Chapter Three
Choosing and Planning

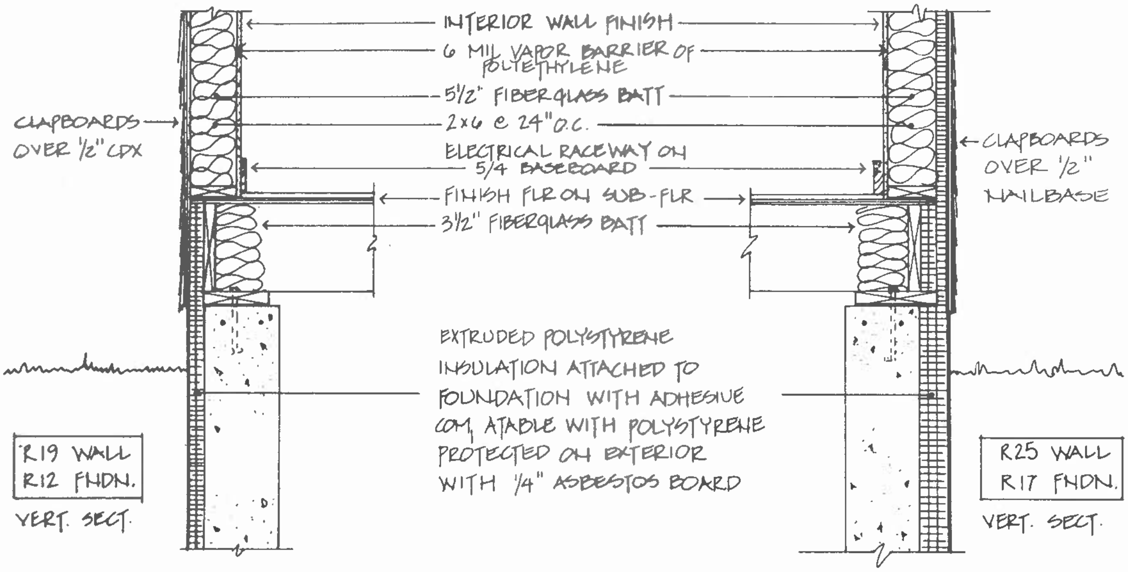
3.1 Solar Design Basics

Energy conservation is essential to good solar home design -- an active or passive solar heating system is chosen only after energy conservation measures have been fully considered. The basic idea, after all, is simply to let sunlight in through windows and keep it there, whether those windows are called collectors or not. So, the first consideration is how to keep the energy in the house.

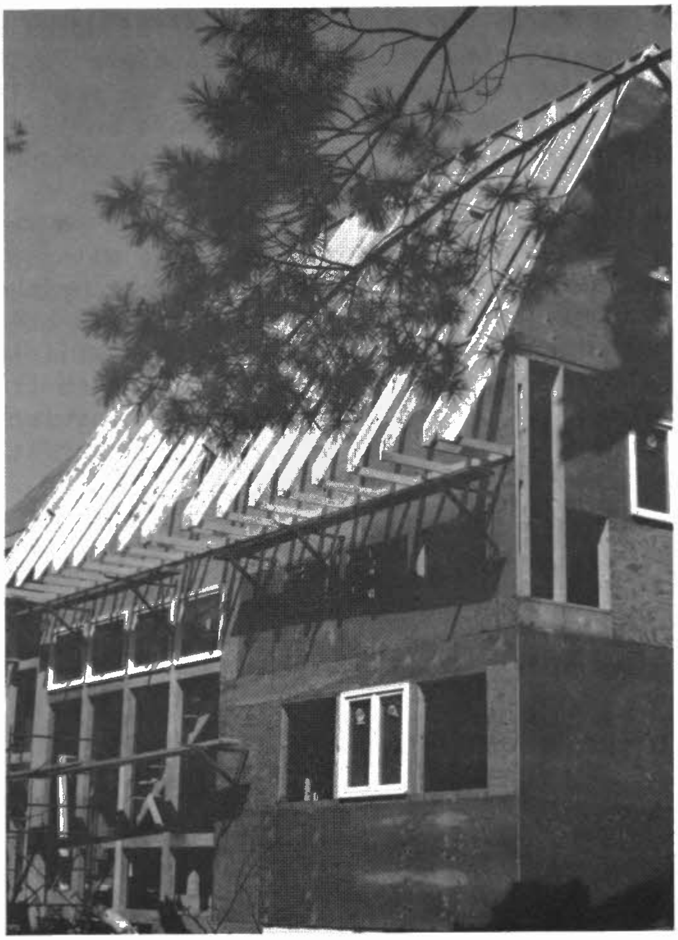
In new construction, energy conservation begins with siting considerations, such as protection from prevailing winds and use of a southern slope, including building into a hill. The next step is the overall building design, taking into account an east-west elongation, natural flow of heat through the structure, natural summer ventilation, airlock entries, and natural lighting. Any building in a climate cold enough to warrant an active solar heating system should be well insulated. In such areas this means a minimum of R-19 wall insulation, and ceiling insulation from R-30 to R-38 for colder regions. Windows should be at least double glazed, and triple glazed in more northern regions. In regions with significant cooling loads (very warm summers), these measures will provide major summertime savings as well. Foundations or slabs should be insulated, windows and doors should be tight, and a complete polyethylene vapor barrier should be used. All of these factors contribute to retaining whatever heat energy the building gains.

Retrofitting energy conservation measures to existing buildings is usually more difficult than dealing with new construction, but still a great deal can be done. Cellulose insulation can be blown into uninsulated wall cavities, attics can be readily insulated, and storm windows and weatherstripping are easily installed. Polyethylene vapor barriers are probably not feasible, but in most cases two coats of

Exterior Insulation/Sheathing



vapor barrier paint and appropriate caulking will suffice. There is much information available on energy conservation measures; the homeowner should consult governmental energy offices and local bookstores.



An Active/Passive Solar Home Under Construction

Direct gain, a type of passive solar, is the simplest and most cost-effective means of transferring solar energy into a house. Windows, which exist for other reasons, can be employed as solar "collectors" by giving consideration to orientation to the sun and shading. If the windows are sealed with insulating shutters at night, they become even more efficient solar collectors. However, if too much area is devoted to windows, energy may be collected at a higher rate than it is needed, and overheating will result. Then there must be a means for storing that surplus heat for a future time, perhaps at night, when it will be useful. This storage can be accomplished by having the direct sunshine fall on slate, stone, tubes of water, or any other material which has a high capacity for storing heat. When the room temperature falls, the heat will be radiated from the storage materials back to the living space. In new construction, it is often possible to design a building so that the majority of the heating requirement can be supplied through direct gain.

When using south-facing windows it is important to remember that the gross building heating requirement increases along with solar aperture area. If night insulation and thermal mass are not employed, the optimum window area may be surprisingly small, particularly in cold climates without a great deal of sun. Double-glazed windows will lose heat at roughly ten times the rate of a well insulated wall, so it definitely does not pay to have large areas of glass without night insulation and added thermal storage capacity. In conclusion, energy conservation measures

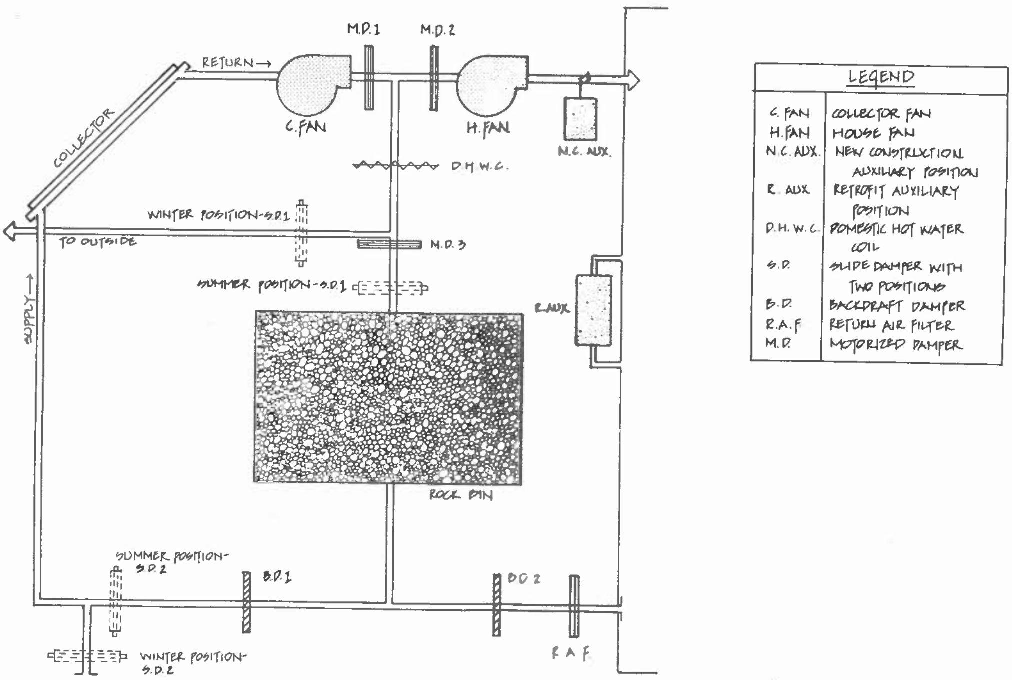


Figure 3.1 System Legend

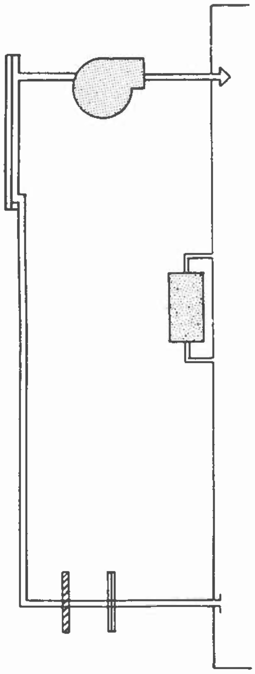


Figure 3.2 Retrofit:
Wall Collector Without Storage

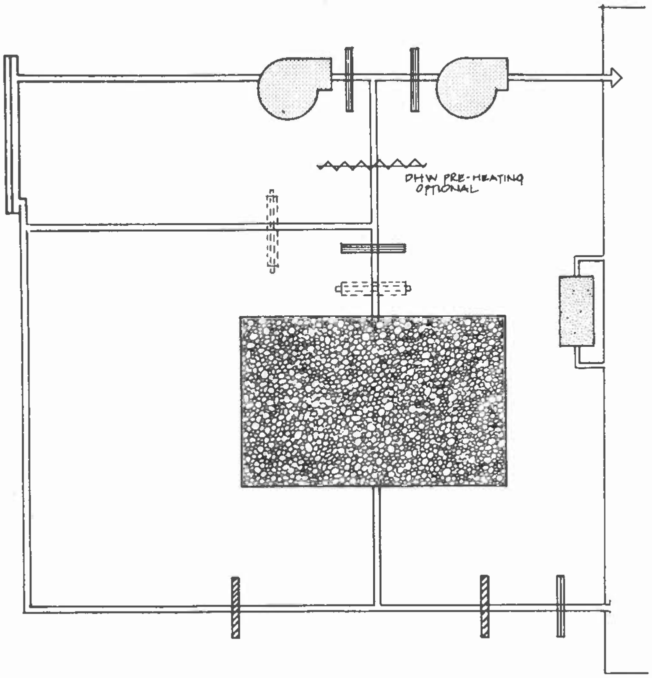


Figure 3.3 Retrofit:
Wall Collector With Storage

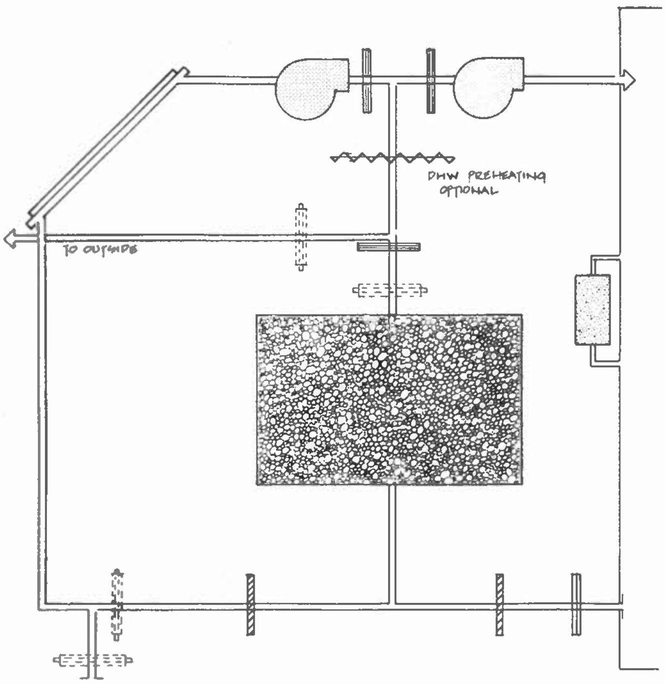


Figure 3.4 Retrofit: Roof Collector With Storage

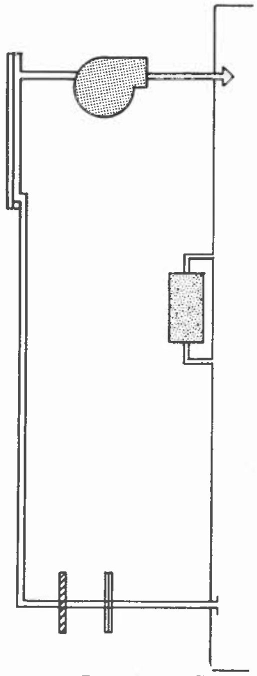


Figure 3.5 New Construction: Wall Collector Without Storage

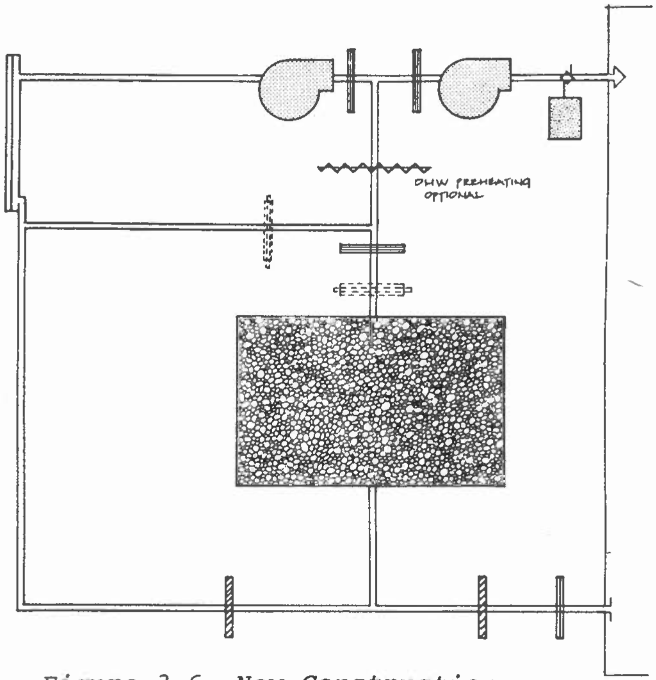


Figure 3.6 New Construction: Wall Collector With Storage

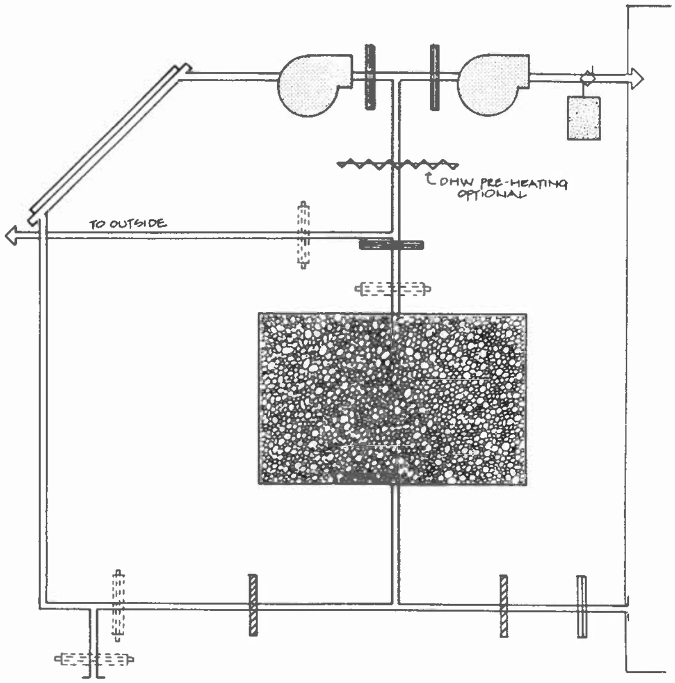


Figure 3.7 New Construction: Roof Collector With Storage

and proper application of passive solar systems, such as direct gain, are the first steps to be taken -- they are the most economical. Once these principles have been applied, there is a definite role for a cost-effective active solar system.

3.2 Collector Choices

The MODEL-TEA collector requires a wall or roof with a southern exposure. The collector may face 10° to either side of true south without a significant decrease in performance, and deviations up to 25° will probably result in only a 5 to 10% decrease. But performance drops off quickly for deviations greater than 30°. The first step in planning for the collector is to assess the building for suitable wall or roof locations. The collector not only requires proper southerly orientation, but it should not be significantly shaded by any nearby trees or buildings. Since the sun is at the lowest angle in December, that angle should be found (for your latitude) and used to check the proposed collector location for full wintertime exposure. Summer shading, such as by deciduous trees, is not harmful. Partial summer shading will not prevent adequate production of solar domestic hot water (DHW), since the collector area will be larger than necessary for that function.

The choice of a wall or roof will impact on the size of the collector. For most single-family houses, a wall application of the MODEL-TEA does not allow a collector area of more than 200 ft^2. On the other hand, most roof applications allow as large a collector as is economically feasible -- usually 350 to 500 ft^2 for moderately-sized houses. In new construction the collector can be carefully integrated into the building design, along with passive solar systems, so the size restrictions mentioned above are more flexible. But in retrofit situations, and new houses of traditional design, those size limits apply.

If a wall collector is much less than 150 to 200 ft^2, and the building is reasonably large, it is not usually cost-effective to install a rock storage bin and the accompanying 3-mode air-handling system. Most of the time, the building will be able to use all of the heat directly available from the collector. The appropriate approach is to use a simple fan and duct delivery system to the living space, and the collector operates whenever there is sufficient sunshine and a concurrent demand for heat. This type of installation is very inexpensive, the only cost being the collector, one fan, and simple controls and ductwork. Since the wall collector is vertical, it does not require power venting in the summer. An attractive retrofit option exists when a building has a window-less south facing wall that is not adjacent to a living space -- such as a garage or storage room wall. This presents a perfect opportunity for a wall collector with a simple delivery system direct to the living space.

The optimum tilt for the roof collector is latitude plus 15°. However, the pitch can vary by 10° without a significant effect, and even a variation of up to 20° will not decrease performance by more than 10%. In new construction the optimum pitch can be easily planned, but in retrofit applications a slight compromise may be required. In any roof application, there should be enough area available to accommodate a full-sized collector. The optimum size is determined primarily by economics; it ranges roughly from 350 ft^2 for small houses to over 500 ft^2 for large ones. For conventionally designed houses it is often convenient and appropriate to use the entire available roof surface. This type of installation will be much more expensive than a small wall collector, since not only is the collector area larger, but storage and a complete air-handling system are required. The estimated costs are given in Section 2.5. A complete roof collector system combined with direct gain on the south wall is the best way to achieve a high solar fraction (fraction of total heating requirement met by solar).

3.3 Planning For Air-Handling and Storage

If a small collector size (less than 150 to 200 ft^2) is chosen, the air-handling system becomes very simple. But if a full-size collector is selected, a number of options are available. First, consider new construction. In designing a new building it is possible to integrate a full-sized collector into either the roof or, in the case of less traditional designs, the wall. For vertical wall collectors power venting will not be required, for roof collectors it will. In either case, a complete air handling and storage system is needed, and this can be either the conventional system or the innovative system. The innovative system is potentially less expensive, but is more critically dependent upon precise sizing and engineering, and requires extensive integration with the building design. The innovative system should not be employed unless the services of an experienced solar designer are available. The conventional system is more flexible in terms of building integration, and since it is a more common design, the costs can be predicted with greater certainty. With either system type, in new construction the auxiliary will be in series with the solar system, and the accompanying controls will assure maximum solar utilization by having the auxiliary draw solar pre-heated air.

In retrofit applications, only the conventional air-handling system is appropriate. This system can be integrated into any building where space can be found for the rock bin and air-handling equipment. If the building has a basement, the rock bin, air-handler, and ductwork should be located there, in a position convenient to both the collector and living space. The rock bin should be located so that it may be readily filled with rocks, perhaps near a window so the rocks may be dumped in through a chute. All the ductwork to the living space can be located in the basement since the solar-heated air need only be delivered to the first floor. Second-floor heating requirements can be met, if necessary, with through-the-ceiling grills or a zoned auxiliary. In houses on slabs the rock bin and air-handler must be integrated into the first floor, and the ductwork must be fitted into the ceiling.

The auxiliary heating system will be in parallel with the solar system in all retrofit applications. This allows the solar system to be integrated into the building no matter what type of existing heating system is present. The accompanying controls are carefully designed to allow solar system air to be delivered to the house whenever both the house thermostat calls for heat and the solar-heated air is above 85°F. If more heat is required, it is provided by the auxiliary heating system simultaneously. If the collector air temperature drops below 85°F but is still more than 20°F warmer than the cool side of the rock bin, then the collector air flow is diverted from the house to the rock bin. The auxiliary continues to heat the house. This control scheme achieves maximum utilization of solar in retrofit situations.

Wall collectors in retrofit applications will usually be small, perhaps no more than 200 ft^2, due to limited wall area. Installations of this size do not require storage and, of course, do not need power venting. Roof collectors always require power venting.

DOMESTIC HOT WATER. A water coil can be inserted into the ductwork in any application of the MODEL-TEA in order to obtain domestic hot water (DHW). However, this is not an attractive option for wall collectors of moderate size or smaller. Vertical collectors receive much less summertime solar radiation than roof collectors, and this is compounded by the small collector size. During the heating season a small wall collector can be well utilized for heating only; a DHW option would probably not increase the system's cost effectiveness. The DHW option adds a major expense to the total installation cost, since in addition to the coil, it requires a pre-heat tank, pump, valves, extra plumbing, and controls. A typical cost for the materials, including the tank, is roughly $700, and the labor for installation could add as much as another $700.

For roof collectors or any large collector the DHW option is very attractive. The extra cost of the coil, controls, tank, and installation is significant, but the cost-effectiveness of the system is improved by allowing useful year long operation. Summertime operation for DHW does not negate the need for power venting of roof collectors. Power venting is a requirement, while DHW is an option. But for all full-size systems, the DHW option is definitely recommended.

It is important that the DHW coil be located in the rock bin duct, as is shown in Figure 3.1. If instead, the coil is placed in the collector return duct, there is a possibility that it could freeze during the storage to house mode if Motorized Damper 1 were to leak. During nighttime storage to house heating, cold air would be pulled down from the collector through the coil. But located correctly, as shown, warm rock bin air is pulled through the coil in this mode.

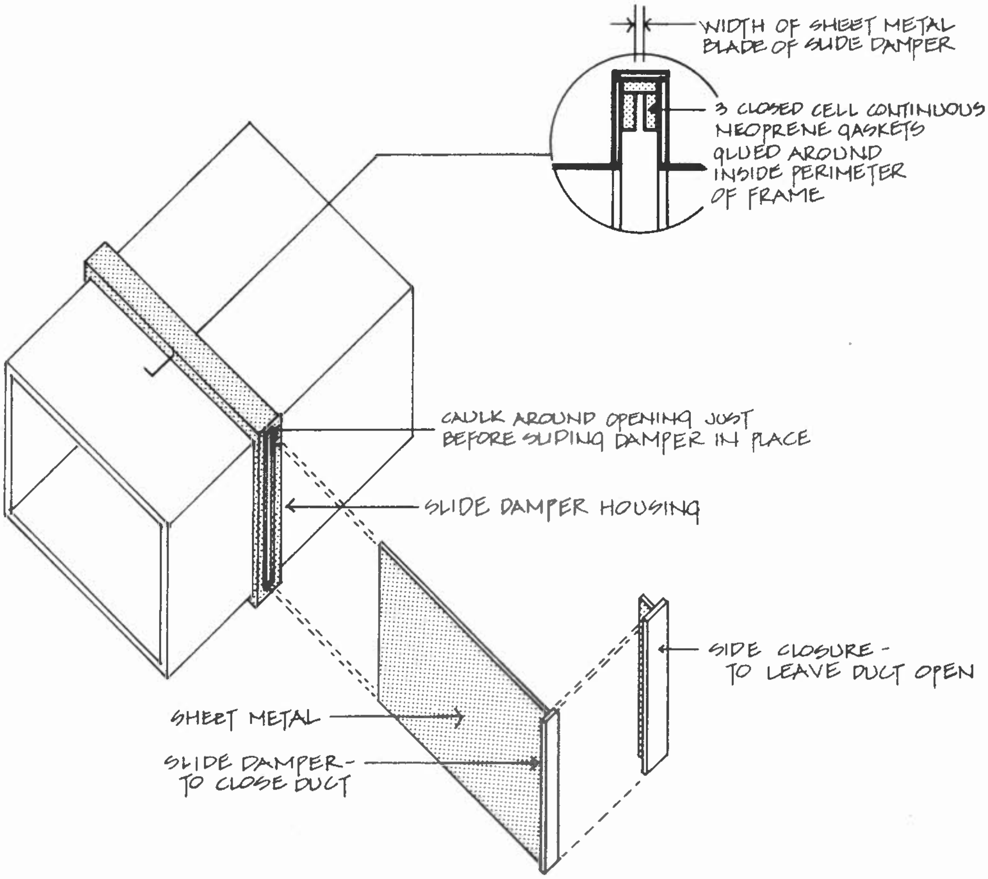


Figure 3.8 Site-Fabricated Slide Damper

POWER VENTING. Tilted collectors are vented in the summer by drawing outside air through the collector and returning it to the outside. The ducts to the outside are opened in the spring, at the end of the heating season, by manually moving the two slide dampers shown in Figure 3.1. At the end of the summer, when the heating season begins, the two slide dampers are returned to their winter position, and carefully sealed. It is extremely important that the dampers be perfectly sealed so that there is absolutely no leakage from the outside during the heating season. Not only can outside air leakage have a devastating effect on overall system efficiency, any leakage past Slide Damper 1 can directly affect the hot water coil.

BACKDRAFT DAMPERS. These dampers allow the passage of air in only one direction and require no external control. There are two backdraft dampers shown in Figure 3.1. The purpose of these dampers is to prevent air leakage into the ductwork; if the duct system were air tight and the control dampers were leak proof, then the backdraft dampers would be unnecessary. However, since backdraft dampers are not expensive, it makes sense to install them as a precautionary measure. These dampers can be either purchased or site-fabricated (see Appendix A).