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DIRECT SOLAR AIR HEATING IN DENMARK (56°N) HEATING STRATEGIES IN THEORY AND PRACTICE

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EXTENDED ABSTRACT

INTRODUCTION

The past five years have witnessed a dramatic increase in the study and the application of solar energy in Denmark. Many useful principles from the wealth of international literature have been applied to advantage. We estimate that more than $10^4 m^2$ collector were installed in this country by mid 1979. It now appears quite clear that the success of solar space and water heating here will be critically dependent upon the adoption of judicious heating strategies and construction practices.

Clearly the cash investment in solar equipment, expressed in terms of the total system cost per unit absorber area P_a is an important variable. This number and the total useful yearly yield Y_y per unit absorber area, when coupled with the expected system life-time and other economic variables, are of central importance. Because of the extreme yearly fluctuation in the available solar radiation and the heating load in northern climates, particular care must be exercised in order to achieve a successful matching of a solar heat source and a heating load. We have found the total yearly heating load per unit absorber area L_y to be a particularly important parameter.

In view of these observations, we have studied the performance of a variety of Danish solar heating systems. The following system types will be discussed: (A) a well-loaded hot water heating system, (B) a large-load direct air heating system with no active storage, and (C) a complementary water-air heating system. Practical experience with a variety of other system types has shown some systems to be inappropriate at present for use in northern climates. In our paper it will be possible to cite a number of practical solar design guidelines with a sound basis in both theory and observation.

HOT WATER HEATING

Hot water heating systems are becoming more and more common in Denmark. Figure 1 shows that yearly hot-water load per unit absorber area L_y equal to about 700 kWh/m²-year or greater will assure that a well-designed water heating system can provide an annual yield Y_y greater than 300 kWh/m²- year. Within a range of realistic economic parameters, such a system is already competitive with some traditional heat sources (central oil furnace, electrical resistance heating) though not with others (e.g. central heating plants). Actual prices and 5 year inflation rates will be reported in the paper.

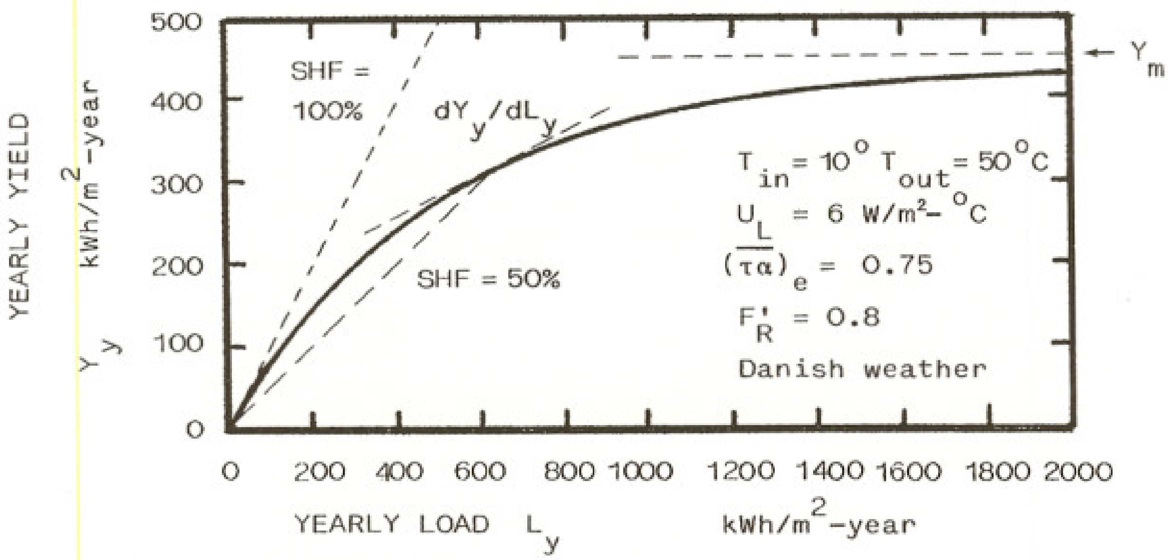

Figure 1: The useful yearly yield per unit collector absorber area is shown as a function of the total yearly load for a solar hot water heating system with constant load. The graph was generated using the f-chart method [1] for the parameters shown and Danish weather conditions. Klein's K_T method was used ($\rho = 0.2$) to determine monthly global on the 45° from horizontal south-facing collector.

Note that the slope of the chord line corresponds to the yearly solar heating fraction (SHF). This is illustrated for the case of SHF = 50%. Observe that the slope of the chord approaches unity for light loading conditions. Another asymptotic limit is the maximum annual yield Y_m approached for very high loading with consequent high system efficiency. The slope of the graph dY_y/dL_y corresponds to the marginal yield increase associated with a marginal increase in the system loading. Note that the graph can be approximately described by a function $Y_y = Y_m[1-\exp(-L_y/Y_m)]$, which is the solution to $dY_y/dL_y = 1 - Y_y/Y_m$. This simple relationship can be exploited in connection with an optimization analysis. The asymptotic performance limit Y_m can also serve as a figure of merit for a given solar heating system configuration.

As figure 1 clearly shows, the high useful annual yield necessary to achieve good economy depends critically on adequate loading. As a consequence, the solar heating fraction must decrease - a situation which will persist as long as efficient and inexpensive long-term storage is unavailable.

DIRECT AIR HEATING

Figure 2 illustrates the poor matching of the available global radiation on a south-facing surface (tilt 45°)

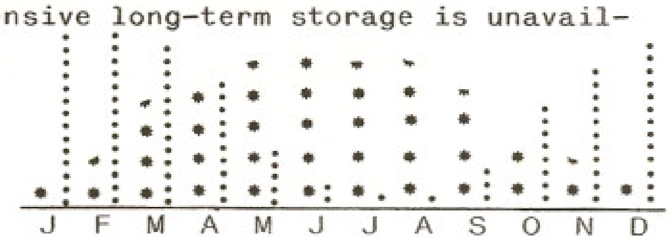

Figure 2: Insolation & Load.

in Denmark (each ✱ corresponding to 33 kWh/m²-month) and our typical space heating load requirements (• = 300 kWh/month). Low outdoor ambient temperatures in winter aggravate the situtation. Autumn and particularly the spring are good periods for space heating with solar. Guided by the available literature [2] and by the importance of reducing system cost, we have proposed the use of direct air space heating with no active storage, delivering heat to a building when heat is needed and solar energy is available.

Such a heating system has been installed and operational in the natural sciences wing of Silkeborg Amtsgymnasium (community college) since late 78. The wing has a total yearly heating load of about 60 MWh/yr with only modest direct solar gain through windows. A south-facing (40°) surface was available for a 33 m² single-pass air collector with two layers of 4 mm glass. A 1 kW blower distributes warm air to 4 lecture halls and a preparation area with a total floor space of 600 m², about 2/3 of the total wing area. Monthly performance summaries for the first 10 months of operation will be available in our final paper. The system has performed as projected with a yearly useful heat output of about 140 kWh/m² expected. Significant cost savings and simplicity were achieved by avoiding active storage. Blower energy requirements are lowered by avoiding storage and air-handling. High efficiency is maintained during operation, since the collector input temperature remains close to room temperature during all periods of operation.

COMPLEMENTARY WATER-AIR HEATING

A prototype collector designed to perform direct air heating when possible, and to store hot water otherwise, has been installed. A measurement program will reveal if the high loading inherent in this heating strategy can in fact produce high values of Y_y. In passing it is noted that an inexpensive microprocessor data-logging system designed for the AIM 65 microcomputer has been developed. Interested parties are welcome to address the authors for copies of our hardware schematics and software solutions.

CONCLUSION

The heating strategies suggested by earlier work [3] have been developed and tested. Our results will be presented more completely in our paper. Briefly, economically attractive solar heating systems for space and water heating in northern climates (above 50°) should be designed to achieve: (1) high yearly system yield Y_y by high loading, (2) low cost by simple, maintenance-free construction, (3) good matching of the size, distribution, and temperature requirements of the heating load to the solar heating system.

LITERATURE

(1) Beckman, Klein, Duffie; Solar Heating Design by the f-Chart Method, Wiley, New York, 1977.

(2) G.O.G.Löf; "Systems for Space Heating with Solar Energy", Applications of Solar Energy for Heating and Cooling of Buildings, ASHRAE, GRP 170, 77.

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