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Simple techniques for reduction of energy consumption peaks in greenhouses

Udjævning af energiforbruget ved hjælp af enkle midler

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Summary

The experiments were started to investigate difficulties in energy supply, when large areas with greenhouses, in the vicinity of Odense, were connected to district heating. This publication presents the results of experiments which demonstrate that by applying a simple technique energy consumption peaks occurring at dawn and dusk can be avoided. In these experiments the environmental control is based upon a traditional (analog) control system. It concludes that peaks can be avoided by applying a strategy based upon high night and low day minimum setpoints (14°/22°C) for room temperature combined with a reduced opening speed (140 minutes from closed to open) of the mixing valves.

As the demand for high effect is reduced, the greenhouse area may be increased without changing the dimension of the heat supply mains to the nurseries.

With this strategy a reduction in energy consumption of approx. 5 per cent was found, Whether this technique can be approved in greenhouse environmental control, depends on the plant reaction to the resulting environment.

Key words: Greenhouse heating, district heating, pot plants.

Resumé

Denne serie af undersøgelser blev begyndt for at finde en fremgangsmåde, hvorved man undgår nogle af de vanskeligheder med varmeforsyningen, der opstår, når store arealer med væksthuse tilsluttes fjernvarme.

Resultaterne viser, at man ved hjælp af enkle midler kan undgå stærke stigninger i energiforbruget, de såkaldte energispidser, om morgenen og aftenen.

Undersøgelserne tager deres udgangspunkt i traditionelt (analogt) klimareguleringsudstyr magen til det, som findes i store dele af danske erhvervsgartnerier.

Et klimaprogram baseret på rumtemperatur

setpunkter på 14°C dag og 22°C nat, kombineret med et »arbejdstid-pause« relæ, der nedsætter motorventilens åbningshastighed (fra 4 til 140 minutter fra lukket til åben), er tilstrækkeligt til at undgå energispidserne om morgenen og aftenen.

Desuden er der i denne forsøgsserie opnået energibesparelser på ca. 5 pct.

Forsøget viser desuden, at behovet for høje effekter er mindre. Dette betyder, at et større væksthusareal kan tilsluttes ved samme mængdebegrænsning.

Om dette temperaturprogram kan accepteres i gartnerierne, er dog først og fremmest afhængig af, at kulturtiden ikke forsinkes, eller at kvaliteten ikke forringes.

Resultaterne af en biologisk undersøgelse vil blive behandlet i en senere beretning.

Nøgleord: Væksthusopvarmning, fjernvarme, potteplanter.

Introduction

On initiative of the Danish Ministry of Energy a working group was formed to look into some of the difficulties which arise when heat for large numbers of greenhouse nurseries is supplied by district heating. It is normally believed that the energy for heating greenhouses can be easily supplied by district heating or waste heat from power production, but one should be well aware of the fact that the combination of large areas of greenhouses and district heating raises some unexpected and unwanted side effects.

The simultaneous increase in energy consumption at sunrise is a result of identical heating strategy and control equipment in nurseries (Fig. 1).

As long as heat is supplied by boilers on the nursery site, it is a local problem.

But when the supply pattern is multiplied by a great number of nurseries it will result in unstability and fluctuations in the heat supply within a very short time.

The energy reserve present in the heat supply pipelines is far from sufficient to provide the amount of heat, which is necessary to raise the room temperature from night setting to day temperature and overcome the increase in heat loss when thermal screens are drawn back.

This sudden increase in heat demand is not a gradual rise of the energy consumption but a peak, which occurs for a few hours (2). As soon as the heat supply is adjusted to the new level, a persistent decrease in heat consumption follows, due to the effect of daylight and eventually sunshine (Fig. 1). In the afternoon a decrease in outside temperature and irradiation results in an increased heat consumption. At sunset the thermal screens are drawn, and traditionally the room temperature set point is lowered which is followed by a sudden decrease in heat demand. This also results in a heat consumption peak (1).

The peaks present difficulties for the powerplant, as a very quick response is required if the heat demand is to be met.

It is therefore possible that heat supply to greenhouse nurseries will be restricted. Restrictions which would have an effect on room temperature and consequently on plant growth.

If the use of district heating for greenhouse nurseries is to have a future in this country it is necessary to find ways in which to alter the heat demand without detriment to plant production.

It is the aim of this paper to show that an adequate adjustment of heat peaks can be obtained by applying a simple temperature control strategy and traditional environmental control equipment modified with a device which reduces opening speed of the mixing valves.

The effect on plant growth will be reported in another publication (3).

Materials and methods

Greenhouses

The experiment was carried out at the Department of Horticultural Engineering, Årslev, 12 km south of Odense.

Two identical east-west orientated greenhouses clad with single glass and 8 × 21.5 m were used.

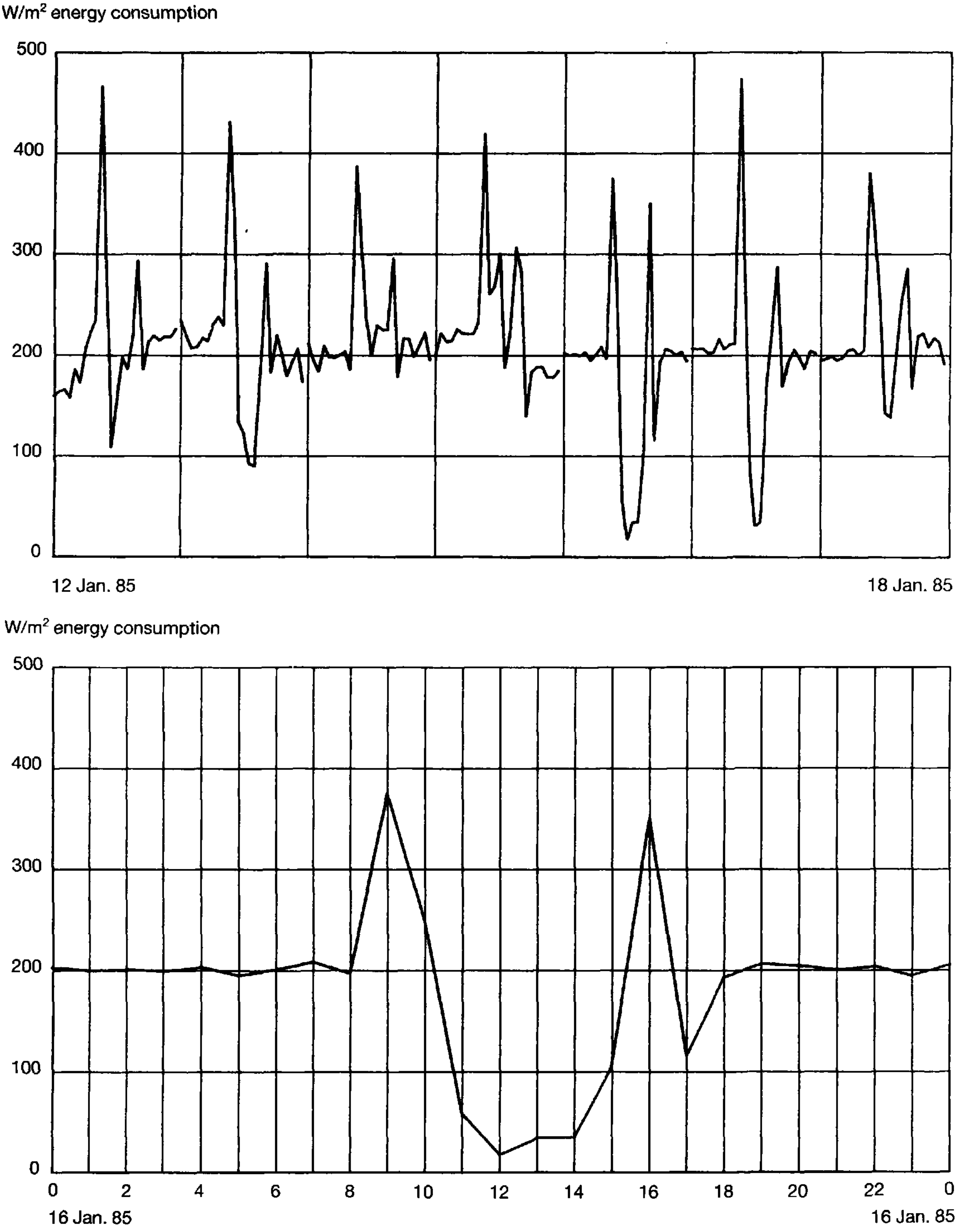

Fig. 1. Greenhouse clad with single glass.
Equipped with thermal screens and shading screens. Room temperature set points: 18°/18°C day/night.

Heating system

The heating system is designed to meet a temperature difference of 30°C between inside and outside air temperature. It consists of two separately operated systems, the top and wall heating and the floor heating system with priority on the floor heating system. The designed heat output is 83 kW. The floor heating system consists of 12 pipes, 0.5 m above the ground level.

Environmental control

Environmental control is based upon traditional (analog) control equipment (DGT Lumix Combi LC 21), which is identical to the equipment used in many commercial nurseries.

Aspirated screen

Dry and wet bulb temperatures for room temperature and air humidity are measured by pt 100 thermosensors placed in an aspirated screen at an air velocity of 1 m/sec.

The aspirated screen is placed 0.3 m above the average plant canopy.

The sensors for the thermostat and the hygrostat are placed in the screen.

Screens

The greenhouses are equipped with top going shading screens, which reduce irradiation with 55 per cent (Louis Svensson No. 15). The screens are also applied during the night as thermal screens.

Benches

Each greenhouse is equipped with four movable benches, 1.6 × 18 m. The benches are equipped with a capillary irrigation system. During the experiment five different types of potplants were grown on the benches.

The irrigation is controlled by an evaporimeter, which supplies 0.8 mm of water, whenever 1 mm is evaporated. The intervals vary from once a week in winter to daily in summer.

Data sampling

The environmental factors are recorded every ten minutes and hourly mean values are stored for analysing.

For some data separate values for day and night as well as diurnal averages are presented. In these cases the separation between night and day is the full hour at sunset or sunrise in which screens are drawn or drawn back.

Energy consumption

The total water flow is measured by a magnetic flowmeter and the total energy consumption calculated from the temperature of the water inlet and water outlet.

Experiment

Room temperature, minimum setpoint day/night:

1. 14°/22°C,
   reduced opening speed (140 minutes from closed to open) of mixing valves.
2. 18°/18°C,
   normal opening speed (4 minutes from closed to open) of mixing valves.

Ventilation at 28°C room temperature.

Relative air humidity control at 92 p.c. relative humidity (RH).

Shading screens applied at an irradiation over 200 W/m^2.

Shading screens applied for insulation at night at an irradiation below 5 W/m^2.

Results

Preliminary investigations

To find the most suitable means for adjusting heat peaks, preliminary experiments were carried out during the summer of 1987. Some simple techniques were tested in empty greenhouses over two or three week intervals, and the effect on energy consumption and room temperature studied.

One way is to supply hot water at a constant pipe temperature, thereby disregarding control of room temperature. The heat supply was cut off whenever room temperature rose above the maximum setpoint for room temperature of 28°C.

This method is easy to apply, but the pipe temperature has to be readjusted approx. once a week, in accordance with the average room temperature desired and the time of the year. It soon showed that morning peaks could be avoided by building up a temperature reserve in the greenhouse air of 6° – 9°C above the daytime room temperature set point. The evening peaks could be avoided by a reduction of the opening speed (from 4 to 140 minutes from closed to open) of the mixing valves.

The combination of the two methods gave an acceptable technical solution.

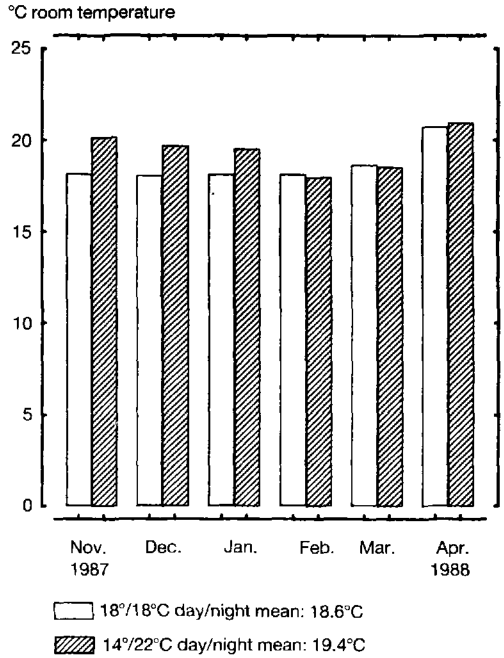

Fig. 2.1 Traditional environmental control compared with high room temperature and reduced opening speed of valve.

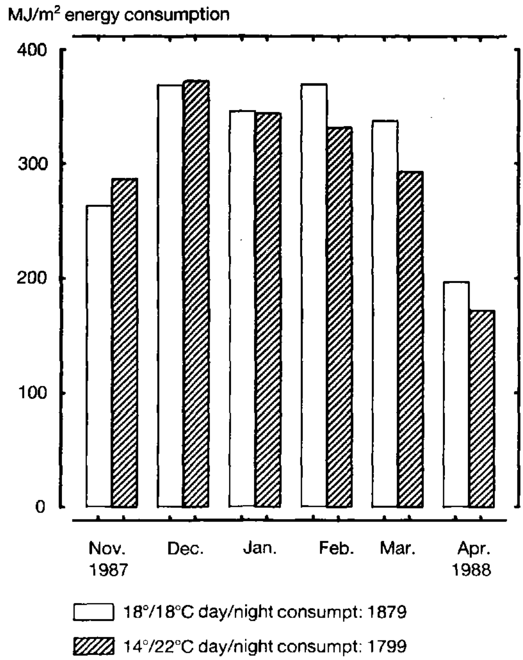

Fig. 3.1. Traditional environmental control compared with high night room temperature and reduced opening speed of valve.

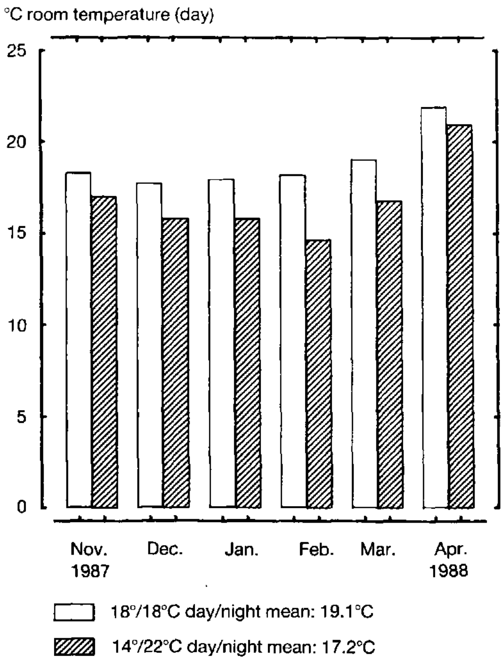

Fig. 2.2 Same treatment as in Fig. 2.1.

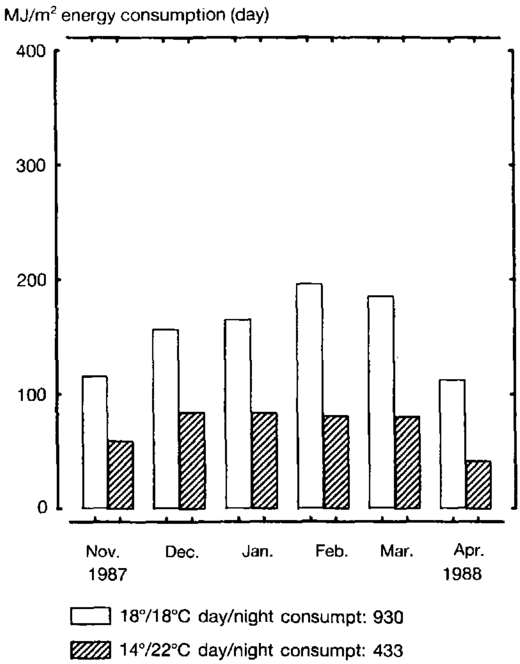

Fig. 3.2 Same treatment as in Fig. 3.1.

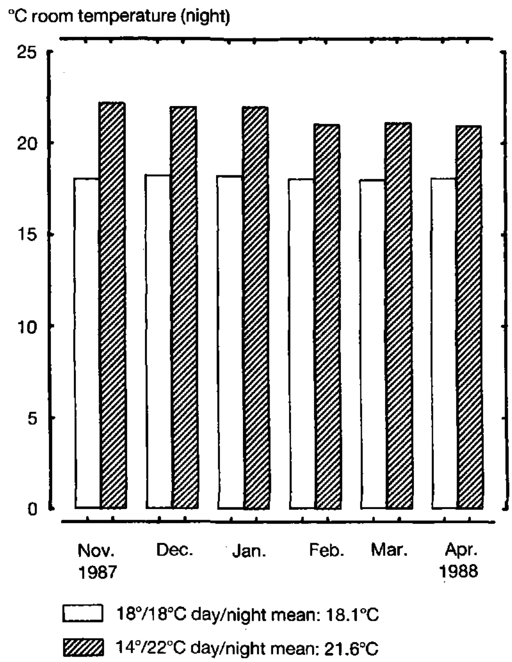

Fig. 2.3. Same treatment as in Fig. 2.1.

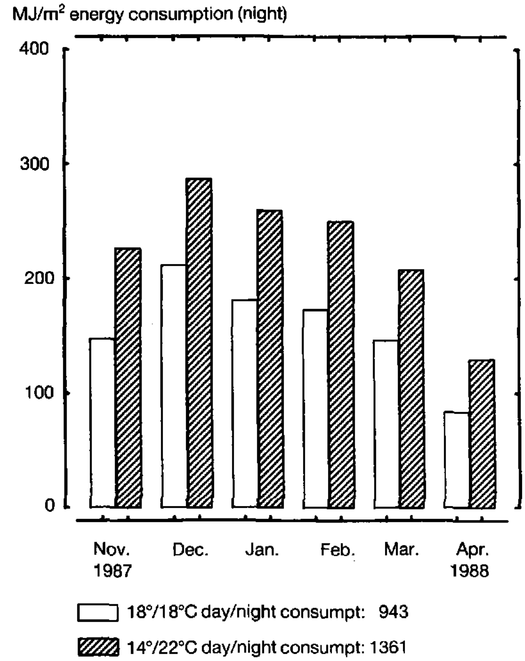

Fig. 3.3. Same treatment as in Fig. 3.1.

On the other hand room temperatures were obtained which might not be acceptable for plant growth.

However, experiments with plant growth have shown that the combination of high night temperatures and low day temperatures in some cases had a beneficial effect on plant growth and plant development (5).

Main experiment

Therefore we choose an environmental control strategy, with a minimum room temperature set point of 14°C during the day and 22°C at night for the biological experiment.

Room temperature

The average room temperature was 19.4°C in the 14°/22°C treatment and 18.6°C in 18°/18°C treatment. Still the higher average temperature has not resulted in an increase in energy consumption.

The histograms over average, day and night-temperatures show (Figs 2.1, 2.2, 2.3) that night temperatures are kept close to the thermostat setpoints and so show a distinct difference between the two treatments during the whole experimental period.

The time of the year is important for day temperatures. The difference between the two treatments becomes less and less pronounced when daylength increases and the effect of irradiation overrules the room temperature setpoints (Fig. 2.2).

Two typical profiles of room temperatures, one from a day with low irradiation and one from a day with high irradiation, are shown in Figs 2.4 and 2.5.

On dull days (Fig. 2.4) the room temperatures follow very closely the change in setpoints. In those cases there is a distinct difference between the two treatments.

When high irradiation prevails (Fig. 2.5), the room temperature in both treatments reaches maximum at the same time. But in the early morning hours, when irradiation is less dominant, the room temperature is allowed to drop to minimum setpoint (14°C) in the treatment with high night temperature.

Energy consumption

In December and January, where energy consumption is equal in both treatments (Fig. 3.1) we find a higher room temperature (Fig. 2.1) in 14°/22°C.

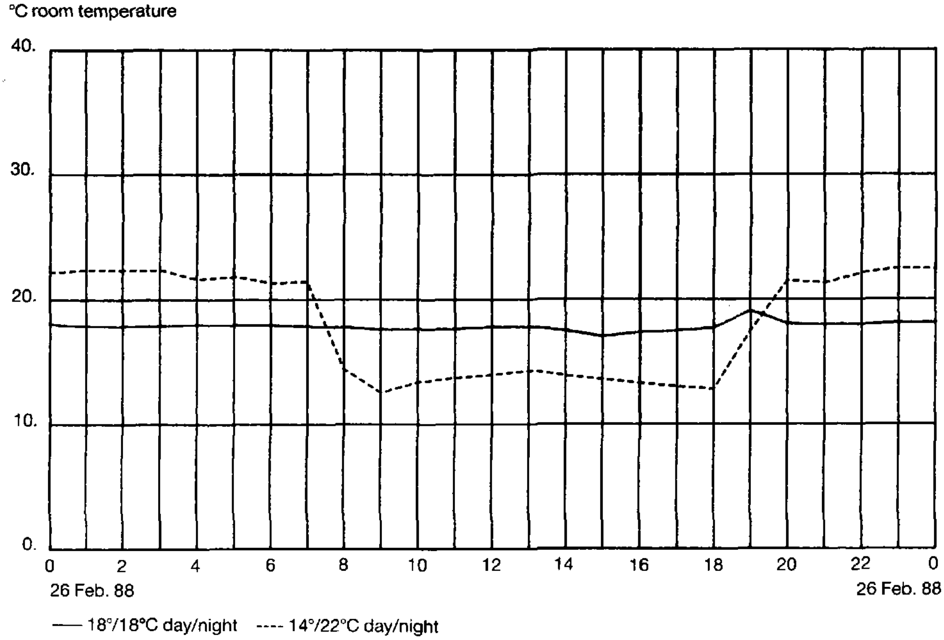

Fig. 2.4. Progress of room temperature on a day with low irradiation. Same treatment as in Fig. 2.1.

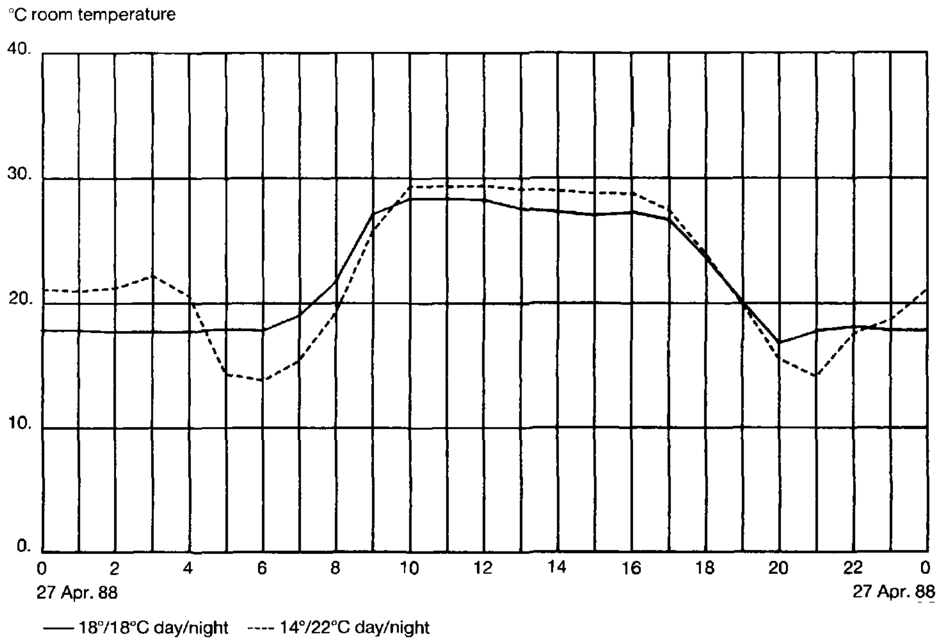

Fig. 2.5. Progress of room temperature on a day with high irradiation. Same treatment as in Fig. 2.1.

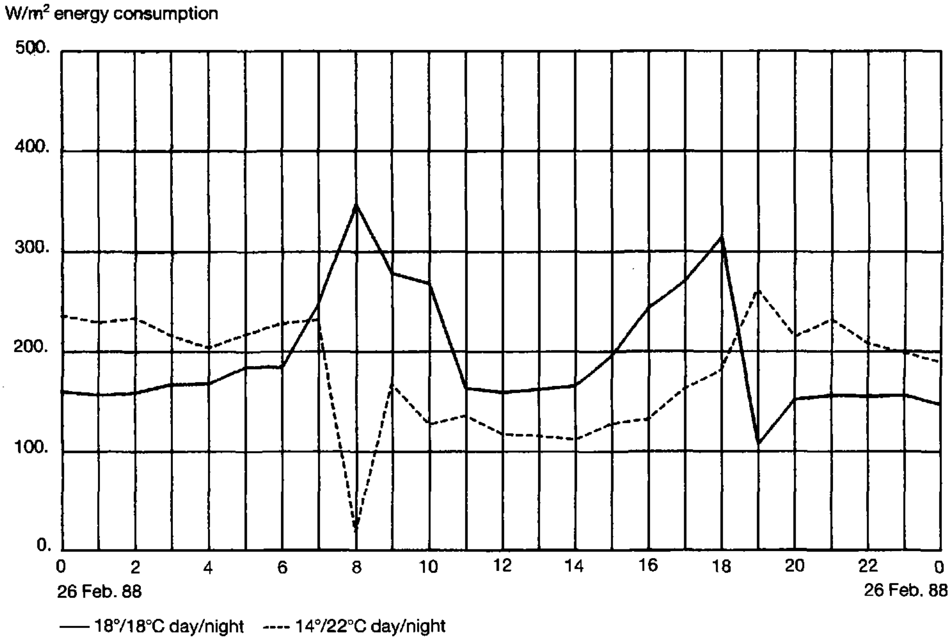

Fig. 3.4. Progress of energy consumption on a day with low irradiation. Same treatment as in Fig. 3.1.

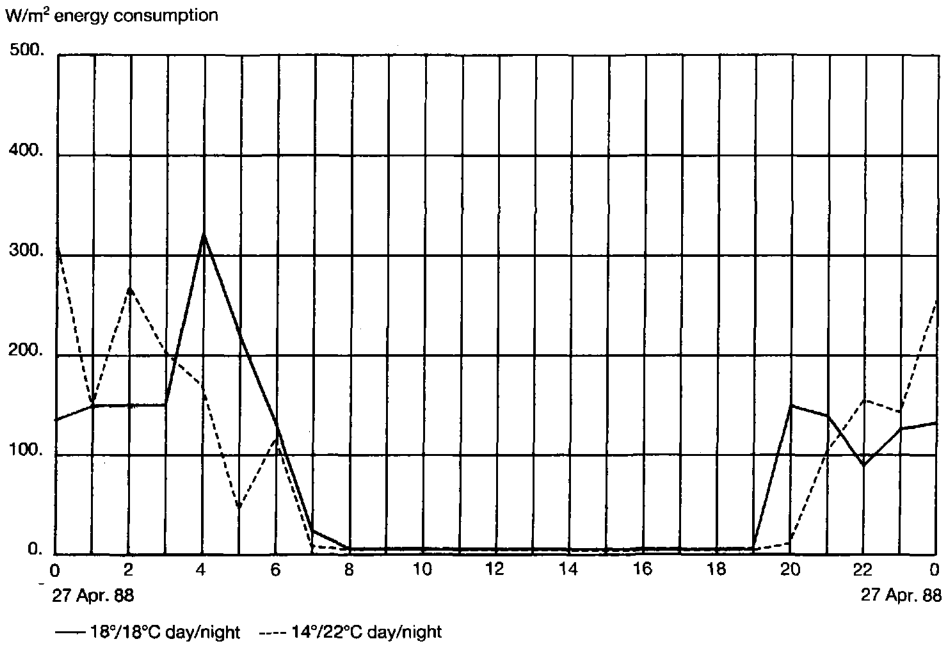

Fig. 3.5. Progress of energy consumption on a day with high irradiation. Same treatment as in Fig. 3.1.

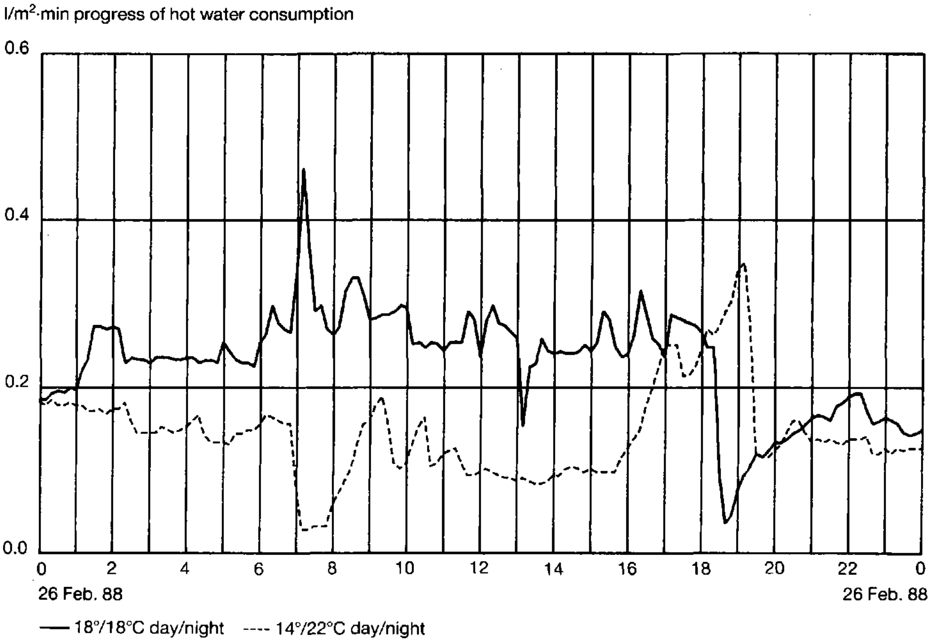

Fig. 4.1. Traditional environmental control compared with high night room temperature and reduced opening speed of valve.
A day with low irradiation.

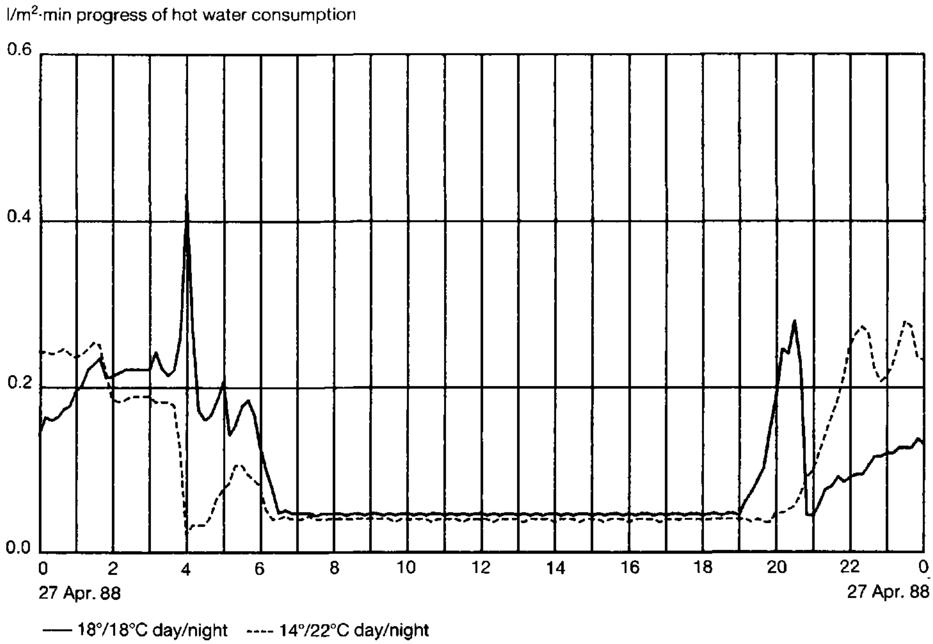

Fig. 4.2. Traditional environmental control compared with high night room temperature and reduced opening speed of valve.
A day with high irradiation.

The higher energy consumption in 18°/18°C in daytime is mainly due to energy peaks in the morning and in the evening hours.

Two typical energy profiles, one from a day with low irradiation, one from a day with high irradiation are shown in Figs 3.4 and 3.5. For both days the morning peaks in 18°/18°C can be clearly recognized.

Simultaneously, there is a drop in 14°/22°C, in the energy consumption, due to the energy reserve built up in the greenhouse air during the night.

Depending on the energy demand, the energy consumptions in the two treatments settle at levels, which are different when irradiation is low but identical when irradiation is high.

Hot water consumption

For district heating, the hot water consumption is of greater interest than energy consumption. The dynamic progress of the hot water consumption gives a more realistic picture of the actual heat transport.

For the same two days as in the previous sections the hot water consumption in the two treatments are shown (Figs 4.1 and 4.2).

The curves are based on 10 minute readings and therefore show a more detailed picture of the progress than the previous curves and the fluctuations in the hot water consumption are more pronounced than can be shown in hourly values.

Discussion and conclusion

The investigations have proved that morning and evening peaks in energy consumption can be avoided. A satisfying result can be obtained also when the environmental control is based on traditional (analog) equipment with minor and cheap modifications.

The morning peaks can be adjusted by a temperature buffer in the greenhouse air in this experiment of 8°C over the minimum day time setpoint.

The evening peak can be counteracted by a device which changes the opening time of the mixing valves. In this experiment from 4 to 140 minutes from closed to open.

Over the whole experimental period we found a reduction in the energy consumption of 5 per cent. As there is a tendency that the energy saving increases as the daylength increases the effect over a whole year may therefore be even better.

When applying high night temperatures the demand for peak loads is reduced. This may indicate that the heated area for the nurseries can be extended, without increasing the dimension of the heat supply mains.

In traditional greenhouse environmental control, room temperature has the highest priority. In this experiment we changed the priority from room temperature towards energy consumption, reduced the heat peak loads and even obtained a minor energy saving.

Whenever we alter the environmental control strategy, it will result in an effect on the room temperature and hence on plant growth and development.

Whether high night temperature can be approved in greenhouses depends on its effect on plant growth and development.

However, environmental control based on analog equipment as used in this experiment has its drawbacks. The main objection is that it works both when wanted, but also when not wanted.

When in winter a sudden change in weather conditions calls for extra heat, the reduction of the opening speed of the valves will restrict the amount of heat which is instantly available and room temperatures lower than can be tolerated may be the result. This has not been the case in this experiment, due to the very mild winter in 1987–88.

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