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MASTER

PASSIVE SOLAR HEATING OF BUILDINGS
WITH ATTACHED GREENHOUSE

Progress Report
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Abstract

Research is being conducted on the attached-greenhouse type of passive solar heating system in the north-central region. The thermal performance of attached-greenhouse buildings is being analyzed in order to determine the component sizes and configurations which optimize performance. The analytical method is dynamic computer simulation using a thermal network model and actual hourly meteorological and solar radiation data from the north-central region. Progress in this, the second quarter, of the project has consisted of a large number of computer simulation runs resulting in performance estimates for certain designs. Preliminary conclusions on design guidelines are suggested by the results. The overall aim of the project is the development of specific design guidelines useful to architects and builders.

Progress Report

Research is being conducted on the attached-greenhouse type of passive solar heating system in the north-central region. General goals of the research are:

- 1) To evaluate attached-greenhouse passive solar heating in terms of the expected fraction of the total heating load provided by solar energy.
- 2) To investigate the constraints imposed on performance by traditional, wood-frame design and construction practices, especially the use of an insulated frame wall between the greenhouse and the residence.
- 3) To develop specific design guidelines for an attached greenhouse incorporated in new construction, or in a retrofit to an existing building, of traditional design and construction.
- 4) To investigate non-traditional designs appropriate to optimum performance, and to develop specific guidelines for any such designs.

The analytical method is dynamic computer simulation using a thermal network model of the building. Actual hourly meteorological and solar radiation data from selected cities in the north-central region will drive the computer simulations. The principal progress in this, the second quarter, of the project is a series of computer simulations for certain attached-greenhouse designs using the hourly typical meteorological year (TMY) data for Bismarck, North Dakota.

The general geometry and parameter definitions are shown in Figure 1. The size and shape of the water-storage container are characterized by its height, HSTOR, and its depth, DSTOR. The volume of storage is $HSTOR \times DSTOR \times WIDTH$. The storage container is detached from the wall and floor and thermally coupled to them by radiation and indirectly by convection through the sunspace air.

Any of the surfaces except the floor and the back wall can be chosen as glazed, but only the two south-facing ones were glazed in the results presented here. The east and west end walls were insulated to R20. The glazings were assumed to be perfectly diffusing in the forward direction, i.e., they scatter the transmitted radiation isotropically into a hemisphere inside the sunspace but there is no backward scattering. The radiation eventually absorbed by each internal surface is the result of multiple internal reflections.

All of the simulation runs were done with a room heat loss coefficient (ULOAD) of 1.0 Btu/hr.° F. sq ft of wall area. A reference case was chosen which includes a water storage container of volume one cubic foot of water per square foot of south wall area and of height-to-depth ratio of two (HSTOR/DSTOR=2; see Figure 1 for definitions of dimensions). The results consist of studies of the sensitivity of building performance to the variation of design parameters. Table 1 lists the values of several of the reference case parameters, and Figure 2 is a sketch of the reference case.

The measure of performance is the Solar Savings Fraction (SSF) defined by

$$SSF = \frac{QLOAD, REF - QHEAT, TOT}{QLOAD, REF}$$

where QLOAD,REF is the room heat loss (excluding south-wall losses) on the basis of a reference room temperature of 65°F, and QHEAT,TOT is the total auxiliary heat added to the sunspace and the room to keep their air temperatures within their respective thermostat set points.

Figure 3 shows the sensitivity of the SSF to storage volume in the form of a container full of water added to a 45 Btu/°F sq ft masonry storage wall. As might be expected, there is a performance improvement with the addition of storage, but it is modest.

Figure 4 shows the more interesting case of the sensitivity of the SSF to the storage volume in the case of an insulated, light-weight wall. Four glazing systems are shown: double-glazed with and without night insulation, and triple-glazed with and without night insulation. The performance increases rapidly from its no-storage level. Added benefit is felt from storage up to very high storage volumes, but the increase is relatively modest beyond about 0.5 to 1.0 cubic feet of storage water per square foot of wall area.

Figures 5, 6, and 7 show the sensitivity of the SSF to the shape of the water storage container. The parameter which characterizes the shape is HSTOR/DSTOR, the ratio of the height to the depth of the container. Figure 5 shows that for the masonry wall case the optimum storage shape is low and thin, a sunspace "water floor" so to speak. Figures 6 and 7 show that the insulated-wall case has a minimum performance for a square-shaped storage container where HSTOR/DSTOR=1. Once again the best performance seems to be the "water floor" shape.

Figure 8 shows the SSF to be only moderately sensitive to XTOP, the ceiling depth. About two percentage points of improvement in solar savings could be achieved by reducing XTOP from its reference value of four feet to zero; about three percentage points would be lost by increasing it to eight feet.

Figure 9 shows that the SSF is very sensitive to the extent to which a vertical segment of glazing is employed. This result quantifies the effect of a very common design decision: to establish a desired sunspace floor and ceiling depth, then use a two-plane glazing system

rather than a single plane as in the present reference case. As is seen from the curve, there is possibly a very substantial performance penalty, at least in the specific case treated here for Bismarck with no night insulation.

Figure 10 shows the sensitivity of the SSF to the sunspace depth. The presumption in this study is that the designer has chosen a geometry which includes a vertical glazing segment, and has fixed the ceiling depth (XTOP) and the height of the vertical glazing segment (YBOT). The decision which remains is what overall depth to choose, or, which is the same thing, what tilt to choose for the upper segment of glazing. The curve indicates an optimum depth, at least for the case studied of Bismarck with no night insulation. The physical effects operative here are the increase in solar aperture with depth and the simultaneous increase in sunspace losses. The aperture increase improves the performance up to the point where the losses begin to just compensate for the gains.

These results are very limited in scope, so far, being for just a single location and for a single building load coefficient, but it can be seen that specific design guidelines are already beginning to emerge. A sufficient number of cases should be finished by the end of the next quarter so that specific guidelines can begin to be formulated.

TABLE 1. Sunspace Reference Case Parameters

Description	Name	Value
Wall height	HWAL	9.0 ft
East-west width	WDTH	30.0 ft
Ceiling depth	XTOP	4.0 ft
Tilt of glazing	TILTG	50 degrees
Emissivity of storage container	EPSST	0.9
Conductance of sunspace back wall	UWALL	0.05 Btu/hr.°F.sqft
Minimum sunspace temperature	TGHMN	45 °F
Maximum sunspace temperature	TGHMX	95 °F
Height of thermocirculation loop	HGHT	8.0 ft
Absorptivity of sunspace back wall	ALFS(1)	0.9
Absorptivity of storage container	ALFS(8) & ALFS(9)	0.9
Resistance of night insulation (when used)	RESNI	9.0 hr.°F. sqft/Btu
Number of glazings	NGL	2

Figure 1. Sunspace Geometry and Definitions of Parameters.

Figure 3. Sensitivity of SSF to Storage Volume

Figure 4. Sensitivity of SSF to Storage Volume

Figure 5. Sensitivity of SSF to Storage Shape

Figure 6. Sensitivity of SSF to Storage Shape

Figure 7. Sensitivity of SSF to Storage Shape

Figure 8. Sensitivity of SSF to Ceiling Depth

Figure 9. Sensitivity of SSF to Extent of Vertical Glazing

Figure 10. Sensitivity of SSF to Greenhouse Depth .