PLAN M-9732

SOLAR VENTILATION WALL WITH HEAT STORAGE

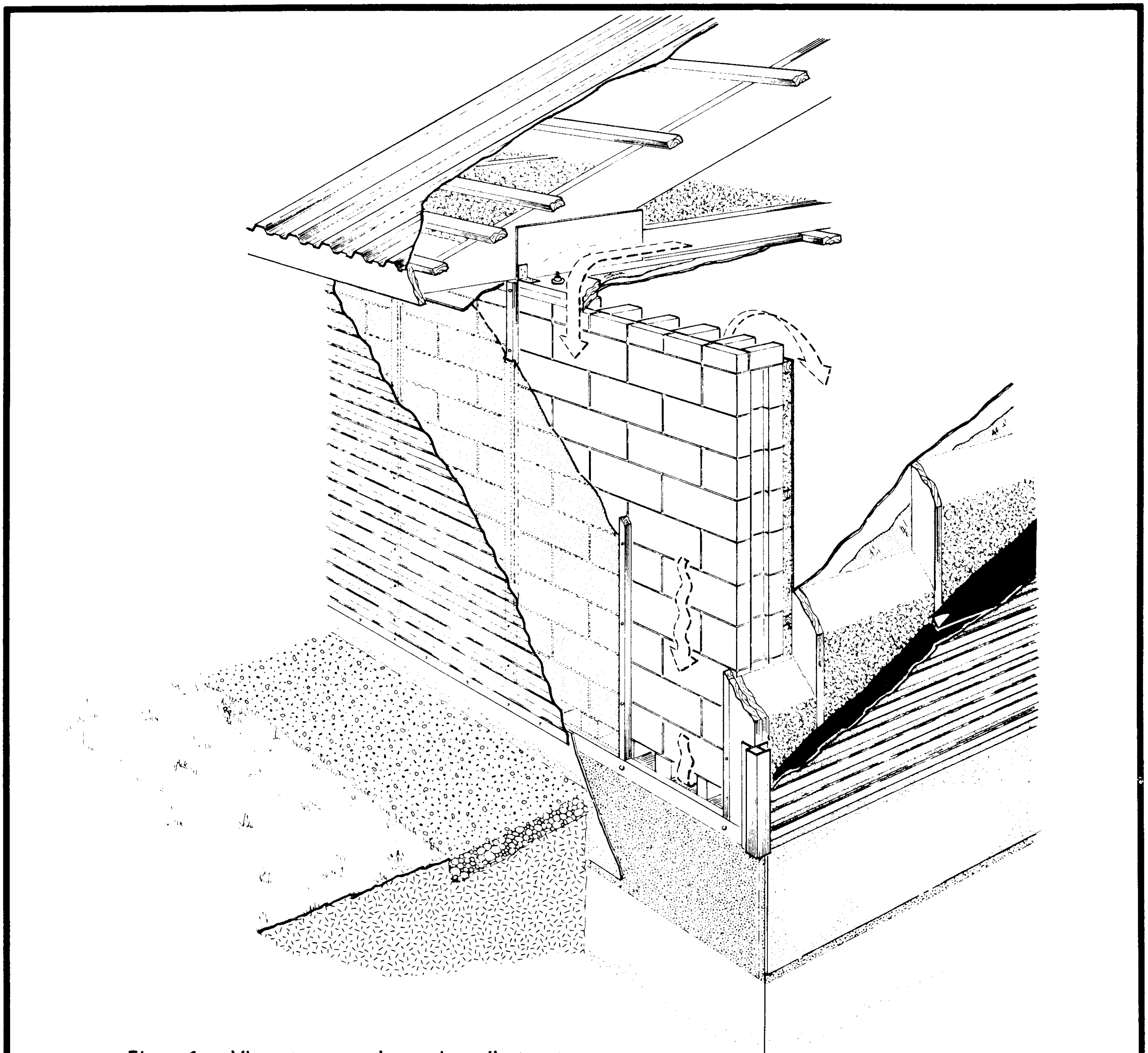

Figure 1. View at corner where solar collector stops.

CANADA PLAN SERVICE

The Canada Plan Service prepares detailed plans showing how to construct modern farm buildings, livestock housing systems, storages and equipment for Canadian Agriculture.

This leaflet gives the details for a farm building component or piece of farmstead equipment. To obtain another copy of this leaflet, contact your local provincial agricultural engineer or extension advisor.

SOLAR VENTILATION WALL WITH HEAT STORAGE

PLAN M-9732 NEW 82:02

Many animal and poultry barns can benefit from solar-assisted winter ventilation. Recent Canadian research shows that a sloping, roof-mounted solar collector is more expensive (and less practical) than one built into a vertical south-facing wall. This is because in winter (when solar-assisted ventilation is needed) the solar angle above the horizon is quite low, even at noon. For example, at Windsor, Ontario, the December 21 noon solar angle is 25°; farther north at Edmonton (Alberta) or Prince Albert (Saskatchewan) this angle is only 13°. In fact, the solar 'boost' due to sunlight reflected from snow-covered ground in front of a solar wall is more significant than the direct noon sun on a roof-mounted collector sloped away from vertical.

Ideally a solar collector on the long wall of the barn should face true south, but buildings can face up to 20° or even 30° either way from south without serious loss of solar heating; an angle slightly away from south simply shifts the time of maximum solar heating away from noon.

This design includes a covered-plate collector and a heat storage, both combined into an outside wall. The collector is an air-space covered outside by clear corrugated fiberglass sheeting (Filon, Excelite or equal), and backed on the inside by black-painted concrete blocks. The heat storage is the concrete block wall. Some research suggests that collector efficiency may be increased up to 20% by adding black aluminum or fiberglass flyscreen midway between the transparent cover and the blocks.

Heat 'storage' is an essential part of this solar preheat system; without the 'thermal flywheel' effect of the massive concrete block wall, inlet air temperature-rise with a bright winter sun can be 30°C or more, but there would be no benefit at night. And night is when the heat is really needed, when heat production from the sleeping animals or poultry is minimal and when outside temperature goes down.

In this design, special heavy concrete blocks are specified (75% solid, 240 mm thick). This provides enough heat storage to give some heat all night after a bright winter day. Ordinary 190 mm concrete blocks are only 17 kg each, compared with 29 kg for the special blocks; this gives the heavy blocks 75% more heat storage capacity.

CONSTRUCTION DETAILS Figure 2 shows details of construction and method of operation. The solar wall may be built as the south wall of a new barn, or it may be added to an existing barn. Of course, the extra cost of the solar feature is much greater for an add-on wall than for a solar wall built as an essential part of a new building.

Cast-in-place concrete is the best choice for the foundation below grade. Depth of the footing depends on how deep the frost penetrates soil in your locality.

The exterior perimeter insulation 3 is essential to conserve the heat collected in the wall and to prevent possible frost-heave. The best way to fasten this insulation and the treated wood sill 4 to the foundation is to tack them to the inside face of the concrete forms, before pouring the foundation concrete. This guarantees a perfect airtight 'fit' between wood, insulation and concrete (any air leakage here will short-circuit the air from the collector and cancel the heating effect). If the wall exceeds 15 m long, add a vertical construction joint through the foundation and blocks at mid-length (for expansion and contraction due to daily and seasonal temperature changes).

The preferred order of construction is outlined by the sequence of the numbered notes in Figure 2. After laying up the concrete block storage wall, it should be washed with 10% muriatic acid solution and then rinsed thoroughly with clean water, to ensure paint adhesion. Paint with two coats of flat black exterior latex, using roller or spray. Paint the cedar strapping 10 as well, after fastening it with ramsets or lead anchors to the painted block wall.

The clear corrugated plastic cover must be installed airtight, otherwise cold air leaks will dilute the warming air as it passes down through the collector. Use a clear caulking cement in all horizontal and vertical lapped joints, and fasten the cover with hex-head plated roofing screws with neoprene washers, _not with roofing nails. The screws cost more than nails, but they will be much easier to replace when you might later want to remove the cover to make repairs or to clean out spiderwebs and dust. To prevent deterioration of the fiberglass cover by ultraviolet light, coat the cover with a UV filter lacquer ('Excelac', by Graham Products Ltd., Inglewood, Ont., or equal). According to the manufacturer, this should be reapplied about every 5-8 years. Also, be sure to caulk the brick-to-plate joint at the top of the wall, as well as between the plates and where the ceiling vapor barrier meets the plates. Any air leaks here will short-circuit the collector and storage, making the system completely ineffective. The glazing must also be sealed against air leakage at both ends of the collector; Figure 1 shows a rectangular 'stop' of sheet metal flashing that provides for caulking where the glazing terminates at the building corner.

Air passes down through the collector and back up through the block wall. To get air into the blocks at the bottom and into the barn at the top, two courses of concrete bricks are placed on edge to replace one full course of blocks. Use six bricks per block (four across, two along the face), with the cross-bricks aligned above the webs of the block to make continuous air channels. To anchor the roof against wind uplift, bolt the wall plate 9 securely to the top courses of block using threaded rod set in mortar, with nuts and washers both top and bottom.

The interior wall insulation 16 is required to prevent wall sweating and building heat loss when the wall has cooled (after a night of heat discharge, or after a cloudy period when solar recharge is not effective). It also prevents unwanted heat gain in summer when the sun warms the blackened block wall.

The gravel splash pad 22 is desirable so mud won't splash up and coat the lower- part of the solar collector.

APPLICATIONS AND DESIGN This solar ventilation wall works only with a continuous exhaust ventilation system, usually with exhaust fans located in the other (north) wall of the barn. These fans must draw air steadily through the collector, storage and air inlet system. Any failure of the continuous ventilation (fan burnout, etc.) can allow a headwind at the fans to force warm moist air back through the collector, fogging and possibly freezing the collector. For winter ventilation, it is a good idea to use two identical small single-speed fans; one gives the continuous 'step 1' ventilation rate, and the second fan doubles this to the 'step 2' rate whenever the thermostat senses high enough temperature for increased ventilation. If either fan fails, the other can be run continuously as a standby until repairs are completed.

Warmed air can enter directly into the animal room (20, direct ventilation), or it can enter a preheat hallway 19, divided from the animal rooms beyond by wall 21

With direct ventilation, soffit doors 15 are closed for the winter, and fresh air 18 from the ventilated attic is drawn into the top of the collector. Velocity through the collector can be up to 2 m/s, which in a 38 mm space corresponds to a fan capacity of 71 L/s per metre of collector length; air flows from 35-70 L/s per metre of wall length are probably suitable. Solar heat warms the air (and the black blocks) as it passes down through the collector, then the air passes some more heat into the block storage as it comes back up through the block cores. Tempered air then accelerates from the wall into the animal room through an adjustable slot such as the Side Air Inlet.
The moveable baffle at the inlet slot
should be adjusted to give at least 3 m/s air velocity through the slot when the ventilation is at the low winter rate. With the step 1 fan ventilating at 35 L/s per metre of wall, 3 m/s corresponds to a slot opening of 12 mm; when the temperature in the animal room rises enough to start the step 2 fan, the ventilation can double to almost 6 m/s.

With the preheat hallway the function of the collector and storage is the same as with direct ventilation, but the solar-heated air can be dumped directly into the hallway, without the slot baffle. Whenever solar heating is not enough, more heat is added in the hallway (such as with electric fan-forced heaters), then the warmed air is passed through adjustable inlets into the animal room(s). The arrangement of these adjustable inlets may or may not be as shown in Figure 2.

If, for example, the shorter wall of the animal room is adjacent to the preheat hallway, it is often better to run a ceiling duct from the hallway into the room and to spread the air from both sides of the duct.

With either direct ventilation or the preheat hallway be sure to allow for some extra air friction when selecting the winter ventilation fans. With a solar wall 2.4 m high, the combined pressure losses for collector, storage and inlet slot (properly adjusted) are estimated as follows:

Winter Air Flow, L/(s.m) of wall length	Collector/ Storage Velocity m/s	Collector/ Storage Static Pressure Pa	Inlet Slot 20 Velocity m/s	Inlet Slot 20 Static Pressure Pa	Total Static Pressure Pa
35	0.9	4	3.0	7	11
50	1.3	7	4.3	15	22
70	1.8	14	6.0	30	43

Performance expectations can vary with clear or cloudy days and with the general maintenance of the system. An experimental collector and storage near London, Ontario performed one clear winter day and night as shown in Figure 3. Notice first that the attic alone provided considerable solar gain (about 12°C rise, at 14 00 h), but that attic temperature dropped to 1-2°C below outside air during the night (re-radiation to the clear night sky). Comparing the temperature curves for 'air in collector' with 'air from wall to barn' shows the helpful flywheel effect of the heat storage; some small benefit was still found up to 6 00 h the following morning. Note also in Figure 3 that if air from the collector were used directly for ventilation (without first passing it through the concrete block storage wall) it would be entering at over 30°C or (32°C above outside air temperature). This would seriously overheat the barn!

The experimental installation was on a furrowing barn with a collector wall 18.3 m long by 2.44 m high, and it collected an average of 2 kWh/m² of collector surface per day, for the 180-day heating season. This represents a heat saving of 18.3 x 2.44 x 2 x 180 = 16 000 kWh. At 5¢/kWh, this represents a saving of $800 per year.

SUMMER VENTILATION For obvious reasons the solar collector must be bypassed during hot weather. With direct ventilation, open the soffit doors 15 to fully ventilate the attic, close the air inlet 20, and provide an auxiliary air inlet system directly from outdoors. One way to do this would be to add a center air inlet.

With the preheat hallway, open the soffit doors, and open the hallway directly to outdoors through large door or window openings. These summer air intakes should also be screened to keep out birds and rodents.

In summer, when the solar collector airflow is bypassed, the air trapped in the collector becomes hotter than it would if kept moving through. However, near London, Ontario (43° N. latitude), no heat damage to the glazing has been observed after three summers of exposure. This is probably due to the increased solar angle in summer.

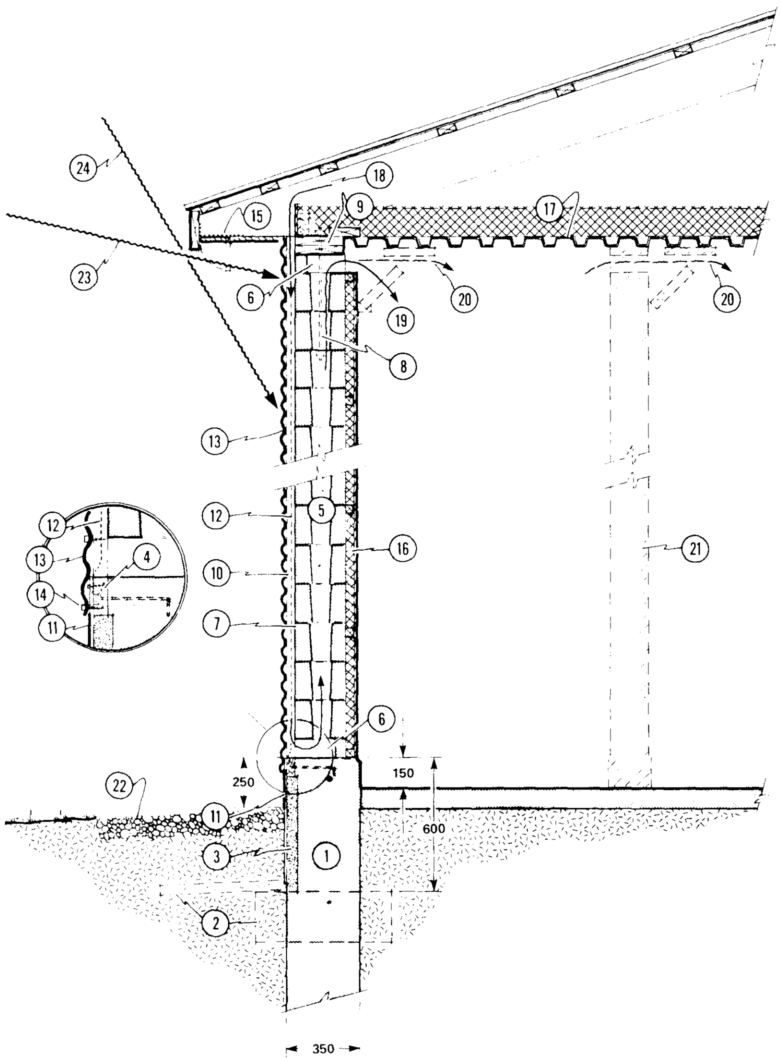

Figure 2. Details of construction.

1. shallow or deep concrete foundation
2. optional shallow footing, 400 x 200 mm, with 50 x 600 mm horizontal perimeter insulation, (Dow Styrofoam SM, or equal)
3. 50 x 550 mm vertical perimeter insulation, (Dow Styrofoam SM, or equal); tack to formwork with finishing nails before placing concrete, or glue if 1 is concrete block
4. 38 x 89 mm wood sill, CCA pressure-treated, anchor to 1 with M10 x 150 mm bolts cast into concrete @ 1200 mm oc or less
5. 240 mm concrete block (size code 25), 3-core, 75% solid, laid in running bond pattern (not stack bond)
6. concrete bricks on edge, 6 bricks per block
7. collector surface, blocks and wood strapping 10 painted flat black
8. M12 x 600 mm threaded rod anchor bolt @ 1200 mm oc, 100 mm square washers and nuts top and bottom, set in mortar
9. 2-38 mm plates continuous, joints staggered @ 2400 mm oc, caulk airtight to bricks, blocking and ceiling
10. 38 x 38 mm cedar strapping @ 600 mm oc
11. 5 x 600 mm high-density recompressed cement-asbestos board, predrill and screw top edge to 4
12. optional black aluminum fly screen absorber bend to midway between blocks 5 and cover 13
13. glass-fibre-reinforced clear corrugated plastic (Filon, Excelite or equal, by Graham Products Ltd.), coat with UV-screen lacquer, caulk and lap all edge joints airtight
14. 3 x 25 mm (#8 x 1") hex-head roofing screws with neoprene washers, drill and drive in valleys @ 600 mm horizontal and 200 mm vertical spacings.
15. soffit vent slot with bird screen; 19 x 140 mm continuous flap door closed in winter, open in summer
16. 38 mm strapping @ 600 mm oc, glass fiber insulation, vapor barrier and plywood panelling; if air 20 enters directly into animal rooms, increase to 89 mm strapping and insulation
17. steel or plywood ceiling diaphragm (see M-9371)
18. winter air enters collector from ventilated attic
19. solar-heated air enters preheating hallway or 20
20. air enters animal room through adjustable slot inlet
21. optional insulated wall divides pre-heat hallway from animal room
22. coarse gravel or crushed stone, stops mud from splashing on wall
23. solar angle on Dec. 21, Winnipeg (50° N)
24. solar angle on June 21, Winnipeg (50° N)

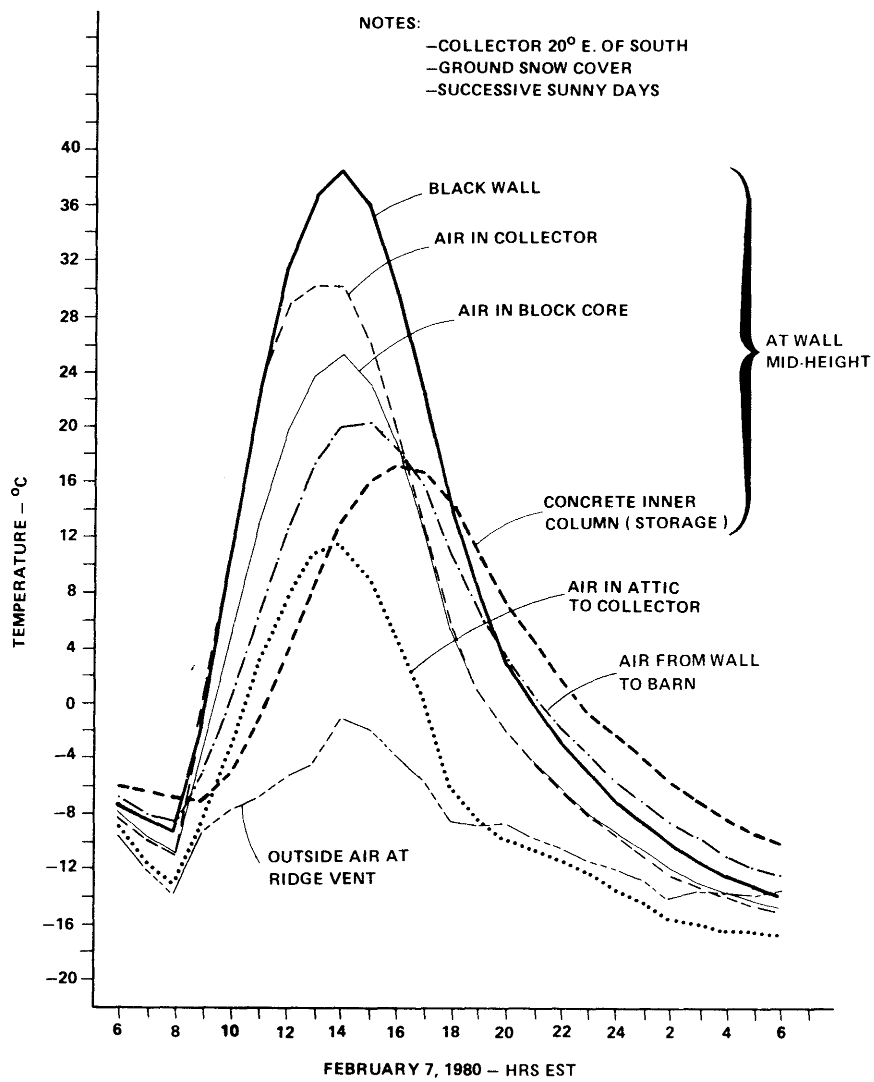

Figure 3. Temperature profiles vs time of day for vertical solar collector/storage wall.