# RESULTS OF THE GRONINGEN CSHPSS PROJECT

J. Havinga and A.J.Th.M. Wijsman
TNO Institute of Applied Physics
P.O. Box 155, 2600 AD Delft
The Netherlands

**Abstract**

In Groningen, the Netherlands, a Central Solar Heating Plant with Seasonal Storage (CSHPSS) in the soil has been realized and has been in operation since the autumn of 1984. The system has been monitored for five years. During this period the system functioned without major problems. The measured solar contribution of the system is about 15% lower than the design value. Main reasons for this lower output are a lower collector output and higher storage heat losses than expected.
This paper summarizes the monitoring results.

## 1. Introduction

In Groningen, the Netherlands, a central solar heating plant with seasonal duct storage in the soil has been realized and has been in operation since the autumn of 1984. The climate at the site has a strong maritime tendency with a moderate character. This means rather low temperatures in summer and relatively high temperatures in winter, except for a few weeks in which (north-)eastern winds from the continent and polar region may occur.
The objective of the project was to gather practical experience with the actual realization of such a system, to monitor the overall behaviour and to gather data for model validation.
During the first two years of operation the project has been monitored extensively (February 1, 1985 - January 31, 1987). Results from this monitoring period were reported in ref [1]. After this a three-years low-level monitoring programme was carried out untill January 31, 1990, in which the number of measurements have been decreased drastically. The goal of this programme was to get information about the overall performance and durability aspects of the system during a longer period of time. Detailed results from this measuring programme have been reported in three yearly progress reports and were summarized in a summary report ref [2].
The project was financed by NOVEM, the Netherlands Association for Energy and the Environment as part of the Dutch National Solar Energy Research Programme and by the Commission of the European Communities.

## 2. Description of the overall system

The system consists of 96 solar houses divided in 9 blocks and grouped around the seasonal duct heat store in the soil and the central boiler house. Each house has a solar heating system consisting of about 25 m$^2$ Philips VTR-261 evacuated tubular solar collectors (total collector area about 2400 m$^2$). The solar heat system contributes to both space heating and domestic hot water preheating. For space heating there is a central auxiliary plant, for domestic hot water each house has its own back-up system.

The houses are well-insulated; at design conditions ($T_{amb}$ = 10 °C, $v_{wind}$ = 5 m/s) the heat demand is 6.3 kW. The space heating system in the house is a low temperature radiator heating system with 42.5 °C supply temperature at design conditions.
The storage system consists of a short term (daily) and a long term (seasonal) store. The short term store is a 100 $m^3$ water tank (length 12m, diameter 3.3m) buried horizontally in the centre of the seasonal heat store. The volume of the seasonal store is 23,000 m3 of soil (38 m diameter, 20 m deep), which can be described as water saturated sand with thick layers of clay and some thin layers of peat (mean heat capacity: 2.7 $MJ/m^3K$, thermal conductivity: 1.5-2.2 W/mK, permeability $5\text{-}20*10^{-12}$ $m^2$). The seasonal storage is not bounded by walls. Only the top to the seasonal store is insulated. Two insulation materials have been applied: foam glass (0.10m) and expanded clay grains (0.40m); k-value top-insulation: 0.20 $W/m^2K$
The heat exchanger is made of 360 flexible polybutene U-shaped tubes (20*16mm, total tube length 15 km) which are vertically inserted into the ground using a specially shaped vibrating lance. The exchange rate of the soil heat exchanger is about 32 kW/K. The groundwater level is about 1 m below the surface.

The distribution network between the solar houses and the seasonal heat store has a total length of 1900 m. To avoid corrosion problems the soil circuit has been separated from the distribution network by a water to water heat-exchanger.

The system is controlled by a PLC computer, which measures various temperatures, the modes of pumps (on/off) and valves (open/closed). Depending on these measurements appropriate actions are taken continuously. The control programme is stored in a EP-ROM.

Figure 1 shows the total system in a schematic form.

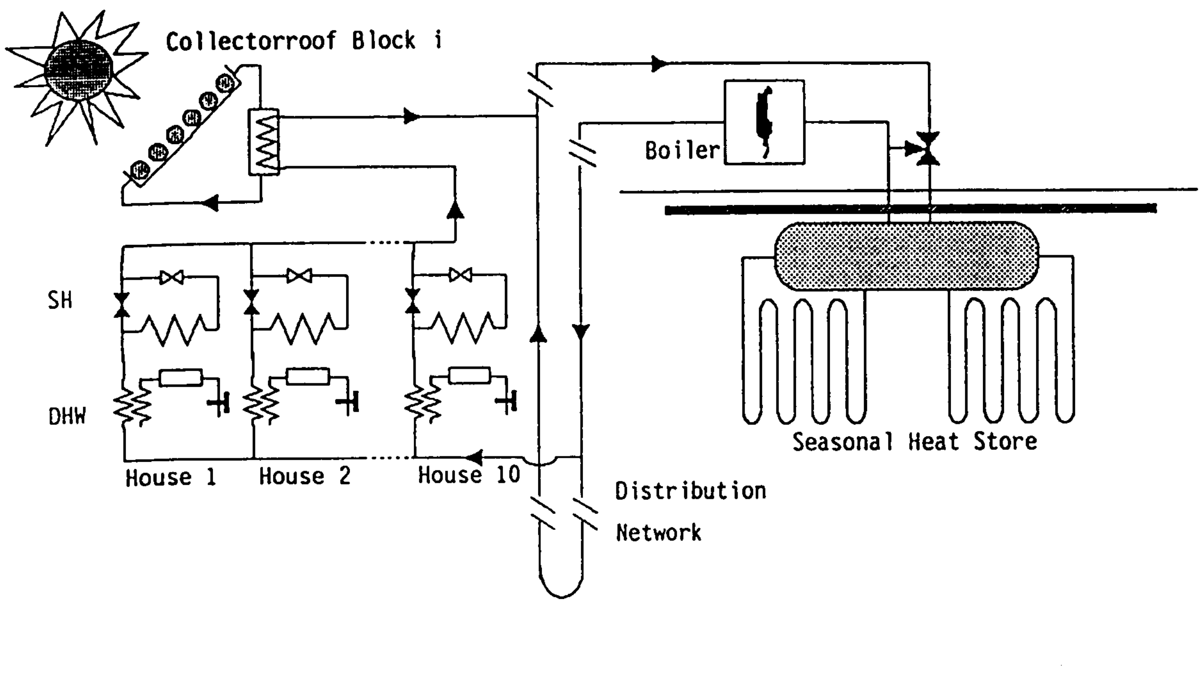


Figure 1: Schematic representation of the total system

## 3. Monitoring Results

### 3.1. Projected solar contribution

For the design work on the system a specially developed computer simulation programme has been used.
The solar contribution of the system after 3 or more years of operation is expected to be 732 MWh, which is 63% of the projected total load (1163 MWh). In figure 2 a energy flow diagram is given for the projected system performance (pumping energy not included).

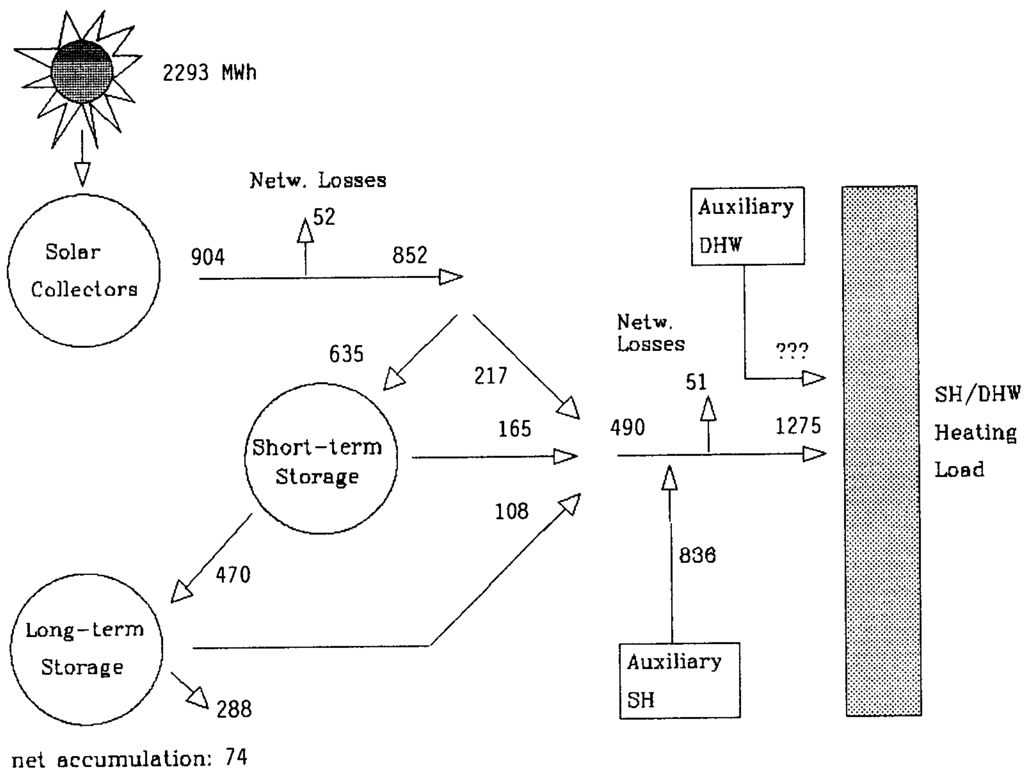


**Figure 2: Projected System performance**

The net solar contribution is 310 kWh per $m^2$ of solar collector. The annual efficiency of the collector roofs is 48%. The seasonal heat store will operate between 30 and 60 °C. The electricity consumption of this system (for pumps) is 77,000 kWh, i.e. 800 kWh per house.

### 3.2. Thermal Performance

After the system came into operation its performance has been monitored extensively during 2 years till the beginning of 1987 [1]. The monitoring programme consisted of measurements on individual houses, on blocks of houses, of central measurements and of detailed measurements on the seasonal heat store. A low level monitoring programme which started in the beginning of 1987 consisted of the same measurements as mentioned above, except for the detailed measurements on individual houses and on the seasonal heat store. Data were now collected as monthly totals from meter read-outs.

The low level monitoring programme lasted until the beginning of 1990.
In figure 3 the measured system performance is given for the second year of monitoring (February 1, 1986 till January 31, 1987).

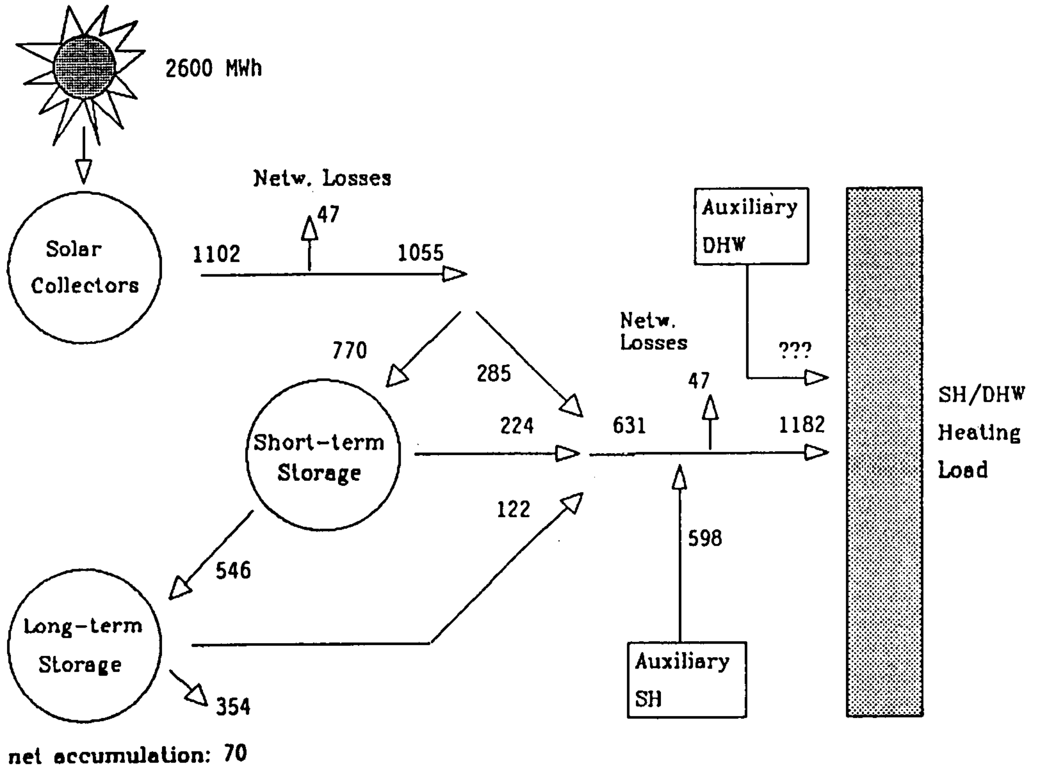


Figure 3: Measured system performance (2nd year)

The solar input to the load distribution network was 631 MWh: 285 MWh via direct use, 224 MWh via short term storage, 122 MWh via seasonal storage; the heat losses of the distribution network were 47 MWh. The annual efficiency of the collector roofs was 42.4%. It was observed, that the several blocks showed differences in performance: 39-45%.
The net heat accumulation of the seasonal heat store was 70 MWh (so a "steady" year cycle has not been reached); the heat losses of the store were 354 MWh.

Figure 4 shows for all five years of operation which part of the net house heating load (so excl. distribution network losses) is covered by the solar system and which part is provided by the auxiliary. In this figure the values as calculated in the design study are also indicated. The numbers in the figure indicate to total yearly house heating load.
This total yearly heating load of the system during the last three years of monitoring is about 20-30 % lower as compared with the first two years of operation. This is caused by the relatively mild winters and the corresponding higher ambient temperatures. This can be seen from a more detailed analysis of the relation between heat consumption by the houses and the ambient temperature. This relation is almost the same for all years indicating that the lower heat consumption is caused by higher ambient temperatures.

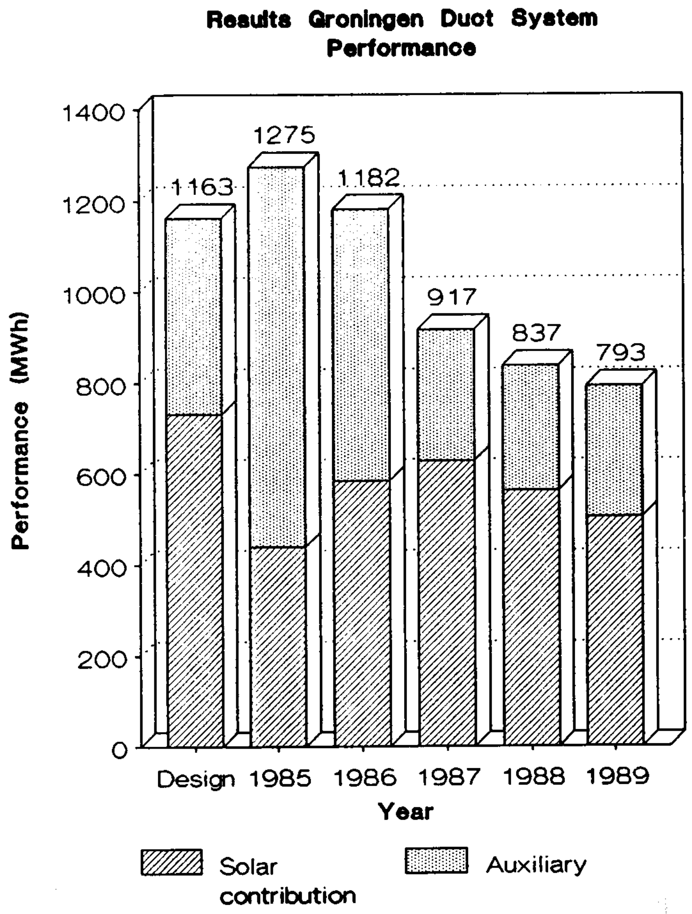


**Figure 4: Summary of system performance during five years of operation**

In figure 5 it is shown for the different years of operation how the solar output from the system to the total heating load (i.e. heating load of the houses plus heat losses in the network) is built up. The contribution from the seasonal heat storage during the first two years was relatively small because this store had to be warmed up from the natural ground temperature (10 °C) to the minimum operating temperature of about 30 °C.
The space heating system in the houses did not function optimally during the second year. This led to heat consumption for space heating in summer time. Also the central control system did not function properly. Modification of the central control resulted in a decrease of the net temperature in the seasonal heat store during the third year. The adaptation of the heating system in the houses resulted in a lower heat consumption during the summer and so to a better seasonal storage function.

After the second year of operation the thermal performance of the system is more or less stable with a 35% direct solar contribution to the load, 30% via the short term buffer and another 35% via the seasonal storage.
As compared with the design values the measured output from the seasonal storage is less than expected i.e. the heat losses of the seasonal store are about 1.6 times higher than expected. A special study has been carried out to look for the reasons for higher heat losses.

The results of this study [3] show that these higher storage heat losses are caused by thtee factors :
- the $U_L$-value of the top insulation is higher than expected
- the minimum useful temperature in the system is slightly higher than the design value
- higher heat losses to the surrounding soil caused by groundwater movement in the store (natural convection and seepage)

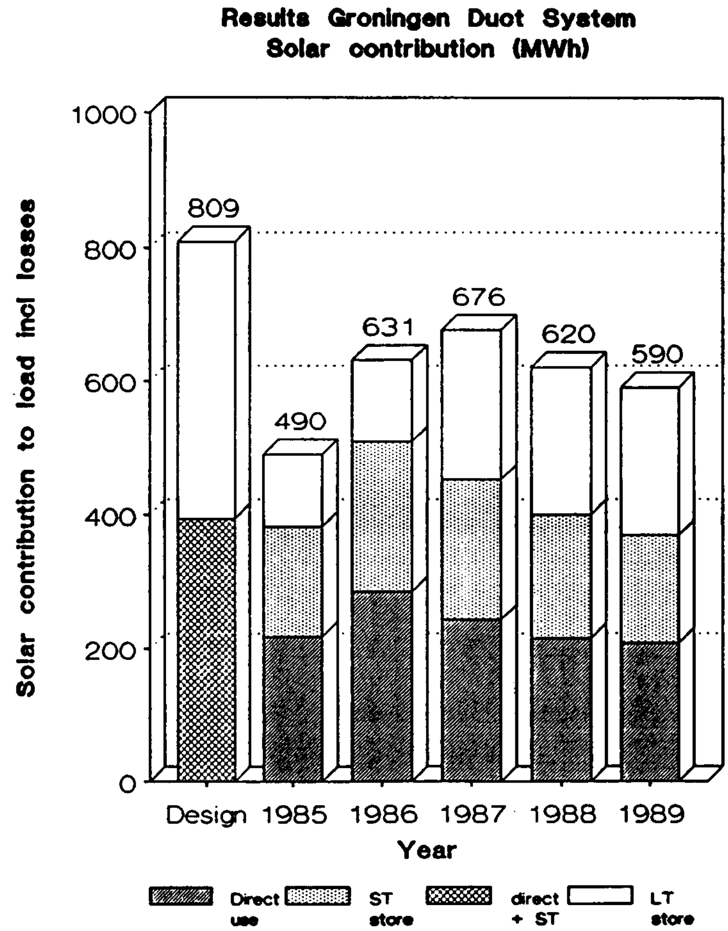


Figure 5: Solar contribution during five years of operation

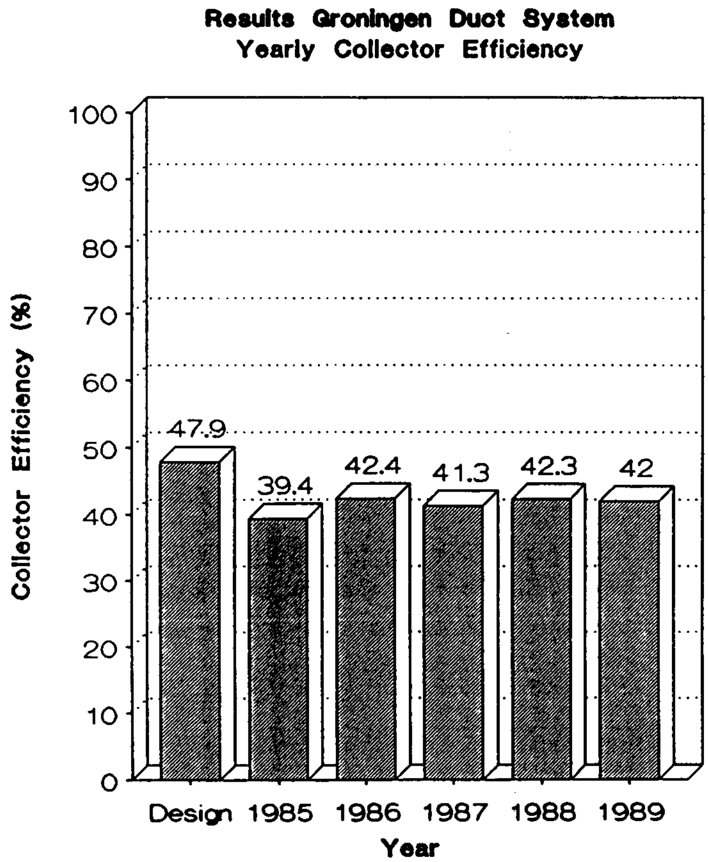


Figure 6: Yearly efficiency of the collectors during five years of system operation

In figure 6 the average yearly efficiency for the collectors is given.

As can be seen the yearly efficiency is somewhat less than the calculated efficiency but does not change significantly during the last four years of the measured period of five years. Only during the first year of operation the overall yearly collector efficiency was less because some of the collectorroofs were out of operation during some months because of frost damage. An additional study yielded the causes for the measured lower performance as compared with the expected collector efficiency.[4]
ation

### 3.3. Electricity consumption

In figure 7 the total electricity consumption of the system is indicated for the design and the last four years of monitoring. Data for the first year are not available. This electricity consumption is divided in the electricity consumption for the pumps in the collector subsystem and the electricity consumption by the central system (pumps, valves and others). The electricity consumption by the pumps in the collectorsubsystem was derived from the measured number of pumping hours while the consumption by pumps, valves etc in the central system was obtained from an electricity meter readout. The actual electricity consumption is higher as compared with the expected values mainly because in the design value electricity consumption for valves, control equipment etc. were not taken into account. Another reason is that the frost protection control had to be adapted which resulted in extra pumping hours.

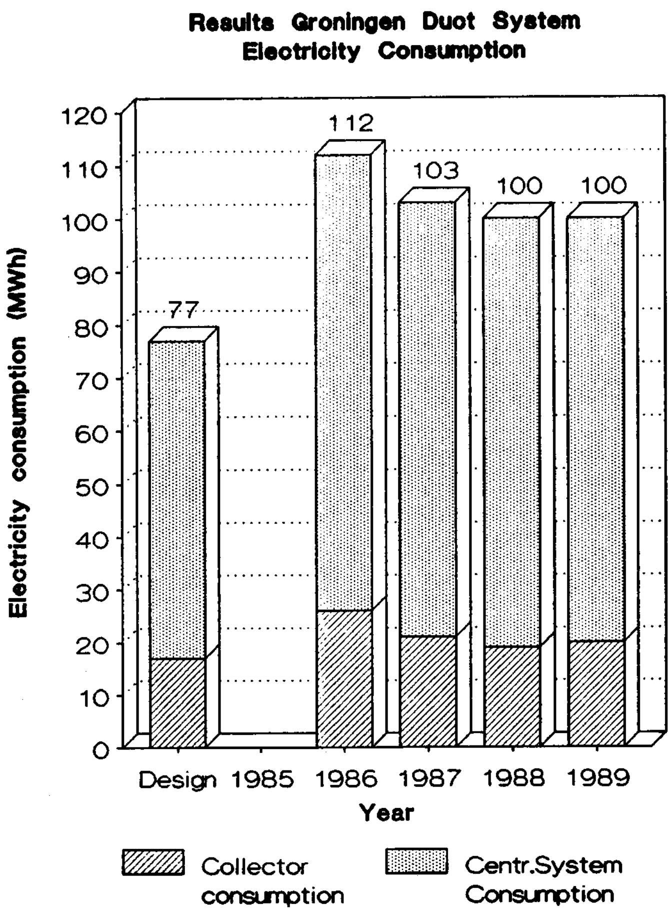


Figure 7: Electricity consumption for the Groningen system during five years of operation

### 3.4. Temperature in the seasonal heat store

In figure 8 the mean temperature in the seasonal heat store is shown for the five years of monitoring. During the second year there was a net temperature increase in the seasonal store from 32 to 36 °C. As already mentioned above, this was caused by the central control system of the system which did not function properly. The adaptation of the control system at the end of the second year resulted during the third year in a net temperature decrease in the seasonal store from 36 to 32 °C .
As can seen in this figure, after this period a more or less steady year-cycle has been reached. The minimum mean storage temperature is about 30 °C in the spring, while a maximum mean storage temperature of about 55 °C is reached by the end of the summer.

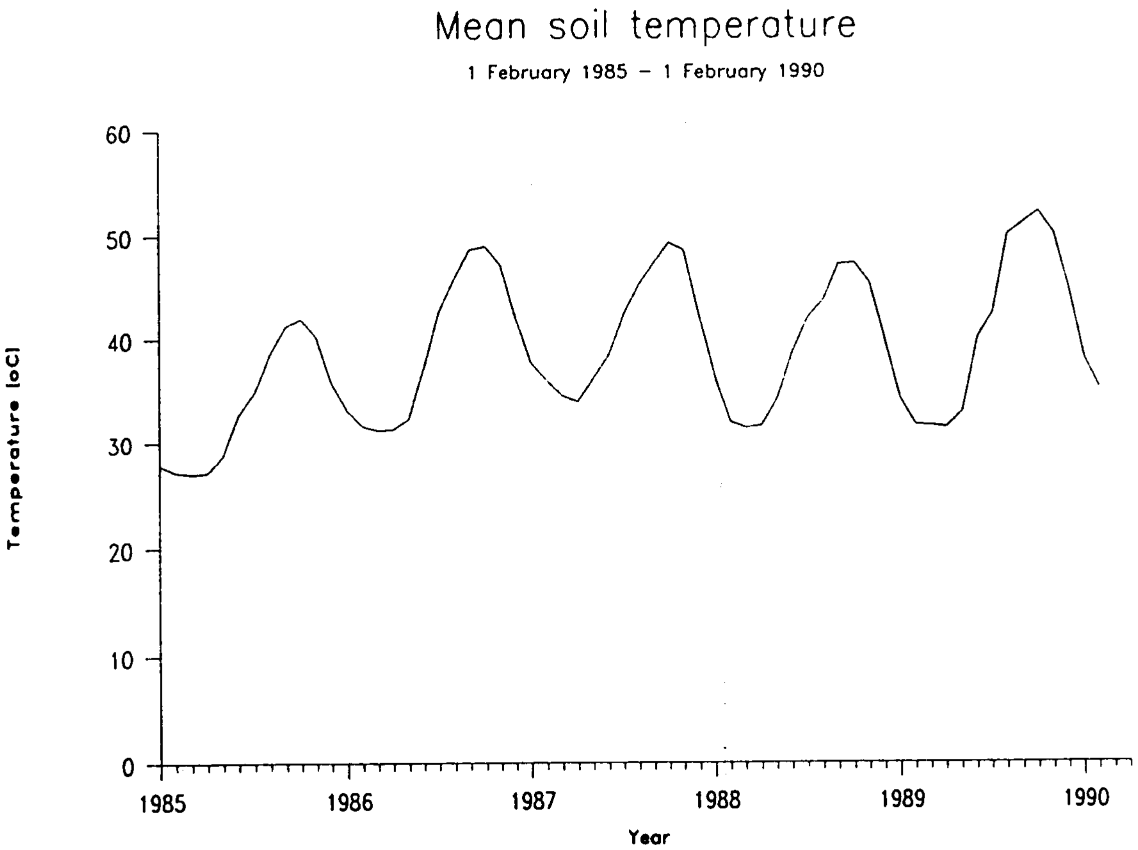


Figure 8: Mean soil temperature during five years of operation

## 4. Discussion of the results

Comparing the monitoring results for 1986 - in which the actual load was about the same as the one used in the design studies -with the performance as expected, it can be concluded that solar contribution of the system, i.e. the natural gas savings, are about 15% lower than expected. As already reported in ref [1] the main reasons herefor are:
- the lower performance of the solar collectors (-13%)
- the higher heat losses of the seasonal store (+60%)

The efficiency of the collector roofs during the five years of operation varies from 39.4 to 42.4%. The lower efficiency during the first year was caused by the fact that in the spring of that year part of the collector roofs were out of operation because of frost damage. According to the design 48% was expected: so the measured efficiency is about 13% lower. An additional study yielded the causes for the lower performance [4].

System performance during the last three years of operation is stable and mutual difference are mainly caused by differences in the heating load which is relatively low in comparison with the heating load used in the design calculations.

During the last three years the plant operated without any serious problems. Except for normal maintenance activities no special actions were needed.
No durability problems with components in the system were encounterd during this period and untill now no degration effects were found.

The electricity consumption of the plant after the second year is nearly constant at about 100,000 kWh per year, which is still higher than projected (77,000 kWh). This is mainly caused by electricity consumption of other apparatus (valves, control equipment and others) than by extra consumption of the pumps. In the design studies only energy consumption by pumps was included.

During the five years of monitoring on the Groningen plant a lot of experience was gained with the operation of the system. Because the Groningen project was the first CSHPSS in the Netherlands and included a lot of research aspects, it is likely that future CSHPSS in the Netherlands may have substantially lower costs.

## 5. References

[1] Wijsman, A.J.Th.M. and D.J. Kortschot,
Monitoring the Groningen solar energy system with seasonal heat storage in the soil - final report. TPD report no. 403.346, 1987.

[2] Havinga, J., Wijsman, A.J.Th.M. and D.J. Kortschot
Monitoring of the Groningen solar energy system with seasonal storage in the soil: Summary Monitoring results period 1987-1989. TPD report nr 714.005, April 1990.

[3] Wijsman, A.J.Th.M.
Oorzaken en maatregelen ter voorkoming van hogere warmteverliezen bij aquifers, TPD report no. 713.020, october 1988

[4] Wijsman, A.J.Th.M. and D.J. Kortschot
Research into the possible causes for the measured lower performance of the collector roofs in the Groningen system. TPD report no 603.004-I, january 1987.

Paper prepared for the workshop on
"Seasonal Thermal Energy Storage in Duct Systems"
Freising, FRG, 19-20 June 1990
Ir. J. Havinga, June 12, 1990