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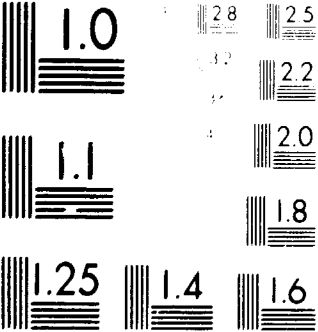
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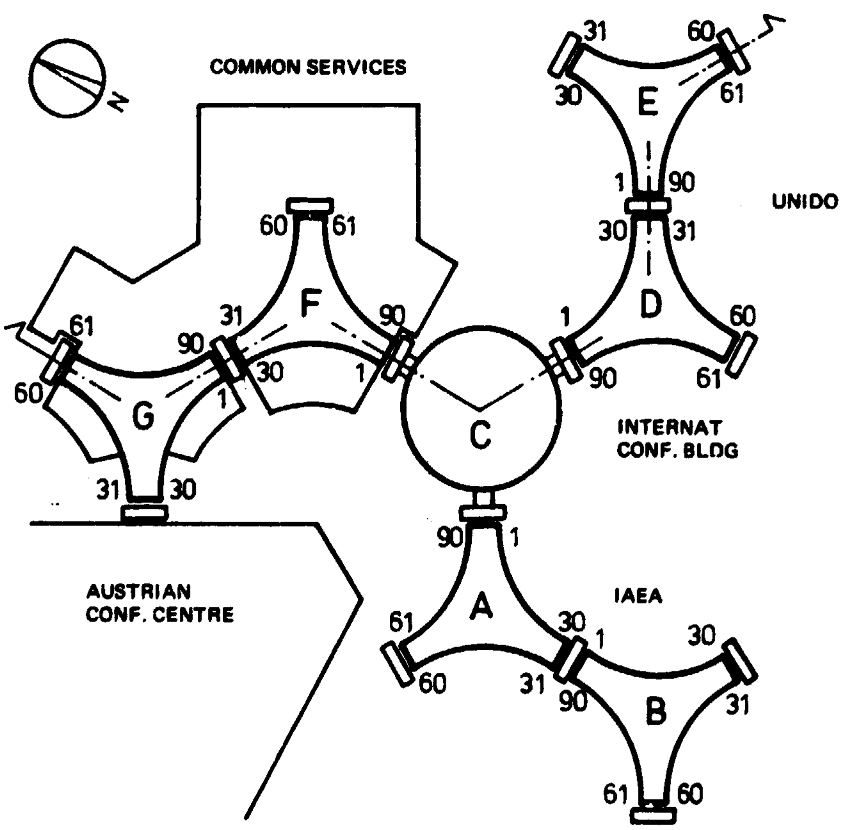
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

A STUDY INTO THE OPTIMIZATION OF THE CONSUMPTION OF ELECTRICITY IN THE VIENNA INTERNATIONAL CENTRE, V.I.C.

JANUARY 1981



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EKONO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

(R) A Study into the Optimization of the Consumption of Electricity

in the

Vienna International Centre (VIC).

UNIDO Contract No. 80/57

Project No. UN-K-28873-048

Activity Code 12

Report ZT-06020-05

January 1981

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Study into Optimization of the Consumption of Electricity in the Vienna International Centre (VIC).

Client

UNITED NATION INDUSTRIAL DEVELOPMENT ORGANIZATION

Purchase and Contract Services (PAC)

1220 Vienna

Task

Carry out a study into research the possible energy-saving by an optimum consumption of energy in the VIC.

Structure

This report is made of seven major chapters, that is:

1. Energy Consumption in the VIC
2. UNIDOs Requirements Versus Actual Design Standards
3. Electrical Equipments
4. Heating, Cooling, Air-Conditioning and Sanitary Equipment
5. Building Automation System
6. Operative Organization
7. Recommendations

The major chapters one and two concern the actual consumption of energy, the standards for heating, ventilation, air-conditioning and lighting equipment, as also the fixing of an aim and the necessity of the energy conservation.

The major chapter three through five deal with the technical equipment, wherein all possibilities of conservation are explained as well as the potential of the energy conservation. Every major chapter is concluded by a subchapter "Costs and Feasibility".

Major chapter six deals with changements and adaptions to the operative organization.

The sevent and last major chapter concludes recommendations and measures as well as the potential on saving money.

The comments on the report, issued by the UNIDO Buildings Management Section, General Services/Division of Administration, and by the joint UNIDO/IAEA Working Group on Energy Conservation, are summarized and listed in Appendix 1.

The replies of the writers of the report are given in Appendix 2.

Realization

The data collection and inquiry of the present situation has taken place between May 5th through 20th 1980 in Vienna. Additional informations have been given upon request. The technical calculations include also the data of last June, whereby the results of calculation became a higher accuracy.

In addition to the main project team many specialist of different departments of the EKONO-group have been consulted in order to guarantee a high level of this report, which is an important aid for the final decision by UNIDO.

Results

The proposed energy-saving measures and electric peak power limitation are classified in three priorities:

1. Measures without investments

Potential on money-saving	appr.	5.600.000,-	S/a
Potential on energy-saving	appr.	10.300	MWh/a

2. Measures requiring investments

Potential on money-saving	appr.	7.800.000,-	S/a
Potential on energy-saving	appr.	13.700	MWh/a

3. Measures requiring investments and further studies in details

Potential on money-saving	appr.	2.000.000,-	S/a
Potential on electric peak power limitation	appr.	2	MW

The majority of the proposed measures aims at intensifying the exploitation of the building automation system, at checking the running times and the requirement standards, at arranging for heat recovery and at changes in the operational areas of the equipment. Thereto belongs also measures, which influence the structures and the field of activity of the operative organization. Further the measures allow energy conservation without negative impact on health or comfort.

The profitableness of the measures requiring investments can be seen favourable at a return of payment less than one to five years.

The economic calculations do generally not include increase of energy prices. All results are based on today's price level inc. VAT.

Finally should be pointed out, the sooner the implementation of the proposed measures is started, the sooner more substantial savings will result.

Vienna, 26 January 1981

Heikki Ranki
Project team leader

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1. Energy Conservation in the VIC

1.1 Energy Consumption

Monthly energy consumption in different buildings since september 1979 is presented in monthly and quartely reports published by IAKW. The rates are measuring results obtained manually from the main and submetres of the building complex. The reading interval has been one calendar month with a few days' accuracy. Remote display or reporting of energy consumption is not connected to the buildings automation system.

It is always unreliable to make conclusions on the consumption during the first operational year. Generally the energy consumption of a building reduces about 10 per cent during the next years due to drying, getting used to operate the building, tuning of the equipment, etc. However, it is necessary to check the amount of energy consumption of a new building as early as since it has been taken into use. The consumption rates of the first year are the starting point for active energy conservation in future.

By means of the consumption data of the IAKW reports and the weather data of Hohe Warte for the corresponding period, energy consumption rates for the VIC have been calculated on the basis of normal weather. Estimations on heat, electricity, and water consumption, extrapolated on a normal year period, are presented in Table 1/1. Heat consumption has been estimated on the basis of the dependence of the measured consumption on a degree-day value. This dependence is presented in Fig. 1/1. Electricity and water consumption, which are less dependent on the seasons, are monthly constants. On the basis of the measured material until the end of juni electricity consumption of the whole building complex seems to be 1750 MWh/month and water consumption correspondingly 15 300 m^3/month. Naturally the values presented in Table 1/1 are only directional, and more accurate results on the consumption will be obtained at the beginning of November, when the building has been in use for the whole year.

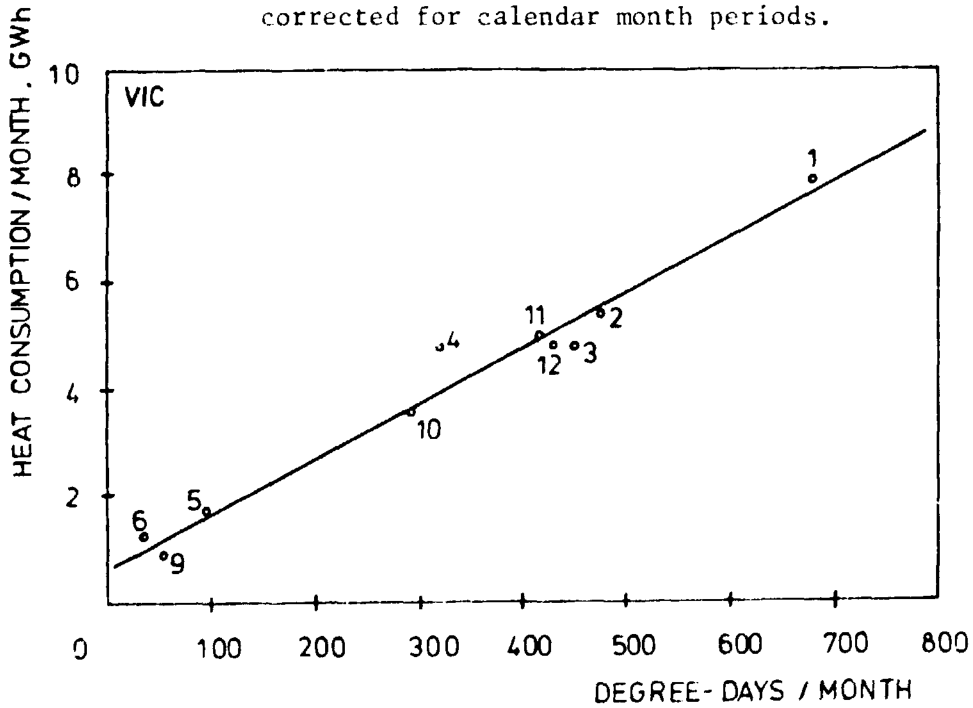
Table 1/1. Heat, electricity and water consumption during a normal year in the VIC

Building	Volume m^3	Heat MWh/a	Electricity MWh/a	Water m^3/a
A	197.800	6580	3940	34430
B	80.700	2690	1610	14050
C	168.600	5610	3360	29350
D	160.500	5340	3200	27940
E	106.000	3530	2110	18450
F	236.300	7860	4700	41140
C	104.800	3490	2080	18240
VIC	1.054.700	35100 MWh	21000 MWh	183600 m^3
Average		33.3 kWh/m^3 129.9 kWh/m^2	19.9 kWh/m^3 77.7 kWh/m^2	0.17 m^3/m^3 0.68 m^3/m^2

Annual energy costs in the VIC with current energy fees (august 1980)

- Heat	17.299.000	ATS
- Electricity	15.715.000	ATS
- Power peak	781.000	ATS
- Water	1.745.000	ATS
Total costs	35.540.000	ATS
Average	33.7 ATS/m^3	131.6 ATS/m^2

Figure 1/1. Dependence of the heat consumption of VIC on monthly degree-day values. The measuring results have been corrected for calendar month periods.



The monthly consumption rates presented in Fig. 1/1 are fairly well located on the same line. This proves that the building properly reacts to outside temperature variations which shows that the control equipment are functioning. Other factors, such as wind and solar radiation, seem to have no greater effect on long term heat consumption.

1.2 Energy Goals

For effective energy conservation, energy use data must be collected and quantified. This must be done continuously in every building separately.

It is useful to determine the possibilities with the buildings of the VIC, located, designed and constructed as they are, but they should be operated with low energy consumption as a primary goal. And this should be done without lowering the existing level of the comfort.

Starting from the present consumption rates presented in Table 1/1 there exist good possibilities in the VIC to save energy in great amount. By proper use and maintenance activities as well as with small investments it is possible to achieve savings of 25 % in heat, 20 % in electricity, and 15 % in water consumption. By purposeful work for energy economy these goals are possible to achieve within some years. Most of the changes in this category can be carried out immediately and the savings will be seen right after. Some of the measures, however, require more time due to designing, construction and tuning of equipment. These plans can be divided for the next few years, and after they have been carried out the first goal will be achieved. This goal is stated in Table 2/1.

Table 2/1. Short term energy goals of the VIC

	Total consumtion		Specific consumption	
Heat	26 325	MWh/a	97.4	kWh/m^2 a
Electricity	16 800	MWh/a	62.2	kWh/m^2 a
Water	156 000	m^3/a	0.58	m^3/m^2 a
Total energy	43 125	MWh/a	159.6	kWh/m^2 a

Annual energy costs of the VIC when energy consumption equal to short term energy coals, calculated with energy fees of august 1980:

- Heat	12.962.000	ATS
- Electricity	12.572.000	ATS
- Peak power	735.000	ATS
- Water	1.483.000	ATS
Total costs	27.752.000	ATS

Average 26.3 ATS/m^3 102.7 ATS/m^2

In the next stage it is possible to set new lower goals, than in the Table 2/1 for the energy consumption of the VIC. However, implementation of these plans requires large investments, which again depend on temporary financial situation and production requirements of the investment.

1.3 Energy Conservation Demands

The VIC is designed and built at times when conservation of energy did not command the urcency it does today. Conditions have dramatically changed, and at present attempts must be done for modifying this complex so that minimum amount of energy is required by its operation.

As one of the most remarkable monuments nowadays the VIC will be in use for a long time. To be able to serve well also in the next centuries, the existing equipment must be utilized with the maximum efficiency. Excess consumption will result in extremely large costs during many decades. The truth is that a building under start-up conditions may wait for decades until any reconstructions. Now it is necessary to take the mechanical and electrical devices of the building as well as the building automation system into effective use. It may require some investments, but they will be paid back as energy savings in a few years.

People working in the VIC come from different climatic and cultural conditions. Their possibilities to save energy are limited in a variable degree, and it is true, that they may not be obliged to any energy conservation measures. They must be given comfortable enough indoor climate conditions for carrying out their work, but the possibilities to waste energy must be eliminated. By eliminating unnecessary heating, cooling and illumination reserves in individual rooms unnecessary consumption can also be eliminated. This means adapting the temperatures of primary air and of supply water of induction units to weather conditions. As to illumination, it might also be possible to reduce the amount or the effect of tubes in many places.

Energy conservation belongs to the maintenance organisation of the building, and for carrying out this work it must have enough expertise, means and will.

2. UNIDOs Requirements versus Actual Design Standards

2.1 Indoor Climate

2.1.1 Occupied Periods

The basic design parameters for the air-conditionings systems of the VIC are very strict. Indoor conditions of 22 to 24 deg. centigrade and of 40 to 50 per cent relative humidity are only a small portion of the acceptable range in many actual standards. This is shown in Figure 1/2 and verified by new ASHRAE Standard 55-74 R "Thermal Environmental Conditions for Human Occupancy". ASHRAE uses here operative temperatures which are approximately the average of the air and mean radiant temperatures and equal to the adjusted dry bulb temperature. In practice, in office environment like the VIC the operative temperature differs roughly 0,5 ^{o}C from the indoor air temperature. Thus ASHRAE's operative temperature-humidity ranges can be compared with Unido's requirements. ASHRAE specifies conditions that are thermally acceptable to 80 % or more of the occupants. Satisfaction with the thermal environment is a complicated subjective response to several interacting variables, like clothing, activity, air velocity, humidity. But ranges in Figure 1/2 can be applied and thus the minimization of energy and sufficient thermal comfort are achieved.

Because of seasonal clothing habits of building occupants, the temperature range for comfort in summer is higher than for winter. The temperature ranges between which at least 80 % of the VIC occupants should find the environment thermally acceptable are recommended in chapter 2.1.4. The rest 20 % of the occupants will find the environment slightly cool or slightly warm.

It can be noticed that 100 % thermal acceptability never can be achieved. In laboratory circumstances with standard clothing and standard activity up to 95 % satisfaction is recorded. But in a real building there always exist nonsatisfaction and compliances.

2.1.2 Unoccupied Periods

The accebtable thermal conditions are naturally requested only at working hours f.ex. 8 to 16. Energy used for heating of buildings to get conditions comfortable when they are unoccupied is wasted. By setting back the temperature level at nights, during weekends and other unoccupied periods saves energy. The amount varies with the length of time and number of degrees that temperatures are set back.

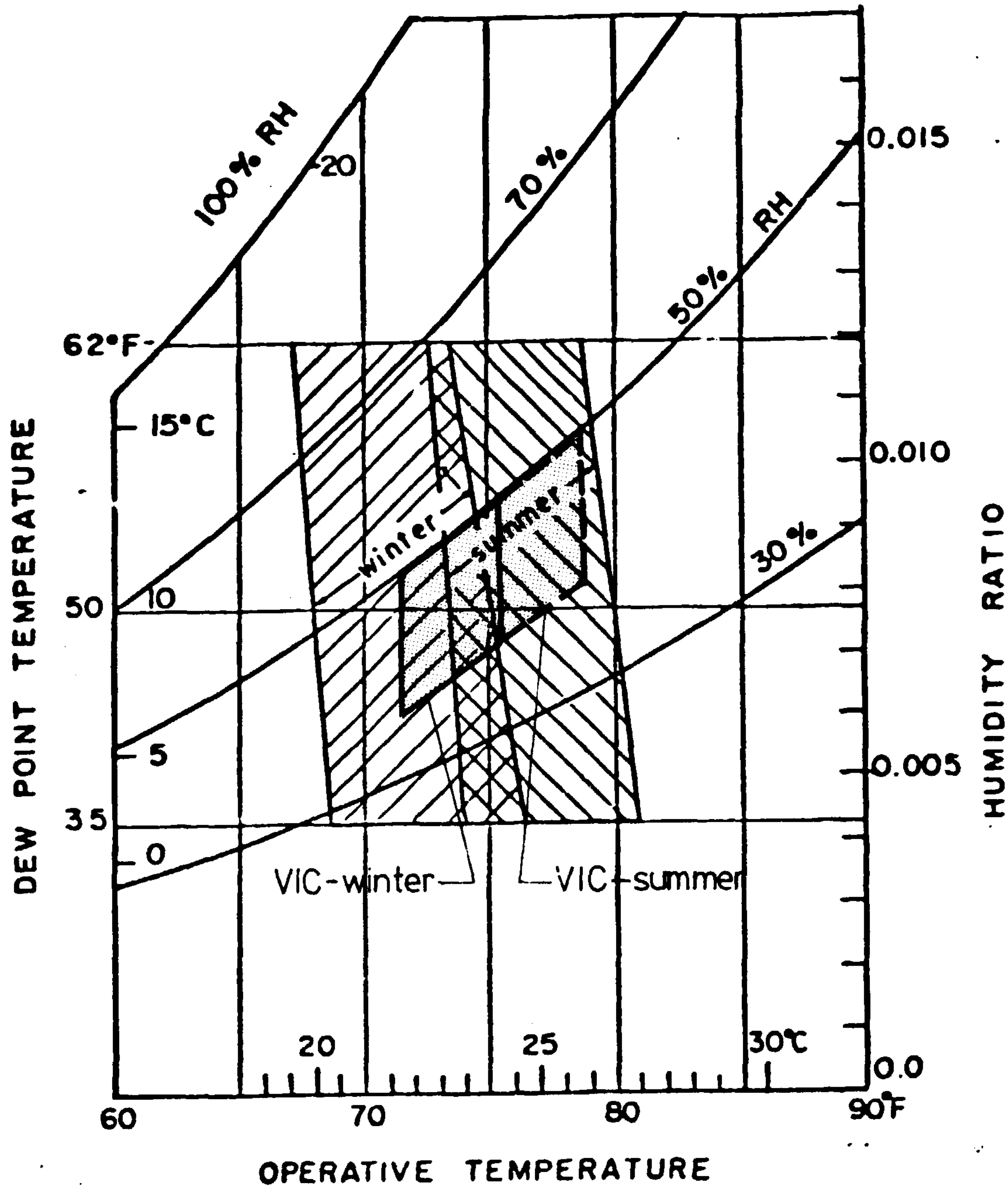


Figure 1/2. Acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light, mainly sedentary, activity

Because of heavyweight construction in the VIC complex, the night set-back in practice cannot be more than 5 °C. Elsewhere the warm-up will take too much time. This temperature set-back causes no harm to the users of the building, because the temperature decreases very slowly after working hours. Thus the cleaning and overtime work can be done in fairly good thermal conditions. In addition, the indoor temperature at the end of working hours is often higher than the minimum accebtable value, that is a wanted room temperature. Thus the energy obtained from internal loads and from the sun helps us to keep the indoor temperature in accebtable range after the air conditioning has been switched off.

2.1.3 Humidity

Designed indoor relative humidity at the VIC is 40 to 50 %. These very strict limits can be extended to 30...60 % r.h. without significant discomfort. Energy saving will be remarkable.

Energy is wasted when humidity is added to a building, since the latent heat of evaporation must be offset. Therefore, no special humidification control should be provided in winter except to maintain a minimum of 30 %.

For areas requiring special humidity control for a process or special material, these standards should be modified, but only for the particular area of the building requiring selected control.

2.1.4 Recommended Indoor Conditions for the VIC

Considering the latest thermal comfort studies and energy savings potential, indoor condition ranges shown in Table 1/2 can be recommended for the VIC.

Table 1/2. Indoor condition ranges recommended for the VIC

Season	Temperature range	Humidity range
Winter	21...24 °C	30...70 %
Summer	23...26 °C	30...60 %

Principally the thermostat set points should be kept in heating season near the lower temperature limit (21 °C) and in cooling season near the higher temperature limit (25 °C). In the practice in the VIC these things can best be done by controlling the heating and cooling supply water temperatures and primary air temperatures to the induction units by means of a building automation system.

2.1.5 Ventilation Standard

Typically, the amount of primary supply air is chosen to meet the ventilation requirement, and air conditioning is achieved by induction coils. Only moisture content of primary air is controlled according to the indoor humidity requirements, but cooling or heating by primary air has a minor role.

At the VIC the primary air rate (outdoor air) is 30 m^3/h respectively with supplementary ventilation in certain rooms 120 m^3/h per induction unit. Thus the minimum fresh air per person is 12,5 l/s (45 m^3/h) when 2 persons occupy the 3 module room. These numbers are fairly high because minimum ventilation requirements per person according to the ASHRAE ventilation standard 62-73 are

- non smokers 2,5 l/s (9 m^3/h)
- heavy smokers 10 l/s (36 m^3/h)

Because of a mixed number of smokers and non-smokers the average minimum ventilation requirement could be 5 l/s (18 m^3/h) per person in the VIC. However, the cooling and heating capacity of an induction unit reduces with decreasing of primary air, and thus the primary air quantity probably can not be reduced lower than 20 m^3/h per unit, i.e. 8.4 l/s (30 m^3/h) per person.

Generally the VIC is much less occupied than is mentioned before, and thus outdoor air flows considerably exceeds the ASHRAE recommendations for heavy smokers although the primary air flow would be reduced to 20 m^3/h per a module.

2.2 Illumination

2.2.1 Lighting Standard

Lighting standard for VIC has been the following:

Office rooms in office towers	600-650 lx
Corridoors and entrance halls	150-200 lx
Other officerooms-outer zone	450-550 lx
Conference halls	450-500 lx
Kitchen	400-500 lx
Restaurant	100-150 lx
Other rooms	150-700 lx
Technical rooms	80-120 lx

Standards followed nowadays indicate that needed illumination levels are the following (Philips, Lighting Manual, 1975).

Office rooms	500 lx
Corridoors and entrance halls	150 lx
Conference halls	300 lx
Kitchen	300 - 500 lx
Restaurant	200 lx

No big differencies can be seen. Office rooms could however have a little lower illumination level.

3. Electrical Equipment

3.1 Lighting

3.1.1 Specific Electricity Power

According to latest recommendations and standards the office room specific electricity power (W/m^2) of Vienna International Centre seems to be relatively high. Normally lighting takes 50 % of the electrical energy consumption in office buildings and this means that lowering of specific electricity power can bring great savings. It is possible to keep illumination at working places the same as now.

Typical office room for one person (D 20 69) has floor area 14.13 m^2 and has nine 40 W light units. Electrical power needed for lighting is then 9 x 48 W = 432 W. That means 30,6 W/m^2. Lights can be controlled so that 1/3, 2/3 or 3/3 is switched on.

In most modern office buildings there is the specific electricity power 19,3 W/m^2 in two persons' rooms and 14,7 W/m^2 in single rooms (Dubin-Mindell-Bloome Associates).

Total office room floor area is 103 500 m^2 for 4 300 persons. Lighting power in office rooms is 9 x 40 W per 14,13 m^2 = [illegible] modules. That means that total office room lighting power is 2640 kW. According to Wiener Stadtwerke electrical energy costs are in winter 0.894 S/kWh and in summer 0.559 S/kWh.

It can be estimated that the lights are normally on 1 050 hours annually of which 600 hours during wintertariff and 450 hours during summertariff. Thus annual office room lighting costs are

Winter	1.08 x 0,894 x 600 x 2640 S	=	1 529 400 ATS
Summer	1.08 x 0,559 x 450 x 2640 S	=	717 200 ATS
Totally inc. VAT			2 246 000 ATS

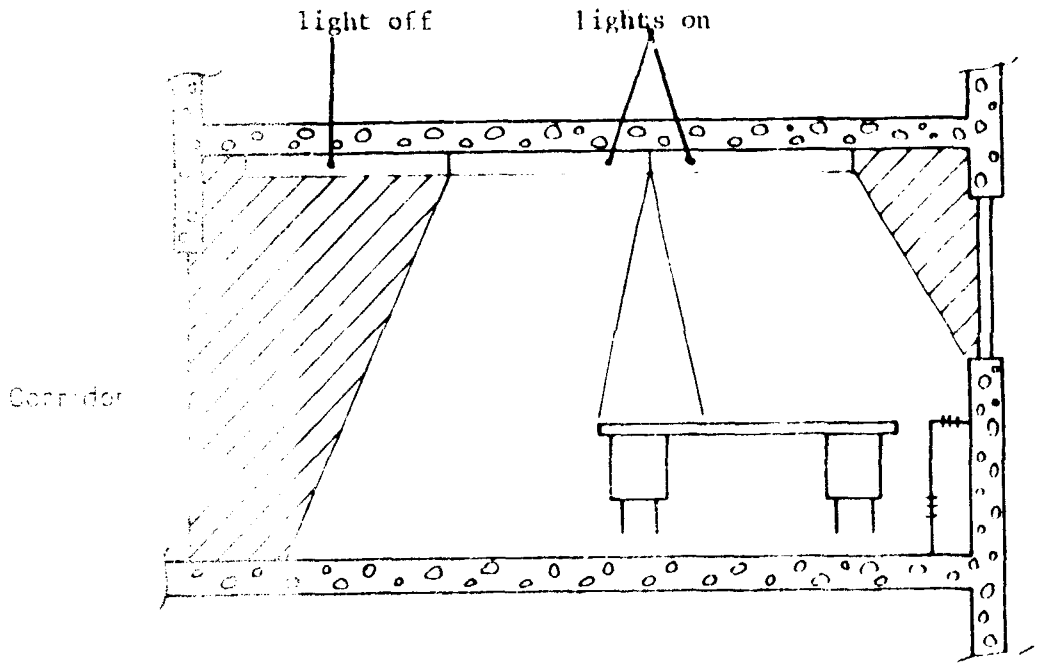
If good orders and control of switching off the light evenings and when leaving the room make it possible to reduce the on-time of lights 1 h/working day and the number of working days is 257/year, the savings would be 349 900 S annually

If lighting power can constantly be as 2/3 instead of 3/3 it can save 743 900 ATS/a assuming that the lights are on 1 050 h/a.

40 W tubes could also gradually be changed to 36 W tubes, which consume less energy and give better illumination. These are more expensive (2-2.5 times) than normal tubes. They are manufactured by Osram, Philips, Airam etc.

Figure 1/3.1

Principle of reducing the specific electricity power (W/m^2) in office rooms



Illumination at working place will remain normal

3.1.2 Lighting Control

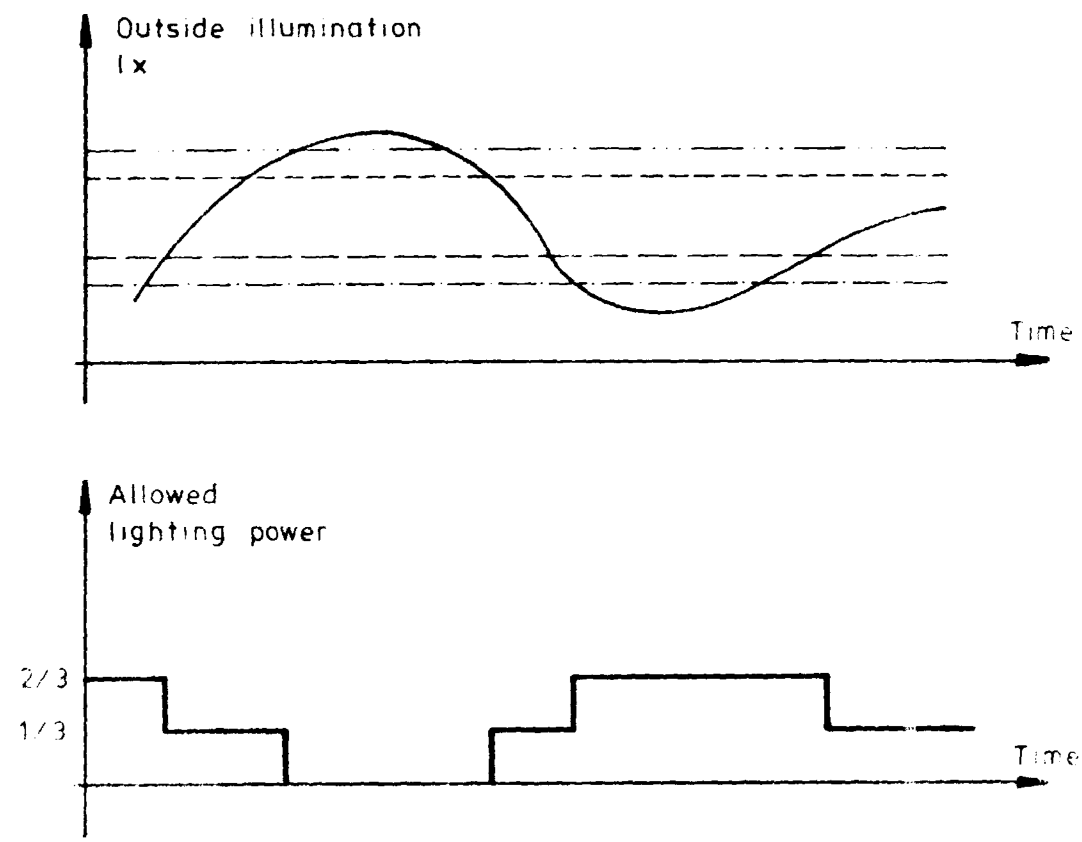
Lighting control after first reducing the maximal lighting power could be made by building automation system so that light groups can automatically be switched to half of maximum or totally off. This can be used in office rooms and also at outer zone lighting groups, when lights are unnecessarily on.

The building automation system should be provided with outside illumination level sensor.

A few sensors (1-4) will maybe be needed to take into account differences between facades.

By using limits for outside illumination level a function can be applied by which inside lighting will automatically be switched off when lighting from outside is enough for good working conditions.

Figure 2/3.1 Principle of lighting control based on outside illumination level sensor



Outside normal working time the lights should by off-command once/hour be automatically switched off by the b.a. system. Local working lamps will be recommended.

Smaller lighting control groups for building automation system would be needed.

Corridor lighting excluded emergency lights should automatically be switched off between 19.00...07.00 and during weekends and holidays. The same concerns technical rooms and WC-groups.

3.1.3 Light Groups

Light groups which now can be switched on and off by building automation system cover a great floor area, in office towers for instance four office room floors form one group. This means that it is very difficult to apply methods by which light groups can be switched off automatically by building automation system. Somebody can always be working in some room of the four floors.

Principally the light control groups are office group, corridoor group, WC-group, technical room group and emergency light group. Each of these group covers four floors.

By using smaller groups and using the working rooms so that always one homogenous working group is behind one light control group as far as possible it would be possible to prevent the lights from being on outside working time.

Now it is possible to switch-off the lights completely so that just emergency lights in corridoors are on. Office rooms can be limited to one third of maximal light power or completely switched off.

Building automation system is provided with a sensor which gives a contact signal when outside light level is over presettled limit (750 lx). By the reaction programs of the building automation system the lights can then be switched off.

Time programs of the building automation system are used so that between 19 ő clock in the evening and seven ő clock in the morning just emergency lights can be kept on.

For evenings the light control could be arranged so that just one third of the lights can manually be switched on and off-switching command will be sent once per hour or two hours from 21 to 24 ő clock.

In restaurant the outer light rows should be built as a separate group which can be switched off manually or automatically when outside illumination level is high enough. The same has already been done in printing halls.

Parking house should be provided with separate light groups for runways and traffic signs and other spaces. Concrete ceilings could be painted white to give better natural lighting if this is practically possible.

Light groups which are not now controlled by building automation system, could be provided with local clock switches by which they can automatically be switched off outside normal working time. It is however, preferrable to connect them to the building automation system if some of the substations of the building automation system is near the right final distribution board.

3.1.4 Costs and Feasibility

The savings consist of lower maximal light effect can be get. If office rooms can manage with just 2/3 of the maximal effect used now the savings can be up to 750 000 ATS annually.

Reconstruction of light control groups can prevent lights from being on unnecessarily. This can bring savings in cafeteria and other deep room spaces. Off-command to these outer light zones can come from the building automation system.

In part or the staircases the lighting level can be reduced to about 1/2 of the level now. Because these lights are always on savings can be great.

Reduction of lspecific electricity power in office rooms can be made very easily by simple wiring changes and it can bring great savings.

Dividing of light control groups to smaller parts means changes to final distribution boards and new outputs to building automation system and some new wiring. Costs of the changes in final distribution boards are difficult to estimate. New output to the building automation system costs about 3000 ATS.

Light power reduction in staircases does not bring any costs but just savings depending the number of tubes that can be removed. At least part of the staircases seem to have double so much light as is needed. Every second 40 W tube can be removed.

3.2 Rotating Machines

3.2.1 Shortening of Running Time

At this phase the only really feasible way to save energy is to make the running time of fans, pumps and chillers as short as possible.

One way to do it is to use the time programs of the building automation system to stop the machines always when it is possible.

Second way is to check the local interlockings between fans and pumps or chillers and pumps to be sure that too big machine groups are not running simultaneously.

Third way is to use the reaction programs of the building automation system to stop heating water circulation pumps if heating is not needed or cooling water circulation pumps if cooling is not needed.

The effect of time programs can be made better by adding to them the so called start/stop optimizing function by which the needed starting time of heating or cooling in the morning or allowed stopping time of heating or cooling in the evening can be calculated.

By using breaks in the normal run of air conditioning units so that they would be stopped for five minutes once per hour the saved running time of ACunits would be 1 hour/working day. This means in buildings A-G about 2 580 kWh per day. This could save in winter about 2 491 S/1 day and in summer 1558 S/1 day. Practically it is not possible to use this kind of method for all machines, but it can be seen from following table how much electrical energy a break of all machines for one hour can save electrical energy in each building object in winter and in summer.

Building object	Power of machines kW	Price of one hour winterday S	Price of one hour summerday/ S
A	468.60	453	283
B	234.70	227	141
C	501.70	485	302
D	237.70	230	144
E	235.40	227	143
F	689.30	667	416
G	213.20	205	129
Totally	2580.6	2491	1558

Taxes 8 % have been taken into account.

3.2.2 Supply Areas

The room areas which each air-conditioning unit is serving are relatively large and there are various types of office functions at those areas so that the working time can be different or at least the functional rhytms are different.

The use of room spaces should be carefully considered in order to find such arrangement that the working time and so also need for heating, ventilating and cooling is the same in the whole area which is served by same air-conditioning unit.

This is important specially in the office towers. There each floor is divided to three parts which are served by different air-conditioning units. Each horn of the star (the form of the floor is star) has its own air-conditioning unit. One unit serves for instance floors 16-28. So people who are working in the same horn of office tower A in floors 16-28 should have as far as possible the same working time to make possible to keep the running time of the air-conditioning unit as short as possible.

Air-conditioning unit ACK 14/003 for instance takes care of 1/3 of office tower B in floors 16-28. The electrical power of that unit is about 84 kW taking in account fans and pumps. One hour of running time of that unit costs during daytime in winter 1.08 x 0.894 S = 81.10 S and in summer 1.08 x 84 x 0.559 S = 50.99 S as electrical energy costs.

If there are 257 working days in the year and 6 winter and 6 summer months per year we find out that one hour daily means at ACK 14/003 electrical energy costs in winter (october-march) about 10.400,- S and in summer (april-september) about 6.500,-S and totally 16.900,- S.

3.2.3 Costs and Feasibility

Shortening of the running time of the machines does not cause any additional costs in the case of machines which have already been connected to the building automation system. In the case of other machines costs are caused by building of new connections to building automation system, changes to final distribution boards and new wiring. Exact costs are found out by asking tenders from electrical and control and building automation system contractors.

The total power of air-conditioning machines and pumps in building parts A-G is about 2580 kW. Shortening of the running time of them one hour brings 2580 kWh savings. The meaning of this is in money, depending on the season and time of the day, following:

Winter day	06-22 ó clock	2580 x 0.894 S x 1.08 = 2491 S
October-march night	22-06	2580 x 0.726 S x 1.08 = 2023 S
Summer day	06-22 ó clock	2580 x 0.559 S x 1.08 = 1558 S
April-september night	22-06	2580 x 0.391 S x 1.08 = 1089 S

Energy prices used above are prices which have been applied from 1.7.1980.

When the number of working days of the year is about 257 does one hour's shortening in the running time of all machines in buildings A-G daily during daytariff bring savings 129 x 2491 S + 128 x 1558 S = 520 800,- S annually.

It is well known that part of the machines do run always and it can be estimated that just 70 % of them can be controlled. Then the shortening of running time one hour daily can bring about 364 600,- S savings annually. During weekends the machines are normally stopped. Just the most important pumps are running.

Two hours daily shortening of the running time would bring 729 200,-S savings annually. Shortening of the running time of the machines saves also heating and cooling energy.

Figure 1/3.2.3 Savings of electrical energy if 70 % of the electrical machines can be stopped one hour daily during daytariff.

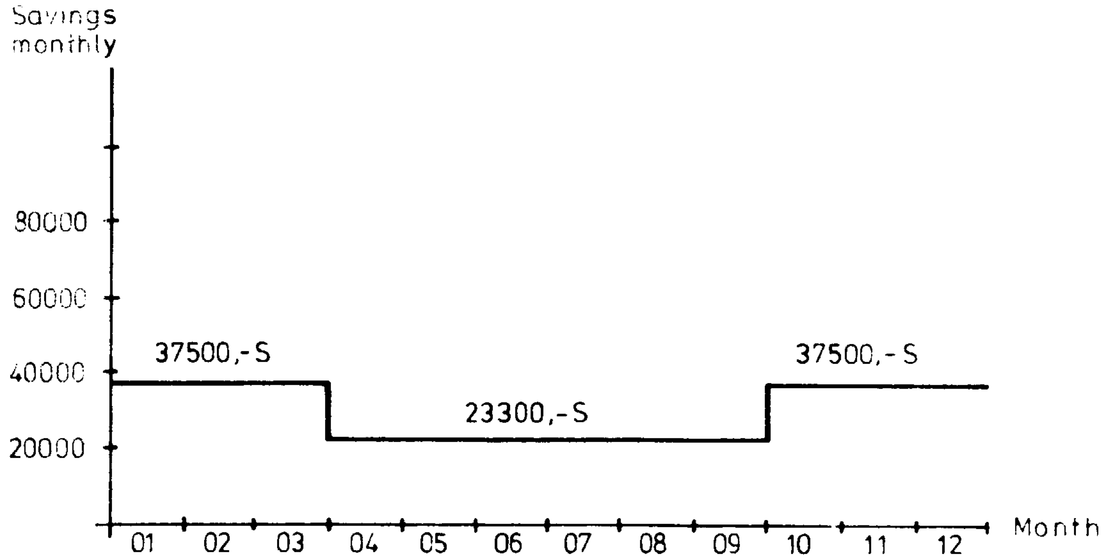
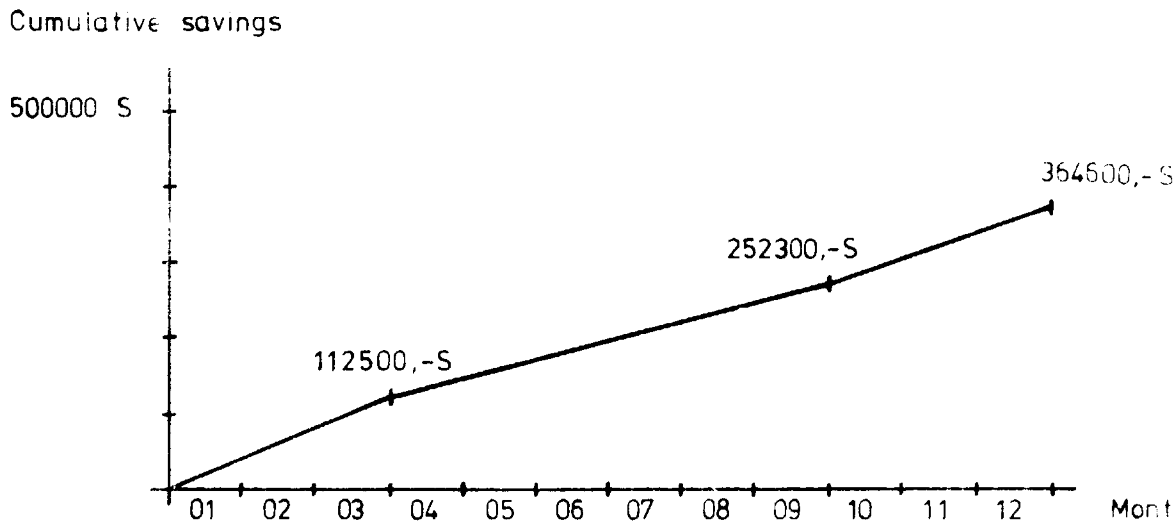


Figure 2/3.2.3 Cumulative savings of electrical energy if 70 % of the electrical machines can be stopped one hour daily during daytariff.



It is reasonable to start first shortening the running time of machines which are already connected to the building automation system and to go through all other machines to find out if they could be stopped for part of the time too. Specially heating and cooling water network pumps are objects which could be stopped for long periods without problems.

3.3 Optimization of Operation by a Building Automation System

3.3.1 Utilization of Time Programs

The building automation system in the VIC consists of 9 different day programs and 2 different week programs, by which the objects under control can be switched on and off. One of the week programs takes into account exceptional weeks, whereas normal weeks are included in the other.

By time programs it is possible to define the time for on/off switching of the equipment and illumination with one minute's accuracy.

For saving electric energy, time programs can be utilized so that starting and stopping of each air-conditioning unit as well as changing of fan speed is continuously kept such that they correspond to the real need, and that all needless operation is prevented. Similarly, needless illumination will be prevented.

For effective utilization of time programs it is provided that the person (operator of the control room or his superior) who takes care of the programs, knows well the use of the spaces in each air-conditioning and illumination area, and is thus able to change the on/off switching times to correspond to the real need. Effective communications between the control room and the organizations using the spaces are necessary.

It is also important that the air-conditioning and illumination areas should synchronize with the working places of the organizations, because otherwise in the area of the same air-conditioning unit or illumination group there may be organizations, whose working hours differ from each other remarkably, and thus units with great energy consumption have to be operated for a longer time than would be necessary.

The supply areas of air-conditioning units are very large in the VIC. One unit can take care of air-conditioning of one third of the floors 16...28 in one office tower. It is very difficult to make organizations so that part of an organisation is using only one third of the floor area in each floor and several floors at the same time. As long as the working hours are the same, this makes no problem, but it will bring us to the fact that adapting of various working hours becomes expensive, if air-conditioning equipment have to be operated since the first person has entered the building in the morning until the last one has left it in the evening.

In spite of these restrictions it is worth aiming at shortening of operation time by starting the apparatus late in the morning and by stopping them early in the evening. During the daytime it is maybe possible to switch off the air-conditioning for 5...10 minutes a few times; thus a one hour's shortening can be easily caused to a daily operation time. It is useful to carry out the starts step by step.

Illumination can be switched on and off with time programs in similar way as air-conditioning. However, illumination groups are rather large, which gives the only possibility to switch on the light at 7.00 in the morning and to switch it off at 19.000 in the evening, as it is done at present. In parts A, B, D, E, F and G. there exist altogether 40 remote-controlled illumination groups, by which the illumination in office rooms can be diminished into 1/3 and in corridors switched off on the whole. In addition, the corridor illumination is connected to outside illumination sensor which above 750 lx gives a sign to the building automation system to switch off the corridor light.

The flexibility to change time programs makes it possible to have large savings, as it can be seen in 3.2.3. However to achieve these savings the users must have activity and knowledge on how much it can be saved by different activities.

3.3.[illegible] Start/Stop Optimization

Start optimization is a function which enables a more exact starting of air-conditioning equipment in the morning, compared with time programs. The starting time is not fixed, but depends on outside temperature, inside temperatures in pilot rooms as well as on the length of the stopping period. The time needed in the morning for setting room conditions back to the normal level is calculated with programs every night, and air-conditioning is started automatically so that the room temperatures are just inside the limits of comfort during times shown by time programs. Thus the operation time of air-conditioning units can be shorted, and the room temperatures can decreased relatively low during the stops. Savings will be achieved both in electric and in heating energy.

Saving achieved in the operation time of air-conditioning equipment is about one hour per day in winter.

Greater savings will still be achieved, when the stopping moment of the air-conditioning equipment is made dependent on room conditions.

3.3.3 Control of Cooling Equipment

By directing the cooling power to those parts of building, where cooling demand is big, and by reducing it in parts, where it is smaller, the annual operation time of the cooling equipment can be reduced.

3.4 Peak Power Limiting

3.4.1 Possibilities, Variation of Electric Power

Variations of electric power are extremely regular in the VIC. Air-conditioning equipment, pumps and illumination make a load, which is switched on appr. at 6.00 in the morning and off. appr. at 17.30-19.00 in the afternoon on working days. During week-ends there exist hardly any other loads but illumination. The power of air-conditioning equipment and pumps is in buildings A-G appr. 2580 kW and that of illumination about 3.000 kW. The increase is caused by the three cooling machines, each 1600 kW, and by a cooling tower, which has pumps of about 1000 kW.

Seven diesel generators with power of about 4255 kVA work as emergency power generators.

Costs for maximum power are at present 86.10 s/kW per month. The maximum power so far has been appr. 8.400 kW.

Maximum power can be limited by carrying out the starting of equipment step by step, by operating them by turns, and by avoiding operating of cooling equipment. Furthermore, a special power limiting program, which enables us to keep the used electric power under a certain limit, is available for the building automation system.

In the VIC good objects for the maximum power limiting program to be used are air-conditioning equipment, chillers and the pumps of the cooling tower, big pumps for water circulation as well as separate exhaust fans.

However, each object to be limited must be carefully considered i.e. what is the limiting priority (1-3), the maximum limiting time, the minimum interval between limiting regulations, and the limited power.

The limiting controls are started from the lowest priority range, and so many objects are stopped as is needed according to the calculated limiting demand. Electric energy measurement of the building by means of which power is calculated with programs, is needed as initial data. For each part of building an independent program can be used, as far as energy measurements have been connected to the building automation system. The program has medium power during 15 minutes under the limit given to it.

3.4.2 Costs and Feasibility

If a 500 kW power lowering can be made by air-conditioning equipment, it is possible to achieve savings of 12 x 500 x 86.10 S = 566 600 S every year.

If 2000 kW maximum power can be compensated by diesel generators at the same time as a chiller or several chillers are operated, annual savings of 12 x 2000 x 86.10 S = 2 066 400 S are achieved.

The price for a maximum power limiting program is appr. 150 000 S, and it can be stated that it will be amortized in no more than four months. Connecting of energy measurements costs about 45 000 S.

Using of diesel generators for peak limiting presupposes changes in the electrical distribution boards, but since the annual savings in maximum power costs are over 2 000 000 S, there should be no problems for carrying out the changes. Starting of the diesel generators can be done by already existing reaction programs of the building automation system. In addition, the system needs control output points for the diesels and information on the status of operation of cooling machines. The costs are appr. 40 000 S.

3.4.3 Utilization of Emergency Power Generators

It may be worth using emergency power generators also for other reasons than for limiting maximum electric power. If they are provided with heat recovery equipment for recovering of cooling heat for ex. to domestic water pipework, it is worth using the diesels almost for the whole winter, as far as the price of energy is concerned.

On the other hand, however, they are not meant for continuous use. Noise and waste gases may also cause problems.

3.5 Equipment Supplies and Needed Work

3.5.1 Limiting of Maximum Power

It is necessary to add the limiting program of maximum power to the building automation system SDC 7001 delivered by ITT. This causes costs of about 150 000 S including start-up.

Electric power measurements have already been connected to the building automation system, but if control and limiting of maximum power in each building is wanted, energy counters have to be connected to the system. If local counters are already provided with an impulse output contact this causes costs of about 3 000 S per one measurement. If a counter has not an impulse output contact, it has to be added to it or the counter has to be changed. Extra costs are about 6000 S per a measurement. It must be noticed that the same measurements can be utilized also in reporting of energy consumption.

If the chillers are used in limiting maximum power, remote control from the building automation system has to be built for them. It may be that the same concerns the pumps of the cooling tower, if they are not locked to the cooling equipment. One extra control output point costs about 3000 $ including cabling and connections.

[illegible] Connection and Control of Emergency Power Generators

Connection changes are needed, because the emergency power generators should be able to feed power, for limiting of maximum power, also to the normal electric network of the building and not only to the part secured by diesel.

It is difficult to estimate the costs of the changes, but the truth is that they are small compared with the profit achieved by it.

For each emergency power generator also control from the building automation system is needed. Actual program changes are not necessary. Starting of the emergency power generators can be carried out by reaction programs similarly with starting of cooling equipment or when the total electric power has exceeded the limit set for it.

4. Heating, Cooling, Air-Conditioning and Sanitary Equipment

4.1 General Systems Description

Heating

Heating energy to the buildings comes from the district heating network of the city of Vienna. The internal 110/70 °C heating network of the VIC is separated from the 140/80° district heating network in the heat distribution centre located in building C.

Cooling

There exist in the technical centre three turbo-compressors provided with cooling towers for cooling of water. Cooling capacity is altogether 75 GJ/h and the total electrical input of 4800 kW. The temperatures of primary cooling water network, going from the refrigerating plant to separate buildings, are 6/12 °C.

Water Supply

Municipal water comes from the network of the city of Vienna. Pressure increase installation are required by buildings over 40 m. In the highest buildings B 120 m and D 100 m there exist two pressure increase steps. Heating of hot water up to 45 °C and in the kitchens up to 65 °C is carried out in the central hot water preparation plants by internal 110/70° heating circuit separately in each pressure stage and supply area.

To decrease corrosion and incrustations in the pipes, phosphates are dosed in raw water. Hardness of warm and cold water going to the kitchen is kept constant 4°...6° dH. The water used for humidifying the air for the air-conditioning systems is also softened. An algaecide is injected to prevent the formation of algal in the humidifiers.

Air-Conditioning

Supply air plants are located on mechanical floors. Each supply air plant serves one third of each of the floors above or below the mechanical room. Supply air is filtered, heated and humidified in winter, cooled and dehumidified in summer. High pressure supply fans then transport the air via vertical ducts to the horizontal distribution system on each floor.

Exhaust air plants are located away from the supply air plants generally on the roof. None recirculation systems exist except in the building C.

The rooms located in exterior zones are supplied by means of high-pressure induction units. A four-pipe induction unit with a primary air rate (outdoor air) of 30 m^3/h is installed under each window (module 88 cms).

The buildings D and E provide the possibility to supply by means of the induction units about 40 modules with an increased air rate of 80 m^3/h. In the buildings A and B a similar effect can be obtained for 18 modules per floor by supplying 110 m^3/h per module throught separate ducting systems with air jet outlets.

The rooms situated in the interior zones are supplied with fresh air blown out over expansion boxes with after-heat coils.

Ventilation of the entrance halls is carried out by low pressure air conditioning. Each entrance hall is additionally equipped with two recirculated air systems.

4.2 Selection of Room Conditions

4.2.1 Temperature Decrease

As it has been presented in chapter 2.1.1, the indoor temperature could be kept in 21 ^oC instead of the present 22...24 ^oC in winter. Decrease of one degree, in average, in indoor temperature reduces the heating energy consumption of a building approximately 1.9 $kWh/m^3/a$, i.e. 6 %, Fig. 1/4. As to the whole complex of the VIC, decrease of one degree means savings of 2000 MWh heating energy in a year.

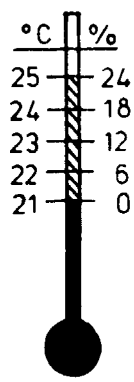


Fig. 1/4. Heating energy consumption of a room is increased a. 6 % by every degree over the minimum set value.

In summer the indoor temperature could be corrrespondingly increased from the present 23 °C to 25 °C. Increase of two degrees in indoor temperature reduces the cooling energy consumption of a building approximately 2.2 $kWh/m^3/h$, i.e. 20 %. For the whole complex of the VIC this means savings of 2300 MWh cooling energy and 850 MWh electric energy in a year.

4.2.4 Humidity

According to chapter 2.1 the allowed limits for humidity in winter are 30...70 % and in summer 30...60 % r.h. Decrease of minimum room air humidity from 40 % to 30 % corresponds to a decrease in humidity of primary air flow from 6.8 to 4.8 g/kg in average. This means savings of appr. 5.0 $kWh/m^3/s$ per year, i.e. appr. 15 % in heating of air-conditioning. Calculated for the VIC as a whole the savings are 3700 MWh/a.

Extension of humidity range has no meaning for cooling energy consumption, because controlling of room temperatures requires intense cooling of primary air and contemporary drying. Since humidity sources of rooms are slight, also the room air remains rather dry in summer.

4.2.5 Costs and Feasibility

Changes of control set points do not cause any delivery costs. If a measure is considered relevant, it is carried out without further delay; savings achieved by the reduction of energy consumption are presented in Table 1/4.

Table [illegible]. Savings achieved by different indoor temperature and humidity ranges in each building.

Building	Indoor temperature range [illegible] Annual savings Heating MWh	Electricity [illegible]	Total [illegible]
A	380	160	285.000
B	150	65	110.000
C	320	135	240,000
D	300	130	225.000
E	200	85	150.000
F	450	190	335.000
G	200	85	150.000
VIC	2.000	850	1.495.000

Indoor humidity [illegible]

Annual savings		
Heating MWh/a	Electricity MWh/a	Total ATS/a
585	-	288.000
250	-	123.000
715	-	352.000
510	-	251.000
330	-	163.000
1.095	-	540.000
215	-	106.000
3.700	-	1.823.000

4.3 Reducing of Primary Air Flows

4.3.1 Objects

Possibilities to reduce air-conditioning have been dealt with in chapter 2.1.5. According to that chapter air flows could be reduced in office towers with one third, i.e. to 20 m^3/h per module. Similarly, basic air-conditioning of the meeting rooms could be reduced, but a possibility to use increased air-conditioning is good to keep for very high occupancy rates. Air flows in the halls of the conference building (C) should also be checked and adapted to the present standards.

4.3.2 Flow Control

Air quantities in office rooms are adjusted by pitch control in axial fans and by changing of wheels in radial fans.

In air-conditioning plants of the conference building, which use recirculation, new rates for outside air flow are best to give by changing the set value of minimum fresh air flow. Then it is always possible to use the present full outside air flow. As far as cooling is concerned, it is advantageous to use much air recirculation, since then power demand is diminished (see enthalpy optimization 4.7.7).

4.3.3 Energy Conservation and Impacts to the Room Units

Reducing of air flows by 33 % reduces at the same time the heating, humidification and cooling demand of primary air as well as electric consumption of the fans, but at the same time also the cooling and heating capacity of induction units is reduced. The figures for these changes are presented in Table 2/4 by using supply air plant ACK 14/003 as an example.

Table 2/4. Influences on power demand and energy consumption after primary air flow has been reduced by 33 1/3 % with an examplary plant ACK 14/003 (16.36 m^3/s).

	Reducing of peak power kW	Reducing of consumption MWh/a
- Heating demand of primary air	330	180
- Cooling demand of primary air	180	50
- Supply air fans	15	47
- Exhaust air fans	6	19
- Humidification water	0.03 l/s	90 m^3/a

Table 3/4. Capacities of the induction units are changed followingly when outside air flow is reduced:

	Present data		Revised data	
Primary air flow	8.33	l/s	5.56	l/s
Heating				
- Primary	40	W	27	W
- Secondary	540	W	555	W
			(supply water temperature increased)	
Cooling				
- Primary	81	W	54	W
- Secondary	326	W	238	W

Due to this measure the electricity power demand for cooling the whole zone (ACK 14/003) is reduced 67 kW, and cooling load of the a/c plant is reduced 180 kW.

4.3.4 Costs and Feasibility

In office rooms it could be possible to reduce the outside air flow, 30 m^3/h per module at present, to 20 m^3/h, i.e. by one third, without causing any horm to indoor air quality. Reduction of air flows is best carried out by an air-conditioning contractor. The costs caused by changing the air flows of altogether 68 fans are approximately 91.000 ATS. Savings are caused by decrease of energy for heating, fans, and cooling compressors, as well as by decrease of electric peak load. Due to this measure the air quality of the rooms remains good, but heating and cooling power of the induction units are reduced by about 26 %. Reduction of heating efficiency can be compensated by increasing the heating water temperature. Reduction of cooling load cannot be entirely compensated by decreasing the cooling water temperature. Humidity in rooms remains unchanged. Energy savings and costs per each building are presented in Table 4/4.

The primary air flows of office rooms are changed also in case that heat recovery equipment are installed in airconditioning plants of the office towers. Thus the supply air flow is reduced about 10 % and the exhaust air flow about 15 % by the pressure loss of heat recovery coils. About one third of the savings presented in Table 4/4 are caused by this reduction of air flows by heat recovery. In addition, there are savings achieved by heat recovery, i.e. approximately 50 % of the energy

energy consumption of air-conditioning. Reduction by heat recovery has also the advantage that in summer the supply air coils are by-passed, and full cooling power is available from induction units. Exhaust air flow could be increased 5 % in connection with heat recovery so that in winter the buildings would be neutral by pressure, and in summer slightly overpressurized.

There exist reducing possibilities of air flows also in other air-conditioning equipment (not only in office rooms). Such spaces are: corridors, office rooms in inner zones, library, etc. Air-conditioning in those spaces should be compared separately with one of the new air-conditioning standards published after the energy crisis and which could be approved by all the groups concerned in the VIC.

Table 4/4. Reduction of Primary Air Flows by 33 % in Office Rooms

Building	No of fans	Intake air existing m^3/s	Intake air new m^3/s	Exhaust air existing m^3/s	Exhaust air new m^3/s	Annual savings heatings MWh/a	Annual savings electricity MWh/a	Annual savings Water m^3/a	Net savings ATS/a	Total investment ATS/a
A	24	49.9	33.3	50.4	33.8	557	220	274	445.000	32.000
B	12	19.0	12.7	20.3	14.0	211	84	104	169.000	16.000
D	12	51.0	34.0	37.4	20.4	571	226	281	455.000	16.000
E	12	36.2	24.1	34.8	22.7	406	161	200	324.000	16.000
F	4	19.4	12.9	14.2	7.7	218	86	107	174.000	55.000
G	4	10.7	7.1	9.1	5.5	121	48	59	96.000	5.500
VIC	68	186.2	124.1	166.2	104.1	2.084	825	1.026	1.660.000	91.000

4.4 Reducing of Cooling Load

4.4.1 Cooling Load Features of the VIC

A rather moderate starting point for arising of cooling load is caused by the building itself in the VIC. Massive frame, location exposed to winds, possibilities to use daylight, and shadows moving from one zone to another, they all reduce the cooling power demand. Due to spacious occupancy air conditioning per person is abundant and cooling load caused by persons will remain small. However, by its behaviour the personnel is able to increase the cooling demand in the VIC very high by keeping the room temperatures low in summer by means of room thermostates, by requiring an unnecessary accurate control of humidification, and by using artificial light without any good reason, or by neglecting efficient use of the blinds.

Electric peak power demand in the VIC is greatest during the cooling period in summer. Contemporary use of the all refrigeration units cause o peak power load effecting the power fees of the whole year. Therefore, using of maximum cooling capacity becomes expensive. All the possibilities have to be used for reducing the cooling power demand, and for making producing of cooling power easier. Marginal activities should neither be neglected, if they will pay the investments back in a moderate time. Rather remarkable savings could be achieved by adapting of indoor climate conditions (chapter 4.2) and by reducing primary air flows (chapter 4.3). The next chapters include other methods for saving of cooling power and energy.

4.4.2 Solar Protection Films in Windows

4.4.2.1 Using of Venetian Blinds

Light coloured Venetian blinds, nowadays used inside of the windows, reduce, if used properly, the cooling load caused by the sunshine about 40 %. Venetian blinds can be used and they are many times used in a wrong way. Too open blinds let the direct radiation in. Too closed blinds prevent enough daylight from getting in, and thus artificial light has to be used also in bright weather. In the night, both in summer and in winter, the blinds should be quite closed, especially on the eastern facade.

The sun, shining very low in the morning, warms easily, also through between the blades the rooms too warm before the working day and starting of air-conditioning. Extra heat, that could have been prevented by closing the Venetian blinds, has to be cooled off by cooling equipment.

Venetian blinds are an effective solar protector, but the efficiency wholly depends on the user, and it can be stated that in spite of instructional leaflets, personal guiding, and training it is not possible to learn the proper use entirely. Furthermore, people easily leave the Venetian blinds open when leaving the room, and then, on sunny days, an empty room is unnecessarily cooled by room thermostates.

4.4.2.2 Influences of Fixed Solar Protection Films

Fixed solar protectors of windows always work independently of the occupants and with the efficiency that has been designed for them. In the VIC solar protection of windows can be actually improved only by solar protection films which are fixed on the window surface.

They are available from several manufacturers in different colours and in different thicknesses. The best place to fix them is the inner surface of an outer window glass, but when insulation glass is concerned, they must be fixed on indoor surface. On the outdoor surface the film cannot bear the strains caused by washing, rain, wind, dust, etc.

Solar protection films reduce transmitting of solar radiation by reflecting and absorbing energy. Due to this also the glass on which the film is fixed is warmed remarkably more than bright glass. The heat absorbed from the film on the outer surface flows outside with the wind. The heat absorbed from the film fixed on the inner surface flows into the room, and a lot of the effect of the film is lost. A risk of the glass getting broken is always connected to fixing of a film on a bright and especially on a large window. Due to higher temperature, heat extension of the glass may exceed the proper extension length, and the glass is broken by the tensions. In insulating glasses the extension length is short. In the VIC also sudden temperature changes may cause a risk of getting broken to the inside glass. The morning sun warms the inner glass, provided with a solar protection film, much warmer than bright glass, and when air-conditioning is started with cooling, the induction units blow the cold air to the lower part of the glass. The temperature differences between the upper and lower parts of the window surface can cause breaking of the glass.

4.4.2.3 Decrease of Daylight and Heat Losses

A fixed solar protection in a window always reduces the cooling demand, but also reduces transmitting of daylight. Decrease of daylight causes in some extent increasing use of artificial light. Increasing electric consumption of lighting is generally estimated small compared with the electric power and electric energy saved in cooling.

Colour of the film should be selected so that as much visible light as possible could be transmitted, but on the other hand so that other wave lengths should be eliminated as efficiently as possible. The best colours in this respect are green, blue, and gold. The worst are grey and bronze.

4.4.2.4 Influence on the Surroundings

Fixing of solar protection films on windows is not only a question concerning air-conditioning, but also architectural views have to be taken into account. Coloured film on windows essentially change the facades and general appearance of a building. Partial shadows cause a special problem in curved facades. It would not be necessary to provide the whole facade with folios, since the sun shines only on part of a surface, but architecturally, this kind of dividing of facades into different coloured sections may be regarded as a questionable solution. Therefore, an assumption has been made, that those facades on which sunshine strongly occurs, are covered entirely with films, i.e. SE, S, and SW. Fig. 2/4.

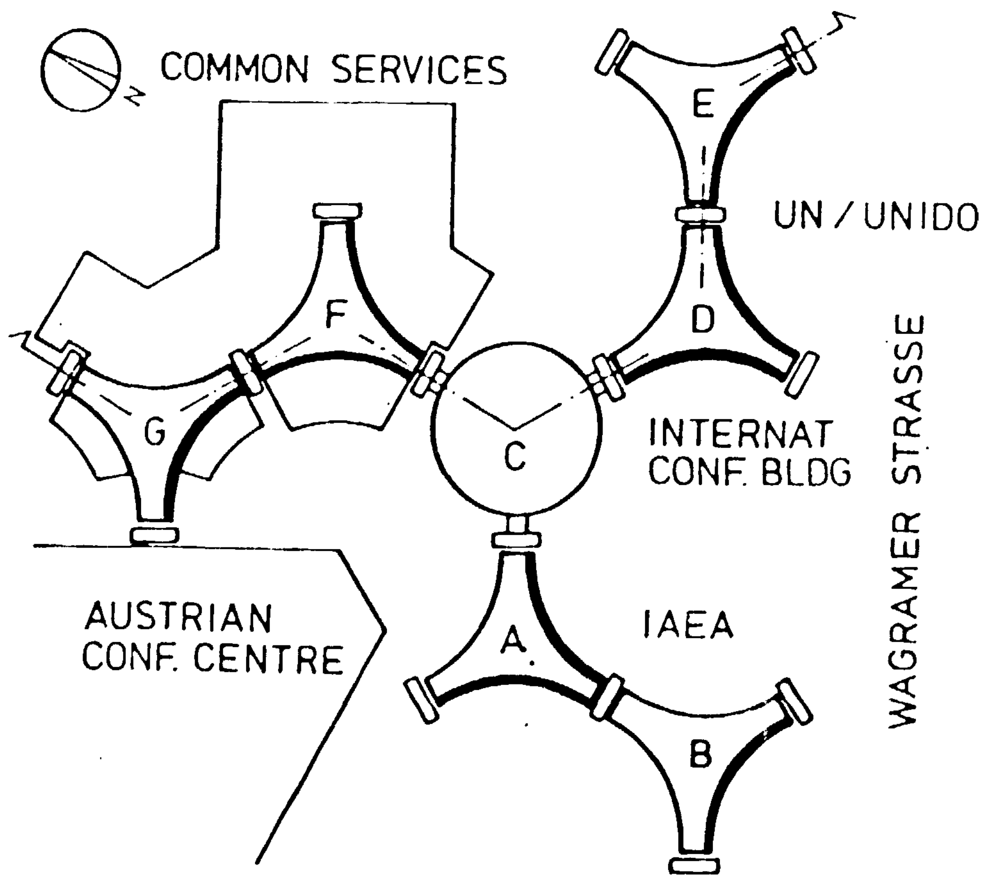


Fig. 2/4. Solar exposed facades drawn with heavy lines

4.4.2.5 Performance of the Solar Protection Films

Solar protection film fixed on a window reduces the heat gain, caused by the window, at most approx. 350 W/m^2. Film influence mainly on room temperatures and cooling energy consumption, but less on cooling peak load.

In extreme outdoor conditions the whole cooling capacity is probably in use, depending on dimensioning, whether there were films on the windows or not. When films are used, the highest room temperatures are lower and better in comfort zone than in a case when films are not used.

Due to films the cooling energy consumption is reduced about 200 kWh per window-m^2 in a year. This means electric energy of about 75 kWh in cooling equipment. A film on the window surface also reduces heat radiation from the window to the surrounding. In winter this means decrease of about 20 % in heat losses of the window. Thus due to films the heating energy consumption is reduced about 43 kWh per window-m^2 in a year.

4.4.3 Reducing of Lighting Power

Possibilities to reduce lighting power and the savings in electricity achieved by the reduction are dealt with in chapter 3.1. In addition, reducing of lighting power also reduces the cooling demand or, when full cooling capacity is in use, decreases high room temperatures a little.

Electricity used in lighting causes almost equal cooling power demand. And for producing cooling effect electricity is needed approximately 0.37 times that because the compressors, pumps, and towers are running. Thus a saving of 1 kW in electricity consumption of cooling equipment is caused by a 3 kW saving in lighting electricity.

4.4.4 Directing of Cooling Power to Different Zones

The maximum cooling power demand and the energy consumption could be reduced, if temperature of cooling waters going to different air-conditioning zones and induction equipment circuits could be adjusted by the building automation system. By keeping the room temperatures of shadowy facades on the upper limit of comfort area, i.e. 25 ^{o}C, more capacity should be available. In principle, these shadowy zones could be cooled beforehand, at the same time as the sun starts shining to them. By advance measures the mass of the structures would be utilized, and the maximum cooling demand would be smaller.

Correspondingly, facades going outside the sunshine should not be cooled any more, but they should be left on the upper limit of comfort area by increasing the cooling water temperature of the group. Carrying out of this method by the building automation system has been dealt with in chapter 4.7.6.

4.4.3 Costs and Feasibility

No costs are caused, in principle by decrease of cooling demand in reducing air flows, or by reduction of lighting load, if they are carried out in connection with normal maintenance work. They are zero-investments, which are carried out immediately, if they are considered relevant.

The only possible way, in practice, to reduce cooling demand by structural means is to improve solar protection of windows. It is a simple task, only fixing of a film on a window, but so far as costs are concerned, it is rather a large investment.

The purchase price for solar protection film, depending on the type, is about 100...300 ATS/m^2. Fixing of films can be carried oyt by the personnel of the VIC in connection with washing of the window.

Due to solar protection folios the cooling energy demand is decreased approx. 200 kWn per window-m^2, which means reduction of 45 ATS/m a in electricity costs of compressors. Correspondingly, heating energy consumption is reduced by about 43 kWh/m^2 a, which means a saving of about 21 ATS/m^2a.

The film requires no maintenance. The age is considered as 15 years.

Table 5/4 presents the heating and cooling energy savings achieved by solar protection films in the whole VIC.

Table 5/4. Savings achieved with solar protection films in cooling and heating

Buildings	Exposed sectors	Film requirements m^2	Annual savings heating MWh/a	Annual savings electricity MWh/a	Net savings S/a	Total investment S
A	red, green	4.680	200	345	306.000	936.000
B	green	890	40	65	59.000	178.000
C						
D	yellow,green	4.010	175	300	207.000	802.000
E	yellow	1.450	60	110	96.000	290.000
F	red,yellow	2.230	95	160	143.000	446.000
G	red	670	30	50	45.000	134.000
VIC		13.930	600	1.030	914.000	2.786.000

4.5 Heat Recovery of Air-Conditioning

4.5.1 Selection of the Objects

In heat recovery as much as possible of the heat in extract air is transferred to supply air. Therefore, it is useful to arrange heat recovery only there where exhaust air flows are remarkable. Let us take zone ACK 14/003 as an example. Air flow of exhaust plant ACK 30/003 is dominant compared with other plant; thus it is chosen as the object of heat recovery. Also air flow of ACK 29/005 is rather great. However, it is not worth installing heat recovery there, because then the whole recovery system would be asymmetric, and adjusting would be inconvenient.

In supply air system heat is conducted to air-conditioning plant ACK 14/003.

4.5.2 Selection of the System

Since the supply and exhaust plants are located far from each other, the only possible systems are a heat pump and an indirect (air/liquid/air) water-glycol-system. Of these two the latter is cheaper and more simple as well as safer in functioning. Furthermore, since exhaust air is remarkably warmer (4 ^oC...6 ^oC) than supply air, reasonable annual energy efficiency is achieved also with a water-glycol-system. In the VIC the water-glycol-system is more adaptable of the heat recovery alternatives.

4.5.3 Principle of the Water-Glycol System

The principle of a recuperative water-glycol heat recovery system is presented diagrammatically in Fig. 3/4. Heat is bound from exhaust air to the liquid that is pumped to a supply air coil. In the supply air coil heat is further transferred into cool supply air.

Adjusting of the system is carreid out by a three-way valve. Liquid flow to supply air coil is limited so that supply air temperature does not exceed the set value, and that humidity of exhaust air does not get frozen in exhaust air coil.

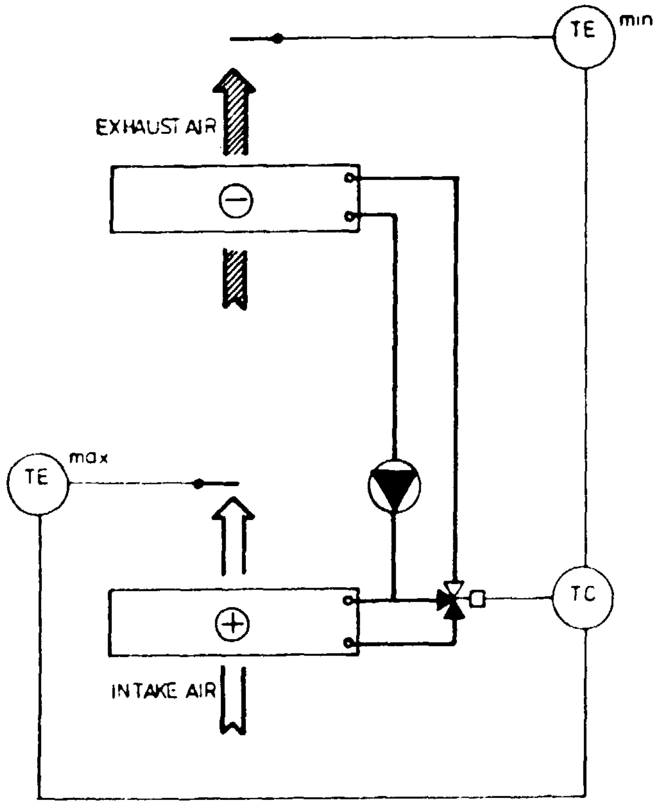


Fig. 3/4. Principle of a water-glycol system

4.5.4 Implementation

An example of installation of exhaust and supply air coils is presented in figures 4/4 and 5/4. Due to the big size it is necessary to divide the coils into smaller parts. There are two exhaust air coils side by side. The supply air coils (4 pc) are installed between dampers and preheating coils. Supply and exhaust air coils are connected to the pipework by a counter-flow principle.

Preliminary dimensioning values have been calculated for the exemplifying ACK 14/003 (summary in the Table 6/4) and on the basis of these values the energy consumption and supply cost estimates have been determined.

4.5.5 Performance of Heat Recovery

In the example the temperature efficiency of the heat recovery system is approximately η_t = 44 %. However, due to the great temperature difference of supply and exhaust air the energy efficiency is remarkably better. The annual energy savings are 50 %. By means of heat recovery 270 MWh/a of heating energy of air-conditioning is saved.

By using heat recovery the peak heating load of the ACK 14/003 is reduced 30 %, i.e. 300 kW.

Pressure losses of the coils cause reduction of air flows, with supply air 10 % and with exhaust air 15 %. Due to this the power demand of fans is increased a little. Reduction of air flows is desirable also for heating energy consumption of air conditioning. By pitch control of fans it is probably possible to prevent the reduction of air quantities, if wanted. However, a risk to overload the fans exists, because the recovery coils will make the system characteristic more strict.

In summer the supply air coils are passed and then the supply air flow is returned as present, and the building becomes slightly overpressurized. Due to this air leakages from outside are prevented, and thus infiltration of impurities of outside air is diminished.

When reduction of air flows both in supply and in exhaust plants is taken into account, the savings of heat recovery are 230 MWh/a, the savings caused by smaller air flow 50 MWh/a, and increasing of electric energy of fans is about 3 MWh/a.

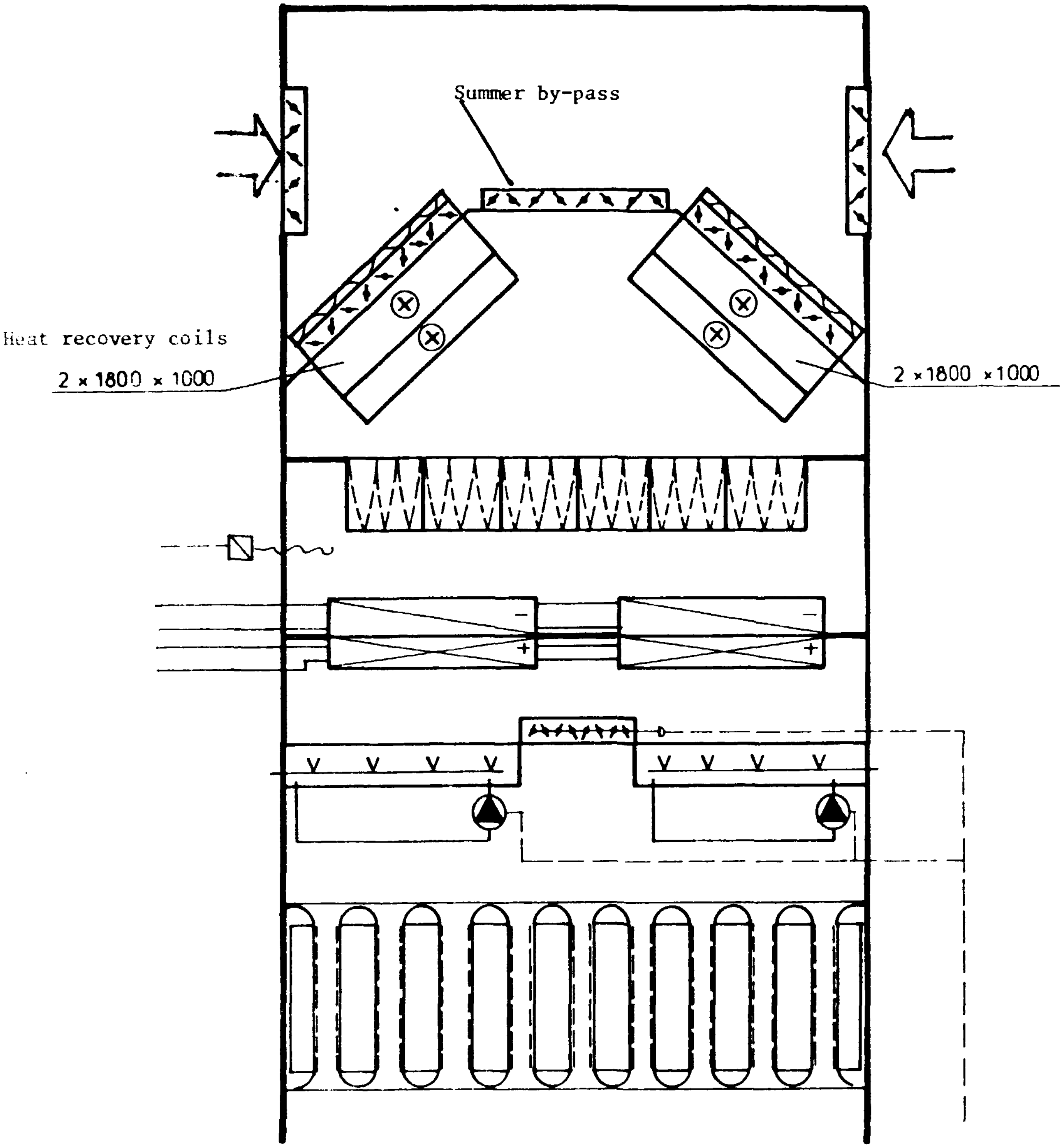


Fig. 4/4. Installation of heating coils to the supply air plant (ACK 14/003 as an example)

RESULT - HEAT RECOVERY

COILS FOR SUPPLY AIR:

COIL.NR:	COIL	HEATING CAPACITY KW P	AIR VELOCITY M/SEC VO	LEAVING AIR TEMP DEG.C TU	LEAVING REL.HUM PER CENT FIU
1	QLRA-16-12- 8-2-F	74	2.2	-5.9	--
2	QLRA-16-12- 8-2-F	74	2.2	-5.9	--
3	QLRA-16-12- 8-2-F	74	2.2	-5.9	--
4	QLRA-16-12- 8-2-F	74	2.2	-5.9	--

COILS FOR EXHAUST AIR:

COIL.NR:	COIL	P	VO	TU	FIU
1	QLRA-24-10- 8-2-F	147	2.4	3.3	97.
2	QLRA-24-10- 8-2-F	147	2.4	3.3	97.

TEMPERATURE EFFICIENCY.................	=	46.3	PER CENT
HEATING CAPACITY........................	=	297.8	KW
WATER FLOW.............................	=	5.39	L/SEC
PRESSURE DROP, WATER SIDE..............	=	82.79	KPA
LOWEST FIN TEMP AT EXHAUST COIL NR 1...	=	.1	DEG.C

RECOMMENDED SET-POINT FOR ANTI-FROST
THERMOSTAT (WATER-MOUNTED)............. = -2.0 DEG.C

*) IN ORDER TO AVOID FROST FORMATION ON EXHAUST COIL THE HEATING CAPACITY IS KEPT CONSTANT AND THE TEMPERATURE EFFICIENCY IS REDUCED AT LOWER ENTERING SUPPLY AIR TEMP THAN..... -10.6 DEG.C

WATER FLOW L/SEC	WATER VELOCITY M/SEC	ENTERING WAT.TEMP DEG.C	LEAVING WAT.TEMP DEG.C	PR.DROP AIR PA	PR.DROP WATER KPA
QR	VR	TRI	TRU	DP	DPR
1.35	.62	11.4	-2.7	91.9	20.52
1.35	.62	11.4	-2.7	91.9	20.52
1.35	.62	11.4	-2.7	91.9	20.52
1.35	.62	11.4	-2.7	91.9	20.52
QR	VR	TRI	TRU	DP	DPR
2.69	1.12	-2.7	11.4	105.4	62.27
2.69	1.12	-2.7	11.4	105.4	62.27

*)

Table 6/4. Heat recovery, example of calculations from exhaust air plant ACK 30/003 to supply air plant ACK 14/003.

	Supply air coils	Exhaust air coils
Number	4 pc	2 pc
Air flow: amount/coil	4,1 m^3/s	5,2 m^3/s
Air velocity in a coil	2,7 m/s	2,6 m/s
Pressure drop/ coil	110 Pa	110 Pa
Liquid:	20 % glycol, 80 % water	
Liquid flow:	5,0 l/s	
Power of pump:	2 000 W	
Size of main pipe	NS 80 + heat insulation 30 mm	

Comparisons with results computed by a SF-program give a good uniformity, table 7/4.

4.5.6 Costs and Feasibility

The supply costs of heat recovery equipment calculated for the exemplifying ACK 14/003 are 630 000 ATS, i.e. 10,7 ATS/m^3/h. The operating costs of the equipment consist of changing of the filter in exhaust air coil, annual inspection, and pumping energy. Total costs are about 9 000 ATS/a, i.e. 1,4 % of the investment.

Table 8/4 present a calculation on energy balances of heat recovery with the exemplifying plant. The balances have been calculated both with nominal air flow and considering the reduction of air flows caused by heat recovery coils.

Table 8/4. Energy savings and profitability of heat recovery equipment of ACK 14/003 & ACK 30/003

	Nominal air flow	Reduced air flow
Total air flow		
- supply	16,4 m^3/s	14,8 m^3/s
- exhaust	10,4 m^3/s	8,8 m^3/s
Heating energy		
- heat recovery	270 MWh/a	230 MWh/a
- extra heating demand	270 MWh/a	260 MWh/a
Total savings	270 MWh/a	280 MWh/a
Electric energy		
- pump	6,2 MWh/a	6,2 MWh/a
- fans	10,0 MWh/a	3,1 MWh/a
Total savings	16,2 MWh/a	9,3 MWh/a
Savings in costs		
- heating energy	123 200 ATS/a	127 800 ATS/a
- electric energy	-15 600 ATS/a	- 9 000 ATS/a
- operating costs	- 9 000 ATS/a	- 9 000 ATS/a
Net savings	98 600 ATS/a	109 800 ATS/a
Supply costs	630 000 ATS	630 000 ATS
Profitability*		
- payback period	5,9 a	5,3 a
- internal interest	18,6 %	21,4 %

* Rate of interest (real) 5 %, increase of enercy fees (real) 4 %/a

Table 9/4 present the savings and costs of heat recovery from air conditioning calculated for all the buildings in the VIC. It is supposed that only the big plant in office towers include heat recovery. Reduction of air flows has been taken into account in the calculations. In building C the possibilities of heat recovery are fewer because of air circulation, and the payback period is longer than in the office towers.

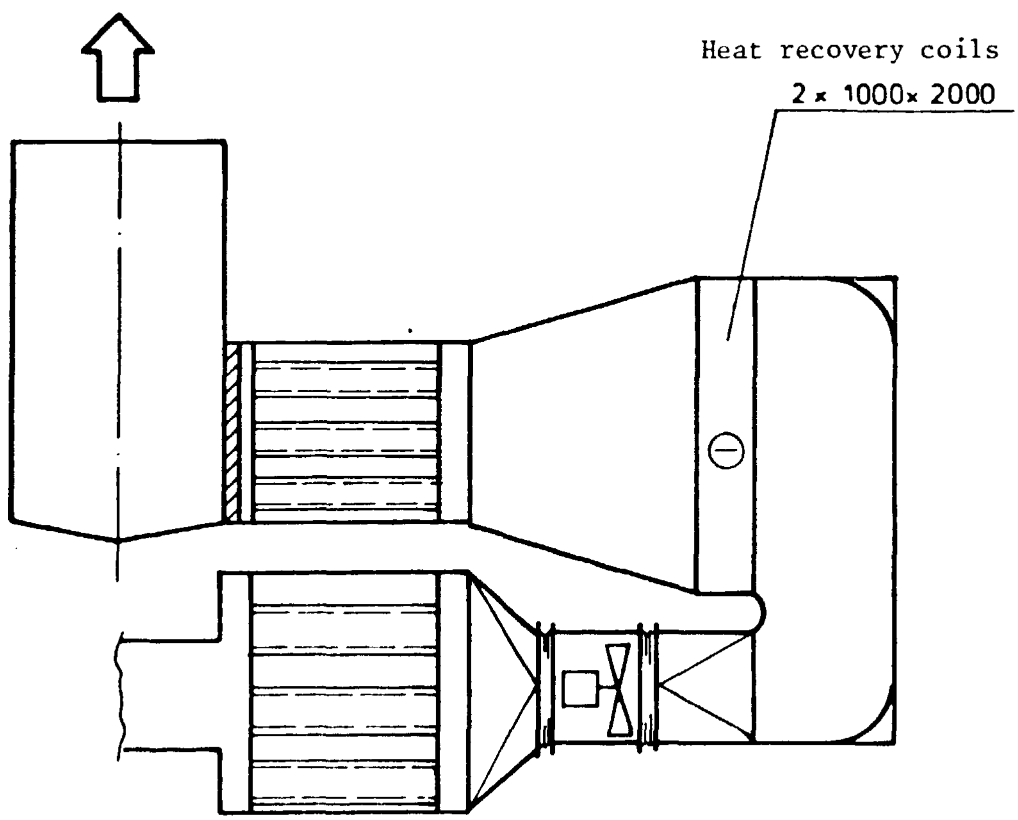


Fig. 5/4. Installation of cooling coils to the exhaust air plant (ACK 30/003 as an example)

Table 9/4. Heat recovery from air conditioning in the office towers of the VIC, and the energy savings and costs caused by it.

Building	No of systems	Intake air m^3/s	Exhaust air m^3/s	Annual savings heating MWh/a	Annual savings electricity, MWh/a	Service costs ATS/a	Net savings* ATS/a	Total investment ATS
A	6	49.9	50.4	1.600	- 53	27.000	710.000	1.940.000
B	3	19.0	20.3	645	- 21	11.000	287.000	780.000
C	To be studied separately							
D	3	51.0	37.4	1.190	- 40	20.000	528.000	1.440.000
E	3	36.2	34.8	1.110	- 37	19.000	492.000	1.340.000
F	12	108.4	104.4	3.320	-110	56.000	1.479.000	4.020.000
G	2	16.5	14.9	475	- 16	8.000	211.000	575.000
VIC	29	281.0	262.2	8.340	-277	141.000	3.702.000	10.095.000

* First year

4.6 Domestic Water

Total water consumption in the VIC is on an average of 15.000 m^3 per month. That is about 125 l/person day (28 gpd) based on occupancy of 4.000 persons.

Because of the height of the buildings, pressure increase stations are needed. Water pressure is relatively high, about 5 kp/cm^2 m causing high tap flows.

4.6.1 Flow Restrictor Taps

By installing new flow restrictors into existing water taps water consumption is reduced. Besids it saves heating energy and somewheat electricity.

By proper flow restrictor water flow in the tap can be kept constant with a wide pressure range (Fig. 6/4).

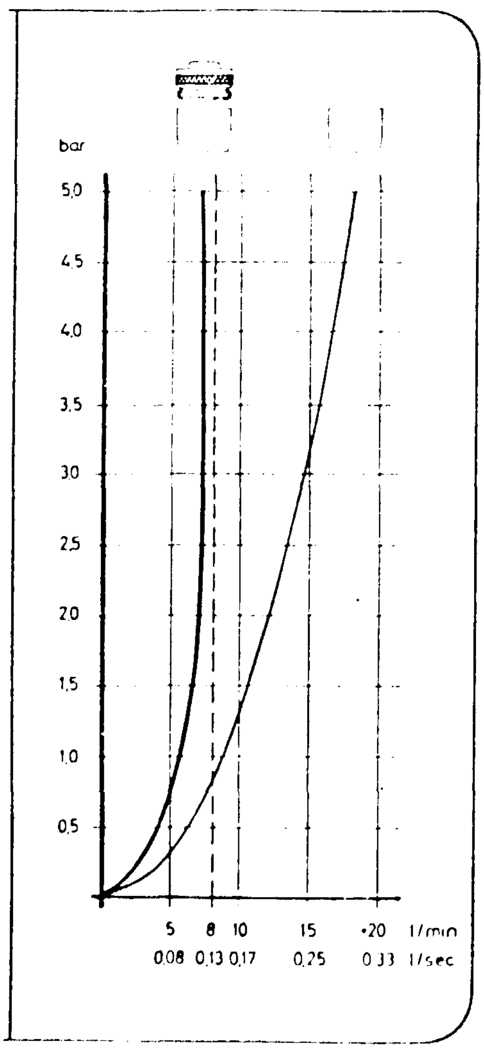


Fig. 6/4. Water flows with and without flow-restrictor as function of pressure.

4.6.2 Reduction of Warm Water Temperature

At present the temperature of warm domestic water is adjusted to 45 degrees, and the branch to the kitchen is reheated up to 65 degrees. It is possible to reduce warm water temperature from 45 degrees to 38 degrees, since water is mainly used for washing of hands, shower and cleaning. Then it would be possible to get water, with the same temperature as the body, straight from the warm water tap of twin-grip mixer.

Thus excess tapping of water needed for balancing of temperature would not be needed, since mixing would not be necessary any more. Lower water consumption (appr. 5 %), smaller heat losses of the pipework (about 25 %), and smaller heating demand for water (about 20 %) would be achieved as savings. Those spaces and equipment which water over 38 ^{o}C is needed should be provided with electric auxiliary heaters.

4.6.3 Reduction of Flows in Water-closet Flushing Reservoirs

The water volume of WC flushing reservoirs in the VIC is 10 l. Water flow needed for flushing could be reduced by locating in a flushing reservoir bottles filled with water, bricks wrapped in plastics, or polystyrene particles, for example. The particles must be insoluble to water, cheap, and 2...3 l by volume per a reservoir. Thus the flushing pressure of a reservoir remains the same, but the flow is reduced, and savings are achieved in cold water consumption.

In reduction of flows in households it has been noticed that when cast iron sewers are used, the risk of obstruction can be seen already with 6 l flushing water. Presumably wastes in household sewers are rougher than those in the VIC.

4.6.4 Costs and Feasibility

Total delivery costs of 1200 copies of 0.1 l/s flow restrictors and 100 copies of 0.2 l/s flow restrictors would be about 140 000 ATS. Installing costs would be minimal because it can be done by general service staff. Total investment is then 150 000 ATS.

Changing of the set value of warm water temperature is a zero-investment. Auxiliary heaters had to be installed in some places which should be considered separately. Total investment is estimated as 100.000 ATS.

Reduction of flushing volume of WC reservoirs can be carried out by the maintenance personnel of the VIC. By using polystyrene particles, the costs for changing of 1100 reservoirs would be about 20.000 ATS.

Table 9/4. presents the savings and costs achieved by measures aimed at water consumption.

Table 9/4. Water consumption measures

Measure	Energy saving MWh/a	Water saving m^3/a	Costs saving ATS/a	Investment ATS
Flow restrictors	250	9000	208 000	150 000
Hot water temperature	370	2500	206 000	100 000
WC flushing reservoir	–	10000	95 000	20 000

4.7 Energy Optimizing by Building Automation System

4.7.1 Time Scheduling Programs

The building automation system at VIC is provided with time scheduling programs by which the running of AC-units, pumps, on/off-control of lights and changing of temperature setpoints can be automatically controlled as a function of time.

Time programs ought to be used so that all energy consuming machines and devices are in action then and just then when they are needed. Each day of the week can have several different times for on/off commands coming from the system and it is also possible to before hand take into account special holidays and abnormal working days.

It can be calculated how muchs energy costs can be saved by preventing some great AC-unit from running one hour too long per day or some lighting group from being on one hour too long per day. These figures are presented at the savings dealing parts of this report.

In order to be able to use time programs effectively the operator at control room must know the times when devices must be on, when lights are needed and how the times change.

4.7.2 Start/stop Optimizing

Start/stop optimizing will be applied for calculating the time needed for heating the house again after night or weekend breaks during which just a minimum temperature level will be guaranteed by night thermostat function of the optimizing program in building automation system based on pilot room temperatures. During the breaks the room temperatures will be kept above 17 °C and room air relative humidity under preselected limit.

The time needed to heat the rooms up again depends on outside temperature, room temperatures, available heating power and time constants of the structures of the house.

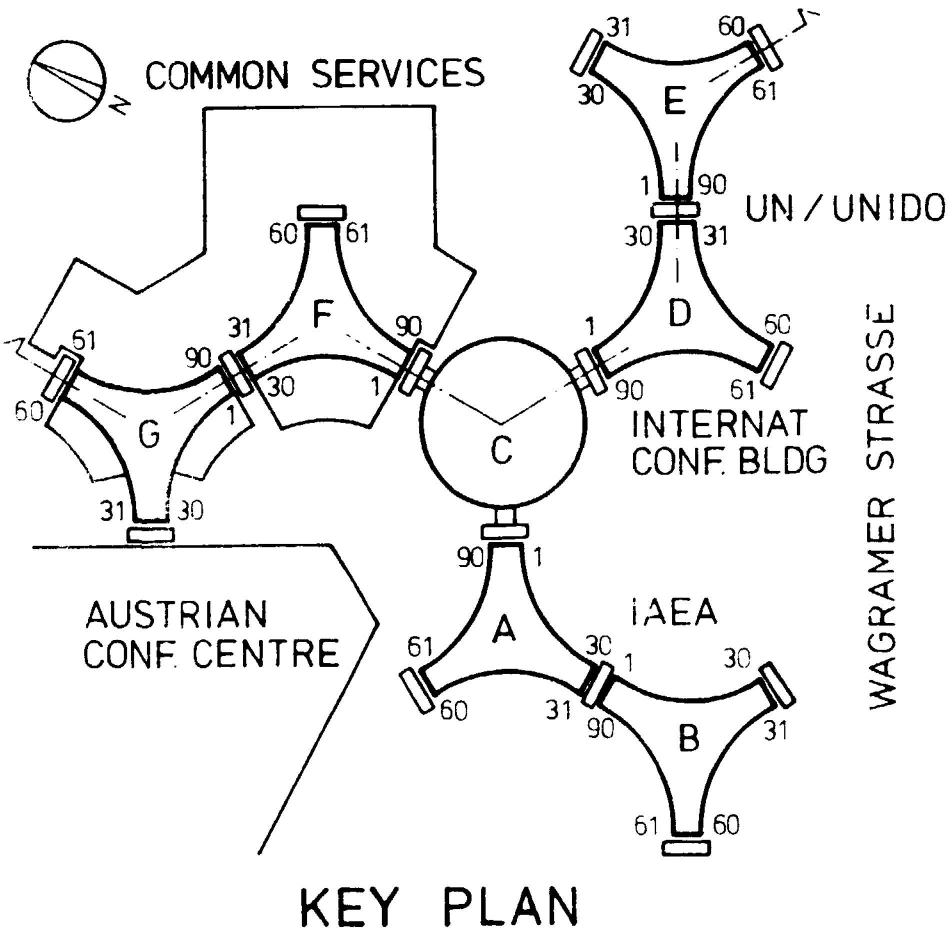
The most economical way to heat up the house is to use high heating power for a short time.

This can be made by giving primary air a high setpoint (30 °C) and heating water network controllers a high supply water setpoint (85 °C). It is feasible to take as much power as possible from the induction units because they use 70 % recirculation air and 30 % primary air which must be taken from outside.

Table 1/4.7 Location of the pilot rooms which are provided with room temperature and relative humidity measurements for the building automation system

Building A	Floor 06	Room 10, 40, 70
	Floor 12	Room 17, 47, 77
	Floor 21	Room 09, 40, 68
	Floor 28	Room 16, 46, 78
Building B	Floor 07	Room 08, 39, 70
	Floor 11	Room 20, 45, 77
Building C	Floor 01	Room 78
	Floor 02	Room 10
Building D	Floor 16	Room 10, 40, 70
	Floor 22	Room 18, 46, 78
Building E	Floor 09	Room 09, 39, 70
	Floor 15	Room 14, 16, Labor
Building F	Floor 07	Room 17, 47, 79
	Floor 09	Room 11, 40
Building G	Floor 05	Room 83

Figure 1/4.7 Key plan for the location of the rooms



Time needed for this schock-heating must be calculated for each main AC-unit by the start/stop optimizing program of the building automation system. Most building automation system manufacturers have standard programs for calculating start-up times.

Basic working times at the area of each AC-unit will be given to the time programs. Start-up program determines how much before hand the unit must start in order to heat the rooms before the time of the time program.

It is also possible to let the building automation system determine how early on the afternoon heating and/or cooling can be stopped without unconvenient changes in room temperatures or humidities before people according to time programs have gone home. Ventilation shall continue until time programs stop it.

By these programs it is possible to shorten the running times of the AC-units and heating and cooling periods. If all main AC-units are running half an hour less than under just time programs electrical and heating energy savings are significant.

4.7.3 Primary Air Temperature Optimizing

It is not reasonable to keep primary air temperature constant round the year but to let it follow the load situation in the rooms. If there is light cooling demand the temperature can be kept higher than in the case of high cooling demand. In the case of low heating demand the temperature can be kept lower than in the case of high heating demand.

The aim is to avoid simultaneous heating and cooling. The air shall not be first heated and then cooled or vice versa.

Measurements needed for determining cooling or heating demand are outside air temperature, wished room temperature real room temperature and primary air temperature.

Between outside temperatures 14 °C and 17 °C the primary air setpoint will follow outside air temperature, but if some pilot room temperature is over 24 °C it will be 14 °C. If outside air temperature is below 14 °C setpoint for primary air temperature will be 14 °C. During start-up heating in the morning the setpoint will be 30 °C. If outside air temperature is over 17 °C and no pilot room temperature is over 24 °C setpoint will be settled to 17 °C.

However if outside air temperature is below -10 °C primary air temperature setpoint will be 17 °C. During start-up period cooling pumps and humidifiers must be switched off.

4.7.4 Night cooling

During the nights in summer outdoor air can be used for cooling the structures of the house and also room air. Expensive cooling energy can so be saved during the working day.

It must however be ensured that cooling and heating pumps and humidifiers are stopped during night cooling periods.

Cooling shall be done during the coldest period of the night after 2.00 a clock. It will be made just if outdoor air temperature is low enough and room temperatures have been at the last evening so high that they indicate cooling need.

The cooling period is a function of temperature difference between outdoor air and mean value of room air temperatures but at least half an hour. Room temperatures are measured from so called pilot rooms where the room sensors of the building automation system are located.

Night cooling shall be stopped if room temperatures are lower than 17 °C.

Start optimization with schock heating shall not be allowed during the same nights as night cooling.

Savings can be calculated by estimating the amount of cooling energy got from night cooling and stored to the house and multiplying it by the price of cooling energy.

Night cooling can also be made simply by time programs between 1. st of april and 30. th of september between 2.00 and 4.00 a clock if weather conditions are followed and changes to time program are made manually through the keyboard of the operating and displaying unit.

4.7.5 Control of Water Network Temperatures to Induction Units

The supply water temperature to the heating water network of the induction units is normally a function of outdoor air temperature. For self convection it can be raised to up to 85 °C when the air conditioning unit is stopped.

The control curve between supply water temperature and outdoor air temperature could be dropped during the night so much that room temperature descends to 17 °C. Alternatively heating network pump can be stopped.

Schock heating in the morning happens by using high (up to 85 °C) supply water temperature. Ventilation could start half an hour before the beginning of occupancy period according to time programs.

4.7.6 Cooling Power Limiting by Directing it to the Most Critical Zone

Cooling power can be limited by directing it to those parts of the building where cooling demand is highest. Parts where it is lower also get less cooling power.

In practice this happens by raising the cooling water temperature to induction units and letting the setpoint of primary air follow outdoor air temperature. AC-units to which this is applied will be determined according to clocktime and sun radiation. Principle is that AC-units the room area of which is in shade do not need as much cooling power as units room area of which is under direct sun radiation.

A completing function is upper limit control of exhaust air temperature. If the temperature rises over 25 °C the AC-unit will be put to cooling mode again. First the cooling water temperature is adjusted to 13 °C again and the primary air setpoint will be lowered to 14 °C (12 °C) again.

It is always more economical to use induction units for cooling because they use secondary air 70 % and 30 % primary air. Primary air comes 100 % from outside and must be cooled as little as possible because it is blown out again.

On the sun radiation side the primary air will be kept at 14 °C and cooling water temperature leaving to induction units at 13 °C. It may be possible to let primary air setpoint float following outdoor air but if exhaust air temperature rises over 25 °C it will be put to 14 °C again.

Pilot room temperature measurements can be used instead of or completing the measurement of exhaust air.

Exact method must be studied more detailed before asking program tender from ITT.

4.7.7 Enthalpy optimizing

In C-building where recirculation air can be used enthalpy optimization for cooling energy saving in the summer and heating energy saving in the winter can be applied.

This means that in summer heat content of exhaust and outdoor air will be calculated. After that they will be compared. If heat content of exhaust air is lower and the AC-unit is cooling, which can be seen by outdoor air, primary air and room temperatures, the supply- and return-air dampers will be driven to minimum fresh air position. If heat content of outdoor air is lower the dampers will be set to fresh air position or some other position determined by local analog controllers or local adjustment knob in conference rooms.

If the AC-unit is heating, which again can be seen from outdoor air, primary air and room temperatures, and exhaust air is warmer than outdoor air the dampers will be set to minimum fresh air position. In practice this means that they are always at minimum fresh air position.

Minimum fresh air position will be adjusted manually to the local analog control devices. It could also be made to be a function of CO_2-content in exhaust air.

Savings can be achieved just at the AC-units of conference building and some hall and corridoor units. Savings can be estimated based on the floor area these units are serving.

4.7.8 Night heating

During the night minimum allowed room temperature is 17 ^{o}C and maximum allowed relative humidity 75 %.

Temperature is kept above 17 ^{o}C by induction units without using the AC-units. After working time temperature of water to the induction units is allowed to decrease to 35 ^{o}C until lowest oom temperatures are 17 ^{o}C or time is 2 ó clock in the morning. After that water temperature is kept at 50 ^{o}C or at the normal outdoor air temperature dependent curve until lowest room temperature is over 18 ^{o}C and then it is dropped to 35 ^{o}C again.

Room temperatures are measured at the pilot rooms.

The aim is to be able to keep the room temperatures as low as possible to sare heating energy as much as possible.

4.7.9 Control of Pumps

Heating and electrical energy can be saved by controlling the running of heating and cooling network pumps according to the cooling and heating need at the room space of each air conditioning unit.

Pumps for the heating and cooling water networks of induction units and pumps for the heating and cooling coils of primary air need their own control strategies.

The needed functions can be realized by the limit value control and reaction programs of the building automation system.

Before the reaction programs are taken into use the operator of the building automation system must have good guidance of how to control the pumps manually on the basis of temperature measurements which he can follow by the process diagram monitor.

4.7.9.1 Primary Air Heating Coil Pumps

The running of the primary air heating coil could be controlled so that they do not run if outside air temperature is over 17 ^{o}C but do run if it is below 16 ^{o}C.

4.7.9.2 Primary Air Cooling Coil Pumps

Primary air cooling coil pumps could be started if outside air temperature is over 17 ^{o}C or some pilot room temperature is over 24 ^{o}C. Otherwise they would be stopped.

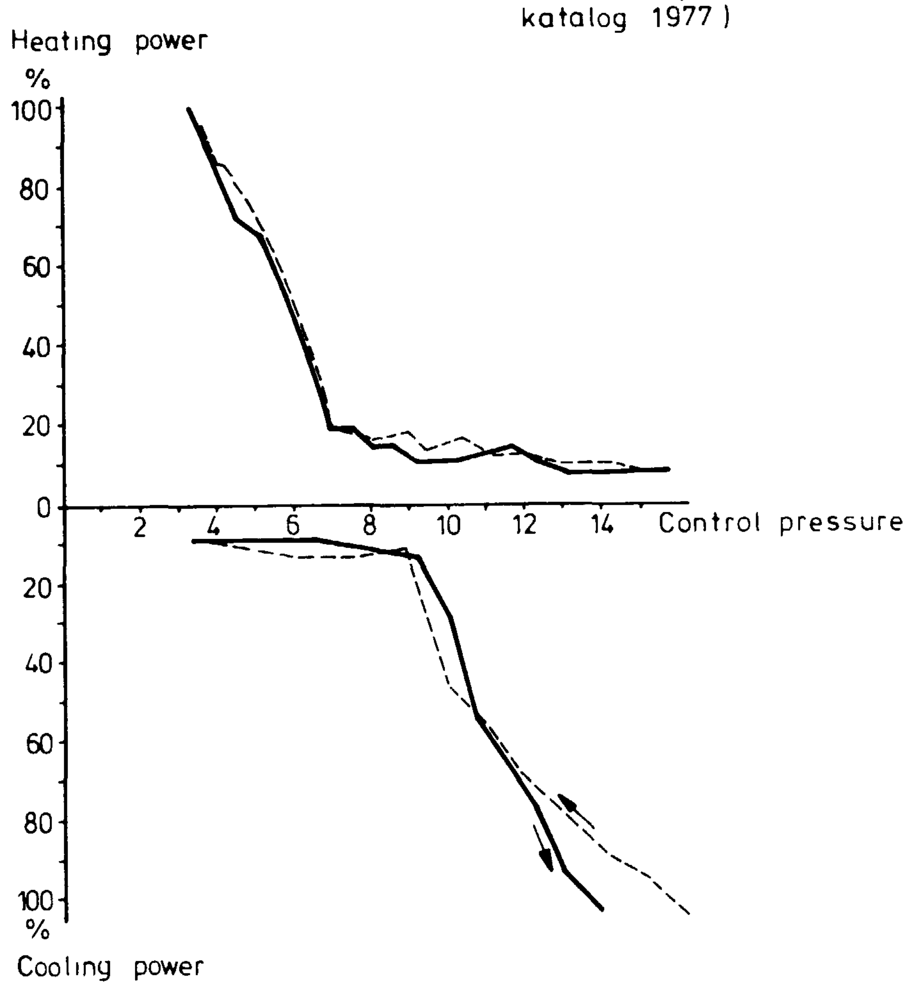
4.7.9.3 Pumps of the Heating and Coolingwater Networks of Induction Units

If the pumps of heating and cooling water networks of the induction units are running simultaneously this causes losses in the induction units even if the control dampers are nearby closed.

In order to avoid these losses which can be up to 10 % of the maximum capacity of cooling or heating coil capacity, is it reasonable to keep the water running just in such networks where it really is necessary.

Figure 2/4.7

Control characteristics of convector as a function of control pressure (Flakt katalog 1977)



It is possible to do this by the building automation system. Cooling or heating need can be seen from the pilot room temperatures and outside air temperature. It is also possible to take into account sun radiation to the facades as a measured data or based on time and outside illumination.

After finding out if there is cooling or heating need in the influence area of some induction unit network is it possible to keep the right pumps running and stop the others.

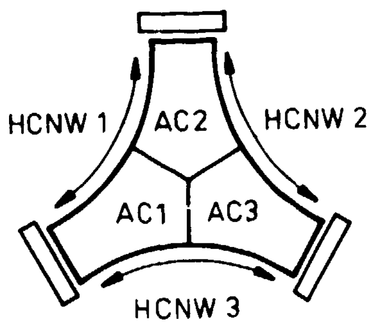
The cooling and heating water networks of induction units are divided according to facades and so differ from the influence areas of air conditioning units but this does not prevent the use of this function.

The pumps of reheating coils can be controlled in the same way as the heating water network pumps of induction units.

4.7.9.4 Practical limitations

It is obvious that temperature limits mentioned above must be adjusted after experiments in practice.

Figure 3/4.7 Principle diagram of the influence areas of air-conditioning machines and induction unit heating and cooling water networks in office towers



AC 1 = Air-conditioning machine 1 for several floors

AC 2 = Air-conditioning machine 2 for several floors

AC 3 = Air-conditioning machine 3 for several floors

HCWN1 = Heating and cooling water networks of induction units at facade 1

HCWN2 = Heating and cooling water networks of induction units at facade 2

HCWN3 = Heating and cooling water networks of induction units at facade 3

4.7.10 Costs and Feasibility

Part of the measures of chapter 4.6 can be realized with present devices and programs but part of them require new control points and programs.

Costs and savings have been described in chapter 5.

5. Building Automation System

5.1 General Description of the System

Vienna International Centre is provided with a computerized building automation system to which about 7 000 control objects are connected.

By these control objects it is possible to supervise the function of the technical devices of the house, indoor climate and energy consumption.

The system gives great possibilities to keep energy consumption of the house low. Savings are a result of several supervision and control functions.

5.1.1 Effective Centralized Alarm Supervision and Guidance of Maintenance

On the basis of alarm supervision and quick maintenance electrical devices and machines can be kept in good order and little energy consuming. Well planned systematic maintenance saves also manpower.

5.1.2 Continuous Running Time Supervision and well Scheduled Service

By systematic use of running time summing function of the building automation system it is possible to plan the service and maintenance of installations so that unpredictable breaks in running and uneconomical function can be avoided.

5.1.3 Temperature and Relative Humidity Displaying in crt-display or Colour Monitor for Process Diagrams

This makes possible to get very quickly an overall picture of the situation at the area of some air conditioning unit. Temperatures can be kept at their optimal values. 1 °C deviation upwards in room temperature can mean 5 % increase in heat energy consumption. Incorrect function of local control devices can also be immediately noticed.

5.1.4 Limit Value Alarm of Measured Temperatures and Humidities

Limit alarms which are displayed on the screen of the crt-display and printed on the alarm printer force the operator to react to disturbancies and to keep the measurements in their normal scale.

5.1.5 On/off Control of Air Conditioning Machines, Pumps and Light Groups

Running and on-times of the electrical energy consuming objects can be kept at the minimum by manual switching on and off according to the real need, which the operator must know, or by automatic time scheduling programs, which have in their memory tables of information about daily and weekly on/off-switching need. Third possibility is to use so called reaction programs by which logic interlockings can be built between input contact signals and output contact signals. Also limit value alarms of measured temperatures, humidities, lighting level and so on can be treated like contact inputs.

By status displaying on the display screen and status change printing the correct status of the control object can be continuously supervised.

5.1.6 Setpoint Control of Local Analog Controllers

By setpoint control of certain local analog controllers it is possible to set the temperature setpoint of air temperature in ducts manually or by specific optimizing programs to its optimum at various running situations in the house; for instance the setpoint of primary air coming to the induction units in the rooms, or that of water temperature coming to different heating and cooling networks.

5.1.7 Energy Consumption Reporting

By connecting the most inportant heat and electrical energy consumption measurements and also service water consumption measurements to the building automation system it is possible to get daily, weekly and monthly reports of these consumption data. Also variables not directly measured but calculated by the computer programs can be included to the reports. This makes possible to take to the reports not just direct energy consumption but also that divided by degree hours of outside air temperature, served floor area in m^2 and served building volume in m^3. Wind velocity and direction can be shown in the reports too. Day and night can have their own reports.

5.1.8 Temperature and Relative Humidity Reporting

Daily and weekly reporting of room temperatures and relative humidities would be very useful for controlling the indoor climate. The report could include mean value of the measurements, maximum value and time, and minimum value and time when it was measured. Day and night can be separated. At the area of each major air conditioning unit for office rooms there are pilot rooms the temperature and relative humidity of which is continuously measured.

5.1.9 12-channel Graphic Recording

The measured values can be recorded also by a twelwe channel recorder by which locig term variations and interrelations of measured and also calculated variables can be visualized. This is useful for following temperature changes and for studying electrical or also heat power peaks.

5.1.10 Reaction Programs

The reaction programs of the system make it possible to build programmable logic by which running of pumps, switching on/off of lights and control of fresh and return air dampers can be done so that they are used in most energy efficient way. Such programs are a standard feature of the installed ITT building automation system.

5.1.11 Peak Power Limiting Program

Peak power limiting program makes possible to keep the electrical power used in the house under preselected value. The program automatically switches off power needing control objects so much as is needed for sufficient limitation, which the program can calculate. Control objects are divided for instance to three priority classes and the limiting starts from the lowest priority class. Each object has its own maximal switching off time and minimum needed on-time between limitations.

5.1.12 Other Energy Consumption Minimizing Functions and Programs

There are also other functions by which the devices can be controlled in highly energy efficient way and which can be automized by the programs of the building automation system.

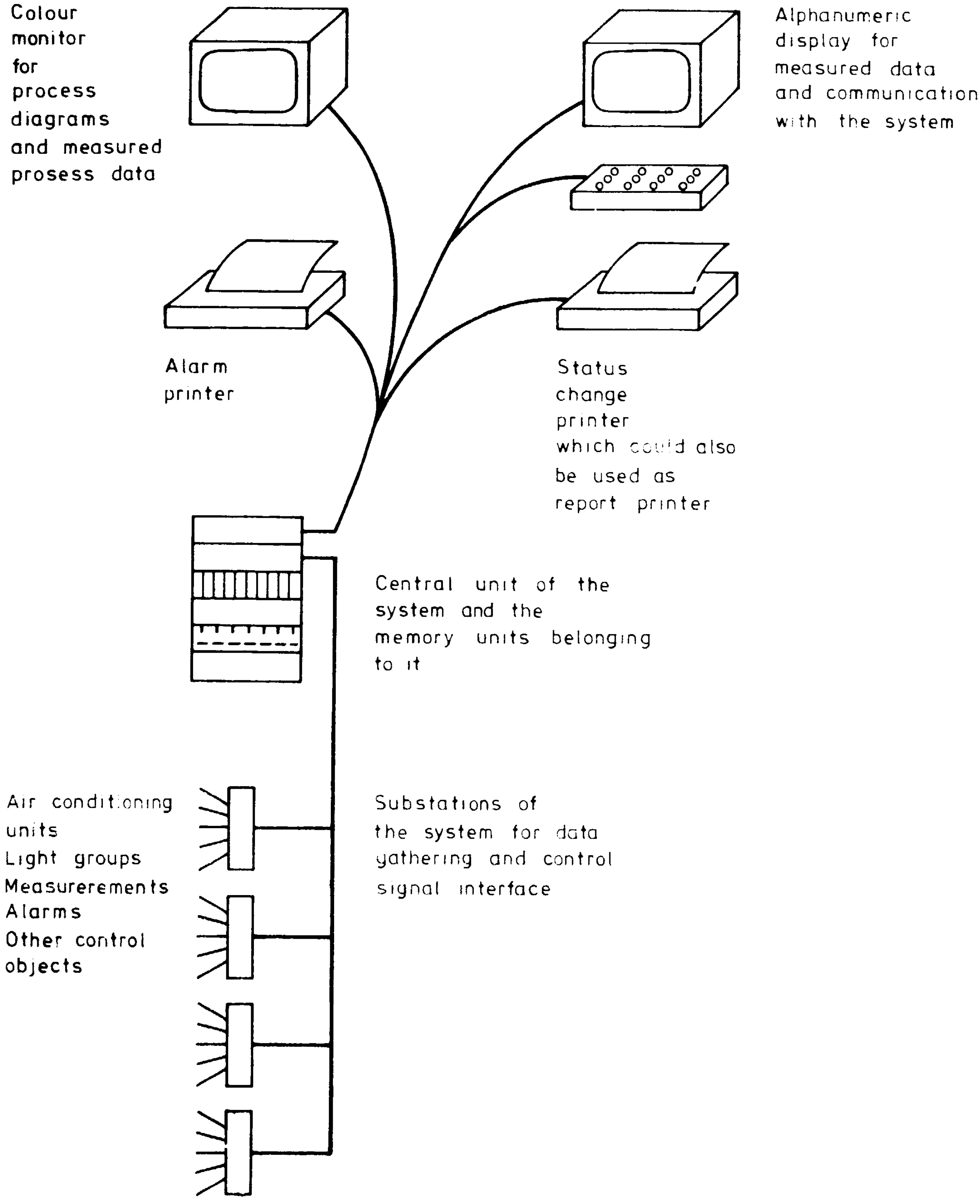
To these belong start/stop -time optimization of air-conditioning, and heating and cooling by induction units, control of night heating, and night cooling, control of heating and cooling, control of heating and cooling of water circulation pumps, setpoint control of primary air temperature, dividing of cooling power to facades, enthalpy-optimizing and control of lighting according to natural light intensity.

5.1.13 Summary

Possibilities that the existing building automation system offers are more detailed described in following chapters. Great part of functions can be realized without major additional costs but some demand programming work, the price of which can be estimated but is difficult to know exactly without getting a tender from ITT or some software house.

Figure 1/5.1

Main parts of the building automation system



5.2 Application of the Basic System

5.2.1 Confirming the Correctness of the Signals

The absolute correctness of the measurement data coming to the display units and printers of the control room as well as the of the controls going to fieldequipments is the first qualification for the usefulness of the building automation-system.

The only way to find out if the signals are correct is to test them all systematically through. This task belongs naturally to the supplier, but also the customer and operator must be personally convinced. Part of the measurements e.g. temperature and relative humidity need attention in the future: they must be calibrated once a year, those of humidity twice.

5.2.2 Checking of Basic Functions

One condition for improving the functions of building automation system is that the basic functions, which are described in section 5.1, have been found to be in good order.

The functions must be checked together with the supplier so that the operator at the same time gets himself well familiar with the function of the system. To those who will be made familiar with the subject must include in addition to the operators of the control room also representatives of UNIDO and IAEA. The representatives of UNIDO and IAEA must also be able to use the system and supervise its use.

5.2.3 Developing of the Follow-up Routines

To exploit the measurement data, alarms and controls, connected to the building automation system involves that there are clear methods for their follow-up and exploitation. Updating of timeprograms and follow-up of their function, updating the parameters of the electrical power limiting program and other special programs and follow-up of function and effect, follow-up of energy reports and making of conclusions, supervision of temperatures and relative humidities and clearing up the disturbancies which caused alarms and taking care of the needed maintenance actions form a field which covers the whole VIC with its numerous technical equipments and in-house functions. This field is very wide and implies knowing as well the technical processes as the requirements involved by the use of the house.

5.2.3.1 Alarms, Limit Values and Operation Status

The undistutbed and beforehand planned function of the equipments (fans, pumps, lighting) is controlled by the alarms connected to the building automation system and by the data of the operation status of equipments.

The alarms must be reacted at once reasons for them must be cleared and the correction must be supervised. The uncorrect alarm points must be kept listed and their incorrect alarms must be eliminated and the points must be put again in order.

The location of the alarming objects must be documented. For each alarm there must be also clear procedure instruction which helps in clearing up the fault. The documents must also include a report of the seriousness and effect of the fault and the name of the person who is to be informed of the fault.

The alarms are to be seen on paper alarm printer, on the schemes of colormonitor and on CRT-display.

They can be written out in alarm classes (1-5) and in parts of the building. Alarms include also limit value alarms of the measurement values. The output of the summary of alarms can also take place at certain time intervals and so the person supervising the maintenance can at the appointed time get a summary of the existing alarms and of deviations in the measurement values and can supervise as well the function of the machines as the action of the operaiting personnel. One can choose from few output times which can be changed.

The outputs can also be formed into smaller poitgroups, which belong to certain equipment units e.g. air conditioning units.

5.2.3.2 Temperatures and Relative Humidities

The measurements of temperature and relative humidity in pilot rooms and air channels in different points and in pipe networks can be followed by asking single measurement points or logical measurement point groups to be shown on the CRT-display or put out on the printer. They are also shown on the schemes of colour monitor.

The follow-up of the measurements regularly and keeping the limit values in sensible scale prevents long deviations from the aimed values and thus the unnecessary energy consumption. The follow-up must be continuous.

Expecially important are temperatures of pilot rooms, primary air and heating and cooling water networks. Temperatures depending on the outdoor air temperature must be furnished with sliding limit values.

The follow-up of the measurement values would be made easier if the programs would give daily and weekly reports about preselected temperatures and relative humidities. These reports would include from one report period.

- meanvalue
- maximum value and its appearance time
- minimum value and its appearance time

Now no such report exists.

5.2.3.3 Energy Consumption

The follow-up of energy consumption is possible manually, but it is much more effective, if the energy consumption measurements are taken with into the building automation system and on that basis reports are made which give correct data to each user level.

The energy report must include daily, weekly and monthly reports for each part of the building (VIC totally, A, B, C, D, E, F, G) about electrical and heating energy and water consumption.

The follow-up of the daily report belongs to the operator of the control room and to his superior, head of operations. The weekly report serves the head of operations and the head of maintenance, monthly report the head maintenance and different administrative organizations in the house.

The report shows the energy consumption separately during the day and night. It includes the following data of each part of the house

- consumption of electrical energy
- consumption of heating energy
- degree hours
- heating energy/m^2
- heating energy/m^3
- electrical energy/m^2
- electirical energy/m^3
- amount of water/m^3

The report gives a good possibility to intensively supervise energy consumption and the effect of saving measures.

In addition to energy consumption the power calculated by the programs on energy consumption data shows how well the use of the equipments is gone. The aim is to keep the power as even as possible. The power report, too, should give information of the parts of the house separately.

It includes

- mean electrical power
- mean heating power
- maximum electrical power and its appearance time
- minimum electrical power and its appearance time
- maximum heating power and its appearance time
- minimum heating power and its appearance time

Report periods are day, week and month.

According to the report can the use of time programs, shifting of the running of the machines and the use of the peak power limiting program be planned optimal.

5.2.3.4 Running time of machines

Building automation system includes running time calculation of the machines. This makes possible to get, it wanted, to CRT-display or printer the running time of each machine belonging to running time calculation after the previous maintenance time and time limit after which it needs maintenance again.

With the help of running time calculation the maintenance plan of the machines can be improved and their extra operation can be controlled. The limits of running time must be adapted to the maintenance instructions of the machines.

5.2.3.5 Time programs and running status

Upkeeping of time programs and their continuous developing need active work. Their times should be tried to be changed towards minimum running time, by which sufficient indoor climate can be achieved. Succession of seasons has to be noticed. Humidifying should be kept off when it only is possible. The switching off of lighting evenings must be made certain.

The running of machines which differ from time programs can be controlled by taking displays of the running status of machines or lighting groups which belong to time programs at different times of the day.

It has been found out in other cases of the use of building automation system that keeping time programs up-to-dace is easily neglected. The situation is the same when following the effects of the succession of seasons.

Humidifying, night cooling and control of supply air and return air dampers are typically such functions which should be controlled differently in summer and in winter.

The time programs in building C should be controlled closely, because the need for the use of this space changes according to the conference situation.

5.2.3.6 Reports and recorder follow-up

The most necessary reports are described in sections 5.2.3.2 and 5.2.3.3. They serve the control of indoor climate, energy consumption and also electrical and heating power. The continuous follow-up of the reports is extremely important, when the aim is to turn potential savings into achieved savings.

The follow-up of reports is divided to different organization levels.

A. Administrative organisations UNIDO, IAEA

- energy reports
- temperature reports

B. Head of maintenance

- energy reports
- temperature reports
- power report
- running time report
- alarm summary
- time program summary
- displays of operating status
- recorder follow-up of temperatures, powers or humidities

C. Head of operations and operator of control room

All the reports made by building automation system go through head of operations and operator of control room. Their task is to find out the reasons for the occuring deviations and take action to climate disturbances.

Head of maintenance should also develop the reporting system on and develop the use of technical equipments basing on the experience and make suggestions to UNIDO and IAEA about the use of the room space if needed and if it seems that the way by which the room space is used causes unreasonable running costs.

Head of operations and operator of control room should also be responsible for the follow-un and operation of the following functions in building automation system: measurement displaying, process diagram display, times of time programs, running times, alarms, printing by paper recorder etc.

5.2.4 Video Diagrams and Documentation

Application of basic system extensiveness includes also the checking of colour monitor process diagrams and of documentation of technical systems in the house which belong to the system, when they are available. Sufficiently detailed and up-to-date documentation is necessary condition for the correct operation and especially for the clearing of disturbances.

Process diagrams of colour-monitors should be taken to use in full extent, because they help in getting a quick general view of the situation on the field of action of different air conditioning machines.

5.3 Higher Level Optimization

By means of the building automation system at the Vienna International Centre, energy savings can be materialized, provided that the system is efficiently exploited. The present system can also be further developed by converting part of the present manual controls into automatic ones. The manual functions often tend to remain unperformed.

Part of the higher level optimization functions are available as standard programs from the supplier of the building automation system, part must be produced individually. Modernizing the system would allow the adaptation of the most recent ITT optimization functions but this would also cause cabling expenses. Expenses to be negotiated with ITT.

5.3.1 Start-Up Optimization and Night Time Heating

Start-up optimization, together with low-level night time heating, shortens the heating and cooling periods, as well as the running of the HVAC machines. Standstills offer more substantial energy savings since room temperatures can be allowed to drop lower down than with time-based programs . In the pilot rooms, room temperatures and relative humidity can be monitored, the former kept above, and the latter below a presettled level during standstills. At the end of the standstill, the optimization program calculates the time required for bringing back the inside conditions to an acceptable level.

Heating is started at a point of time calculated by the optimization program.

While raising the temperature, it is attempted to apply maximum heating effect, to reduce the heating time. Figure 1/5.3 shows an example of the formation of the heating time when using calculation based on linear correlations. The correlations can also be adaptive.

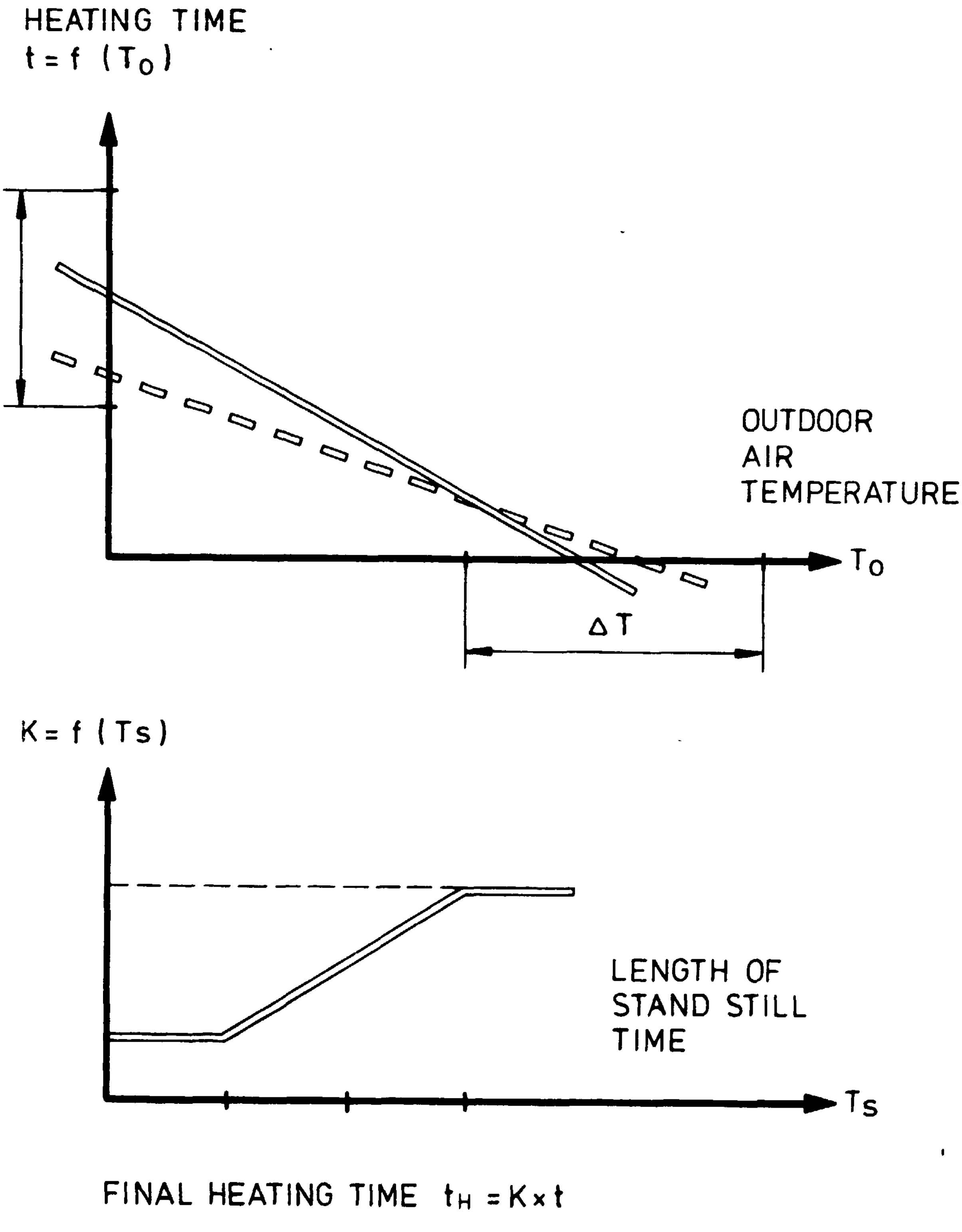


Fig. 1/5.3 Example of the formation of heating time

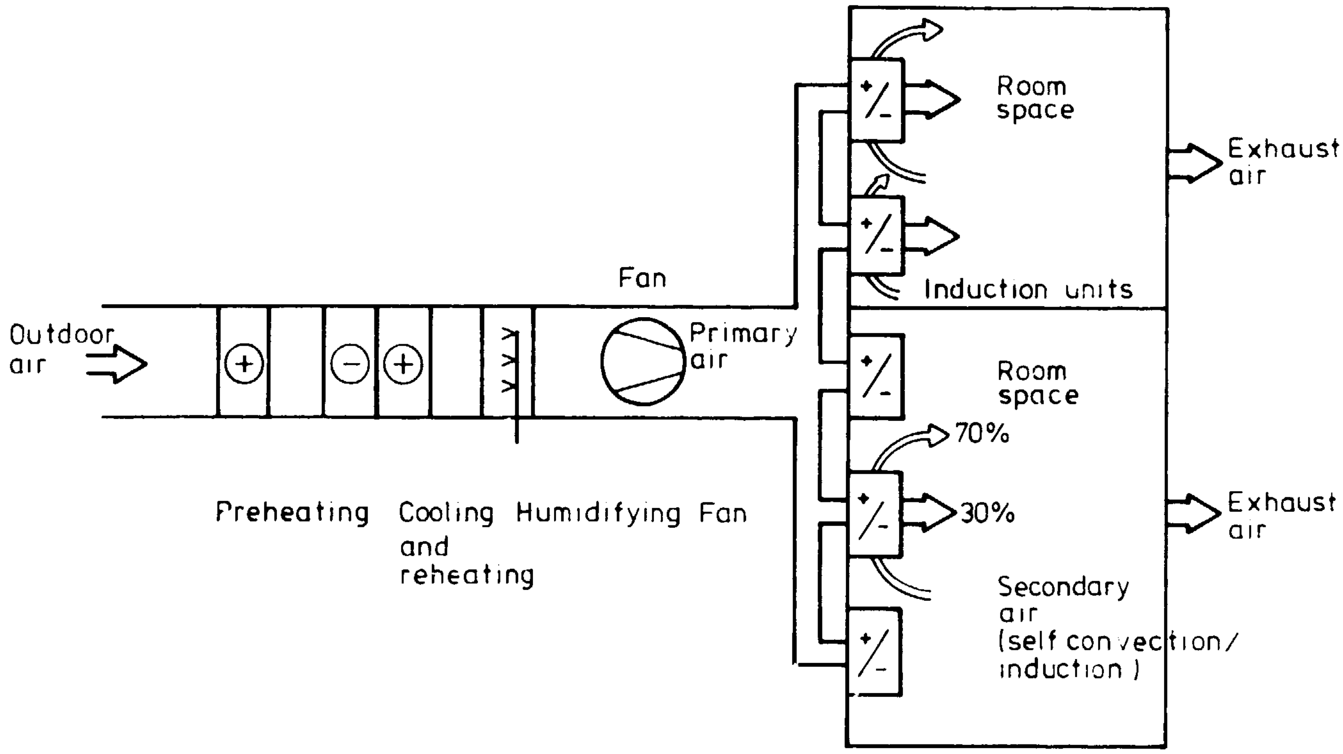


Figure 2/5.3 A simplified process diagram of the VIC office air conditioning

During normal day time use, the primary air temperature is about 17 °C, and the individual induction units in each room assure the required temperature. After day time use, the air conditioning units and the pumps stop, except the heating water pumps of the induction units which perform the heating by means of self-convection. At present the temperature of the heating water of the induction units is raised to 85 °C. This temperature could actually be lower, if the temperature and humidity measurements in the pilot rooms were exploited and the water temperature be raised to 85 °C only when room temperatures drop too much, or when relative humidity goes high enough to risk condensation. Even in this case the temperature is to be raised only for long enough to keep the room temperature above the allowed lower limit and not to start an unnecessary rise.

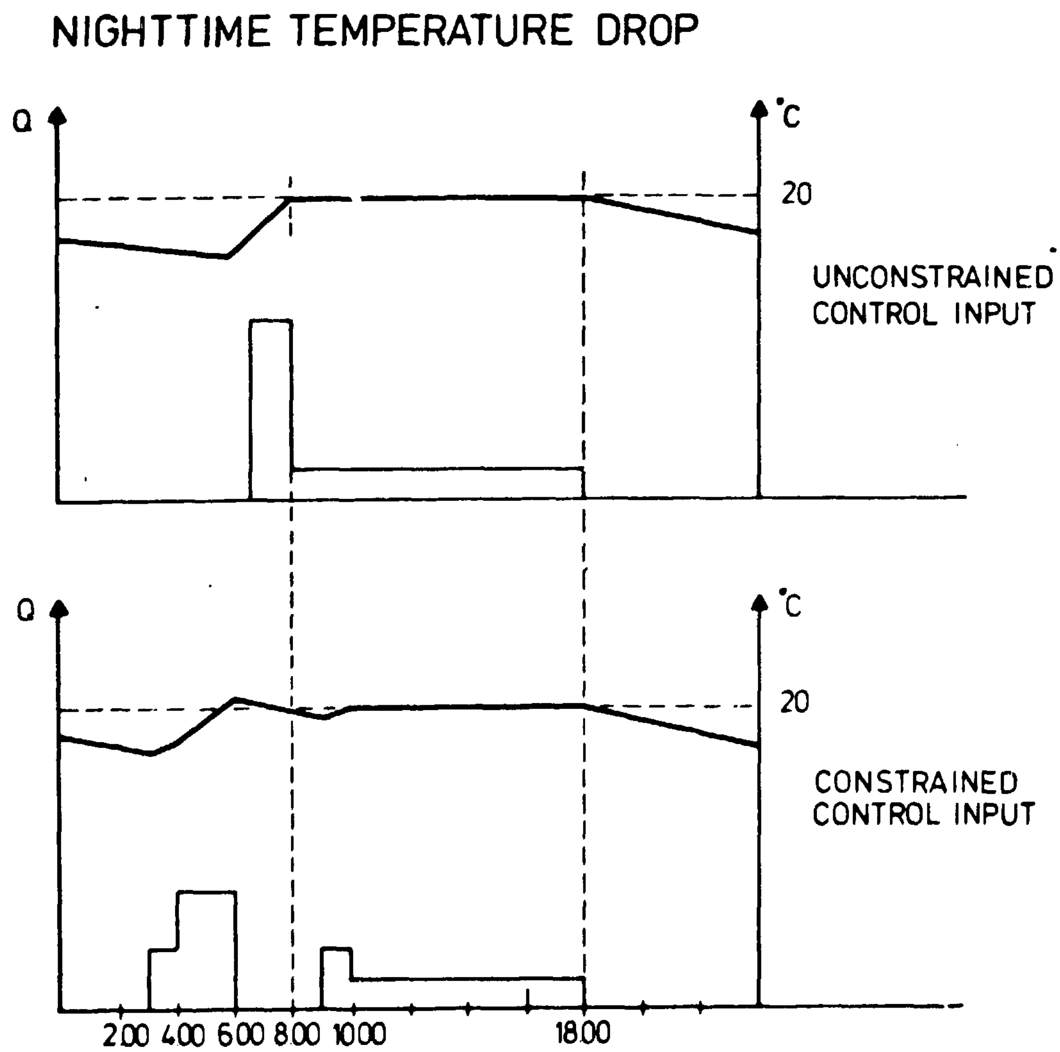


Figure 3/5.3 An example of room temperature change during standstill

Return to normal room temperature and humidity is performed by higher temperature of the induction units heating water and air conditioning, resulting from the use of higher temperature of the primary air. The air conditioning equipment is started prior to the point of time set in the time program only if the self-convection of the induction units is insufficient for raising the temperature. Where is it possible to use recirculation air, return of temperature is performed 100 per cent by circulation air and by higher temperature of the supply air.

The return phase of the temperatures ends and normal day time use starts when room temperatures have reached their set values, or when the using time of the spaces as defined in the time program has started. Illumination and other inside heat sources raise the temperatures to their normal day time values.

During the return phase, both the cooling water pumps and the humidifiers are to be switched off. Too high supply air temperatures are to be avoided because of the risk to break the windows if they are subject to very fast variations and differences of temperature.

To determine the stopping time for heating and cooling at the end of day time use, a corresponding method can be used.

The optimization described here can be applied to the most important VIC air conditioning zones. Standard programs are available and the necessary measurements are already included in the building automation system. The information on the possibilities to change set values is insufficient but the additional costs induced by the modifications are rather reasonable, however.

The optimization ought to be performed individually per each air conditioning machine. If no room temperature measurements are performed, the application is difficult.

5.3.2 Set Value Control of Primary Air Temperature

Under item 4.7.3, methods of changing the set value of primary air a e described, depen whether there is need for cooling or heating in the space served by the air conditioning unit in question. The functions can be performed by means of limit value monitoring and by means of reaction programs included in the building automation system.

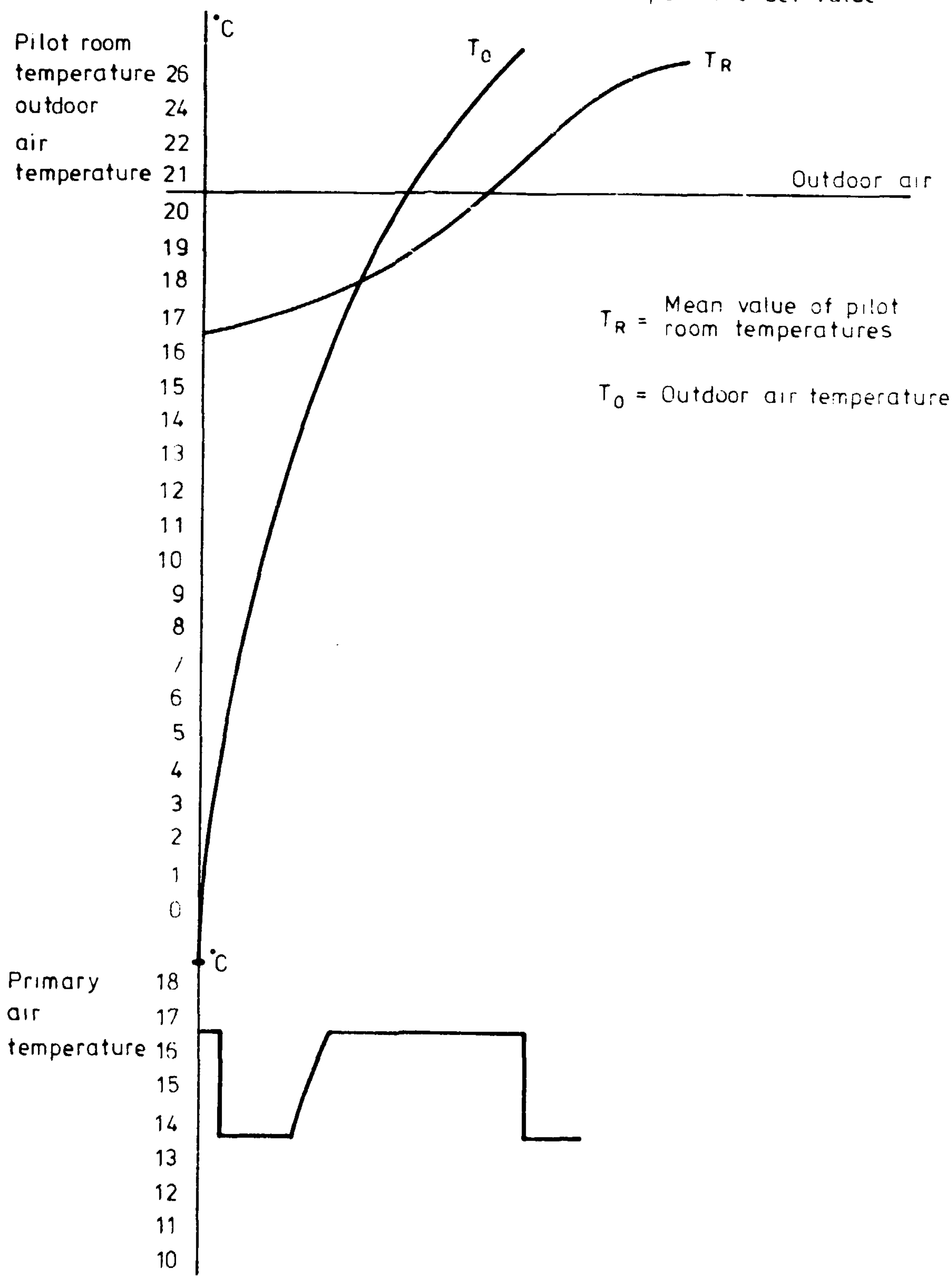
The choise of the correct set value is to be based on temperature measurements in the pilot rooms and outdoors. More information can be obtained from the difference between supply and return water temperatures of the heating and cooling water system.

Successive cooling and heating is to be avoided, and the major portion of the cooling and heating need is to be satisfied with the induction units.

Standard programs for the building automation system are also available but it is possible to perform the necessary functions with reaction programs and limit value monitoring. Only the adoption work of the functions cause expenses but the work can be done without disturbing the operation of the rest of the programs.

The function is suitable for air conditioning equipment covering pilot rooms, and in a simplified version for all air conditioning equipment allowing the change of the set value of the primary air.

Figure 4/5.3 Example of changing primary air temperature set value



5.3.3 Night Cooling

The idea with night cooling is to save cooling energy during day time by cooling the building during the night when cool air is available at no cost and also the electric energy is less expensive.

The night cooling program can be realized as follows:

At abt. 21.00 hours the temperature measurements of the pilot rooms are checked for whether the constructions and inside air need to be cooled. If the average value of room temperatures exceeds the present limit, at abt. 02.00 a.m., at the coldest moment of the night, the night air is checked for being cool enough for cooling. If it is, air conditioning is started without cooling, heating and humidifying for a period the length of which depends on the temperature difference between outside and inside air. The room temperature has a certain lower limit until which the cooling can continue. Simultaneous operation of the start-up omtimization, night heating, and night cooling is not allowed.

It is not possible to perform night cooling with the present reaction programs but time programs can be used, if by means of pump control heating or cooling in any part of the process can be avoided during night cooling. Suppliers of building automation systems can offer suitable standard programs.

5.3.4 Set Value Control of Water Temperatures of Induction Units

At the moment the temperature set value of the supply water of the heating water network is dependent of outside air temperature. When the air conditioning equipment is stopped, the temperature raises to 85 °C intensifying the self-convection.

For the night time, the set value would be dropped to abt. 35 °C and returned to normal only when the room temperature in any one of the pilot rooms drops below 17 °C. This would be performed with the start-up optimization program which would also raise the value to 85 °C under the room temperature restoration period. The cooling water pump should always be kept switched off during the heating period.

To realize this function, local water temperature controllers are to be modified to be made remote-controlled by the building automation system.

5.3.5 Directing the Cooling Efficiency

Cooling efficiency can be directed to those parts of the building in which it is most needed by reducing it in space where need for cooling is smaller. See point 4.7.6 for instructions.

It is rather uncomplicated to realize the necessary functions by means of the building automation system but no standard programs are available.

On the basis of pilot room and exhaust air temperatures and time of the clock the air conditioning units serving space needing most cooling can be identified. This implies the forming of a table into the memory of the building automation system computer. The program can then read which part of the building is exposed to direct solar radiation.

The variables to be controlled are the supply water temperatures of the cooling water system, possibly also the circulation pumps and the temperature of the primary air.

In most cases the needed measurements are existing but realization of this function requires more detailed studies.

5.3.6 Enthalpy Optimization

Standard programs for enthalpy optimization are available from the suppliers of building automation systems. The principle is described chapter 4.6.7.

Required outdoor and exhaust air relative humidity and temperature measurements are available but it will be necessary to rebuild the control of supply- and return air dampers.

Enthalpy optimization can be applied to the air conditioning units in Building C, with air recirculation possibilities.

5.3.7 Humidity Control

Humidity control can be performed by means of reaction programs, keeping room humdity within the set values. When the room humidity measurement reaches the lower limit of the acceptable scale humidifying is switched on and switched off when the room humidity has risen 10 per cent over the lower limit. This is a simple method for minimizing the use of humidifying, and it can be realized with reaction programs. Only the control of the humidifier must be changed into on/off/ auto type and connected to the building automation system.

5.3.8 Peak Power Limiting

The electrical peak power can be cut down with standard programs available from ITT. It is possible that detailed study of points to be cut down may require more control points in the building automation system.

5.4 Costs and Profitableness

5.4.1 Adoption to Use of the Basic System Extensiveness

To intensify the exploitation of the building automation system, labour costs will ensue from checking, producing the operation plan and adopting to use various existing functions. This will require a substantial amount of time, depending on how well the supplier of the building automation system will succeed in his own adoption work.

5.4.2 Completion of the Reporting

Completing the reporting to include the reports described under items 5.2.3.2 and 5.2.3.3 will necessitate the connection of energy and water flow measurements to the building automation system and the programming of the reports for the computer of the central unit. ITT has not provided any cost estimate but the costs may be abt. 300.000 ATS. Efficient reporting, however, is a solid base for the exploitation of the building automation system which is why it ought to be one of the first steps to take.

5.4.3 Higher Level Optimization

Higher level optimization can be realized in several phases, by completing the program and increasing the number of points step by step.

5.4.3.1 Peak power limiting

Costs for the program, including adoption to use and trial use, will amount to abt. ATS 150.000, after the inclusion of energy measurements to the building automation system. No estimate has been provided by ITT. This program will assure abt. ATS 520.000 savings per year, meaning that the investment costs will be covered in abt. four months' time.

5.4.3.2 Start-Up Optimization

As compared to more time-based programs, start-up optimization assures a daily half an hour time saving in the running of the air conditioning equipment and the heating and cooling time. Additional efficiency will be gained by allowing the room temperatures to drop freely to the set lower limit during standstills. The additional saving will amount to 8 per cent of annual heating energy costs.

Table No. 1 shows the annual savings, if the running of the air conditioning equipment is daily cut down by one hour on the average, by means of intensifying the use of time-based programs, and by half an hour daily, by means of start-up optimization. The table also includes the 8 per cent saving of heating energy, achieved by letting the room temperatures drop during night time.

Table 1/5.4 Heating and cooling energy savings when air conditioning is stopped daily for 1.5 hours and room temperatures are allowed to drop freely during standstill

Part of Building	Heating Energy MWh/a	Dropping of temperature at night time MWh/a	Cooling Energy MWh/a
A	335	316	107
B	244	117	46
C	614	521	131
D	302	253	44
E	191	176	64
F	741	158	196
G	140	113	42
Total	2467	1654	679

Conversion of cooling energy into electric energy is performed by a cold coefficient which is 2.7. Thus 679 MWh/a cooling energy saving equals to 252 MWh/a electric energy.

Electric and heating energy savings by stopping the air conditioning equipment is shown in Table 2.

Table 2/5.4. Electric energy savings when air conditioning is stopped for a period exceeding by 1.5 hours the present standstill during working days. Number of working days per annum estimated to 257.

Part of	Effect of Air Conditioning equipment and pumps kW	Energy Saving MWh	Saving ATS/a
A	468,6	180,6	141 800,-
B	234,7	90,5	71 000,-
C	501,7	193,4	151 800,-
D	237,7	91,6	71 900,-
E	235,4	90,7	71 200,-
F	689,3	265,7	208 600,-
G	213,2	82,2	64 500,-
Total	2580,6	994,7	780 800,-

Building part H is not included. Conversion from MWh into money has been performed by using the mean value of the summer and winter (day) tariff 0.727 S/kWh and by adding 8 per cent VAT.

The previous Tables can be summarized in the following Table 3, which includes heating, cooling, and electric energy savings in building parts A-G.

Table 3/5.4

Part of Building	Heating Energy ATS/s	Cooling Energy ATS/a	Electric Energy ATS/a	Total ATS/a
A	320 900,-	23 900,-	141 800,-	486 000,-
B	177 900,-	10 300,-	71 000,-	259 200,-
C	559 400,-	29 300,-	151 800,-	740 500,-
D	273 500,-	21 000,-	71 900,-	366 400,-
E	180 900,-	14 300,-	71 200,-	266 400,-
F	443 100,-	43 800,-	208 600,-	695 500,-
G	124 700,-	9 400,-	64 500,-	148 600,-
Total	2 080 400,-	152 000,-	780 800,-	3 013 200,-

Price for the heating energy has been calculated on the basis of 456.35 ATS/MWh and that for the electric energy for cooling ATS 0.559/kWh, in accordance with summer tariffs. 8 per cent VAT has been added.

Thanks to more efficient use of the time-based programs and to start-up optimization, an annual saving of about ATS 3.000.000 can be achieved. Start-up optimization includes also the free dropping of room temperatures during standstills to abt. 17 ^{0}C.

Costs arise from planning the more efficient use of time-based programs and from adding the start-up optimization to the building automation system. Costs for completing the programs amount to abt. ATS 300.000 and the modification costs of the equipment to abt. ATS 3 000...10 000 per air conditioning unit including the following measures:

- remote control for supply water temperature to the induction units or supply air temperature
- set value control for primary air temperature
- circulation air damper control in Building C
- changes in pump interlockings

It is extremely difficult to estimate the cost for equipment modifications and the calculated figures are to be handled with precaution. However, it is to be noted that the savings will cover the investment within less than two years.

It is recommendable to start the work from the biggest air conditioning equipment, covering the highest number of pilot rooms. A quotation to be requested from ITT, including completion of the programs of the building automation system, as well as the necessary supplementary control points and local automatic control.

The intensified use of the [illegible] programs can be initiated without any direct costs.

5.4.3.3 Other Higher Level Optimization Functions

The other optimization functions, described in chapters 4.7 and 5.3, do not necessitate particular modification work per air conditioning unit apart from those mentioned under item 5.4.3.2. On the other hand, that is not the case with completing the programs which can be estimated to amount to ATS 500.000.

Letting the room temperatures and relative humidities saves abt. 6 per cent heating and 20 % cooling energy annually ATS 1 300 000 and night cooling abt. 20 per cent cooling energy annually ATS 500 000.

Control of humidifiers saves annually ATS 1 800 000.

Control of [illegible] pumps saves annually ATS 1 200 000.

5.5 Experiences from Possibilities offered by Building Automation Systems for Energy Economy

Experiences from building automation systems containing the same kind of optimization functions show that energy savings up to 30...40 per cent can be achieved. Studies performed in the United Kingdom claim that after having done everything else to save energy in an office building, a building automation system will guarantee further 15...20 per cent energy savings.

6. Operative Organization

In several buildings the meaning of a functioning operative organization has been noticed. It is not enough to have the best technical level of the equipment, but, furthermore, it is necessary that there is competent personnel interested in the work, and also organization for the personnel, which makes it possible to carry out the operation and maintenance tasks in the best possible way.

For efficient utilization of the building automation system there must be a person in the operative organization who knows the possibilities within the system and also the characteristics of the technical systems as well as the limits caused by those characteristics. The person must be the leader in trying to find still a better way to regulate and control the functioning of different technical equipment. He must also know different possibilities of energy conservation and the energy consumption level which can be achieved. However, the essential point is that he is active and initiative, since many problems connected with the work have no ready made solution, but it has to be found by yourself.

VIC is such a large complex, and such a great amount of equipment is included in it that a person in charge of the operation should be extremely well acquainted with computer based building automation systems, modern HVAC control equipment main electric distribution centres, transformers, emergency power diesels, fire safety systems, access control systems, cooling equipment, water treatment equipment, air conditioning equipment, HVAC equipment, energy economy of buildings, questions concerning indoor climate and supervision of work, etc. It is obvious that the operative organization has to be built on many levels. Part of the organizational levels can be taken care of by outside maintenance companies, but tasks connected especially with the control of energy consumption should be in charge of those organizations which will pay the energy bills (UNIDO, IAEA).

6.1 Maintenance

Straight-lined direct maintenance, where alarm control status control, and operation time summing of the building automation system are utilized, can be carried out by a separate "maintenance company", at least so far as the routine work itself is concerned. Also the operator of the control room could be employed by a separate maintenance company.

6.2 Control of Energy Consumption and Indoor Climate Conditions

Control of energy consumption and indoor climate conditions belongs to the organisation which pays for the energy consumption, and which usually works in the building.

UNIDO and IAEA should have at least one engineer specialized in HVAC and one engineer qualified in automation and electronics. They would supervise and control efficient utilization of the building automation system, control the maintenance services, as well as control the energy consumption and indoor climate conditions by means of the reports of the building automation system. Except these tasks, the engineers would work as superiors of the operator of the control room.

Another possibility is to buy these services from an outside company, which should be working in the building until energy consumption and proper way of operating the equipment have been learnt.

6.3 Future Development

In a building like VIC reducing of energy consumption with all the design and implementation work connected with it is such a far-stretching task that for continuous development enough capacity that is not wholly tied to everyday routine tasks, has to be reserved.

Future development work belongs to the same persons who take care of the control of energy consumption and indoor climate conditions.

It is also important that they have firm connections to other people working for energy management and building maintenance, and that they keep themselves aware of the latest development in this field.

7. Recommendations

7.1 Measures Carried out Immediately

7.1.1 Electrical Equipment

7.1.1.1 Lighting

It is recommended to reduce the specific electricity consumption of office rooms by disconnecting the row of tubes adjoining the corridor. The saving could be as high as ATS 750.000 per year. Instead of 40 W mercury-vapour tubes, it is recommended to install gradually 36 W high effect tubes. The possibility of adding reflectors should be studied.

The illumination level in staircases can be lowered by removing one of the dual-tubes.

It is recommended to divide the lighting groups to smaller parts in the restaurant where presently the outer zone illumination is unnecessarily on. This goes also for other deep spaces.

Outside illumination level should be more efficiently used in illumination control, i.e. by setting two illumination level limits according to which, by means of the building automation system, office room illumination can be reduced to half of the maximum, or its use can be totally prevented.

Reducing the illumination time in office rooms by one hour per working day would result in abt. ATS 550.000 annual savings. This can be achieved by instructing the personnel and by the time programs of the building automation system.

7.1.1.2 Rotating Machines

Shortening of the running time of machines with the time programs of the building automation system saves both heating, cooling and electrical energy. Reducing the running time of all machines daily by one hour would result in an annual saving of ATS 2.000.000.

Savings can also be achieved by cyclic running of the machines, on the basis of the time programs of the building automation system ATS 500.000 annually.

Start-up optimization of the building automation system reduces the running time of the fans and pumps by approximately half an hour per day, resulting in an annual saving of ATS 1.000.000. Minimizing the running time of induction unit cooling water network pumps and heating water network pumps, by means of normal stops that prevent the running of heating water network pumps during cooling periods and the running of cooling water network pumps during heating time, will save 10 per cent heating and cooling energy in the induction units.

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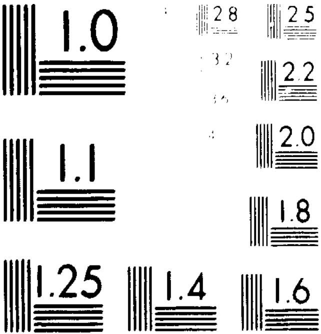
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The running time of the chillers can be reduced by allowing a more tolerable range for variations in room temperatures, and by applying the night cooling first with time programs and later by a control program for the night cooling, to be included in the building automation system.

Electric peak power limitation can immediately be realized by alternate running of the machines and by turning them on stepwise. Limit value control allows the control of the formation of the peak and subsequent manual limitation measures. Use of a peak effect limitation program, to be included in the building automation system, would in any case assure quicker and more reliable limitation. Savings would be about ATS 520.000 annually.

When switching on the cooling equipment, other loads ought to be switched off. With reaction programs to be included in the building automation system, the use of diesel generators for cutting the peak effect of the chillers would become possible. This necessitates modifications in the electrical distribution boards and new control points to the building automation system. Savings could amount to abt. ATS 2.000.000 per year.

In the location of the personnel of the organizations working in the building, the supply areas of air-conditioning units should be taken into consideration. This is difficult to realize because the supply areas are very large, and the running periods of the air-conditioning equipment tend easily to be long.

7.1.2 Heating, Cooling, Air-Conditioning, and Sanitary Equipment

Operation times of air-conditioning equipment should be adapted to times when the building is used. Tables on weekly operation, Fig. 1/7, can be drawn up according to supply areas of the plants, and the equipment ought to be run only when the area is occupied by at least 10 %, of the total occupancy. It does not require any investment, but the savings for the whole VIC can be altogether ATS 2.000.000 since the equipment are run on an average of one hour per day less than at present.

The temprątures in office rooms could be set in 21 ^{o}C (70^{o}F) in winter and 25 ^{o}C (78 ^{o}F) in summer during the day time. In winter the cooling water circulation of induction units should be kept closed or in free-cooling connection. In summer the heating water circulation is to be closed. No investments are required, but the savings for the whole VIC can be altogether ATS 1.500.000 when the room temperatures are 1^{o} lower than at present in winter and 2^{o} higher in summer.

Humidity in office rooms should be adapted to outside humidity. Humidification should be used only for keeping the room humidity at least in 30 %. Drying by cooling and heating shouldn't be used. Room air is sufficiently dried by cooling the primary air to 18 degrees. No investments are required, but savings of 1.800.000 ATS can be achieved, when room air is humidified only to 30 % instead of 40 %.

Flow restrictors can be installed in shower pipes of water fittings of the basins and the showers. Restrictors of a maximum flow of 0.1 l/s are used in basins and of 0.2 l/s in showers. Costs for these changes are ATS 160.000 and the savings for the whole VIC altogether 208.000 ATS/a. The work can also be carried out by stages during several years.

Warm water temperature should be decreased from 45° to 38°. Thus it is possible to get water, with the same temperature as the body, for washing and shower straight from the hot water tap of twin-grip mixer and excess tapping is reduced. In a branch to the kitchen warm water temperature ought to be kept unchanged. Equipment in other spaces requiring water over 38° have to be provided with local preheaters. Price for the changes is about ATS 100.000 and annual savings about 206.000 ATS/a. The work can be carried out by stages one supply area at a time.

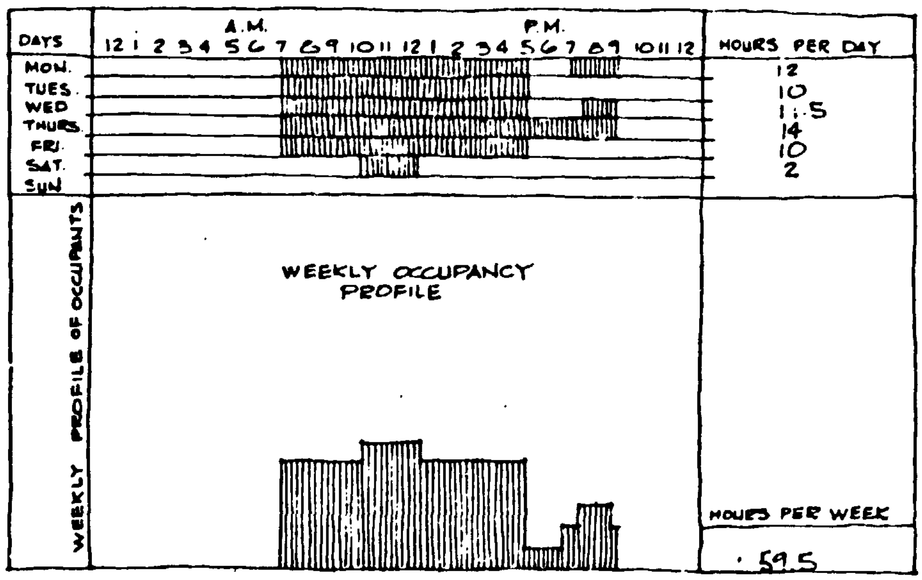


Fig. 1/7 Building weekly usage program

7.1.3 Building Automation System

It is extremely important and urgent to adopt into use the basic extent of the building automation system. Both the reliability of measurement data and the correct operation of the controls has to be ascertained. Exploitation of the system can only be based on reliable data transfer between the central unit in the control room and the monitoring and control points in various parts of the building.

The functions of the system are to be tested, in the presence of the supplier, designer, and user, and the user thereby to be introduced to the possibilities of the system and above all to the processes to be monitored and controlled.

In addition to getting acquainted with the operation and maintenance of the system, methods and routine for making use of the information received and for performing maintenance measures necessary for the basic functions are to be developed.

Energy consumption measurements are to be included in the building automation system, and an energy consumption reporting system to be built, on the basis of which it will be easy to follow the effect of energy saving measures. Also the reporting serving control of indoor climate conditions is to be developed further.

The documentation of the technical systems of the VIC is to be completed, to enable its daily effective use for operation and maintenance. Full set of colour monitor schemes should be made available.

The use of time programs is to be intensified, and the limits determined by indoor climate conditions should be found.

Calculation of the running time is to be adopted for the benefit of maintenance operations.

At the first stage, the peak effect limitation program could be adopted to use on the basis of measuring the total electrical effect of the VIC, and later on the basis of individual energy measurements per part of building.

Night cooling can be applied with time programs to begin with, at the coldest time of the night during cooling periods. Later a separate control program for night cooling can be included in the building automation system.

On the basis of temperature measurements in pilot rooms, the heating and cooling water pumps of the induction units can be controlled with reaction programs.

During standstills the water temperature of the induction unit heating water network should be lowered, or the heating water pump stopped until the temperature in one of the pilot rooms has dropped to 17 °C. Only then the temperature is raised to 85 °C by reaction programs, or the pump is started.

Raising of the temperatures after standstills is performed by time programs. Later, the building automation system will be completed with a start/stop optimization program.

Humidity is controlled by means of lower and upper limit alarms of the humidity measurements. Humidity is kept sufficient but not unnecessarily high.

Costs resulting from other energy saving measures should be studied in detail.

7.1.4 Operational Organization

The operational organization is to be such that UNIDO and IAEA have a firm grip of the operation of the staff on duty at the central control room and of the method of monitoring and controlling the technical equipment of the VIC.

For this purpose, UNIDO and IAEA are to employ a person who is familiar with the possibilities offered by the building automation system, and also with the characteristics of the provesses to be monitored and controlled. He could supervise and guide the work of the operator at the control room and the head of operations. Above all, he is to concentrate on reducing the energy consumption and on developing new methods serving this objective.

Maintenance operations can be performed by a separate maintenance company. The chief of the total operational organization will, however, have to be employed by the organization using the spaces.

7.2 Measures Reguiring Considerable Investments

7.2.1 Electrical Equipment

7.2.1.1 Lighting

Groups of lighting that can be controlled by the building automation system are to be modified to correspond to the working zones of the various organizations.

Lamps to be furnished with reflectors in office rooms.

To limit the indoor lighting measurement of outdoor illumination should be performed on each facade.

7.2.1.2 Rotating Machines

Diesel generators can be used to cut the peak effect, coupling modifications should be performed.

The control couplings of the pumps should be modified, to enable their use for peak effect limitation. They can then also be used by the optimization programs of the building automation system.

7.2.2 Heating, Cooling, Air-Conditioning, and Sanitary Equipment

Air Flows

Air flows of air-conditioning equipment of office rooms can be reduced by 25...33 % for saving energy in heating, humidification, and cooling of primary air. At the same time the heating efficiency of induction units is reduced by 18...26 %, which can be compensated, if needed, by increasing the temperatures of water circuit. Also the cooling efficiency is reduced by 18...26 %, which can be partly compensated by different temperature ranges during the day time. Directing of cooling loads to sunny facades contributes to the control of room temperatures. Investments are 91.000 S, and the savings possible to achieve for the whole VIC altogether 1.660.000 S/a, when primary air flow is reduced by 33 %. The work can be carried out by stages one air-conditioning group at a time. Exhaust air flows ought to be always reduced as much as supply air flows.

Heat Recovery

Heat recovery should be installed in air-conditioning equipment of office rooms. The waste heat can be collected from the exhaust air flow by cooling coils and delivered to supply air heating coils, using antifreesing solution as medium. The piping network between mechanical facilities on the roof and the intermediate floor ought to be located into the shaft. Some 50 per cent of the heat content of exhaust air can be collected by liquid recovery. This means an annual saving of ATS 3.700.00 for the whole VIC, and the estimated investment amounts to about ATS 10.095.000. The accurate price can be requested in the form of tenders from air-conditioning contractors; calculations to be based then on a detailed design of the heat recovery. Heat recovery can also be realized in stages over several years, one a/c unit at a time.

Solar Film

Solar protection films might be mounted on the inner surfaces of the windows. The film type ought to have high reflection and low absorption coefficients. Transmittance for visible light should be higher than for the solar radiation band as a whole. Solar radiation shading factor to be about 0.3...0.6. When choosing the colour of the film, in addition to technical, also architectural aspects should be taken into account.

The film assure direct savings of about ATS 914.000 calculated as reduced cooling and heating expenses. Further savings can be achieved thanks to the films allowing the reducing of primary air flow by about one third (cf. 7.2.2). The film also helps in the more effective use of floating room temperature control.

The film investment is about ATS 2.800.000. The work can be performed gradually, preferably one facade also be at a time, controlled by one air-conditioning unit. Films can removed and the windows restored, if so desired. If mounted on the outer surface the films might be more effective but they are likely to be damaged by rain, wind, dust, cleaning, frost, etc.

7.2.3 Building Automation System

The adoption to use of the optimization programs described under item 5 will necessaritate investments. The programs of the building automation system are to be completed, and additional couplings between the building automation system and local control devices are to be made.

The savings to be achieved can be up to 30 per cent of the energy expences which is why the continuous completing of the building automation system and the continuous expanding of its control points is motivated.

A lot of design work will be required, but if realized phase by phase, the economy of VIC will be strained to such an extent only as to correspond to the accumulating savings.

7.3 Measures Requiring Additional Studies

7.3.1 Electrical Equipment

It is worth while to check the measures of the fan motors. Changing the motors, however, is presumably such an expensive measure that it is not likely to be motivated.

It is probable that the interlockings between chillers and cooling tower pumps are in correct order, but, however, it is recommendable to make sure that an unnecessary number of pumps is not running if only part of the cooling equipment is running.

During the winter period, it may be recommendable to use diesel generators even for longer periods if they are furnished with heat recovery equipment.

7.3.2 Heating, Cooling, Air-Conditioning and Sanitary Equipment

Waste Heat Systems

The condensing heat of the chillers could be used for preheating the domestic hot water, and this would probably not require any complicated measures. A heat exchanger in the cooling tower will transfer the heat to the hot water circuit, and the preheated water is then conducted from the technical centre in the pipe collector to the hot water preparation stations in Building C. This item is to be studied in detail by measuring the momentary flow variations and storing requirements of the hot water supply of the whole VIC complex.

Infiltration

Outdoor air infiltrations to be minimized where cracks are observed, because the air infiltarations means a significant and continuous heat loss and having no beneficial role under unoccupied periods. To minimize the cross-flow in the staircases, possibilities of building vestibules at the bottom of the staircases should be studied. Also air-lock ventilation is to be assured by the vestibules. Natural ventilation through air-lock ventilation ducts should be decreased by tightening the dampers.

Envelope

Possibilities of using further air curtains at service doors and loading platforms should be studied. Possibilities of improving the heat insulation at weak points of the building envelope should also be looked into. One such point is the glass wall behind the induction units on the entrance level. Heat losses are substantial during winter time and the cooling load is considerable during the summer through the glass area which does not offer any benefit in the form of natural light. Adding an insulation sheet on the lower part of the window involves an architectural issue but would assure an annual saving of about 130 ATS/m^2.

7.3.3 Building Automation System

Optimization Programs

The possibilities of exploiting the optimization programs included in the most modern ITT building automation systems in the VIC system should be studied. At least by replacing the present VIC central unit by a new type the adaptation is possible, but this causes expenses also on the substation level.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
1	2.1.4	Change Temperature Range from 22°C - 24°C to 21°C - 26°C	1.500.000		These standards are acceptable. BMS will contact IAKW to adjust equipment accordingly. *Impossible - over 5000 thermostats would have to be adjusted by hand twice yearly.
2	2.1.4	Change relative humidity range from 40% - 50% to 30% - 60%	1.800.000		This range cannot be altered due to the static electricity created when humidity is less than 40 - 50 %. *The humidifying equipment is only used from October through May.
3	2.1.5	Reduce air flow from 12.5 l/s to 10 l/s	1.660.000	91.000	Difficult to implement because the air jets of each induction unit will require modification. *This will be tested in buildings A, D during week 44/80.
4	2.2.1	Reduce illumination levels in offices to 500 lx from 600 - 650 lx			Accepted - means of implementation embodied in later recommendations (6, 7, etc.).

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
[illegible]	3.1.1	Control the switching off of lights in the evening and in unoccupied rooms	549.000		Accepted - tied to software improvements in the b.a. system. * Implementation commenced during the summer of 1980.
6	3.1.1	Eliminate the outer row of lights in each office room	750.000	BMS Labour	Accepted - BMS investigating means of implementation.
7	3.1.1	Replace 40W tubes with 36W tubes			Accepted. BMS has been able to take advantage of a special offer by Philips and is acquiring 36 W tubes at a price which is just marginally greater than that of the 40 W tube.
8	3.1.2	Use lighting sensors in the building automation system to reduce illumination levels by 50% or completely switch off when unnecessary	n.a.	BMS Labour and hardware	Accepted - tied to b.a. system. * Additional lux meters and wiring required for the b.a. system could be expensive.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in A$)	Investment Required	Disposition
9	3.1.3	Reduce the lighting control groups presently covering four floors to a smaller one which would permit more lights to be turned off during unoccupied hours.	n.a.	BMS labour and hardware	Appears reasonable. BMS to investigate complications of rewiring. * Additional distributors and relays required - could be expensive.
10	3.1.3	Paint the ceiling of the parking houses white to increase illumination.			Accepted with very low priority. Test should be made to check benefits.
11	3.1.3	Attach clock switches to those light groups not included in the building automation system.			Not accepted - an effort will be made to expand the b .a.system to include all lighting groups.
12	3.1.4	Reduce illumination in parts of the staircases			Accepted - BMS is in the process of implementing this recommendation.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
13	3.2.1	Reduce the running time of fans, pumps and chillers by 1. turning them off via the b.a. system 2. checking the local interlockings for redundancy of grou-			Requires discussion with IAKW, ITT (b.a. system supplier), and BMS staff to verify capabilities. * Step 1 is very difficult due to the slow reaction time of the equipment; Step 2 - technically impossible Step 3 - large investments for the b.a. system needed.
13	continued	pings 3. utilizing the sensor devices of the b.a. system to react when heating or cooling unnecessary.			
14	3.2.1 3.3.1 [illegible]	Optimize time programs by allowing for start/stop features.	550.000		Accepted - tied to b.a. system. *This has been in operation since 16/10/80 - 90 minutes reduction in running time introduced.
15	3.2.1	Turn off some machines automatically for five minutes each hour.	364.600		Accepted dubiously - it could be better to shut down the system for one hour over lunch time. BMS investigating. * IAKW is firmly opposed to this recommendation.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
16	3.4.1	Phase the start-up of electrically powered equipment to reduce peak-load demand.	566.600		Accepted - tied to b.a. system. * The peak power demand has been spread over 28 minutes.
17	3.4.1	Use the emergency generators to decrease peak load demand.	2.066.400	40.000	Not accepted - the two sources are mutually exclusive and Austrian law prohibits the ~~not~~ procedure.
18	4.4.2.1	Instruct occupants to properly use venetian blinds, e.g. by lowering and closing them each evening prior to departure			Accepted - savings dubious.
19	4.4.2.2 4.4.2.3	Install solar protective film on those facades of the VIC complex which are exposed to prolonged direct sunlight.			Basically not accepted. Tests show that proper use of blinds achieves the same results.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
20	4.5.1 4.5.6	Install a water-glycol heat recovery system to trap warm exhaust air for re-use in the heating system.	3.702.000	10.095.000	Accepted in principle - must be thoroughly reviewd with IAKW. * This is impossible in Bldg. C. In the other buildings, despite severe space limitations it is possible. Total estimated cost - AS 20.000.000
21	4.6.1	Install flow restrictors in the water taps to reduce water consumption volume.	200.000	150.000	Accepted. BMS will proceed to implement.
22	4.6.2	Reduce the temperature of the warm water system from 45°C to 38°C, supplying auxiliary electric heaters to those areas requiring water warmer than 38°C.	100.000	206.000	Accepted. BMS to co-ordinate implementation with IAKW. * Reduction to 38 °C is impossible because the temperature is set at 5° intervals. The temperature was reduced to 40°C in summer 1980.
23	4.6.3	Reduce the volume of WC flushing reservoirs by placing 2 to 3 litres of polystyrene particles in each reservoir.	95.000	20.000	Accepted in principle. BMS will check other means of flow reduction. * Flow can be reduced by adjusting the float. The polystyrene particles are unnecessary.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
24	4.7.3	Optimize the primary air setpoint temperature through correlation with the outside temperature.			Accepted - tied to b.a. system. * IAKW must investigate this recommendation further.
25	4.7.4	Use outdoor air to cool the complex overnight in summer.			Accepted - requires software modifications in the b.a. system. * This recommendation will be tested by IAKW next summer.
26	4.7.5	Allow the water temperature in the induction unit net-work to drop at night and re-heat by shock treatment just prior to building occupancy in the morning.			To be checked with IAKW. Shock treatment may not be possible with present equipment. * Further investigation by IAKW required.
27	4.7.6	Limit cooling power by directing it to those parts of the complex where cooling demand is highest.			Probably impossible due to building and system design. To be investigated further by PMS. * Further investigation by IAKW required.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
28	4.7.7	Compare the temperature of exhaust air from building C with that of the outdoor air and adjust the supply and return air dampers accordingly (Enthalpy optimization)			Accepted in principle. A detailed study is required. In view of the priority (Bldg. C uses least heating and cooling power of all buildings) probably not feasible. * This recommendation has been, in effect, implemented.
29	4.7.8	Allow minimum room temperature to reach 17°C and relative humidity to reach a maximum level of 75%.			Accepted tentatively - tied to b.a. system. * Further investigation by IAKW required.
30	4.7.9.1	Set the primary air heating coil pumps to run only when outside air temperature is below 16°C.			Accepted - tied to b.a. system. * This recommendation is operative - automatic adjustment is impossible but is done manually.
31	4.7.9.2	Set the primary air cooling coil pumps to run only when outside air temperature is above 17°C or pilot room temperature is above 24°C.			Accepted - tied to b.a. system.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
37	4.7.9.3	Set the induction unit pumps so that the heating and cooling net works cannot operate simultaneously.			Accepted - to be implemented in due course by BMS. * IAKW reports that this is impossible due to the 4-pipe design of the system.
3[illegible]	5.2.1	Confirm the accuracy of the b.a. system sensors - calibrate temperature devices annually and humidity devices semi-annually.			Accepted - but in view of the basic priority to achieve a functioning b.a. system, these refinements will require significant time to implement.
3[illegible]	5.2.2	Train BMS and maintenance contractor staff thoroughly in the functions of the b.a. system.			- " -
[illegible]	5.2.3	Ensure follow-up of messages and reports received from the b.a. system.			- " -

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
36	5.2.3.2 5.2.3.3	Develop specialized reports (e.g. for temperature and humidity) from the b.a. system.			see Rec. Nos. 33 - 35 * Implemented in October 1980
37	6.2 6.3	Tasks related to energy conservation should be assigned to BMS staff (not contracted out).			Accepted - Vacant posts are under recruitment. Available staff are involved to the extent possible.
38	7.1.1.1	Study the possibility of adding reflectors to the light housings.			Accepted - study of this recommendation has already commenced. * Partial implementation achieved. Balance subject to investment.
[illegible]	7.1.1.1	Divide the lighting groups into smaller sections in the restaurant and other wider areas to minimize the need for illumination in outer areas.			Accepted - rewiring and modification of the switching is required. Will be implemented in due course.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
[illegible]	7.1.2	Adapt the operating time of the air conditioning units to the working hours.	1.500.000		Accepted - will be implemented after agreement with Head, GSS and Director, Administration. * See Recommendation 14.
[illegible]	7.1.2	Arrange completion of documentation of all VIC technical systems including a full set of colour monitor schemes.			Accepted - BMS has consistently requested this documentation. To date, some 10 % is completed. * By end '80 10 - 15 of a possible 200 diagrams will be available. This item has lower priority.
42	7.1.3	Increase the use of time programs in the b.a. system			Accepted. Due to the generally tentative condition of the b.a. system and the seeming lack of progress in achieving the full potential of the b.a. system, consideration should be given to intervening at the highest possible level in order to resolve the many shortcomings of the system. *)
43	7.3.2	Attach heat exchangers to the chillers in order to preheat domestic hot water.			This is an expensive proposition and involves the "Ubergabebauwerk" which is not the property of the organizations. The legal, technical and fiscal aspects of the recommendation remain to be investigated. *)

*) see attached page

Disposition
ad 42) * Since October '80, the supplier has made significant progress in making software of the b.a. system available.
ad 43) * IAKW reports that this recommendation is impossible to implement.

VIC Energy Consumption Study - Disposition of Recommendations

Rec. No.	Chapter Reference	Recommendation	Potential Annual Savings (in AS)	Investment Required	Disposition
44	7.3.2	Build vestibules at the bottom of all staircases to minimize cross-flow.			Accepted. The matter is being further studied in order to determine how much of the cost will be assumed by the host government. * MA 35 prohibits such construction Cross-flow is the only source of ventilation in the staircase.
45	7.3.3 2	Decrease natural ventilation through airlock ducts by tightening the dampers.			Cannot be accepted - there are no dampers. The Fire Safety Unit will be requested to investigate the matter further.
46	7.3.4 2	Study the possiblity of using air curtains at service doors and loading platforms			The possibility of installing an air curtain at the commissary loading platform is being studied. Otherwise wind breaks will be erected at the service doors. * An air curtain is presently installed at the commissary loading platform. Wind breaks will be used [illegible] energy in order to fulfill their purpose.
47	7.3.4.2	Investigate weak points of heat insulation, e.g. the glass wall behind the induction units on the entrance level.			Accepted. The application of reflecting insulation has already commenced.

Replies to the Comments

UNIDO Buildings Management Section, General Services/ Division of Administration, and UNIDO/IAEA Joint Working Group on Energy Conservation, have studied the draft report. A summary listing of their findings is enclosed as Appendix 1.

At many points, the opinions of the client and the consultant run parallel, and these points do not necessitate further handling, Those proposals contained in the report calling for more specific explanations are dealt with hereunder.

Rec. No. Report Chapter

15 3.2.1 Shortening of Running Time

Short-time machine stops have been successfully applied among others in the United States of America, with encouraging energy saving results. The possibilities to use this method depend on the building object, on quality level requirements for the air-conditioning, and on prevailing official air-conditioning regulations.

19 4.4.2.2 Influences of Fixed Solar Protection Films

It is often recommended to retrofit solar protection films on windows of existing buildings, and when one-glass windows are concerned, the results are good. A recently developed combination of an ordinary solar protection film and a heat protection film (3M:P19) can be recommended for inside installation also on two-glass windows.

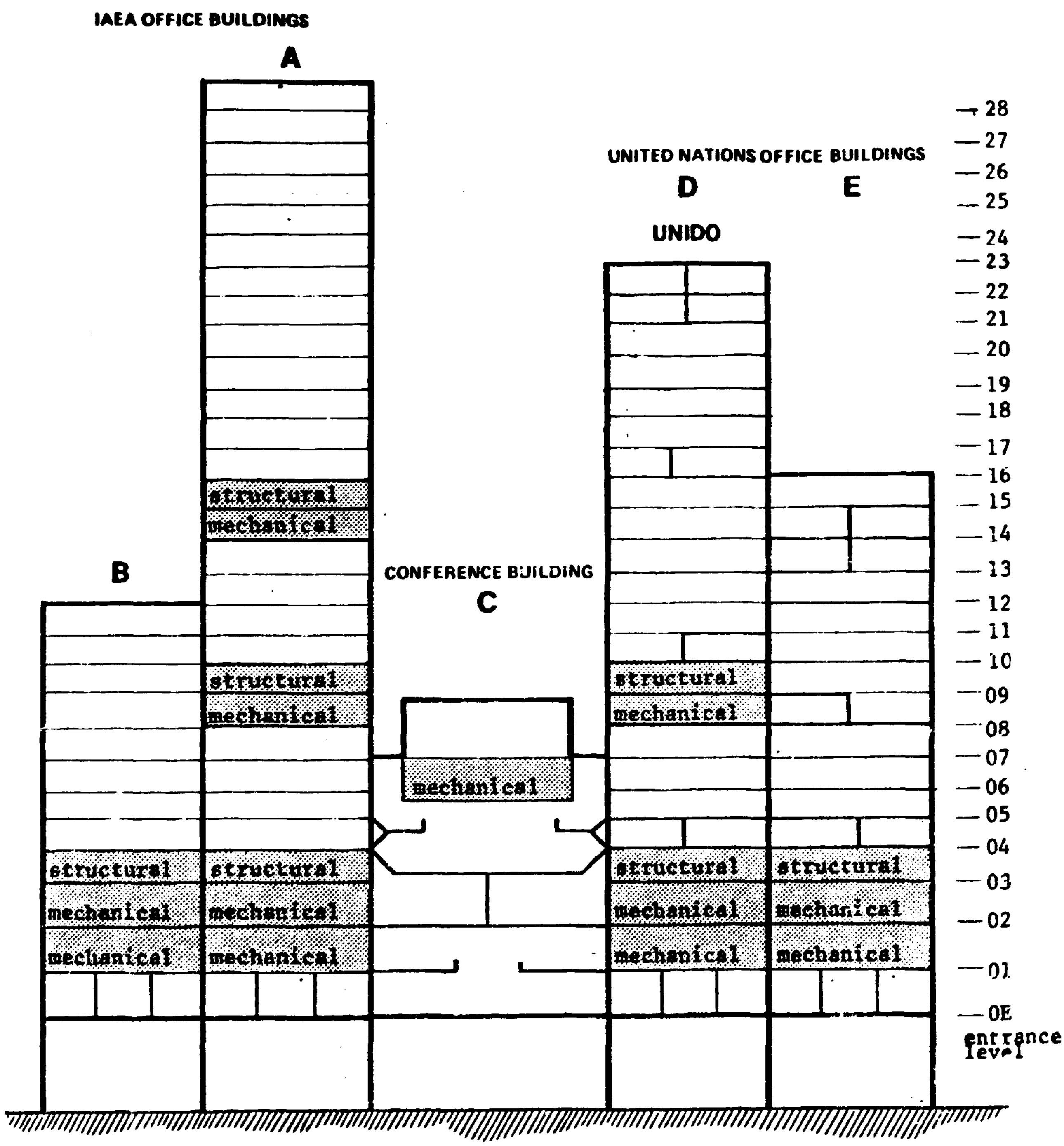
This film has beem used to retrofit the windows of two utility company office buildings in California (Fresno and San Jose). All windows in both eight-store and eleven-store buildings have been retrofit. Remarkable energy conservation and operational benefits are expected. Further information available from: Mr. Stan Blois, Pacific Gas & Electric, Room 740, 215 Market Street, San Francisco, California 94106, USA.

33 5.2.1 According to our experience, the quality of the sensors varies, depending on the supplier. That is why we suggest you annyally check the accuracy of the b.a. system sensors - calibrate temperature devices, and semi-annually the accuracy of the humidity devices. At least random checkings are to be performed and the sensors calibrated when necessary.

42 7.1.3 Time Programs and other improvements
The b.a. system has several unused features, with which significant energy and operational benefits could be gained. The time programs, higher level optimization programs and energy reporting together help to save energy and operational work. Such programs are available from your b.a. system supplier and spezialized consulting companies.

43 7.3.2 Heat Recovery in the Chillers
The internal energy saving of the cooling machines and the exploitation of the condensing heat are generally worth while a closer study. In the VIC case, administrational limits make the exploitation more difficult.

45 7.3.2 Smoke Exhaust Openings in Staircases
During normal operation, it is attempted to minimize air leaks from front doors through the staircase into the smoke exhaust openings. In a fire-case, the openings are to be open.



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10
09
08
07
06
05
04
03
02
01
0E
entrance level