Bilaga 4

Field Experiences in three supermarkets in Sweden.

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1.Introduction

The replacement of CFC and HCFC refrigerants and the effective use of energy have influenced the refrigeration systems in supermarkets in Sweden. New solutions with energy efficient equipment and completely indirect refrigeration systems have been developed to decrease the energy use and to minimise the refrigerant charge. The decision on the appropriate refrigeration system design for a supermarket is quite complicated when several options are available at the same time. A computer program that calculates the energy use in a supermarket with different innovative solutions can be a good tool when designing a refrigeration system. In January 1998 The Department of Energy Technology, Division of Applied Thermodynamics and Refrigeration started a project in co-operation with four companies and the Swedish National Energy Administration. The goal of the project is a user-friendly computer model able to deal with technical solutions, investment economics and environmental impact for supermarket refrigeration systems. To validate the computer program it is necessary to compare the numerical results with field experience. Measurements of different parameters such as temperatures, relative humidity and compressor power started in three supermarkets last year and the results from these measurements will be presented in this paper.

2.Description of Method

Field measurements in three supermarkets in Sweden have been carried out to facilitate validation of the computer model, currently under development, that calculates the energy use in a supermarket. The measurements have been divided in three different periods to reduce the amount of measurements and to cover the most important parameters in supermarkets. In Period 1 (during one year), measurements have been done on the outdoor temperature, indoor temperature, air relative humidity, brine temperature before and after the chiller and the compressor power of the medium temperature system. In Period 2 (during one week) measurements have been done on the air temperature in the inlet, middle and outlet of a display case and the compressor power of the low temperature system. In Period 3 (during one hour) measurements have been done on the air temperature in the inlet, middle and outlet of a display case.

In July 1999 measurements for Period 1 in two supermarkets, Gröna Konsum in Hjo and Prix in Sala started and in October 1999 measurements in the supermarkets Gröna Konsum in Farsta Centrum started. The measurements for Period 2 have been implemented during the weeks 20, 21, 27 and 29 in Prix Sala and during 17 May, 15 June, 19 July for Period 3

The system design in Sala is a cascade system (figure 1). The refrigeration system has two different temperature levels utilising secondary loops. The brine in the intermediate temperature system cools the display cases and the condenser of the chiller for the low temperature system. In this supermarket there is a heat recovery system.

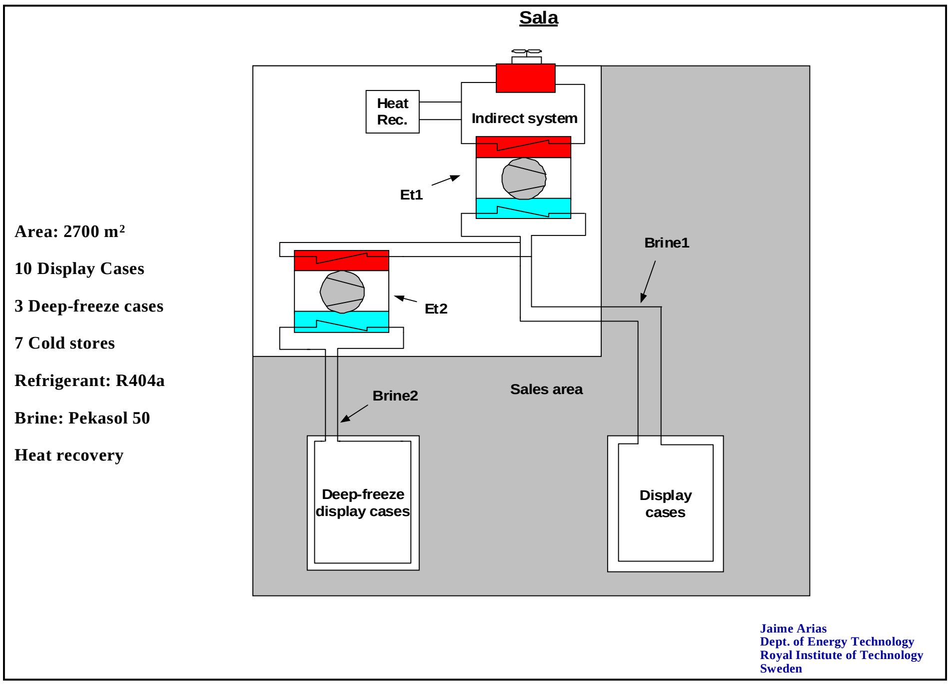

Figure 1. Refrigeration system design in Sala

The system design in the supermarket Gröna Konsum in Hjo is also a cascade system (figure 2). In this case there is a refrigeration system in every deep-freeze cabinet. The condensers for those machines and the display cases are cooled with a chiller situated in the machine room. In this supermarket there is also a heat recovery system.

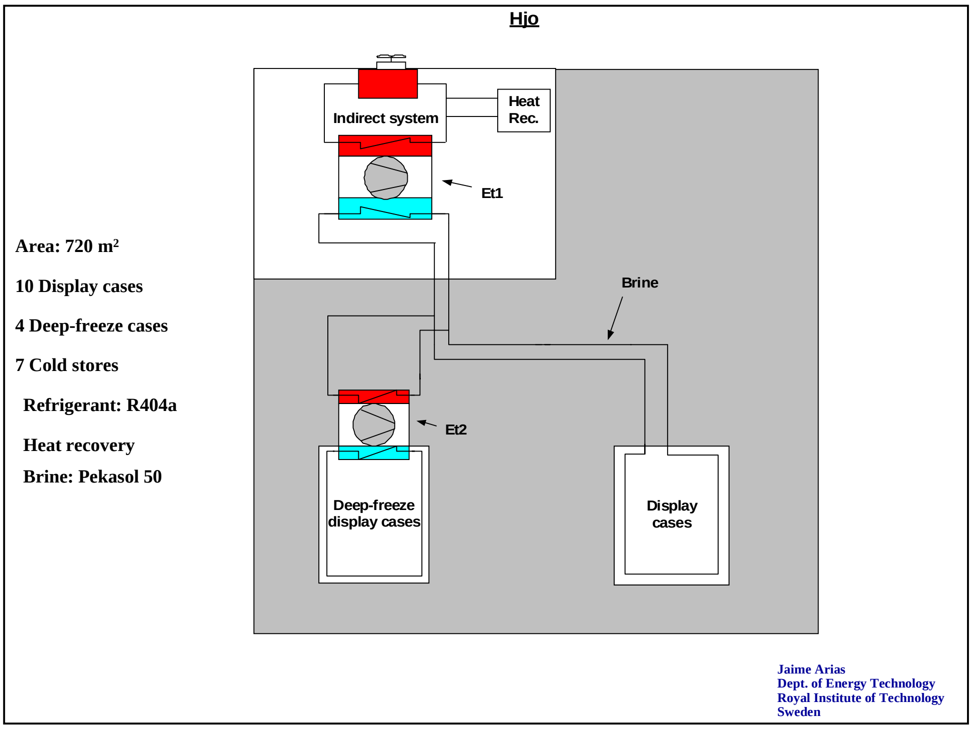

Figure 2. Refrigeration system design in Hjo

The system design in supermarket Gröna Konsum in Farsta Centrum has one chiller that cools the condensers of the refrigeration equipment in every deep-freeze cabinet, display case and cool storage via a brine loop. The supermarket is divided in two different zones, a cold zone for products requiring refrigeration and where all the display cases are located, and a warm zone for non refrigerated products. The refrigeration system has 46 compressors distributed in the cold zone and the supermarket has no heat recovery system.

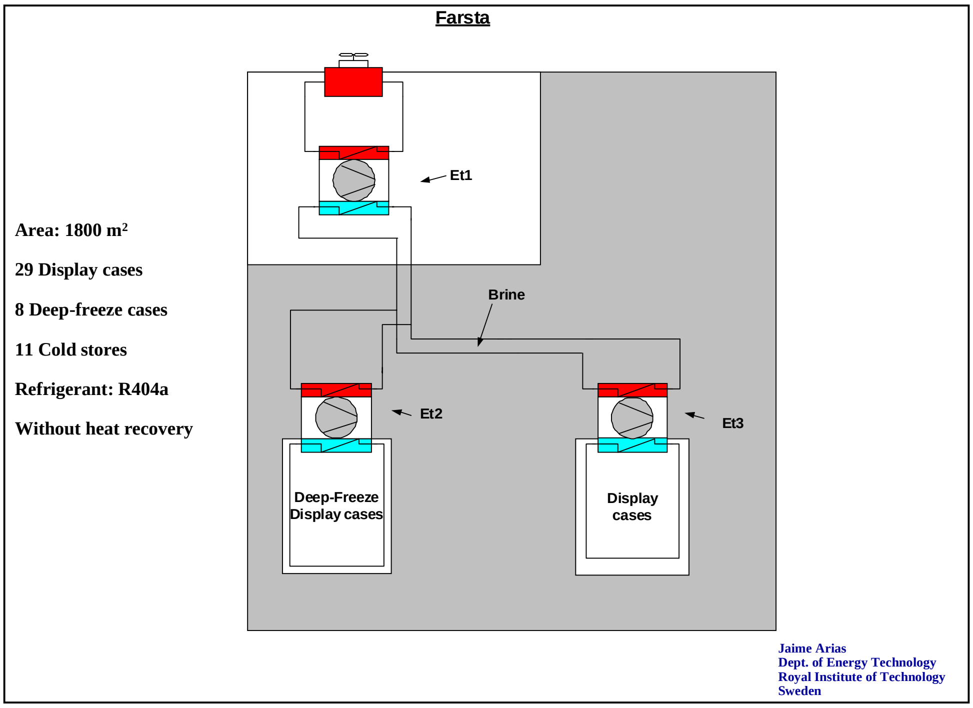

Figure 3. Refrigeration system design in Farsta Centrum.

The temperatures and air humidity have been measured with Tinytag-loggers from Intab, and the compressor power with Energy-logger Elit 4 from Pacific Science & Technology. The temperatures and relative humidity have been measured momentary and stored every hour. The compressor power is also stored every hour but in this case the value represents the mean power during the last hour.

3.Results

The results from the measurements confirm the importance and the influence of the outdoor temperature, indoor temperature and relative humidity of air on the compressor power. Figure 4 shows the average values during one day for compressor power, indoor temperature and outdoor temperature in the course of one year at Gröna Konsum in Hjo. The variations of the compressor power follow the variations of outdoor temperature for the whole year including the heating season that starts in the middle of October and ends in the middle of March. In figure 1 it is also possible to see the influence of the indoor temperature on the compressor power. During the period 15-Dec. to 4-Jan. a malfunctioning fan resulted in low air temperatures in the supermarket, which in turn strongly influenced the compressor power.

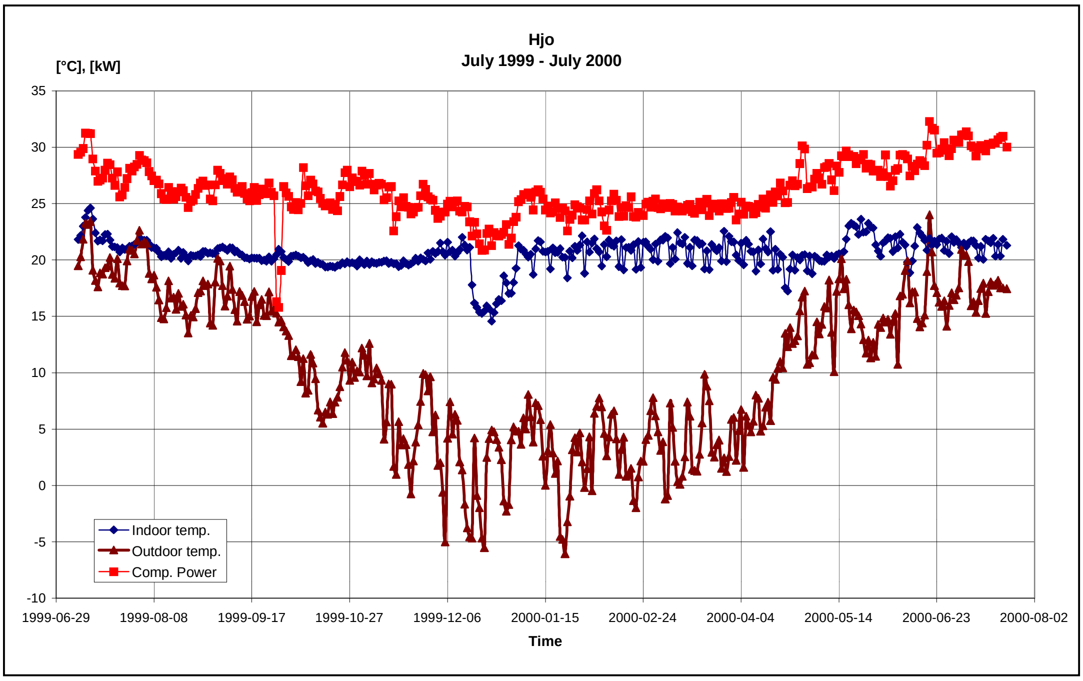

Figure 4. Indoor-temperature, outdoor-temperature and compressor power in Hjo

Figure 5, which presents the measurements in Farsta Centrum of indoor temperature in the cold and warm zones, outdoor temperature and compressor power for the chiller, corroborates the assertion about the influence of those temperatures on the compressor power. The difference between the temperatures in the cold and warm zones is about 2°C.

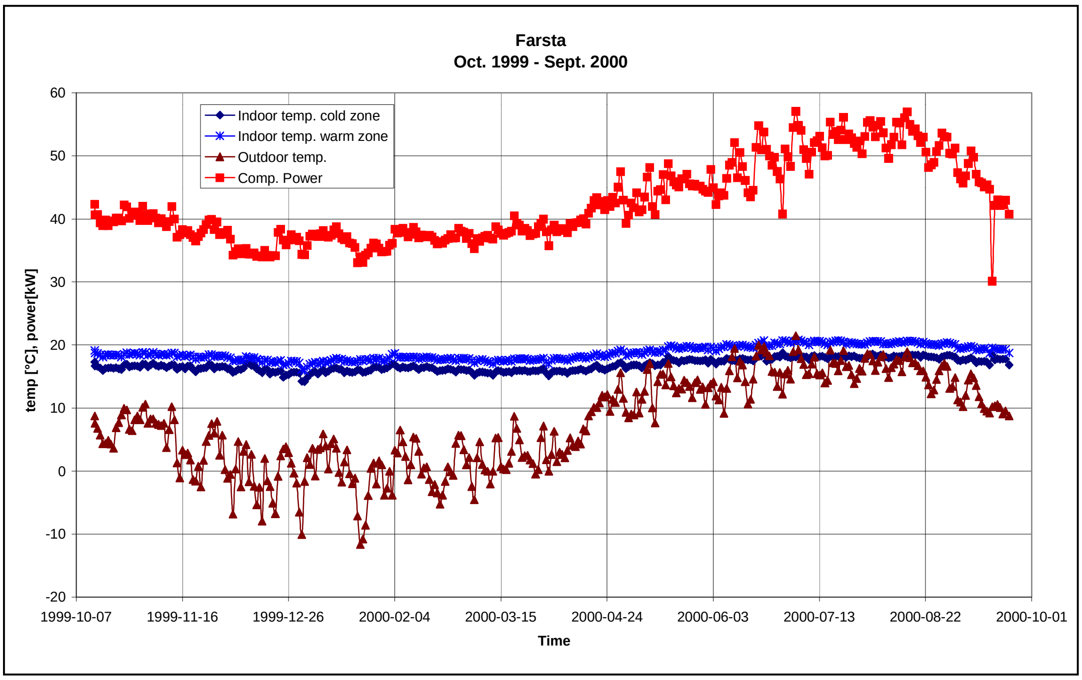

Figure 5. Indoor temperature, outdoor temperature and compressor power in Farsta

Figure 6 presents the outdoor temperature, indoor temperature, relative humidity, brine temperatures before and after chiller and the compressor power during two days. The 14th of July was a rainy and warm day in Sala that affected the moisture in the supermarket and caused the highest compressor power during the summer of 1999.

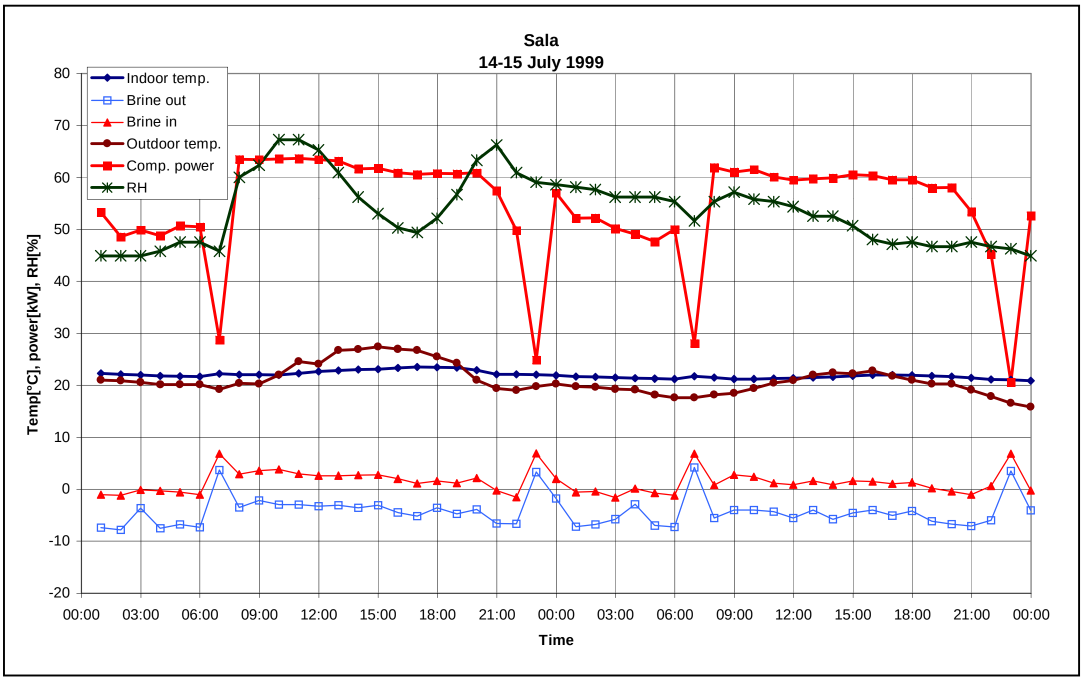

Figure 6. Temperatures, Moisture and Compressor Power in Sala

The variations of temperatures, moisture and compressor power during the week 32 in August 1999 in Sala are shown in figure 7. In both figure 6 and 7 it is also possible to see the influence of night covering of display cases and defrosting on the compressor Power.

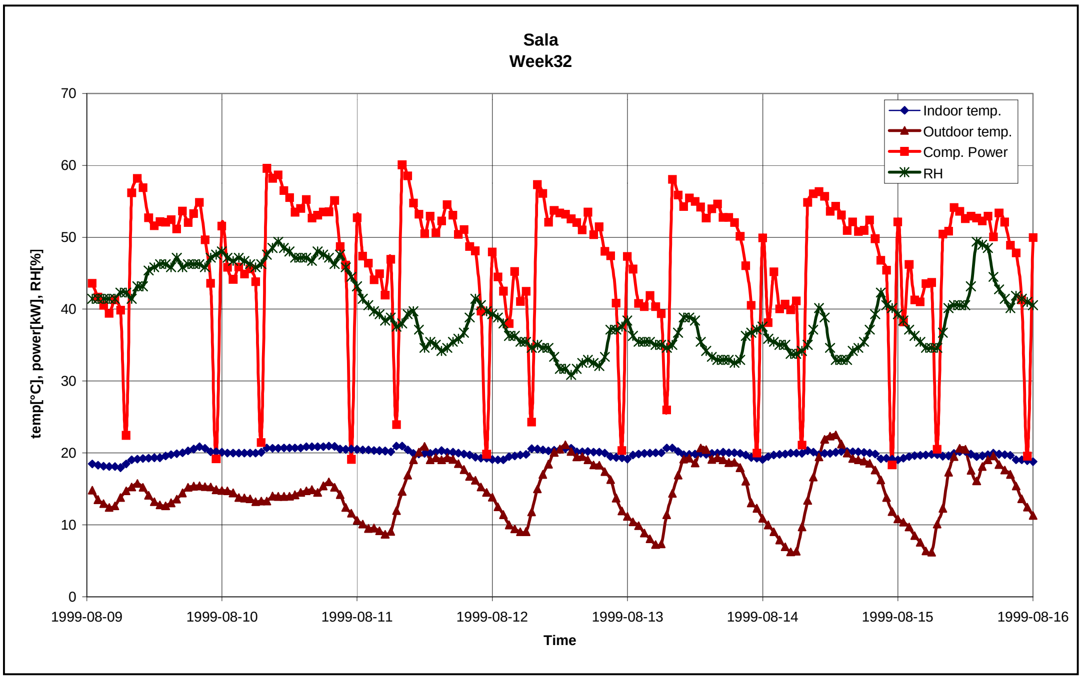

Figure 7. Temperatures, relative humidity and compressor power in Sala

The cabinets are defrosted with electrical heaters that decrease the compressor power during the defrosting but increase the compressor power after defrosting. The compressor power is reduced to between 10 and 20 % by night covering of the cabinets. The covering occurs automatically when the supermarket closes at 21.00 and ends at 8.00 in the morning. However the positive effect on energy saving of night covering is necessary to improve the quality of the curtains. More than 30 % of the cabinets night covering in Sala are out of operation.

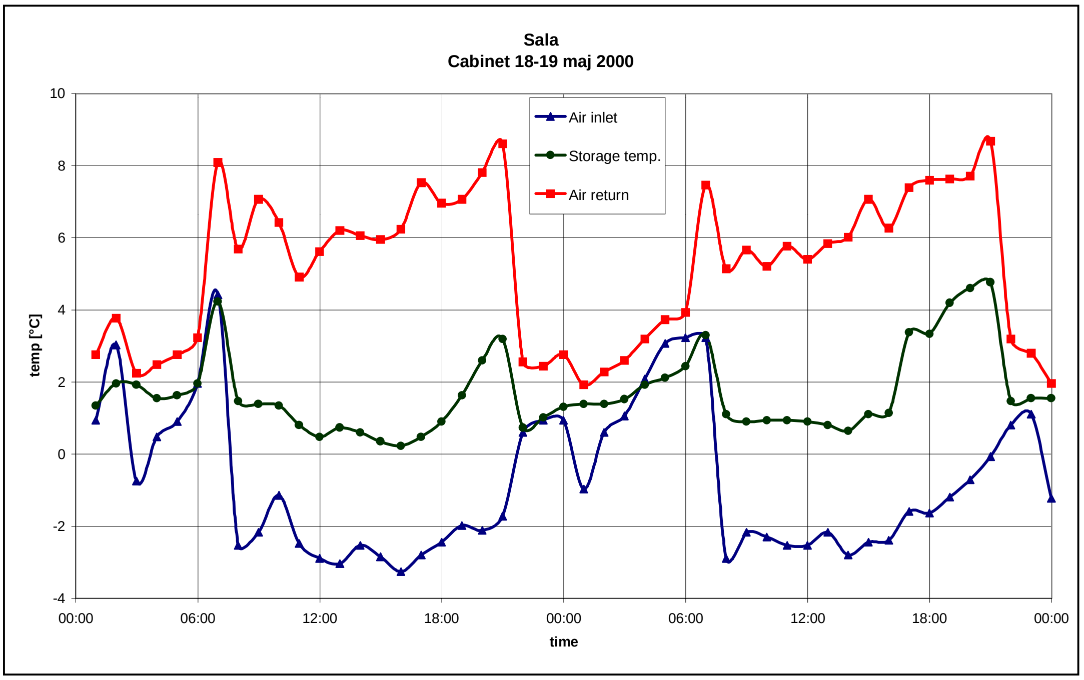

Figure 8. Temperatures in the cabinet in Sala

The measurements in the cabinet in Sala confirm the influence of night covering on temperatures in the display cases and on the compressor power. In figure 8, the air inlet temperature, average temperature and air return temperature of a display case, are presented. The heat extraction rate, according to the manufactures technical data for climate class 25°C/60%RH, is 9,0 kW, the storage temperature is +1°C, the air inlet is –2°C and the air return is +5°C. During the period when the supermarket is open, the variation of temperatures agree with the cabinets technical data. When the cabinet is covered the air inlet temperature and the air return temperature converge toward the storage temperature.

The measurements in the cabinet during Period 3 (one hour), the 17th of May 2000 are presented in figure 9 and corroborate the technical data of the display case. The temperatures have been measured momentary and stored every 15 second. In the diagram it is also possible to see the influence of customers and employees on the storage temperature and air return temperature when they are shopping, the influence in air inlet temperature is insignificant.

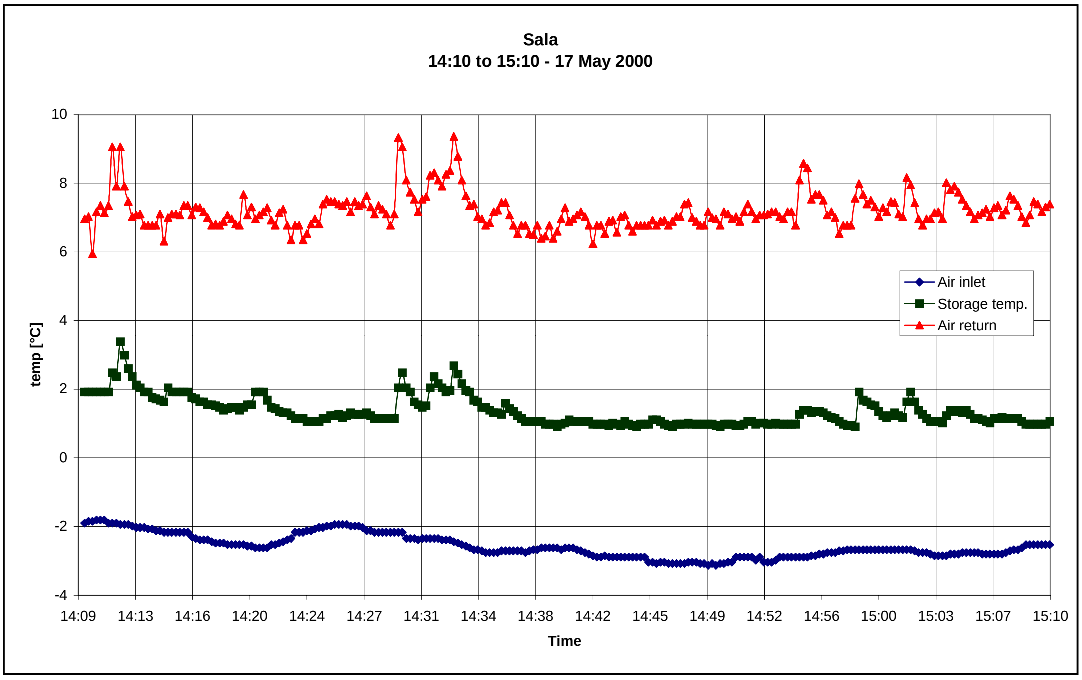

Figure 9. Measurements during period three in the cabinet in Sala.

A high outdoor temperature and relative humidity increase the compressor power and the refrigeration capacity. The influence of high compressor power in air temperatures in the cabinet can be seen in figure 10 when temperatures, moisture and compressor power are presented during two days in June. The compressor works at full speed and cannot support the air inlet temperature in the display cases below –2°C. The storage temperature in the cabinet also increased to a temperature around 3°C.

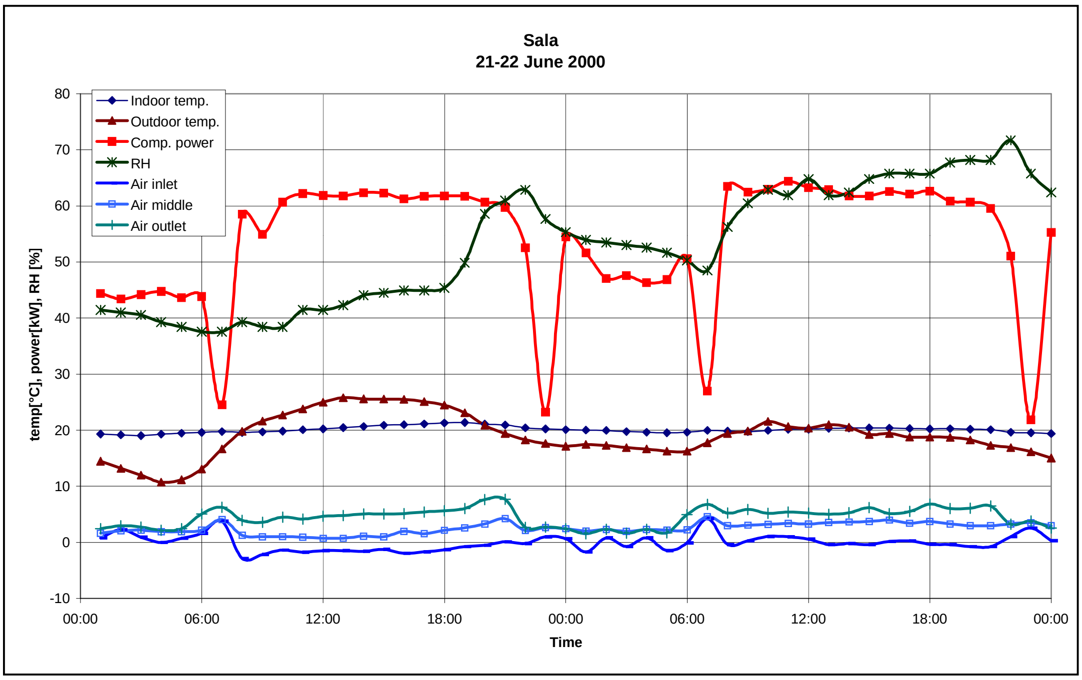

Figure 10. Temperatures, moisture and compressor power during two days in Sala.

Another parameter to take into consideration is the humidity ratio. The variation of humidity ratio in Sala between July 1999 and July 2000 is shown in figure 11. The low values during the winter period occur in the three supermarkets and it can produce a reduction of weight in fruits, vegetables and other products. The magnitude of the weight loses depends on the time that the products are in the supermarket.

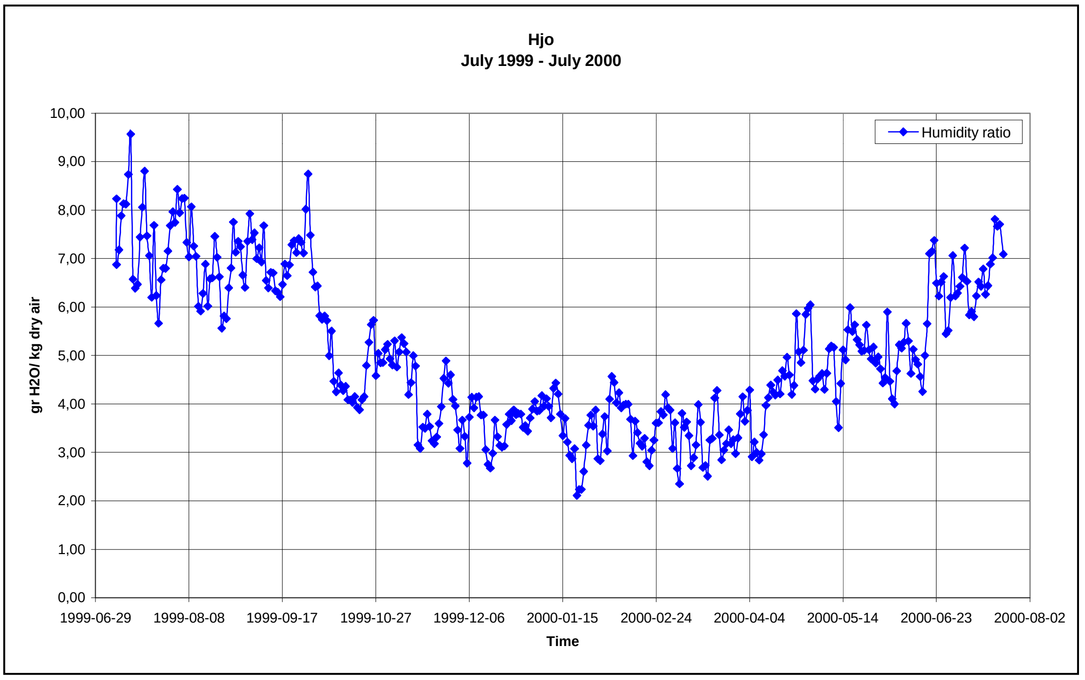

Figure 11. Humidity ratio in Hjo.

The difference of the humidity ratio between cool and warm zones in Farsta Centrum is shown in figure 12 and are minimal. The average of the humidity ratio during the winter are about 3,5 [gram H_2O/ kg. dry air], as in Hjo. During summer there are some days over 9 [gram H_2O/ kg. dry air].

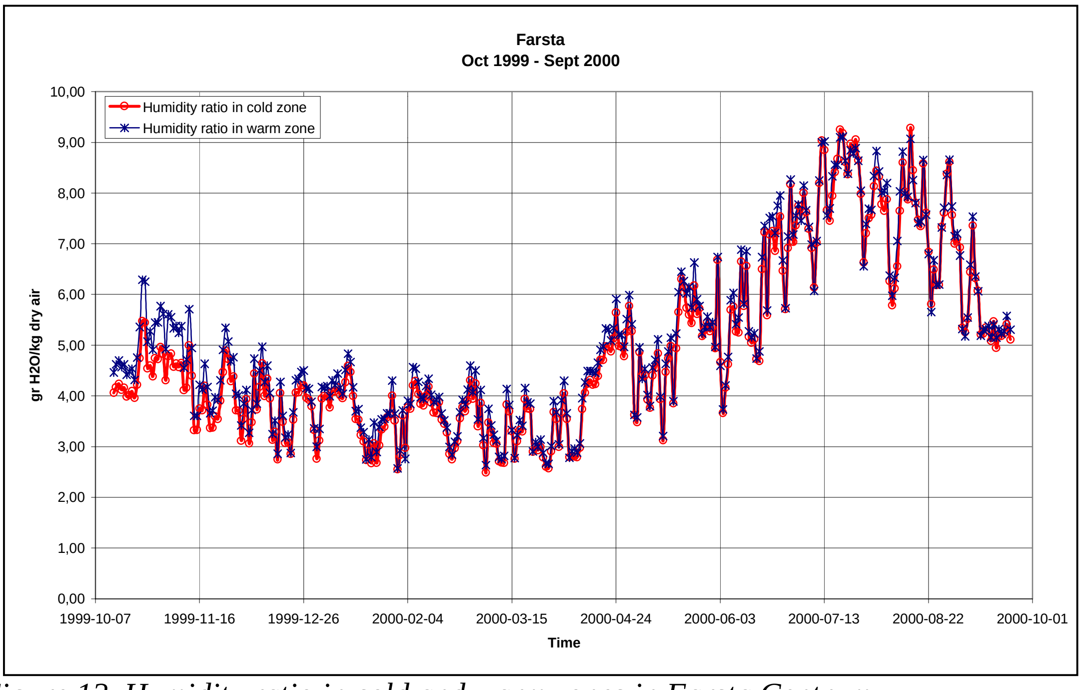

Figure 12. Humidity ratio in cold and warm zones in Farsta Centrum.

4.Conclusions

The measurements confirm the influence of outdoor temperature, indoor temperature and relative humidity on the compressor power. Higher outdoor temperature and moisture affect the compressor power and the temperatures in display cases.

Night covering of display cases and deep-freeze display cases reduce the energy consumption in supermarkets about 10%. However it is necessary to improve the quality and construction of the curtains.

The use of air dehumidification in the air conditioning system during the summer depends on the number of days when the values of humidity ratio are over 12 [gr. H_2O/ kg. dry air]in the supermarket. The climate in Sweden is quite dry during the summer with few days over 9 [gr H_2O/ kg. dry air] as shown in figures 11 and 12. The use of a humidifier during the winter depends on the time that the products are in the supermarkets and on the thermal sensation from the people in the supermarkets. A humidity ratio below 4 [gr. H_2O/ kg. dry] can affect the sense of comfort of people in the supermarkets.

5. References

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