Investigation of Design and Performance of an Air Conditioning Experiment Room to Work with Minimum Energy Consumption

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Abstract

The air in a certain area, an experimental facility was set up to keep the temperature, humidity, velocity and mix ratio at the desired level and to minimize the energy used. The behavior and performance of this system are examined experimentally. Human health and comfort and the use of energy for industrial purposes are inevitable. The aim here is to achieve the minimum energy consumption of the system used. The computer was used as the control organ to minimize energy use. For this purpose, studies on the prepared test facility were continued. The circuit between the system and the computer was designed. Heater, humidifier, mixing system, design and necessary transfer between the sensors and the computer realized. This experiment room was controlled by the computer assisted open-close method within the limits of the comfort zone. As a result, it was seen to perform well. In addition, this facility can be easily adapted to the application of other types of control.

Keywords: Controlled room, technique of conditioning, boundaries of comfort region, an environmental space.

1. Introduction

The technique of conditioning is a technique that is obligatory for life and provides suitable weather conditions. In the future, this technique will become mandatory in people's homes and production facilities. With increasing importance of air conditioning, the control of this system for the desired purposes is of special importance. Automatic control is inevitable to ensure minimum energy use and comfort. Using many automatic control systems, climate control systems can be controlled. The necessary advanced technology is available. Control equipments have fallen in prices and become more flexible in their application areas. After these developments, efficient, high quality, fast and minimum energy usage, the necessary comfort conditions can be achieved.

An air-conditioned room shown in Figure 1 (Akgüney 1987&1994) was designed, built and used under experimental conditions. This air-conditioning experiment facility was utilized for graduate studies for open-close control (Ozturk 1991). Then, with some difficulties seen in this study, Akgüney (1994) made a significant change and redesigned and worked again.

In this study, using computer and control technology, the control of minimum energy usage within comfort limits was examined. (ASHRAE 1972) gave a comfort zone on the psychrometric diagram (Figure 4a). The limits of this comfort zone, relative humidity, temperature and air velocity, as shown in Figure 4b (Akgüney 1994). Comfort zone for moderate activity and lightweight clothing. Hardware and software required for computer control of the installation were realized. Open-close control of this improved installation was carried out. At the same time it was seen that this system was also suitable for all kinds of control methods.

Benefits of using the computer for automatic control were specified. In general the comfort zone and the control information for this process were provided for climate control. The structure of the measuring and control elements and the desired properties are defined. Here the working principle the constituent units and their properties are explained. The results of some experimental applications were discussed.

2. Material and Method

The controlled area is an air-conditioned room and is shown in Figures 1 and 2. In this regard (Kaya 1978, 1981) studies were found. This work was designed, built and worked by this model (Akgüney 1994). In this way, some comparisons were made.

Figure 1. Experimental room

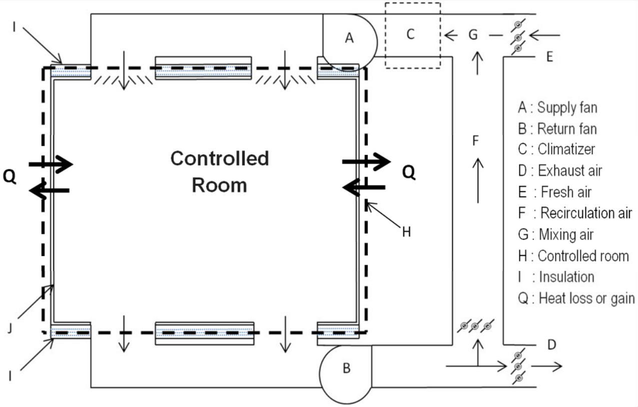

Figure 2. The construction of the test chamber.

The outlet air of the system was reintroduced again, provided that the air contained fresh air. The pollution criterion within the area was provided under the comfort conditions, that is, the required fresh air ratio was determined, and a mixture air containing fresh air was provided to the room.

A chipboard of 0.018 m thickness was used in the control area. The inlet, outlet and return air ducts were made of 0.65 mm galvanized sheet metal. The lower surface, the upper surfaces and the channels, were isolated. On the other surfaces, however, an insulation that is proportional to the heat transfer coefficient of the platform could be provided and no additional insulation material was used. The surfaces were painted with oil paint so that chipboard material did not work as a moisture capacitor. For uniform distribution of air velocity within the control area, distributor and collecting grilles adjustable in terms of flow and direction were used on the ceiling and base of the room.

Some features and dimensions of the room are given in Figure 2. Some of these values are as follows;

Outer wall thickness: 0.018 m, the density of the wall material: 500 kg/m^3, the specific heat of the wall material: 2.5 kJ/kg^{0}C, heat transfer coefficient of wall material: 0.5 kJ/mh^{0}C, horizontal section : 2 m^2, volume: 3.6 m^3, unsealed surface area: 10.8 m^2, ınner surface film coefficient : 50 kJ/m^{2}h^{0}C, outer surface film coefficient: 30 kJ/m^{2}h^{0}C.

Since there is no standard value for the properties of the wall material here, approximate results are used. Heat transfer coefficients on inner and outer surfaces (surface film coefficients), velocity of air, density etc. experimental values were used because they were dependent on their properties. In practice, the internal surface film coefficient of the buildings is accepted as 7 kcal/m^{2}h^{0}C and for the external surface 20 kcal/m^{2}h^{0}C. Since the outer surface of this system was in normal room conditions, 30 kJ/m^{2}h^{0}C was accepted. On the surface, a faster airflow than the natural circulation, but with a slower flow from the outside, was accepted at around 50 kJ/m^{2}h^{0}C.

3. Air Conditioning and Importance

Conditioning, conditioning the air in these volumes to keep the indoor volumes temperature, humidity, cleanliness and air movement at the most appropriate levels for human health and comfort or for industrial processing. The significance of these variables appears in large measure in various fields.

3.1 Air Conditioning for Human Health and Comfort

As the human body is influenced by hot and cold, ıt is also affected by excessively dry and extremely humid air. In particular the negative effect of moisture on the human body is greater than the effect of temperature variation. For an air at an appropriate temperature, when the air is stationary, there is such an equilibrium point for the human being, at this point the body can maintain equilibrium without taking any physiological measures. At this point, a person feels no warmth or coldness and is called comfort. If the air movement increases, the human body will have to take a physiological measure because heat loss will increase with convection. In addition, the effect on the comfort of the moisture is also big. It is difficult to tolerate the high temperature humid temperature, nor is it tolerable to the low temperature humid coolness. The increase in humidity also increases the effect of temperature difference on human body.

Researches on the effects of climatic conditions in rooms on human health, changes in environmental conditions due to seasonal changes have been shown to significantly affect respiratory diseases, especially with various serious diseases. If the internal conditions are well controlled, the related diseases have declined significantly (Gurses 1987).

3.2 Air Conditioning for Industrial Purpose

If the ambient air at work is kept at a certain temperature, humidity, cleanliness and velocity, It is possible to ensure the health and comfort of the employees and to increase the quality and productivity in production.

Most of the materials in the industry can only be produced under certain weather conditions. Studies show that, chemical, textile, sugar, tobacco, medicine, rubber industry, especially in the production of explosives, in the production of photo and electrical goods, in the production of bread, air, if kept at a certain temperature, humidity and velocity, production is much more efficient and high quality. Particularly in information centers, submarines and space vehicles, it is necessary to observe the appropriate climate conditions at the maximum level. Precise measurements in research laboratories can be made independently of the weather conditions by climate facilities. Ventilation facilities are needed in the mines to cool the mines when temperatures rise hundreds of meters deep, to provide respiration to employees and to prevent the accumulation of dangerous gases. It is possible to reproduce these examples further.

Developments showed that, importance of climate conditioned air is increasing in the atomic-related industry, precision and all kinds of industries requiring high technical standards.

3.3 Features Required in a Control System

If a system has limited response to each limited entry, it is defined as stable for that system. In control systems, stable operation of the system, fast response and sensitivity are the most important minimum qualities to be achieved.

In control systems operating under a fixed reference, it is desirable that the controlled magnitude be equal to or within accepted tolerances. Due to disturbance effects or changes in the reference value, the system output can change and go beyond the desired tolerance. In this case, the system output must be brought back to the reference value and regularly protected. In a control system, the system output must reach a constant regime value as soon as possible with a steady transition regime, if it deviates from the continuous regime value due to impairing influences or reference changes. In continuous mode operation, if the system output is equal to the reference value, ie if the error is zero, the accuracy is too high. Since it usually increases the cost of zero errors, it can be assumed that the output remains within certain tolerances by determining an optimum point between cost and accuracy.

Although control systems are required to operate steadily, precisely and quickly, they are often subject to very stable systems that are slow, while very fast and very sensitive systems are subject to unstable operation.

3.4 Benefits of Using Automatic Control in the Air Conditioning System

Control operations can be performed by a decision mechanism established around the event to be controlled without direct human intervention (Özdaş et al. 1988).

In air conditioning systems all devices and machines are determined according to the maximum loads. However these maximum loads are often not available and the system will operate at partial capacity. Automatic control ensures efficient precise and stable operation at these partial loads. Namely;

- Reduces operational costs through labor, fuel and energy savings.
- Thermal load changes can be detected more quickly, compliance with new loads and thus comfort conditions, process control, precise climate conditions etc. fulfill needs.

The benefits of using electronic / computerized control in air conditioning systems include.

- Feel the variable value (temperature, humidity, etc.) quickly and give the control signal very fast. The controlled element takes this signal very quickly and evaluates it.
- The electronic sensing elements are simple-structured and since they are not moving parts they are long-lived have little maintenance and repair difficulties.
- It works with low current installation, insulator and conductor inceir and there is no danger of electric shock. It can be used wherever there is electricity.
- According to other systems, they are easy to adapt and can be used together.
- Controlled values (temperature, humidity, air velocity, etc.) are stored in memory within a certain time period. If necessary, these values can be used to analyze the system.
- The control parameters can be monitored at any time or continuously from the computer screen.
- More than one parameter can be entered on the computer by doing various operations with software. The desired control conditions are easily generated by software. All control types can be easily adapted to the system with appropriate software and hardware.
- Process, automatic or manual operation and control possibilities.

3.5 Classic Controls

The heating / cooling thermostat is installed in the room. A humidistat is also placed in the return air duct and the thermostat independently controls the humidity. At classic controls, the return air is completely re-circulated.

The temperature is 21 °C and the relative humidity is 40 % in the winter conditions and 24 °C and the relative humidity is 50 % in the summer conditions. The control of the conditioning equipment is provided by the thermostat and humidistat by energizing the bobbins. This is a typical system (Kaya 1981, 1982).

3.6 Optimal Controls

The optimal control system uses the same hardware and control relays. Relay end connections are made with a microprocessor control not with conventional control equipment. In this case the microprocessor takes over the control of the equipment. The output of the microcontroller is transmitted to the semiconductor relays via translators and the bobbin of the hardware relays there is energized. (Akgüney 1987&1994) a general control loop diagram with microprocessor is given in Figure 3.

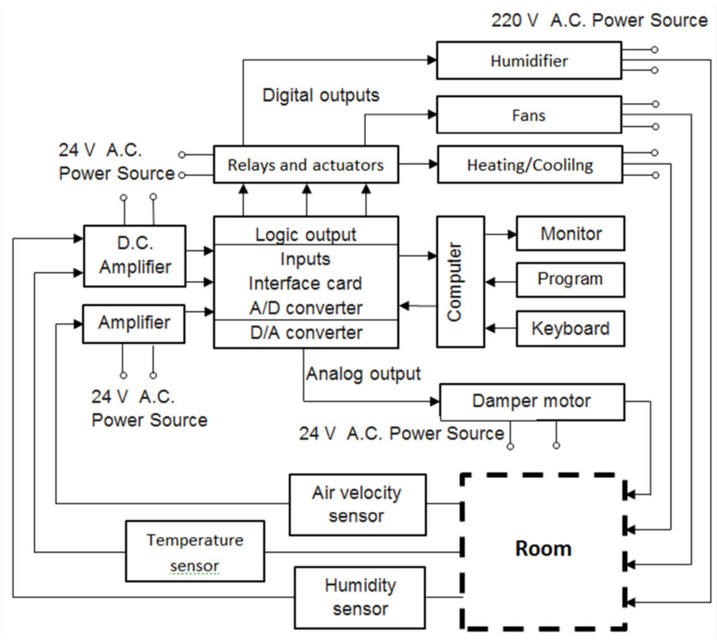

Figure 3. Block diagram of test room control equipment

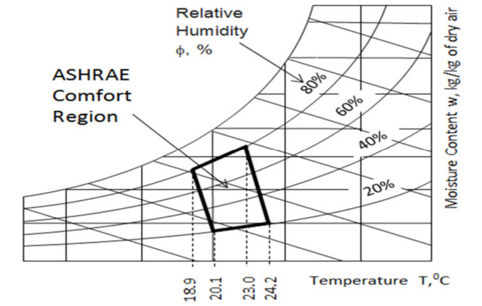

Figure 4a- Comfort region in the psychometric chart

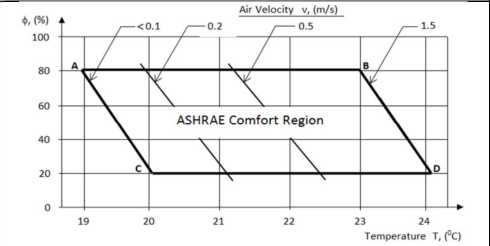

Figure 4b- Boundaries of comfort region

Internal and external temperature and relative humidity should be measured for optimum control. For temperature measurement, temperature-sensitive diodes and operational amplifiers are used. The output of the amplifier feeds the multiplexers.

In relative humidity detection, a separate sensing element is used for the outside and a separate sensing element for the inside. The output of the relative node function in volts is taken with this sensor.

3.7 Determination of Energy Efficiency

Energy efficiency is obtained by dividing the actual energy used by the energy load in the space (heating, cooling). If the energy load is equal to the temperature in the room and the relative value of the classical controls, then the resulting energy load is the heat loss in the building. That is, the energy load is calculated when the room temperature during heating is 21 °C and the relative humidity is 40 %, the room temperature during cooling is 24 °C and the relative humidity is 50 %.

The energy load is calculated by taking the average of a time period (a preferred day or more). The total value of this load can be used as kJ instead of kW. The energy output is calculated as follows.

$$n_e = \frac{Energy\ Used}{Energy\ Load},\ (\%) \qquad (1)$$

Energy use is calculated on the basis of the currently used equipment and the energy used by that equipment. Equation (1) compensates for changes in energy overload and thus forms a common basis on which we can make comparisons.

If the room is held correctly in the classical control values, the energy use must be equal to the energy load. In addition, if there is any doubt about whether it is held correctly, it is sufficient to compare the values of energy load and energy use. Energy use is usually calculated correctly but can not be used as a basis. Because, such as door opening and the like, can change the use of energy, but it does not affect the energy load calculations. Energy cost efficiency and energy cost are calculated as follows.

$$n_c = \frac{Energy\ Cost}{Energy\ Load},\ (USD/kJ) \qquad (2)$$

$$Enerji\ Cost\ (USD) = \Sigma(Enrgy\ Used, kJ)(Cost\ of\ Unit\ Energy, USD/kJ) \qquad (3)$$

Since the changes in energy and costs are possible, two yield criteria are used. However, when comparison between classical and optimum controls is required, the data are calculated as expressed by the same fuel type and cost (Kaya 1981, 1982).

3.7.1 Calculation of Energy Load

The heat loss (energy load), the relative humidity and temperature in the room and the measurement result of the temperature on the outside wall of the room are calculated.

$$Q = \sum_{i=1}^{\infty} K_i\, S_i\, (T - T_i) + k\, g\, (v_a)\, h \qquad (4)$$

Some of the parameter values in this equation are entered directly into the computer's memory. Others are measured on sensitive sensors and loaded on the computer. The values entered into the memory of the computer are calculated. T and T_i values are measured, h is calculated or known from the measurements, other parameters are known as k, g and v_a (Kaya 1981, 1982).

3.7.2 Calculation of Energy Use

Energy use is calculated by calculating the average values of the energy used in a time period (one day or more). This value can be obtained from the currently used equipment and the energy used by that equipment (at kW). For an electric heater, this value is based on unit power. For others, nominal power values (dampers, fans, humidifiers, etc.) are used. This information is sufficient for calculation as expressed by energy use (Kaya 1981, 1982).

3.8 System Operation

The block diagram of the test setup is given in Figure 3. The sensors are located in the appropriate places in the installation. The temperature and humidity sensor is one piece connected to the output terminals. The output of the air velocity sensor is 0-10 V DC, so it is not connected to the amplifier. The temperature and humidity depend on the A/D inputs of the voltages at the amplifier outputs with sensor information. In addition two analog measuring instruments which are nematic are connected in parallel to the amplifier outputs.

Two heaters, humidifiers and ventilators were placed in the air conditioned cell, and an aspirator was placed at the outlet of the volume. The inlet outlet and return canals are well insulated. There are three dampers and one damper motor in order to provide mixing air. Humidification is achieved by the pump being pumped into the air as a result of the pressurization of the water.

The fans, heaters, pump and computer in the plant are supplied with 220 Volt voltage, all the electrical and electronic components outside them are working with low voltage. A good grounding is made in the installation and the connecting cables for shopping are kept short.

3.8.1 Multifunctional Data Input-Output Interface Card

Numerical computer was used in the system experiment. Data exchange between the system and the computer, high-performance, high-speed, multi-function, multi-input and two-output data acquisition interface card. It is suitable for a wide range of use in industrial and laboratory applications and includes data communication and information communication in factory automation. It is a general purpose and multifunctional (A/D, D/A, D/O, timer, counter etc.) and software controlled interface that generates a control signal based on the control program of the computer card. The supply voltage of the card is derived from the power supply of the computer. Before using the card the A/D inputs and D/A outputs are calibrated.

3.8.2 Measuring Elements

Measuring elements (transformers) transform any variables (temperature, humidity, liquid and air flow, etc.) expressed as a size into an analog. Variable variables in the control environment with the help of converters are obtained by monitoring and control purposes.

The temperature sensor used in this study is a direct temperature sensor with the ability to change temperature and change resistance. It is a nickel resistance with 1000 Ω value at 0 ^{0}C in the test installation. The temperature coefficient is 0.5 % (1/^{0}C). The temperature step is given for 0-50 °C. The time constant is 3.5 minutes depending on the air movement and the thermal coupling. Also called passive temperature detector.

A humidity sensor with a resistance change was used to control the control volume. In this type of sensors, which are mostly used in air conditioning sensors, the resistance value of the sensor also changes as the amount of moisture in the air changes. The resistance-type humidity sensor consists of two electrodes separated by a thin layer of lithium chloride (Sheet 1985). The lithium chloride film layer has the ability to hold airborne particles and is called hygroscopic material. As the relative humidity increases, the resistance of the element increases and this change is perceived potentiometrically. The value is a potentiometer that varies according to nourishment. This value ranges from 1000-2000 Ω için for a relative humidity of 30-90 %. The bridge method also measures the change in relative humidity through the change in resistance.

A hot wire anammeter was used to measure air velocity. With this method one of the two very thin, heated wires is based on the principle of cooling by the air current passing around the sensor. The change in the amount of energy with the measuring transformer in the circuit is regulated as the air velocity and is transferred to the output as 0-10 V DC. The measuring range of the sensor is 0-10 m/s for the test facility.

In the system the measuring amplifier unit is used for humidity and temperature. It actively converts resistance changes in temperature and humidity passive sensors to 10 V DC.

3.9 Control Elements

In order to keep the control magnitudes of the system, temperature, humidity and air velocity changes to desired levels, it is necessary to control the amount of heat, water vapor and air supplied from the outside of the system. These three magnitudes give us the control vector, which is called control magnitude.

Electric resistors are used to supply the necessary heat energy to the system. The change of the effective value of the voltage can be controlled by the signals from the computer. In order to maximize the heat transfer between the heater and the air, a finned tube heater is preferred. Table 1 shows the maximum power of the heaters.

Table 1. Maximum power of heaters

Heater I		Heater II		Heater I + II	
Amper	Watt	Amper	Watt	Amper	Watt
6	1440	11	2600	17.8	3920

Moisturization is carried out by pressurizing and spraying the water into the air. The pressurized water is adiabatically moistened by the fountain. The control of the humidifying pump is done like a heater control.

In order to change the air movement in the control volume, two fans are used for blowing and sucking air working with 220 V DC. Their tension is made like a heater and a humidifier. The maximum flow rate when the fans are working together is 2160 m^3/h. Table 1 gives the necessary information about fans.

Table 2. Some parameters related to fans

Room Air Velocity (m/s)	Amper	Volt	Watt	Room Air Velocity (m/s)	Amper	Volt	Watt
0.30	1.7	216	270	0.15	3.3	216	320
0.25	2.2	216	280	0.10	3.2	216	300
0.20	2.9	216	290	0.05	2.9	216	220

One of the most important processes in the air conditioning systems is to mix fresh air and return air at a certain point in the mixing process. To achieve this, there are fresh air, exhaust air and mixture air dampers and a damper motor to drive these dampers. In this case the exhaust and fresh air damper are parallel, and the mixing (return) air damper is connected mechanically by a mechanism so as to move in the opposite direction. The fresh and exhaust air dampers are fully open in the vertical position while the mix air damper is in the horizontal position and completely closed. In Tables 3, 4 and 5, measured air velocities and calculated flow rates at various mixing ratios with back-circulation of bulk leaving air at 0.1, 0.2 and 0.3 m/s room air velocities are given. The following values are available.

Table 3. Velocity and calculated flow rate values measured in the wing at mixing ratios while room air velocity is 0.1 m/s

v_r m/s	f_r m^3/h	Y_U Volt	D_a (^{0})	r %	v_{eg} m/s	f_{eg} m^3/h	v_{ex} m/s	f m^3/h	v m/s
0.00	0	0	90	0	1.00	720	1	720	0.1
0.05	36	1	81	05	0.95	684	1	720	0.1
0.15	108	2	72	15	0.85	612	1	720	0.1
0.30	216	3	63	30	0.70	504	1	720	0.1
0.45	324	4	54	45	0.55	396	1	720	0.1
0.60	432	5	45	60	0.40	288	1	720	0.1
0.73	525	6	36	73	0.27	194	1	720	0.1
0.83	597	7	27	83	0.17	122	1	720	0.1
0.90	648	8	18	90	0.10	72	1	720	0.1
0.95	684	9	9	95	0.05	36	1	720	0.1
1.00	720	10	0	100	0.00	0	1	720	0.1

Table 4. Velocity and calculated flow rate values measured in the wing at the mixing ratios while the room air velocity is 0.2 m/s

v_r m/s	f_r m^3/h	Y_U Volt	D_a (^{0})	r %	v_{eg} m/s	f_{eg} m^3/h	v_{ex} m/s	f m^3/h	v m/s
0.00	0	0	90	0	2.00	1440	2	1440	0.2
0.10	72	1	81	05	1.90	1368	2	1440	0.2
0.40	288	2	72	15	1.60	1152	2	1440	0.2
0.75	540	3	63	30	1.25	900	2	1440	0.2
1.10	792	4	54	45	0.90	648	2	1440	0.2
1.40	1008	5	45	60	0.60	432	2	1440	0.2
1.60	1152	6	36	73	0.40	288	2	1440	0.2
1.75	1260	7	27	83	0.25	180	2	1440	0.2
1.85	1332	8	18	90	0.15	108	2	1440	0.2
1.95	1404	9	9	95	0.05	36	2	1440	0.2
2.00	1440	10	0	100	0.00	0	2	1440	0.2

Table 5. Velocity and calculated flow rates measured in the wing in the mixing ratios while the room air velocity is 0.3 m/s

v_r m/s	f_r m^3/h	Y_U Volt	D_a (^{0})	r %	v_{eg} m/s	f_{eg} m^3/h	v_{ex} m/s	f m^3/h	v m/s
0.00	0	0	90	0	3.00	2160	3	2160	0.3
0.15	108	1	81	05	2.85	2052	3	2160	0.3
0.55	396	2	72	15	2.45	1764	3	2160	0.3
1.10	792	3	63	30	1.90	1368	3	2160	0.3
1.60	1152	4	54	45	1.40	1008	3	2160	0.3
2.00	1440	5	45	60	1.00	720	3	2160	0.3
2.35	1692	6	36	73	0.65	468	3	2160	0.3
2.63	1893	7	27	83	0.37	266	3	2160	0.3
2.80	2016	8	18	90	0.20	144	3	2160	0.3
2.92	2102	9	9	95	0.08	57	3	2160	0.3
3.00	20160	10	0	100	0.00	0	3	2160	0.3

In the graph of Figure 5, the state of the three different damper characteristics is shown on the "flow-angle" coordinates according to the results of the experiment. In this chart, velocity, flow rate and mixture ratio (in terms of dampers), the comparison of the damper characteristics can easily be made. Also in Figure 6 a damper control signal at three different room air velocities, and a graph of the return air flow provided by the damper angle as a function of mixing.

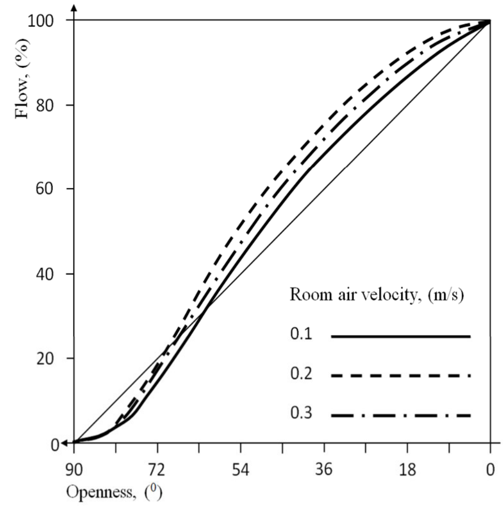

Figure 5. Damper characterization

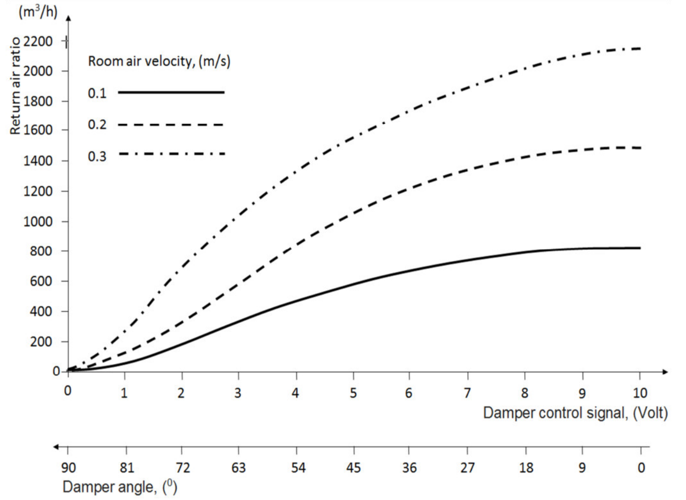

Figure 6. Change of return (back-circulation) air flow according to damper drive signal / damper angle

4. Conclusion and Discussion

In computer-implemented processes, the number of data collection and control applications is increasing steadily. Because of the high reliability, speed and control process implemented by software, it is easy to renew the system according to the new conditions. It is also possible to transfer the control algorithm to the system. With the use of personal computers in processes, the real-time control operation is performed with high efficiency, and at the same time, the collected data is evaluated later, providing great benefits to the user. The control and data collection systems to be installed with personal computers make it easy to control and display together with data collection.

In the experimental chamber which was established as a multi-inlet and multi-outlet real system necessary experiments were carried out taking into account the air circulation back.

An IBM compatible computer was used for data collection at the test facility. The computer consists of basic elements such as hard disk, cd drive, keyboard and screen. The data input-output card is located in one of the empty expansion slots in the computer.

Experiments were provided with a software support. The data entry-exit card also has powerful and easy-to-use software driver operations in particular. With this card, application programs are more easily created with software driver routines when it comes to using some complex features such as possible interput or DMA data transfer.

While the data collection program for the climate control experiment facility was being developed, the function programs that provided the interface card software were utilized. Each function program is numbered and used.

The damper which regulates the mixing ratios of recirculated air recirculated with fresh air, provides this mixture everywhere. The air mixture can be adjusted with the dampers by applying a control signal between 0-10 volts DC to the dampers opening and closing the dampers. The control signal is an analog-to-digital converter that is found on the interface card.

In the control room a number of experiments were carried out at actual air velocities of 0.1 and 0.2 m/s, six different mixing conditions and different climatic conditions. Some graphs of the measured temperature, relative humidity and air velocity measurements were obtained. Figure 7c shows the measurement graph of velocity measured in air duct at room air velocity of 0.2 m/s. The measurement error at air velocity does not exceed 5 %.

T: 23 ^{0}C, T_a: 20.5 ^{0}C, ϕ: 33 %, ϕ_a: 33.4 %, D_a: 54 (^{0}), Y_U: 4 Volt, r: 55 %, f_r: 792 m^3/h, T_w: 23 ^{0}C, v: 0.2 m/s and in the case of heating+humidification, the temperature, relative humidity and air velocity measurement graphs of the control volume are given in Figures 7a-b-c, (Akgüney 1994).

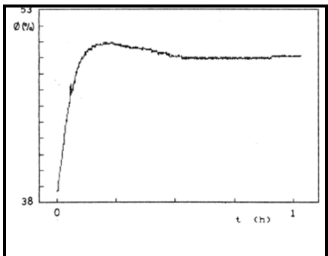

Figure 7a. Moisture measurement chart

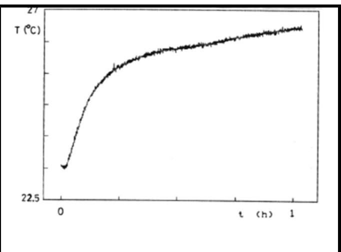

Figure 7b. Temperature measurement chart

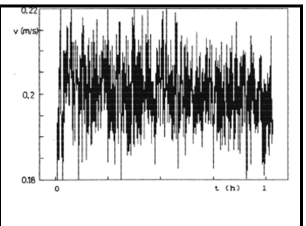

Figure 7c. Air velocity measurement chart

Numerous experiments have been carried out on air blends which are circulating again and again at various angles of the dampers and depending on these openings. In these experiments, the air velocities in the room were carried out at three constant velocity of 0.1, 0.2 and 0.3 m/s.

Application I- Desired relative humidity 55.6 %, desired temperature 19.5 ^{0}C, inlet and outlet dampers completely closed, return damper completely open. In this case, the system response under control is shown in Figures 8a-b. The deviation in temperature is the desired magnitude (± 1 °C) and the settling time is too long. When the inlet and outlet dampers are completely closed, the room is naturally cooled by heat transfer from the wall. Relative humidity is controlled by a deviation of 0.5 %. It oscillates around the desired value. Deviations are within acceptable limits.

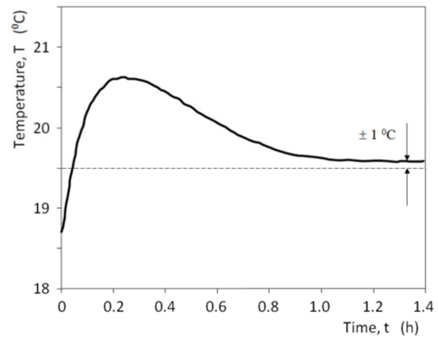

Figure 8a. Temperature change

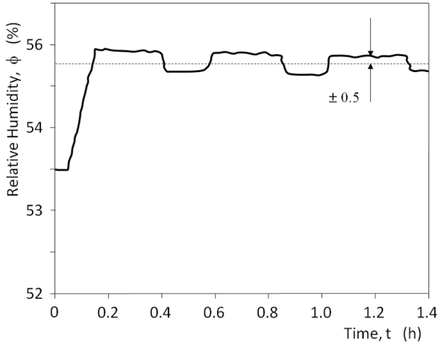

Figure 8b. Relative humidity change

Application II- Desired relative humidity 55.6 %, desired temperature 19.5 ^{0}C, inlet, outlet and return dampers 50 % open. The results obtained are shown in Figures 9a-b. Some of the air in the heated and humidified room is thrown out and fresh and cold air is taken in as much as the thrown amount. Half of the air that is heated and humidified is sent back to the room. For this reason, the desired temperature level is reached more quickly. When the desired level is lowered, the heater is inserted into the circuit. Even if the heater voltage is cut off due to the heater inertia, the heating process continues for a while. For this reason, it is seen that the capacity of the humidifier is slightly lower.

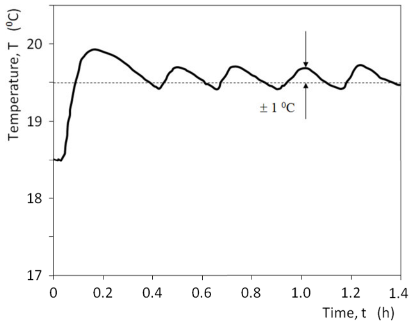

Figure 9a. Temperature change

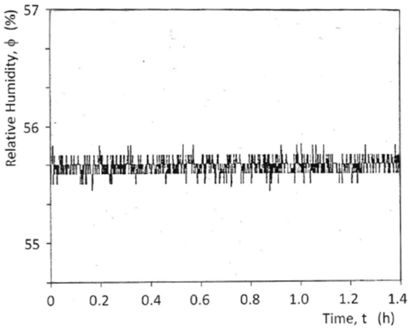

Figure 9b. Relative humidity change

Application III- Desired relative humidity 55.6 %, desired temperature 19.5 ^{0}C, inlet and outlet dampers 78 % closed, return damper 78 % open, disturbing effect. 22 % of return air is thrown out, 78 % is returned to the room. Fresh air is taken in as much as the amount taken. In this case the system is under better control. Figures 10a-b show experimental results. In this experiment, after the room temperature became stable, the door of the room was opened for 1 minute and the disturbance was included in the system, and the behavior of the control system was observed. The system responded that there were damped oscillations, but eventually the system was under control.

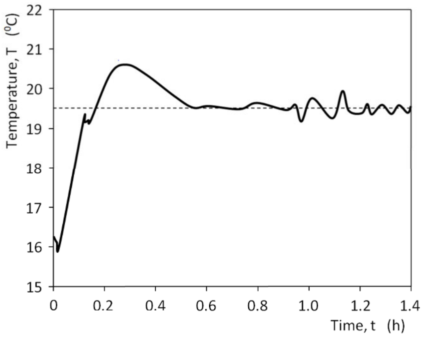

Figure 10a. Temperature change

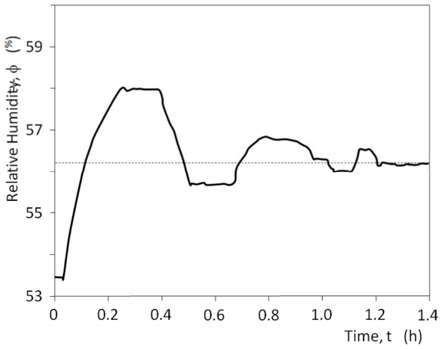

Figure 10b. Relative humidity change

Buradaki çalışmada öğrenci eğitiminde kullanılacak bir iklimlendirme odası kompütürize edilmiştir. Odayı istenen konfor şartlarında tutmak için aç-kapa kontrol yöntemi kullanılmıştır. Üçüncü uygulama, konfor şartlarını daha iyi sağlamaktadır. Sıcaklık değişimi en fazla ± 1 ^{0}C, bağıl nem değişimi ± % 5 civarında olmuştur. Ortamda bozucu etki yokken, sıcaklıkta % 1.6 ^{0}C, bağıl nemde % 2.6 hata ile ortam kontrol edilmiştir. Bozucu etki varken, hata oranları sıcaklıkta % 2.5 ^{0}C ve bağıl nemde % 4 olmuştur. Çok daha iyi konfor şartları için, modern kontrol yöntemleri geliştirilerek kullanılmalıdır.

In this study, an air conditioning room for training purposes was computed. Open-close control method is used to keep the room in desired comfort conditions. The third application provides better comfort conditions. The temperature change is at most ± 1 °C and the relative humidity change is ± 5 %. The environment was controlled with 1.6% ^{0}C at temperature and 2.6 % at relative humidity when there was no interference effect in the environment. While there was a detrimental effect, the error rates were 2.5 ^{0}C at temperature and 4 % at relative humidity. These results also coincide with the results of the study (Can at.al. 1993). Modern control methods should be developed and used for much better comfort conditions.

5. Symbols

D_a : Damper angle adjusting mix air, (^{0})
f : Total air flow, (m^3/h)
f_{eg} : Incoming air flow, (m^3/h)
f_r : Return (back-circulation) air flow, (m^3/h)
g : A function
h : Enthalpy intensity of room air, (kJ/kg)
K_i : Heat transfer coefficient, (kJ/m^{2}h^{0}C)
k : Leak constant
Q : Heat loss, (kW)
r : Mixing ratio of return (recirculation) air, (%)
S_i : Wall area, (m^2)
T_i : Wall outside surface temperature, (^{0}C)
T : Room air temperature, (^{0}C)
T_a : Ambient air temperature, (^{0}C)
T_w : Average humidifier water temperature, (^{0}C)
v : Room air average velocity, (m/s)
v_a : Ambient air velocity, (m/s)
v_{eg} : Input air velocity, (m/s)
v_{ex} : Average air velocity in the outlet channel, (m/s)
v_r : Reference air velocity, (m/s)
Y_U : Damper motor control voltage, (Volt)
ϕ : Room air relative humidity, (%)
ϕ_a : External air (ambient air) relative humidity, (%)

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