This chapter is devoted to the discussion of storage tanks of crude oil and other hydrocarbons, vapor recovery units (VRUs), and piping in the oil field, including gathering schemes.

8.1 STORAGE TANKS

8.1.1 Introduction

The design of storage tanks for crude oil and petroleum products requires, in general, careful consideration of the following important factors:

- The vapor pressure of the materials to be stored
- The storage temperature and pressure
- Toxicity of the petroleum material

In order to meet the environmental constraints on air pollution, to prevent fire hazards, and to avoid losses of valuable petroleum products at the same time, it is recommended to adopt the following:

- The use of floating-roof tanks for petroleum materials with a vapor pressure of 1.12–11.5 psia (at the storage temperature) or
- Using fixed-roof tanks along with the VRU system (to be described later).

These alternatives are schematically illustrated in Figure 1.

Storage tanks for crude oil are needed in order to receive and collect oil produced by wells, before pumping to the pipelines as well as to allow for measuring oil properties, sampling, and gauging.
8.1.2 Types of Storage Tank

The main features of some of the common types of storage tank used by the petroleum industry in general are presented in Table 1. The atmospheric tank, or standard storage tank, is one that is designed to be used within plus or minus a few pounds per square inch of atmospheric pressure. It may be open to the atmosphere (vented) or enclosed.

As will be explained next, an effective method of preventing vent loss in a storage tank is to use one of the many types of variable-volume tank.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Standard Storage Tanks</th>
<th>Conservation-Type Storage Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation losses</td>
<td>High</td>
<td>Significantly reduced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Significantly reduced</td>
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<tr>
<td></td>
<td></td>
<td>Prevented or eliminated</td>
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<tr>
<td>Operating conditions</td>
<td>Recommended for</td>
<td>Allow no vapor space above the</td>
</tr>
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<td></td>
<td>liquids whose vapor</td>
<td>liquid; level (no venting)</td>
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<td></td>
<td>pressure is atmospheric</td>
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<tr>
<td></td>
<td>or below at storage</td>
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</tr>
<tr>
<td></td>
<td>conditions (vented).</td>
<td></td>
</tr>
<tr>
<td>Sub-classification</td>
<td>1. Rectangular</td>
<td>1. Lifter roof, which</td>
</tr>
<tr>
<td></td>
<td>2. Cylindrical:</td>
<td>is a gas holder mounted on a</td>
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<tr>
<td></td>
<td>a) Horizontal</td>
<td>standard storage tank.</td>
</tr>
<tr>
<td></td>
<td>b) Vertical</td>
<td>2. Vapor-dome</td>
</tr>
<tr>
<td>Typical types</td>
<td>Cone-roof-vertical</td>
<td>Floating-roof, wiggins-Hidek</td>
</tr>
<tr>
<td></td>
<td>(cylindrical tanks)</td>
<td>type</td>
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<td></td>
<td></td>
<td>Lifter roof tanks, wiggins dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>seal type</td>
</tr>
<tr>
<td>Applications</td>
<td>Heavy refinery products</td>
<td>Sour crude oils, light crude</td>
</tr>
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<td></td>
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<td>oils, light products.</td>
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<tr>
<td></td>
<td>Light refinery product</td>
<td>Light refinery product and</td>
</tr>
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<td></td>
<td></td>
<td>distillates</td>
</tr>
</tbody>
</table>

| III (Pressure Storage)   |                        | Spheroids and hemispheroids for |
|                          |                        | low pressure storage, spheres   |
|                          |                        | for high pressure storage       |
|                          |                        | Spheroids are used to store     |
|                          |                        | aviation, motor, jet fuels.     |
|                          |                        | Spheres are used to store       |
|                          |                        | natural gasoline and LPG.        |
(type II in Table 1). These are built under API Standard 650. They may have floating roofs of the double-deck or single-deck type. These are lifter-roof types in which the roof either has a skirt moving up and down in an annular seal or is connected to the tank shell by a flexible membrane.

### 8.1.3 Sizing the Storage Tanks

The following is the guidelines to estimate the storage capacity for an oil-producing facility; select the number of storage tanks of crude oil.

1. To determine the capacity of storage tanks, the following rules apply:
   
   (a) For one well, the capacity per storage tank should be adequate enough for at least 2–3 days’ production.
   
   (b) For a group of wells (entire field), the total tank capacity should be adequate enough for at least 3–4 days of oil production by that field.

2. To determine the number of storage tanks as a function of the number of producing wells. This relationship is represented graphically in Figure 2.

To illustrate the application of these guidelines, the following example is cited. However, it should be emphasized that their use is restricted to small- to medium-size oil field installations.

![Figure 2](image)

**Figure 2** Guidelines for selecting the number of storage tanks as a function of the number of producing wells (for small- to medium-size installations).
Example 1
For a lease consisting of five producing wells, each with an average production capacity of 10,000 bbl/day, find the approximate total storage capacity and the number of storage tanks.

Solution
Using rule a,

\[
\text{Capacity or the size of one tank} = \frac{2-3 \text{ days of oil production/well}}{C_0} = (2.5)(10,000) = 25,000 \text{ bbl/well}
\]

Now, for five wells,

\[
\text{Total storage capacity} = (5)(25,000) = 125,000 \text{ bbl}
\]

Using correlation,

\[
\text{Storage capacity for the entire lease} = \frac{3-4 \text{ days of oil production by lease}}{C_0} = (3.5)(50,000) = 175,000 \text{ bbl}
\]

Conclusions:

The number of storage tanks according to rule a is 125,000/25,000 = 5 tanks
The number of storage tanks according to rule b, assuming storage capacity per tank the same as computed in rule a is 175,000/25,000 = 7 tanks

Finally, the number of storage tanks as computed graphically, using Figure 2 is 4. Now, comparing the results obtained, the appropriate number of storage tanks required by the lease is five to six.

8.2 VAPOR RECOVERY UNITS

8.2.1 Background
The loss of hydrocarbon vapors formed above crude oil or its products—when stored—could be minimized using what is called vapor recovery units (VRUs). If allowed to escape to the atmosphere, these vapors will
not only cause a loss of income due to loss of hydrocarbon volume and change in the API of the oil but will also lead to pollution and fire hazards.

The three main functions for the vapor recovery system are (as illustrated in Fig. 3) as follows:

1. To collect vapor from storage/loading facilities
2. To reliquefy vapors
3. To return liquid hydrocarbons to storage

Basically, when we talk about a VRU, what we are looking for is to hook our storage tanks to a “breather” system such as the following:

- During the day, when the temperature rises and vaporization of the hydrocarbons occur, excess vapors can be released and collected by the VRU.
- At night, when the vapors cool and condensation takes place leading to partial vacuum, vapors from the VRU will be admitted into the tanks.
- While pumping in and pumping out liquids to and from the storage tanks, vapors could be vented, [i.e., collected and drawn in, respectively, by such a breather system (VRU)].
8.2.2 Types of Storage Loss

In general, hydrocarbon losses in storage tanks are identified as follows:

Working losses
   (a) Filling
   (b) Emptying

Other losses
   (a) Breathing
   (b) Standing
   (c) Boiling

*Filling losses* occur when vapors are expelled from a tank as it is filled, no matter how the vapors are produced. This loss occurs when the pressure inside the tank exceeds the relief-valve pressure. For API tanks, the relief pressure is low and, therefore, filling losses can be relatively high.

*Emptying losses* are experienced by the vapors that are expelled from a tank after the liquid is removed from it. Because vaporization lags behind the expansion of the vapor space during withdrawal, the partial pressure of a hydrocarbon vapor drops. Enough air enters during the withdrawal to maintain the total pressure at the barometric value. However, when vaporization into the new air reaches equilibrium, the increase in the vapor volume will cause some vapor expansion.

*Breathing losses* occur when vapors are expelled from a tank under one of the following conditions:

1. The thermal expansion of the existing vapors
2. An expansion caused by barometric pressure changes
3. An increase in the amount of vapors from added vaporization in the absence of a liquid level change

Breathing losses take place in most types of tanks and occurs when the tank’s limits of pressure or volume changes are exceeded.

The fixed-roof API type tanks used to store stock tank oil are designed for only for a few inches of water pressure or vacuum and suffer relatively large breathing losses.

*Standing losses* are losses of vapor which result from causes other than breathing or a change in liquid level in tanks. Sources of standing losses are vapor escape from hatches or other openings and from glands, valves, and fittings.

*Boiling losses* occur when liquid boils in a tank and vapors are expelled. In other words, the vapor pressure of the liquid exceeds the surrounding pressure.
8.2.3 Vapor Recovery Methods

Ideally, it would be best to design a tank or a storage system to operate at pressures high enough to suppress evaporation; hence minimizing evaporation losses. However, this is not generally economical; also, refiners require crude oil to meet maximum vapor pressure specifications.

Various methods can be recommended to recover vapors generated in storage tanks and from other sources such as liquified petroleum gas (LPG) tankers. These usually involve one or a combination of the following schemes implemented through what is referred to as the VRU:

- **Absorption**: Usually carried out under pressure using a liquid solvent of higher molecular weight than that of the vapors being recovered. Vapors are then separated from the rich solvent, which is recycled in the process as “lean solvent.”
- **Condensation**: Vapors can be totally or partially condensed by compression and cooling, as shown in Figure 3.
- **Simple cooling**: Cooling the vapors without compression may condense the vapors, but it is not normally economical unless refrigeration is applied.
- **Adsorption**: Hydrocarbon vapors mixed with noncondensable gases, such as air, can be adsorbed by molecular sieves, activated charcoal, or silica gel. Heat or depressurization will remove the adsorbed vapors from the solid bed. The vapors could then be condensed for recovery.

The basic part of equipment operating the VRU is the vapor regulator setup (see Figure 4). The basic functions of the regulator are the following:

1. Release vapor from the storage tank battery when the normal operating pressure within the system increases beyond a preset value

![Figure 4](image)  
**Figure 4**  Vapor regulator system connected to storage tanks.
2. Add vapor to the battery system if the normal operating pressure decreases and reaches a preset value.

One should mention that, in addition to this vapor regulator, other automatic relief valves are found in the VRU. The system works automatically and in harmony. The breather valve operates if excessive pressure or vacuum exists, whereas the manhole relief functions if abnormal pressure or vacuum is experienced in the system. Values of pressure settings of the different instruments in the system are illustrated in Figure 5.

**Figure 5** Chart for pressure setting for the VRU. (After Chilingar and Beeson.)
Finally, it should be pointed out that the loss of vapors from oil during storage results in the following:

- A decrease in the API gravity of the oil, which degrades its quality
- A reduction in the volume of oil to be sold

The loss in volume of oil per degree of API gravity reduction varies depending on the original gravity of the oil. On average, a 2% volume loss is experienced per one degree reduction in the API gravity of the oil, as exemplified in Figure 6.

8.3 PIPING AND THE OIL FIELDS

8.3.1 Introduction

Today, there is great diversity in size of pipes used to carry crude oil and refined products, ranging from 2 in. to as much as 36 in. and in some cases, even 48-in. piping is used. In general, there are four types of pipeline:

1. Oil field gathering pipelines; their function in an oil field is of great impact on production operations.
2. Pipelines which run from the oil field to loading ports and are complementary to ocean transport.
3. Long-distance pipelines, which naturally shorten the alternative sea route.
4. Pipelines which transport oil from ports of discharge to inland refineries located in industrial areas, remote from a seaport.

### 8.3.2 Pipeline Gathering Schemes

Figure 7 illustrates the transport of oil by pipelines. It is a collection of pipelines that takes oil from wellhead all the way to the loading ports or refineries. Crude oil is collected from each individual wellhead by small-diameter pipelines, which then converge on a collecting center. At the collecting center, oil is directed to the gas–oil separating plant (GOSP) to

**Figure 8** Oil field gathering system: typical four schemes. (After Yocum.)
Figure 7  Piping system and oil field. (After Abdel-Aal and Schmelzlee.)
separate gas from oil. Usually, a number of collecting centers are found in an oil field.

From the collecting center, pipes of large diameter lead the crude oil to a tank farm. From there, oil is conveyed either to refineries or to storage tanks at the terminals for overseas delivery by tankers or by long-

Figure 9  Different functions of piping. (After Yocum.)
distant pipelines. Figure 8 presents a block diagram for the different functions of piping in an oil field.

As far as the design of a gathering system in an oil field is concerned, four different schemes are presented:

1. Individual (gathering) flow lines through which oil wells are connected to a central GOSP.
2. Trunklines and short flow lines. Well effluents, in this scheme, are directed into a large trunkline via short flow lines. Crude oil is directed to the GOSP by a trunkline.
3. Trunkline and branches, where major trunklines are 30–50 miles long and 24–30 in. in diameter, gather crude oil from branch trunklines, which, in turn, collect oil from short flow lines connected to the wells. The branch trunklines are smaller in diameter than the main trunklines (16–20 in.) and much shorter.
4. Wellhead separation, in which case the oil exiting different wells is delivered to the GOSP through very short gathering lines. The separated crude oil is then transferred from GOSP using trunklines.

The function of the four schemes described are diagrammatically sketched in Figure 9.

BIBLIOGRAPHY

REVIEW QUESTIONS

1. List the different types of storage tank.
2. What is the difference between floating-roof tanks and fixed-roof tanks? Which one requires the installation of a vapor recovery unit? Why?
3. A small field has 20 producing wells, each well produces an average of 8000 bbl/day. Determine the required field storage capacity and the number of storage tanks needed.
4. Describe the five types of storage-tank loss.
5. What effects does vapor loss have on the stored crude oil?
6. Under what conditions should a vapor recovery unit be included in field facilities? Why?
7. What are the main functions of vapor recovery units?
8. Describe briefly the four methods used for vapor recovery.
9. What are the main functions of the vapor regulator in a vapor recovery unit?