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An Inexpensive Solar Collector for Livestock Structures

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While solar energy can provide some livestock facility heating needs, the cost of the collector and associated equipment must be kept low to economically compete with fossil fuels. Research and demonstration projects from 1979 to 1985 have shown three-year simple payback periods are possible. Systems frequently have six- to 10-year paybacks, and with some designs, the payback is longer than the collector's life expectancy.

Solar energy's availability varies considerably from day to day, as well as from season to season.

A complete radiation probability analysis is given in NDSU Bulletin 516, "The Climatology of Solar Radiation at Bismarck, North Dakota."

Average radiation levels on various surface angles are given in table 1.

Table 1. Radiation Levels on Various Surface Angles as Measured at Bismarck, North Dakota, BTU/sq. ft./day.

Month	Average Daily Temp (°F)	Collector Tilt Angle (degrees above horizontal)			
		0	50	60	90
		BTU/sq. ft./day			
Jan	8.6	581	1402	1467	1421
Feb	12.2	924	1728	1765	1599
Mar	26.6	1292	1789	1760	1422
Apr	42.8	1653	1742	1639	1138
May	53.6	2029	1796	1635	1011
June	62.6	2161	1773	1591	938
July	69.8	2253	1910	1723	1023
Aug	68.0	1907	1870	1734	1139
Sept	57.2	1406	1731	1672	1272
Oct	44.6	1005	1681	1696	1484
Nov	30.2	592	1279	1327	1258
Dec	15.8	456	1152	1210	1188

Eastern North Dakota has a slight tendency for more cloud cover. Table 2 shows the average percentage of possible sunshine for three North Dakota cities.

You need to insulate and control air leakage to minimize heating needs and, as a result, the collector's size. Some type of storage is desirable on a large collector. You'll also need to bypass the solar collector or shade it during mild weather and summer conditions.

Sizing Solar Collector

There are several techniques for sizing a solar collector depending upon the percentage of total heat a solar system supplies. If space is limited, you may decide to build a collector utilizing all available space and provide the remaining heating needs with a conventional heating system. If you provide 100 percent of your heating needs with solar, you will also need to plan some storage.

A solar collector's expected savings will average the equivalent of one gallon of fuel oil per year per square foot of collector.

For large collector systems, you need a detailed heating load and solar availability analysis to determine collector size and storage needs. One technique is to estimate the total heating needs for a typical cloudy period. Table 3 lists the amount of heat stored in three materials for various temperature changes.

For example, if a rock storage temperature is 80 degrees Fahrenheit when fully charged and 60 degrees Fahrenheit when fully discharged, there are four BTUs stored in each pound of rocks.

Table 3. BTUs of Heat Stored in Various Materials with Given Temperature Difference Between Fully Warmed and Fully Cooled.

	Temperature Difference (Maximum Temp. – Minimum Temp.) °F			Volume ft^3
	20	50	80	
Rocks (1 lb)	4	10	16	.01
Water (1 lb)	20	50	80	.016
Concrete (1 lb)	4	10	16	.0067

Table 2. Average Percentage of Possible Sunshine for Selected Locations in North Dakota, (based on 30-year average).

City	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
Bismarck	55	55	60	58	63	65	76	73	66	59	45	47	62
Fargo	51	57	58	57	58	60	71	68	60	56	40	43	58
Williston	50	56	61	56	61	66	75	75	65	59	43	48	61

Provide about one square foot of solar collector for each 50 to 100 pounds of rock storage or each two gallons of water. This usually provides a good balance between the collector's ability to warm the storage media and cost. For detailed design information, see MWPS-23, "Solar Livestock Housing Handbook," available at county extension offices.

For North Dakota winter conditions, a vertical collector facing due south will capture about 85 percent of the energy the same collector mounted at 62 degrees (optimum angle) will capture. This makes it possible to utilize south-facing walls to support the collector rather than building an elaborate support system. Any heat lost through the back of the collector then passes directly into the building to be heated.

Collector Systems

Research at Kansas State University has shown a solid concrete block wall on a livestock building's south side can serve as a solar collector with a ventilation air preheater and storage system (Figure 1).

One advantage of this system is that it only needs about 24 inches of additional space. Wintertime collection efficiency is good, while summer shading is easily accomplished and, with proper controls, some daytime cooling is possible.

Typical expected savings amount to one to two gallons of LP gas per square foot of collector surface per year.

Construction

1. Erect a 16-inch thick wall of solid concrete blocks on a concrete footing about 6 inches outside the building's south wall. All blocks are perpendicular to the wall. Mortar only the horizontal joints and leave 1/8-3/16 inch vertical gaps between the blocks.
2. Spray the wall's south surface with two coats of flat black paint.
3. Attach vertical 2 x 2s to the wall's south side.
4. Fasten a layer of transparent cover material to the 2 x 2s. Leave a 4" air gap at bottom.
5. Attach another framework of 2 x 2s over the first, sandwiching the cover material between them.
6. Fasten another layer of cover material to the outer 2 x 2s with battens and wood screws. Leave a screened 2" air inlet at the top of this cover.

See Figures 2 and 3.

Plan MWPS-81902, available from Extension Agricultural Engineering at NDSU, Box 5626, University Station, Fargo, ND 58105, has construction details and a wiring diagram for the controls for a 20-sow farrowing house.

Operation

During winter, operate the collector/storage system for heating with stored heat. Outdoor air is pulled between the covers, through the block, and into the building. Heat is stored in the blocks during the day ventilating air leaves them only slightly warmer than outdoor air. At night, ventilating air picks up heat from the warm blocks to help maintain building temperature.

During the summer, operate the system for cooling. The building ventilating fan bypasses the collector wall during the night, pulling air into the building through an outdoor air duct. A separate fan pulls night air through the blocks and exhausts it back outdoors. During the day, the system operates the same as it does during the winter. The blocks cool the ventilating air. Shading the collector with the building overhang or a cover is desirable.

System Performance

In tests at Kansas State University, the block wall provided 32 BTU of heat storage per degree Fahrenheit temperature change per square foot of collector surface area. At one cubic foot per minute ventilation airflow per square foot of collector area, peak solar insolation was about nine hours ahead of the peak temperature of the ventilating air and even farther ahead of the peak temperature rise. Under Kansas conditions, average all-day collector efficiency was:

Airflow	Efficiency
1 cfm/sq. ft.	45%
2 cfm/sq. ft.	55%
3 cfm/sq. ft.	60%
4 cfm/sq. ft.	62%
5 cfm/sq. ft.	63%

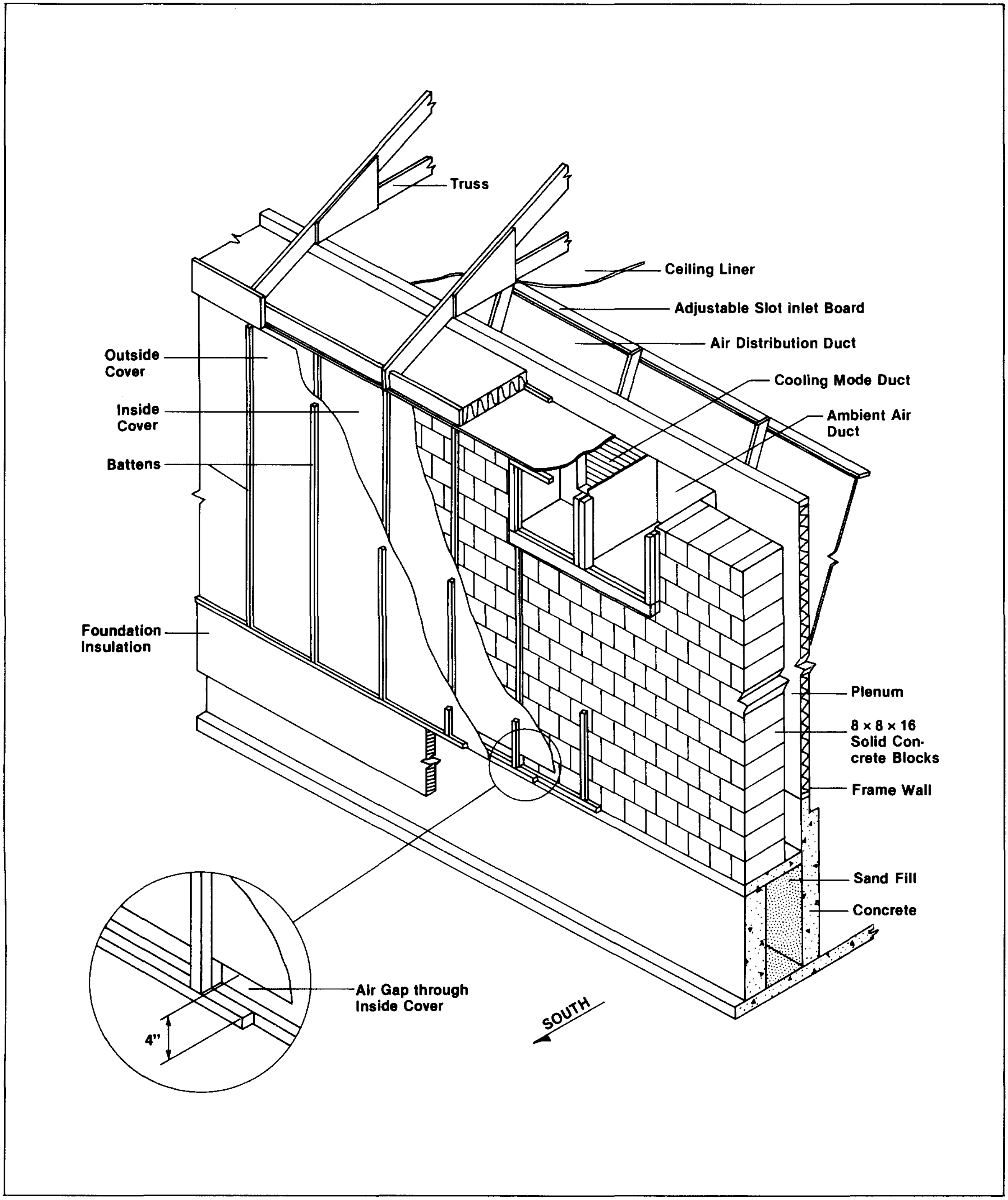

Figure 1. Kansas solid block wall—south wall detail.

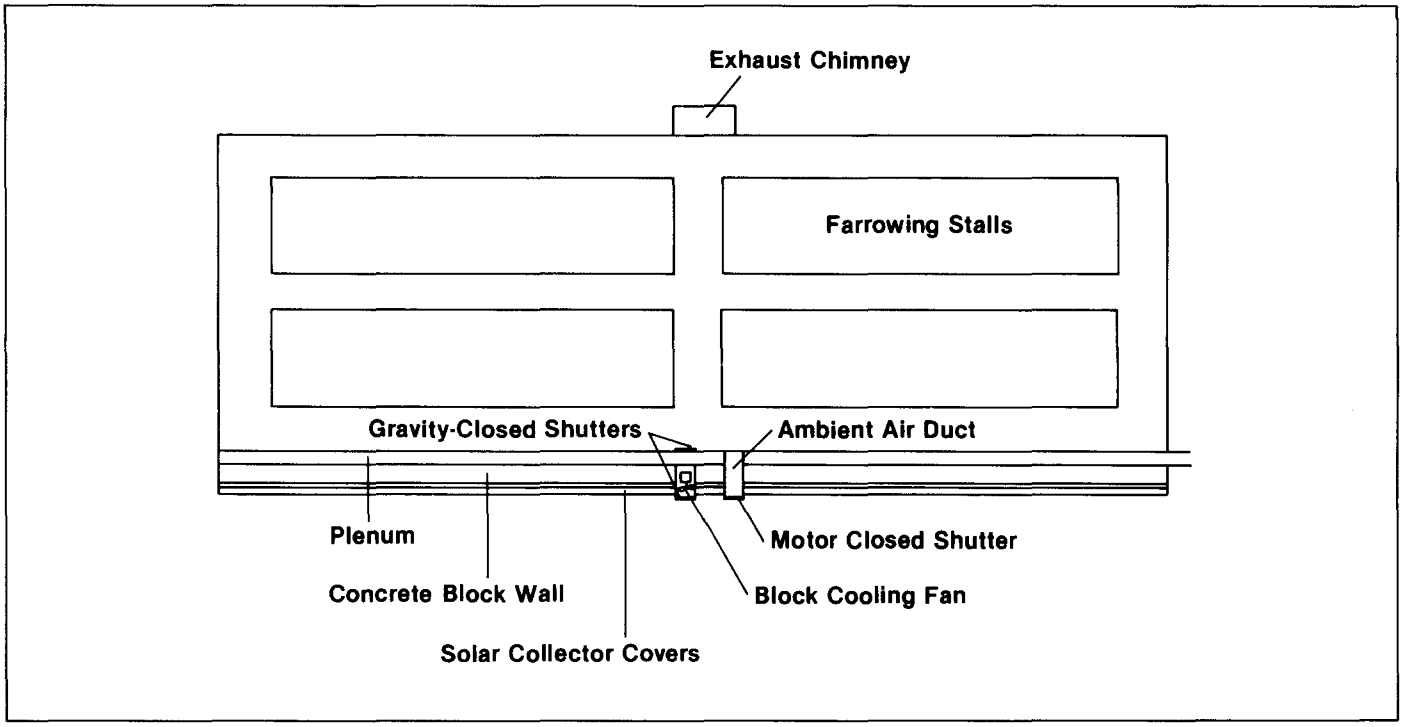

Figure 2. Kansas solid block wall—floor plan.

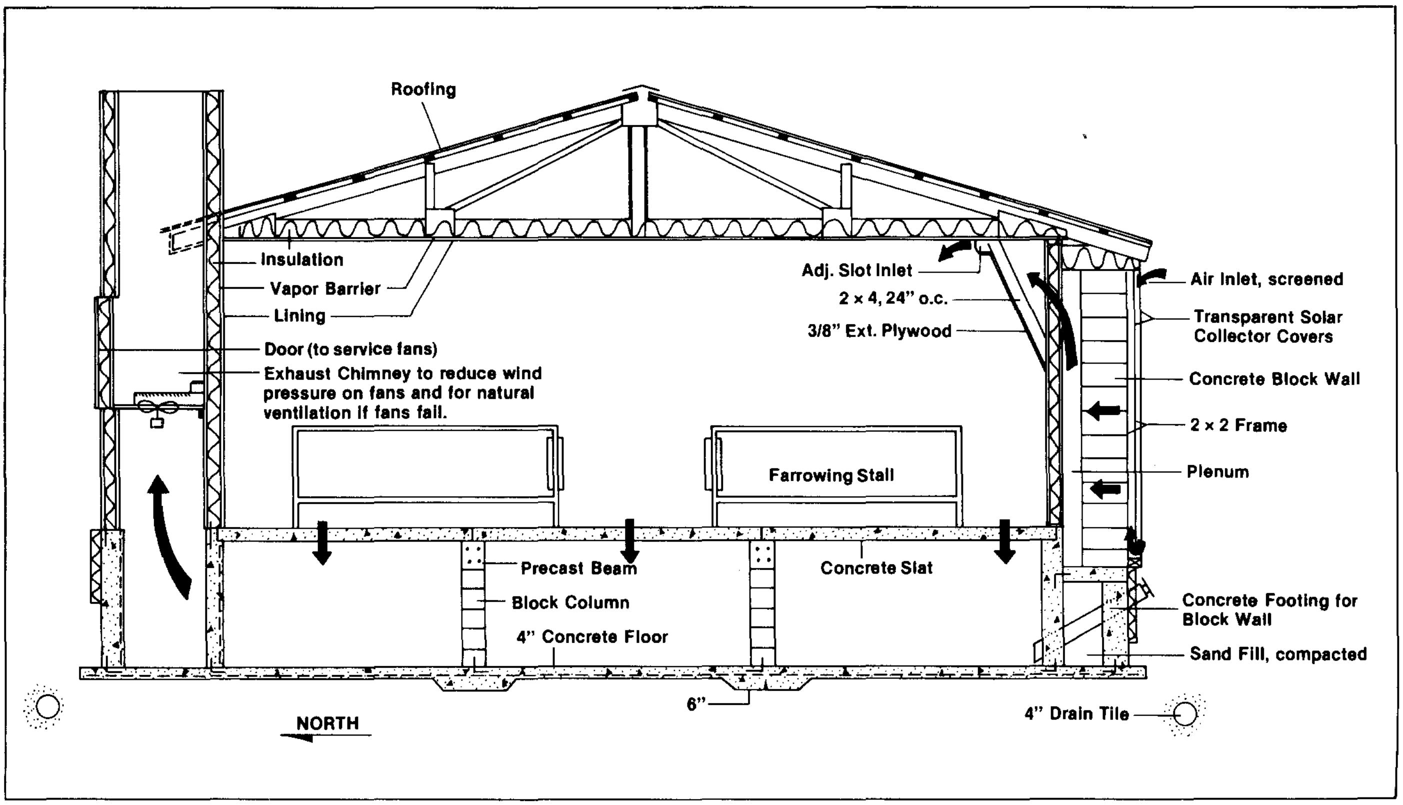

Figure 3. Kansas solid block wall—cross section.

You need about 20 square feet of collector area per farrowing stall in North Dakota.

A modification of the Kansas plan uses the concrete block cores as air passages (Figure 4).

At the Energy Demonstration Farm at NDSU, a one-pass solar collector has been used for preheating calf barn ventilation air without storage. It was developed for facilities where there is not enough collector area to justify utilizing stored heat. In other words, the total heat collected will seldom exceed heating needs. Other than some leakage problems, this installation has worked as an addition to an existing building (Figures 5 and 6). Estimated fuel savings are about one gallon LP gas per square foot of collector per year.

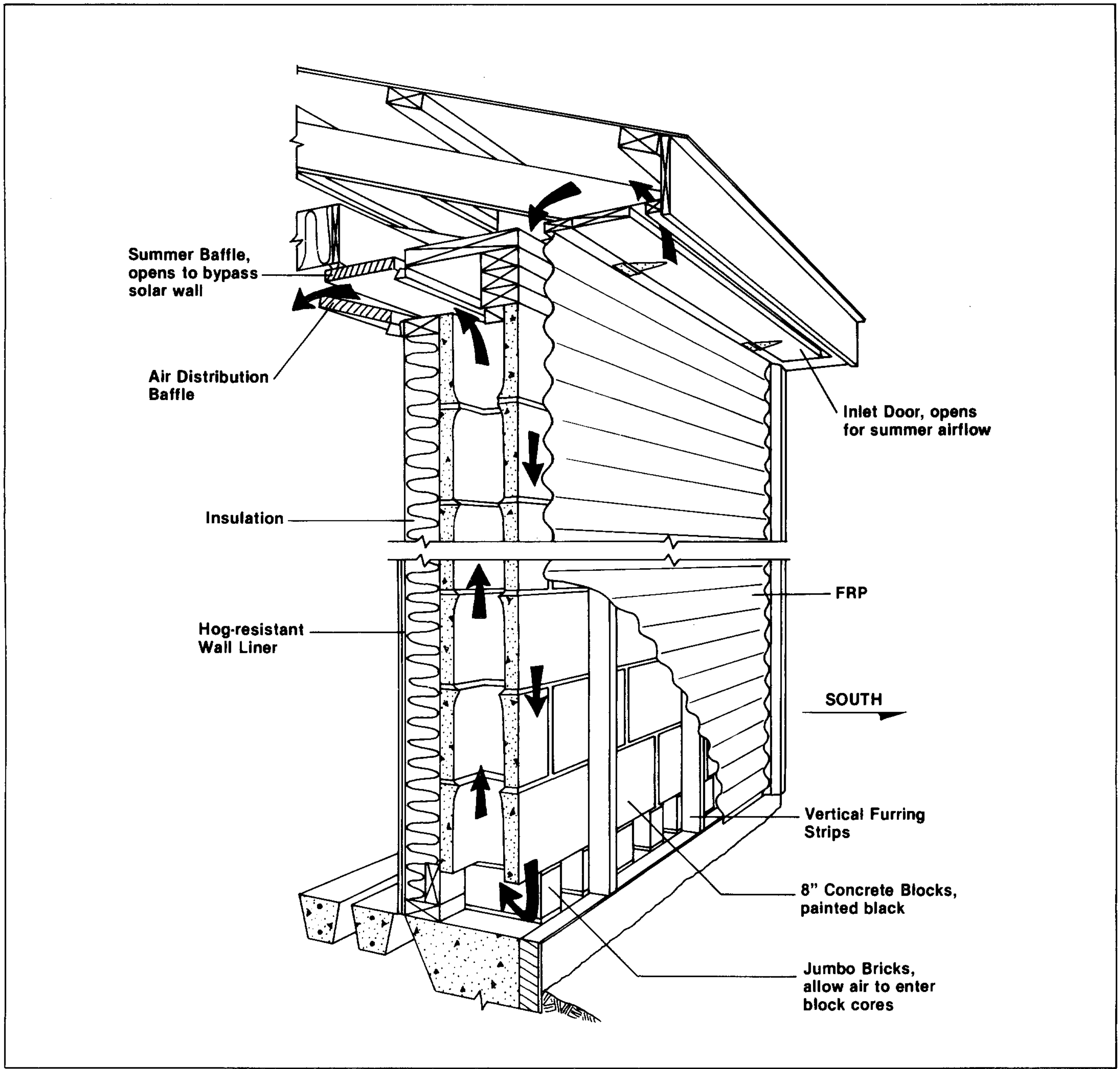

Figure 4. Iowa hollow block wall.

Construction

1. Determine size of air channel. An air velocity through the collector of 500 to 1,000 feet per minute is desirable. The size of the space between the wall and the glazing can be determined by the equation.

   $$S = cfm \times 12 \div (750 \times W)$$

   S = space between glazing and wall in inches.
   cfm = total volume of air passing through the channel
   W = width of airflow channel in feet.
2. Nail furring strips to wall.
3. Caulk all joints.
4. Paint collector interior a dark color.
5. Attach glazing to furring strips.
6. Place a 1 x 2" finish board over glazing to cover nail or screw holes in glazing.

Performance

You can determine the total heat collected by the equation

$$Q = cfm \Delta T \div 1.08$$

Q = total heat added to ventilation air.
cfm = airflow through the collector.
ΔT = change in air temperature as it passes through the collector.

With an airflow of 600 cfm through a 200-square-foot collector, the NDSU collector experienced a 40 degree Fahrenheit temperature rise at solar noon. (Figures 7 through 10). Performance significantly improved when a fresh snow cover was on the ground adjacent to the collector (Figure 10). A maximum temperature rise of 90 degrees was obtained for one week. After one week, the snow became dirty and collector performance decreased.

Research at Iowa State University on a similar facility using metal siding had a collector efficiency of about 30 to 35 percent (Figure 11).

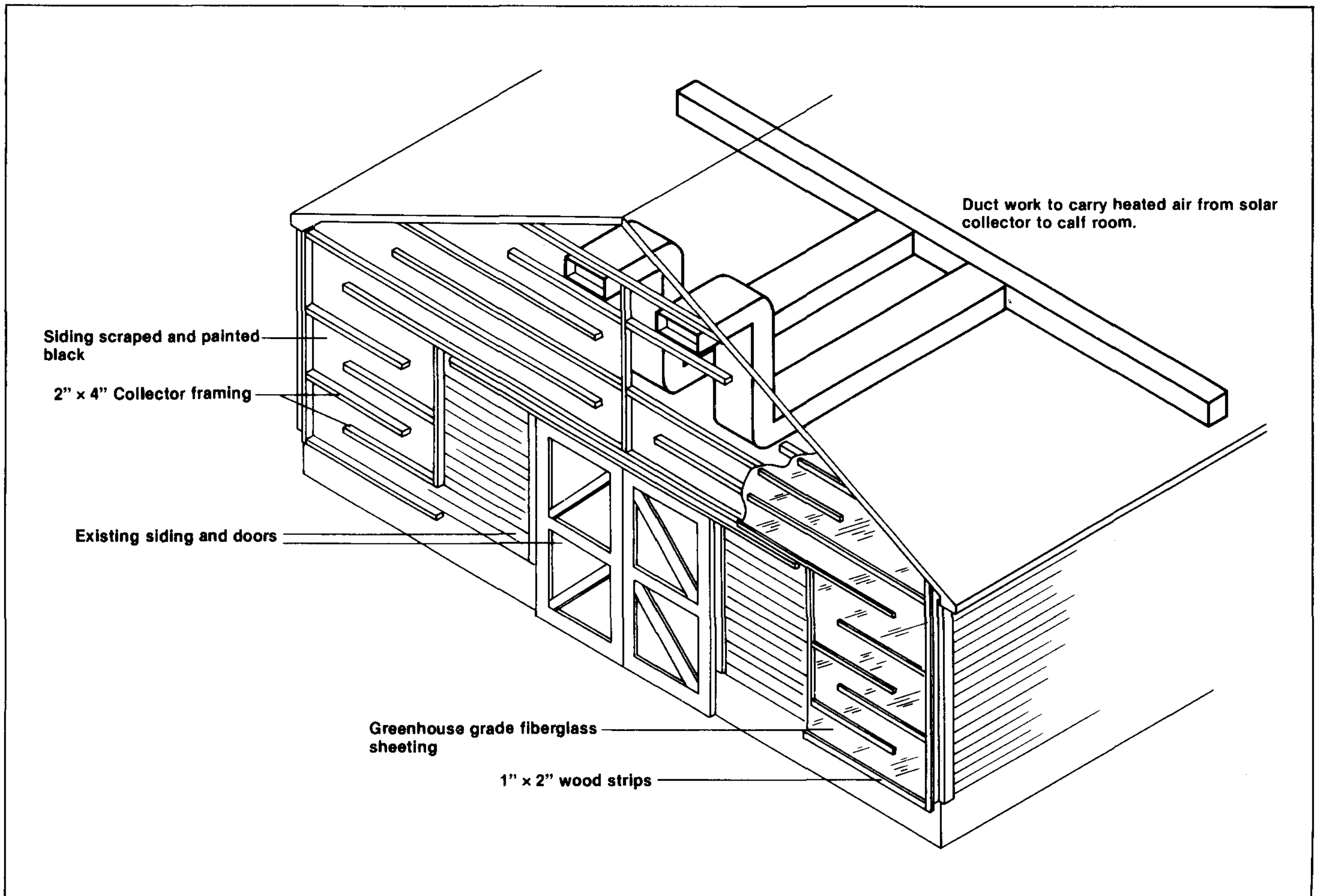

Figure 5. View of solar collector framing and duct work.

Caution

- Avoid using low-melting-point foamed plastic insulation materials.
- Locate exhaust fans so ventilation air will not recirculate through the collector.
- Screen collector inlets to prevent birds and mice from getting into collector.
- Locate collector inlets high enough above the ground to avoid blockage.
- Avoid long ducts between the collector and the use point.

Additional sources of information:
- MWPS-23 "Solar Livestock Housing Handbook"
- MWPS-81902 "20 Sow Solar Farrowing House Plan"
- NDSU Energy Integrated Farm Demonstration Final Report
- On-Farm Demonstrations of Solar Heating of Livestock Shelter Final Report
- Bulletin 516 "The Climatology of Solar Radiation at Bismarck, North Dakota"

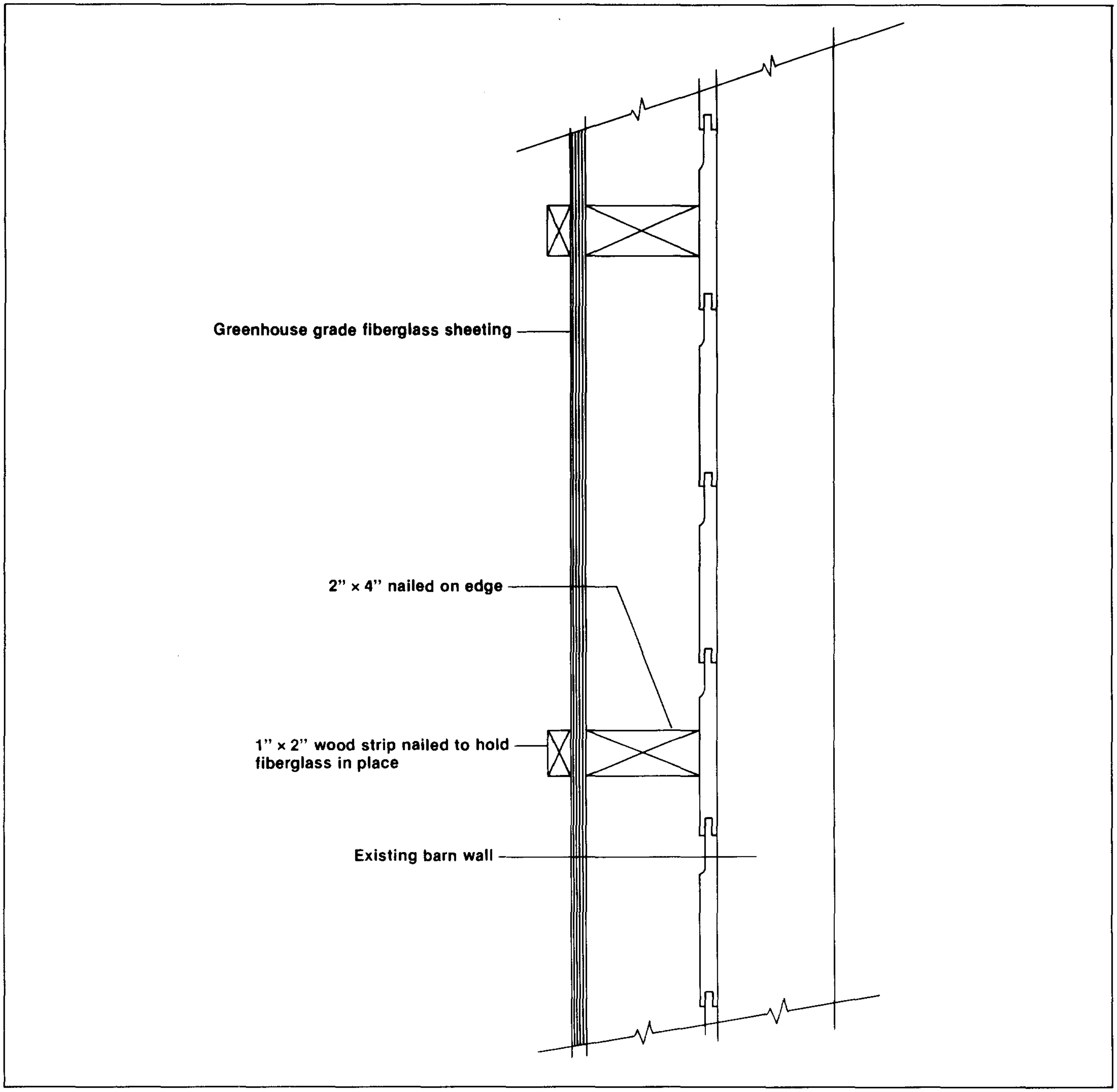

Figure 6. Cross section of solar collector on wall.

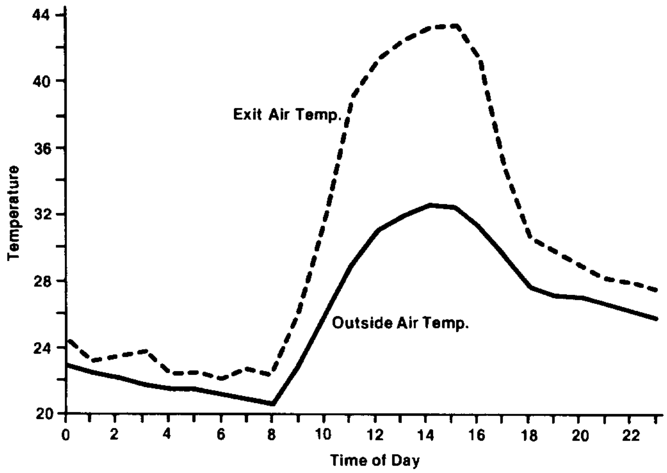

Figure 7. Solar Collector Performance, Feb 8-14, 1983

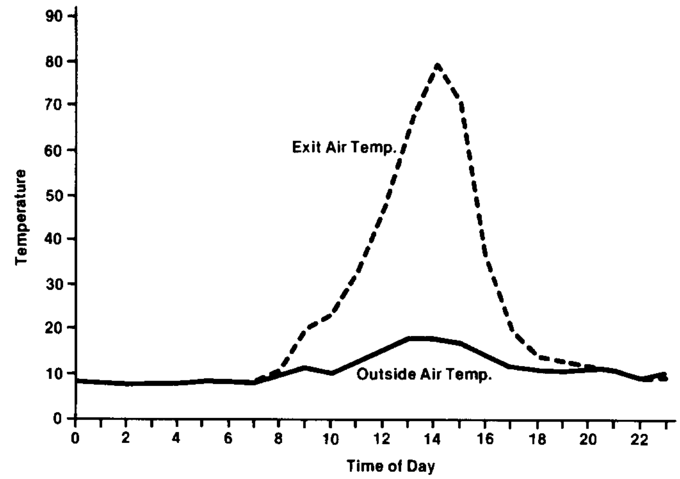

Figure 8. Solar Collector Performance, Dec 1-7, 1983

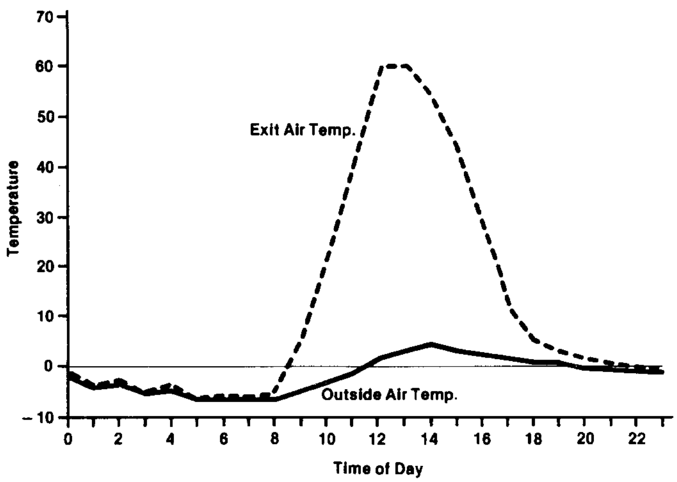

Figure 9. Solar Collector Performance, Jan 8-14, 1984

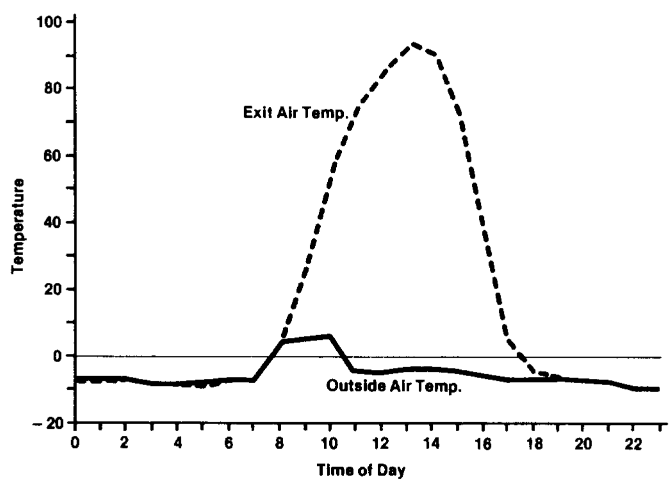

Figure 10. Solar Collector Performance, Jan 15-21, 1984

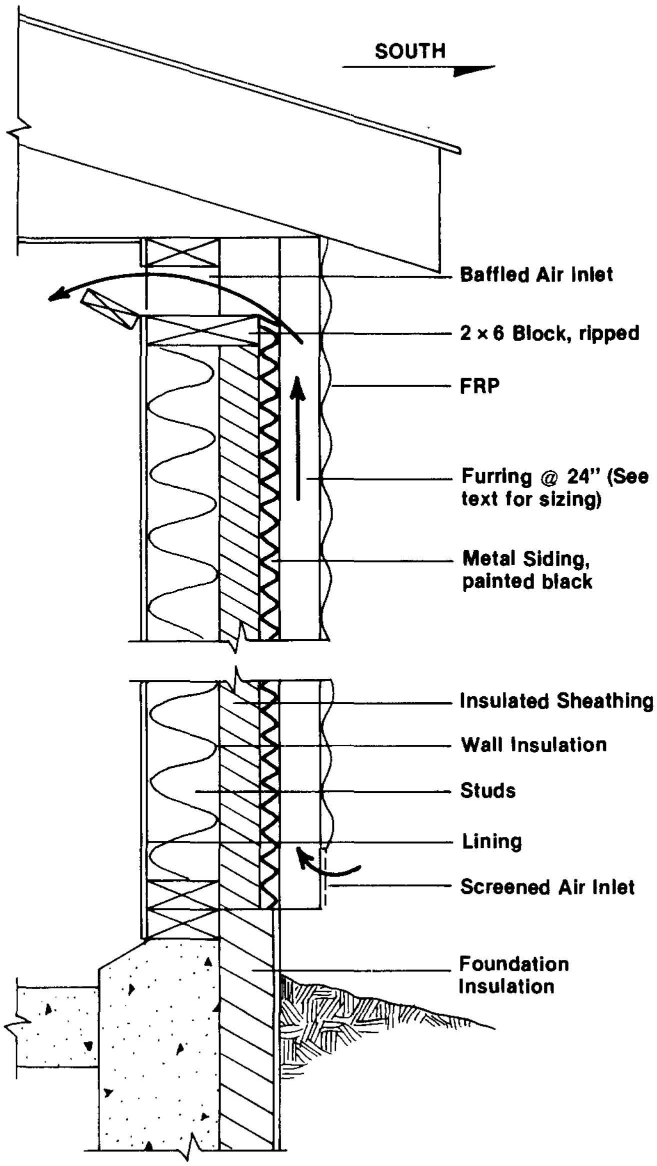

Figure 11. South wall collector.

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