CONSERVAL ENGINEERING INC.

Design Guide for the SOLARWALL® Air Heating System

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Description

The principle of the SOLARWALL® collector is simple. Outside air is drawn through perforations in the dark-colored, sun-warmed metal panel. As the air passes over and through the panel it is heated. A ventilation fan creates negative pressure in the wall cavity to draw air through the holes. The SOLARWALL® heater is also referred to as a transpired solar collector or unglazed perforated collector.

The design is highly reliable and very economical. Low costs are achieved by reducing the material in the collector to a single metal sheet mounted out from a wall or roof to form an air cavity with the building. The SOLARWALL® heater looks like a conventional metal wall, but collection efficiency can exceed 70% at high air flow rates.

Figure 1: Photo of unglazed transpired solar collector

Applications

SOLARWALL® technology is now North America's leading solar collector for heating ventilation air. Ideal building types for the SOLARWALL® heaters fall into two main groups - all new buildings and retrofits.

In new construction, a SOLARWALL® heater will normally be cost effective and can improve the indoor air quality of the building as more fresh air can be heated for free. It should be considered for all new buildings which require a heating system.

In retrofit applications, SOLARWALL® can be cost effective in many industrial buildings with large wall surfaces, sports halls, schools, offices, shopping malls, maintenance buildings, apartment buildings and other buildings with a need for heating outside or process air. Another excellent application is in providing low temperature process heat for agricultural or industrial purposes (i.e. crops, drying cardboard, textiles, or paint).

Space heating: The SOLARWALL® panels can also be used as a space heater in milder climates or in the warmer spring and fall months. Whenever the fresh air is heated above 20° C (68° F), the solar heat will provide space heating benefits.

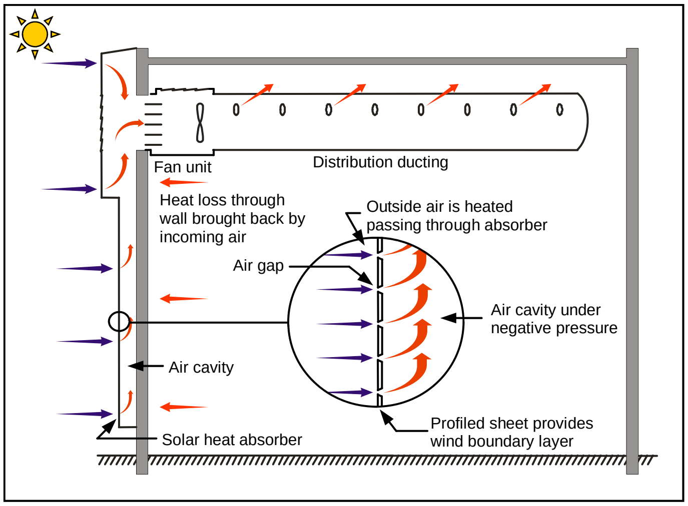

Figure 2: SOLARWALL® panel integrated into a wall and connected to interior fan

Summer Cooling: If the walls and roofs are not insulated or poorly insulated, the reduction in solar load on the main wall can be very significant when SOLARWALL® panels cover the wall or roof. In fact, in some climates, the summer cooling benefit can exceed the winter heating benefit. The wall is cooled by ambient air entering the bottom half of the wall, rising by convection, then exiting through the top half removing the solar heat. The main wall is spared the direct heat from the sun, reducing the cooling demands of the building. *Figure 3* illustrates the summer cooling effect.

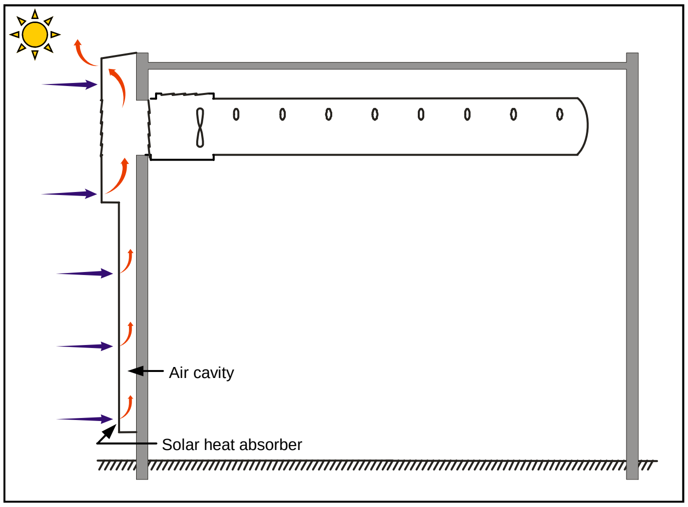

Figure 3: Summer cooling with perforated unglazed panels

Major Design Criteria

1. Select the wall (or roof) for mounting the SOLARWALL® panels.
2. Determine the volume of outside air to heat

Select the wall or roof: The perforated cladding absorbs the most sunlight when facing south plus or minus 20 degrees. If the south wall is not suitable, consider one or both of the east and west walls. If a large volume of air is to be heated, all three walls can be utilized. Only the solar contribution is affected by collector orientation, the heat recovery benefit remains the same for all walls.

The wall area to be considered does not have to be free from openings. Wall surfaces around doors and windows may be suitable if they can be connected together or to fans which deliver air inside the building. This is an important consideration since many buildings will not have large wall surfaces without windows and doors. Consider using the perforated panels as the building material for covering the wall around doors and windows and do not be overly concerned about optimizing the design. Rather, cover as much of the wall as possible and utilize as much of the free heat as possible. If parts of the wall are shaded or not readily accessible for uniform air flow distribution, again, do not sacrifice appearance for highest efficiency, instead design the air flow for a range of heating curves, as long as some air is moving through the perforations. In new construction, the capital cost of a perforated metal cladding system is similar to conventional walls. In retrofit situations, the perforated solar cladding can be applied over most existing walls of block, metal, glazing, or precast concrete (see *Figure 4*).

If no wall is suitable or available, consider using a south facing roof. The slope of the roof should be at least 30° and preferably more. If snowfall occurs often at the proposed site, the minimum slope should be 45° to allow the snow to slide off.

Determine air volume to heat: SOLARWALL® heats outside air, not recirculated building air. Obtain the volume of outside air to be heated and desired temperature are dictated by the use of the building. In *Figure 5*, Curve A represents flow rates for applications where higher temperatures are needed and the panels can provide some space heating needs for the building as well as ventilation air heating. Curve B is typical of most ventilation heating designs. Curve C and higher air flows are used in industrial applications where large volumes of air must be heated and only a small temperature rise is needed.

If the quantity of outside air to be heated is low in proportion to wall area, then a perforated canopy design may be the most cost effective choice. The capital cost would be less than covering an entire wall. A wall with numerous shipping doors, windows or other obstructions may not be suitable for other styles so a canopy may be the only option. In such a case, if the doors are a dark color, they will collect heat when closed and the heat would rise to the canopy as illustrated in *Figure 9*. The face of the canopy would be constructed from the perforated cladding to increase collection efficiency.

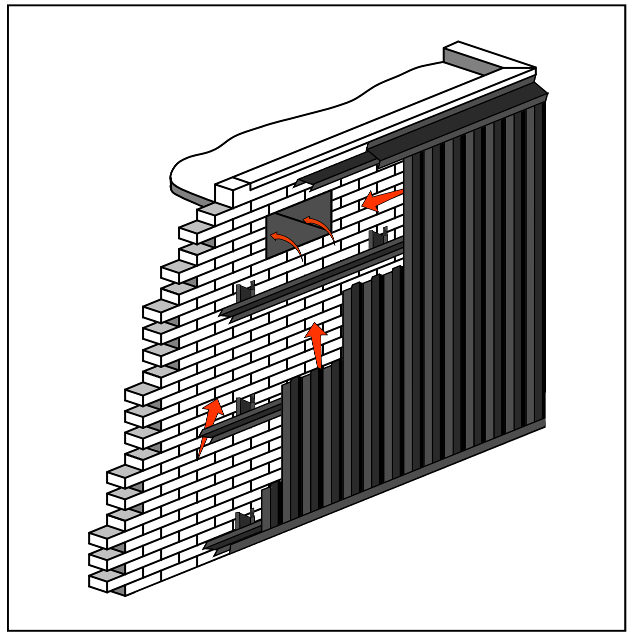

Figure 4: SOLARWALL® panels mounted over existing wall

Air flow direction: Air behind a perforated panel system normally travels in two directions: vertically along the wall to the top of the wall or canopy, then horizontally to the nearest fan intake. The two directions simplify balancing to ensure that air is drawn through the entire panel surface, otherwise, some of the solar heat may be lost.

Air mixing: Industrial buildings usually require a large amount of fresh air and the usual practice is to supply separate fans with mixing dampers and ducting that distribute the solar air at ceiling level as far into a building as practical. The mixing dampers are temperature controlled and will mix hotter ceiling air with the solar heated air. The mixing is necessary for night use or cloudy days. For non industrial buildings, most solar heating projects use the perforated panels as a preheater to the conventional ventilation fan with a provision to bypass the solar panels in the summer months when heating is not necessary.

Design Guide

The method of sizing a SOLARWALL® solar air heater is relatively simple and not as precise as one might think since different quantities of air can be heated by the same panel area. The temperature rise through the solar panels is dependant on the volume of air per square meter or square foot of solar panel. For sunny days, a high temperature rise is normally in the range of 25° C to 35° C (45° F to 63° F) over ambient. If higher temperatures are required, it can be supplied by additional heat from a conventional heater with SOLARWALL® acting as a preheater. Typical solar designs are sized in the range of 17° C to 25° C (30° F to 45° F) over ambient. This gives an economical panel area and good solar efficiencies. Higher air volumes through the solar panels will provide temperature rises of 10° C to 17° C (20° F to 30° F) over ambient. Velocity is calculated by dividing the air volume to be heated by the solar panel area.

If high temperature rise (25° C to 35° C) is needed or low volumes of ventilation air are to be heated, design for lower velocity across the solar collectors (lowest solar collection efficiency). Use:

18 m/h to 54 m/h (meters per hour)
0.005 m/s to 0.015 m/s (meters per second)
1 to 3 fpm (feet per minute)

For ventilation air heating in schools, offices, factories, (17° C to 25° C) (typical selection criteria) design for:

54 m/h to 108 m/h
0.015 m/s to 0.03 m/s
3 to 6 fpm

For higher air volumes (10° C to 17° C), preheating of air and low temperature rise, (highest solar efficiency) design for:

108 m/h to 180 m/h
0.03 m/s to 0.05 m/s
6 to 10 fpm

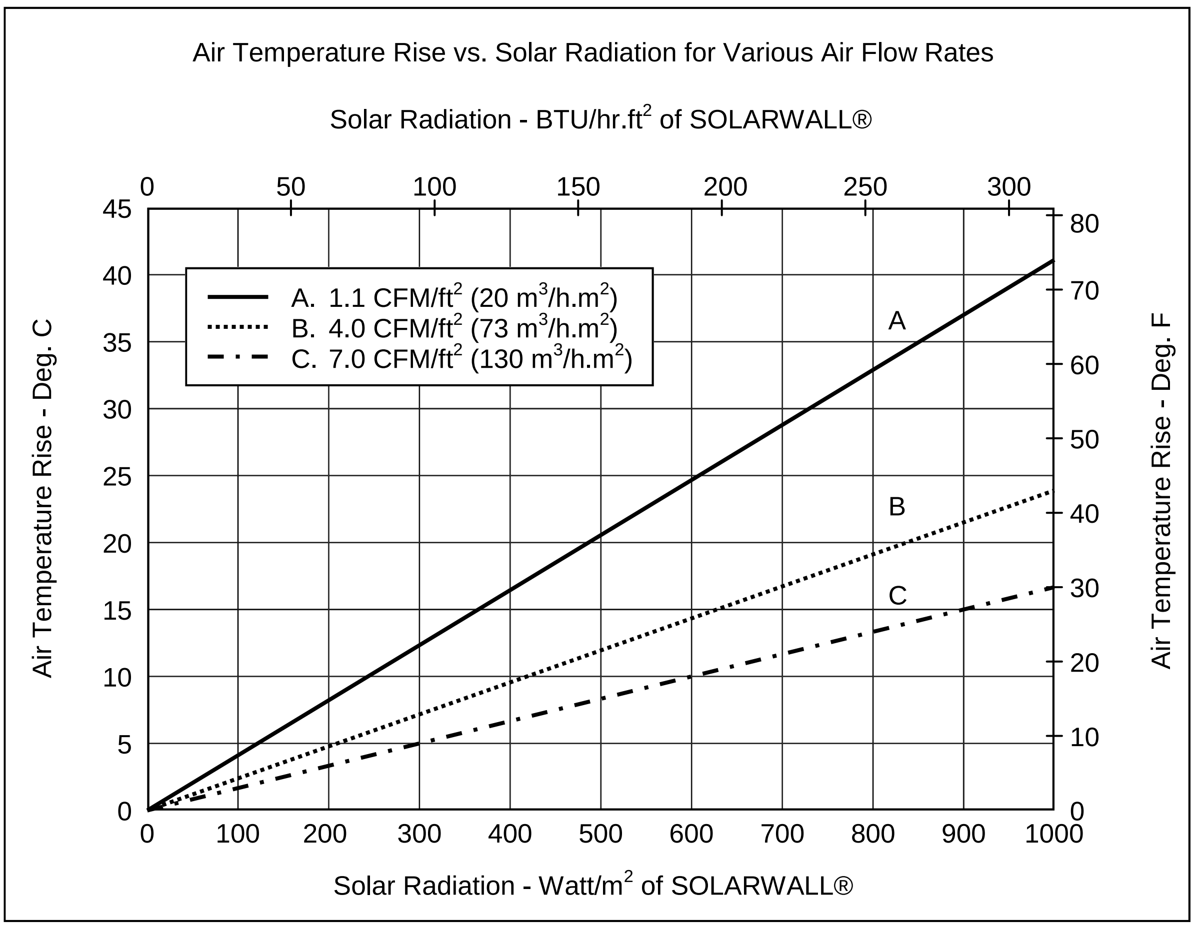

Figure 5: Solar radiation graph.

Perforated panels can be roof-mounted provided the main roof is waterproof. The solar sheets directly over the air intake opening must not be perforated to prevent water from entering air intake.

Pressure drop through the perforated metal panels is approximately 25 Pa and the total pressure drop through the solar wall panels, canopy and into the fan is approximately 50 - 100 Pa. The pressure drop from the inside of the solar wall to the ventilation system should be calculated in the normal manner taking into account duct and other losses.

The air velocity behind the perforated metal panels should not be higher than 3 m/s (600 fpm) when it reaches the top. The maximum horizontal velocity at the top is 5 m/s (1,000 fpm). If multiple fans or duct connections are made to the canopy, then the canopy can be smaller or even eliminated.

If the solar collector area is known calculate the volume of air that can be heated by multiplying the panel area by the desired temperature curve flow rate from *Figure 5* or by using the velocity guide shown above. The curves show the temperature rise of air at different flow rates.

Example: a school gymnasium has a panel area of 500 m^2 (5,000 ft^2) and a large temperature rise is desired. Pick Curve B at 73 $m^3/h.m^2$ (4 cfm/ft^2) to give an airflow rate of 36,500 m^3/h (20,000 cfm).

If both panel area and volume of outside air to be heated are known, panel area = 500 m^2 and airflow is 50,000 m^3/h. Airflow through panel is 50,000 m^3/h / 500 m^2 = 100 $m^3/h.m^2$. Referring to *Figure 5*, 100 $m^3/h.m^2$ (m/h) corresponds to flow rate between Curves B & C for temperature rise of air.

Step-by-step design procedure

1. Decide on solar panel size and location. Is the south wall suitable? If not, consider east or west walls. Note that a south wall may actually be south west, and the east wall would then be south east. In this case, both walls could be utilized effectively.

2. Determine the volume of outside air required in building. Heat as much fresh air as possible. This will improve indoor air quality without increased fuel costs.

3. Calculate the volume of air per area of solar heater, then refer to temperature chart to determine expected temperature rise.

4. Select color.

5. Determine spacing of solar cladding from main wall and whether a separate or internal canopy plenum will be used.

6. Locate fans as close to solar panels as possible. Position the solar fan connections at a maximum spacing of 30 meters (100 ft) apart. Closer spacing will mean a smaller canopy plenum.

7. Industrial buildings can save additional energy from destratification. For additional information, refer to Conserval's Design Guide for Industrial Ventilation Systems. Determine the amount of ventilation or make-up air required and then position the ducting to distribute the air throughout the building. The distribution ducting should be located in the areas where the ceiling temperature is the hottest to disperse the heat and save energy.

CONSTRUCTION

Integration with Building

Panels: The metal panels are perforated with very small holes or slits and resemble a conventional metal facade. Panels are available in many colors including black, and dark shades of brown, gray, red, blue and green. They are usually one meter wide (39.3”) overlapping panels of varying lengths and installed to give a continuous appearance along the entire wall. To add structural strength and rigidity, the material is processed through rollers to form corrugations. The corrugations are 35 mm (1.25”) tall and spaced approximately 200 mm (7.9”) apart. The standard solar panel profiles are shown in *Figure 6*.

The perforated panels are made of either aluminum or galvanized steel. Initially the panels were made from aluminum as there was concern about possible corrosion around the holes if steel was used. Corrosion experts have examined galvanized panels which have been in use since 1989 and found no rust formation. The galvanizing protects the steel from rusting and the air movement through the holes dries any moisture that may exist. As the wall is generally vertical, water runs off the wall and the holes are so small that the surface tension prevents most water from entering the holes. Both materials perform the same. In North America and most developing countries galvanized steel is the preferred material due to lower costs. Aluminum is more expensive but is still popular in Europe and Japan.

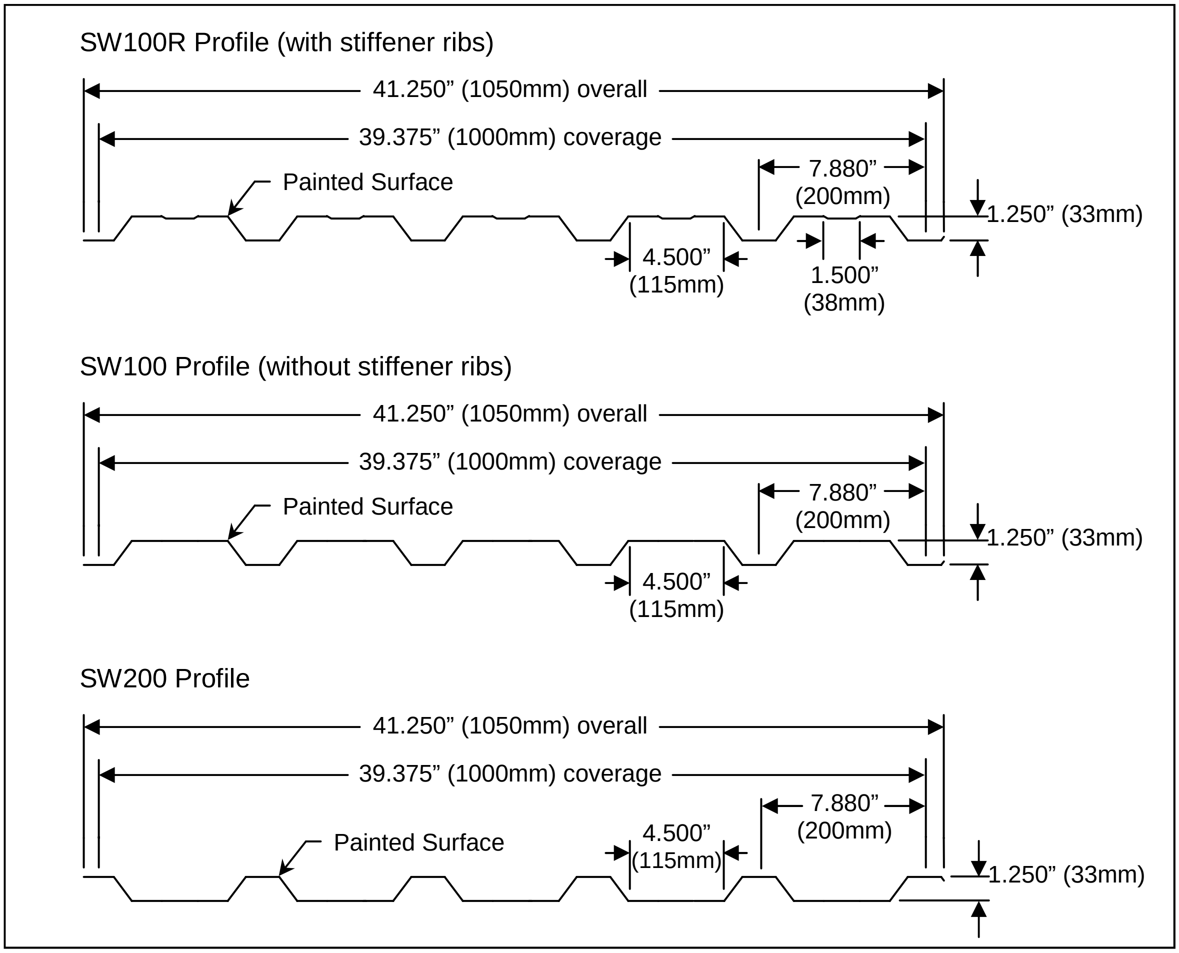

Figure 6: SOLARWALL® Profiles

Color: The colors and paint systems are non selective. As the solar panels are part of the building it is important that a durable and proven paint system be used which will last for decades without maintenance or repainting. The perforated panels can be any dark color. The darker the better, as dark colors absorb more of the sun's energy. Black is the best, followed by dark brown. Other colors which have been used are dark shades of gray, green, blue and red (see Figure 12 and Table 1 for colors available and solar absorption properties).

Coating: The solar absorber coating on the panels is the same premium coating used extensively in the building industry. The dark coatings are designed to last for decades and may come with an extended non-fade warranty similar to the metal building industry warranty.

Air cavity: A certain air gap is necessary to allow the heated air to travel up the wall and across to the nearest fan intake. The air gap can be reduced if air is drawn off at more locations. Connecting the fan or fans at multiple points reduces the required size of the canopy since the volume of air going through the canopy to each connection is lower.

The cladding and canopy can be mounted onto a wall in different ways as listed below and illustrated in *Figure 7*.

1. The entire wall mounted out same distance but not more than 300 mm (12").
2. The cladding tapered with larger distance at top and smaller distance at bottom.
3. Cladding mounted out from wall with canopy at top.
4. Cladding mounted against wall with canopy at top.
5. Cladding mounted against wall with collection duct behind solar panels on the roof (see *Figure 8*).
6. Cladding on a canopy over dark section of wall, doors or windows (see *Figure 9*).

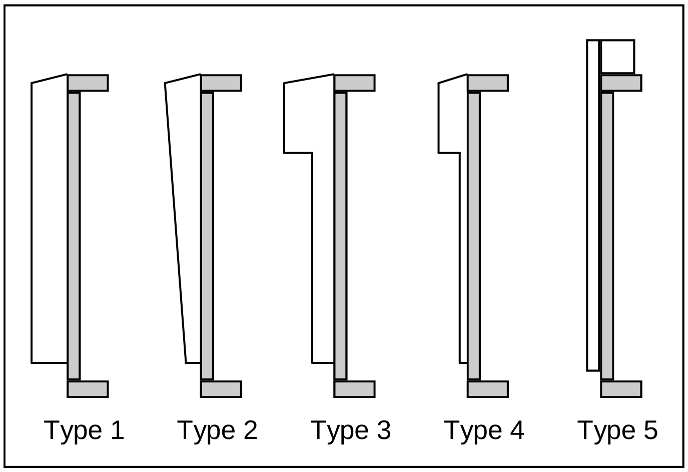

Figure 7: Wall designs to collect solar heated air from SOLARWALL® panels

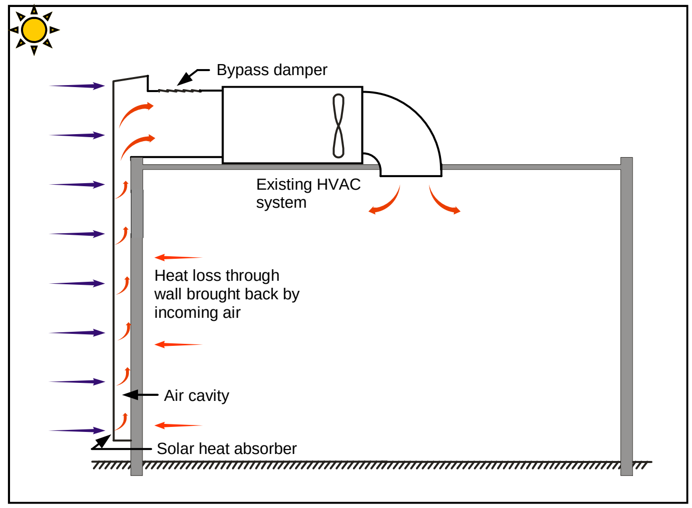

Figure 8: SOLARWALL® panel integrated into a wall, supplying an existing HVAC unit.

The wall and canopy designs are based on three factors, volume of air, cost and appearance. The volume criteria were discussed earlier. The cost and appearance issues are related as a canopy is more expensive than a flat wall but it can also enhance the appearance of the building. If a separate canopy can be omitted and an internal canopy utilized, construction costs will be lower.

The air space within the cladding profile may be sufficient for low flow designs but not sufficient for higher air volumes. If more air space is needed, the solar panel must be mounted further from the main wall. The method of securing the panel out from the wall will vary depending on the option selected.

The lowest cost options are the internal canopy Types 1 & 2 followed by Type 4. Type 4 saves costs on the main wall as the panels are mounted directly to the wall but a canopy is necessary to collect the air. The most expensive designs are Type 3 & 5 since both require separate support structures for the solar cladding and the canopy. Type 5 is suitable for designs where the fan is on the roof or the existing air intake to a fan is above the roof line of the wall (see *Figure 8*). Type 6 is used when a fascia or canopy is built over windows or doors and can serve as a decorative feature.

If the architect is planning to include an architectural feature along the top of the wall such as a canopy or mansard roof, then it should be designed to also act as the plenum to collect the solar heated air. A glazed canopy is also possible for higher temperatures and it may blend in with architecture requiring glazing.

Variations

Canopy: The main variation for wall mounting is the method of collecting the solar heated air at the top of the solar wall array. For small air volumes all of the air can normally be accommodated in the air gap between the perforated absorber and the wall. For larger air volumes, either multiple air connections to the fan(s) or a larger air space is needed. The larger air plenum is called a canopy and can be either on the face of the wall built as an architectural feature or behind the wall and on the roof. The canopy can also be glazed to provide an extra heat charge before the ventilation air enters the building.

In some cases, the canopy will be built above a wall, which is not perforated to collect the solar heated air as it rises up the exterior of the wall (see *Figure 9*). This would be suitable for walls with numerous windows or doors. The canopy would be made from the perforated panel and air entering the perforations would have been preheated by the lower wall surface.

Two stage solar heating: The unglazed solar heater can raise the air temperature to a maximum of 33° C (60° F) above ambient. If a higher temperature is desired, a two stage system can be designed. The first stage is the unglazed perforated panel, the second stage is a glazed solar panel which would be supplied with preheated air from the first stage. This tandem configuration can elevate temperatures an additional 10° to 20° C. The glazed section can be the surface for the canopy so air entering the canopy would be heated again as a back pass collector as it travels horizontally to the nearest fan intake.

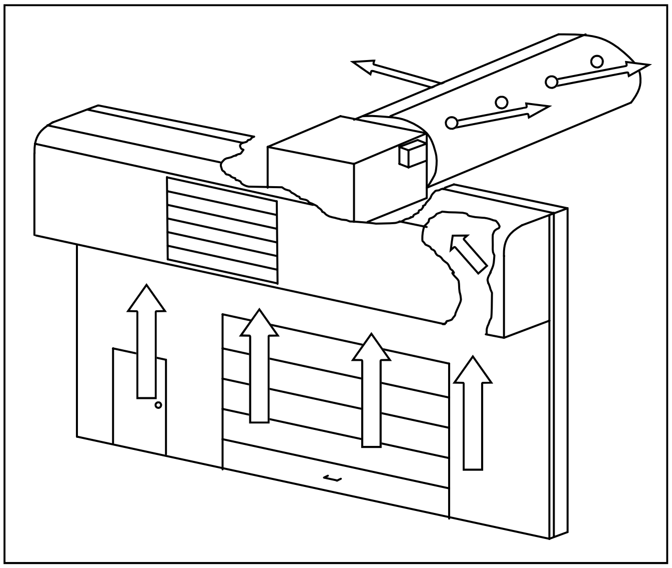

Figure 9: Canopy constructed over wall with doors or windows captures rising heat

Roof mounting: Roof mount systems are equally efficient but only suitable if snow accumulation is not a concern. Walls are preferred in northern latitudes due to the lower sun angle in winter, possible buildup of snow on a roof and the added reflection of sun off the snow in front of the wall. Roof panels are better for countries closer to the equator or if drying or process applications are operated in the summer.

Advantages

- **Low cost:** the collector consists of a single sheet of metal and uses the building wall for support.
- **High efficiency at high flow rates:** with no glazing, panels receive 100% of sunlight and operating temperatures are low minimizing radiation heat losses.
- **No maintenance:** the wall has no moving parts and the coating is designed for decades.
- **Attractive appearance:** similar to other building wall facades and is architecturally attractive and versatile. Choice of colors increases consumer acceptance
- **Improves indoor air quality:** more air can be heated for free so no need to skimp on fresh air.
- **Savings can be substantial:** ventilation air can represent 50% of a building's heating needs.
- **The absorber recovers heat:** otherwise the heat would be transmitted through the wall to the ambient. Heat losses are picked up by the air stream and returned to the building when the fans are running.

Energy Performance

The collector is efficient. This is explained by several facts:

With no glazing in front of the absorber it receives 100% of the sun's energy. Heat loss with no protective glazing is less than intuition might indicate. The boundary air layer in front of the metal is pulled into the collector through the perforations before the heat can be lost to the ambient. Accordingly, the collection efficiency is highest at high air flow rates. Even on cloudy days, the unglazed panels can still generate a few degrees of heat and act as a preheater for the air before it reaches the auxiliary heater.

The efficiency of any solar collector is highest when the temperature of the air entering the solar panel equals the ambient. This occurs with the perforated plate collector. Most solar efficiency curves show the panel efficiency based on a formula which includes ambient air and air temperature entering the solar panel. The efficiency drops as the difference between the two temperatures increases. With the perforated panel, the two temperatures are always the same and the solar panel operates at the maximum efficiency.

In space heating designs, building air enters a solar panel to be heated above room temperature. On cold, overcast days, there may be insufficient solar energy to achieve this, whereas, the SOLARWALL® panel generates heat above ambient, whether it be a rise of two degrees or twenty degrees, and this gain is useful energy.

The solar heated air delivered to the ventilation system will vary in temperature depending on the flow rate and solar intensity and ambient air temperature. Typical temperature rise data is shown in *Figure 5* .

Construction Details

The unglazed panels are installed in a similar manner as other metal wall facades with one difference. The panels are mounted out from the main wall to create the cavity for collecting the solar heated air. The wall must be structurally sound and built in accordance with local building codes.

If the main wall is masonry, attaching the perforated panels with an air gap is relatively simple since the clip and support system can usually be fastened anywhere on the wall. If the main wall is a metal wall with support bars or girts spaced two or three meters apart, the supports for the solar wall panels must be connected to the structural supports and not to the metal sheets. The masonry wall example also includes a canopy. It is recommended that Conserval be contacted when designing a solar air heating system. Typical installation drawings are available upon request.

Air will be flowing against the main wall which must be a waterproof and non-combustible surface such as bricks, blocks, metal, glass, stucco or foil covered insulation. If masonry is used, it may provide some heat storage and heating benefit for one or two hours after the sun sets.

Heat Storage

The SOLARWALL® system is generally used as a daytime heater, converting the solar energy to useful heat as it becomes available. Most commercial, industrial and institutional applications have their main heating loads during the day, when the sun is shining so heat storage is not included. Heat storage can be added but at higher costs. Please contact Conserval for additional information if heat storage is to be specified.

Computer Models

There are two programs that model the SOLARWALL® heating system. Both were produced by Natural Resources Canada and are based on actual test data and field monitoring results.

- SWIFT 99, Solarwall International Feasibility Tool; simulates solar energy savings with SOLARWALL®, uses hourly or monthly weather data.
- RETScreen - 2000 feasibility analysis of ventilation solar air heating using Microsoft Excel software. It uses monthly average weather data and is available free of charge from: http://www.retscreen.net/ (go to SAH 2000 Module).

For additional information:

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Modes of Operation

Figure 10: **Daytime Winter Operation**

Solar heated outside air is brought into a building and distributed.

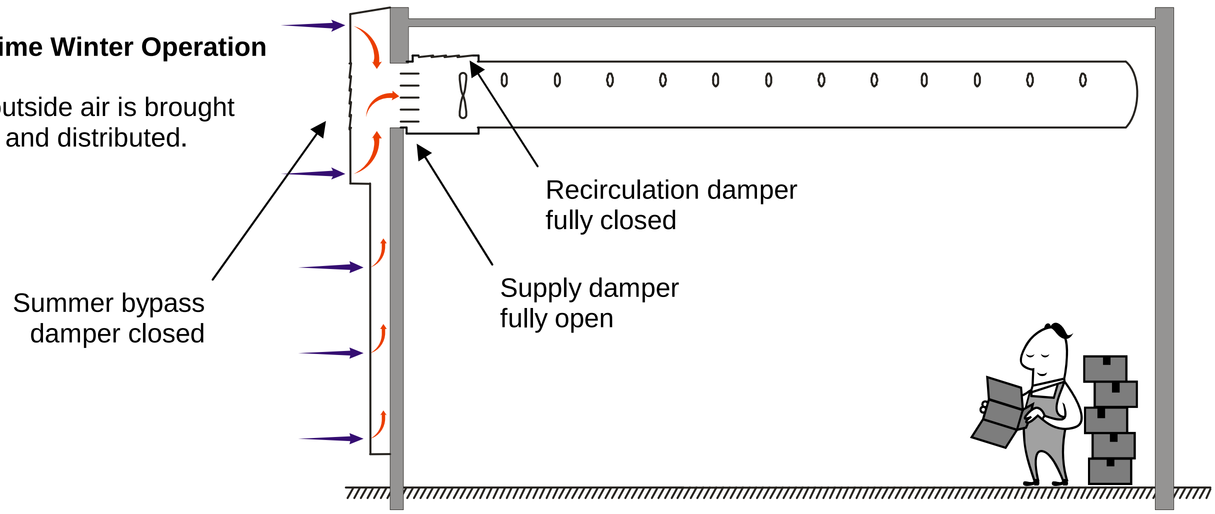

Figure 11: **Nighttime Winter Operation**

Tempered outside air is mixed with plant air and distributed in a building. Auxiliary unit heaters may be added to supplement the SOLARWALL®

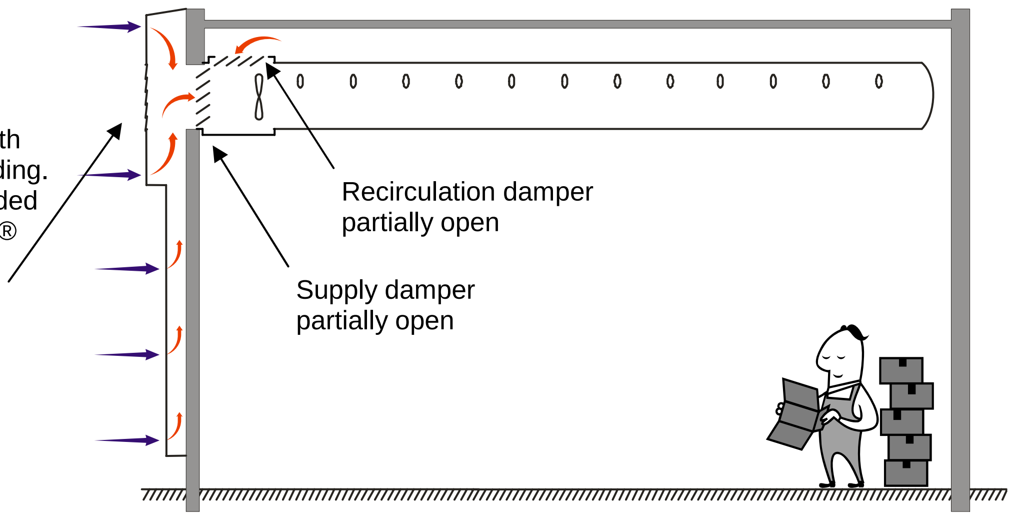

Figure 12: **Day & Nighttime Summer Operation**

SOLARWALL® is bypassed and fresh air is brought directly into the building

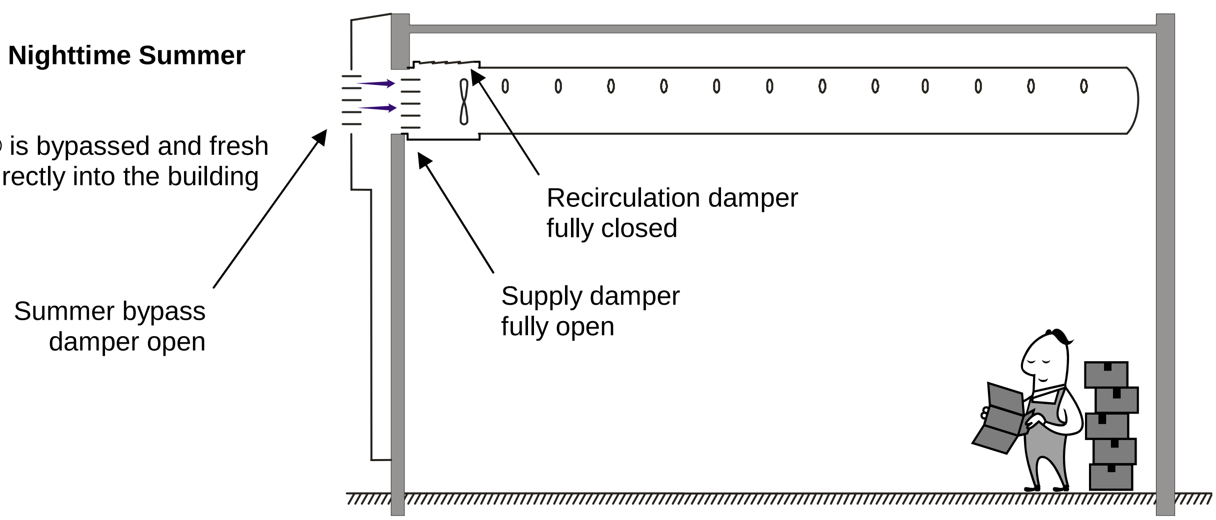

Figure 13: Available SOLARWALL® Colors

Table 1: Solar Absorptivity

Color Name	Color #	Solar Absorptivity
Black	02	0.94
Classic Bronze	01	0.91
Chocolate Brown	04	0.90
Hartford Green	27	0.90
Med. Bronze	03	0.89
Boysenberry	25	0.86
Rocky Grey	16	0.85
Regal Blue	18	0.85
Forest Green	11	0.84
Hemlock Green	30	0.82
Slate Blue	21	0.80
Redwod	07	0.79
Teal	19	0.79
Slate Grey	20	0.79
Patina Green	12	0.77
Mint Green	22	0.71
Dove Gray	13	0.69
Siam Blue	14	0.69
Mission Red	08	0.69
Sierra Tan	09	0.65
Brite Red	17	0.59
Rawhide	15	0.57
Sandstone	06	0.54
Silversmith	28	0.53
Coppertone	23	0.51
Concord Cream	05	0.45
Ascot White	10	0.40
Bone White	26	0.30

NOTE: The colors that are not shown above are primarily used for accent colors. For a complete color chart, please contact Conserval.