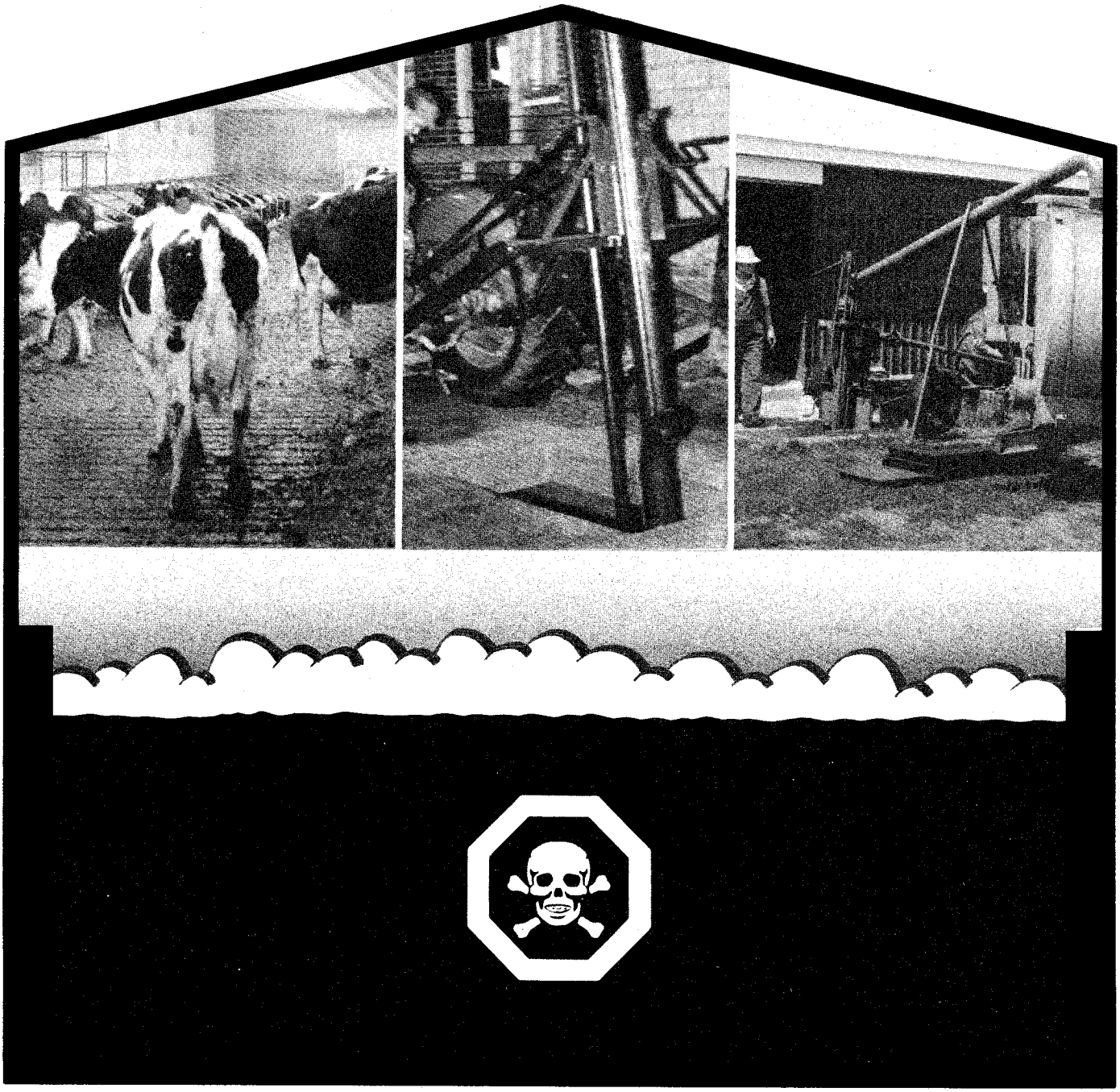
CANADA
PLAN SERVICE

MANURE GAS

M-10710



COMPLETE INSTRUCTIONS

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MANURE GAS

PLAN M-10710 NEW 86:02

Manitoba, 1966. Liquid manure under the slotted floor of a closed confinement beef barn was being mixed through an opening in the slotted floor by a tractor pump installed indoors. Two feeder cattle died within 5 minutes of starting the mixer-pump.

Ontario, 1967. Sixteen feeder pigs died in a fully slotted finishing barn while the manure tank under the slotted floor was being mixed from an outside pumping -port. Two men entered the barn to increase the ventilation; they had to be helped out of the barn, but fortunately both recovered.

Alberta, 1968. A steel cover plate was dropped accidentally through the scrape-in slot in the concrete top of a dairy manure tank. The farmer went down a ladder to retrieve the plate, but quickly collapsed and fell facedown in shallow manure at the bottom of the ladder. Second and third persons each attempted rescue, and in turn collapsed. A fourth rescuer took down a rescue rope, held his breath each time while in the tank, and managed to pull out the three victims. Only the third victim and his rescuer survived.

Quebec, 1982. While repairing a dairy manure transfer pump in a tank 3.6 m deep, a farm worker became dizzy and fell down. A second worker went down into the tank to help, and immediately collapsed. By this time, manure was flowing back unchecked from the larger outside storage and was rapidly rising in the transfer tank. A third helper went down, and in turn lost consciousness. All three drowned in the manure before rescue could be started.

Ontario, 1982. Working alone, a hired man entered a pig manure transfer tank to unclog the sewer pipes connecting the pig stall area to the long-term storage. He was not missed until he did not come back to the house for lunch. He was subsequently found dead, face-down in the bottom of the transfer tank.

Ontario, 1979. When starting to fill an old-model manure tanker, a farmer's son noticed that the discharge valve was leaking, apparently jammed partly open by some gravel. He grabbed a shovel and climbed down into the tanker, using the inside ladder rungs. He got out one shovelful of gravel, went down again, felt 'woozy' and passed out. Almost an hour later, others noticed he was missing and started a search. They found him lying inside the tanker, luckily with his face near the partly-opened discharge valve. He was revived in hospital several hours later.

Newer models of the tanker have no inside ladder, and allow the valves to be serviced from outside.

Manure gas caused each of the above form accidents. These typical cases were taken from newspapers, scientific reports and coroners' files, and are only a few of many that have been recorded.

The tragic part of many manure gas accidents is that they often claim two or three victims before others realize the extreme danger.

Gas is not a serious problem with fresh manure. But when manure is stored for several weeks or months it is attacked by anaerobic bacteria that produce many different gases. Some of these are dangerous. If manure is stored in a covered tank or similar enclosed space, gases can accumulate in the tank's headspace, as well as in the form of bubbles and dissolved vapors trapped within the manure itself.

The most dangerous of these gases are hydrogen sulphide (H_2S), carbon dioxide (CO_2), ammonia (NH_3) and methane (CH_4). It is important to know the physical properties of each gas if you are to set up effective safety procedures.

HYDROGEN SULPHIDE (H_2S) is the most dangerous of the manure gases. It is easy to detect by smell at concentrations safely below the TLV (see table), but unfortunately, lethal concentrations paralyze the nerves of smell. Thus, a person's ability to smell the gas disappears rapidly with continued exposure or high concentration. A strong dose paralyzes the nerves controlling the diaphragm, so that the victim stops breathing.

Because it is heavier than air, hydrogen sulphide tends to lie like a 'pool' of gas near the manure surface until something causes it to overfill the tank and spill up through slotted floors or sewer pipes into the animal pens above. Most cases of H_2S poisoning result from either mixing the manure (which suddenly releases gas trapped in the manure), or from some-one going down into the tank. Animals lying in the pen (or sniffing at the slotted floor) are of course more vulnerable to this low-lying gas than humans standing up.

CARBON DIOXIDE (CO_2) is produced by all living organisms, including manure bacteria. The principal danger with CO_2 is that it replaces the oxygen of the air (natural. air is about 21% oxygen, 79% nitrogen and 0.03% carbon dioxide). In manure tanks, a victim is likely to be put down by H2S long before CO_2 could have any detrimental effect. Like H_2S, CO_2 is heavier than air and will concentrate at the bottom of the manure tank and pumping pit headspaces.

AMMONIA (NH_3) is produced by decomposition of the nitrogenous parts of animal manures (proteins, for example). It is easy to detect by its chara(,teristic sharp smell, and being lighter than air it rises and mixes with the ventilation air as fast as it is produced. Therefore, in properly ventilated buildings there is little risk of it accumulating to dangerous concentrations. Ammonia is more frequently noticed with poultry manure; its presence indicates excessive moisture in the manure pits (too much spillage from the drinkers, etc.) and imperfect ventilation in the room above.

METHANE (CH_4) is the principal 'fuel' gas produced from manure by anaerobic digesters. The methaneproducing bacteria work better at high temperatures (35°C and above), so the quantity from a cool underground manure storage is likely to be small. Nevertheless, there is some danger of explosion from a careless spark or a lighted match dropped into a covered manure tank. Methane is considerably lighter than air (see table), so it will not accumulate in opentop tanks.

GOOD DESIGN MINIMIZES GAS HAZARDS

A good design minimizes the time manure is in the barn by moving it frequently to separate storage, while providing effective gas traps between the two areas.

SWINE BARNS Figure 1 shows a total-slotted floor system that was very popular some years ago for swine finishing (a somewhat similar arrangement was also used for confined beef production). This is not recommended now! The concrete basement occupied the entire space under the floor, and the whole floor (or at least the part under the animal pens) was slotted. Manure accumulated under the floor for winter periods of 6 months or more, and the tank was deep enough to provide the necessary long-term storage.

Because the pen floors were totally slotted, they required no daily scraping or cleaning, and the total system was a little cheaper to build because the manure storage shared the same foundation as the building.

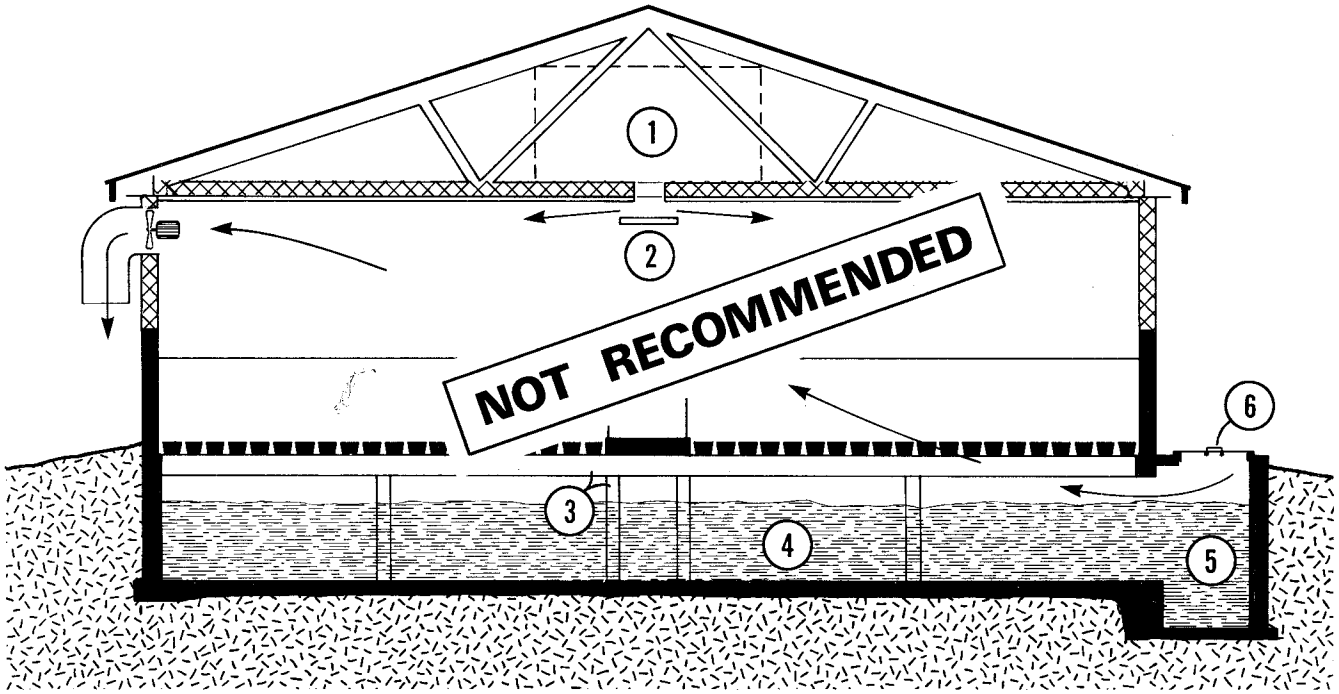
Unfortunately, the disavantages far outweighed the few advantages. Manure gases from the tank under the floor produced strong odors. At cleanout time, a tractor owered pit pump was put into the pumping ports (5) and manure was recirculated throughout the storage (4) to loosen any settled sludge that would not drain out easily. With negative-pressure ventilation (2) and the open hatch at (6) the manure gases released with the first flush were drawn into the pens.

CHARACTERISTICS OF THE MOST DANGEROUS MANURE GASES

Gas	Symbol	Density (relative to air)	Odor	TLV TWA* (ppm)**	Concentration (ppm)** and corresponding effects on humans
Hydrogen sulphide	H2S	1.19	like rotten eggs, nauseating	10	5 - offensive odor 150 - olfactory nerve paralysis, death within 30 min 700 - rapidly fatal
Carbon dioxide	C02	1.53	none	5000	30000 - increased rate of breathing 40000 - drousiness, headache 300000 - could be fatal in 30min
Ammonia	NH3	0.6	sharp, pungent	25	100-500 - irritates eyes, nose and throat in 30 min 5000 - respiratory spasm, may be fatal
Methane	CH4	0.5	none	-	500000 - could Asphyxiate by displacing oxygen

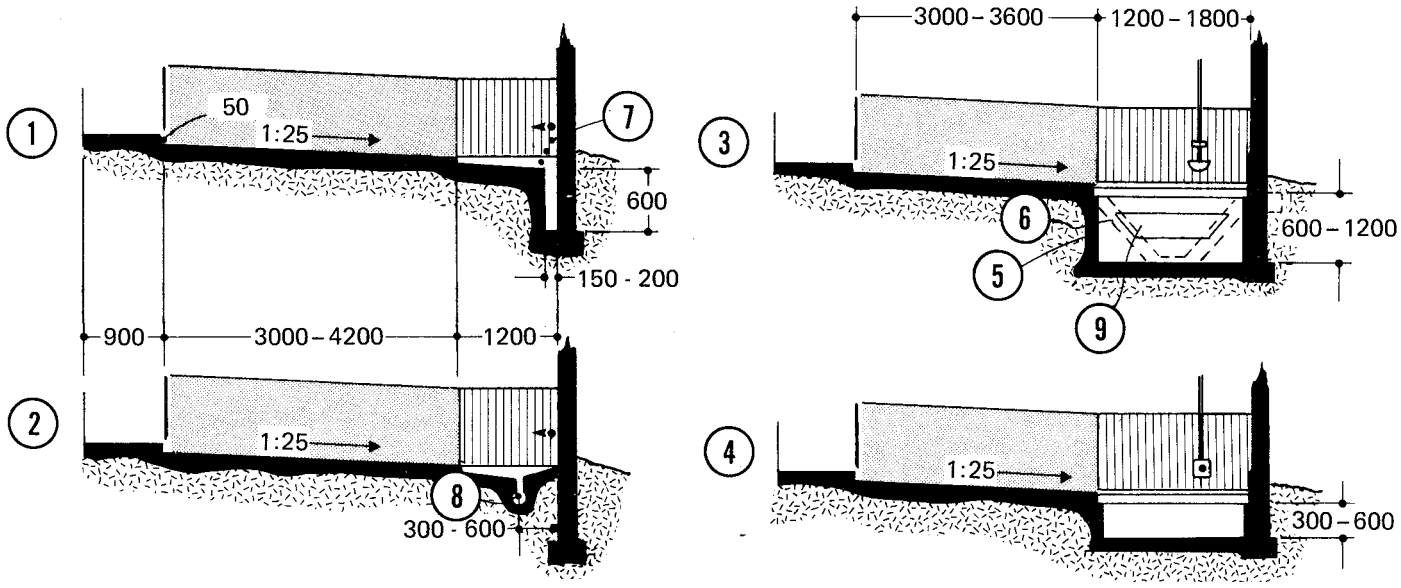
* TLV TWA (Threshold Limit Value, Time-weighted Average), the concentration under which nearly all workers may be repeatedly exposed for an 8 h workday and 40 h work week without apparent adverse effects. Established by the American Conference of Government Industrial Hygienists, P0. Box 1937, Cincinnati, OH 45201, U.S.

** ppm (parts per million) of a gas in atmospheric air; to convert to percentage by volume, divide ppm by 10 000.



1 insulated building
2 ventilation system with exhaust fans and adjustable slot air inlets
3 concrete or treated wood beams and columns support a slotted concrete floor
4 long-term manure storage
5 outside mixing-pump out ports at intervals along the wall
6 removable cover plate, access to 5

Figure 1 Totally slotted floor manure system with outside pumping pit for cleanout (not recommended)



1 pen with deep narrow gutter
2 pen with flushing pipe gutter
3 partly slotted floor with rectangular gutter 5 or V-gutter
4 partly slotted floor with shallow gutter, mechanical scraper or flushing system
5 rectangular gutter
6 V-gutter
7 steel rod gutter guard
8 150 mm dia. pipe, slopes 1:100, 38 mm slot
9 baffles at 6-9 m spacing

Figure 2 Manure gutter designs for swine growing, finishing and gestation pens

Animals died; see examples from Manitoba, 1966, and Ontario, 1967. Even a small air leak around the hatch cover at (6) was enough to ventilate the barn with foul air from the manure pit instead of fresh air from the inlets (2) . This system of manure handling is not recommended with closed barns and negative-pressure ventilation.

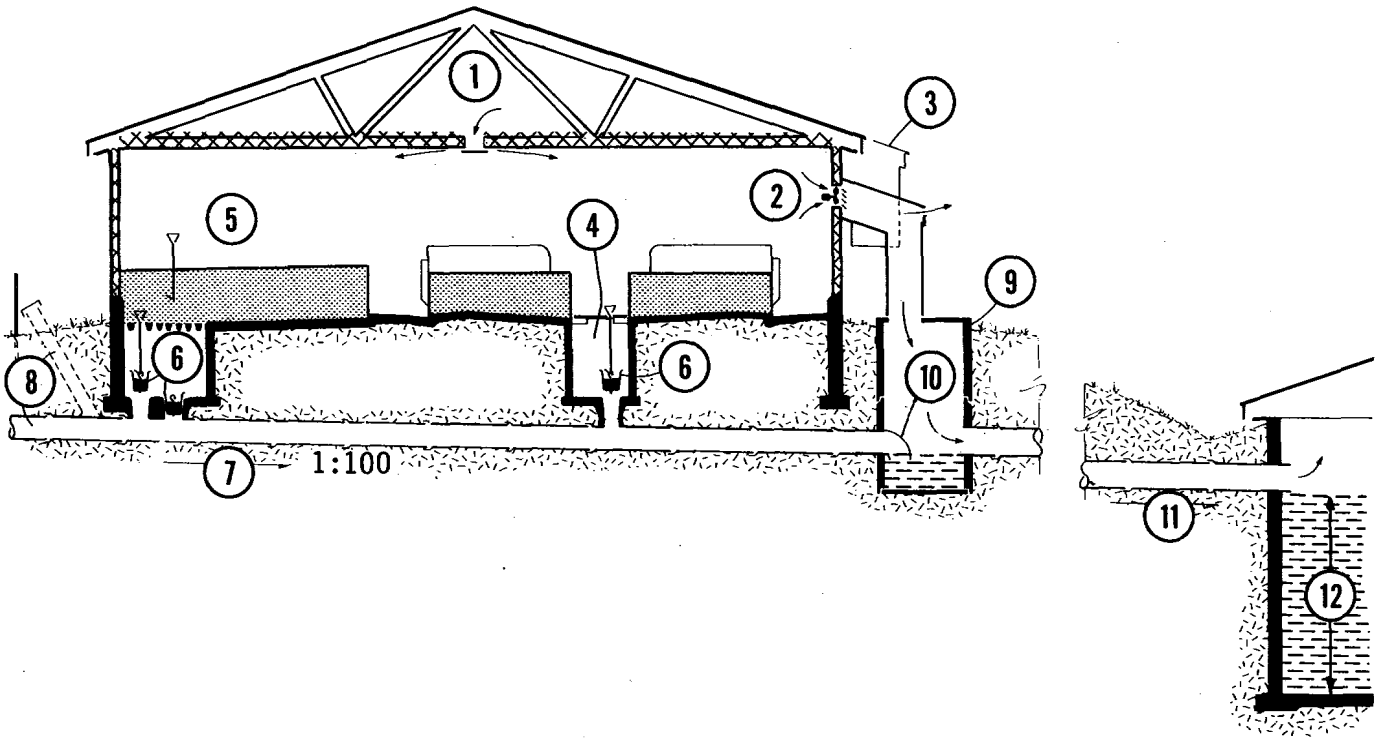
Figure 2 shows several improved manure systems for growing, finishing and breeding pigs. They feature smaller gutters under partly slotted floors. These minimize both the quantity of stored manure and the storage time, considerably reducing gases and odors inside the barn.

The deep narrow gutter (1) fills very quickly (1-2 days in fully-occupied growing and finishing pens), then a manure-tight valve under one end of the gutter is opened. This drains the manure through a gas trap into the long-term storage. The flushing pipe gutter (2) is pump-flushed dailywith fresh liquid manure (CPS plan M-3711). Solid pen floors may require some manual scraping into both the deep narrow gutter (1) and the flushing pipe gutter (2) , so the partly slotted floors (3) and (4) are now more popular in new swine barns.

With the shallow rectangular gutter (5) and the V-gutter (6), the stop-and-flow system is the most popular method for removing manure regularly from the gutters.

Figure 3 shows some special features to make the stop-and-flow system safer and easier to service. Sewer pipes (7) and (11) are smooth, watertight and big enough (at least 200 mm, better 250 mm). They always run in straight lines to minimize plugging. An important feature is the Yconnection and cleanout pipe (8), preferably outdoors for running a hose or sewer-cleaner through, in case of blockage. The gas trap (10) is the most important safety feature; it prevents manure gas from being drawn back up the sewer pipe (11) from (12) .

Figure 4 shows more features that make the stop-andflow system more trouble-free and safer. Where two shallow gutters (6) can run side-by-side, it has been useful to cross-connect the remote ends of the gutters at (4). Then one valve (3) will flush both gutters. When the gutters are again ready for flushing 1 or 2 weeks later, the other valve (3) is pulled, reversing the flow. This seems to help dislodge settled solids that previously accumulated at the blind end of each gutter.



1 fresh air enters thru attic and adjustable ceiling inlet
2 continuous fan exhausts into insulated duct; duct is removed in summer
3 weather hood for other exhaust fans, beyond
4 farrowing area; gutters are scraped to sump box
5 weaner area with slotted floor over stop and-flow gutter
6 stop-and-flow valve
7 250 mm branch sewer pipe
8 100 mm cleanout pipe with cap
9 collector pit made from 1200 mm concrete pipe
10 gas trap of 250 mm pipe elbow
11 250 mm main sewer pipe to 12
12 long-term manure storage: maxim m liquid level is at bottom of outlet 11

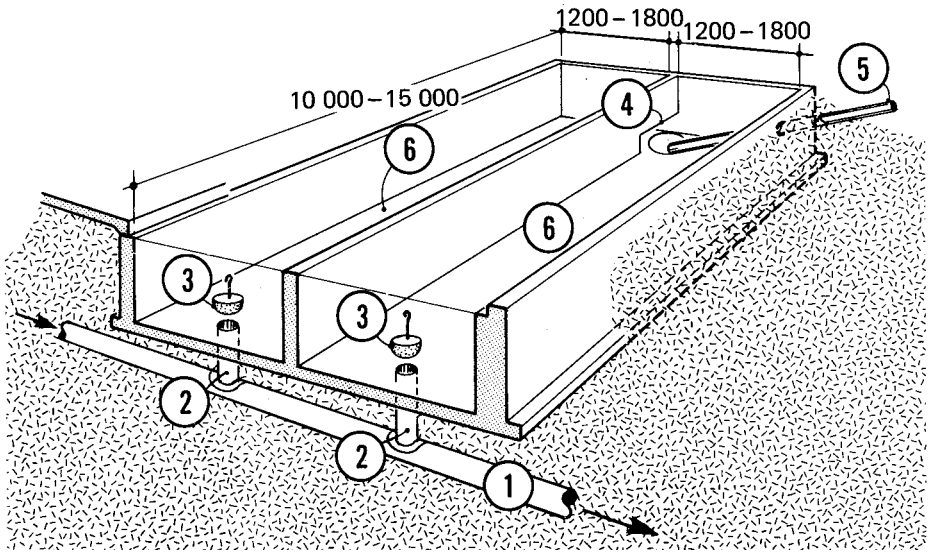
Figure 3 Typical stop-and-flow liquid manure system with gravity flow, remote long-term storage and exhaust ventilation protection

Another feature in Figure 4 is the emergency pumpout pipe (5) that can be connected to a vacuum tanker to flush and pump out settled solids. Note that this pipe opens below the floor level of the gutters; just a small amount of liquid remaining in the floor depression forms a gas trap. All of these features are designed to solve manure gas and plugging problems at the source, without requiring anyone to lift out slotted floor units and go down into the gutters where the manure gas will be concentrated.

Another way to remove manure from shallow gutters under slotted floors is to use the cable scraper shown in Figure 7. This equipment, first developed for cleaning shallow gutters under poultry cages and wire floors, is now being used for cattle and swine manure. The reciprocating scrapers only need about 300 mm of clearance to travel under the slotted floor supports. This permits daily cleaning, and completely eliminates the danger of manure gases provided there is a gas trap between the manure drop (5) and the long-term storage.

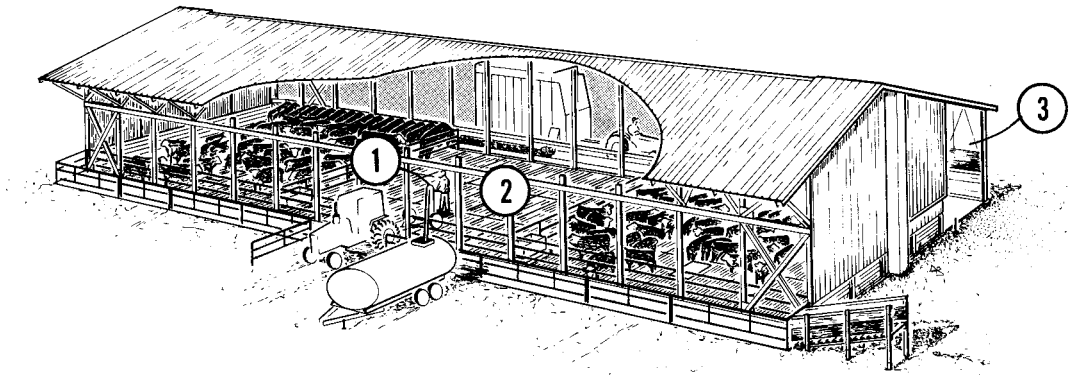
BEEF BARNS Confinement beef barns with deep manure storage under slotted floors (like Figure 1) have not been without manure gas problems (see 1966 example from Manitoba).

Figure 5 shows a safer option for finishing beef on slotted floors. Instead of a totally closed building with fan ventilation, this building has a full open front that faces south, as well as a north wall that can be opened during hot weather and while pumping manure. The only special precautions when pumping out manure are to pick a day when there is some wind, move cattle from the pen above the compartment being pumped (if possible), and open all doors and ventilation openings for maximum natural ventilation.



1 250 mm sewer pipe, to storage
2 200 mm saddle-tee and pipe riser
3 stop-and-flow valve
4 crossover opening between gutters
5 125 mm vacuum tanker pipe connection; top of pipe opening is below floor
6 gutter bottoms made level

Figure 4 Stop-and-flow gutter system with 'hairpin' feature



1 tractor-powered manure pump installed in one separate compartment of manure tank
2 if possible, cattle removed from pen where manure is being pumped
3 rear wall and doors opened for maximum ventilation

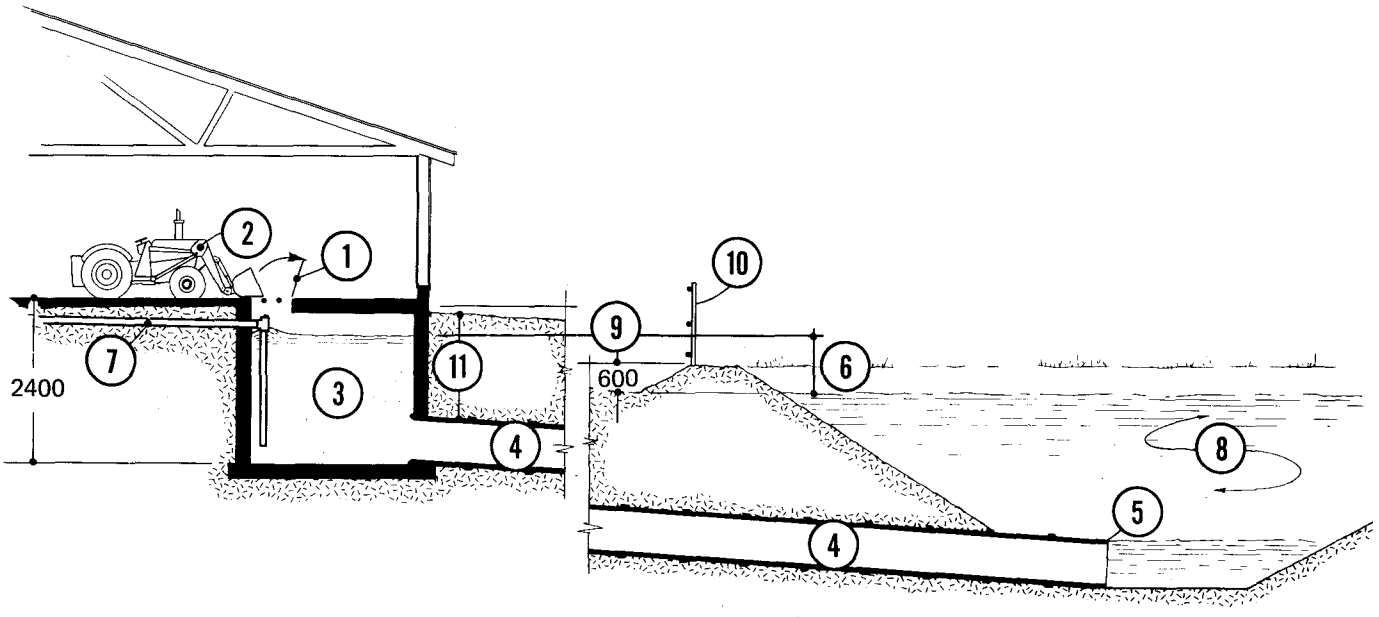
Figure 5 Open-front slotted-floor beef barn (from CPS plan M-1463)

DAIRY BARNS With tie-stalls, gutter cleaner and outdoor manure stacker, there is little risk of a serious manure gas problem. However, free-stalls use many different manure systems; those with underfloortanks could be dangerous. Do not use long-term underfloor manure storage, but move the manure frequently to a separate storage outside the barn.

If you already have a dairy barn that o erates like Figure 1, make sure that the outside hatch (6) is sealed airtight (for example, with a heavy steel cover with a soft rubber gasket). When pumping or flushing manure from under the slotted floors, remove the cattle and open all doors for natural ventilation.

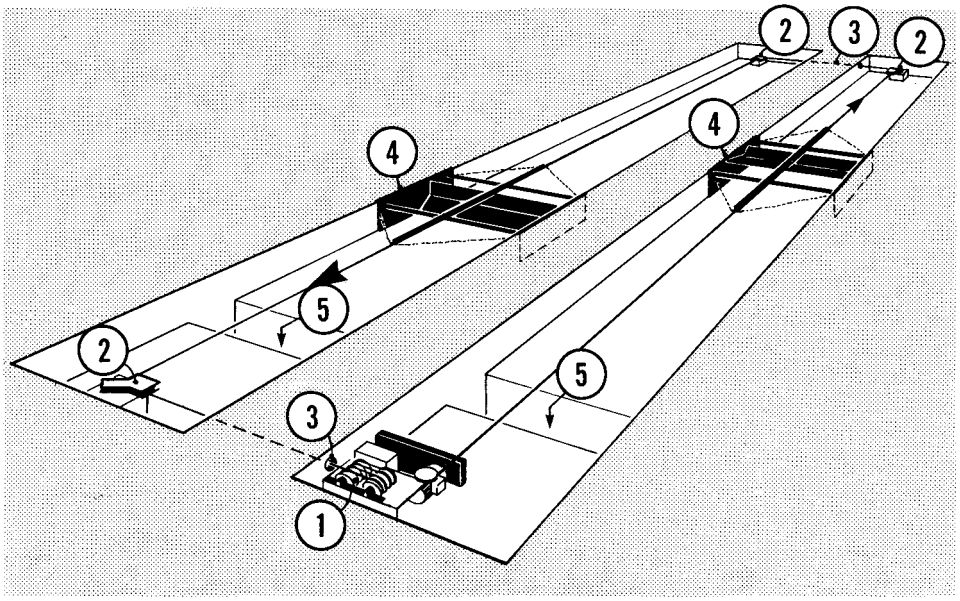
Figure 6 shows a free-stall dairy manure system adapted to a hillside site where the manure can be drained by gravity from the barn to a storage pond or tank at a lower level. It illustrates some important safety principles:

- The sump (3) is just big enough to hold a little over 1 day's production of manure and washwater. This minimizes in-barn storage time, but lets the tractor operator scrape manure quickly into the sump without waiting for it to move slowly down the pipe (4).
- The sump opening (1) is protected with a safety grill (shown), and a cover plate or safety railing; these prevent people and livestock from falling through. Also, the cover plate (if used) must be fastened with a safety chain or hinges so that it cannot fall in.
- There is no fixed ladder into the sump to tempt anyone to go down to retrieve something (like a dropped pair of glasses). It's better to fish out the fallen article with a hook or net. The Canadian Farm Building Code (1983) prohibits fixed ladders in closed liquid manure tanks (article 4.1.1.31.
- The long-term manure storage (8) is banked up (9) to keep out field runoff water, and fenced (10) to keep out children and livestock.
- The manure pipe (4) enters the bottom of the longterm storage, so that a gas trap is formed as soon as the liquid rises to (5) .
- Some municipalities will not permit the clay-lined storage pond, but insist on a concrete tank or similar watertl ht structure for the long-term outdoor storage (8) . Where these open-top tanks have smooth vertical walls, a permanent escape ladder could prevent a drowning in case someone falls in. The Canadian Farm Building Code does not prohibit the safety ladder where an outdoor tank is open at the top for natural wind ventilation.



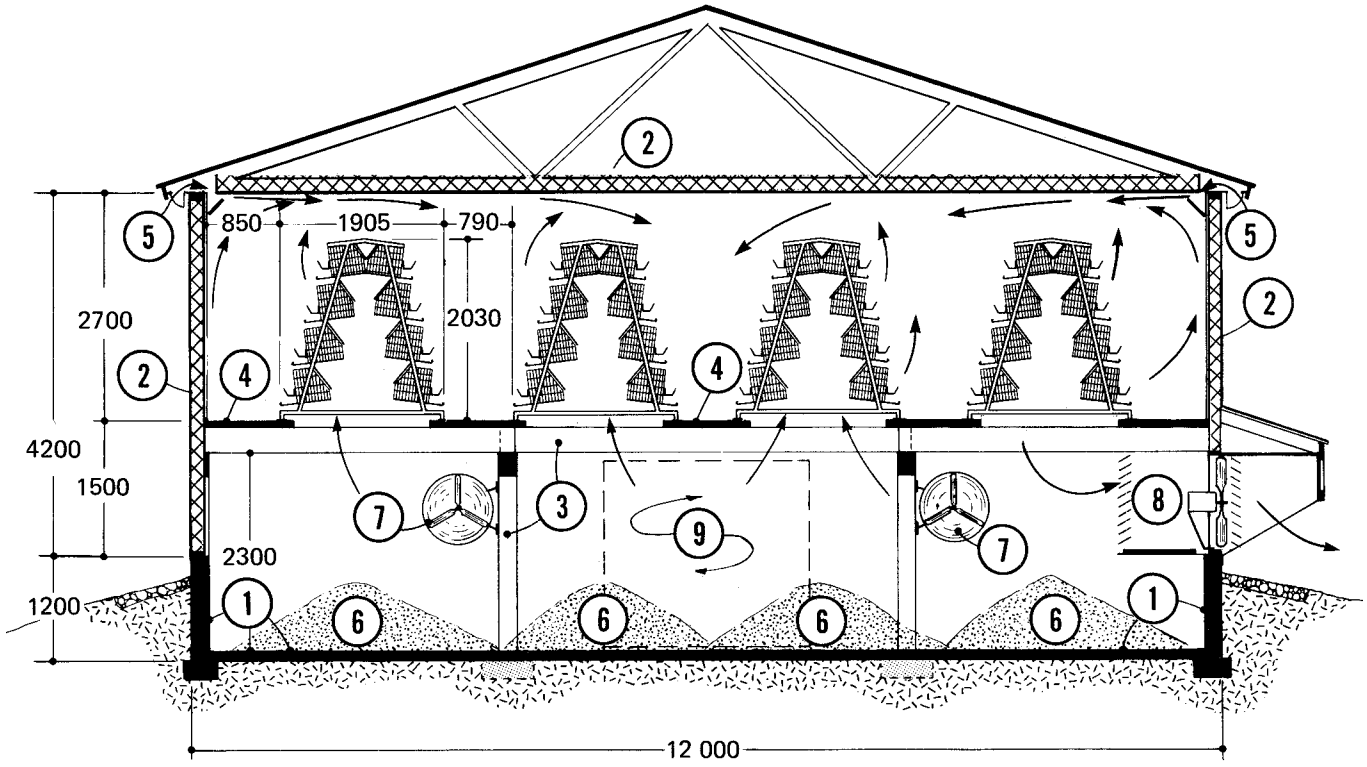
1 **floor slot with safety grill, and either hinged cover plate or guard rail**
2 **tractor scrapes manure to slot in floor**
3 **concrete sump box with volume to match 1 day's manure and washwater production**
4 **600-750 mm concrete pipe laid straight with a uniform slope below frost, and joints sealed watertight**
5 **pipe enters bottom of storage; minimum fill is to top of pipe (for gas trap)**
6 **maximum liquid vel is 1.2 m below flushwater pipe (7) or the floor of the barn, whichever is lower**
7 **flushwater pipe from sump and pump in milking parlor, with plugged tee and drop pipe for gas trap. or add a gas trap at the parlor end**
8 **clay-lined manure storage pond**
9 **earth bank all around storage keeps out field runoff water**
10 **safety fence, with locked gates at all access points to storage**
11 **pipe below frost**

Figure 6 Gravity flow liquid manure system in a dairy free stall barn (after West,1984)



1 automatic-reversing electric winch
2 corner idler pulley, anchored to gutter floor
3 stainless-steel cable passes through drainage pipe between gutters
4 travelling scraper with rollover blade
5 manure drop (or cross-conveyor) to storage

Figure 7 Cable scraper system for cleaning shallow gutters under poultry cages and slotted floors in swine buildings (adapted from Favorite Mfg. Inc., New Holland, PA, U.S.A.)



1 concrete foundation made watertight
2 well-insulated wood frame construction
3 timber floor joists on post-and-beam supports
4 wood plank walkways between cage rows
5 adjustable fresh-air inlet slot
6 solid manure accumulates in basement
7 air-circulating fans improve drying of manure
8 exhaust ventilation fans below floor
9 access door for cleaning basement

Figure 8 High-rise chicken laying house, designed for 400 mm deep, modified stair-step cages (by Favorite Mfg. Inc., New Holland, PA, U.S.A.)

POULTRY BARNS Modern poultry buildings pose little risk of manure gas poisoning because the manure is either removed frequently, or dries in place as it accumulates. Under caged chickens, for example, a mechanical scraper (Figure 7) removes the manure daily. The main precaution here is to use an effective gas trap between the dump slot (5) and the long-term storage.

The popular 'high-rise' layin house (Figure 8) has long-term manure storage (6) under the cage-room floor (3) . To avoid serious problems with manure gas (in this case, mostly ammonia) it is important to choose and maintain the cage drinkers carefully to minimize dripping and spillage. Together with supplementary fans to help dry the droppings, this keeps the manure dry enough to prevent bacterial activity from producing too much gas. The usual precautions still apply when the storage is opened for cleaning with a small tractor and loader; that is, remove the chickens, pick a mild windy day and open all doors.

MANURE PUMPS

If the ground is flat, the water table high or bedrock close to the surface, the gravity flow systems shown in Figures 3, 4 and 6 are not feasible. In such cases, pumps are usually used to transfer liquid manure from gutters to long-term storage. However, they frequently plug up, and may tempt the unwary down into the sump to clear the blockage.

Better-designed pumps (Figure 9) now have blades that chop up problem solids like hair and straw. More important, they can be easily uncoupled and lifted from the pit for servicing.

SUMMARY- DEALING SAFELY WITH MANURE GAS

Design, build and manage with safety in mind! Follow these principles and guidelines carefully:

1. Avoid long-term manure storage under slotted floors in fully enclosed barns, especially with negative-pressure ventilation. Instead, build the main storage outdoors or at least separate from the livestock part, and remove the manure frequently from under the floors.

2. Provide a gas trap between the barn and any connected long-term manure storage (Canadian Farm Building Code 1983, Article 4.1.1.2).

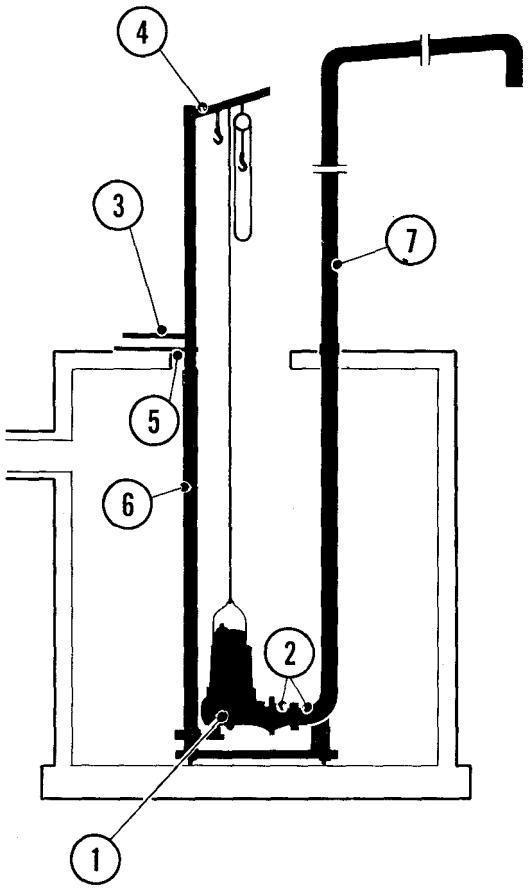
3. Use reliable, easy-to-service manure pumps and plumbing components. The best pumps have chopper-blades that precut problem manure solids (hair, baler twine, straw, etc.), and are easy to uncouple and hoist out of the pit for servicing (see Figure 9).

4. For mixing, pumping or draining any manure stored for a long term under the barn floors, choose a mild, windy day, and open all doors and windows to maximize natural ventilation. Temporarily move all livestock from the pens under which manure is being removed.

5. Remember that the deadliest manure gas (HZS) lurks in lowconfined spaces like manuretanks and pumping pits. Never go down into a manure tank without proper respiratory protection (even for an emergency rescue!).

6. If a rescue becomes necessary, call your local fire department or similar emergency service. Many rural fire departments have the required pressure-demand breathing apparatus (with full face-mask and remote air-tank with hose). SCUBA-diving gear is designed to work under water and is not considered safe here.

7. Apply first-aid to victims as given in manuals and courses for cardio-pulmonary resuscitation (CPR). Respiratory failure is usually the first result of a manure gas accident.



1 submersible electric pump with chopper blades to cut manure solids
2 discharge nozzle and outflow pipe can be uncoupled by rotating control handle (3) at safety platform
3 control handle
4 lifting davit with portable chain hoist
5 guide bracket bolted to safety platform
6 guide bar controls pump position when coupling at (2) or hoisting pump (1)
7 discharge pipe

Figure 9 Submersible electric manure pump that can be uncoupled from plumbing and hoisted for servicing (from Flygt AB, Halmstad, Sweden)

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