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APPENDIX A

Description of Fixed Roof Tank

A.1 General Information [1]

A fixed roof tank is a minimum accepted standard storage of volatile liquids. Large, modern fixed roof tanks are of all welded construction and are designed to be liquid and vapor tight. Some older fixed roof tanks may be of riveted or bolted construction. In this research, it is assumed that the tank roof and shell are vapor tight. Figure A-1 shows a typical fixed roof tank. Fixed roof tanks are vessels that have a vertical cylindrical shell and a fixed roof. In addition to the shell and roof, the basic components and construction features include :

a) Roof fitting that penetrate the fixed roof and serve operational functions.

b) Shell and roof paint.

Fixed roof tanks are used in the U.S. to store volatile liquids with a true vapor pressure less than 1.5 pounds per square inch absolute. They are available in a range of sizes from 20 to 300 feet in diameter and up to 65 feet in shell height. The fixed roof may be column - supported or self - supported, and may be cone - shaped, dome - shaped, or flat. Some fixed roof tanks incorporate internal floating roofs.

A fixed roof tank will accommodate only a very low internal pressure or vacuum. For tanks built in accordance with API Standard 650

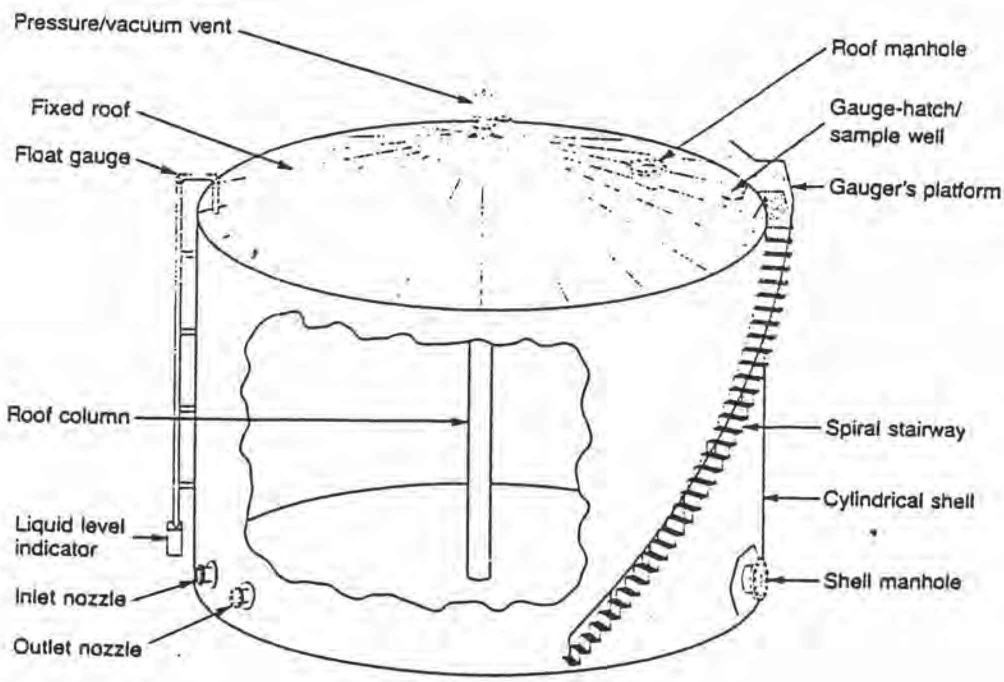


Figure A-1 Typical Fixed-Roof Tank [1]

[6], the maximum safe pressure of vacuum for larger tanks is usually 1.5 inches of water column, or approximately 1 ounce per square inch. This is the pressure that produces the force required to lift the weight of 3/16 inch - thick roof plates. Any higher pressure may cause damage. The vacuum is limited by the safe buckling strength of the upper part of tank shell. These pressure and vacuum limits may be exceeded on small tanks ; however, before doing so, the tank strength should be carefully checked.

A.2 Roof Fittings

Several roof fittings penetrate the tank roof to allow for operational functions and are potential sources of evaporative loss. Other accessories are not penetrating the roof or shell are not potential sources of evaporative loss. Roof fittings can be a source of evaporative loss when they are not sealed. The most common types of roof fittings used on fixed roof tanks are described in A.2.1 through A.2.4

The evaporative loss contribution of properly sealed roof fittings is negligible in comparison to the standing loss and the working loss, and thus no roof fitting loss estimation procedure is included in this work.

A.2.1 Pressure - Vacuum Vents

Pressure - vacuum (PV) vents are mounted on the tank roof to provide sufficient venting capacity to protect the tank from the damaging effects of overpressure or overvacuum.

When pressure within the tank vapor space exceeds a set point, the PV vent opens to release vapors from the tank until the pressure is reduced below its set point. On the other hand, when a vacuum within the tank vapor space exceeds the vacuum set point, the PV vent opens to admit air into the tank until the vacuum is reduced below its set point.

API Bulletin 2521 [4] describes the use of PV vents on fixed roof tanks and presents factors that should be considered 2000 [5] describes the sizing requirements for PV vents on fixed roof tanks and covers both normal and emergency venting conditions.

PV vents on atmospheric pressure fixed roof tanks are usually set at 0.75 inches of water column, or approximately 0.5 ounce per square inch. The required normal pressure venting capacity or vacuum venting capacity should accommodate breathing and product movement up to the maximum safe working pressure or vacuum of the tank.

Open vents of the mushroom or return - bend type are not normally used on fixed roof tanks storing volatile liquids since they permit higher losses.

PV vents should be regularly inspected and overhaulted the frequency depending upon local conditions. PV vents are sometimes equipped with flame arrestors. When a flame arrestor is used, additional consideration must be given in sizing the PV vent to allow for the flow restriction caused by the flame arrestor. The use of a flame arrestor also increases maintenance requirements, since the flame arrestor must receive frequent inspections and cleaning to ensure blockage - free operation.

A.2.2 Gauge - Hatch / Sample Wells

Gauge - hatch / sample wells provide access for manually gauging the stock level in the tank and for taking thief samples of the contents. Gauge-hatch / sample wells consist of a pipe penetration on the tank roof that is equipped with a self - closing cover. A gasketed cover may be used to further reduce evaporative losses. Gauge - hatch / sample wells are usually located by the gauger's platform, which is mounted at the top of the tank shell.

Some vapor loss may occur during manual gauging and stock sampling operations , during which time the gauge - hatch / sample well cover is opened. This loss can be minimized by reducing the period of time that the cover is left open.

A.2.3 Float Gauges

Float gauges are used to indicate the level of stock within the tank. Float gauges consist of a float that rests on the liquid surface and is connected to a liquid level indicator mounted on the exterior of the tank shell by a cable or tape that passes through a guide system. The cable or tape passes through the tank roof and is normally contained in a sealed conduit to eliminate evaporative loss.

A.2.4 Roof Manholes

Roof manholes are used to provide access to the interior of the tank for the purpose of construction or maintenance. Roof manholes normally consist of a circular opening in the tank roof with a peripheral vertical neck attached to the roof and a removable cover. The opening is sized to provide for the passage of personnel and materials through the tank roof. The cover can rest directly on the neck, or a gasket can be used between the cover and the neck to reduce evaporative loss. Bolting the cover to the neck further reduces evaporative loss.

A.3 Paint

Painting the tank shell and roof is important in both reducing evaporative loss and preserving the tank . The use of a highly reflective paint. Such as white paint , will result in lower tank metal temperatures and lower heat input to the tank vapor space, thereby reducing the breathing loss. If it important to establish a tank paint inspection and maintenance program to preserve the paint reflectance and eliminate tank exterior corrosion.

APPENDIX B

Description of Internal Floating Roof Tank

B.1 General Information [2]

Internal floating roof tanks are cylindrical vessels that have both a fixed roof over the top of the tanks , and a floating deck that rests on the liquid stock surface. There are two basic types of internal floating roof tanks : (1) tanks with fixed roofs supported by vertical columns are typical of fixed roof tanks fitted with an internal floating deck ; and (2) tanks with a self - supporting fixed roof, with no internal support columns are typical of external floating roof tanks covered with a fixed roof. Tanks initially constructed with both a fixed roof and a floating deck may be of either type.

In addition to a cylindrical shell and fixed roof , the basic components of an internal floating roof tank include : (1) a floating deck : (2) an annular rim seal attached to the perimeter of the floating deck : and (3) fittings that penetrate the floating deck and provide support for the fixed roof or serve operational functions. General types of these components, which are available in a range of commercial designs, are described in this section. Included in these descriptions are comments on evaporative loss potential , as well as some design and operational characteristics. The use of an internal floating deck will reduce the concentration of hydrocarbon vapor in the space between the floating deck and the fixed roof from that which would occur in a fixed roof tank.

This could result in the occurrence of flammable vapor - air mixtures within the tank. To minimize the occurrence of flammable vapor- air mixtures, vents are installed at the top of the tank shell or in the fixed roof to provide circulation of air through the space between the fixed roof and the floating deal. API Standard 650 [6], specifies the use of such vents and outlines design details for the storage of petroleum liquids. Such tank is referred to as *freely vented* internal floating roof tanks and are those for which the loss estimating procedures in Chapter 3.2 are applicable.

Closed internal floating roof tanks refer to those which are vented only through a pressure / vacuum relief vent. Such tank is sometimes used in chemical liquid service and in petroleum liquid service where API Standard 650 is not used. These tanks are typically designed with auxiliary safety devices, as specified by the user. The loss estimating procedures in Chapter 3.2 are not applicable to closed internal floating roof tanks.

B.2 Floating Decks

Floating decks are typically used to control evaporative stock loss. The basic design concept is to reduce the liquid surface exposed to evaporation to a minimum by placing a floating deck in contact with the liquid surface or by confining a layer of saturated vapor under a vapor - tight deck floating above the liquid. The loss of vapor otherwise displaced from fixed roof tanks by filling and breathing is virtually eliminated. Evaporation loss does occur during standing storage through annular rim space, deck fittings, and, in some cases, deck seams.

Floating decks are used in volatile stock service, for stocks with a true vapor pressure at storage conditions below atmospheric pressure (that is, nonbiting). They are available in virtually all commercial tank sizes, with diameters renging form about 400 feet to 20 feet, and with slight modification, down to 8 feet. Methods and materials have been developed to properly seal the annular space between the tank shell and the deck rimplate , as well as sealing around any number of fittings that penetrate the deck.

Floating decks are currently of two general types : (1) decks constructed by bolting (or mechanically joining by any method) sheets or panels of deck material and (2) decks of welded construction. Decks with bolted seams are typically made of lightweight materials, whereas welded decks are typically made of steel plates. Both types of decks are typically designed in accordance with API Standard 650. Floating decks can be further characterized by the location of the deck relative to the liquid stock surface. A deck supported above the liquid stock surface by buoyant structures is referred to as a noncontact deck. A deck floating directly on the liquid stock surface is referred to as a contact deck. Steel decks are typically of contact design, whereas nonferrous materials are used in both noncontact and contact designs.

These general types and designs of floating decks are currently available in many different materials and with various design features. The basic types of floating decks used in internal floating roof tanks are described in B.2.1 thought B.2.4 and illustrated in Figure B-1. More detailed descriptions are included in Bulletin 2513 [7] for the welded deck types.

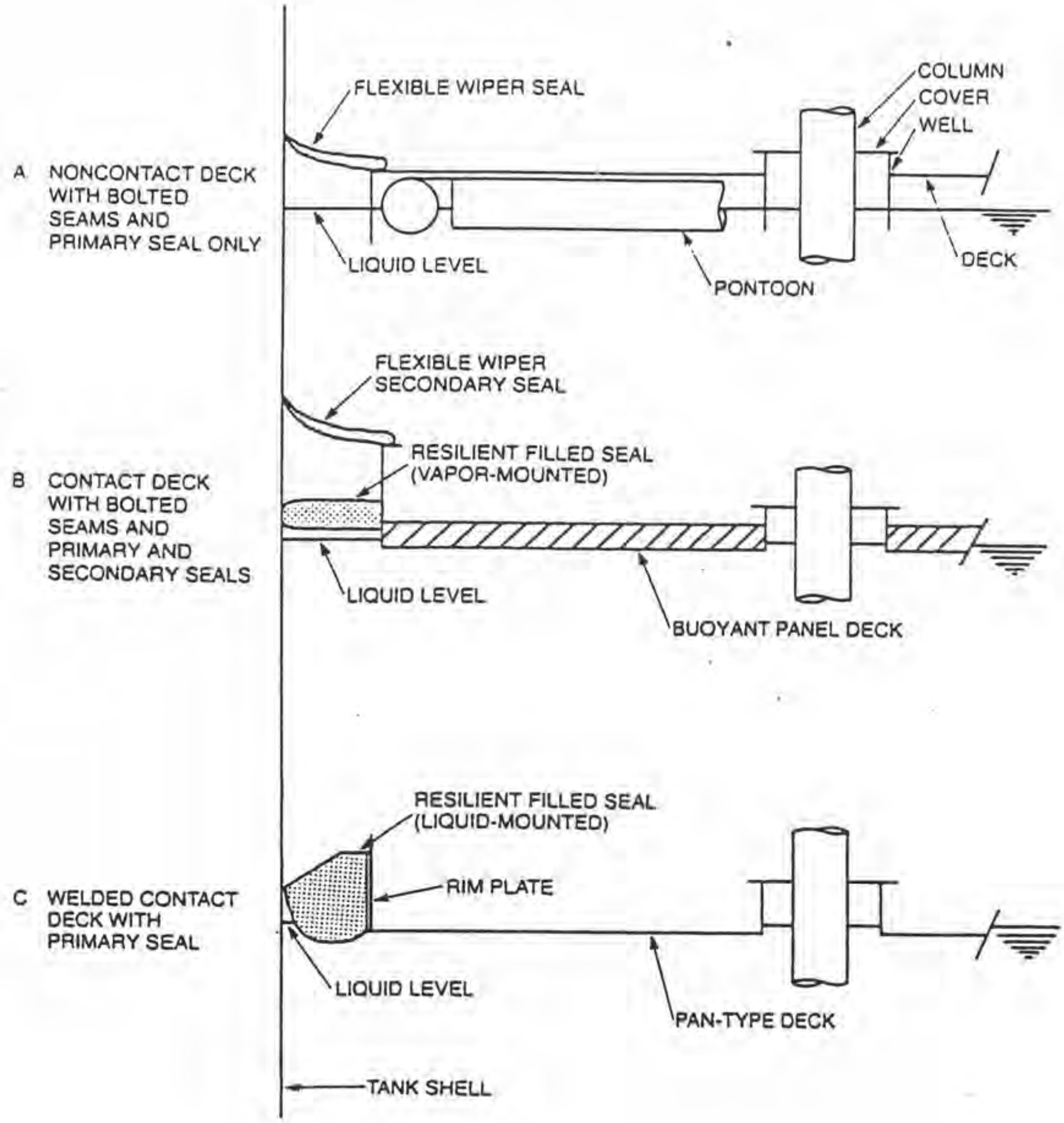


Figure B-1 Typical Internal Floating Decks and Typical Rim Seal Systems [2]

B.2.1 Noncontact Deck with Bolted Seams (Figure B-1, drawing A)

This deck type is currently available in two basic designs. The most common design consists of aluminum sheet bolted to an aluminum grid framework to form a substantially tight barrier below which the stock vapor is contained in the space created by the means of deck flotation . The flotation is provided by sealed tubular aluminum pontoons, which are approximately half - immersed in the liquid stock. The grid and pontoons are structurally interconnected and tied to a system of legs or hangers, which support the internal floating deck when the tank is nearly empty. Wherever penetrations occur in the deck sheeting, vertical skirts or wells are fastened to the deck and extend into the liquid stock to contain the vapor below the deck. In addition , a skirt extends into the liquid stock at the perimeter of the deck.

A second design consists of aluminum panels on an aluminum grid framework supported above the liquid surface by aluminum floats filled with polyurethane foam. While details vary somewhat from those described above , the concept is similar in that buoyancy is provided to maintain the deck above the liquid surface, with a resulting vapor space below the deck. Vertical skirts are used with deck penetrations at the deck perimeter to contain this vapor.

B.2.2 Contact Decks with Bolted Seams (Figure B-1, drawing B)

This deck type is also currently available in two basic designs. The most common design consists of aluminum sandwich panels, with a honeycombed aluminum core, which floats directly on the liquid surface. The aluminum honeycombed core is about 1/2 inches thick and is adhesively bonded to the aluminum panels on the top and bottom surfaces. This sandwich - type construction results in a self - buoyant deck. A number of panels are bolted at their edges to form the deck. Since no vapor space exists under the deck, vertical skirts are not used for the deck fittings or the deck perimeter.

B.2.3 Welded Contact Decks (Figure B-1, drawing C)

This deck type consists of steel plates that are welded together along their edges to form a continuous deck. A vertical rim plate is provided around the edge of the deck to provide flotation and to support the rim seal. In a pan - type welded deck, flotation occurs only as a result of displacement of the deck into the liquid stock. Flotation may be enhanced by the use of buoyant volumes on the top surface of the deck, which may take the form of an annular ring (as in a pontoon - type external floating roof) ; discrete volumes distributed over the deck surface ; or the entire deck surface (as in a double deck, type external floating roof). Since there is no vapor space under the deck, no vertical skirting is used.

B.2.4 Other Deck Designs

Floating deck designs other than the most common designs discussed above are currently available or may become available in the future. One example is a contact deck with panel joined by adhesion and a continuous fiberglass - reinforced laminate. The panels are made of rigid foam enclosed in a fiberglass - reinforced polyester skin. No information is currently available on the evaporative loss characteristics of this type of adhesively joined deck.

B.3 Rim Seals

All types of floating decks have an annular space between the perimeter or rim of the deck and the tank shell to permit travel of the deck within the tank. A rim seal is used with all types of floating decks to control evaporative loss from this annular rim area. An effective seal closes this rim space and accommodated irregularities between the deck and the tank shell. Normally, a single or primary seal is provided, although a second seal can be installed above the primary seal to provide some additional evaporative loss control.

Rim seals for internal floating roof tanks are usually nonmetallic, except when the tank , which is initially designed as an external floating roof tank with either nonmetallic or metallic seals is typically used. The use of nonmetallic materials results in a lightweight seal, which is typically constructed with a small vertical dimension. A lightweight seal is of particular interest with lightweight, nonferrous decks to limit the possibility of immersion of the edge of the deck. One possible cause of malfunction of internal floating decks is the overfilling of the tank and the consequent interference of the fixed roof rafters with the deck. Hence a low seal height and mounting do become necessary. Proper attention should be given height and mounting, and selection of the materials used in the seal construction because of the potential for chemical incompatibility with the stored product.

Two basic types of nonmetallic rim seals, namely flexible wiper seals and resilient filled seals are currently in widespread use. These rim seal types can be further characterized by the location of the seal relative to the stock liquid surface. Rim seals mounted on the floating deck, such that a vapor space exists between the liquid stock and the bottom of the seal, are referred to as vapormounted. If the bottom of the rim seal touches the liquid , it is referred to as a liquid - mounted seal. These primary seal types, as well as secondary seals, are described in B.3.1 through B.3.3 and illustrated in Figure B-1. Metallic seals are described in this work 2517 [3].

B.3.1 Flexible Wiper Seals (Vapor-Mounted)

Flexible wiper seals consist of a continuous annular blade of flexible material fastened to a mounting on the deck perimeter, spanning the annular in space, and contacting the tank shell. This seal type is shown in Figure B-1, drawing A. The mounting blade is flexible and its elasticity provides a sealing pressure against the tank shell. A vapor space exists between the liquid stock and the bottom of the seal . For evaporative loss control, it is important that the mounting and radial seal joints be essentially vapor - tight ; the seal be continuous around the circumference ; the blade be generally in substantial contact with the tank shell ; and the top of the seal not extend into the liquid during upward travel of the deck.

Two types of flexible wipers are commonly use. One type consists of a cellular, elastomeric material tapered in cross section with the thicker portion at the mounting. Buna - N rubber is a commonly - used material ; urethane and cellular plastic are also available.

A second type of wiper seal construction uses an open - cell foam core enclosed in a coated fabric. Polyurethane - coated nylon fabric and polyurethane foam are common materials. Reinforced Teflon and fluorocarbon fabrics are also available. The core provides the flexibility and support, while the fabric provides the vapor barrier and wear surface.

B.3.2 Resilient Filled Seals (Vapor - or Liquid - Mounted)

Resilient filled seals work on the principle of expansion and compression of a resilient material to maintain contact with the tank shell, while accommodating varying annular rim space widths. These seals consist of a core of open-cell foam enclosed in a coated fabric. The resiliency of the foam core pushes the fabric into contact with the tank shell. This seal type is shown in Figure B-1 , drawings B and C. The seals are attached to a mounting on the deck perimeter. Polyurethane-coated nylon fabric and polyurethane foam are commonly used materials. For evaporative loss control, it is important that the mounting and radial seal joints must be vaportight and the seal must be generally in substantial contact with the tank shell.

Resilient filled seals can be either vapor or liquid mounted. Figure B-1 shows a vapor-mounted seal in drawing B and a liquid-mounted seal in drawing C. The choice of mounting position is influenced by several design and operation factors.

B.3.3 Secondary Seals

Secondary seals may be used to provide some additional evaporative loss control. The secondary seal can be mounted to an extended vertical rim plate, as shown in Figure B-1, drawing B, Secondary seals can be either flexible wiper seals or resilient filled seals. The use of a secondary seal further limits the operating capacity of a tank because of the need to avoid interference of the seal with the fixed-roof raffers when the tank is filled. Currently , secondary seals are not commonly used on internal folating-roof tanks.

B.4 Deck Fittings

There are numerous fittings that pass through or are attached to a floating deck. These fittings serve to accommodate structural support members or to allow for operational functions. The fittings can be a source of evaporative loss because they require openings in the deck. Because other accessories used do not penetrate the deck, they are not sources of evaporative loss. The most common fittings that require deck openings are described B.4.1 through B.4.8.

B.4.1 Access Hatches

An access hatch consists of an opening in the deck with a peripheral vertical well attached to the deck and a removeable cover to close the opening. An access hatch is sized to provide for passage of workers and materials through the deck for construction or servicing. The cover can rest directly on the well, or a gasket can be used between the cover and the well to reduce evaporative loss. Bolting the cover to the well provides further loss reduction. With noncontact decks, the well extends into the liquid stock to seal off the vapor space below the deck.

B.4.2 Column Wells

The most common fixed-roof designs are supported from inside the tank by means of vertical columns, which necessarily penetrate the floating deck. Some fixed roofs are entirely self-supporting and, therefore, have no support columns. Columns are made of pipe, with a support columns. Columns are made of pipe, with a circular cross section, or are built up from structural shapes with irregular cross sections. The number of columns varies with tank diameter , from a minimum of 0 to over 80 for very large tanks.

The columns pass through deck openings with peripheral vertical wells. With noncontact decks, the well extends into the liquid stock. A closure exists between the top of the well and the column. Several proprietary designs exist for this closure, including sliding covers and fabric sleeves, which must accommodate the movements of the deck relative to the column as the stock level changes. A gasket interface between the cover and the well reduces evaporative loss.

B.4.3 Deck Legs or Hanger Wells

To prevent damage to fittings underneath the deck and to allow for tank cleaning or repair, supports are provided to hold the deck a predetermined distance from the tank bottom. These supports consist of : (1) adjustable or fixed legs attached to the floating deck or (2) hangers that suspend the deck from the fixed roof. For adjustable legs or hangers, the load-carrying element passes through a well or sleeve in the deck. With noncontact decks, the well extends into the liquid stock.

B.4.4 Gauge Float Wells

Gauge floats are used to indicate the level of stock within the tank. They usually consist of a float contained within a well that passes through the deck. The float is connected to an indicator on the exterior of the tank via a tape passing through a guide system on the fixed roof. The well is closed by a cover, which rests on the well. Evaporation loss can be reduced by gasketing and/or bolting the cover to the well. As with other similar deck penetrations, the well extends into the liquid stock on noncontact decks.

B.4.5 Ladder Wells

Some tanks are equipped with internal ladders, going from a manhole in the fixed roof to the tank bottom. The deck opening through which the ladder passes is constructed with disign details and considerations similar to those previously discussed for column wells.

B.4.6 Sample Pipes or Wells

A sample well may be provided to allow for sampling of the liquid stock. Typically, the well is funnel-shaped to allow for easy entry of a sample thief. A closure is typically located at the lower end of the funnel and frequently consists of a horizontal diaphragm slit radially to allow entry of the sample thief. The well extends into the liquid stock on non-contact decks.

Alternatively , a sample well may consist of a slotted pipe extending into the liquid stock, equipped with an ungasketed or gasketed sliding cover.

B.4.7 Stub Drains

These small penetrations may be spaces over the deck on bolted decks to allow any stock that may be on the deck surface to drain back to the underside of the deck. Typically, the drains are 1 inch in diameter and attached to the upper surface of the deck. The drains also extend into the liquid stock on non-contact decks.

B.4.8 Vacuum Breakers

A vacuum breaker is used to equalize the pressure of the vapor space across the deck, when the deck is either being landed on its legs or floated off its legs. This is accomplished by opening a deck fitting, which usually consists of a well formed of pipe or framing on which is a cover rest. The cover is attached to a guided leg of such length that it contacts the tank bottom when the deck just freely floats on the stock. During contacting with the tank bottom, the guided leg mechanically opens the vacuum breaker by fifting the cover off the well. When the leg is not contacting the bottom , the opening is closed by the cover resting on the well. The closure may be with or without a gasket between the cover and the well. Since the purpose of the vacuum breaker is to allow the free exhange of air and/or vapor, the well does not extend appreciably below the deck.

APPENDIX C

Description of External Floating Roof Tank

C.1 General Information [3]

External floating roof tanks are cylindrical vessels having a roof that floats on the surface of the liquid stock. In addition to a cylindrical shell, the basic components include (a) a floating roof, (b) an annular rim seal attached to the perimeter of the floating roof, and (c) roof fittings that penetrate the floating roof and serve operational functions. General types of these components, which are available in a range of commercial designs, are described in this section. Included in these descriptions are comments on the potential for evaporative loss, as well as some design and operational characteristics.

C.2 Floating Roofs

Floating roofs are used to control evaporative stock loss. The basic design concept is to reduce the liquid surface exposed to evaporation to a minimum by placing a floating roof in direct contact with the liquid surface. Evaporative loss due to standing storage is then limited to rim seal system and roof fittings. Floating roofs are used in volatile stock service, for stocks with a true vapor pressure at storage conditions below atmosphere pressure (that is, nonboiling). They are available in virtually all commercial tank sizes, from about 20 to 400 feet in diameter. Methods and materials have been developed to properly seal the annular rim space, which is located between the tank shell and the floating-roof rim, and to seal around the fittings that penetrate the floating roof.

Floating roofs currently constructed of welded steel plate are of three general types: pan, pontoon, and double deck. Although numerous pan-type floating roofs are currently in use, the present trend is toward pontoon and double-deck floating roofs. Figure C-1 and C-2 show an external floating-roof tank with a pontoon floating roof and a double-deck floating roof, respectively. Manufacturers supply various versions of these basic types of floating roof. Manufacturers supply various version of these basic types of floating roofs, which are tailored to emphasize particular features, such as full liquid contact, load-carrying capacity, roof stability , or pontoon arrangement.

C.3 Rim Seals

C.3.1 General Information

All types of floating roofs have an annular space between the tank shell and the floating roof rim to permit travel of the floating roof within the tank. A rim-seal system is used with all types of floating roofs to control evaporative loss from the rim space. Effective rim-seal systems close the rim space, accommodate irregularities between the floating roof and the tank shell, and help to center the roof, yet permit normal roof movement.

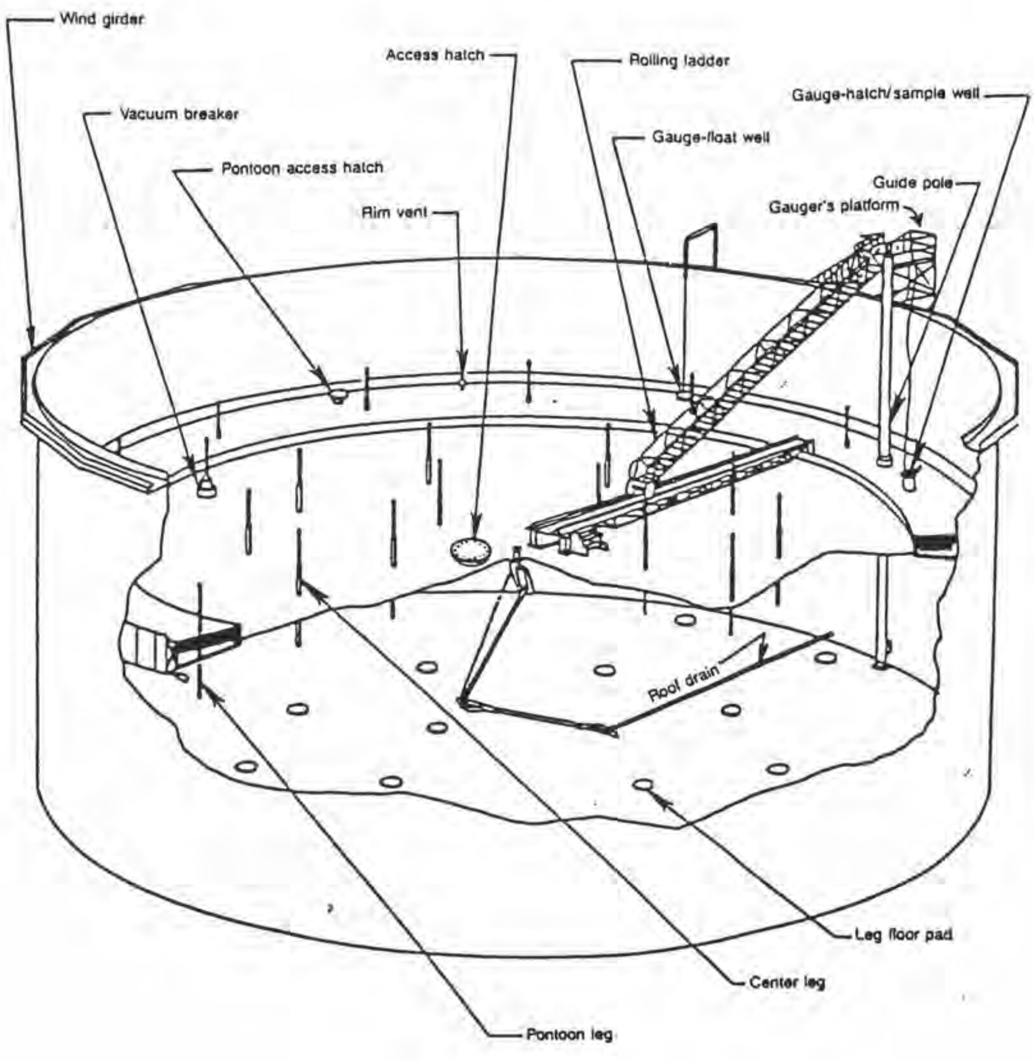


Figure C-1 External Floating-Roof Tank with Pontoon Floating Roof [3]

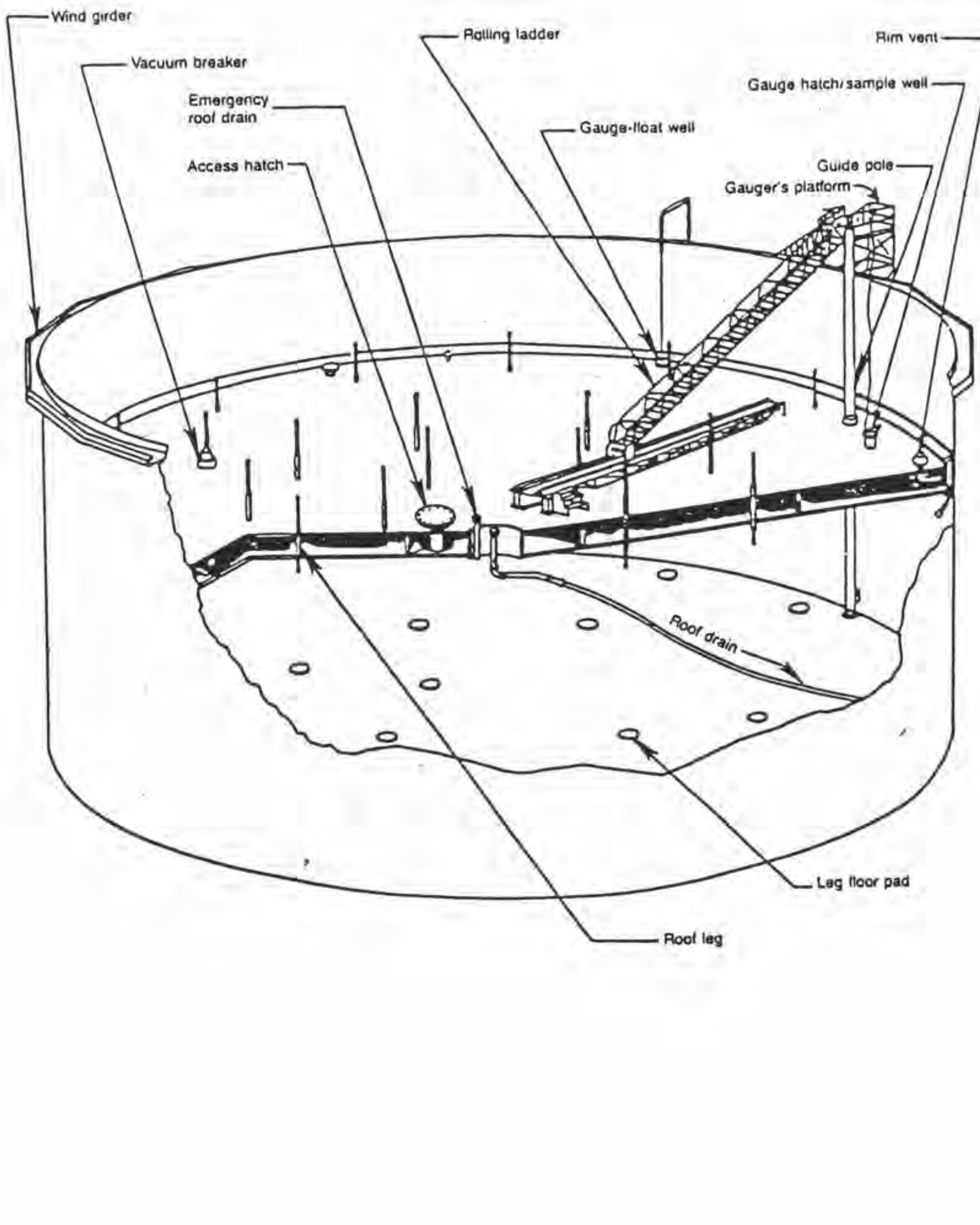


Figure C-2 External Floating-Roof Tank with Double Floating Roof [3]

A rim-seal system may consist of one or two separate seals : (a) the primary seal and (b) the secondary seal, which is mounted above the primary seal.

Three basic types of primary seals are currently in widespread use : (a) mechanical shoe (metallic), (b) resilient filled (nonmetallic), and (c) flexible wiper. Two basic configurations of secondary seals ae currently available : shoe mounted and rim mounted. In addition, some rim-seal systems include a weather shield. Other types of primary and secondary seals have been or are being developed , but these rim seals are not presently in wide use. A number of specific types of rim seals and weather shields, which represent most of the rim-seal systems currently in use, are described in C.3.2 through C.3.6

Factors used to determine evaporative loss have been developed only for rim seal systems with mechanical-shoe and resilient-filled primary seals.

Proper attention should be given to the selection of the materials used in the construction of rim seal systems because of the potential for chemical incompatibility with the stored product.

C.3.2 Mechanical-shoe Primary Seals

Mechanical-shoe (or metallic) primary seals have been in wide use for many years. Figure C-3 shows a typical mechanical-shoe primary seal. The identifying characteristic of this rim seal is that it uses a light-gauge metallic band as the sliding contact with the tank shell.

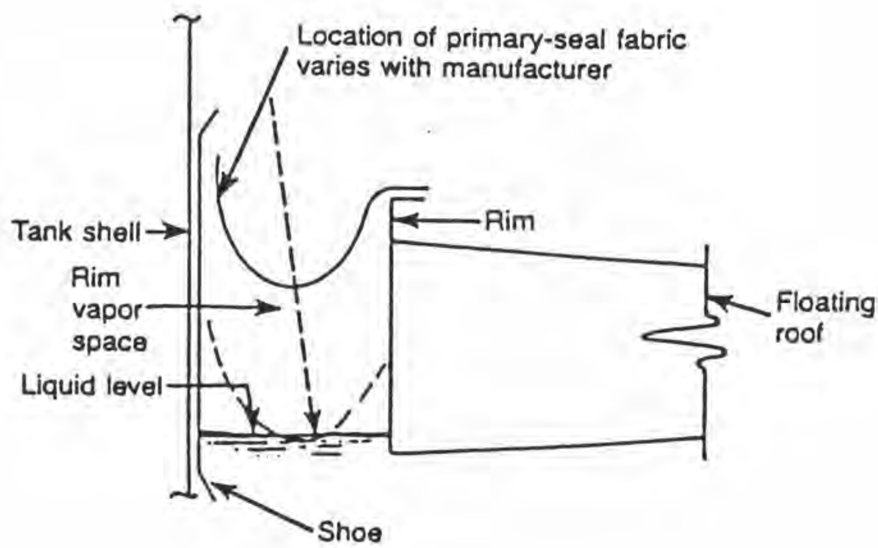


Figure C-3 Mechanical-Shoe Primary Seal [3]

The metallic band is supported and held against the tank shell by a mechanical device. The mechanical device varies with different manufacturers. The band is formed of sheets (shoes) and may vary in size with different manufacturers. The shoes are joined together to form a ring. The shoes are normally 3-5 feet dee[and thus provide a potentially large contact area with the tank shell. Expansion and contraction of the ring is provided for as the ring passes over shell irregularities or rivets.

This is accomplished by jointing narrow pieces of fabric into the ring or by crimping the shoes at intervals. The bottoms of the shoes extend below the liquid surface to confine the rim vapor space between the shoe and the floating-roof rim.

The rim vapor space, which is bounded by the shoe, the floating-roof rim, and the liquid surface, is sealed from the atmosphere by bolting or clamping a coated fabric, called the primary-seal fabric, that extends from the shoe to the rim. The specific type of fabric used varies with the tank manufacturer and the type of service.

Two locations are used for attaching the primary-seal fabric. With the most commonly used method, the fabric is attached to the top of the shoe and the floating-roof rim. With the reduced-rim-vapor-space method, the fabric is attached to the shoe and the floating-roof rim near the surface of the stored stock. These two positions of the primary-seal fabric are shown in Figure C-3. Rim vents (see C.4.10) can be used to relieve any excess pressure or vacuum in the rim vapor space.

Mechanical-shoe seals are usually designed to accommodate a local variation of +/- 5 inches in a normal 8-inch-wide rim space. Different design details ae available for tanks with large diameters or with rim spaces wider than 8 inches. The shoe sealing ring and mechanism ordinarily provide suffcient flexibility to accommodate nominal irregularities in the tank shell. Mechanical-shoe seals can easily be fitted with wear plates for longer service life in riveted tanks.

In normal use (that is , when the floating roof is kept continuously floating) mechanical-shoe seals have a good service life. In general, the primary-seal fabric begins to show signs of aging before the metallic parts show wear. Where mechanical-shoe seals are used with a corrosive product or with unusual operating practices, such as when the underside of the floating roof is frequently exposed to air, corrosion may be severe. In such service, the use of corrosion-resistant metals or special coatings can be advantageous.

Since the integrity of the enclosed rim vapor space is important with respect to controlling evaporative loss, repair of holes and other defects in the rim-seal system is desirable.

C.3.3 Resilient - Filled Primary Seals

Resilient-filled (or nonmetallic) primary seals have increased in popularity over the years. The identifying characteristic of this type of rim seal is the use of an elastomer-coated fabric envelope as the sliding contact with the tank shell as shown in Figure C-4. The envelop is

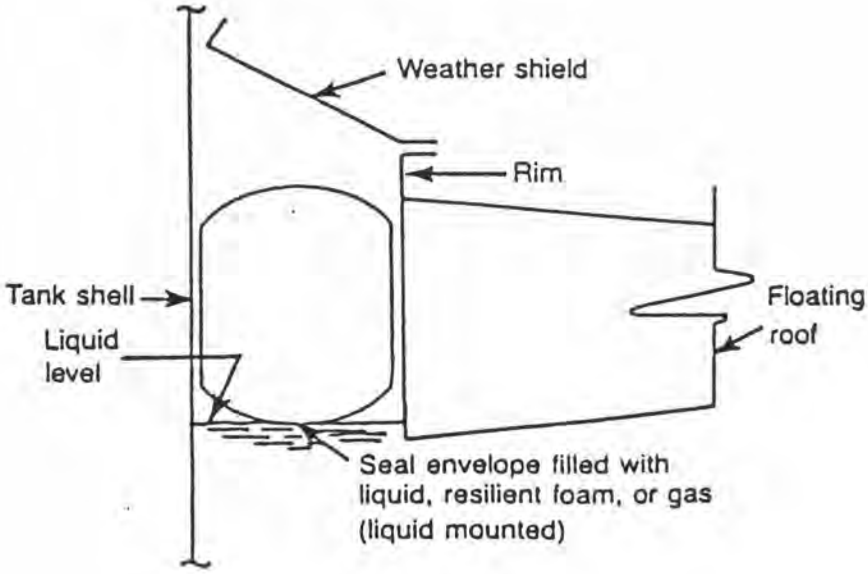


Figure C-4 Resilient-Filled Primary Seal [3] expanded by being filled with liquid, resilient foam, or gas, thus providing contact with the tank shell. The seal is attached to the rim of the floating roof so that it either touches the liquid surface (liquid mounted) or allows for a rim vapor space between the liquid and the seal (vapor mounted). Tanks with resilient-filled seals are often equipped with a weather shield or a secondary seal.

The main advantage of the resilient-filled seal is its flexibility. The fabrics used for the envelope are much more flexible than are mechanical-shoe seals, so there is better conformity to the tank shell. Most resilient-filled seals are designed to accommodate a normal variation of +/– 4 inches in a normal 8-inch-wide rim space. Different design details are available for tanks with large diameters or with rim spaces wider than 8 inches.

Since they are less abrasive than mechanical - shoe seals, resilient-filled seals are typically used if an interior coating has been applied to the tank shell. However, since the envelope rubs against the tank shell, projections from the shell, such as rivet heads or weld burrs, may cause wear and reduce the service life of this seal. Projections that might damage the envelope should be removed.

Vapor-mounted seals have an associated rim vapor space, which tends to contribute to evaporative loss. Also, since these rim seals have a relatively short vertical area in contact with the tank shell (compared with mechanical-shoe seals), gaps between the rim seal and the tank shell that communicate with the rim vapor space permit additional evaporative loss. On the other hand, vapor-mounted seals are not subject to deterioration from contact with the liquid stock surface.

Liquid-mounted seals, which touch the liquid surface, significantly reduce evaporative loss. However, coated fabrics in contact with hydrocarbon products , especially those with high aromatic content, have in some cases experienced reduced life or required increased maintenance. Recent advances in synthetic compounding have resulted in fabrics with increased compatibility with hydrocarbon products. Seal manufacturers can recommend the most suitable envelope fabric for particular applications.

Although resilient-filled seals have not been in service as long as mechanical-shoe seals, they too are known to have a good service life. Unlike mechanical-shoe seals, resilient-filled seals have only a few metallic parts that are subject to corrosion.

C.3.4 Flexible-Wiper Primary Seals

Flexible-wiper primary seals have been developed in recent years. The identifying characteristic of this type of rim seal is its use of an elastomeric blade as the sliding contact with the tank shell, as shown in Figure C-5. The flexible-wiper seal bridges the annulus between the floating-roof rim and the tank shell and uses its own stiffness or mechanical means to push the seal against the tank shell.

An advantage of this type of rim seal is its flexibility. The wiper is usually more flexible than are mechanical-shoe seals, so there may be

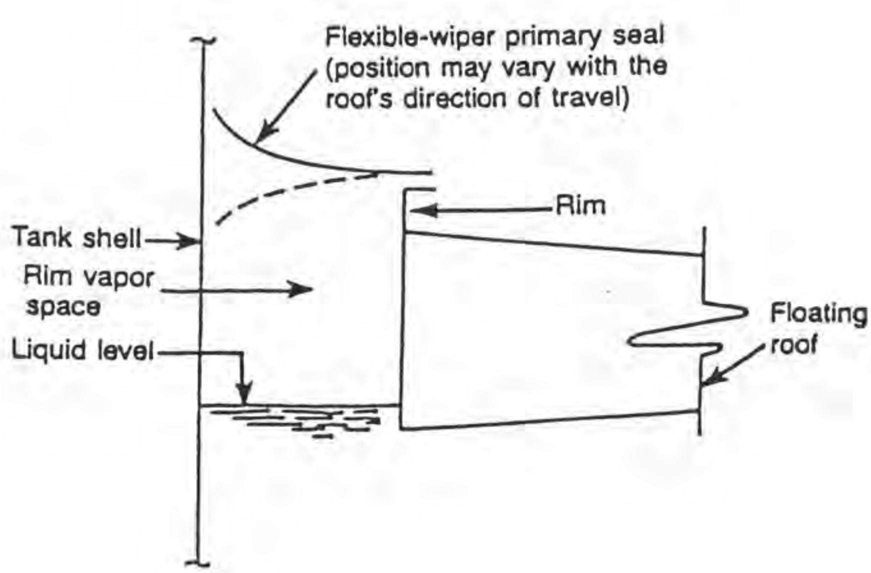


Figure C-5 Flexible-Wiper Primary Seal [3] better conformity to the tank shell. The flexible-wiper seal is usually mounted above the liquid to avoid any potential deterioration from liquid contact. Most flexible-wiper seals are designed to accommodate a local variation of about + / - 4 inches in a normal 8-inch-wide rim space. Special details may be required for tanks with large diameters or with rim spaces wider than 8 inches. Some flexible-wiper seals are designed to reverse when the floating roof's direction of travel reverses, as shown by the dotted line in Figure C-5.

Flexible-wiper seals have an associated rim vapor space, which tends to contribute to evaporative loss. Depending on the length of the vertical contact area between the flexible wiper and the tank shell, gaps between the rim seal and the tank shell permit additional evaporative loss, since they lead directly to the rim vapor space.

Because flexible-wiper seals have been used for a relatively short time, the expected service life is not well defined. As is the case for resilient-filled seals , the nonmetallic parts of flexible-wiper seals are not subject to corrosion.

C.3.5 Secondary Seals

Secondary seals can generally be divided into two categories : shoe mounted (see Figure C-6) and rim mounted (see Figure C-7). Rim-mounted secondary seals are more effective in reducing losses because they cover the entire rim vapor space. Shoe-mounted secondary seals, which are used only with mechanical-shoe primary seals, are effective in reducing losses

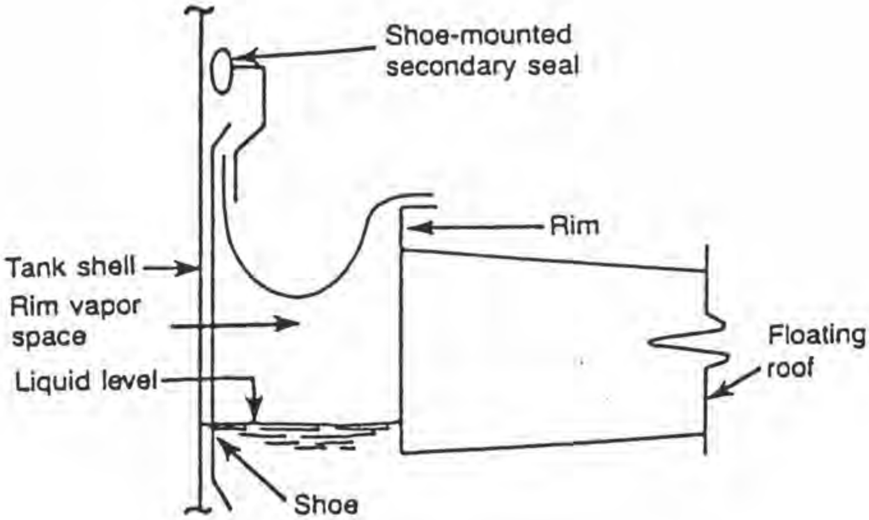


Figure C-6 Mechanical-Shoe Primary Seal with Shoe-Mounted Secondary Seal [3]

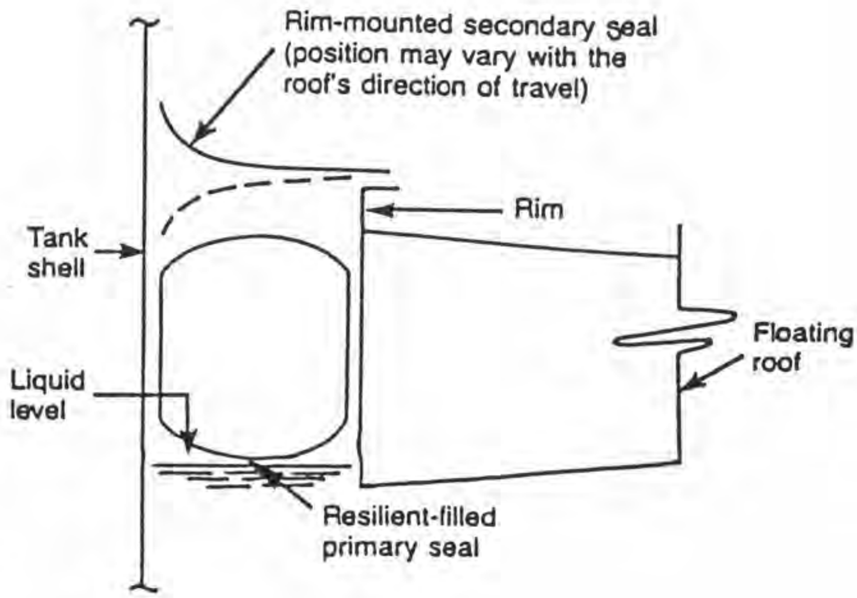


Figure C-7 Resilient-Filled Primary Seal with Rim-Mounted Secondary Seal [3] from gaps between the shoe and tank shell but do not reduce losses caused by defects in the primary-seal fabric.

Secondary seals are usually made from fabric or elastomeric materials, sometimes reinforced with metallic or nonmetallic stiffeners or guided by external attachments. Some secondary seals are designed to reverse as the floating roof's direction of travel reverses, as shown by the dotted line in Figure C-7. For secondary seals to be effective, they must maintain contact with the tank shell. Thus, the use of a secondary seal may reduce the effective capacity of the tank.

Properly fitted shoe-mounted secondary seals are known to provide a good service life. The service life of rim-mounted secondary seals has not yet been determined because of their recent use.

C.3.6 Weater Shields

When floating roofs that have a resilient-filled primary seal are not equipped with a secondary seal, most are furnished with weather shields, as shown in Figure C-4. Weather shields are usually of a leaf-type construction and have numerous radial joints to allow for movement of the floating roof and irregularities in the tank shell. Weather shields may be of metallic, elastomeric, or composite construction. They are normally attached to the floating roof with either a mechanical or a pliablehinge connection. Weather shields generally provide the primary seal with longer life by protecting the primary-seal fabric from deterioration due to exposure to weather , debris, and sunlight.

C.4 Roof Fittings

C.4.1 General Information

Numerous fittings pass through or are attached to a floating roof to allow for operational functions. Roof fittings can be a source of evaporative loss when they require openings in the floating rood. Other accessories are used that do not penetrate the floating roof and are thus not sources of evaporative loss. The most common fittings that require openings in the floating roof are described in C.4.2 through C.4.10.

C.4.2 Access Hatches

Figure C-8 shows a typical access hatch, which consists of an opening in the floating roof with a peripheral vertical well attached to the roof and a removable cover. An access hatch is sized to provide for passage of workers and materials through the floating roof for construction and maintenance. The cover can rest directly on the well, or a gasket can be used between the cover and the well to reduce evaporative loss. Bolting the cover to the well further reduces evaporative loss.

C.4.3 Unslotted Guide-Pole Wells

Figure C-9 shows a typical unslotted guide-pole well. Antirotation devices are used to prevent floating roofs from rotating and damaging rolling ladders, roof-drain systems, and rim seals and from interfering with float gauges. One commonly used antrirotation device is a guide pole that

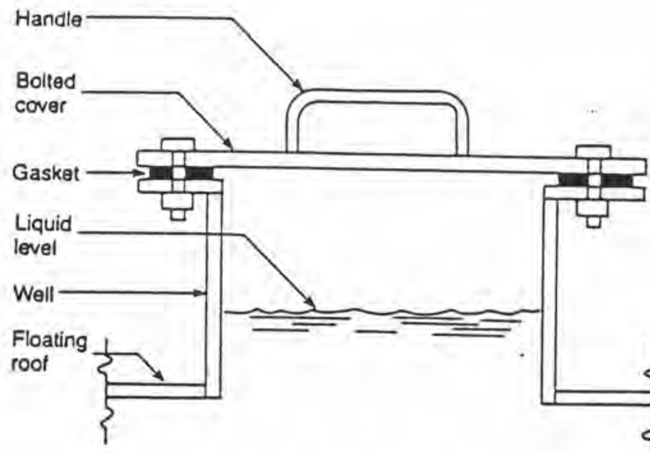


Figure C-8 Access Hatch [3]

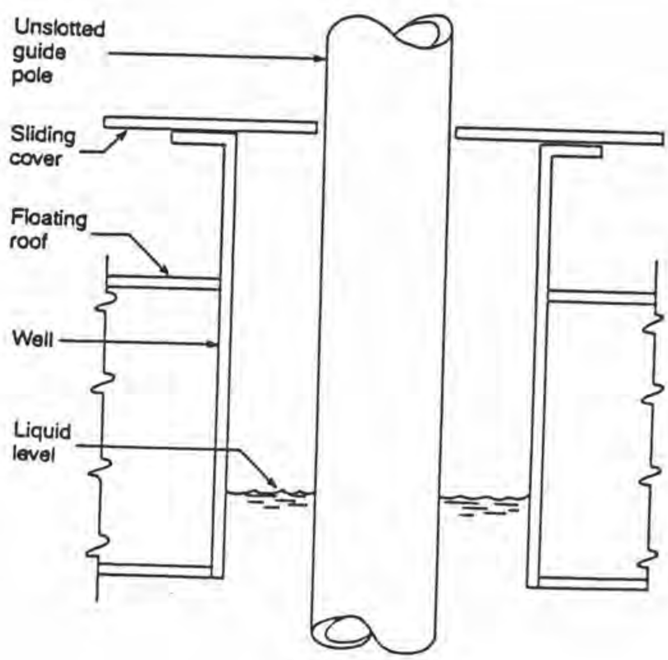


Figure C-9 Unslotted Guide-Pole Well [3] is fixed at the top and bottom of the tank. The guide pole passes through a well on the floating roof. Rollers attached to the top of the well ride on the outside surface of the guide pole to prevent rotation of the floating roof. The guide-pole well has a sliding cover to accommodate limited radial movement of the roof. The sliding cover can be equipped with a gasket between the guide pole and the cover to reduce evaporative loss. The guide-pole well can also be equipped with a gasket between the sliding cover and the top of the well to reduce evaporative loss. Openings at the top and bottom of the guide pole provide a means of hand gauging the tank level and of tanking bottom samples.

C.4.4 Slotted Guide-Pole/Sample Wells

Figure C-10 shows a typical slotted guide-pole/sample well. In this application, the wall of the guide pole is constructed with a series of holes or slots that allow the product to mix freely in the guide pole and thus have the same composition and liquid level as the product in the tank. To reduce evaporative loss caused by these openings, a removable float is sometimes placed inside the guide pole.

C.4.5 Gauge-Float Wells

Figure C-11 shows a typical gauge-float well. Gauge floats are used to indicate the level of stock within the tank. They usually consist of a float contained within a well that passes through the floating roof. The float is connected to an indicator on the exterior of the tank by a cable or tape that passes through a guide system. The well is closed by a cover

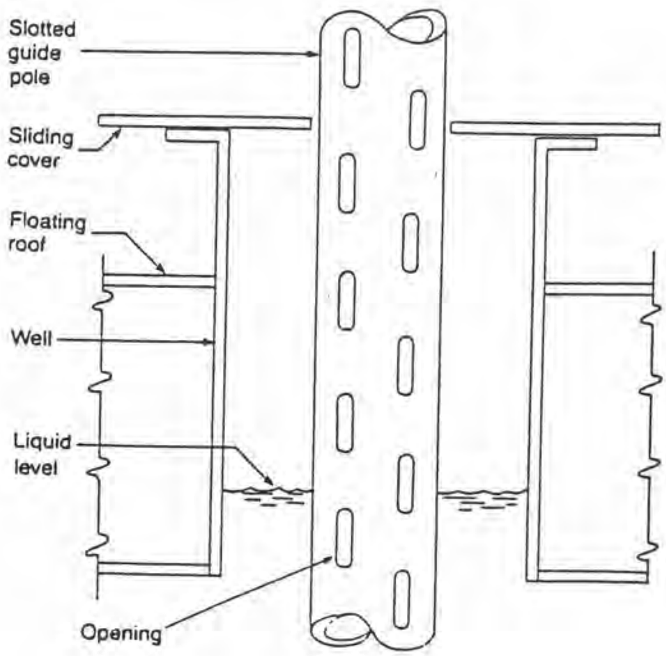


Figure C-10 Slotted Guide-Pole / Sample Well [3]

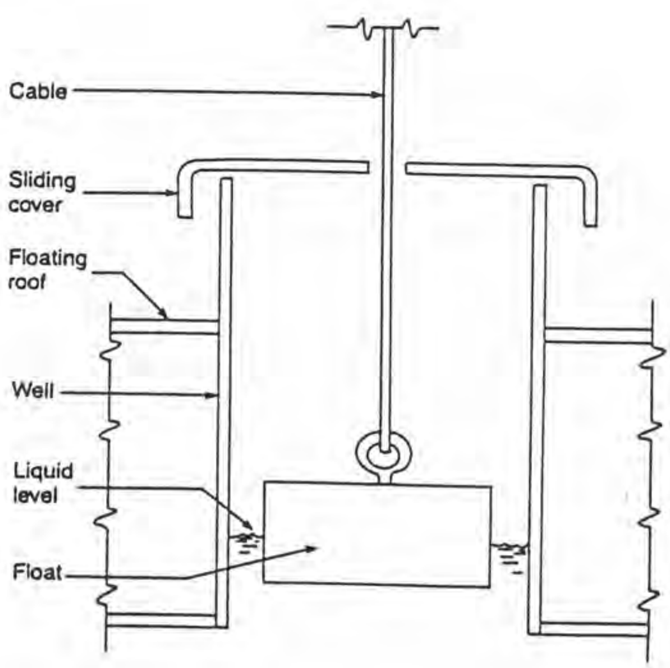


Figure C-11 Gauge-Float Well [3]

that contains a hole through which the cable or tape passes. Evaporative loss can be reduced by gasketing and/or bolting the cover to the well.

C.4.6 Gauge-Hatch / Sample Wells

Figure C-12 shows a typical gauge-hatch/sample well. Gauge-hatch/sample wells provide access for hand gauging the level of stock in the tank and for taking thief samples of the tank contents. A gauge-hatch/sample well consists of a pipe sleeve through the floaing roof and a self-closing gasketed cover. Gauge hatch/sample wells are usually located under the gauger's platform, which is mounted on the top of the tank shell. The cover may have a cord attached so that it can be opened from the gauger's platform. A gasketed cover will reduce evaporative losses.

C.4.7 Vacuum Breakers

Figure C-13 shows a typical vacuum breaker. A vacuum breaker is used to equalize the pressure in the vapor space beneath the floating roof when the roof is either landed on its legs or floated of its legs. This is accomplished by opening a roof fitting, usually a well formed of pipe on which rests a cover. A guided leg is attached to the underside of the cover and comes in contact with the tank bottom just at the point when the roof floats freely on the stock. When the leg is in contact with the tank bottom, it mechanically opens the vacuum breaker by lifting the cover off the well. When the leg is not in contact with the bottom, the opening is closed by the cover resting on the well. Some vacuum breakers have adjustable legs to permit changing the roof level at which the leg

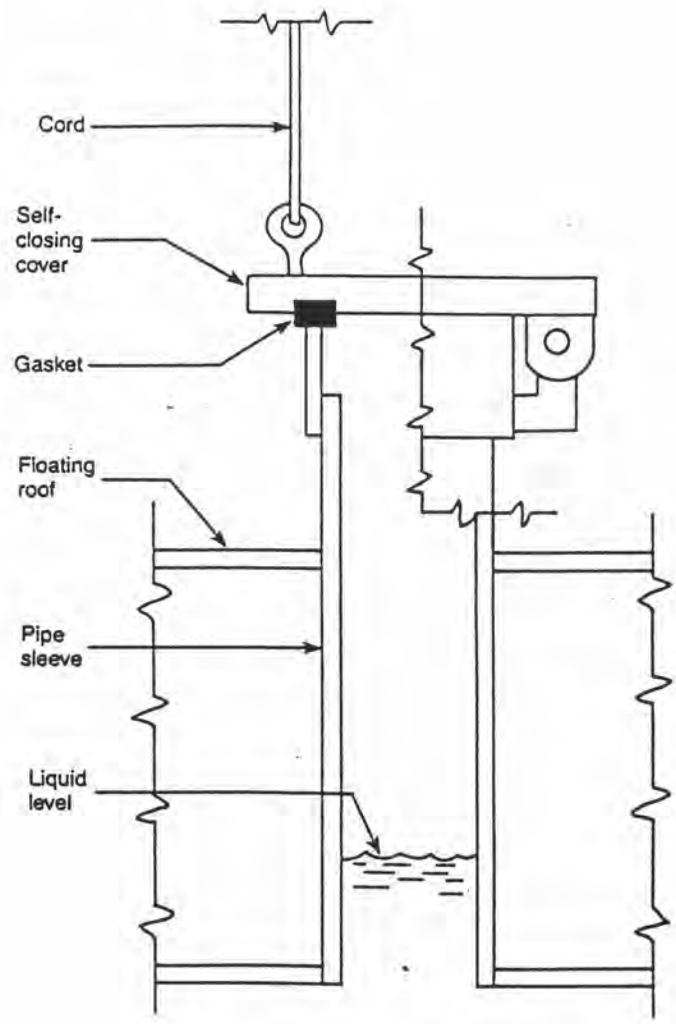


Figure C-12 Gauge-Hatch / Sample Well [3]

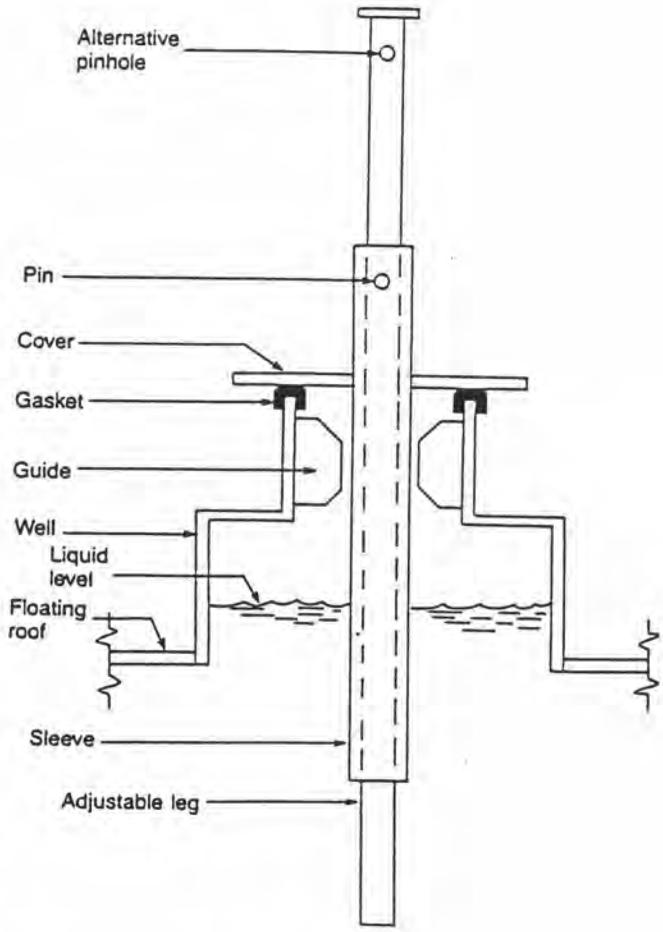


Figure C-13 Vacuum Breaker [3]

contacts the bottom. Since the purpose of the vacuum breaker is to allow the free exchange of air or vapor, the well does not extend appreciably below the bottom of the floating roof. A gasket can be used to reduce the evaporative loss when the cover is seated on the well.

C.4.8 Roof Drains

Roof drains permit removal of rainwater from the surface of floating roofs. Two types of floating-roof drainage systems are currently used : closed and open.

Closed drainage systems carry rainwater from the surface of the floating roof to the outside of the tank through a flexible or articulated piping system or throuth a flexible hose system located below the floating roof in the product space. Since product does not enter this closed drainate system, there is no associated evaporative loss.

Open drainage systems permit drainage of rainwater from the surface of the floating roof into the product. Roof drains in these systems consist of an open pipe that extends a short distance below the bottom of the floating roof. Since these drainpipes are filled with product to the product level in the tank, evaporative loss occurs from the top of the drainpipes. Open drainage systems can only be used on double-deck floating roofs.

Two types of roof drains are currently in common use in open drainage systems : flush drains and overflow drains. Flush drains have a drain opening that is flush with the top surface of the double deck. They permit raineater to drain into the product. Overflow drains consist of a drain into the product. Overflow drains consist of a drain opening that is elevated above the top surface of the floating roof. Overflow drains limit the maximum amount of rainwater that can accumulate on the floating roof and are thus used to provide emergency drainage of rainwater. They are normally used in conjunction with a closed drainage system to carry rainwater to the outside of the tank. Figure C-14 shows a typical overflow roof drain.

For pontoon floating roofs, proprietary drain designs that employ manometer or membrane seals are available but are not commonly used. Some open roof drains are equipped with an insert to reduce the evaporative loss. Care must be taken in the design and use of the insert to avoid impairment of the fitting's drainage ability.

C.4.9 Roof Legs

Figure C-15 shows a typical roof leg. To prevent damage to fittings located beneath the floating roof and to allow clearance for tank cleaning or repair, roof legs are provided to hold the floating roof at a predetermined distance above the tank bottom when the tanks is emptied. The larger the diameter of the tank, the greater the number of legs required. Roof legs generally consist of an adjustable pipe leg that passes through a slightly larger diameter vertical pipe sleeve. The sleeve is welded to the floating roof, extending both above and below it. Steel pins are passed through holes in the sleeve and leg to permit height adjustment. The length of the sleeve above the floating roof varies, depending on its

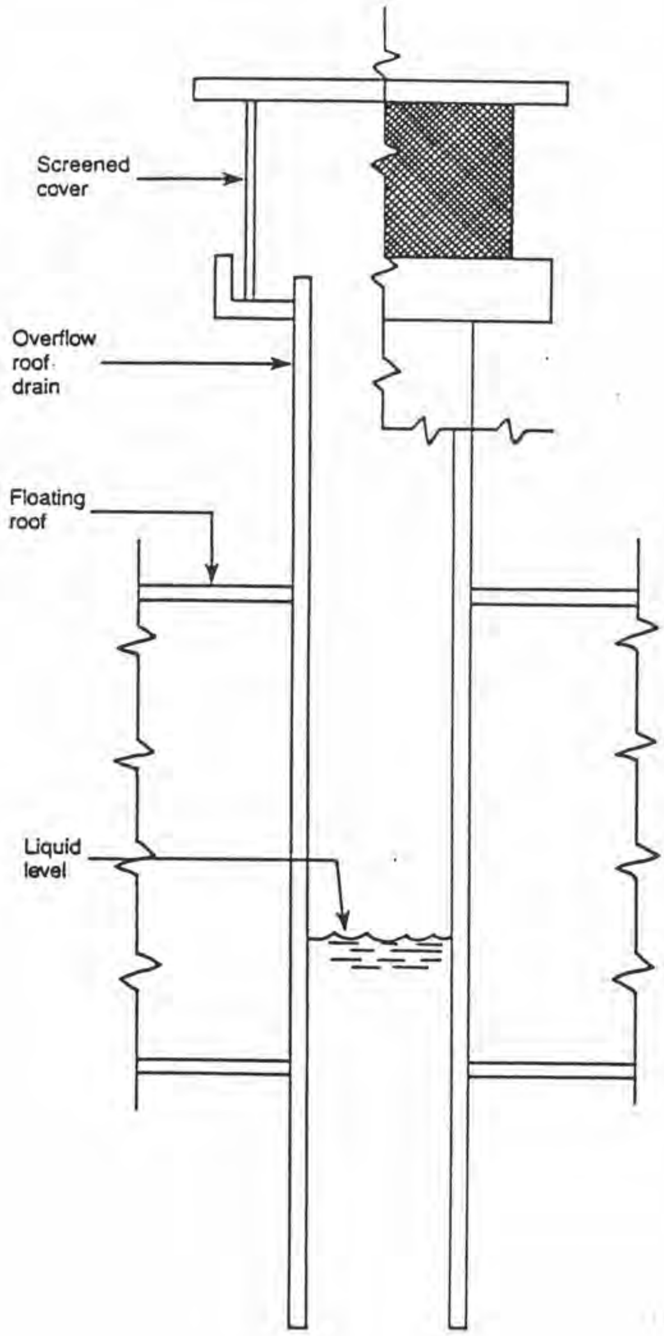


Figure C-14 Over Flow Roof Drain [3]

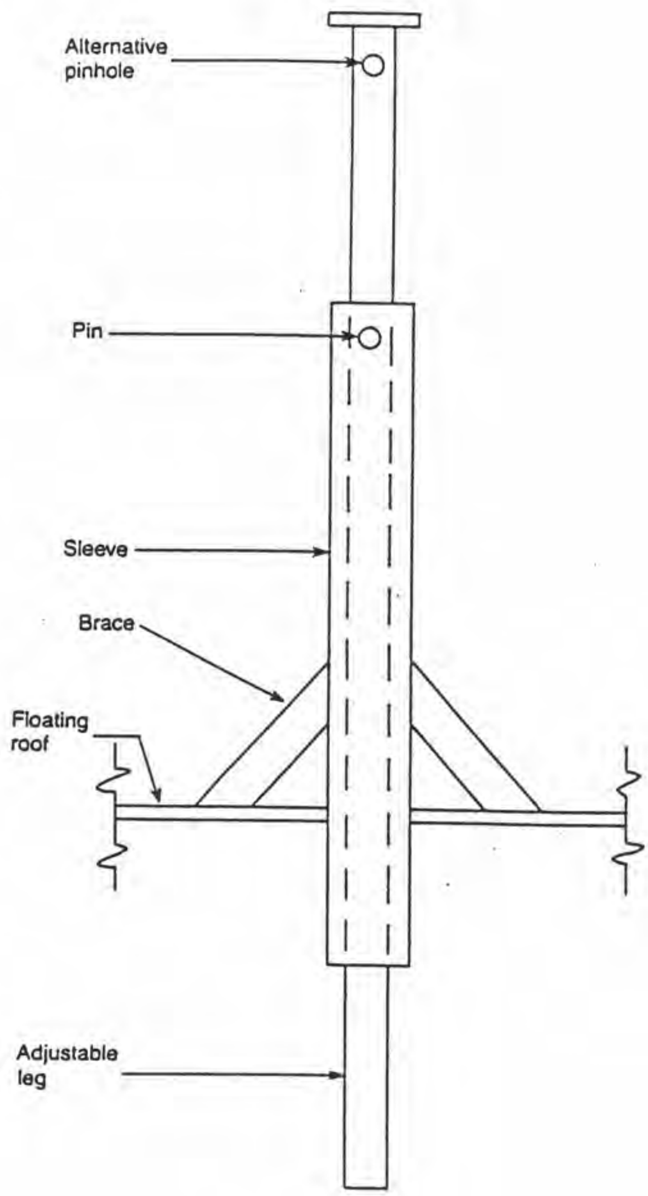
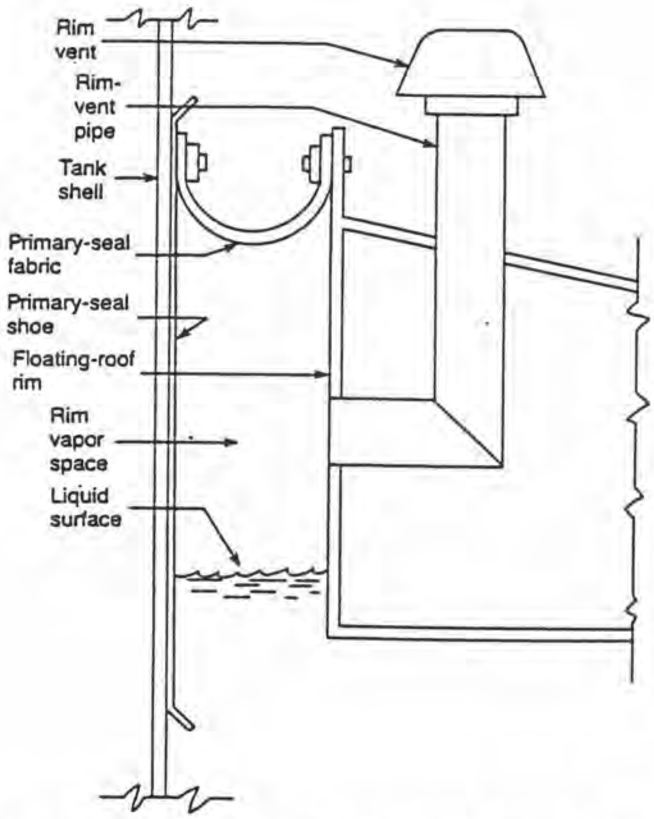


Figure C-15 Roof Leg [3]

location on the roof. Evaporative loss occurs in the annulus between the leg and its sleeve.

C.4.10 Rim Vents

Figure C-16 shows a typical rim vent. Rim vents are normally supplied only on tanks equipped with a mechanical-shoe primary seal. The rim vent is connected to the rim vapor space by a pipe and releases any excess pressure or vacuum that is present. The rim vapor space is bounded by the floating-roof rim, the primary-seal shoe, the liquid surface, and the primary-seal fabric , as shown in Figure C-16. Rim vents usually consist of weighted pallets that rest on gasketed surfaces.



Note: Rim vents are normally supplied only on tanks equipped with a mechanical-shoe primary seal.

Figure C-16 Rim Vent [3]

APPENDIX D

Thailand Meteorological Data [9]

Location	Average Temperature(°F)	Average Min. Temperature(°F)	Average Max. Temperature(°F)	Wind Speed (Miles / Hr.)
Chiang Mai	78.4	68.7	89.9	2.21
Lampang	79.0	69.3	92.2	1.38
Phare	79.3	70.4	91.9	2.78
Phitsanulok	82.2	73.9	92.4	1.49
Udonthani	81.1	71.7	90.1	2.20
Khonkhaen	80.4	72.7	91.0	2.12
Ubonratchathani	80.7	71.7	91.2	3.97
Nakhonratchasima	81.1	72.6	91.4	2.05
Lopburi	82.7	74.9	93.4	3.34
Bangkok Metropolis	82.8	76.0	91.4	3.27
Don Muang Airport	83.4	76.6	92.0	5.05
Chonburi	83.1	76.6	92.0	4.04
Pattaya	81.9	77.0	88.4	4.97
Rayong	82.6	76.9	90.1	5.30
Suratthani	80.1	72.8	90.6	1.90
Songkhla	82.6	76.7	88.6	6.68
Phuket	82.6	76.6	90.6	3.04

VITA

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