Selection and use of oxygen-limiting silos

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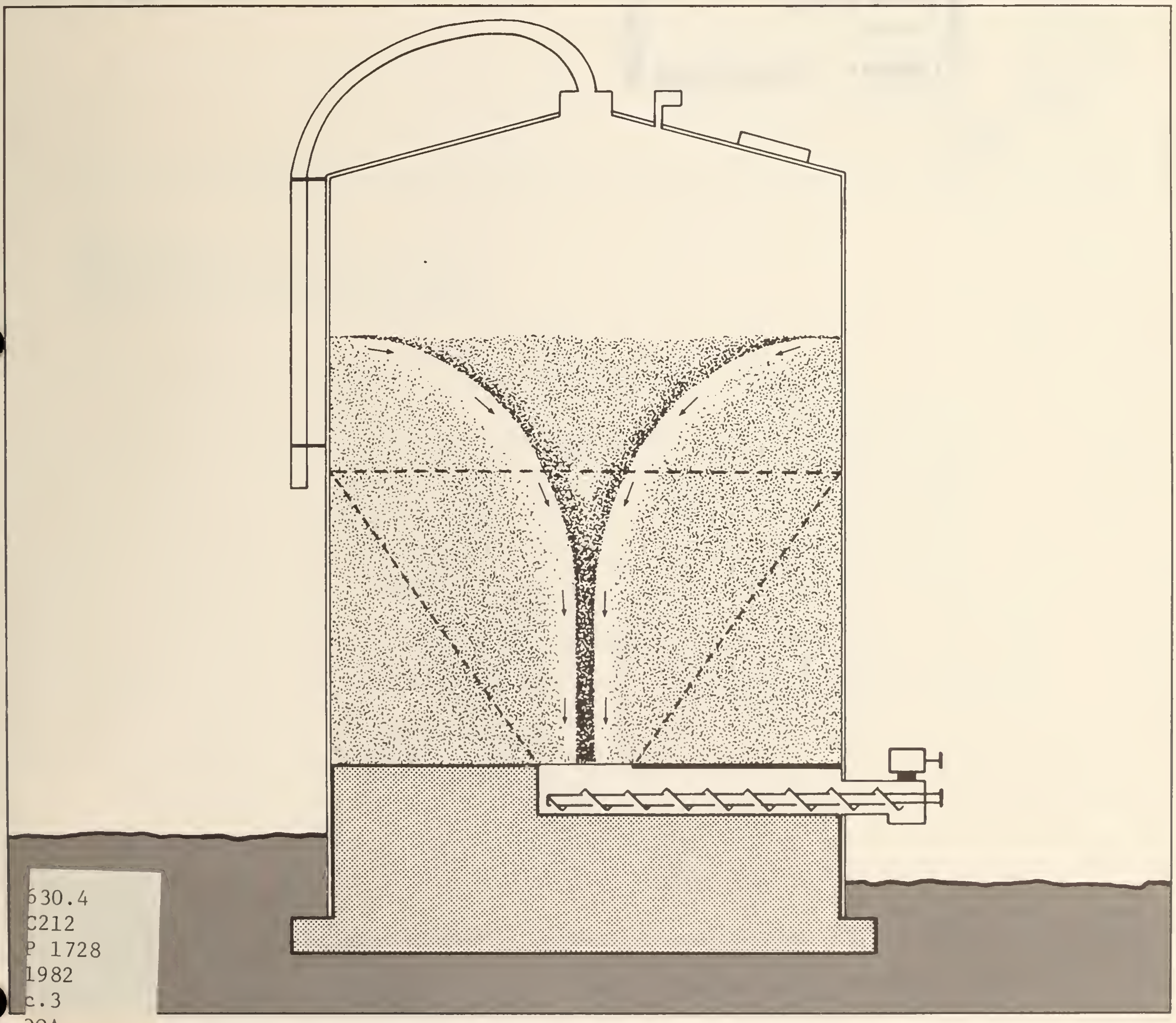

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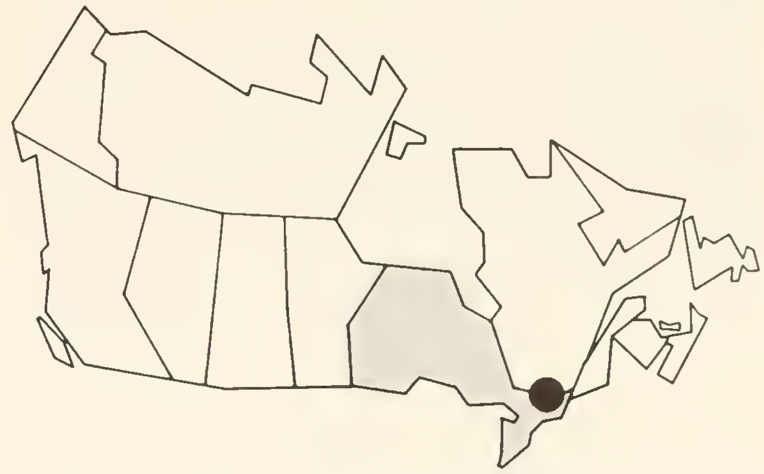

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An oxygen-limiting silo is a storage structure that has gastight walls, floor and roof. Gastight hatchways in the sidewall and top allow access from the outside for filling, unloading, and servicing. Equipped with a breathing system, the structure provides a controlled atmosphere in which ensiled materials can be stored with a minimum loss of both quantity and quality. It can be adapted to store many different livestock feeds.

Mention of company and brand names (or their omission) in this publication is not in any way to be taken as positive or negative endorsement. Names are included only for illustration.

Operation of oxygen-limiting silos

Chopped, whole-plant forages above 35-40% moisture and grains above 22-25% moisture, when placed in an oxygen-limiting silo, go through the various phases of respiration and fermentation normal to the ensiling process. As the material ferments, it consumes oxygen and produces carbon dioxide. This gas is heavier than air, and normally fills the interspaces in the silage mass, and the space immediately above. Because the structure is "sealed", the atmosphere inside changes from natural air containing about 20% oxygen to one with almost no oxygen but mostly carbon dioxide. The degree of success with this type of storage rests primarily with the structure's ability to maintain enough carbon dioxide in and around the ensiled mass to prevent spoilage.

However, sealing the silo is not enough. In addition, some type of pressure-equalizing system is needed because pressure changes occur during the use of the silo. These changes are primarily caused by silage removal from the bottom of the silo (creating a vacuum above the silage mass) and day-night air temperature and radiation changes that cause expansion or contraction of the gases within the silo (creating either pressure or vacuum).

Any appreciable vacuum can buckle thin sidewalls. Furthermore, any leaks that develop in the structure will allow air into the silo and promote feed deterioration.

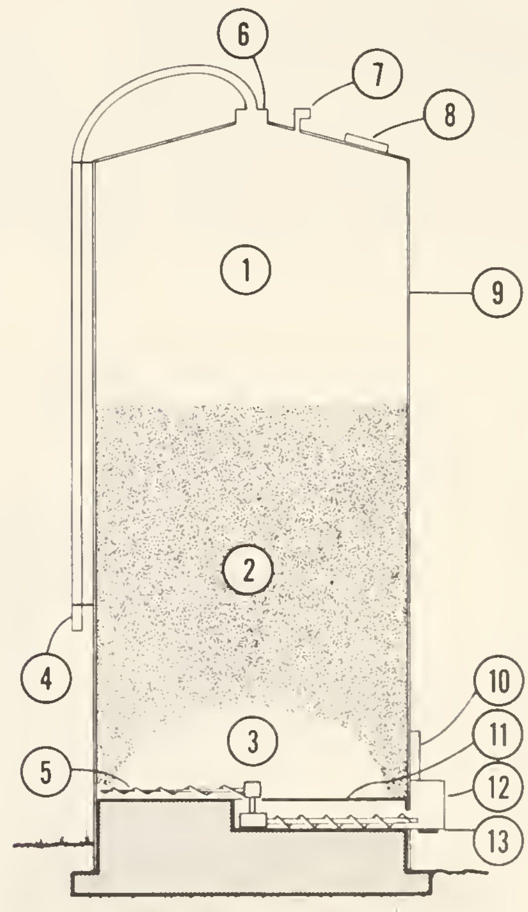
Various methods are used to equalize pressure, depending on silo type and make. With one or two exceptions, all oxygen-limiting silos are equipped with a two-way pressure relief valve. This acts as a safety device that allows gas to be released if pressure builds up and air to enter if a vacuum forms. This valve also relieves vacuum when any appreciable amount of silage is removed.

It may be somewhat misleading to call these silos "sealed" or "airtight"; it is more accurate to say that they are oxygen-controlled or oxygen-limiting.

To minimize the amount of air that must be admitted, some manufacturers equip their silos with specially designed secondary breathing mechanisms.

Depending on the manufacturer of the silo, several different breathing systems are currently being used. One system makes use of large plastic bags. In one variation (e.g. Harvestore, Crop Handler) the bags form a doughnut-shaped ring that is suspended inside the roof cavity and vented to the outside. Another variation (e.g. Continu-store) uses two bags in the foundation cavity below the elevated silo floor; the bags are connected by pipe to the inside of the silo at the top. In each of these systems the bags compensate for gas pressure changes inside the silo by expanding or contracting (breathing). This equalizes pressure without allowing air to come in contact with the silage.

One manufacturer (Feedstor) uses a series of air chambers below the floor in the silo foundation. These are connected by pipe to the top of the silo. The gases above the silage are thus able to move into or return from these chambers as the pressure changes, without letting oxygen reach the surface of the silage.



1. oxygen-controlled atmosphere (mostly CO_2)
2. ensiled feed
3. cavity over unloader (with non-free-flowing feed)
4. fill pipe
5. unloader sweep-arm
6. sealed fill hatch
7. two-way pressure relief valve
8. sealed hatch
9. airtight container
10. sealed entry hatch
11. silo floor
12. power head for unloader
13. sealed unloader discharge port

FIGURE 1 Basic components of an oxygen-limiting silo.

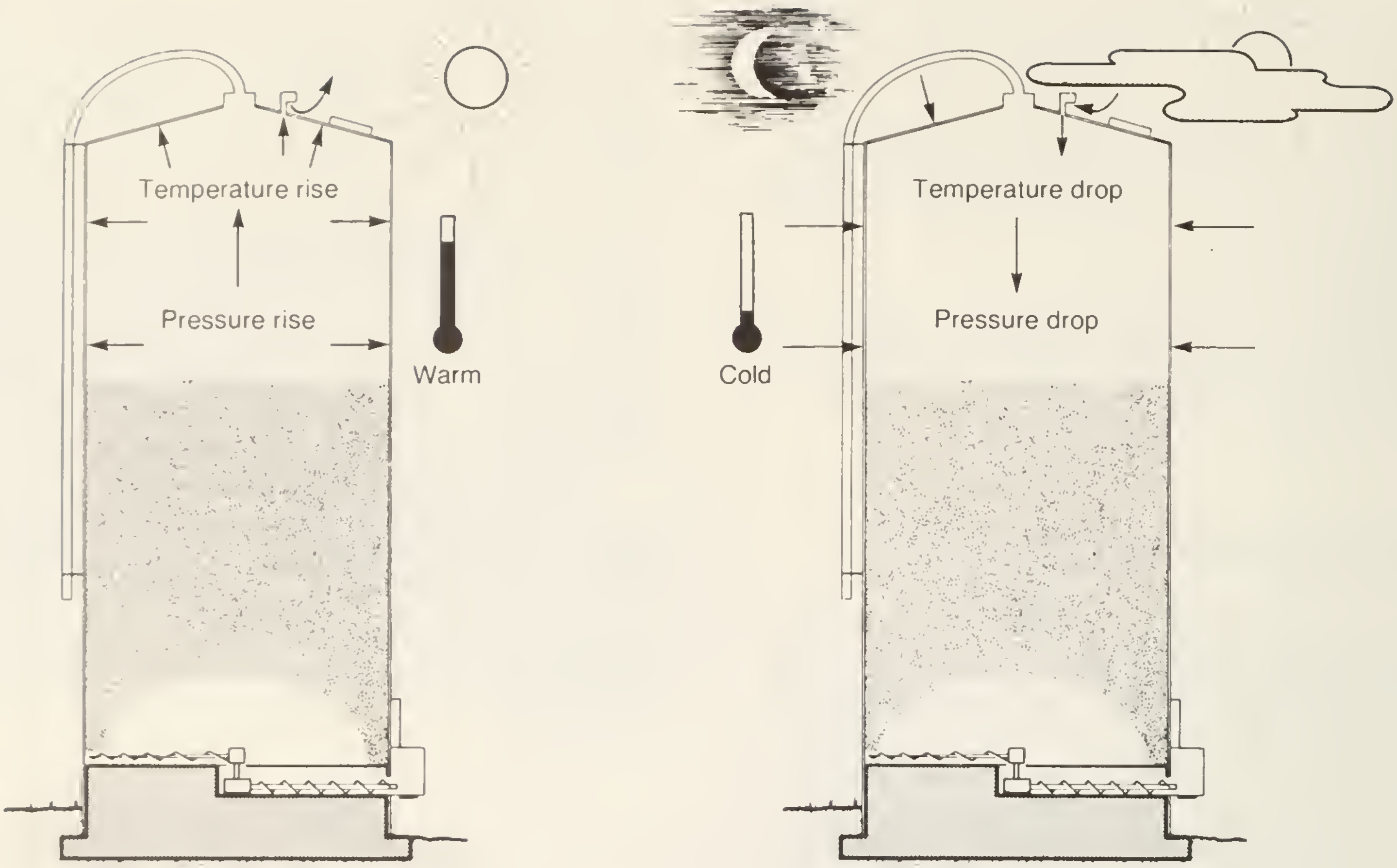


FIGURE 2 Oxygen-limiting silos must "breathe" to compensate for temperature and pressure changes.

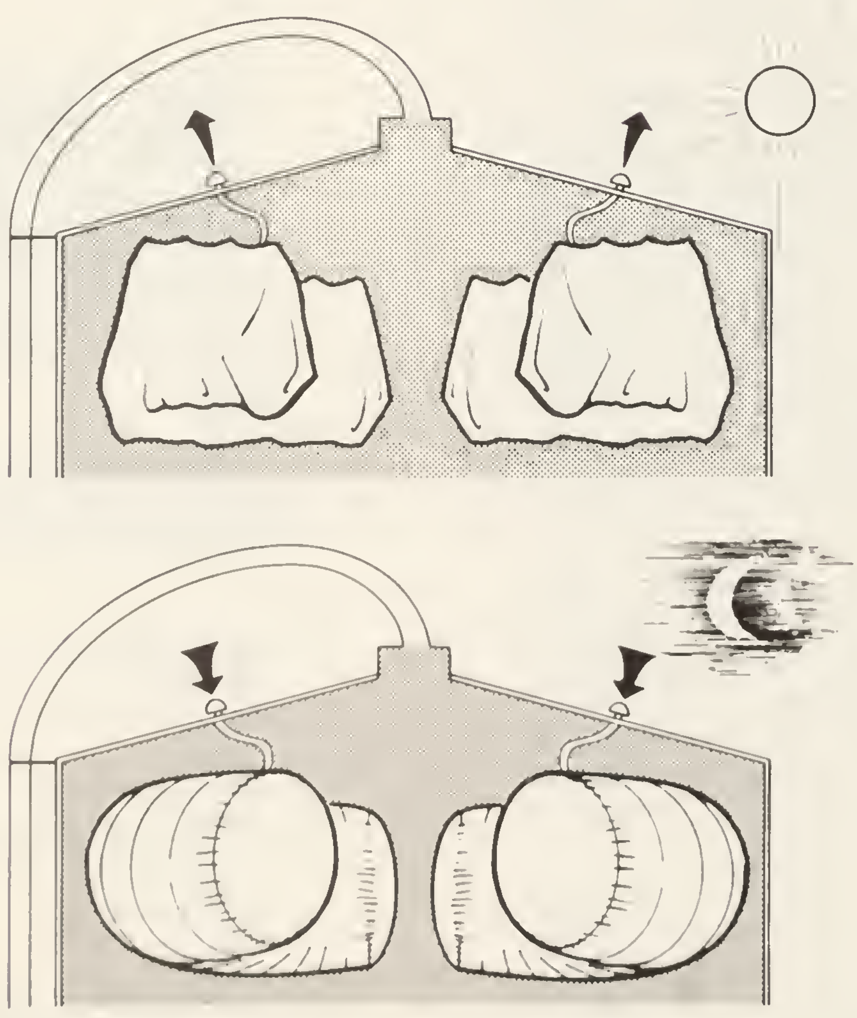


FIGURE 3 Large plastic bags suspended in the top of the silo "breathe" to minimize the inside-outside pressure differences, thus reducing total oxygen intake.

The actual need for some form of secondary breathing equipment has not been well established. Some manufacturers of oxygen-limiting silos claim they have sufficient control of the movement of air into the silo using a primary breathing system only (in most cases just a relief valve).

Types of oxygen-limiting silos

Steel

These include silos using glass-coated steel, stainless steel, aluminized steel, and galvanized steel with some type of inner coating. There are two basic types:

1. The silo walls and roof are made from prefabricated, preformed panels or sections that are shipped to the site and erected on a specially prepared base. The sections are bolted together, usually with some type of sealing compound between the joints to make the silo airtight. Airtight hatches are installed in the roof and sidewall.

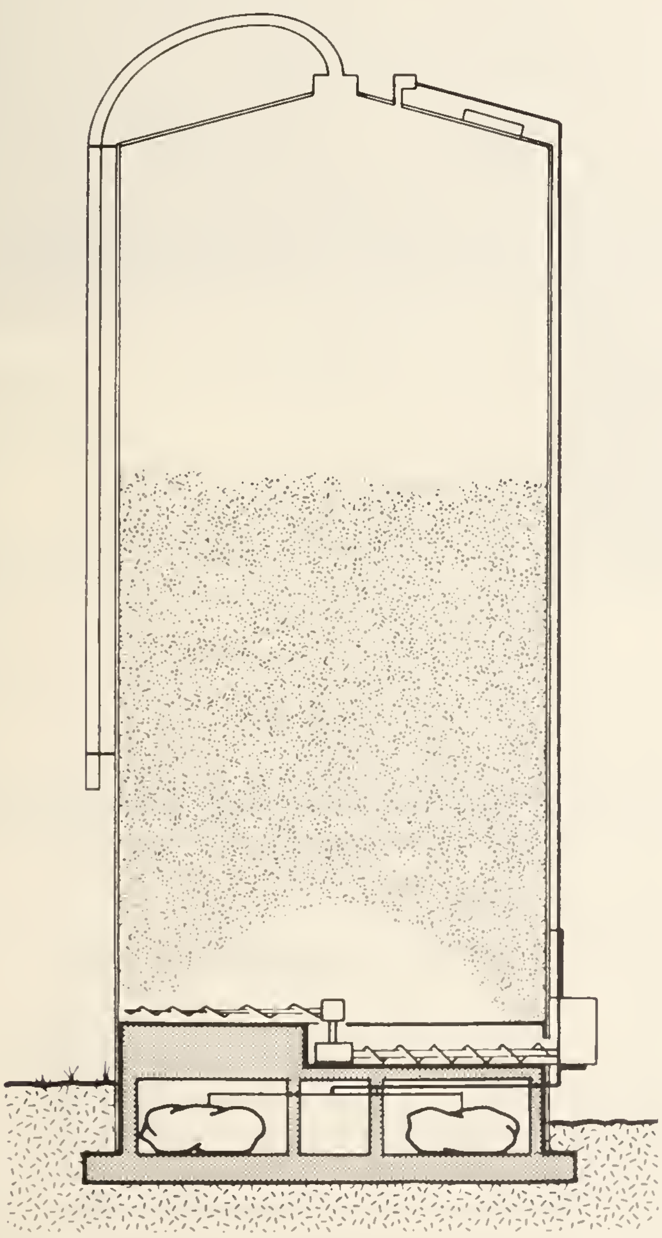


FIGURE 4 Another place for the breather bags is inside the foundation.

2. The silo wall is formed using coils of sheet steel that are passed through a former set up on the prepared silo base. The wall is formed as a continuous spiral with the edges of adjacent spirals crimped to form an airtight joint that is smooth on the inside. A steel or fiberglass roof and airtight hatches complete the structure.

Concrete

This type of silo is similar in appearance to a standard concrete tower silo, but includes additional construction details to ensure it is gastight and strong enough for bottom-unloading. The usual chute and doors are replaced with airtight steel hatches embedded in the wall at the bottom of the silo. Reinforced concrete roofs are usually used, although some have been equipped with sealed fiberglass or steel roofs. Again, these roofs are fitted with airtight hatches for filling. Until recently, nearly all oxygen-limiting concrete tower silos have been built using cast-in-place walls. However, within the past few years several companies have built precast concrete stave walls, together with some type of gastight liner. The horizontal and vertical pressures of bottom unloading (particularly with forages) often require a double-wall construction at the bottom if the silo is made from concrete staves.

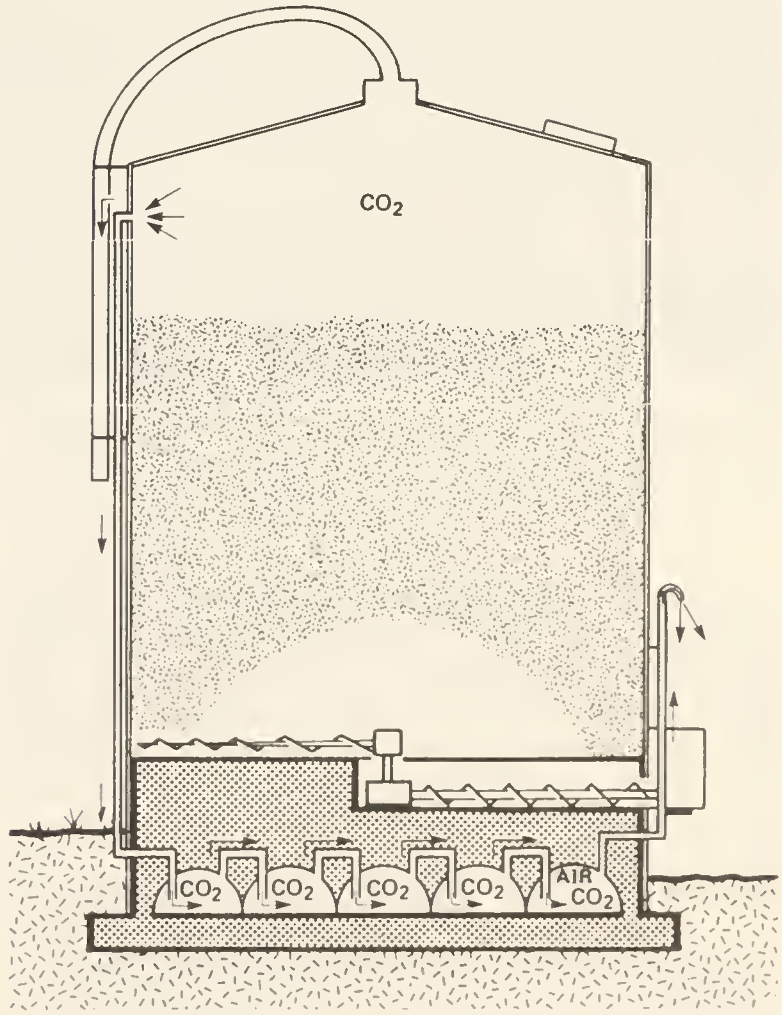
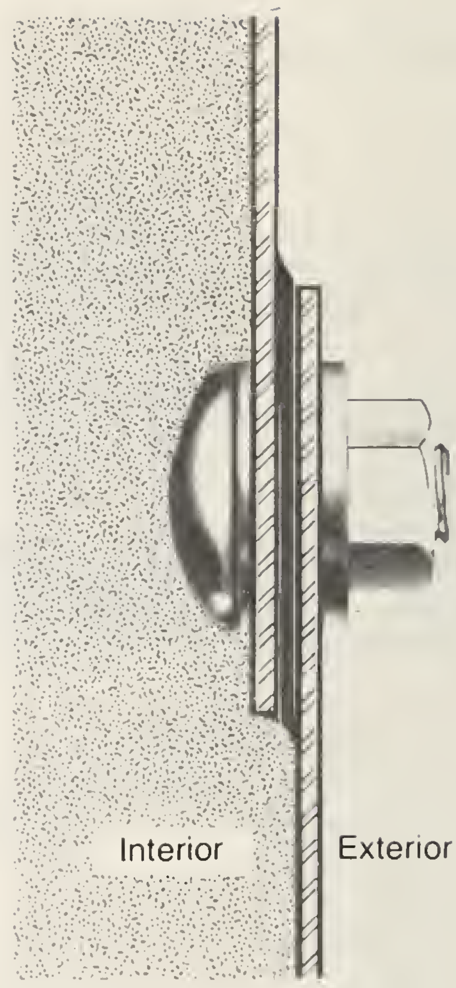


FIGURE 5 A series of chambers cast into the foundation is another method used to let the silo "breathe" without ventilating the storage.



SEALED JOINTS

FIGURE 6 Some silos are made from panels of glass-coated steel bolted together on all sides. Sealing compound squeezed within each joint forms an airtight container.

As well as being airtight, the wall of an oxygen-limiting silo must also be gastight. Since concrete in itself is not a complete gas barrier, oxygen and carbon dioxide will slowly diffuse through the silo wall unless some type of seal material is applied to the inside. Epoxy coating is normally used.

Glassfiber-reinforced plastic, or 'fiberglass'

Over the years, several Ontario companies have tried to develop and maintain a business selling and erecting silos made of these materials. Unfortunately these companies usually run into difficulty and cease to operate. Although the material shows great potential for silos it would seem that costs are too high for the present agricultural market.

Unloaders for oxygen-limiting silos

Most oxygen-limiting silos are equipped with a bottom unloader. For whole-plant silage the three most common types are the chain-saw sweep-arm unit, the auger sweep-arm unit, and the chain flail unit. In addition, a unit that is essentially a top unloader with bottom delivery is used in several makes of silos. For free-flowing ensiled grain a relatively simple auger unloader is common.

FIGURE 7 Three examples of oxygen-limiting silos using glass-fused-to-steel for walls and roof. (Photos courtesy of Ontario Harvestore Systems, J. & H. Feedstor, and Croplander)

Whole-plant silage

Sweep-arm unloaders

Two bottom unloaders use a sweep-arm to remove the silage, and both operate on the same basic principle. The unloader consists of a sweep-arm about equal in length to the silo radius. This arm rests on the silo floor and pivots around a central power input shaft. As the arm operates it drags silage along the floor to a discharge opening at the pivot point. From here the silage is conveyed horizontally to an airtight hatchway that is unsealed for unloading.

One of the interesting happenings during the operation of a bottom unloader is the development of a cavity in the silage over the central discharge area. At the beginning of unloader operation, as silage is removed over the discharge opening, pressures develop within the bottom portion of the silage mass. This forms a self-supporting arch of material, resulting in a dome-like cavity. Fully developed, this cavity at floor level may extend almost to the silo wall, and have a height of approximately 40-70% the silo radius. Thus the normal floor load of the silage mass is supported on a relatively narrow band of material next to the silo wall. The main task of the unloader sweep-arm is to cut away this supporting material. As this takes place the overhead arch collapses a little at a time, and this material too is dragged to the discharge opening. Often, during the initial formation of this cavity, operators shorten the sweep-arm somewhat the first few times around the silo. This reduces the load on the unloader (this is often referred to as "short-arming" the unloader). Once the cavity is formed the sweep-arm length is increased to cut closer to the outside wall.

The actual shape and dimensions of the cavity will vary somewhat from silo to silo, depending on the type of unloader, the initial length of the sweep-arm, and the length of chop and moisture content of the silage.

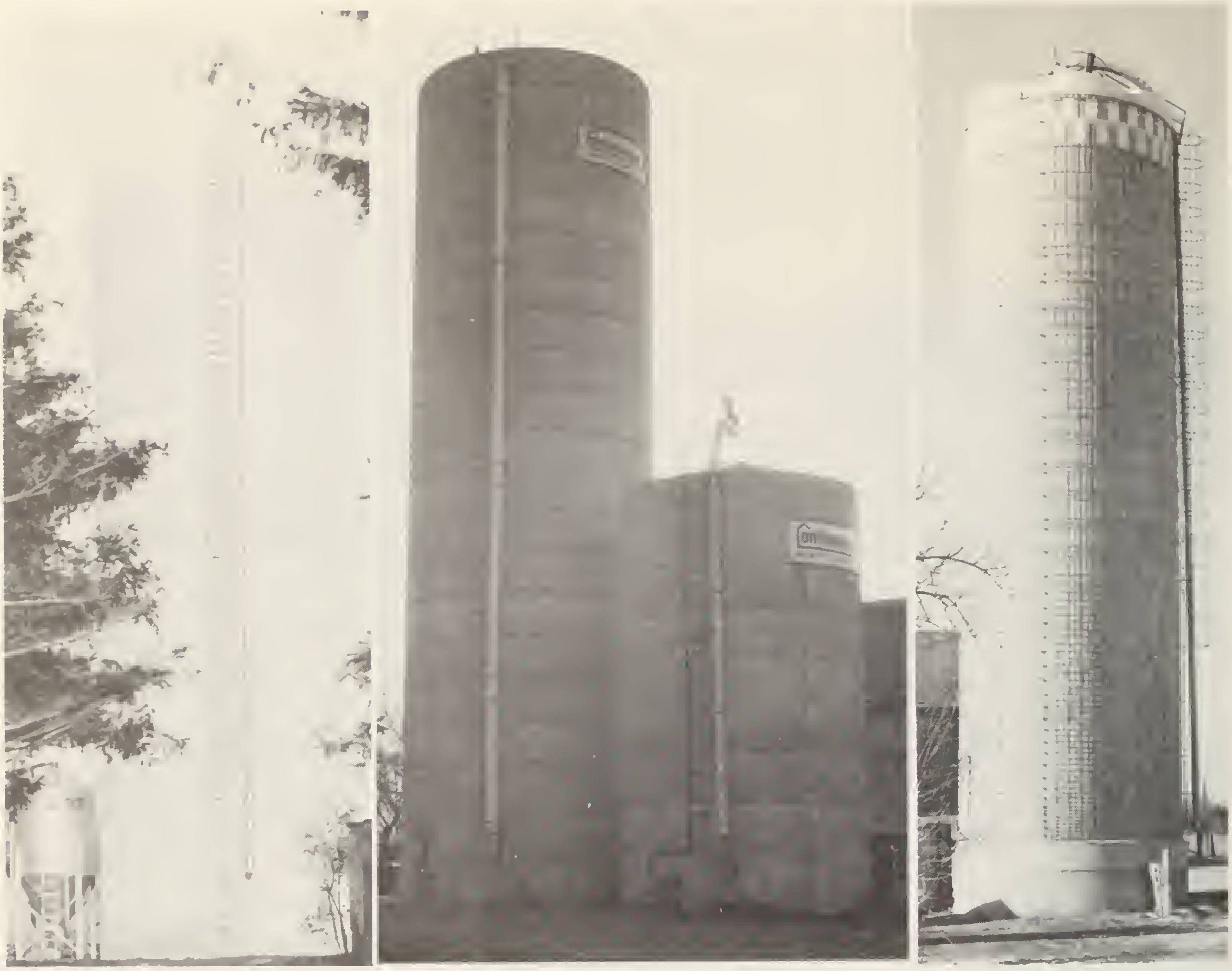


FIGURE 8 Three examples of oxygen-limiting silos using precast concrete stave and cast-in-place concrete walls.

CHAIN-SAW SWEEP-ARM UNLOADER One manufacturer of oxygen-limiting silos (Harvestore) has developed a bottom unloader that uses a gathering mechanism that works like a chain-saw, pivoted as a sweep-arm about the silo center. This sweep-arm slowly rotates under the silage around a drive unit, while large teeth on the endless chain cut and drag the silage to a central discharge opening. A single motor drives the sweep-arm and cutting-gathering chain. An under-the-floor chain-and-slat conveyor drags the silage from the discharge opening to the outside.

AUGER SWEEP-ARM UNLOADERS Several companies (e.g. Laidig, Weaver) have developed unloaders that use a large, aggressive auger as the sweep-arm cutting and gathering device. The auger looks like a very heavy grain auger with shark's teeth fastened to the flighting. Two separate and independently controlled motors operate the gathering unit — one to rotate the sweep-arm into the silage, and one to turn the cutting auger within the sweep-arm. As the cutting auger turns around within the sweep-arm, the teeth tear at the silage, dislodging the material so the flighting can convey it

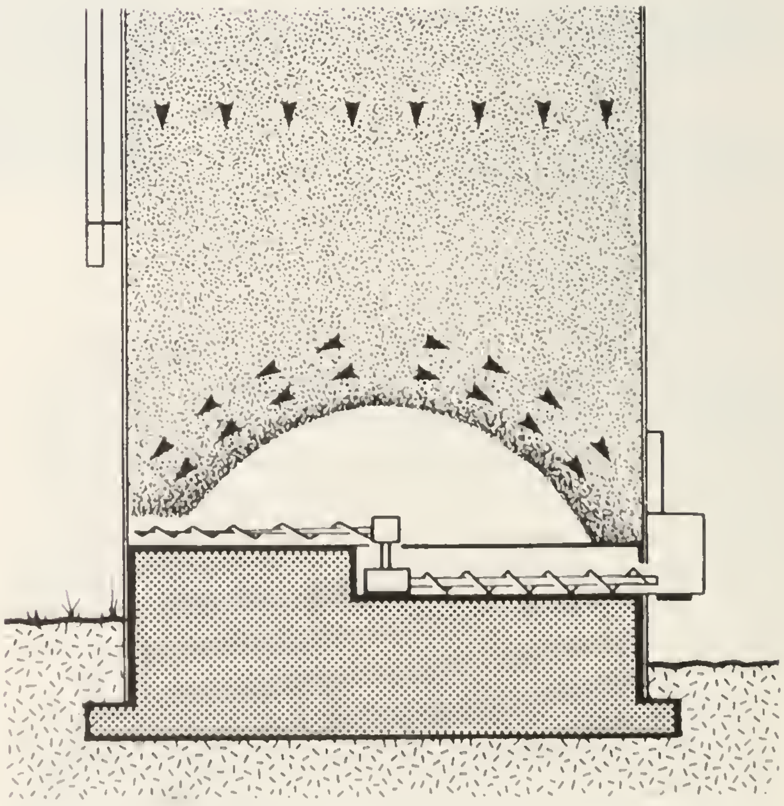


FIGURE 9 Bottom unloader forms an arch-shaped cavity in chopped forage. Silage pressures are carried towards the base of the silo wall.

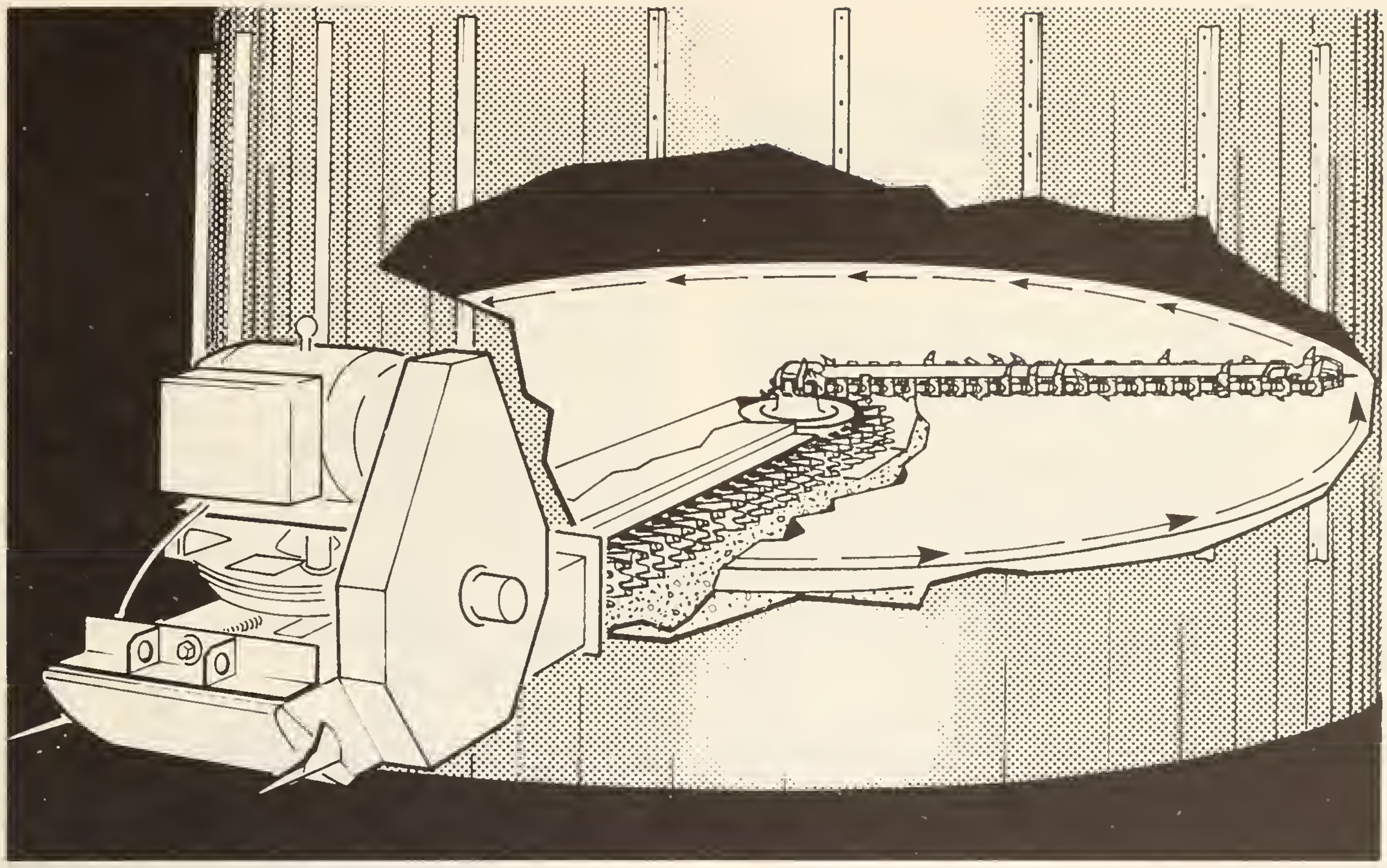


FIGURE 10 Chain-saw gathering arm cuts away the silage at the wall, drags it to the center, and drops it into a horizontal conveyor below.

FIGURE 11 Silage from a chain-saw unloader is delivered to the outside through a discharge hatch that is sealed off when the unloader is not operating. (Photo courtesy of Ontario Harvestore Systems)

to the central opening in the floor. From here the silage is moved to the outside by an under-the-floor conveyor.

Chain flail unloaders

Although several companies have had a hand in developing this type of unloader, it is now marketed in Canada and the U.S. by only one company (Supreme). Basically this unit consists of a motor-driven central shaft (about equal in length to the silo radius) that projects up from the bottom of the silo. Attached to this are several chains with cutter heads at the outer ends. The top chain is the longest (almost equal to the silo radius), the bottom one next to the discharge opening is the shortest, and the intermediate chains vary to form a tapered or inverted cone. When power is applied, the central shaft spins at 60-80 r/min making the chains flail out by centrifugal action. The cutting heads on the ends of the chains loosen some of the silage, causing it to move down the sloped silage surface to the center. Here a short section of auger on the bottom of the shaft helps pass the silage through an opening in the floor to a conveyor below. As with other unloaders, a cavity forms in the bottom of the silo, this one being an inverted cone around the unloader, with a curved dome overhead.

Top unloader-bottom delivery

Several manufacturers (e.g. Feedstor, Clayton & Lambert) equip their oxygen-limiting silos with a top unloader. This uses a cable-suspended steel ring, just slightly smaller in diameter than the silo, that provides the drive for the gathering mechanism. At the time of filling the silo a steel flue-former about 500 mm in diameter is pulled up through the silage, forming a continuous center hole from the bottom to the top. During filling, the gathering mechanism is reversed to act as a levelling device. To unload the silo, the unloader drags the silage to the central vertical hole, where it falls to a conveyor for discharge to the outside through an airtight hatch.

High-moisture grains

Where high-moisture grain is to be stored in an oxygen-limiting silo, the characteristics of that grain (ground or whole, moisture content, etc.) will determine to a large extent the type of unloader required. For example, with high-moisture whole-shelled corn or whole-kernel barley, a relatively simple auger unloader may be used to remove the grain from an opening in the center of the floor.

If the grain is clean and in the right moisture range, it will flow freely by gravity into the auger. The flow pattern is very similar to that of dry grain where the mass turns inside out, the top layers coming out first.

Most manufacturers add to this simple unloading system some type of sweep-arm auger to unload that portion of the grain that will not flow by gravity. The simplest arrangement is a sweep-arm pivoted at the central discharge opening. The sweep-arm remains stationary under a protective hood as long as gravity flow continues. When flow ceases, the sweep-arm is released to work its way around the silo, thereby pulling the remaining grain to the opening (e.g. Harvestore, Neco).

Some manufacturers, to ensure uninterrupted flow of grain to the unloading auger, use a constantly running sweep-arm (e.g. Laidig, Weaver, Neco). This uses a tapered or stepped auger (smal-

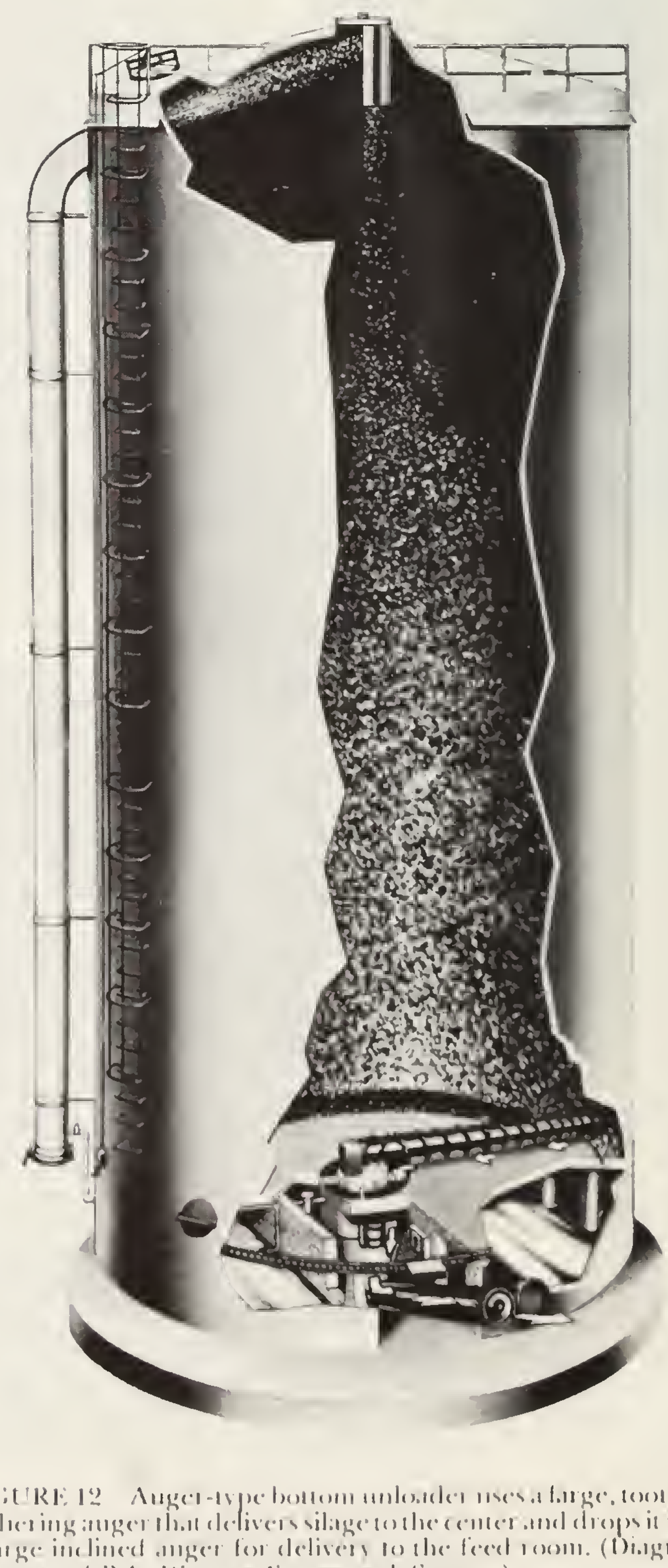


FIGURE 12 Auger-type bottom unloader uses a large, toothed gathering auger that delivers silage to the center and drops it into a large inclined auger for delivery to the feed room. (Diagram courtesy of R.L. Weaver, Energy-pak System.)

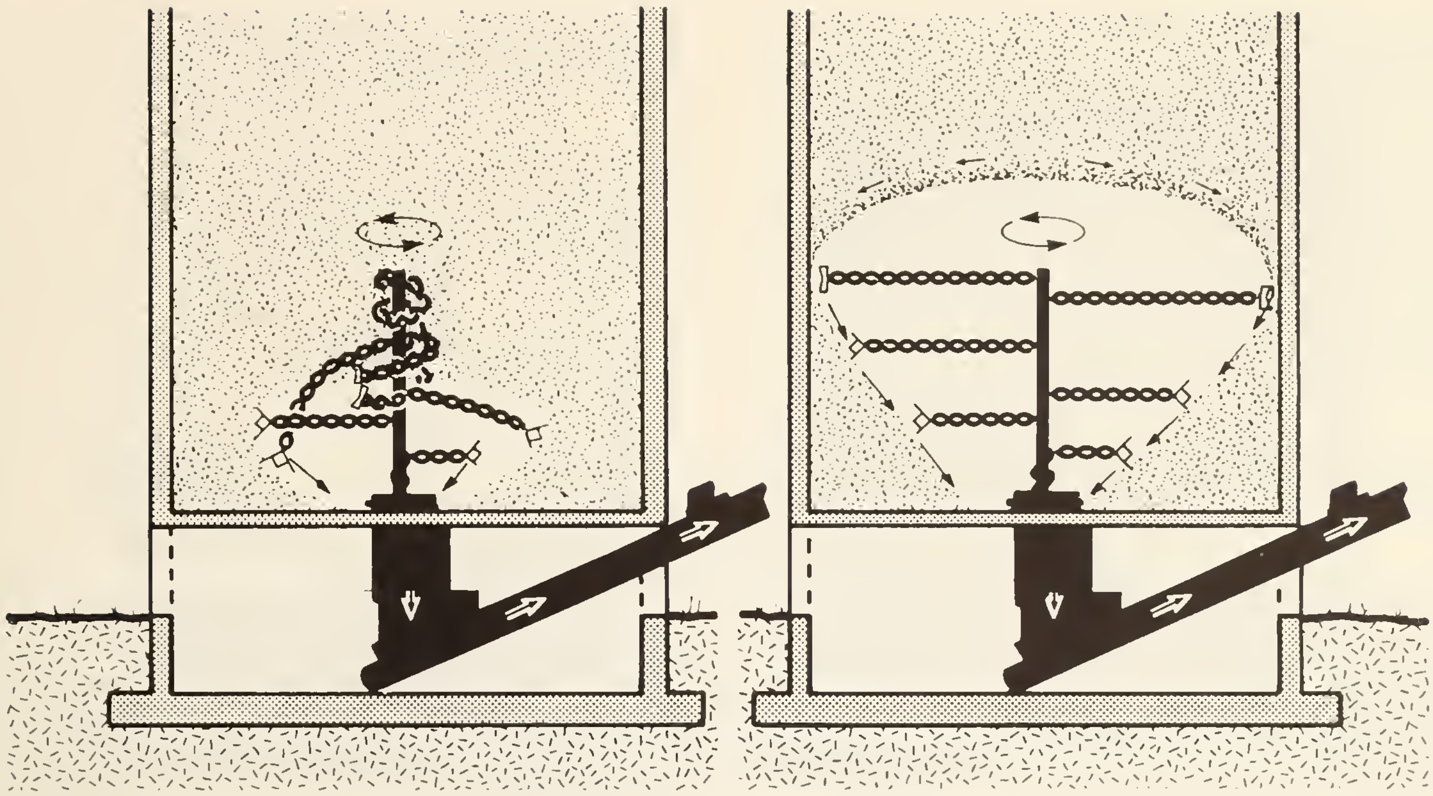


FIGURE 13 Flail-type bottom unloader uses chains with cutter heads, attached to a rotating vertical shaft. The chains fly outward due to centrifugal force, tearing at the silage and carrying it down the inclined surface to the central discharge.

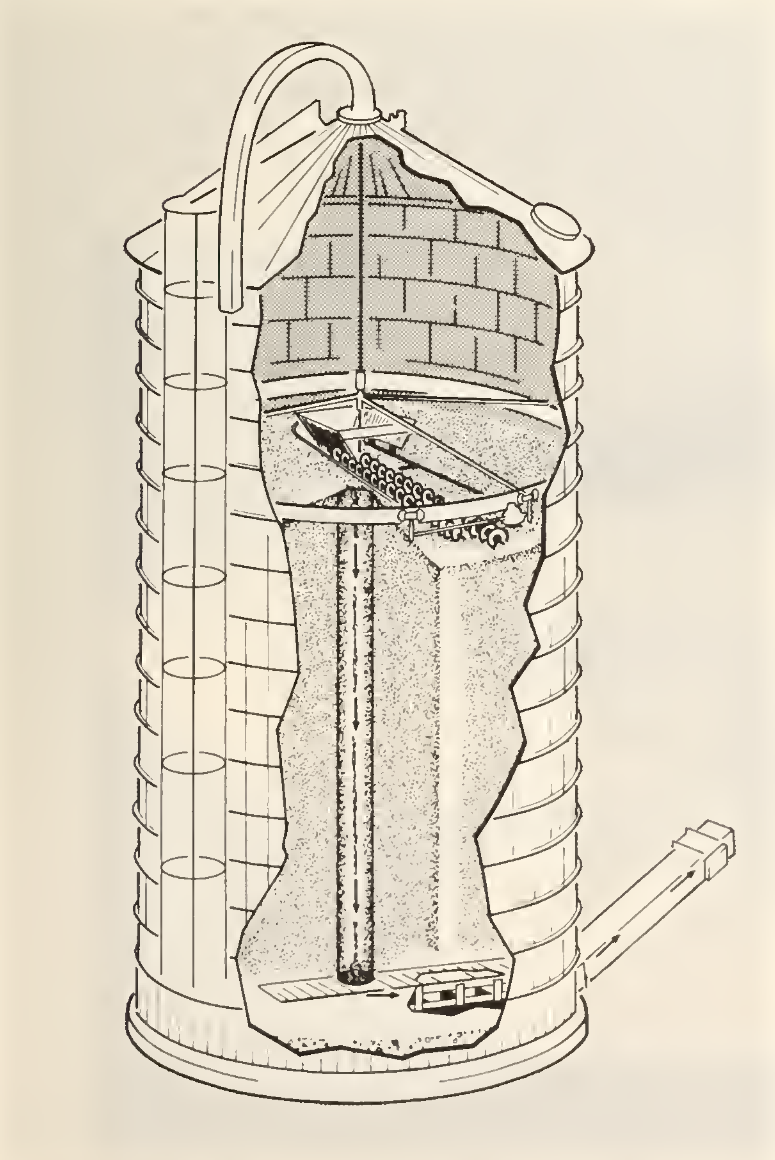


FIGURE 14 Top unloader uses a ring-driven pair of augers which cut and drag silage into a preformed central hole.

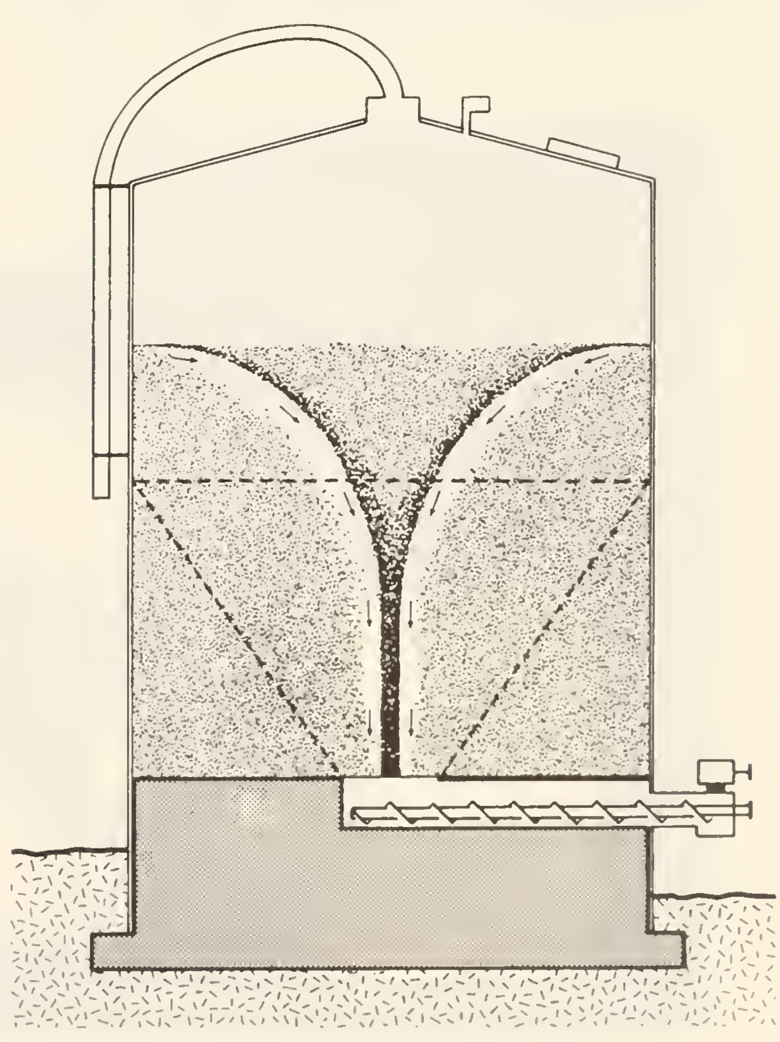


FIGURE 15 The top layers of high-moisture whole-kernel grain flow by gravity down through the mass to a central opening, in effect turning the mass inside out.

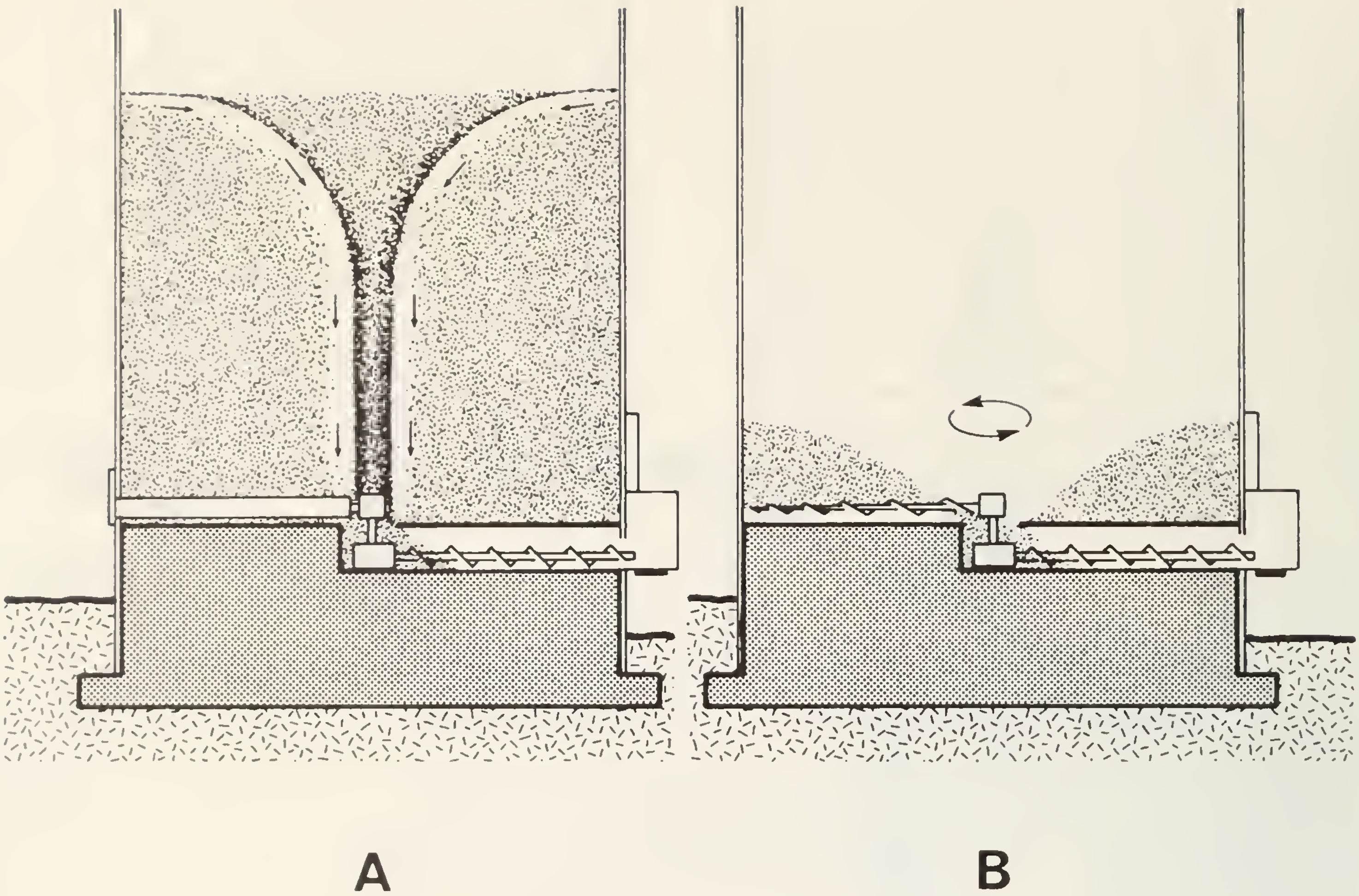


FIGURE 16. (A) Bottom unloader for whole-kernel high-moisture grains removes most of the grain by gravity, with the sweep-arm auger stored under a hood. (B) Near the end of unloading the sweep-arm auger is engaged to remove the remaining grain that won't flow by gravity.

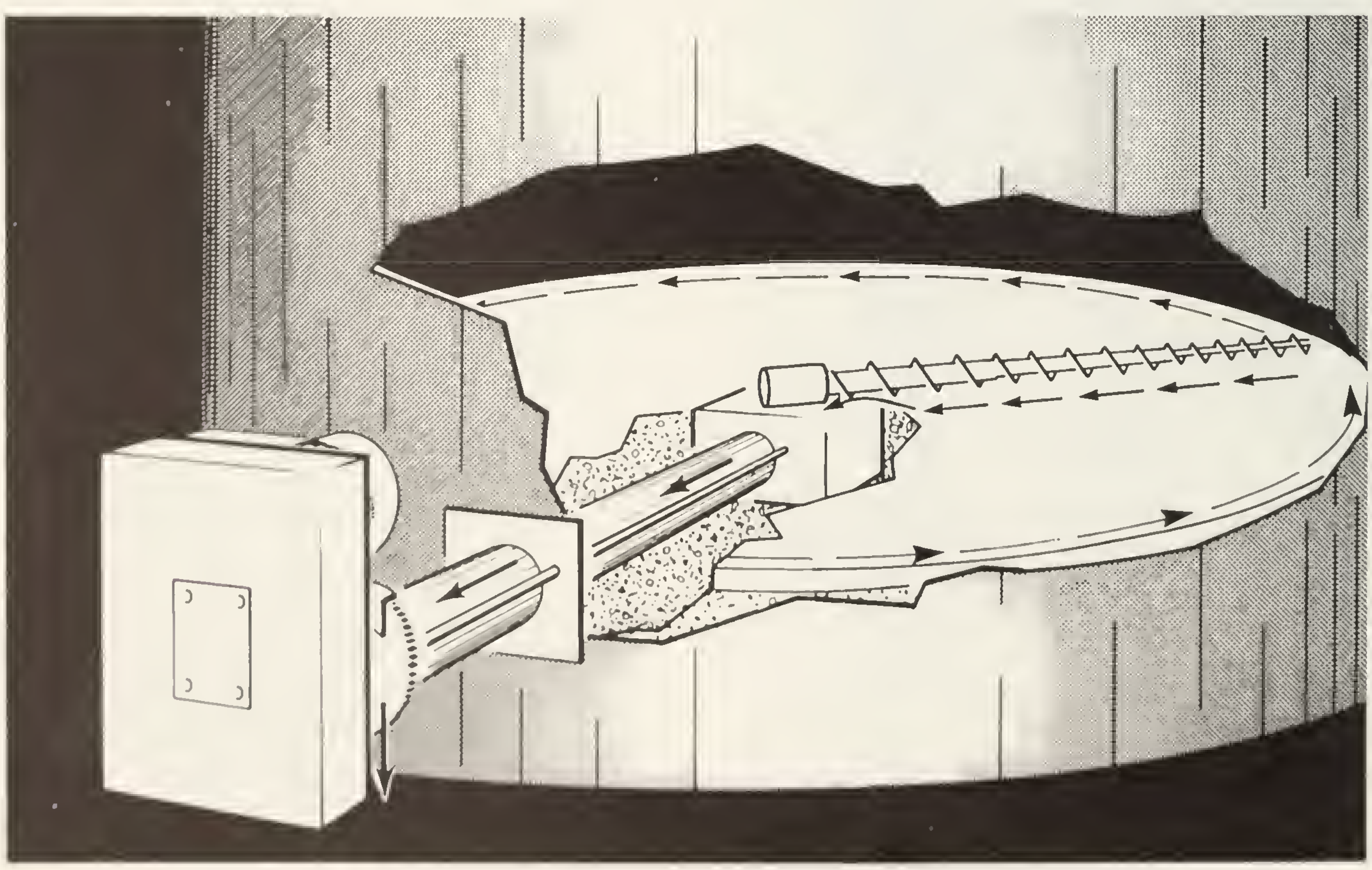


FIGURE 17. A constantly operating tapered sweep auger is used on some high-moisture grain unloaders to ensure positive flow into the discharge auger.

lest diameter flighting at the outer end of the arm). In this way grain is constantly dragged to the central discharge opening so that at least part of the total volume removed is taken from the bottom.

For non-free-flowing material such as ground high-moisture corn or barley, an unloading system that does not rely on gravity flow must be used. Unloaders used for whole-plant silage are probably the best and most reliable.

To prevent the entry of air into the silage mass, all bottom unloaders must be equipped with a sealed head and a valve or cover plate to seal off the discharge opening when material is not being withdrawn. This is necessary regardless of the type of unloader used and the type of feed being handled.

Bottom unloaders, particularly for whole-plant silage, are fairly expensive. For each unloader type a special base must be built to accommodate the unloader and all the auxiliary equipment. Each unloader is unique and incompatible with other types and makes. You must buy a specific unloader as part of a complete silo storage unit (not like top unloaders for open-top silos).

Advantages of oxygen-limiting silos

1. An oxygen-limiting silo gives a high degree of control over the in-storage atmosphere, thus promoting proper fermentation. This control can, with proper silage management, result in low storage loss, about 3-5% dry matter (lowest of all silo types).
2. This type of silo gives the farmer a great deal of flexibility in his feeding program. Because of the controlled atmosphere, feed can be taken out at any rate without causing appreciable deterioration of the remaining feed. There is no need (from a feed quality standpoint) to select a silo size with dimensions (diameter and height) that match the daily feeding rate while at the same time matching the volume required to the total feeding period (so necessary with open-top silos to prevent feed deterioration). This is a particular advantage to operators with smaller herds (e.g. feeding hay-crop silage, high-moisture corn, etc., or where "all-in, all-out" feeding operations require a pause in feeding).
3. Most oxygen-limiting silos bring with them the several advantages of bottom-unloading. These include:

   The motor and drive unit are at ground level outside the silo and readily accessible for adjustment, servicing and repair. (The unloader unit itself, however, is not as accessible as that of a top unloader.) Silo climbing is eliminated for unloader maintenance and repair.

   The silage placed first in the silo is the first out. Continuous feeding of fermented silage can take place even while new material is being added on top, with no sudden change occurring in the ration.

   The silo can be filled (or refilled) without moving the unloader (although this is sometimes recommended when filling an empty silo).

   It is not necessary to climb the silo to open the chute doors for unloading. In addition to convenience, this feature eliminates the risk of silo gas poisoning when installing a top-unloader (that is, unless the operator enters the doubly-dangerous silage cavity at the bottom!).