

1.2 STORAGE OF LPG

INVESTIGATIONS AND DESIGN

1. Site selection and geo mapping
2. Seismic surveying
3. Core drillings, water loss measurements, and water table observations
4. Logging of core samples and rock mass quality assessment
5. Laboratory tests
6. Inspection, monitoring, and control during excavation

The design of cavern projects as consisting of four distinct steps.

- 1. Selection of location:**

This is the most important single step in the design chain, and every effort should be directed toward making the right selection.

- 2. Orienting the longitudinal axis of the opening:**

This is to be done so as to minimize stability problems and over break.

- 3. Shaping the opening:**

Properly shaped openings will favorably distribute stresses along the periphery.

- 4. Dimensioning the opening:**

In Norway, this is usually based on empirical techniques. Economic and operational considerations must also be taken into account here.

UNDERGROUND STORAGE TECHNOLOGY

The following types of underground storage technologies are in application:

- Underground unlined storage
- Underground lined storage

Underground Unlined Storage

More than 200 facilities for the underground storage of petroleum products in unlined caverns have been completed successfully in Finland, Norway, and Sweden since the mid-1960s.

For successful application of this storage technique, four prerequisites must be fulfilled

1. Competent and stable rock conditions, suitable for construction of large openings, must exist
2. The stored product must be lighter than water.
3. The stored product must be insoluble in water.
4. The rock surface in contact with the stored product must hold a pore water pressure higher than the static pressure exerted by the stored product.

Storage under Atmospheric Pressure

Products such as kerosene, gasoline, light oil, and heavy fuel oils are usually stored under atmospheric pressure. This is carried out in the following way

1. A cavern is blasted out immediately below the absolute lowest groundwater level.
2. Groundwater leaking into the cavern is pumped out, with the result that the groundwater table around the cavern sinks until it is on a level with the bottom of the cavern. Continuous pumping ensures that the groundwater surface is maintained at this lower level.
3. The product can now be stored in the cavern, floating freely on the groundwater surface at the bottom of the cavern.

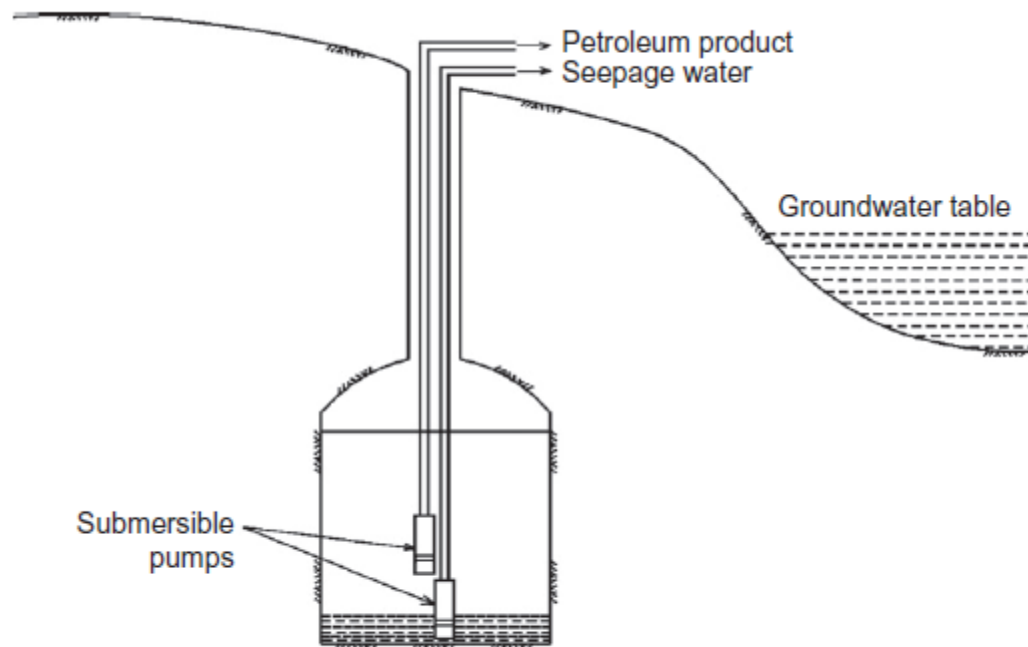


FIGURE 9.2 Petroleum product stored in a cavern under atmospheric pressure.

Storage under High Pressure

- In case of pressurized storage, the rock cavern is located at such a depth below the groundwater level that the hydrostatic pressure exceeds the gas liquefaction pressure at the temperature of the rock.
- This means, for example, that a storage plant for propane must be located approximately 100 m below the groundwater level to meet the pressure requirements (requisite pressure approximately 9.0 bar at a rock temperature of approximately 25°C).
- The principle has been used successfully in Sweden and other European countries

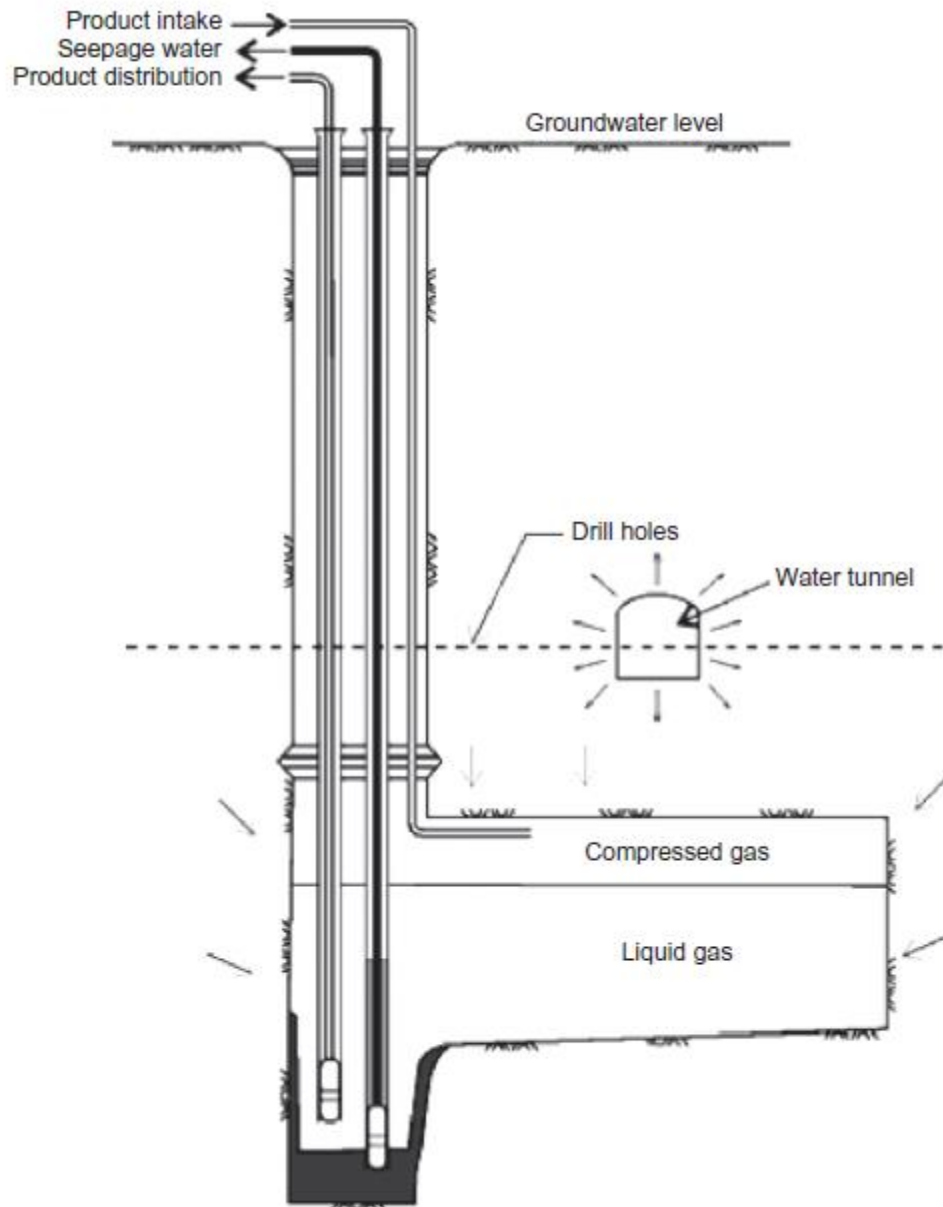


FIGURE 9.4 Storage of petroleum product under pressure [5].

Underground Lined Storage

As the name indicates, this is a system of storage in which the stored product remains in contact with the lining applied all around the exposed rock of the cavern. The lining could be plastic or steel.

Underground lined storage is contemplated in preference to other methods of storage when the site is unfit due to bad-quality rock or in such regions where no

groundwater table is present or where an artificial water table cannot be established. The storage cavern can be excavated at a shallow depth or in a hillock.

Access to the cavern is by means of a drift or tunnel that is usually very short in length compared with an unlined cavern. Such storage can be operated at very high pressures even at moderate depths.

Although lining in combination with rock presents an extremely stable design to withstand internal pressure, under empty conditions the hydrostatic pressure may act from outside, which may pose a threat to storage. It is therefore necessary to provide proper drainage around the cavern to make it safe.

Lined caverns are favored because of the following reasons.

- Caverns excavated in competent rock formations can be made leak proof at an additional cost of 15 to 20% of an unlined cavern's cost. This extra cost is insurance against possible leakage of material in case of unlined caverns. The advantage of lined caverns may outstrip the high initial cost over a period of time.
- Natural groundwater pressures are created by artificial means to contain the oil. Ground water pressure depends on the groundwater table and the porosity of the rock medium, as these may change with time and thus may not be in conformity with the theoretical design stipulations. Such a situation may, therefore, lead to leakage. This problem is avoided altogether in lined caverns.
- In case of unlined caverns, the water comes into contact with the crude oil and products. Crude oil had been found to be unaffected by the water however, micro biological activities at the interface of water and the stored products had been found to affect its quality adversely.
- Unlined caverns disturb the groundwater regime greatly; in case of arid and semiarid conditions, the precious fresh water meant for human consumption is lost.

Advantage

Underground lined storage has the following advantages:

- Non flammability.
- Strong resistance to external water pressure.
- Strong resistance to cracking in supporting wall.

