Design of storage structure

Lecture 16

Design of storage structure

- The layout and the design of a grain storage facility or silo building should aim towards a reliable and efficient unit, easy to survey and operate.
- The following two main groups of factors affect the design of silo construction.

1. **Fundamental factors:** Adequate volume of storage, proper protection of stored products and adequate methods of loading of grains, storage and discharge.
2. **Structural factors:** The silo should be strong enough to resist all the loads like dead load or the weight of structure and the attached items; live loads-forces from stored products (pressures); floor and roof live loads and wind and seismic loads.

Fundamental factors

- The storage system capacity is dependent upon the **quantity of grain** to be stored and the **number of bins** to be used. This further depends on the range and **characteristics of the products** to be stored, the methods, **rate and frequency of loading and discharge**, simultaneous loading discharge etc.
- Design of bin, apart from above is also dependent upon factors such as **position of inlet** and **outlet gates** like, central or eccentric outflow, the **bin geometry, the hopper shape, the outlet opening** etc.
- The required storage time affects the decision about horizontal and vertical storage structures. When **high capacity gravitational outflow is needed, vertical storage facility is preferred.**

Fundamental factors

- Location and orientation of grain storages remarkably affect the system efficiency and suitability as a grain handling centre. If the storage structure is to be used for storing feed grains for animals, it should be located near or a convenient place to the feed processing centre, otherwise excessive handling will not only increase the capital investment on handling equipment but will also increase labour requirements.
- The storage facility should preferably be located such that it is accessible in all seasons. The storage installations will also have aeration and drying facilities, adequate electrical power should be made available to the site selected.

Factors for consideration for creation of storage structures

(1) Orientation of individual bins should be such that aeration or drying does not work against prevailing wind.

(2) Provision of adequate space for future expansion.

(3) Storage site should be on firm soil with good drainage.

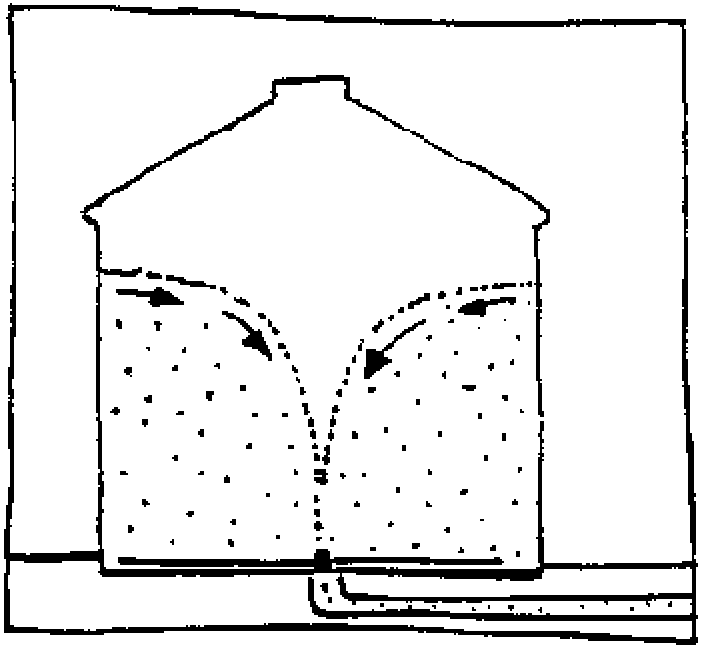
(4) Checking for the high water tables in areas where below ground pits are to be located.

(5) The bins and floor should be at least 24-28 cm above the graded ground level.

(6) The slope of floor should be away from the bin for protecting the foundation of bins.

Overpressure during emptying

- In a loaded silo, the discharge of grain occurs through a **small opening.**
- The quantity of discharged grain is insignificant as compared to stored mass.
- The small quantity of outflow is sufficient to produce a **downward movement in the entire stocked grains**.
- No sooner the discharge gate is opened downward movement of ensiled grain starts disturbing the equilibrium of stored mass.
- This results in increase of thrusts on the storage structure walls.



Overpressure during emptying

- The rate of movement of grain **near the walls is lesser** due to friction on the walls. But at the **centre of bin** the downward movement of grain is faster.
- This phenomenon causes overpressure on storage structure walls during emptying. Dynamic loads resulting from discharge of stored grain are the most frequent reasons of **structural failures of grain storage bins.**
- The **dynamic loads factor** is defined as the **ratio of the load during discharge** to **the load under static conditions.**

Overpressure during emptying

- The **highest lateral pressures** are measured in grain bins **during unloading** when grain is in motion along the bin wall.
- For this reason, the **dynamic coefficient of friction** between the grain and the bin wall is used to calculate design and the bin wall is used to calculate design lateral pressures in tall bins that unload in mass flow and in hoppers.
- **Kinetic friction,** also known as **dynamic friction or sliding friction,** occurs when two objects are moving relative to each other and rub together. The coefficient of kinetic friction is typically denoted as μ_k, and is **usually less** than the coefficient of static friction for the same materials

Construction materials

- Basically, the choice of construction materials for modern permanent storages is between **steel** and **concrete**, though brick is also used in some countries.
- As far material is concerned for safe and quality storage, its **durability and gas tightness** is of prime concern. The selection between steel and concrete can involve many considerations. Metal bins are mainly used for smaller storage units and for provisional installation.

Advantages of Metal bins

- Their dead weight is low
- Prefabrication of the component parts in workshop is possible
- Standard material readily available in the market can be used
- They provide a smoother surface and lower coefficient of friction
- Installation inside a building is easier
- Complicated designs are possible and
- When needed, they can be enlarged.

Advantages of concrete bins

- Concrete bins are used for larger permanent storage structures.
- maintenance requirements are low,
- they reduce risk of condensation
- Corner curves are easy to construct
- They are water and fire proof, easy to clean. But the concrete bins have high dead weight, need stronger foundation.
- The interior walls of the bins are relatively rough and air bubbles are also possible.
- There is loss of volume by way of thickness of bin walls.

Durability - Concrete silos

- Concrete silos are not maintenance free.
- If their design is inadequate, they may crack, thereby allow moisture migration and loss of fumigants.
- Crack repair can be an expensive process.
- Carbon dioxide reacts readily with Concrete. Carbon dioxide reacts with **calcium hydroxide** molecules in the cement matrix to form **calcium carbonate**.

Durability - Concrete silos

- Calcium hydroxide is an alkaline substance which gives chemical protection against corrosion of the reinforcing steel. Carbonation removes the alkalinity and the protection. Carbonation takes place in all concrete as a result of reaction with carbon dioxide in the atmosphere.
- The concentration of carbon dioxide in atmosphere is 0.03%, hence the reaction is very slow. In a chemically clean rural atmosphere, the carbonation may penetrate at less than **1 mm per year.**
- Due to metabolic activity, grain produces carbon dioxide. Storage of grain in concrete silos thus produces an accelerated rate of carbonation. It is possible that the **200 mm thick silo** may completely be carbonated in **50 years**.

Durability - Concrete silos

- At **controlled atmosphere** for disinfestation of grain, the carbon dioxide concentration may be **60%**, therefore, carbonation reaction is very vigorous.
- In such situation the chemical protection against corrosion of reinforcing steel may be lost in a very short time.
- **Good compaction of concrete** results in better corrosion protection because compaction controls the cracks and gives strength.
- The rate of carbonation can be reduced by the application of certain high build **paints**. But this adds both to capital investment and maintenance costs of a concrete silo.
- The concrete silo if well designed and constructed, does not require any special treatment for making **gastight**.

Durability - Steel silos

- In steel silos, the **zinc galvanisation** also does not provide long term corrosion protection in chemically active environments.
- The galvanised surfaces should be overcoated with an appropriate **paint** system. Painting adds cost to steel constructions and also towards its maintenance.

Durability - Steel silos

- The welded steel silos require no special sealing provisions except at the joint between floor and wall.
- Since joint movement from grain pressure seldom occurs in practice, it is safer to design the walls with a rigid base.
- Light gauge bolted steel silos have **not proven easy to make gastight** due to their light flexible construction and multiple screw fixings.
- The joint between **roof-to-wall is also difficult to seal**.
- The **cost of sealing of such silos becomes very high** and thus reduces the cost competitiveness.

Aeration

Aeration is the process of moving air through stored grain at low flow rates to maintain or improve its quality. Aeration can provide three major benefits in the storage of grains.

- It cools the grain and slows down insect activity.
- By cooling the grain, aeration prolongs the effectiveness of pesticides.
- It can provide an appreciable drying function.

Some other benefits of aeration are —

- It prevents storage odours. Grains stored for longer periods often develop objectionable odours. Aeration provides the grains a new, fresh smell.
- It reduces moisture accumulation. Moisture condensation by changes in temperature and relative humidity can be reduced by aeration.
- Application of fumigants through an aeration system is an easy and practical method for controlling insects in stored grains.

Air flow rates

Aeration systems can be installed in both horizontal and vertical storages. The following set of basic design parameters are found suitable for cooling of dry grains by aeration.

Air flow rate : Silos 0.8 litre/second/tonne

Sheds 1.6 litre/second/tonne

Maximum duct velocity : 10 m/s

Maximum entry velocity of air into grain : 0.15 m/s

The most common air flow rates for aerating paddy range from 0.07–0.28 m^3/min./tonne of paddy. The above air flow rates for aeration are only a fraction of the air volume needed to dry grains.

Aeration

- Air can be pulled or pushed through the grain in storage.
- The air can be moved from the top to bottom or from the bottom to the top of the bin.
- In a vertical duct system the top part of the central duct is solid and the **lower half section is perforated**.
- A fan at the top of the duct pulls the air through the grain and perforations.
- The sucked air is blown out of the bin by the fan.

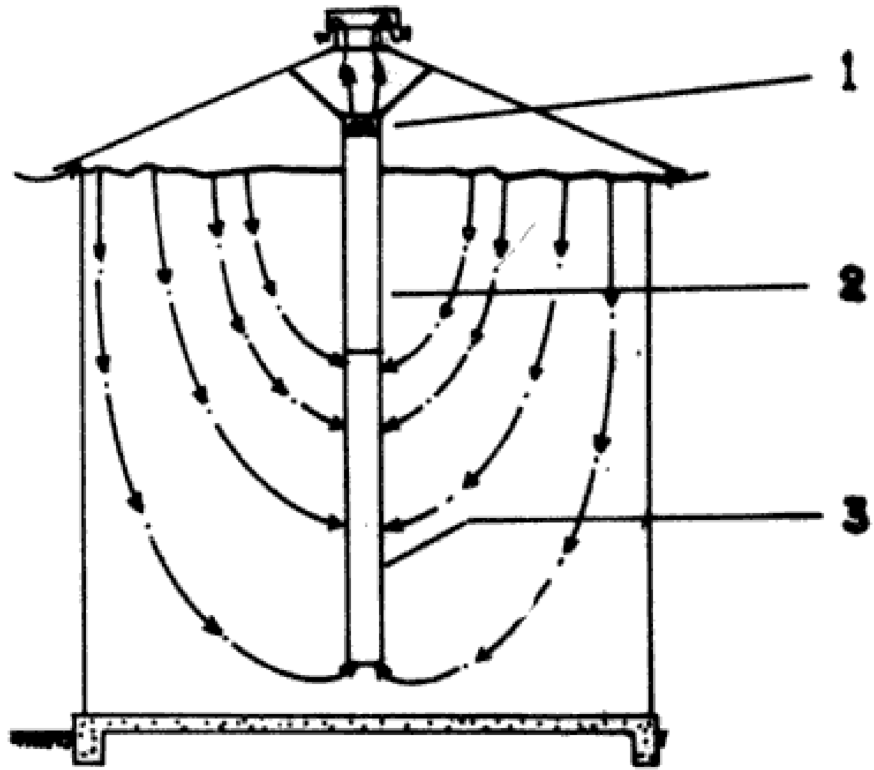


Fig. 4.25 : Central aeration system in vertical silo
1. fan 2. solid duct 3. perforated section

Aeration in tropical climates

- In the tropical climates, aeration should be done from bottom to top because any air trapped under the roof of a storage structure is usually at high temperature.
- This high temperature air can be forced out easily from the top. The cooler air from bottom also cools the warmer grain stored in bin.

Floor ducting for aeration

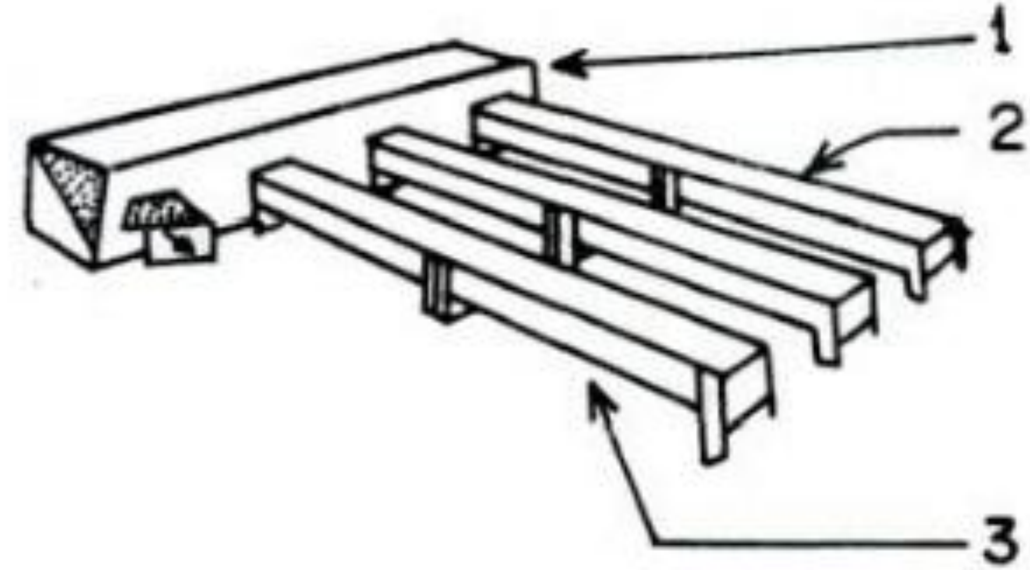
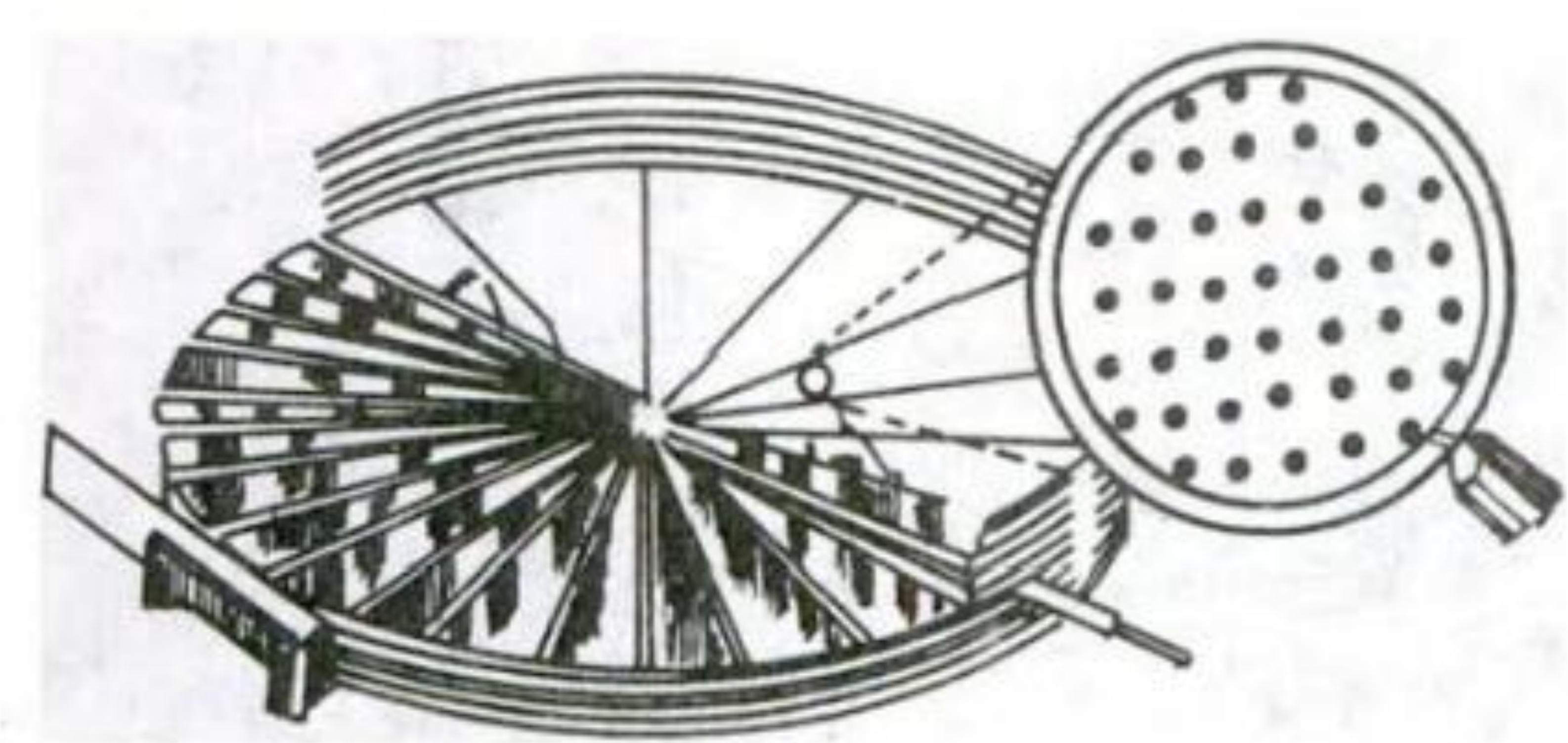


Fig. 4.26 : Floor ducts for aeration
1. main duct 2. transferable lateral ducts 3. interspace on floor

Floor ducting for aeration

- When on-floor ducting is used, it is often important to allow for its removal to facilitate floor sweeping.
- For this reason, full round ducting is usually used in sheds where grain loads are moderate.
- Both longitudinal and cross-floor ducting can be used in sheds.
- Generally ducting is made from galvanised steel sheet with **2.5 mm perforations at 6 mm centres**.
- Ducting in silos is normally exposed to considerably higher grain pressures.

Perforated floor for aeration



Perforated floor for aeration

- In-floor ducting requires the use of flat perforated sheet.
- Cost of such system is significantly higher because of requirement of a structural frame below the perforated sheet for its support.
- An alternative is **perimeter ducting** formed from quarter round corrugated ducting.

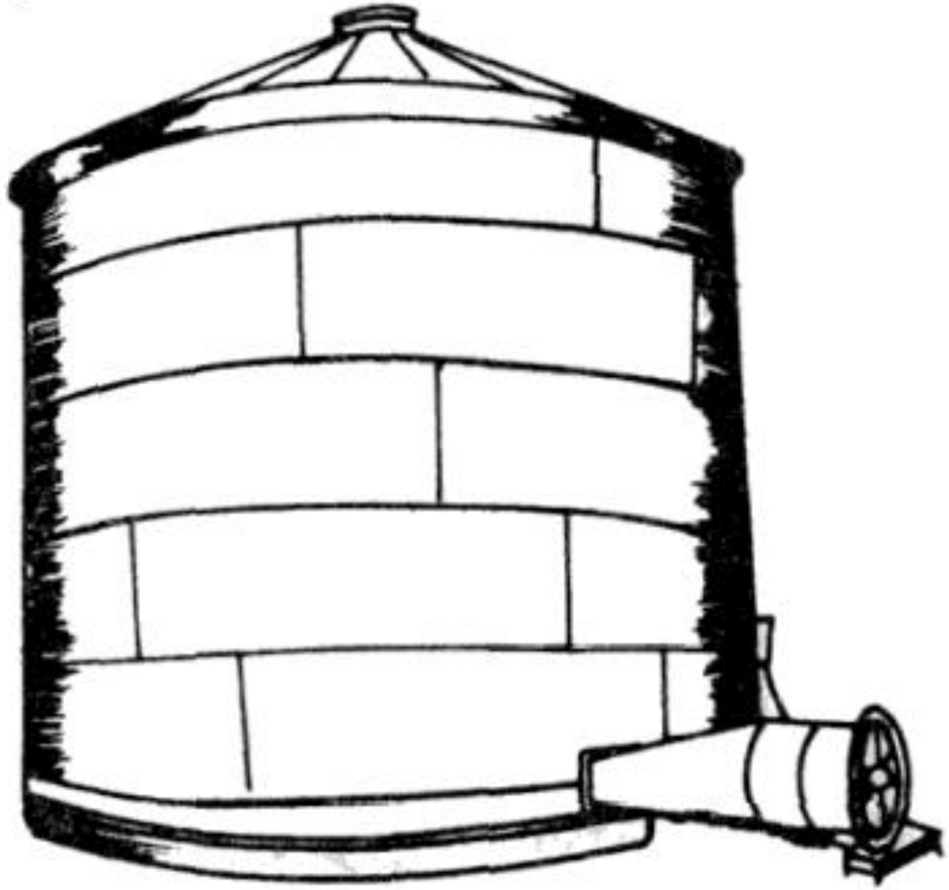


Fig. 4.28 : Fan connected with a single bin for aeration

•For aerating the storage structures the aeration system may have a single fan connected with a single bin.

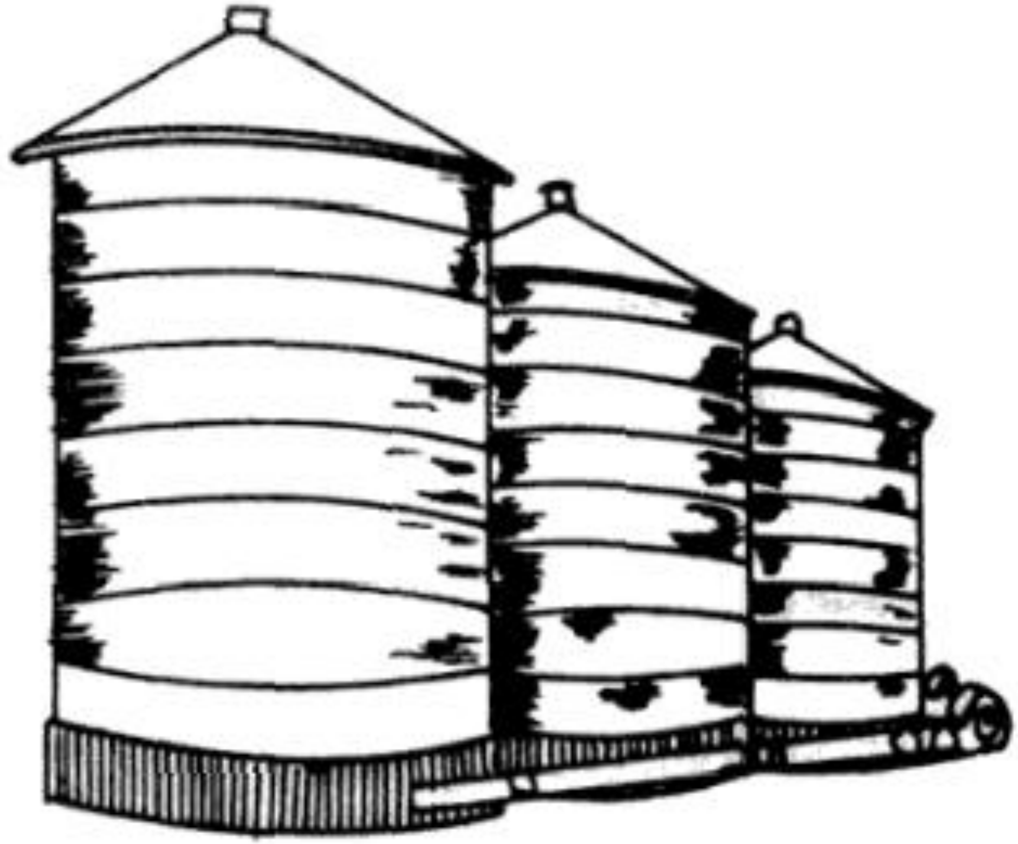


Fig. 4.29 : A large capacity fan connected with many bins for aeration

- There may be other system in which a large capacity fan is connected to a manifold system.
- With such arrangement, aeration could be done in a single bin or in many bins simultaneously as per the requirement.

Perforated floor for aeration

- Perforated ducts may be circular, semicircular, rectangular or inverted V- shaped.
- The required cross-section area of a duct may be determined by the following expression

$$\text{cross-section area, } m^2 = \frac{\text{Total air volume, } m^3/min}{\text{Air velocity, } m/min}$$

- The perforations should be uniformly spaced with a minimum perforated area of 10% and preferably 15%.
- Often a portable fan mounted on a trolley is used. This can be moved from one duct or one manifold system to another.
- The initial cost of the fan and system is reduced but the operating cost is increased because of labour requirement to move and connect the fans.