply with all of the requirements given in SI units or shall comply with all of the requirements given in US Customary units. The selection of which set of requirements (SI or US Customary) shall apply to a given tank shall be by mutual agreement between the manufacturer and purchaser

2.9Evaporations loss from internal floating roof tank:

Sources of evaporative loss during standing storage include the rim seal area, the apertures for fittings which penetrate the floating deck and the bolted seam in the floating deck.

I. Rim seal area loss mechanisms

In the case of the rim space between the floating deck and the tank wall a vapor space exists beneath the seal .When air within the space between the bottom of the seal and the liquid passes through the gap between the tank shell and the seal there is a reduction of hydrocarbon concentration so more liquid vaporizes in order to re establish the equilibrium concentration.

Another potential mechanism is vertical mixing of vapor in the gap between the tank shell and the seal resulting from diffusion and air turbulence, Thetemperature and pressure change causes the rim vapor space breathing as the rim vapor space temperature increases, an expansion of gas occurs in the rim vapor space which expels the air vapor mixture to the atmosphere .As the rim vapor space temperature decreases, the vapor in the rim space contracts

Fresh air is drawn into the rim vapor space resulting in reduction of concentration of hydrocarbon vapor in this space and so more liquid evaporates .This results in an expulsion of vapor from the vapor space. The change in vapor temperature can cause varying air solubility. When the stock liquid temperature increases, gas solubility decreases thus air evolves from the stock liquid. This gas which leaves the liquid may carry some hydrocarbon vapor with it.

The magnitude of emission depends upon the type of seal and the size of the gap between the tank shell and the seal.

II. Withdrawal loss mechanisms

Withdrawal loss occurs during stock liquid withdrawal. When the floating deck descends with the liquid level, some liquid remains in a coating on the tank wall and the support column. When this liquid is exposed to the air, some evaporation occurs to the atmosphere before the exposed area is again covered.

III. Displacement loss

When the storage tank is used and some fuel is drawn, a vapor space is created above the liquid surface. Some of the liquid which remains in the tank vaporizes into the vapor space until it reaches saturated conditions within the air which is drawn into the tank during fuel draw out.

When the tank is filled with liquid, the vapor is compressed in the tank. Air vapor mixture is forced out through a vapor vent which represents a displacement loss. This loss is similar to the working loss in a fixed roof tank.

The difference is, vapor in the fixed roof tank will be released only when pressure in the tank exceeds the PV vent pressure setting.

Displacement losses occur during the loading of fuel from a storage tank to a tank truck and from a tank truck to an underground storage tank and also during vehicle refueling at the service station.

2.10 Safety Systems:

These are the various items of equipment provided to address problem a rising from gas leakage, cold liquid leakage, pool fires and adjacent tank or plant fires. Fire protection systems are either classified as being active (water spray systems, deluge or sprinkler systems) or passive(fire proofing coatings or shielding systems).

2.10.1 Fire water systems:

The application of water to items of plant and equipment has more to do with keeping them cool, when they are the subject of heat radiation from fires in adjacent areas, than its contribution to the efforts to extinguish fires. Indeed, in certain circumstances, the application of water to liquid pool fires may Agra lf insufficient fresh water is available on the site, it will be necessary to feed the fire water system with sea water in the event of an emergency.

In the interests of corrosion protection following exposure of all or part of the system to salt water, it will be necessary to arrange suitable facilities for flushing the appropriate parts of system with fresh water. It is usual to require the system to be tested on at regular intervals.

This is normally carried out with fresh water and limitation in the available quantities of fresh water may necessitate the subdivision of the system such that it can be tested in smaller sections.

The system illustrated. which is for roof deluging only is for this reason divided into six section The equipment used to set the deluge system into action is often large, sophisticated and expensive Roof mounted deluge valves will themselves require a high level of fire protection In addition to the deluge system, it is common to add a number of fire monitors.

A monitor is a means of providing a spray stream of waterfrom a fixed station to a location where it is required for firefighting or equipment cooling.

The control of the water spray and its direction can be achieved by either manual or remote operation.

2.10.2 Foam systems:

For areas where liquid may accumulate such as tank bunds or spillage impounding basins, it is usual to install a system of high expansion foam generators These will allow remotely controlled blanketing of the spilled liquid which will either douse the fire or reduce the flame size and consequently the radiation rate.

Suitable systems, designed and tailored for the specific circumstances, are supplied by fire protection companies who specialize in this type of work.

System would consist of the following element:

. High expansion foam generator

. Stool valves

. Foam concentrate storage tanks

. Foam inductors

It is usual to test the system at least once per year

2.10.3 Dry powder systems:

Fires in pressure relief valve tailpipes are not unknown For this reason it is common practice to fit a dry powder extinguishing system. This will inject into the relief valve tailpipes a mixture carbon dioxide and fire extinguishing powder in the event of tailpipe fire.

The system is fitted localto the reliefvalves on the tank roof and should be capable of local or remote operation is usualtoallowsufficient storage of powderandpropellant gas to allow for two attempts to extinguish the fire.Thesesystems are the product of specialist companies and are often supplied skid mounted.

2.10.4 Local protection of vulnerable equipment:

It is important that certain equipment associated with low temperature storage tanks continue to perform their intended functions when the tank is exposed to heat radiation, perhaps arising from an adjacent tankfire. items which fall into this category are relief valves, deluge valves and certain parts of the structural steel supporting critical equipment.

These are roof mounted and may require specific fire protection. This is usually passive fire protection and can take the form of proprietary in tumescent paints, compendious coatings on purpose designed shielding.

The principal value of this fireproofing is realized during the early stages of a fire when efforts are mainly directed at setting in motion the various fire suppression equipment and preventing exacerbation by way of the addition of further fuel to them event.

lf the fire is intense and prolonged' then passive fireproofing may prove ineffectual in preventing damage should be such that a safety shut down of the pumping equipment(often the delivering ship's pumps) is triggered bythe various high level alarms.

If the tank level measuring equipment is to be used to measure the exact capacity ofthe tank, or the amount of liquid product introduced to or abstracted from the tank for commercial or customs purposes, it is important that the equipment is as accurate as Possible and that the tank has been calibrated.

Calibration is the precise measuring of the finished or as built primary liquid containing element of the tank. When the measurements have been made, and appropriate corrections have been made for thermal contraction and mechanical expansion. a set of calibration tables are produced which relate the measured liquid level to the liquid capacity.

This activity is the preserve of specialist companies who carryout this service. it used to be the case that the various measurements were made by mechanical strapping of the structure, but nowadays there are clever electronic surveying instruments which can gather the necessary information from a single site within the tank.

Chapter 3

Material and Method

This chapter presents the evaporation estimation procedures for internal floating roof tank.

This procedures are valid for pure volatile organic liquids, the factors presented in this case study are currently available and have been reviewed and approved by U.S Environmental Protection Agency, because these factors are not available in Sudan which are varies according to daily average temperature .We use this data to estimate evaporation loss.

3.1Case study:

Gasoline in an Internal Floating Roof Tank

Here we are going to determine emissions of product from 1 million gallon, internal floating roof tank containing gasoline: (RVP 13), tank is painted white, at (X) location

-The annualnumber of turnover is 50.

-Tank diameter is 70 ft and 35 ft high, equipped with a liquid-mounted primary seal plus a secondary seal.

-The tank has column-supported fixed roof.

-Tank's deck is welded and equipped with the following:(two access hatches with unbolted un gasket cover, an automatic gauge float well with an unbolted, un gasket cover, a pipe column with a flexible fabric sleeve seal, a sliding cover, gasket ladder well, adjustable deck legs, a slotted sample pipe well with a gasket sliding cover, and a weighted, gasket vacuum breaker).

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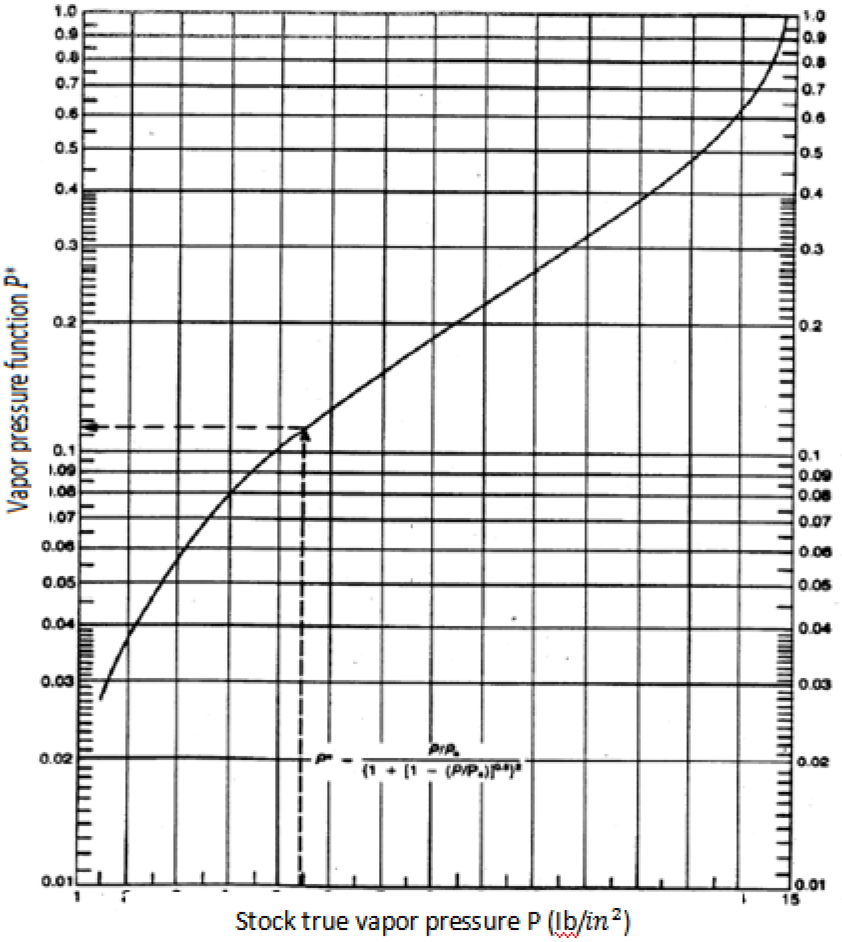
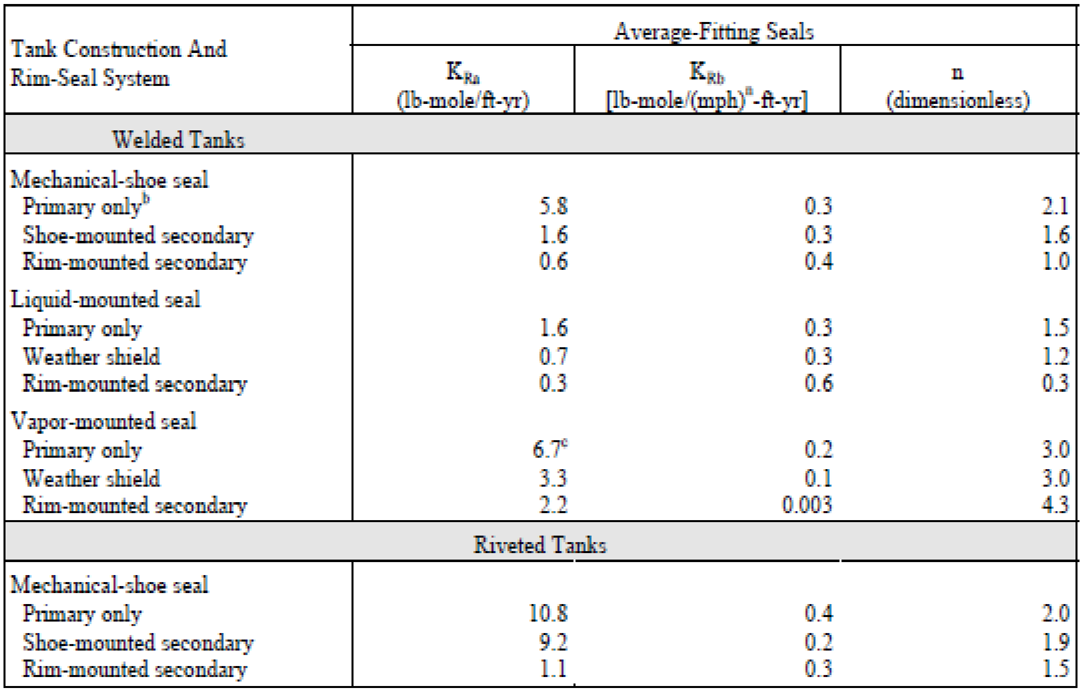


Figure (3.1) to obtain vapor pressure function $P^{*[3]}$

Table (3.1) rim seal loss factors $K_{Ra}, K_{Rb}, andn$ for floating roof tank$s$[3]

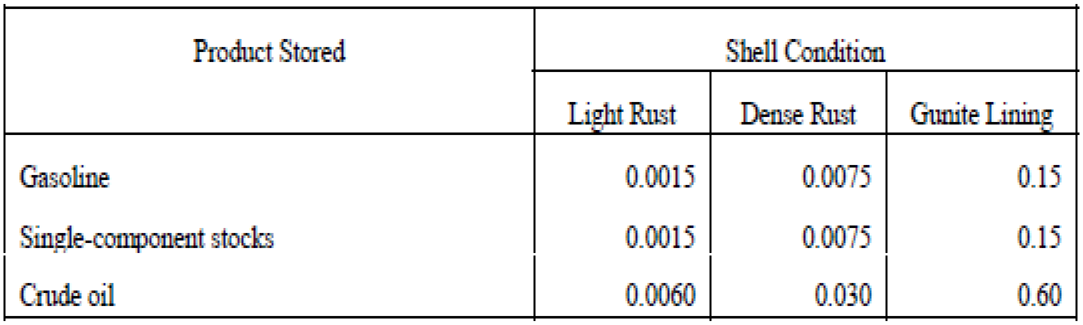


Tank Construction And Rim-Seal System	Average-Fitting Seals		
	K_{Ra} (lb-mole/ft-yr)	K_{Rb} [lb-mole/(mph)^n-ft-yr]	n (dimensionless)
Welded Tanks			
Mechanical-shoe seal			
Primary only[b]	5.8	0.3	2.1
Shoe-mounted secondary	1.6	0.3	1.6
Rim-mounted secondary	0.6	0.4	1.0
Liquid-mounted seal			
Primary only	1.6	0.3	1.5
Weather shield	0.7	0.3	1.2
Rim-mounted secondary	0.3	0.6	0.3
Vapor-mounted seal			
Primary only	6.7[c]	0.2	3.0
Weather shield	3.3	0.1	3.0
Rim-mounted secondary	2.2	0.003	4.3
Riveted Tanks			
Mechanical-shoe seal			
Primary only	10.8	0.4	2.0
Shoe-mounted secondary	9.2	0.2	1.9
Rim-mounted secondary	1.1	0.3	1.5

Note:

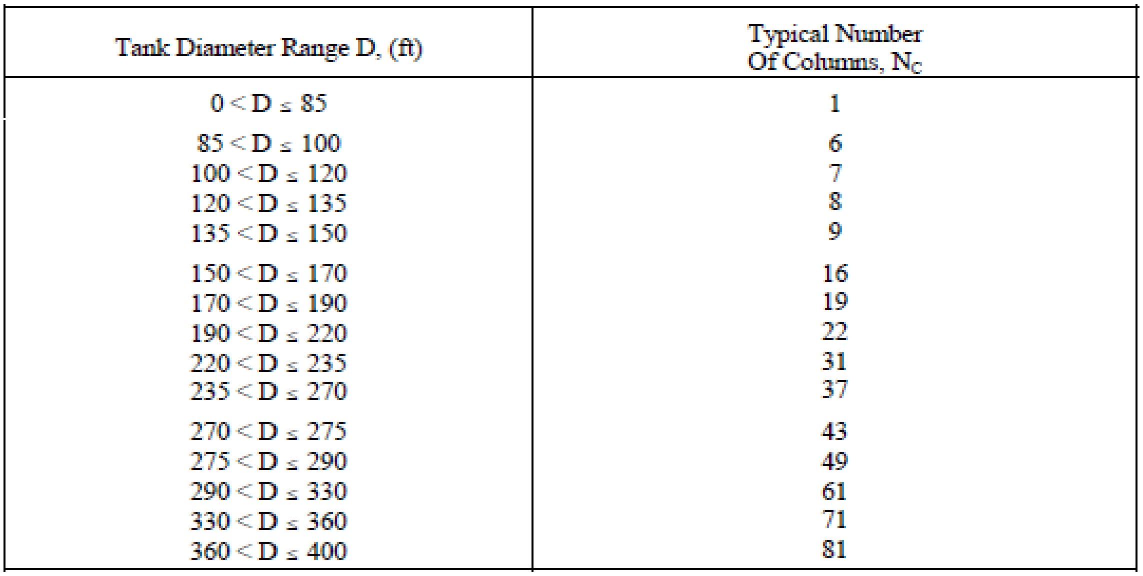
The rim-seal loss factors K_{Ra}, K_{Rb}, and n may only be used for wind speeds below 15 miles per hour.

Table(3.2) average clingage factors C_s (bbl/$10^3 ft^2$)[3]



Product Stored	Shell Condition		
	Light Rust	Dense Rust	Gunite Lining
Gasoline	0.0015	0.0075	0.15
Single-component stocks	0.0015	0.0075	0.15
Crude oil	0.0060	0.030	0.60

Table (3.3) typical number of columns as a function of tank diameter for internal floating roof tanks with column supported fixed roofs[3]



Tank Diameter Range D, (ft)	Typical Number Of Columns, N_C
$0 < D \leq 85$	1
$85 < D \leq 100$	6
$100 < D \leq 120$	7
$120 < D \leq 135$	8
$135 < D \leq 150$	9
$150 < D \leq 170$	16
$170 < D \leq 190$	19
$190 < D \leq 220$	22
$220 < D \leq 235$	31
$235 < D \leq 270$	37
$270 < D \leq 275$	43
$275 < D \leq 290$	49
$290 < D \leq 330$	61
$330 < D \leq 360$	71
$360 < D \leq 400$	81

3.2Types of losses from floating roof tanks:

Total floating roof tank emissions are the sum of rim seal, withdrawal, deck fitting, and deck Seam losses. The equations presented in this subsection apply only to floating roof tanks. The equationsare not intended to be used in the following applications:

- To estimate losses from unstable or boiling stocks or from mixtures of hydrocarbons or petrochemicals for which the vapor pressure is not known or cannot readily be predicted;
- To estimate losses from closed internal or closed domed external floating roof tanks (tanks vented only through a pressure/vacuum vent).
- To estimate losses from tanks in which the materials used in the rim seal and/or deck fittings are either deteriorated or significantly permeated by the stored liquid.

This section contains equations for estimating emissions from floating roof tanks in two Situations:

During normal operation

During roof landing

3.2.1Losses during Normal Operation:

Total losses from floating roof tanks may be written as:

$$L_T = L_R + L_{WD} + L_F + L_D \quad (3.1)$$

Where:

L_T = total loss, lb/yr

L_R = rim seal loss, lb/yr

L_{WD} = withdrawal loss, lb/yr

L_F = deck fitting loss, lb/yr

L_D = deck seam loss (internal floating roof tanks only)

i. Rim Seal Loss:

Rim seal loss from floating roof tanks can be estimated using the following equation:

$$L_R = (K_{Ra} + K_{Rb} V^n) \mathrm{D} P^* M_V K_C \quad (3.2)$$

Where:

L_R = rim seal loss, lb/yr

K_{Ra}= zero wind speed rim seal loss factor, lb-mole/ft .yr, Table(3.1)

K_{Rb}= wind speed dependent rim seal loss factor, lb-mole/(mph)^{n}ft .yr; Table(3.1)

v = average ambient wind speed at tank site, mph see Note 1

n = seal-related wind speed exponent, dimensionless Table(3.1)

P^* = vapor pressure function, dimensionless sees Note 2

$$P^{*} = \frac{\frac{P_{VA}}{P_{A}}}{\left[1+\left(1-\frac{P_{AV}}{P_{A}}\right)^{0.5}\right]^{2}} \qquad (3.3)$$

Where:

P_{VA} = vapor pressure at daily average liquid surface temperature, psia;

See Note 3 below

P_{A} = atmospheric pressure, psia

D = tank diameter, ft

M_{V} = average vapor molecular weight, lb/lb-mole;

K_{C} = product factor;

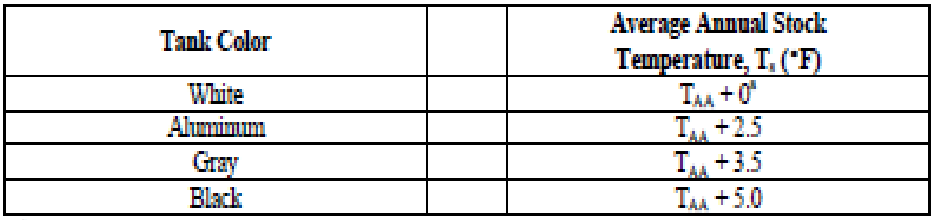
K_{C} = 0.4 for crude oils;

K_{C} = 1 for all other organic liquids.

Notes:

1. If the ambient wind speed at the tank site is not available, use wind speed data from the nearestlocal weather station or values from AP - (A) If the tank is an internal or domed external floating rooftank, the value of v is zero.
2. P_{*} can be calculated or read directly from Figure (3.1)
3. The API recommends using the stock liquid temperature to calculate P_{VA} for use inEquation (3.3) in lieu of the liquid surface temperature. If the stock liquid temperature is unknown, APIrecommends the following equations to estimate the stock temperature

Table (3.4) equations to estimate stock temperature[3]



Tank Color		Average Annual Stock Temperature, T_s (°F)
White		$T_{AA} + 0^{a}$
Aluminum		$T_{AA} + 2.5$
Gray		$T_{AA} + 3.5$
Black		$T_{AA} + 5.0$

T_{AA} is the average annual ambient temperature in degrees Fahrenheit

ii. Withdrawal loss:

$$L_{WD} = \frac{(.943)QC_S W_L}{D}\left[1 + \frac{N_C F_C}{D}\right] \qquad (3.4)$$

Where:

L_{WD} = withdrawal loss, lb/yr

Q = annual throughput (tank capacity [bbl] times annual turnover rate), bbl/yr

C_S = shell clingage factor, bbl/1,000 ft2; Table(3.2)

W_L = average organic liquid density, lb/gal; Note 1

D = tank diameter, ft

0.943 = constant, 1,000 ft^3. gal/bbl^2

N_C = number of fixed roof support columns, dimensionless; Note 2

F_C = effective column diameter, ft (column perimeter [ft]/π); Note 3

Notes:

1. A listing of the average organic liquid density for select petrochemicals is provided inAP(B)and AP(C). If W_L is not known for gasoline, an average value of 6.1 lb/gal can be assumed.

2. for a self-supporting fixed roof or an external floating roof tank:

N_C = 0.

For a column-supported fixed roof:

N_C = use tank-specific information or from Table (3.3)

3. Use tank-specific effective column diameter or

F_C = 1.1 for 9-inch by 7-inch built-up columns, 0.7 for 8-inch-diameter pipecolumns, and 1.0 if column construction details are not known

iii. Deck Fitting Loss:

Deck fitting losses from floating roof tanks can be estimated by the followingequation:

$$L_F = F_F K_C M_V P^* \qquad (3.5)$$

Where:

L_F = the deck fitting loss, lb/yr

F_F = total deck fitting loss factor, lb-mole/yr

$$F_F = [(N_{F1} K_{F1}) + (N_{F2} K_{F2}) + \ldots + (N_{F_{nf}} K_{F_{nf}})] \qquad (3.6)$$

Where:

N_{F_i} = number of deck fittings of a particular type (i = 0,1,2,...,nf), dimensionless

K_{F_i} = deck fitting loss factor for a particular type fitting

(i = 0,1,2,...,nf), lb-mole/yr;

nf= total number of different types of fittings, dimensionless

The value of F_F may be calculated by using actual tank-specific data for the number of eachfitting type (N_F and then multiplying by the fitting loss factor for each fitting (K_F).

The deck fitting loss factor, K_{F_i} for a particular type of fitting, can be estimated by the followingequation:

$$K_{F_i} = K_{F_{ai}} + K_{F_{bi}} (K_V V)^{mi} \qquad (3.7)$$

Where:

K_{F_i} = loss factor for a particular type of deck fitting, lb-mole/yr

$K_{F_{ai}}$ = zero wind speed loss factor for a particular type of fitting, lb-mole/yr

$K_{F_{bi}}$ = wind speed dependent loss factor for a particular type of fitting, lb-mole/$(mph)^m$.yr

mi= loss factor for a particular type of deck fitting, dimensionless

i = 1, 2, ..., n, dimensionless

Kv= fitting wind speed correction factor, dimensionless; see below

v = average ambient wind speed, mph

For external floating roof tanks, the fitting wind speed correction factor, Kv, is equal to 0.7. For internal and domed external floating roof tanks, the value of V in Equation(3.7) is zero and the equation becomes:

$$K_{F_i} = K_{F_{ai}} \qquad (3.8)$$

Loss factors K_{F_a} , K_{F_b} and m are provided in API

iv. Deck Seam Loss :

Neither welded deck internal floating roof tanks nor external floating roof tanks have deck seam losses. Internal floating roof tanks with bolted decks may have deck seam losses. Deck seam loss can be estimated by the following equation:

$$L_D = K_D S_D D_2 P_* M_V K_C \qquad (3.9)$$

Where:

K_D = deck seam loss per unit seam length factor, lb-mole/ft-yr

= 0.0 for welded deck

= 0.14 for bolted deck;

S_D = deck seam length factor, ft/ft2

$$= \frac{L_{seam}}{A_{deck}}$$

Where:

L_{seam} = total length of deck seams, ft

A_{deck} = area of the deck, $ft^2 = \frac{\pi \cdot D^2}{4}$

If the total length of the deck seam is not known, AP-(D) can be used to determineS_D. For adeck constructed from continuous metal sheets with a 7-ft spacing between the seams, a value of 0.14ft/ft^2 can be used. A value of 0.33 ft/ft^2 can be used for S_D when a deck is constructed from Rectangularpanels 5 ft by 7.5 ft. Where tank-specific data concerning width of deck sheets or size of deck panels areunavailable, a default value for S_D can be assigned. A value of 0.20 ft/ft^2 can be assumed to represent themost common bolted decks currently in use.

3.2.2 Losses during Roof Landings

When using floating roof tanks, the roof floats on the surface of the liquid inside the tank andreduces evaporative losses during normal operation. However, when the tank is emptied to the point thatthe roof lands on deck legs, there is a period where the roof is not floating and other mechanisms must beused to estimate emissions. These emissions continue until the tank is refilled to a sufficient level to againfloat the roof. Therefore, these emission estimate calculations are applicable each time there is a landingof the floating roof.This model does not address standing idle losses for partial days. It would be conservative (i.e. potentially overestimate emissions) to apply the model to episodes during which the floating roof remainslanded for less than a day.The total loss from floating roof tanks during a roof landing is the sum of the standing idle lossesand the filling losses. This relationship may be written in the form of an equation:

$$L_{TL} = L_{SL} + L_{FL} \qquad (3.9)$$

Where:

L_{TL} = total losses during roof landing, lb per landing episode

L_{LS} = standing idle losses during roof landing, lb per landing episode

L_{FL} = filling losses during roof landing, lb per landing episode

The group of applicable equations to estimate the landing losses differs according to the type offloating roof tank that is being used. The equations needed to estimate landing losses from internal floating roof tanks are contained in AP - (E).

Standing Idle Losses:

After the floating roof is landed and the liquid level in the tank continues to drop, a vacuum iscreated which could cause the floating roof to collapse. To prevent damage and to equalize the pressure, abreather vent is actuated. Then, a vapor space is formed between the floating roof and the liquid. Thebreather vent remains open until the roof is again floated, so whenever the roof is landed, vapor can belost through this vent. These losses are called “standing idle losses.”

The three different mechanisms that contribute to standing idle losses are (1) breathing lossesfrom vapor space, (2) wind losses, and (3) clingage losses. The specific loss mechanism is dependent onthe type of floating roof tank.

For internal floating roof tanks with nominally flat bottoms (including those built with a slightupward cone), the breathing losses originate from a discernible level of liquid that remains in the tank atall times due to the flatness of the tank bottom and the position of the withdrawal line (a liquid “heel”).The liquid evaporates into the vapor space and daily changes in ambient temperature cause the tank tobreathe in a manner similar to a fixed roof tank

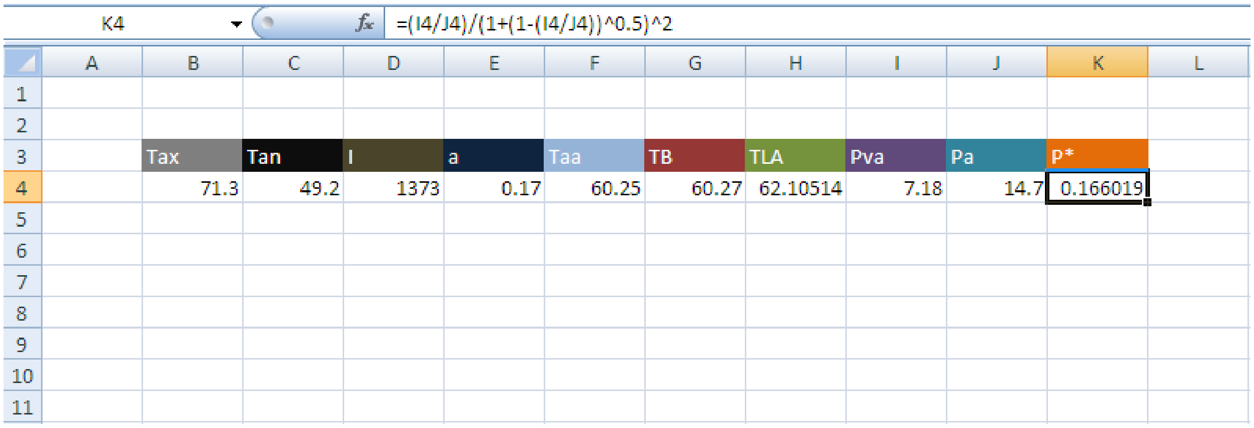
Chapter 4

Results and Discussion

Calculation of Vapor Presure Function:

From the gasoline storage internal floating roof tank location and specifications we calculate the daily average temperature and pressure function .

Table (4.1) show the calculation of daily average liquid surface temperature & pressure function



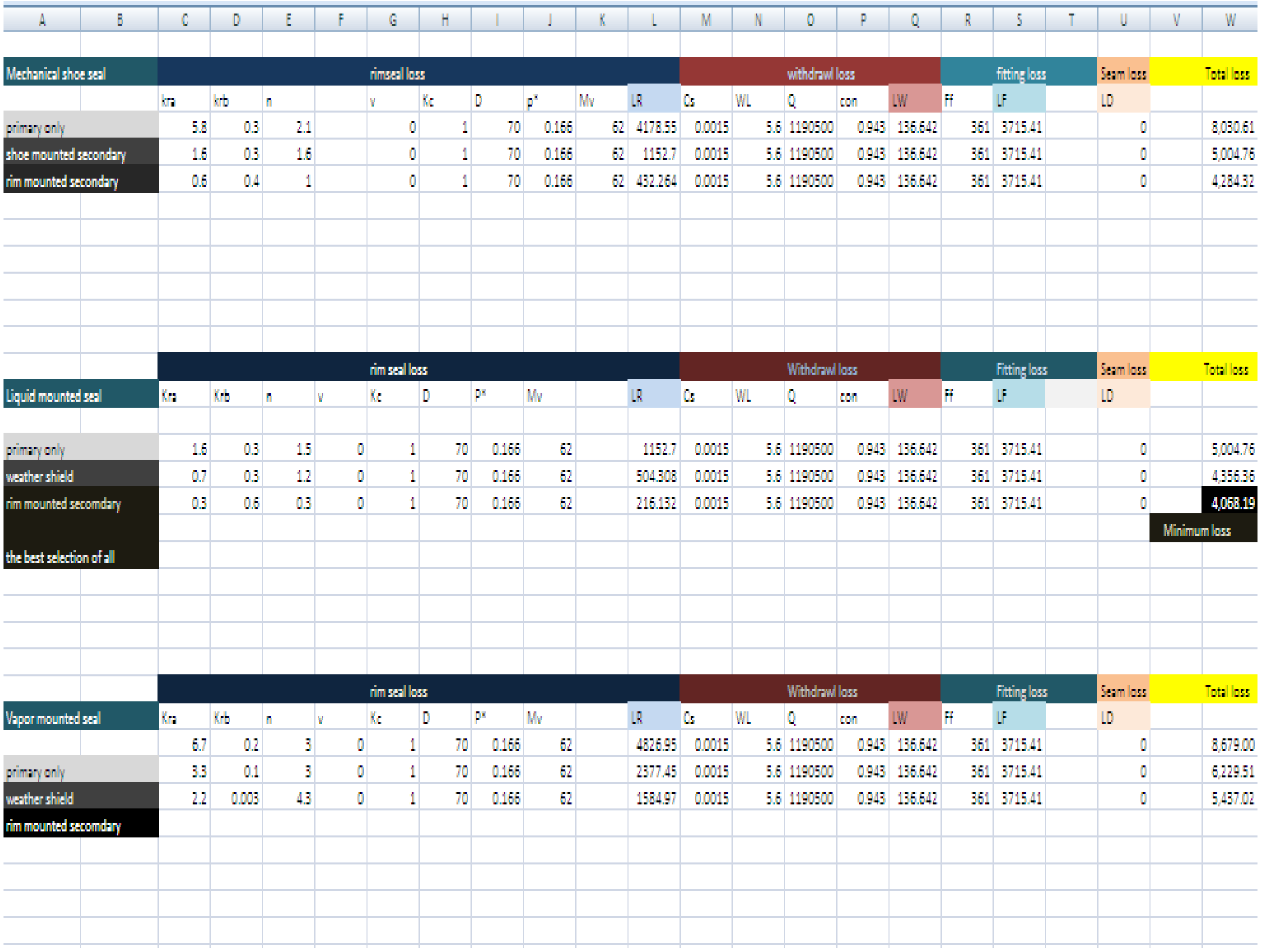
K4 =(I4/J4)/(1+(1-(I4/J4))^0.5)^2

	A	B	C	D	E	F	G	H	I	J	K	L
1												
2												
3		Tax	Tan	I	a	Taa	TB	TLA	Pva	Pa	P*	
4		71.3	49.2	1373	0.17	60.25	60.27	62.10514	7.18	14.7	0.166019	
5												
6												
7												
8												
9												
10												
11												

After we caculate the pressure function which is equal to .166 , we use this value and other needed values of factors from tables to calculate the values of with drawl , Deck fitting and Rim seal losses to estimate the total evaporation losses for differents rim seal systems,. Table(4.2) show the results .

Calculation of Total Losses:

Table (4.2) show the calculation of total evaporation loss by changing rim seal loss factors



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Mechanical shoe seal		rimseal loss										withdrawl loss					fitting loss			Seam loss	Total loss	
		kra	krb	n		v	Kc	D	p*	Mv	LR	Cs	WL	Q	con	LW	Ff	LF		LD		
primary only		5.8	0.3	2.1		0	1	70	0.166	62	4178.55	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		8,030.61
shoe mounted secondary		1.6	0.3	1.6		0	1	70	0.166	62	1152.7	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		5,004.76
rim mounted secondary		0.6	0.4	1		0	1	70	0.166	62	432.264	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		4,284.32

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
		rim seal loss										Withdrawl loss					Fitting loss			Seam loss	Total loss	
Liquid mounted seal		Kra	Krb	n	v	Kc	D	P*	Mv		LR	Cs	WL	Q	con	LW	Ff	LF		LD		
primary only		1.6	0.3	1.5	0	1	70	0.166	62		1152.7	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		5,004.76
weather shield		0.7	0.3	1.2	0	1	70	0.166	62		504.308	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		4,356.36
rim mounted secomdary		0.3	0.6	0.3	0	1	70	0.166	62		216.132	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		4,068.19
																					Minimum loss	
the best selection of all																						

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
		rim seal loss										Withdrawl loss					Fitting loss			Seam loss	Total loss	
Vapor mounted seal		Kra	Krb	n	v	Kc	D	P*	Mv		LR	Cs	WL	Q	con	LW	Ff	LF		LD		
		6.7	0.2	3	0	1	70	0.166	62		4826.95	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		8,679.00
primary only		3.3	0.1	3	0	1	70	0.166	62		2377.45	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		6,229.51
weather shield		2.2	0.003	4.3	0	1	70	0.166	62		1584.97	0.0015	5.6	1190500	0.943	136.642	361	3715.41		0		5,437.02
rim mounted secomdary																						

Figure(4.1) show the total loss when using mechanical Shoe seal welded tank. When we use the rim seal system with primary only the total loss was 8030.605508 Ib/yr , with shoe-mounted secondary the total loss was 5004.757508 Ib/yr, with rim-mounted secondary the total loss was 4284.317508 Ib/yr which is the best selection in this case

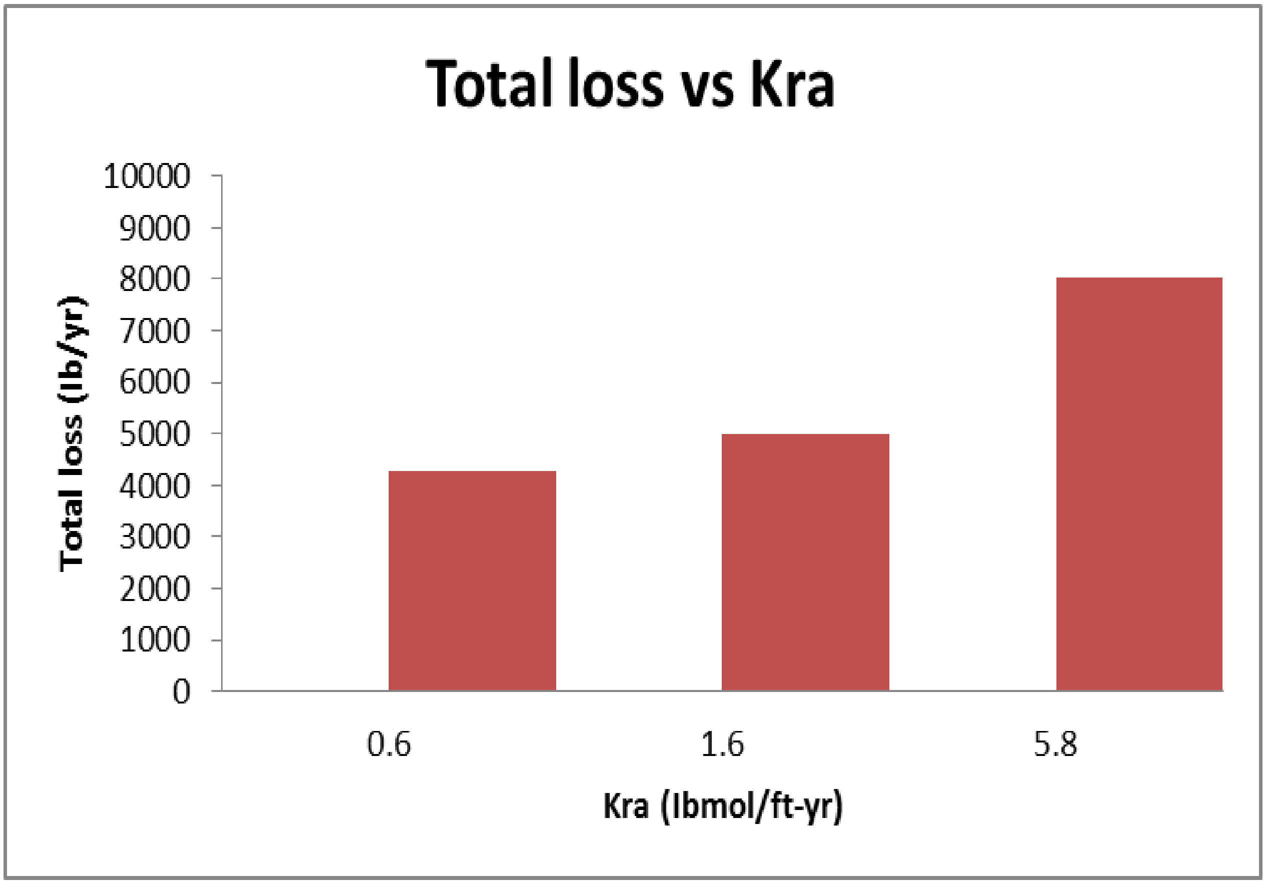


Figure (4.1) Mechanical Shoe Seal Total Loss

Figure(4.2) show the total loss when using liquid-mounted seal welded tank. When we use primary only loss factors the total loss was 5004.757508Ib/yr, with weather shield loss factors the total loss was 4356.361508 Ib/yr , with rim-mounted seal loss factors the total loss was 4068.185508 Ib/yr which is the best selection in this case.

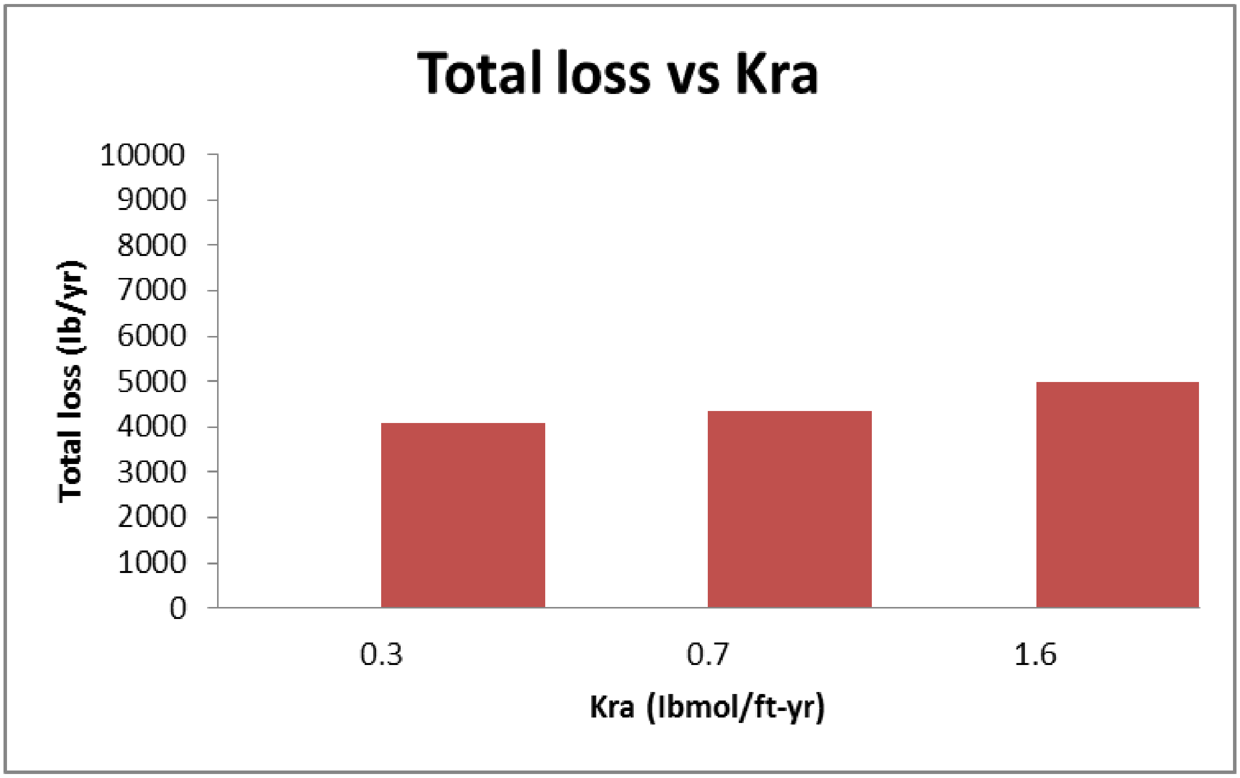


Figure (4.2) Liquid Mounted Seal Total Loss

Figure(4.3) show the total loss when using vapor-mounted seal welded tank. When we use primary only loss factors the total loss was 8679.001508 Ib/yr, with weather shield the total loss was 6229.505508 Ib/yr, in case of rim-mounted secondary the total loss was 5437.021508Ib/yr which the best selection in this case.

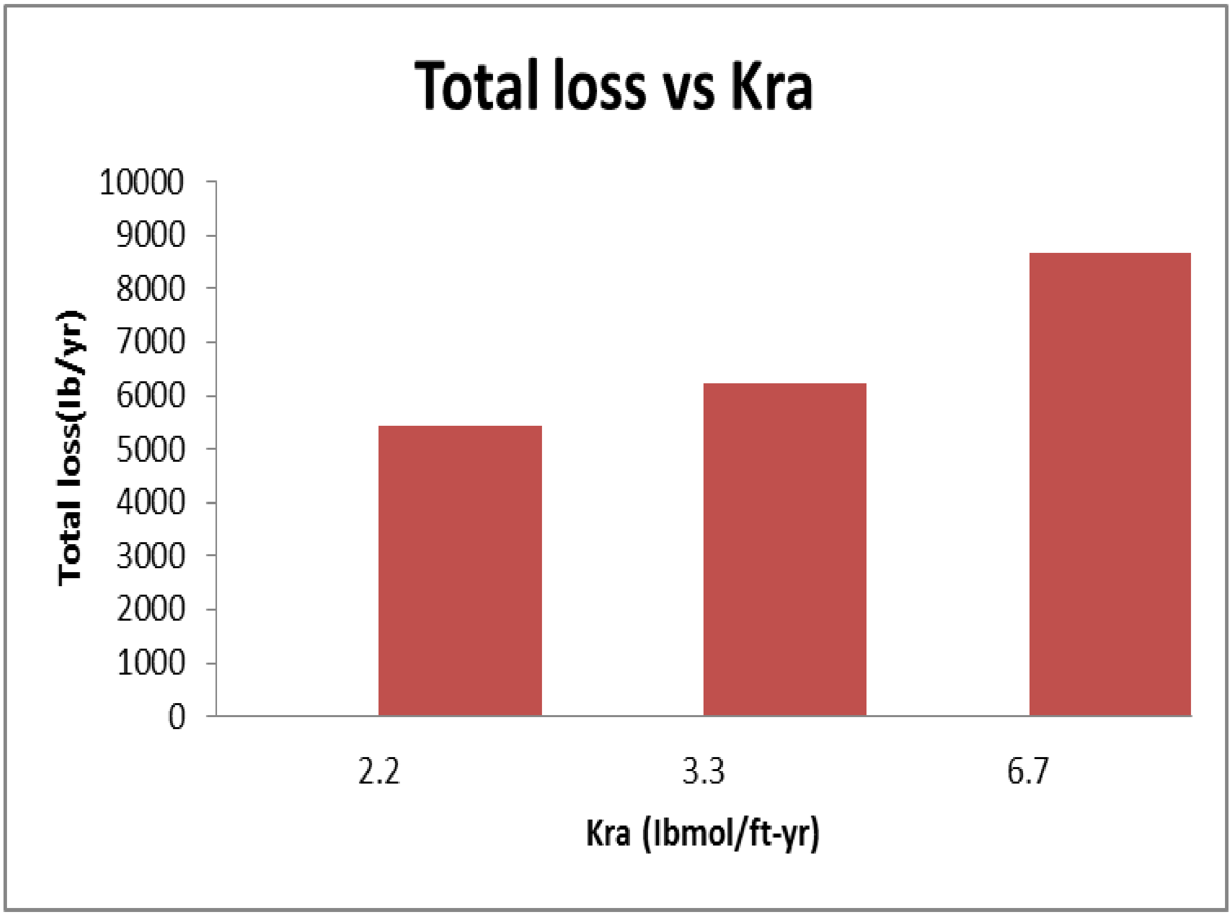
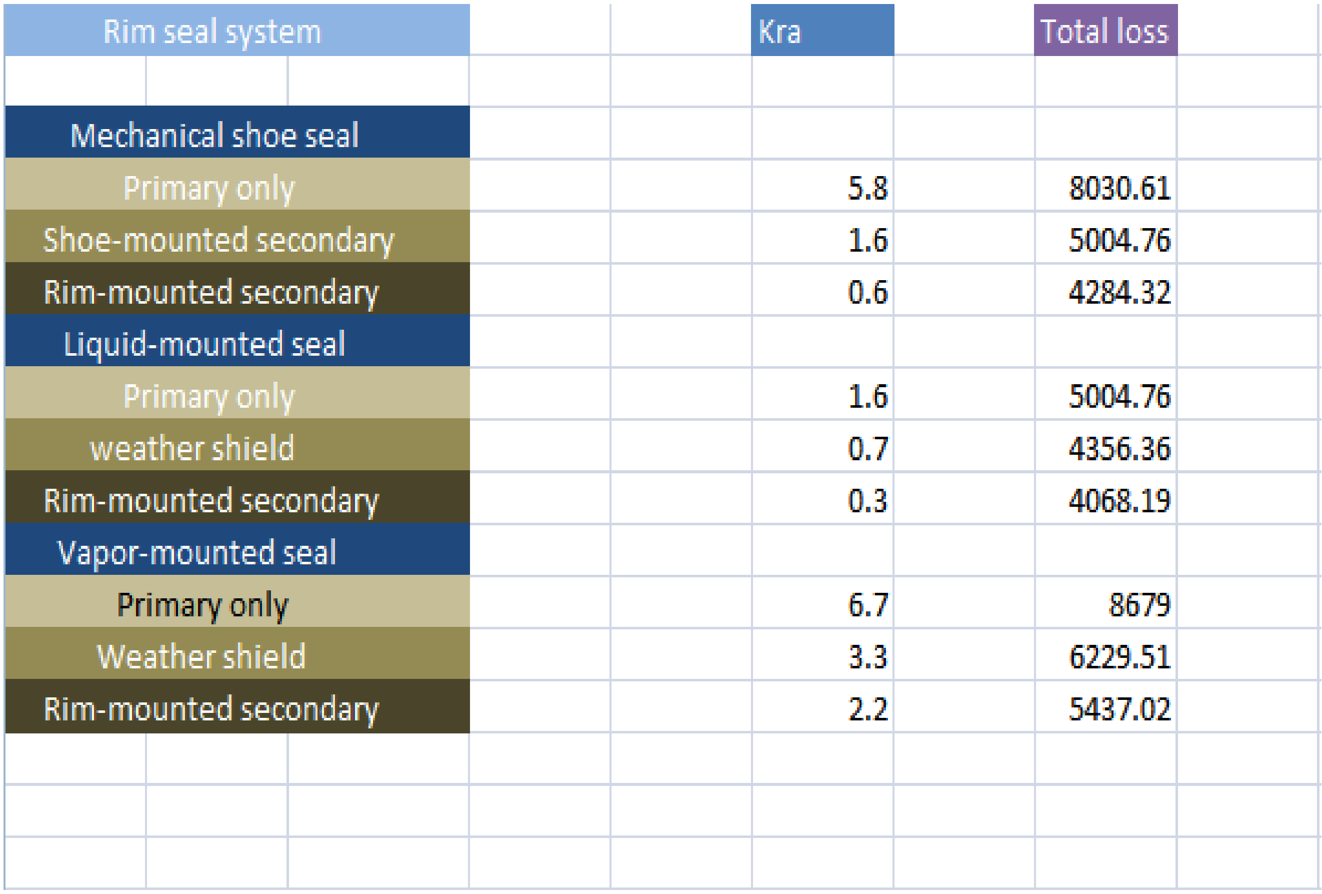


Figure (4.3) Vapor Mounted Seal Total Loss

Table (4.3)show rim seal system, Kra factor and total loss



Rim seal system	Kra	Total loss
Mechanical shoe seal		
Primary only	5.8	8030.61
Shoe-mounted secondary	1.6	5004.76
Rim-mounted secondary	0.6	4284.32
Liquid-mounted seal		
Primary only	1.6	5004.76
weather shield	0.7	4356.36
Rim-mounted secondary	0.3	4068.19
Vapor-mounted seal		
Primary only	6.7	8679
Weather shield	3.3	6229.51
Rim-mounted secondary	2.2	5437.02

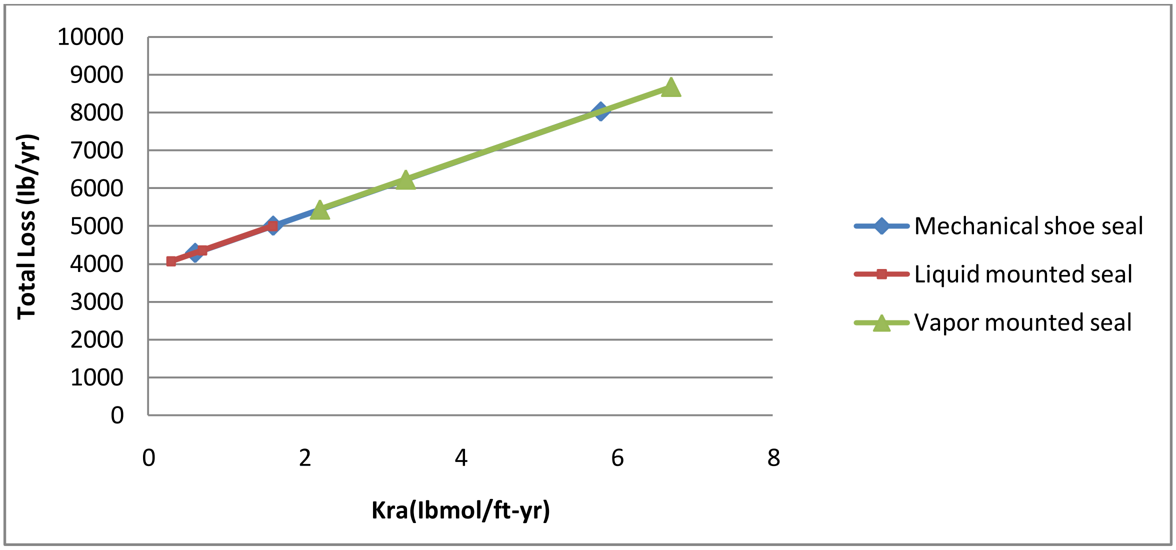


Figure (4.4) show total loss vsK_{Ra} rim seal system factor

Depend on rim seal type with welded tanks according to table (4.3) we found that the lowest rim seal loss factor (K_{Ra}) gives the minimum evaporation loss.

By comparing the above figures we found that the liquid-mounted seal system with rim-mounted secondary results in minimum evaporation loss which is the best selection of all rim seal system with welded tanks construction.

Above gasoline evaporation loss value reflects the average lossvalue within thestorage facilities, and it does not include the transportation and handlingevaporation loss from the refinery location to service stations.

4.1 Economic impacts:

Hydrocarbon products have high demand in all world countries. this demand is growing at an average of .8% /year , because they are cheap fuels .

Gasoline fuel is a most important fuel due to their high calorific value when it consumed in car engine but it classify as very high volatile organic components (VOC) as result of it is high Reid vapor pressure (RVP)

In Sudan the price of gasoline at service stations is (21) pound per gal (1 gal = 5.6Ibmol of gasoline) AP – (B)

The total estimated evaporation losses when we use different rim seal system and their total money loss due to evaporation loss

Table(4.4) show the total loss and money lost due to it

Rim seal system	Total loss (Ib/yr)	Money lost due loss (Sudanese pound)
Mechanical _ shoe seal		
Primary only	8,030.61	30,114.78
Weather shield	5,004.76	18,767.85
Rim _ mounted secondary	4,284.32	16,066.2
Liquid _ mounted seal		
Primary only	5,004.76	18,767.85
Weather shield	4,356.36	16,336.35
Rim _ mounted secondary	4,068.19 minimum loss	15,255.71
Vapor _ mounted seal		

Primary only	8,679.00	32,546.25
Weather shield	6,229.51	23,360.66
Rim _ mounted secondary	5,437.02	20,388.83

From the table (4.4) we show that the most economical rim seal system is liquid _ mounted seal with rim _ mounted secondary which give minimum money lost due to minimum loss.

4.2 Environmental Impacts:

The tank system or component must be designed with an adequate foundation, structural support and corrosion protection to prevent collapse, rupture, or failure of the unit. Seams and,connections must be sealed adequately and pressure controls must be installed if necessary to, assessment attesting to the structural integrity of the tank. The design assessment must bereviewed and certified by an independent, qualified, registered, professional engineer,

Because even the most flawlessly designed tanks can fail if installed improperly, new tanksystems must be inspected prior to use by an independent qualified expert to ensure that nodamage to the integrity of the tank occurred during installation.

Should damage occur during the course of installation, the owner and operator must correct the problem before the installations complete or the system is in use .All new tanks and ancillary equipment must be tested for tightness, and leaks discovered must be remedied before the tanks are covered enclosed or placed in use as a results of all this recommendation all types of evaporation loss will reduce which lead to high stability and explosion dangers reduction and successful environmental impact.

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Chapter 5

Conclusion and Recommendations

5.1 Conclusion

From the figure (4.2) we show that the evaporation loss from the gasoline internal floating roof storage tank of company A is minimum when usedwelded mechanicalstorage tank liquid mounted seal system with rim mounted secondary which gives total loss (4068.19 Ib/yr).

From the figure (4.3) we show that the evaporation loss when used vapor mounted seal system primary only gives total loss (8679.00Ib/yr) which is more than twice of liquid mounted seal system with rim mounted secondary .

The figure (4.4) presents that total loss of others rim seals systems between those values.

Finally the selection of rim seal system has very important effect in reducing total loss beside average ambient temperatureand Reid vapor pressure (RVP).

5.2 Recommendations:

There are two areas of controls that can be implemented to control gasoline evaporation loss from internal floating roof tank:

I. Metrological conditions

From the calculation reduction of temperature has the direct effect on the rim seal loss, Reduction in daily ambient temperature and average liquid surface temperature can be achieved by plantation and shadow area around the storage tanks location.

Plantation will have the direct effect in reducing temperature and will work as wind speed breakers as well, that beside the positive environmental impact. Specially if the sprinklers arrogation method is used

The only disadvantage for plantation is requiring high Safety regulation, which can be resolved by using intensive orientation programs regarding the safety measurements and standers for the work force in the refinery area.

II. Tank design and mechanical upgrades

Selection of rim seal system has large effect in reduction of evaporation loss by reducing the rim seal factor Kra according to table (3.1) which show the liquid mounted seal with rim mounted secondary is economical system.

Install vapor recovery /destruction system which a future method for controlling evaporative loss is to adapt a vapor recovery system, the cost of this method is quite high because it needs special equipment to convert hydro carbon vapor to liquid before liquid fuel is sent back to the storage tank .

Selection of the deck fitting according to AP - (F)will participate in the reduction of deck fitting during the filling process this can be done:

- Deck access hatch can be bolted covers and gasket type.
- Deck legs can be adjustable pontoon area gasket type.

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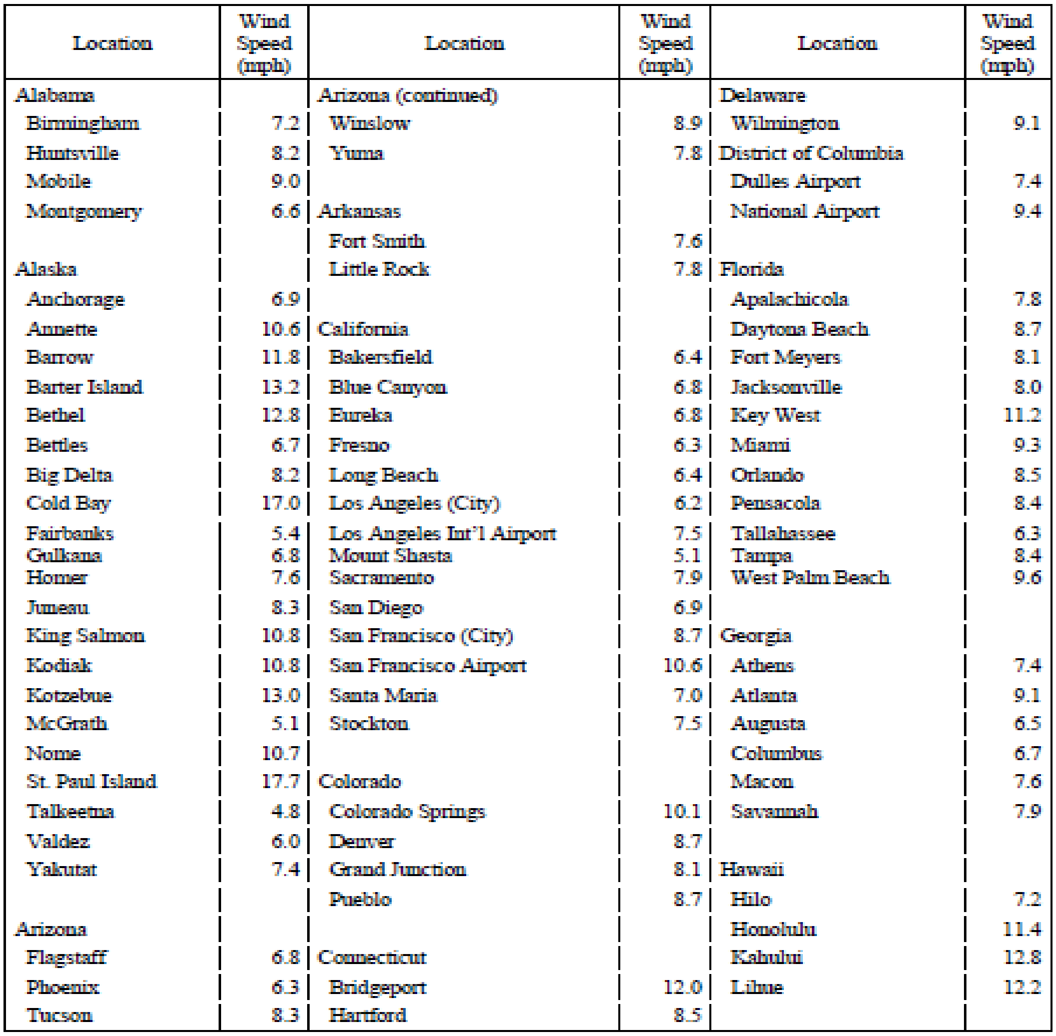
Appendixes[3]

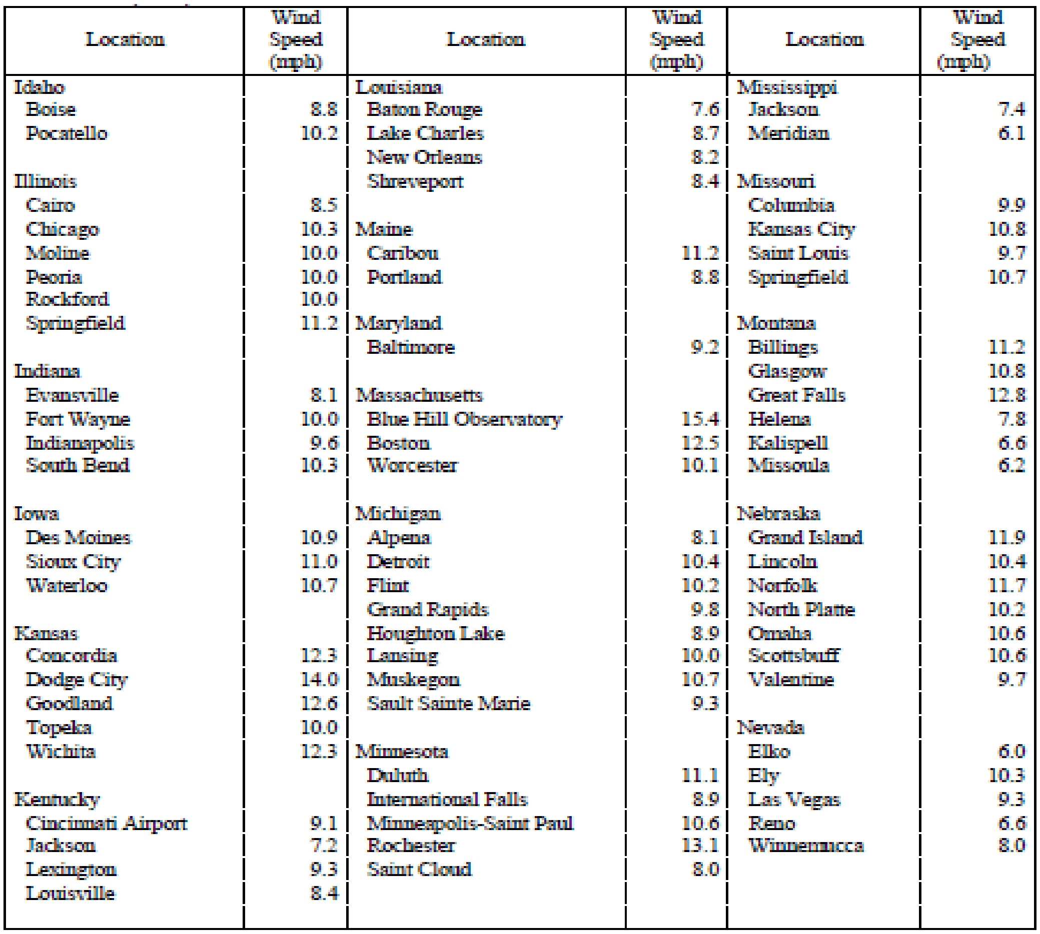
<u>Appendix (A)</u>

Table (A) average annual wind speed (v) for selected X location



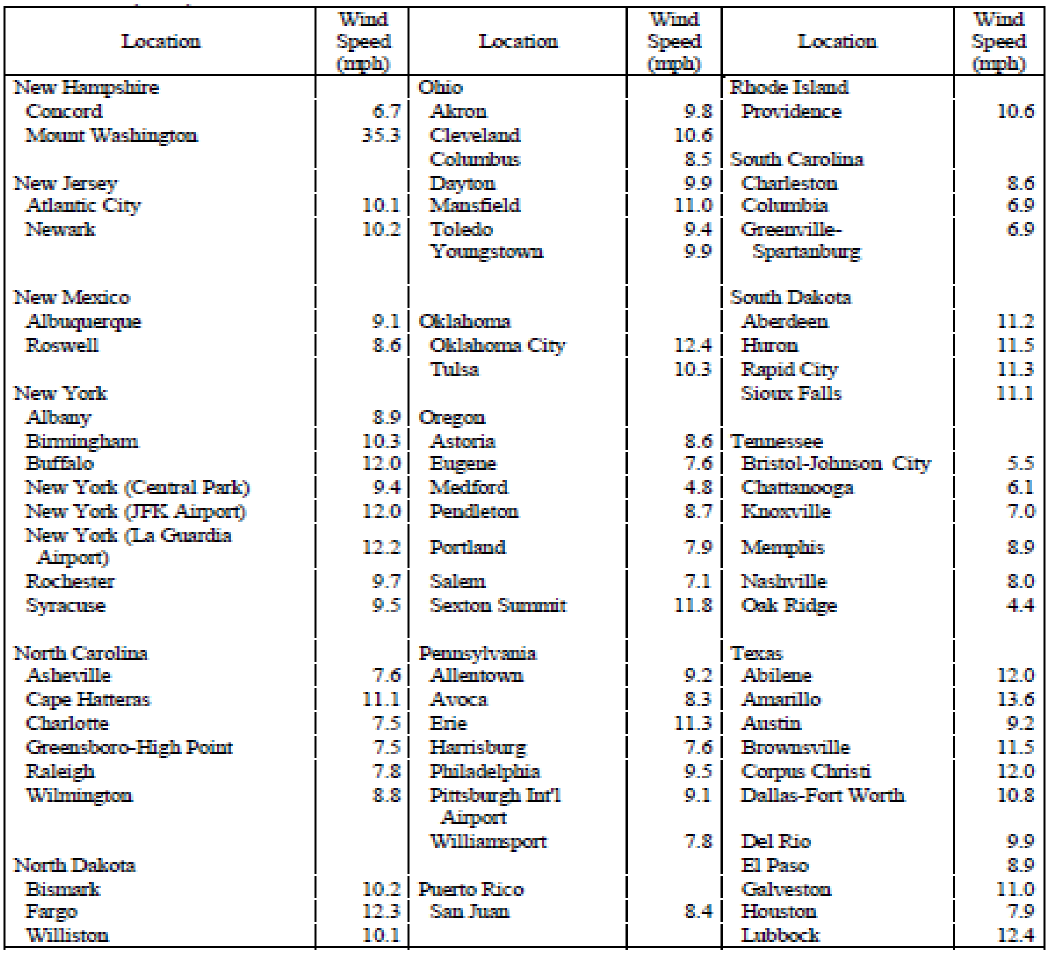
Location	Wind Speed (mph)	Location	Wind Speed (mph)	Location	Wind Speed (mph)
Alabama		Arizona (continued)		Delaware	
Birmingham	7.2	Winslow	8.9	Wilmington	9.1
Huntsville	8.2	Yuma	7.8	District of Columbia	
Mobile	9.0			Dulles Airport	7.4
Montgomery	6.6	Arkansas		National Airport	9.4
		Fort Smith	7.6		
Alaska		Little Rock	7.8	Florida	
Anchorage	6.9			Apalachicola	7.8
Annette	10.6	California		Daytona Beach	8.7
Barrow	11.8	Bakersfield	6.4	Fort Meyers	8.1
Barter Island	13.2	Blue Canyon	6.8	Jacksonville	8.0
Bethel	12.8	Eureka	6.8	Key West	11.2
Bettles	6.7	Fresno	6.3	Miami	9.3
Big Delta	8.2	Long Beach	6.4	Orlando	8.5
Cold Bay	17.0	Los Angeles (City)	6.2	Pensacola	8.4
Fairbanks	5.4	Los Angeles Int'l Airport	7.5	Tallahassee	6.3
Gulkana	6.8	Mount Shasta	5.1	Tampa	8.4
Homer	7.6	Sacramento	7.9	West Palm Beach	9.6
Juneau	8.3	San Diego	6.9		
King Salmon	10.8	San Francisco (City)	8.7	Georgia	
Kodiak	10.8	San Francisco Airport	10.6	Athens	7.4
Kotzebue	13.0	Santa Maria	7.0	Atlanta	9.1
McGrath	5.1	Stockton	7.5	Augusta	6.5
Nome	10.7			Columbus	6.7
St. Paul Island	17.7	Colorado		Macon	7.6
Talkeetna	4.8	Colorado Springs	10.1	Savannah	7.9
Valdez	6.0	Denver	8.7		
Yakutat	7.4	Grand Junction	8.1	Hawaii	
		Pueblo	8.7	Hilo	7.2
Arizona				Honolulu	11.4
Flagstaff	6.8	Connecticut		Kahului	12.8
Phoenix	6.3	Bridgeport	12.0	Lihue	12.2
Tucson	8.3	Hartford	8.5		

Table (A) average annual wind speed (v) for selected X location



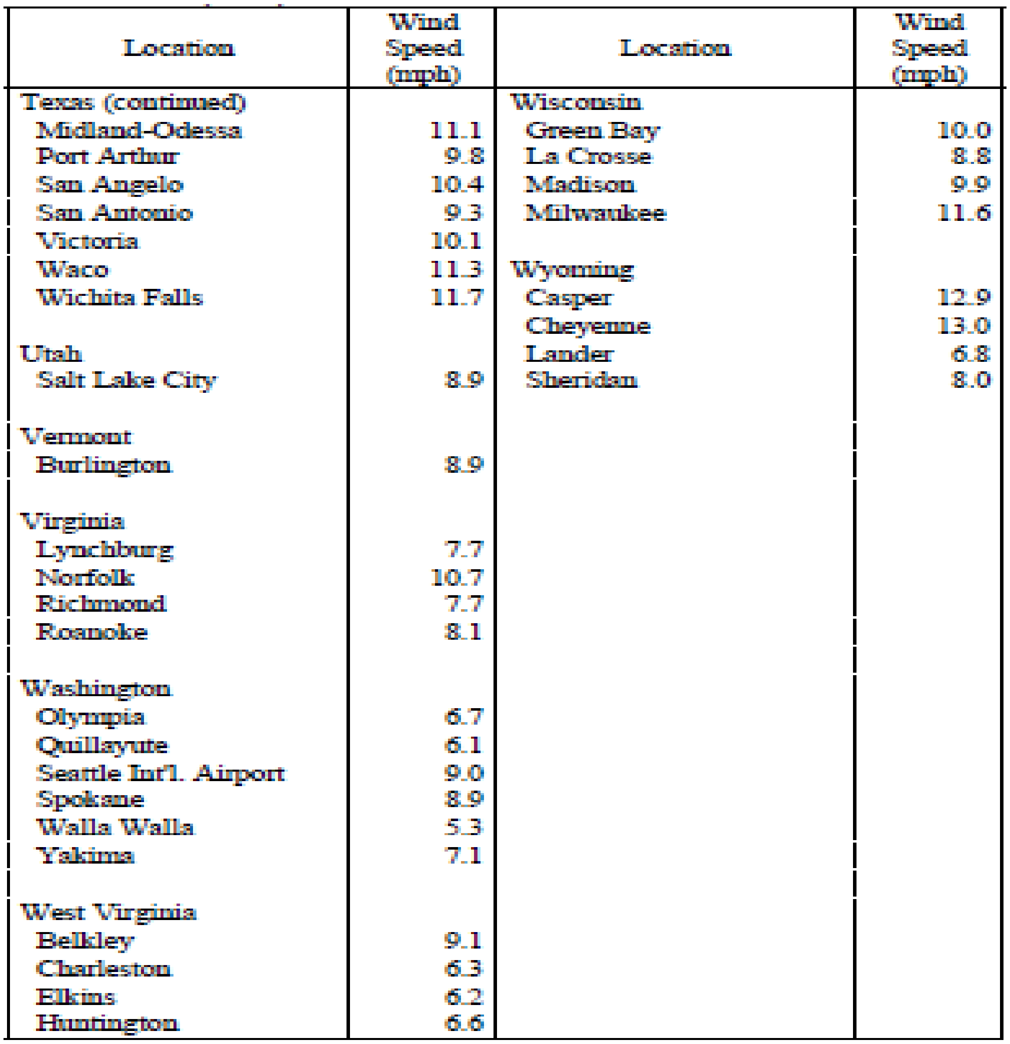
Location	Wind Speed (mph)	Location	Wind Speed (mph)	Location	Wind Speed (mph)
Idaho		Louisiana		Mississippi	
Boise	8.8	Baton Rouge	7.6	Jackson	7.4
Pocatello	10.2	Lake Charles	8.7	Meridian	6.1
		New Orleans	8.2		
Illinois		Shreveport	8.4	Missouri	
Cairo	8.5			Columbia	9.9
Chicago	10.3	Maine		Kansas City	10.8
Moline	10.0	Caribou	11.2	Saint Louis	9.7
Peoria	10.0	Portland	8.8	Springfield	10.7
Rockford	10.0				
Springfield	11.2	Maryland		Montana	
		Baltimore	9.2	Billings	11.2
Indiana				Glasgow	10.8
Evansville	8.1	Massachusetts		Great Falls	12.8
Fort Wayne	10.0	Blue Hill Observatory	15.4	Helena	7.8
Indianapolis	9.6	Boston	12.5	Kalispell	6.6
South Bend	10.3	Worcester	10.1	Missoula	6.2
Iowa		Michigan		Nebraska	
Des Moines	10.9	Alpena	8.1	Grand Island	11.9
Sioux City	11.0	Detroit	10.4	Lincoln	10.4
Waterloo	10.7	Flint	10.2	Norfolk	11.7
		Grand Rapids	9.8	North Platte	10.2
Kansas		Houghton Lake	8.9	Omaha	10.6
Concordia	12.3	Lansing	10.0	Scottsbuff	10.6
Dodge City	14.0	Muskegon	10.7	Valentine	9.7
Goodland	12.6	Sault Sainte Marie	9.3		
Topeka	10.0			Nevada	
Wichita	12.3	Minnesota		Elko	6.0
		Duluth	11.1	Ely	10.3
Kentucky		International Falls	8.9	Las Vegas	9.3
Cincinnati Airport	9.1	Minneapolis-Saint Paul	10.6	Reno	6.6
Jackson	7.2	Rochester	13.1	Winnemucca	8.0
Lexington	9.3	Saint Cloud	8.0		
Louisville	8.4				

Table (A) average annual wind speed (v) for selected X location



Location	Wind Speed (mph)	Location	Wind Speed (mph)	Location	Wind Speed (mph)
New Hampshire		Ohio		Rhode Island	
Concord	6.7	Akron	9.8	Providence	10.6
Mount Washington	35.3	Cleveland	10.6		
		Columbus	8.5	South Carolina	
New Jersey		Dayton	9.9	Charleston	8.6
Atlantic City	10.1	Mansfield	11.0	Columbia	6.9
Newark	10.2	Toledo	9.4	Greenville-Spartanburg	6.9
		Youngstown	9.9		
New Mexico				South Dakota	
Albuquerque	9.1	Oklahoma		Aberdeen	11.2
Roswell	8.6	Oklahoma City	12.4	Huron	11.5
		Tulsa	10.3	Rapid City	11.3
New York				Sioux Falls	11.1
Albany	8.9	Oregon			
Birmingham	10.3	Astoria	8.6	Tennessee	
Buffalo	12.0	Eugene	7.6	Bristol-Johnson City	5.5
New York (Central Park)	9.4	Medford	4.8	Chattanooga	6.1
New York (JFK Airport)	12.0	Pendleton	8.7	Knoxville	7.0
New York (La Guardia Airport)	12.2	Portland	7.9	Memphis	8.9
Rochester	9.7	Salem	7.1	Nashville	8.0
Syracuse	9.5	Sexton Summit	11.8	Oak Ridge	4.4
North Carolina		Pennsylvania		Texas	
Asheville	7.6	Allentown	9.2	Abilene	12.0
Cape Hatteras	11.1	Avoca	8.3	Amarillo	13.6
Charlotte	7.5	Erie	11.3	Austin	9.2
Greensboro-High Point	7.5	Harrisburg	7.6	Brownsville	11.5
Raleigh	7.8	Philadelphia	9.5	Corpus Christi	12.0
Wilmington	8.8	Pittsburgh Int'l Airport	9.1	Dallas-Fort Worth	10.8
		Williamsport	7.8	Del Rio	9.9
North Dakota				El Paso	8.9
Bismark	10.2	Puerto Rico		Galveston	11.0
Fargo	12.3	San Juan	8.4	Houston	7.9
Williston	10.1			Lubbock	12.4

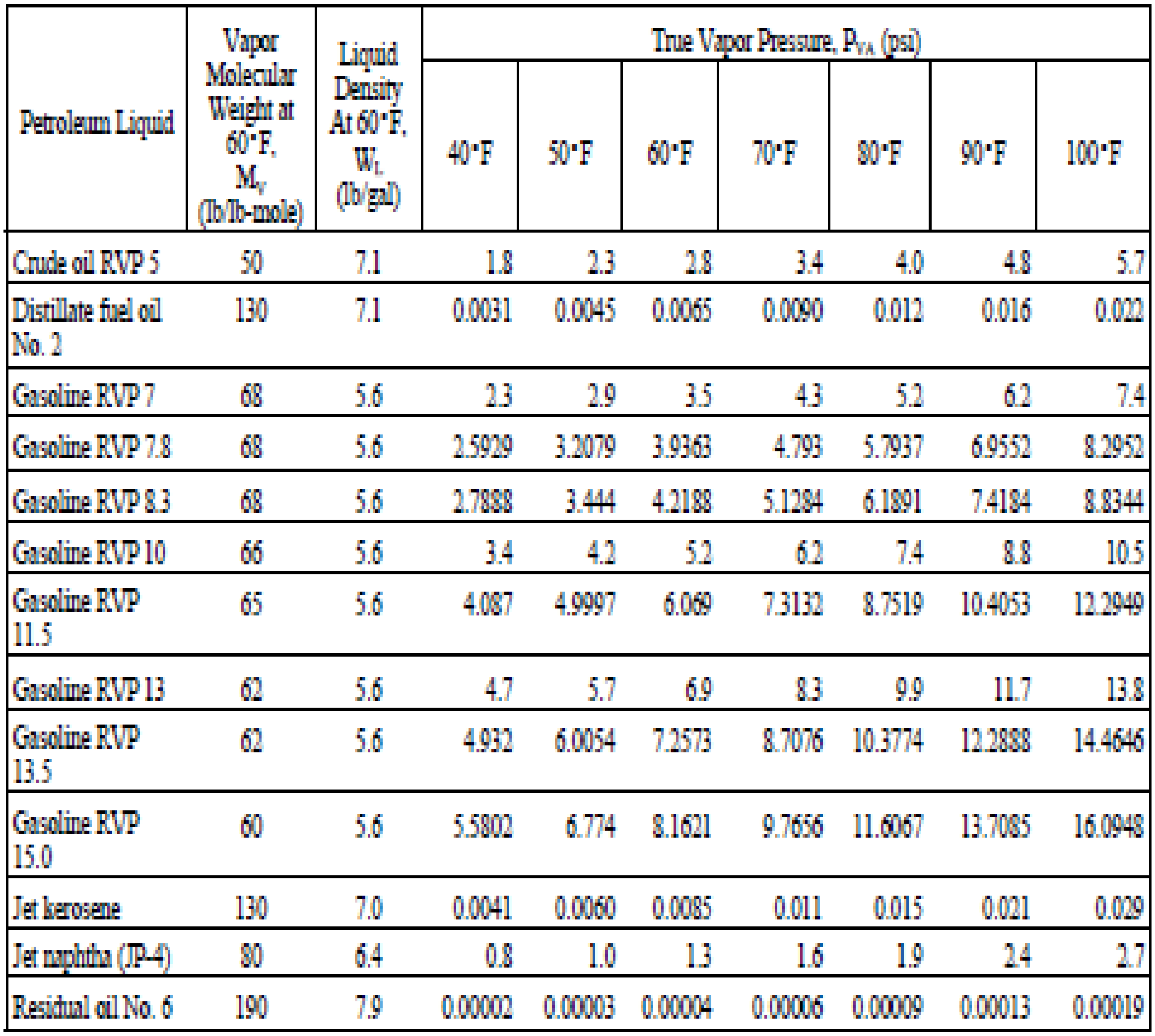
Table (A) average annual wind speed (v) for selected X location



Location	Wind Speed (mph)	Location	Wind Speed (mph)
Texas (continued)		Wisconsin	
Midland-Odessa	11.1	Green Bay	10.0
Port Arthur	9.8	La Crosse	8.8
San Angelo	10.4	Madison	9.9
San Antonio	9.3	Milwaukee	11.6
Victoria	10.1		
Waco	11.3	Wyoming	
Wichita Falls	11.7	Casper	12.9
		Cheyenne	13.0
Utah		Lander	6.8
Salt Lake City	8.9	Sheridan	8.0
Vermont			
Burlington	8.9		
Virginia			
Lynchburg	7.7		
Norfolk	10.7		
Richmond	7.7		
Roanoke	8.1		
Washington			
Olympia	6.7		
Quillayute	6.1		
Seattle Int'l. Airport	9.0		
Spokane	8.9		
Walla Walla	5.3		
Yakima	7.1		
West Virginia			
Belkley	9.1		
Charleston	6.3		
Elkins	6.2		
Huntington	6.6		

Appendix (B):

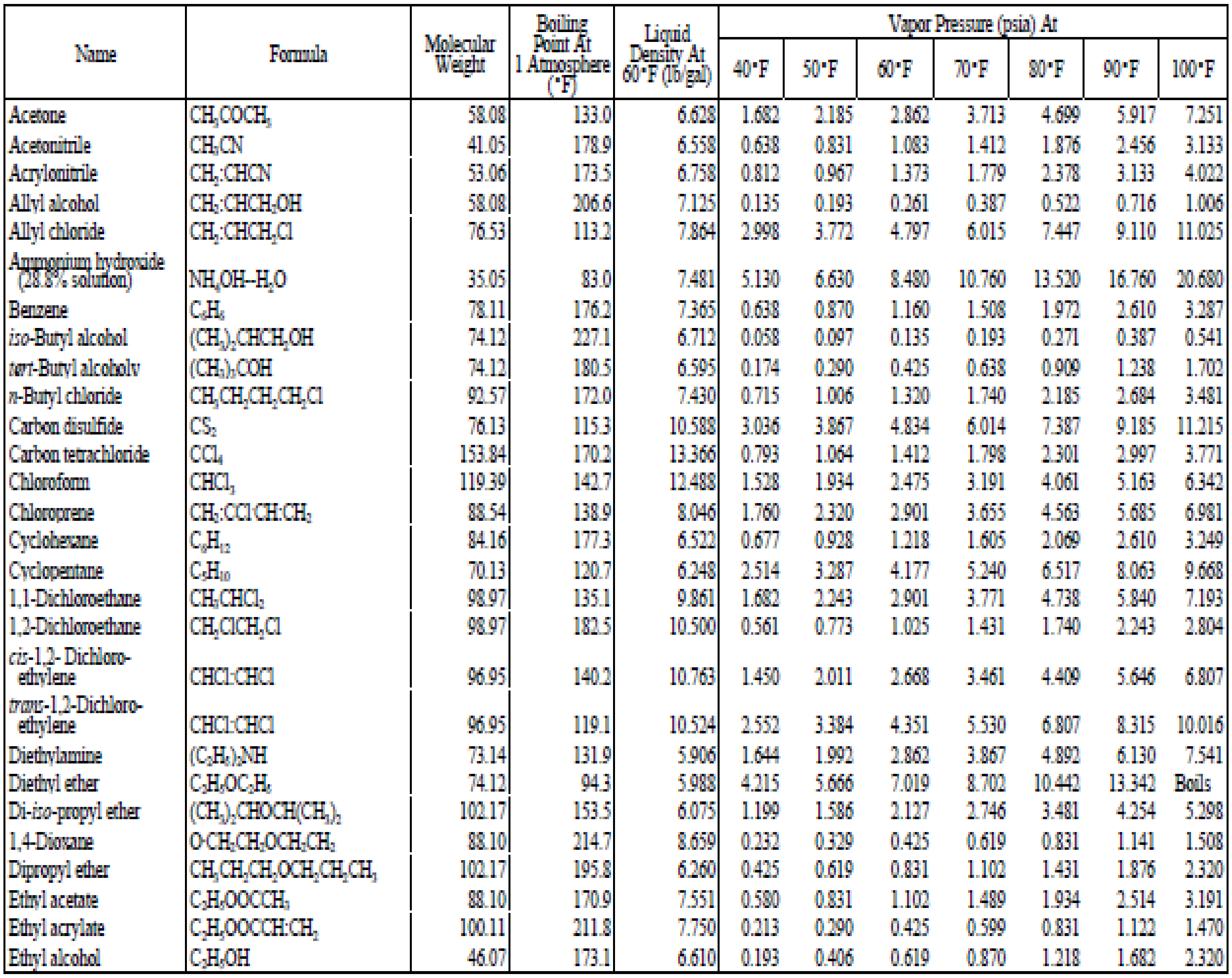
Table (B) Properties (M_V,P_{VA} ,W_L) of selected petroleum liquid



Petroleum Liquid	Vapor Molecular Weight at 60°F, M_V (lb/lb-mole)	Liquid Density At 60°F, W_L (lb/gal)	True Vapor Pressure, P_{VA} (psi)						
			40°F	50°F	60°F	70°F	80°F	90°F	100°F
Crude oil RVP 5	50	7.1	1.8	2.3	2.8	3.4	4.0	4.8	5.7
Distillate fuel oil No. 2	130	7.1	0.0031	0.0045	0.0065	0.0090	0.012	0.016	0.022
Gasoline RVP 7	68	5.6	2.3	2.9	3.5	4.3	5.2	6.2	7.4
Gasoline RVP 7.8	68	5.6	2.5929	3.2079	3.9363	4.793	5.7937	6.9552	8.2952
Gasoline RVP 8.3	68	5.6	2.7888	3.444	4.2188	5.1284	6.1891	7.4184	8.8344
Gasoline RVP 10	66	5.6	3.4	4.2	5.2	6.2	7.4	8.8	10.5
Gasoline RVP 11.5	65	5.6	4.087	4.9997	6.069	7.3132	8.7519	10.4053	12.2949
Gasoline RVP 13	62	5.6	4.7	5.7	6.9	8.3	9.9	11.7	13.8
Gasoline RVP 13.5	62	5.6	4.932	6.0054	7.2573	8.7076	10.3774	12.2888	14.4646
Gasoline RVP 15.0	60	5.6	5.5802	6.774	8.1621	9.7656	11.6067	13.7085	16.0948
Jet kerosene	130	7.0	0.0041	0.0060	0.0085	0.011	0.015	0.021	0.029
Jet naphtha (JP-4)	80	6.4	0.8	1.0	1.3	1.6	1.9	2.4	2.7
Residual oil No. 6	190	7.9	0.00002	0.00003	0.00004	0.00006	0.00009	0.00013	0.00019

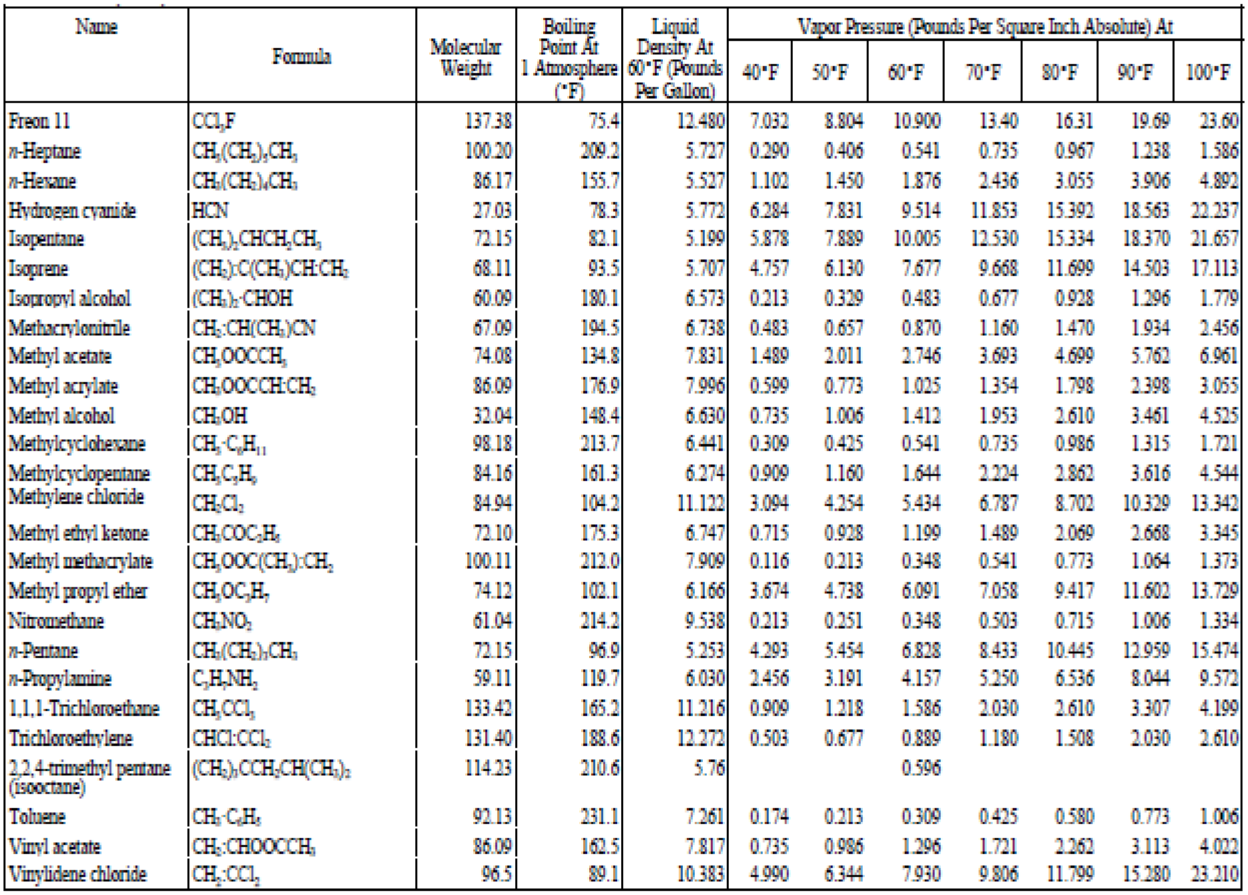
Appendix (C):

Table(C) Physical properties of selected petrochemicals



Name	Formula	Molecular Weight	Boiling Point At 1 Atmosphere (°F)	Liquid Density At 60°F (lb/gal)	Vapor Pressure (psia) At						
					40°F	50°F	60°F	70°F	80°F	90°F	100°F
Acetone	CH_3COCH_3	58.08	133.0	6.628	1.682	2.185	2.862	3.713	4.699	5.917	7.251
Acetonitrile	CH_3CN	41.05	178.9	6.558	0.638	0.831	1.083	1.412	1.876	2.456	3.133
Acrylonitrile	$CH_2{:}CHCN$	53.06	173.5	6.758	0.812	0.967	1.373	1.779	2.378	3.133	4.022
Allyl alcohol	$CH_2{:}CHCH_2OH$	58.08	206.6	7.125	0.135	0.193	0.261	0.387	0.522	0.716	1.006
Allyl chloride	$CH_2{:}CHCH_2Cl$	76.53	113.2	7.864	2.998	3.772	4.797	6.015	7.447	9.110	11.025
Ammonium hydroxide (28.8% solution)	$NH_4OH{-}{-}H_2O$	35.05	83.0	7.481	5.130	6.630	8.480	10.760	13.520	16.760	20.680
Benzene	C_6H_6	78.11	176.2	7.365	0.638	0.870	1.160	1.508	1.972	2.610	3.287
iso-Butyl alcohol	$(CH_3)_2CHCH_2OH$	74.12	227.1	6.712	0.058	0.097	0.135	0.193	0.271	0.387	0.541
tert-Butyl alcoholv	$(CH_3)_3COH$	74.12	180.5	6.595	0.174	0.290	0.425	0.638	0.909	1.238	1.702
n-Butyl chloride	$CH_3CH_2CH_2CH_2Cl$	92.57	172.0	7.430	0.715	1.006	1.320	1.740	2.185	2.684	3.481
Carbon disulfide	CS_2	76.13	115.3	10.588	3.036	3.867	4.834	6.014	7.387	9.185	11.215
Carbon tetrachloride	CCl_4	153.84	170.2	13.366	0.793	1.064	1.412	1.798	2.301	2.997	3.771
Chloroform	$CHCl_3$	119.39	142.7	12.488	1.528	1.934	2.475	3.191	4.061	5.163	6.342
Chloroprene	$CH_2{:}CCl{\cdot}CH{:}CH_2$	88.54	138.9	8.046	1.760	2.320	2.901	3.655	4.563	5.685	6.981
Cyclohexane	C_6H_{12}	84.16	177.3	6.522	0.677	0.928	1.218	1.605	2.069	2.610	3.249
Cyclopentane	C_5H_{10}	70.13	120.7	6.248	2.514	3.287	4.177	5.240	6.517	8.063	9.668
1,1-Dichloroethane	CH_3CHCl_2	98.97	135.1	9.861	1.682	2.243	2.901	3.771	4.738	5.840	7.193
1,2-Dichloroethane	CH_2ClCH_2Cl	98.97	182.5	10.500	0.561	0.773	1.025	1.431	1.740	2.243	2.804
cis-1,2- Dichloroethylene	$CHCl{:}CHCl$	96.95	140.2	10.763	1.450	2.011	2.668	3.461	4.409	5.646	6.807
trans-1,2-Dichloroethylene	$CHCl{:}CHCl$	96.95	119.1	10.524	2.552	3.384	4.351	5.530	6.807	8.315	10.016
Diethylamine	$(C_2H_5)_2NH$	73.14	131.9	5.906	1.644	1.992	2.862	3.867	4.892	6.130	7.541
Diethyl ether	$C_2H_5OC_2H_5$	74.12	94.3	5.988	4.215	5.666	7.019	8.702	10.442	13.342	Boils
Di-*iso*-propyl ether	$(CH_3)_2CHOCH(CH_3)_2$	102.17	153.5	6.075	1.199	1.586	2.127	2.746	3.481	4.254	5.298
1,4-Dioxane	$O{\cdot}CH_2CH_2OCH_2CH_2$	88.10	214.7	8.659	0.232	0.329	0.425	0.619	0.831	1.141	1.508
Dipropyl ether	$CH_3CH_2CH_2OCH_2CH_2CH_3$	102.17	195.8	6.260	0.425	0.619	0.831	1.102	1.431	1.876	2.320
Ethyl acetate	$C_2H_5OOCCH_3$	88.10	170.9	7.551	0.580	0.831	1.102	1.489	1.934	2.514	3.191
Ethyl acrylate	$C_2H_5OOCCH{:}CH_2$	100.11	211.8	7.750	0.213	0.290	0.425	0.599	0.831	1.122	1.470
Ethyl alcohol	C_2H_5OH	46.07	173.1	6.610	0.193	0.406	0.619	0.870	1.218	1.682	2.320

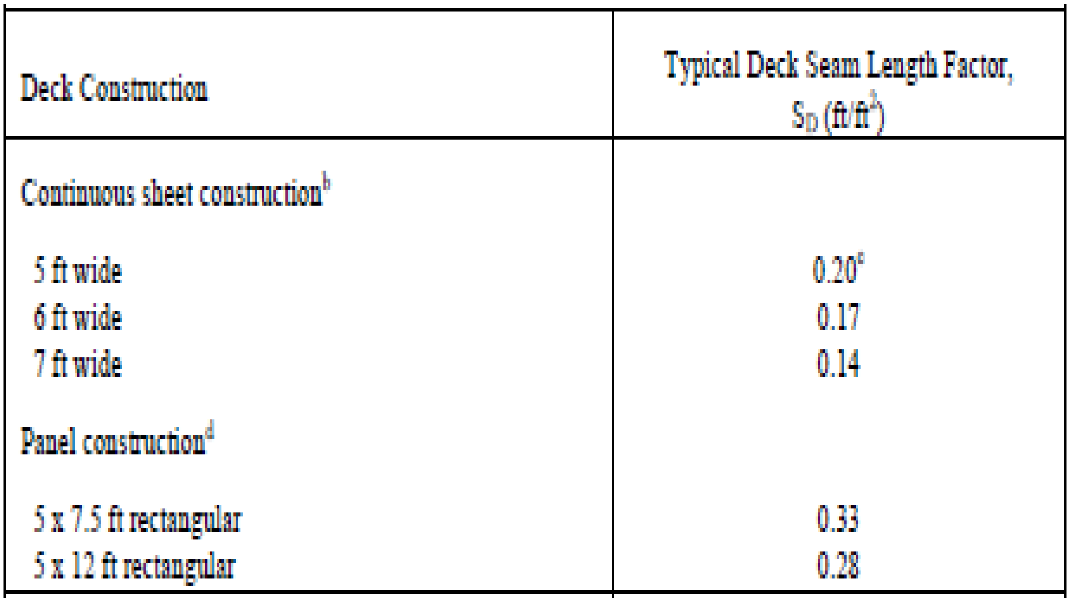
Table (C)Physical properties of selected petrochemicals



Name	Formula	Molecular Weight	Boiling Point At 1 Atmosphere (°F)	Liquid Density At 60°F (Pounds Per Gallon)	Vapor Pressure (Pounds Per Square Inch Absolute) At						
					40°F	50°F	60°F	70°F	80°F	90°F	100°F
Freon 11	CCl_3F	137.38	75.4	12.480	7.032	8.804	10.900	13.40	16.31	19.69	23.60
n-Heptane	$CH_3(CH_2)_5CH_3$	100.20	209.2	5.727	0.290	0.406	0.541	0.735	0.967	1.238	1.586
n-Hexane	$CH_3(CH_2)_4CH_3$	86.17	155.7	5.527	1.102	1.450	1.876	2.436	3.055	3.906	4.892
Hydrogen cyanide	HCN	27.03	78.3	5.772	6.284	7.831	9.514	11.853	15.392	18.563	22.237
Isopentane	$(CH_3)_2CHCH_2CH_3$	72.15	82.1	5.199	5.878	7.889	10.005	12.530	15.334	18.370	21.657
Isoprene	$(CH_2):C(CH_3)CH:CH_2$	68.11	93.5	5.707	4.757	6.130	7.677	9.668	11.699	14.503	17.113
Isopropyl alcohol	$(CH_3)_2 \cdot CHOH$	60.09	180.1	6.573	0.213	0.329	0.483	0.677	0.928	1.296	1.779
Methacrylonitrile	$CH_2:CH(CH_3)CN$	67.09	194.5	6.738	0.483	0.657	0.870	1.160	1.470	1.934	2.456
Methyl acetate	CH_3OOCCH_3	74.08	134.8	7.831	1.489	2.011	2.746	3.693	4.699	5.762	6.961
Methyl acrylate	$CH_3OOCCH:CH_2$	86.09	176.9	7.996	0.599	0.773	1.025	1.354	1.798	2.398	3.055
Methyl alcohol	CH_3OH	32.04	148.4	6.630	0.735	1.006	1.412	1.953	2.610	3.461	4.525
Methylcyclohexane	$CH_3 \cdot C_6H_{11}$	98.18	213.7	6.441	0.309	0.425	0.541	0.735	0.986	1.315	1.721
Methylcyclopentane	$CH_3C_5H_9$	84.16	161.3	6.274	0.909	1.160	1.644	2.224	2.862	3.616	4.544
Methylene chloride	CH_2Cl_2	84.94	104.2	11.122	3.094	4.254	5.434	6.787	8.702	10.329	13.342
Methyl ethyl ketone	$CH_3COC_2H_5$	72.10	175.3	6.747	0.715	0.928	1.199	1.489	2.069	2.668	3.345
Methyl methacrylate	$CH_3OOC(CH_3):CH_2$	100.11	212.0	7.909	0.116	0.213	0.348	0.541	0.773	1.064	1.373
Methyl propyl ether	$CH_3OC_3H_7$	74.12	102.1	6.166	3.674	4.738	6.091	7.058	9.417	11.602	13.729
Nitromethane	CH_3NO_2	61.04	214.2	9.538	0.213	0.251	0.348	0.503	0.715	1.006	1.334
n-Pentane	$CH_3(CH_2)_3CH_3$	72.15	96.9	5.253	4.293	5.454	6.828	8.433	10.445	12.959	15.474
n-Propylamine	$C_3H_7NH_2$	59.11	119.7	6.030	2.456	3.191	4.157	5.250	6.536	8.044	9.572
1,1,1-Trichloroethane	CH_3CCl_3	133.42	165.2	11.216	0.909	1.218	1.586	2.030	2.610	3.307	4.199
Trichloroethylene	$CHCl:CCl_2$	131.40	188.6	12.272	0.503	0.677	0.889	1.180	1.508	2.030	2.610
2,2,4-trimethyl pentane (isooctane)	$(CH_3)_3CCH_2CH(CH_3)_2$	114.23	210.6	5.76			0.596				
Toluene	$CH_3 \cdot C_6H_5$	92.13	231.1	7.261	0.174	0.213	0.309	0.425	0.580	0.773	1.006
Vinyl acetate	$CH_2:CHOOCCH_3$	86.09	162.5	7.817	0.735	0.986	1.296	1.721	2.262	3.113	4.022
Vinylidene chloride	$CH_2:CCl_2$	96.5	89.1	10.383	4.990	6.344	7.930	9.806	11.799	15.280	23.210

Appendix (D):

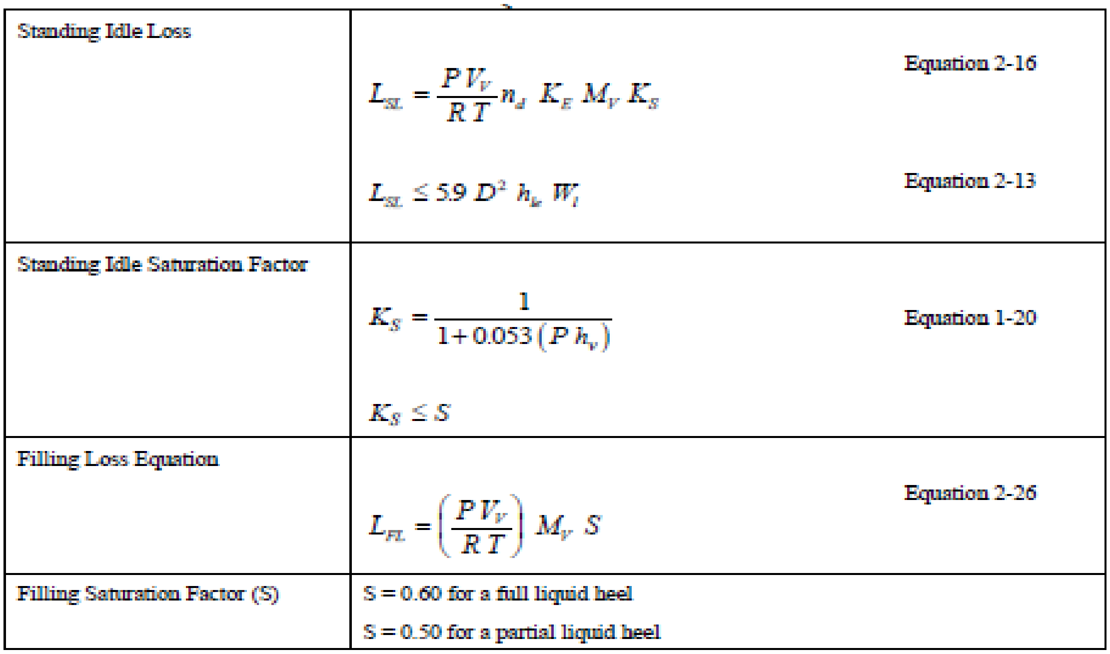
Table (D) Deck seam length factors (S_D) for typical construction for (IFRT)



Deck Construction	Typical Deck Seam Length Factor, S_D (ft/ft^2)
Continuous sheet construction[b]	
5 ft wide	0.20[c]
6 ft wide	0.17
7 ft wide	0.14
Panel construction[d]	
5 x 7.5 ft rectangular	0.33
5 x 12 ft rectangular	0.28

Appendix (E):

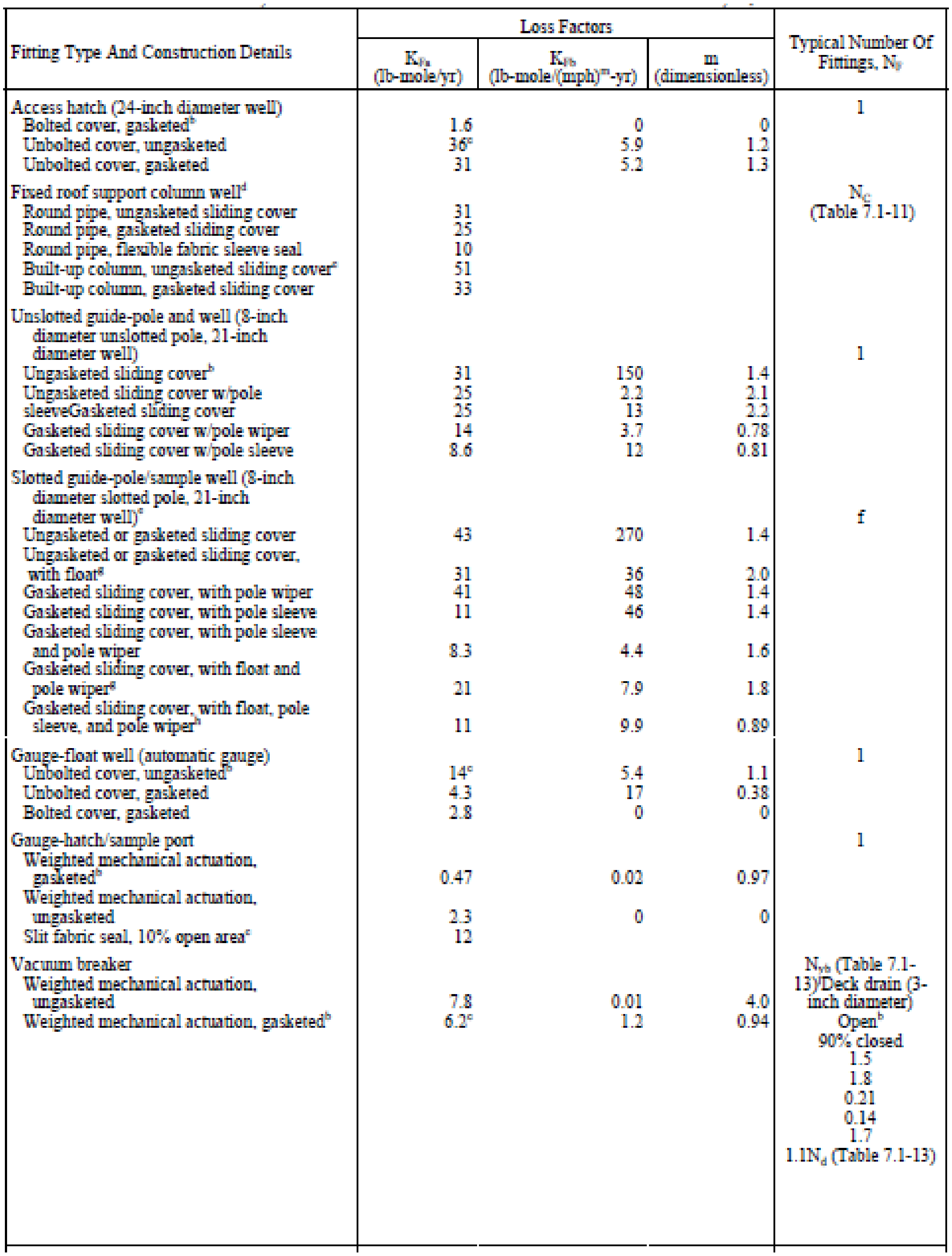
Table (E) roof landing losses for (IFRT) with a liquid heel



Standing Idle Loss	$L_{SL} = \frac{P V_V}{R T} n_d \; K_E \; M_V \; K_S$ $L_{SL} \leq 5.9 \; D^2 \; h_{le} \; W_l$	Equation 2-16 Equation 2-13
Standing Idle Saturation Factor	$K_S = \frac{1}{1 + 0.053 \left(P \; h_v \right)}$ $K_S \leq S$	Equation 1-20
Filling Loss Equation	$L_{FL} = \left(\frac{P V_V}{R T} \right) M_V \; S$	Equation 2-26
Filling Saturation Factor (S)	S = 0.60 for a full liquid heel S = 0.50 for a partial liquid heel	

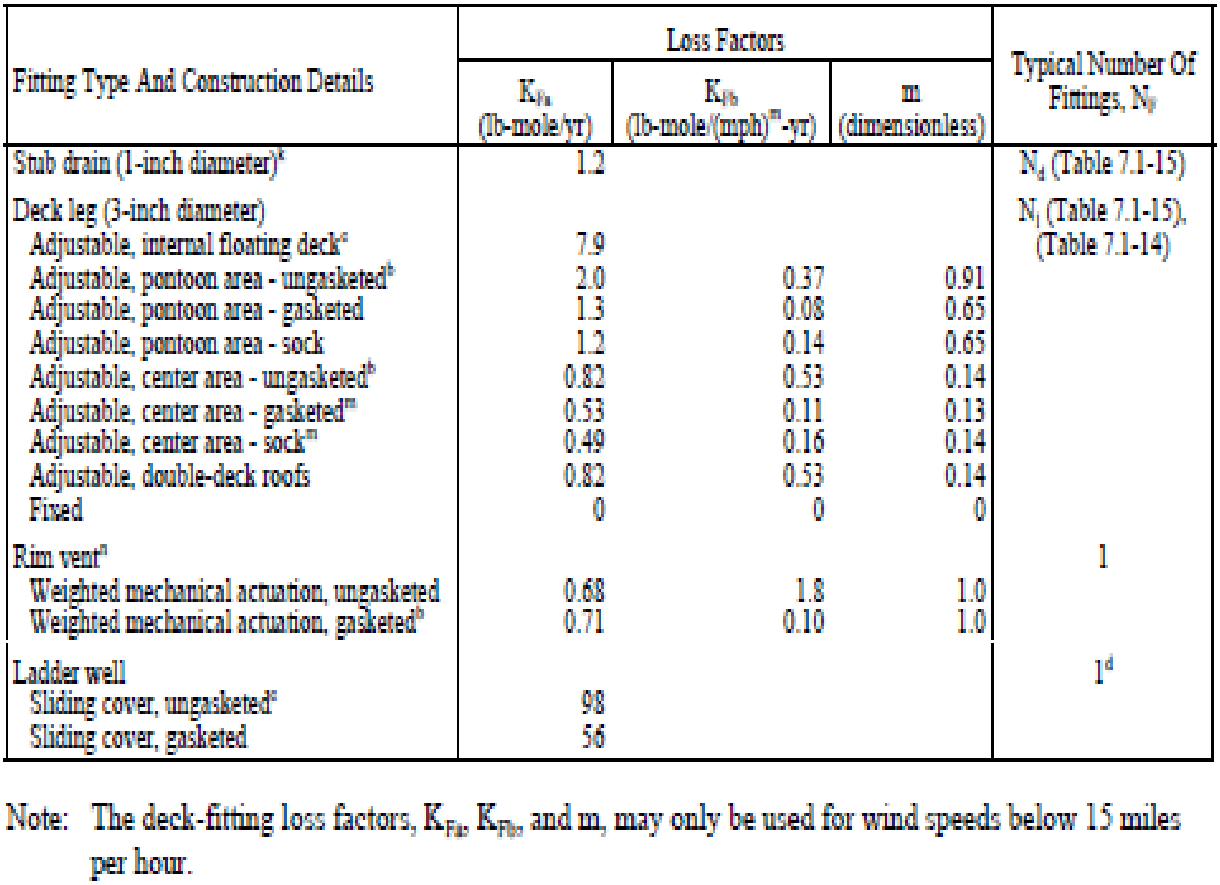
Appendix (F):

Table (F) deck fitting loss factors K_{F_a} K_{F_b} and m, and typical number of deck fittings N_F



Fitting Type And Construction Details	Loss Factors			Typical Number Of Fittings, N_F
	K_{Fa} (lb-mole/yr)	K_{Fb} (lb-mole/(mph)^m-yr)	m (dimensionless)	
Access hatch (24-inch diameter well)				1
Bolted cover, gasketed[b]	1.6	0	0	
Unbolted cover, ungasketed	36[c]	5.9	1.2	
Unbolted cover, gasketed	31	5.2	1.3	
Fixed roof support column well[d]				N_C (Table 7.1-11)
Round pipe, ungasketed sliding cover	31			
Round pipe, gasketed sliding cover	25			
Round pipe, flexible fabric sleeve seal	10			
Built-up column, ungasketed sliding cover[c]	51			
Built-up column, gasketed sliding cover	33			
Unslotted guide-pole and well (8-inch diameter unslotted pole, 21-inch diameter well)				1
Ungasketed sliding cover[b]	31	150	1.4	
Ungasketed sliding cover w/pole sleeveGasketed sliding cover	25 25	2.2 13	2.1 2.2	
Gasketed sliding cover w/pole wiper	14	3.7	0.78	
Gasketed sliding cover w/pole sleeve	8.6	12	0.81	
Slotted guide-pole/sample well (8-inch diameter slotted pole, 21-inch diameter well)[e]				f
Ungasketed or gasketed sliding cover	43	270	1.4	
Ungasketed or gasketed sliding cover, with float[g]	31	36	2.0	
Gasketed sliding cover, with pole wiper	41	48	1.4	
Gasketed sliding cover, with pole sleeve	11	46	1.4	
Gasketed sliding cover, with pole sleeve and pole wiper	8.3	4.4	1.6	
Gasketed sliding cover, with float and pole wiper[g]	21	7.9	1.8	
Gasketed sliding cover, with float, pole sleeve, and pole wiper[h]	11	9.9	0.89	
Gauge-float well (automatic gauge)				1
Unbolted cover, ungasketed[b]	14[c]	5.4	1.1	
Unbolted cover, gasketed	4.3	17	0.38	
Bolted cover, gasketed	2.8	0	0	
Gauge-hatch/sample port				1
Weighted mechanical actuation, gasketed[b]	0.47	0.02	0.97	
Weighted mechanical actuation, ungasketed	2.3	0	0	
Slit fabric seal, 10% open area[c]	12			
Vacuum breaker				N_{vb} (Table 7.1-13)/Deck drain (3-inch diameter)
Weighted mechanical actuation, ungasketed	7.8	0.01	4.0	
Weighted mechanical actuation, gasketed[b]	6.2[c]	1.2	0.94	Open[b] 90% closed 1.5 1.8 0.21 0.14 1.7 $1.1N_d$ (Table 7.1-13)

Table (F) cont.deck fitting loss factors K_{F_a} K_{F_b} and m, and typical number of deck fittings N_F



Fitting Type And Construction Details	Loss Factors			Typical Number Of Fittings, N_F
	K_{Fa} (lb-mole/yr)	K_{Fb} (lb-mole/(mph)^m-yr)	m (dimensionless)	
Stub drain (1-inch diameter)[k]	1.2			N_d (Table 7.1-15)
Deck leg (3-inch diameter)				N_l (Table 7.1-15), (Table 7.1-14)
Adjustable, internal floating deck[c]	7.9			
Adjustable, pontoon area - ungasketed[b]	2.0	0.37	0.91	
Adjustable, pontoon area - gasketed	1.3	0.08	0.65	
Adjustable, pontoon area - sock	1.2	0.14	0.65	
Adjustable, center area - ungasketed[b]	0.82	0.53	0.14	
Adjustable, center area - gasketed[m]	0.53	0.11	0.13	
Adjustable, center area - sock[m]	0.49	0.16	0.14	
Adjustable, double-deck roofs	0.82	0.53	0.14	
Fixed	0	0	0	
Rim vent[n]				1
Weighted mechanical actuation, ungasketed	0.68	1.8	1.0	
Weighted mechanical actuation, gasketed[b]	0.71	0.10	1.0	
Ladder well				1[d]
Sliding cover, ungasketed[c]	98			
Sliding cover, gasketed	56			

Note: The deck-fitting loss factors, K_{Fa}, K_{Fb}, and m, may only be used for wind speeds below 15 miles per hour.