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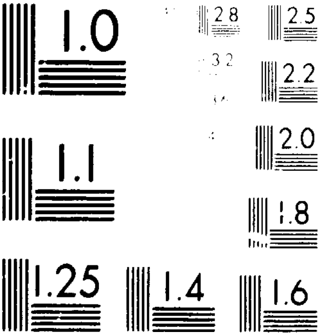
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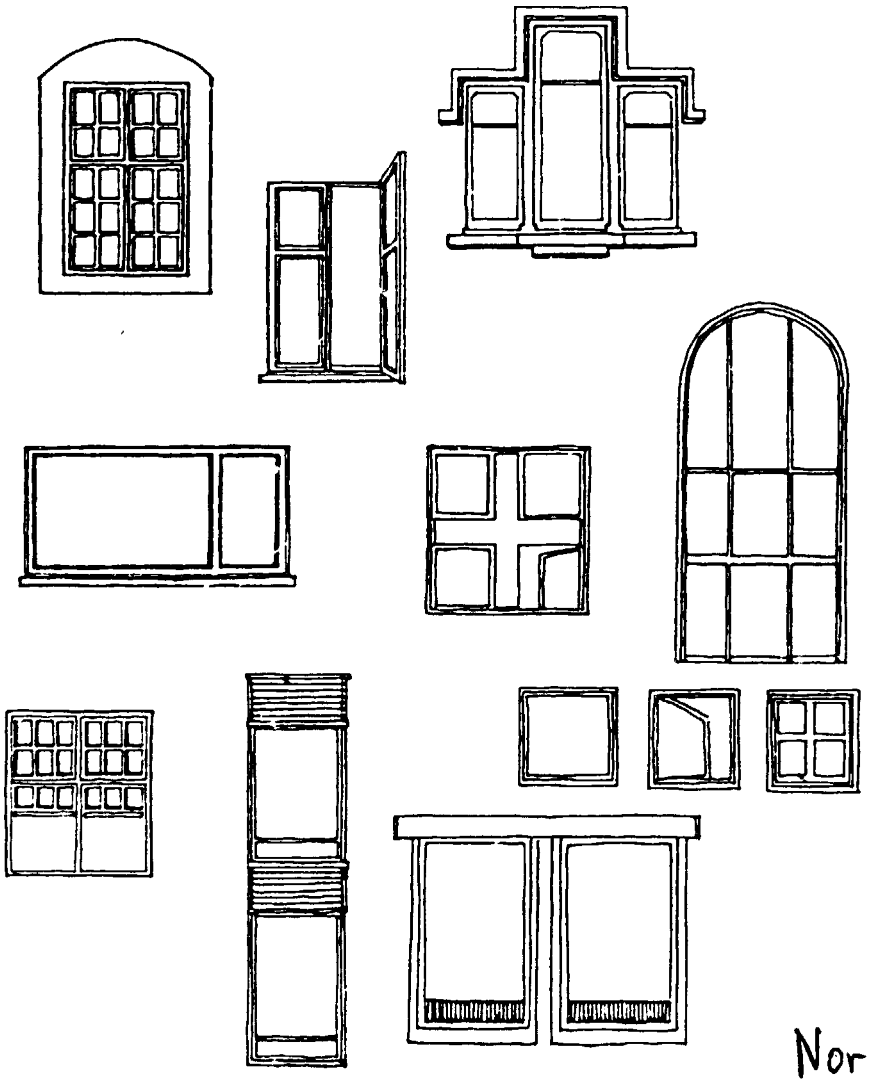


Nordstroem S

Study and report of the feasibility of installing openable windows at the Vienna International Centre - VIC.

1982-01-20

CONTENTS

ANNEXES

1 INTRODUCTION

1.1 Background

The Vienna International Centre is a gigantic complex of buildings. It has accomodation for some 4.000 persons and it is situated on "virgin soil" at the edge of the Vienna townscape. The centre is not connected directly with the downtown area, the old Vienna, which is enhanced even more by the fact that there is as yet no underground service to the centre of the city, and that a trip with the tram across the Danube takes much time.

The building complex seems to be more influenced by the American way of life than the European one. The dimensions, the architecture, and the technical systems are unusual in Austria as well as in other parts of Europe. It is therefore a matter of course, that the building produces a number of issues which, for the individual, are hard to classify and separate, and difficult to understand the real reason for.

When a building first begins to be used it will always be subject to critical observations. However, as time goes by, and you grow accustomed to the unfamiliar environment, most of the negative and positive experiences that cannot really be attributed to the building itself will wear off and features that may be necessary to adjust or improve will remain only.

During the visit in September 1981, our team also noted that the question if openable windows is only a part of a larger group of questions, concerning the working environment within the building and how the people working there experience the building. One particular type of experience is counterbalanced by openable windows, namely the feeling of being shut up. The size of the building, the dependence upon technical installations which you cannot influence, the close corridors at the different floors, etc, of course enhance the feeling that you have no real contact with the climate out of doors.

We have previously stated that our experiences from the Building Board of small as well as large office buildings plainly indicate that windows should be openable. We therefore sympathize with the complaints that the staff has put forward.

Being a complex of buildings, the Vienna International Centre has also been equipped with advanced air conditioning systems. There are approximately 30 central air conditioning plants for the office premises, which plants filter the air, heat, cool and moisten it. The air is then distributed in the building to so-called window units, positioned under the windows. These finishing units can cool the air as well as heat it and the employee working in the room may select desired temperature within the interval 3 - 4°C.

It is possible that the systems are rumoured to demand more energy than they really need. The operating costs are indeed high, but, as the air can be re-treated locally to suit the requirements of the separate rooms, the energy consumption is still rather moderate, with a view to the high standard offered.

It may be of interest to make comparisons with buildings in southern Sweden, which has relatively similar outdoor climatic conditions. The VIC building consumed during the heating season 1979/80 as heating energy 33,3 kWh/m3 building volyme and as refrigerating energy for the A/c system ca 10 kWh/m3.The electric power consumption during the same period was altogether 19,9 kWh/mr or 77,7 kWh/m2.

According to statistics conducted the the National Board of Public Building for office buildings in southern Sweden heating energy was consumed amounting to 30 - 40 kWh/m3. and electric power amounting to 14 kWh/m3.
Concerning cooling energy it is difficult to compare with conditions in Sweden.

The normal procedure was, at least for older American systems, to cool all air in central plants in order to supply the hottest room with as cool air as required. The other rooms must then be re-heated to a suitable level. Consequently, this means that the air is treated two times, first cooling, and then heating, and this is expensive. In VIC, it is possible to cool as well as heat the air locally, and this at least limits the double treatment of the air. As we will show in this report, the double treatment could be completely eliminated if the temperature requirements for the rooms are somewhat moderated and the mode of operation changed.

1.2 Conclusion

The study we present here on the feasibility of equipping the VIC with openable windows, in a manner both economical and practical, will show that this is possible.

We have focussed the study on the windows of the high rise buildings. The low rise buildings have windows constructed differently; as these constructions already contain solutions for openable windows we have not included this part. The cost estimate is based on 5,000 windows which figure could probably be reduced when going through the estimate in detail together with the Building Management Staff.

If, at the same time as offering the openable windows and consequently better contact with the climate out of doors, it was possible to make an agreement with the staff on relaxed temperature requirements, primarily during the summertime, the energy consumption could be cut down considerably. We have chosen to calculate the consequences of a mode of operation which allows the temperature to "float" and thus utilizes the thermal dynamics inherent in the building; the calculations have been based upon a new, suggested level of requirements. The conclusion of our calculations is that the reduction of energy consumption gives a depreciation period for investment in openable windows of some 7-10 years. No capital cost is then included.

2 SCOPE OF THE STUDY

We have tried in the study to examine what the consequences would be when a number of windows of the multi-storey buildings of the VIC are changed to openable windows, or as an alternative, are fitted out with equipment for direct supply of fresh air. We have however rejected the latter alternative at an early stage.

The emphasis has been put on the study of energy consumption in the buildings before and after the introduction of openable windows. We have examined in a great number of calculations - we put forward only a few of these in our report - how different operating conditions and different climate requirements affect the energy consumption. In view of how the building functions and behaves, thermally, we suggest new climatic requirements which we feel the users should be able to accept if they are at the same time offered openable windows.

Various technical alternatives are presented, with advantages and disadvantages. The costs for those alternatives that we recommend are given, as well as the operating costs which could be saved by using the new suggested mode of operation. Special attention has been directed to factors mentioned in the Terms of Reference, for instance architectural effects, safety and security issues, etc.

As the main purpose of making the windows openable is saving energy, according to the Terms of Reference, our team has also examined how it would be possible to cut down operating costs for the air conditioning plants. We suggest a 30% reduction of the fresh air put in the building which saves both fan energy and heating energy.

The study roughly contains the following parts:

- visit to Vienna; ca 1 week for interviews and discussions with the staff of the Building Management and General Services;
- comprehensive tours of the buildings to study methods of work and to learn the reactions of the individuals
- visit to IAKW to discuss construction of windows and visit to "die Centralanstalt für Metrologie und Geotechnik" to discuss climatic data
- examination of the facade construction by dismounting parts easily removed
- exhaustive examination together with the operating staff of the operation of the air conditioning plant and possible changes of it
- preparation of three alternative suggestions for openable windows - one of these was selected for further treatment and preliminary tenders from a number of suppliers/manufacturers
- calculation of the energy consumption based upon present mode of operation, and upon suggested mode of operation
- analyses of costs, energy consumption and periods and suggested plan for realization.

The below persons have participated in this study:

Mr Sören NOrdström, team leader
Mr Lars-Olof Andersson,
Mr Engelbrekt Isfält,
Mr Göran Lundquist

Mr Egil Herdan of the UNIDO has been the liason officer.

3 OPENABLE WINDOWS

3.1 General

The change to openable windows will affect the appearance of the facade - its architectural impact - the exterior and the interior.

Aesthetic judgements are always subjective evaluations and therefore no general opinion as to the beauty of the building could be ascribed to all observers. However, our team is of the opinion that the building would appear more substantial and distinctive. The facades, that may appear monotonous today, will be split up by double aluminium profiles which recur in every three window module and which contain the openable window. Each three-module unit will thus be seen in the facade and the impact of the building will be adequate as to its exterior. To our minds, a corresponding positive impact will be the result also for the interior of the building.

The constructive features of the facade to resist the static and dynamic forces it was built for, will not be affected in a negative way by installing openable windows.

Possible problems because of draughts, high wind speed in the rooms, the consequences when opened windows are forgotto and other safety and security details, have been dealt with by us in that we try to confine the size, as well as put the openable part of the window relatively high from the floor. This is shown in figure 1.

The limited open window area moderates the effect of wind impact and the placing prevents furthermore direct draught across the writing desk. For the same reason it is inconceivable that a person accidently should fall out through an open window.

In connection with this it should also be pointed out that problems apprehended with regard to openable windows must not be exaggerated. In fact, most people work in buildings with openable windows, the controrary being an exception. The problems concerning draught, for example when windows on the leeward and the windward sides respectively are being opened at the same time, are normally solved by closing the window. This will certainly also be the case in VIC. It has been suggested that a disturbing draught may occur in the long corridors. We believe that due to the fairly tight doors between room and corridor amongst other conditions will neutralize this possibility.

An important question is whether the fire protection property of the building will be impaired. Our team has consequently consulted the special fire protection expert available with the Board.

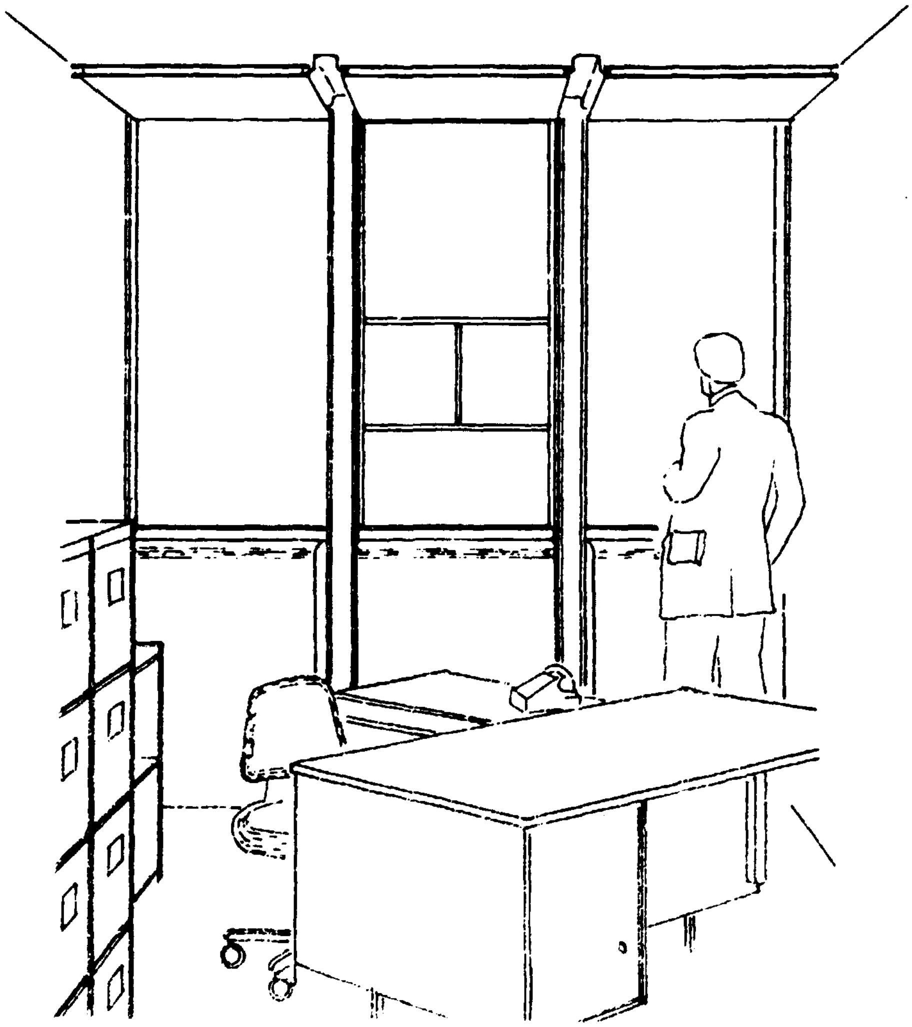


Fig. 1

Building materials are usually classified with regard to fire hazards based on the number of minutes the material can resist fire. The external wall in this case has been reported to meet requirements for 90 minutes fire resistance. Glazing in windows is however regarded to have a resistance equal to zero.

If a window is open or not it is thus not being considered to be of any importance worth mentioning as regards spreading of fire from one floor to another. The probability for the occurence of fire just in room where the windows has been left open is neither too imminent. It is even possible to maintain that the proposed window with regard to its frame sections is a more robust structure which in certain situations provides improved resistance to fire than the present undevided pane.

According to our experience the height of a building has never had any influence on the design of the external wall as regards fire protection except that tall buildings must be constructed in incondustable wall materiels. The requirements concerning exit routes and fire alarm increase however. A positive fact as regards fire protection in VIC is also that the doors and partition between offices and corridor are fire resistant.

As the windows have been put rather high up, we do not think there will be any problems with occasional gusts of wind. Draughts in the rooms when weather is constantly windy will be avoided by the person occopying the room by simple closing the window. The types of windows suggested are of a kind that cannot be slammed shot by the draught.

As concerns the security and safety issues, we would refer to similar and taller buildings in the U.S.A. where openable windows are common. Characteristic of these windows is that the size is restricted. So for instance the U.N. Plaza Hotel. One might even say that these buildings have been equipped with openable windows to add to the feeling of security and safety.

3.2 A technical description of different window alternatives

We have chosen to examine three types of windows: pivot window, casement window and side sliding windows (the alternatives are shown in figure 2 page 9).

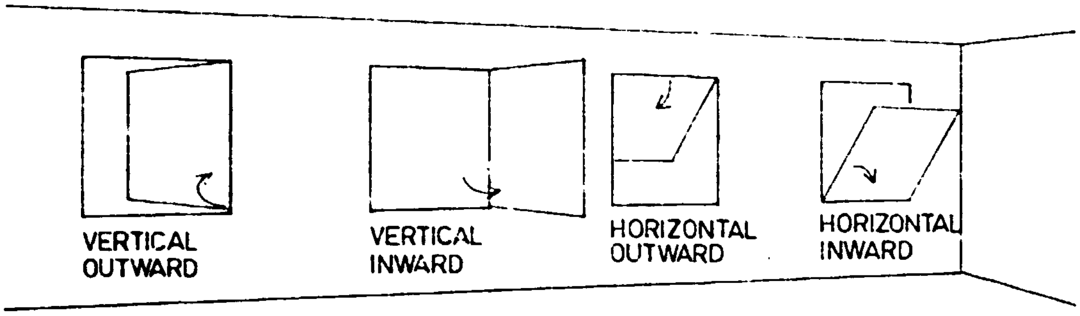
The alternatives with some kind of equipment for direct fresh air ventilation cannot solve the problem that people feel shut up, which would be the primary function of the openable window. Neither is it possible to show that the ventilation requirements of the building would decrease and thus also the energy consumption. This alternative is in addition relatively expensive - the cost of installtion is of the same order of magnitude as for the openable window - and we have consequently together with the representatives of the Building Management found that these points of view suffice to reject this alternative as a possible suggestion for the VIC.

Pivot window

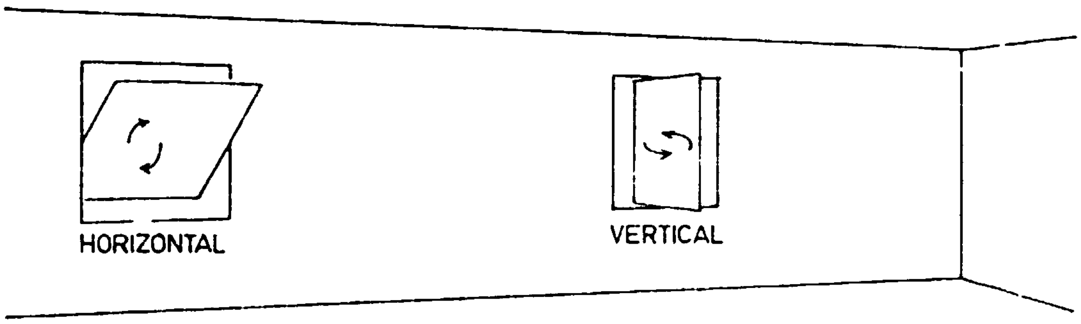
The main advantage of the pivot window is that both

WINDOWS

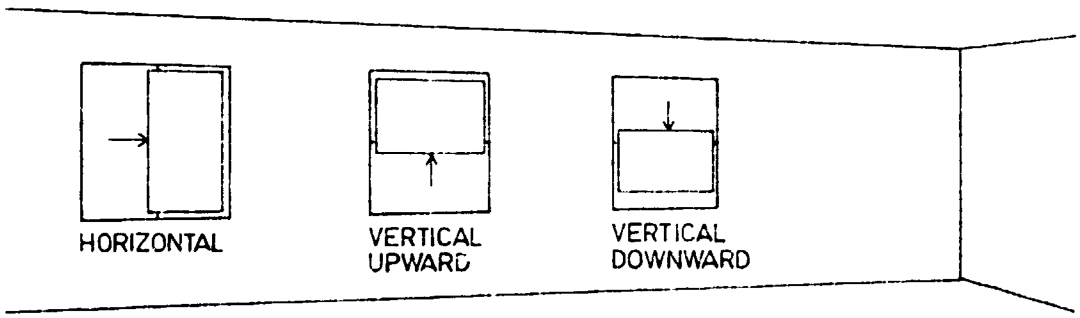
CASEMENT/ HINGED WINDOW



PIVOT HUNG WINDOW



SLIDE WINDOW



FOLDING WINDOW

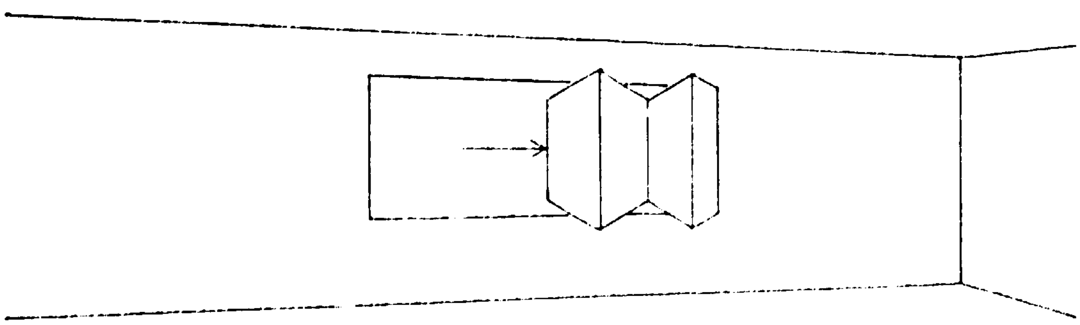


Fig. 2

outside and inside are within easy reach för cleaning. This kind of window however also has many disadvantages:

- it will not open completely when in the raised position
- it is difficult to provide adequate weatherproofing, especially at the axis of rotation,
- the construction is complicated and demands exceedingly elaborate manufacture
- stresses that could result in distortions occur easily in the attachment of the pivot fittings
- when the window is open, the draught will easily get hold of the frame
- the window will affect the furnishing of the rooms, and interior Venetian blinds

Hinged/casement window

The casement window has several advantages, the main ones are that the construction is well-known and well-tried and that it is possible to get adequate weatherproofing by simple means.

The disadvantages of the casement window are mainly that the draught easily gets hold of the window frame and that it affects the furnishing and blinds.

Side sliding windows

The main advantages of the sliding window are:

- well-known and well-tried construction
- easy to regulate how much the window should be opened
- the position of the frame is not affected by draughts
- furnishing and blinds are affected only to a small extent

The disadvantage of the sliding window is the weatherproofing, which can be complicated and demands careful work.

3.3 Considerations and suggestions

Double-glazed windows have been used for a long time in the Nordic countries because of the rough climate. The double-glazed windows were previously easier to produce with two separate side-hinged frames, one of which was opened outwards and the other inwards. In the Nordic countries we therefore have long experience and tradition in casement windows.

The sliding windows occur to a much greater extent in countries with warmer climate, for instance in the Anglo-Saxon countries. Today however, sliding windows for cold climates can be manufactured because of new constructions and materials.

Openable windows improves the out of door contact as it is then possible to "sense" the out of door climate. A free view and sounds from outside are qualities that can be conveyed through openable windows only. From experience it is apparent that small sliding windows can offer these qualities satisfactorily and thus counterbalance the feeling of beeing shut up which easily arises where there is no openable window.

The ventilation epuipment of the VIC is constructed in the manner that the air to the room is re-treated and supplied to the room by window units put under the windows respectively. Consequently, during the cold season warm air is blown on the window from underneath. This warm air will then also prevent condesation between the casement and the frame and thus in addition counter-act any inconvenience arising on account of insufficient weatherproofing in connection with openable windows. Windows can today be constructed with broken thermal bridges as well as unbroken thermal bridges. The most slender profiles are obtained when using the unbroken thermal bridges but from energy point of view we prefer windows with unbroken thermal bridges.
When we have assessed the advantages and disadvantages of the different types of window we have found that the sliding window should be chosen. We have therefor also selected this alternative as a starting-point for the cost estimates given below in part 5 Costs.

As alternatives for the companies that are invited to hand in cost and construction proposals we would advocate a casement window opening inwards and bottom-hinged.
Its main advantage is that it is easy to make weatherproof and it should not be rejected until the complete statement of costs is clear.

Both types of window shall be manufactured using 4 mm glass and 6 mm where wind conditions make it necessary. We have assumed that 10 % of all windows have 6 mm glass in our cost calculations.

4 CALCULATIONS OF EFFECT AND ENERGY REQUIREMENTS

4.1 General

As mentioned above, the calculations do not depend upon which of the alternatives for opening windows is chosen. This is so as it is not possible to prove and to quantify the distinctions between the window alternatives in such a manner as to take the distinctions into account. In addition, the distinctions are definitely not very big.

This examination must not be regarded as giving exact computations of what will happen when rooms are aired and when openable windows are introduced. It should instead be considered to provide calculations/illustrations of what could happen in a number of imaginary cases based upon certain selected conditions. Based upon the results from these examples and experience from a number of similar calculations it is still possible to come to some conclusions as shown later on.

The modern air conditioning plant has two main tasks, to ventilate rooms, and to regulate the temperature during the hot season. The latter task is the predominant one as concerns type of equipment, quantity and size of air treatment plants, dimensioning of the size of ducts etc. If the restrictions were only to meet with hygienic and health requirements, evacuation of bad smells and carbon dioxide etc, the plants could be considerably restricted. For the hygienics ventilation of office premises, the air volume 15 m3/hour and person is sufficient. Within the VIC the smallest room is at present supplied with 90 m3 fresh air per hour.

Consequently, if taking into account hygienic and health demands only, it would be possible considerably to reduce the supply of air to each room and it is therefore of interest to examine whether the regulation of temperature could be arranged in some way which would demand less energy.

Following up the Terms of Reference and our previous suggestions, the energy consumption for the present operational conditions has been compared to the energy consumption that could be obtained if the requirements were lowered somewhat during summertime and thus other conditions for the operation of the equipment were created. We have selected to propose these new conditions so that cooling shall no longer be included in the central treatment of the air. These temperature requirements, that are less rigid, are not motivated by the ventilating and temperature regulating effect of the openable windows, but rather by the feeling of contact with the outdoor temperature and climate which the openable windows will produce.

4.2 Bases for calculations

Primary data according to present requirements and mode of operation

Primary flow of air	30 m3/h, and window module. The air is centrally cooled so the temperature of the intake air to the window unit is 14 - 17°C
Operating time	Daytime operation 06.00 - 18.00
Room temperature	Room temperature is adjustable around 22°C (20,5 - 23,5°C). During heat waves higher temperatures are permitted as shown in table 1. The table also gives the number of days annually when denoted t_{out}, max is reached or exceeded.
Relative humidity	40 - 50 %
Dimensioning stipulations	Wintertime -18°C 80% RH Summertime +32°C 40% RH

(These data are presupposed when dimensioning the equipment, media lines, etc.)

Table 1 Accepted room temperature (t_{room}) summertime and number of days anually that the denoted outdoor temperature ($t_{out, max}$) is reached or exceeded.

$t_{outside}$ °C	t_{room} °C	days/year
below 22	22	226-228
22	22	90
25	23	43
30	25	3-4
32	26	0-1

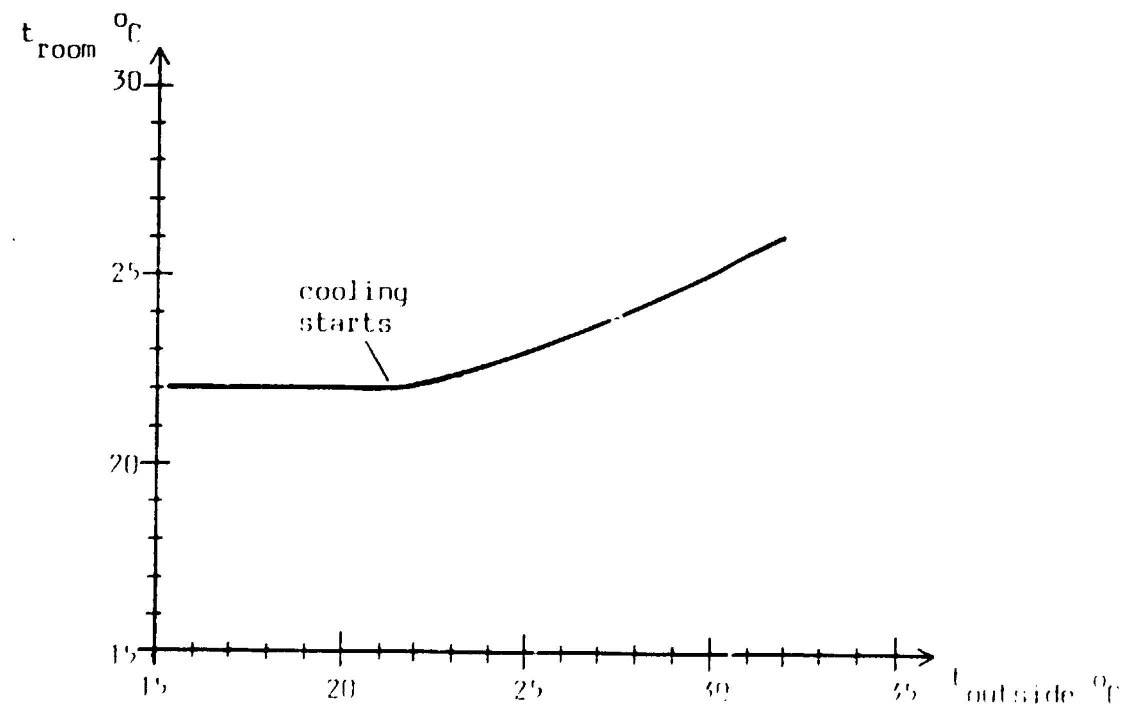


Fig. 1 Primary operationmode.

Suggested new primary data - with openable windows

Primary flow of air 21 m3/h, and window module
No central cooling of the air; consequently the intake air to the windows before the window units will add 1°C to the outdoor temperature in the summertime (May-September) (heating in fans and ducts). In the winter-time (October-April) the air is heated centrally to +17°C.

Operating time	October-April	06.00-18.00
	May-September	00.00-24.00
Room temperature	October-April	21°C (minimum)
	May-September	during the daytime the temperature is allowed to "float" up to the below values

Table 2 Accepted room temperature (t_{room}) summertime and number of days annually that the denoted outdoor temperature ($t_{out,max}$) is reached or exceeded.

$t_{outside}$ °C	t_{room} °C	days/year
below 22	22	226-228
22	23	90
25	25	43
30	27	3-4
32	28	0-1

The temperature accepted in the summertime is consequently raised by 2°C.

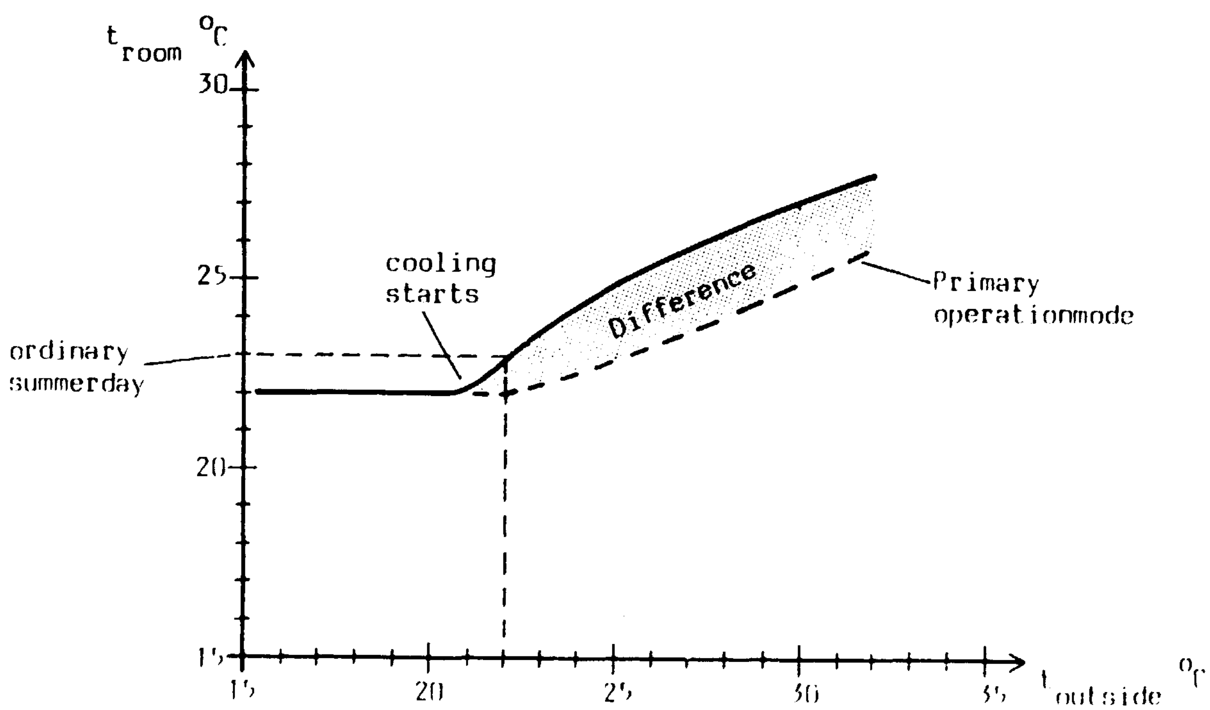


Fig. 2 Suggested operationmode summer - with openable windows.

Relative humidity 40 - 60 %

Dimensioning stipulations — As before

Remaining bases for calculations and comments

We have chosen to base our study upon two contrary types of room, a triple-modular room at the facade facing the north and a corresponding room at the facade facing the south.

As the final cooling of the air as well as the heating of the air take place locally in the rooms, it is possible to calculate for the "average" room in view of the different location of the rooms and the varying exposure to the sun - the final result of our energy calculations has been based upon this average room.

We assume that the rooms examined have the below interior heat load from:

- individuals	100 W	
- illumination	360 W	(200 W is proposed)
sum total	460 W	

The flow of air is at present 90 m3/h - in the new proposal it is assumed to be 63 m3/h.

The calculations illustrate what possibilities there are to reduce the present cooling capacity, by reducing the primary flow of air to 70% of the present flow as well as by letting the fans operate the whole day and night during the summertime and not cooling the primary flow of air. The fans are switched off during nights and week-ends when the selected lowest temperature of the exhaust air is obtained. This mode of operation utilizes the capacity of the relatively heavy concrete structure of the building to absorb heat and give heat respectively. To make this dynamic process go on functioning through the day and night, we must also presuppose/accept the "floating" temperature denoted above by the primary data.

All air is at present cooled centrally to appr. 14°C. Consequently, rooms facing the north and rooms that do not get any heat load from individuals in the daytime will occasionally be cooled to a temperature below the desired temperature. The air heater of the window unit will then be activated and the air is then heated to the set level. This of course results in an exaggerated energy consumption. This undesireable pre-cooling as well as reheating in the summertime has been rejected in our proposal as we assume that the above data can be complied with without having to, at any time, resort to cooling of the air in the central plant.

In our calculations, we have also taken into consideration increased unintentional ventilation on account of the openable windows.

The result is given as the difference in capacity and energy requirements for operating fans, heating and cooling between the present mode of operation and the suggested mode of operation.

The computer evaluations have been made using a computer program designed by the Swedish building research. For more detailed information on this program and experiences from it we refer you to the article in annex 1.

4.3 Calculation results

To begin with we discuss the summertime case.

The average twenty-four hour temperatur during the summer months is assumed to be normally distributed around the average monthly value. The standard deviation is appr. 3°C. The frequency of different temperature levels has thus been determined. The temperature varies some ± 5°C around the average twenty-four hour value from night to day. Table 2 shows the heat balance for a room facing south at various times of the day and for the whole day and night. It can be seen in the table how the heat is supplied and evacuated by the present mode of operation as well as the suggested mode of operation. For these calculations a heat wave with sunny weather and an out door temperature swing of 25 ± 5°C has been presupposed i.e. quite extreme conditions with a statistical frequency of once a year.

Tabel 2 — Heat balance for a room facing south

	3 o´clock a.m mode of operat.		11 o´clock a.m mode of operat.		8 o´clock a.m mode of operat.		day and night mode of operat.	
	present	sugg´d	present	sugg´d	present	sugg´d	present	sugg´d
Qmass	·73	+275	-204	-398	+4	+73	+13	+9
Qsun	0	0	+1054	+1061	0	0	+300	+302
t_r	26,2	25,4	24,0	27,0	26,9	28,1	26,5	26,3

Symbols:

Qmass heat to/from walls, floors and roofs, W

Qsun solar heat through windows, W

t_r temperature of air in room

A complete heat balance is shown in app. 4

Figures with + sign denotes that the room is supplied with heat and consequently, figures with - sign that heat is evacuated from the room. It is apparent that the heat leakage from the sun through the window is the major and dominating intake of heat.

By the quantity "Q-mass" the great importance of the night ventilation for the whole twenty-four hour process can be seen. At three o'clock in the morning there are only two small items in the heat balance as concerns the present system - 73 W is transmitted through the window and as much as that is also emitted from the building construction (walls, floors and roofs). No noticeable cooling of the room takes place by this small effect. Much more heat is taken from the construction in the suggested mode of operation - 275 W. At 11 o'clock in the morning when the load is great, the building construction will absorb appr. 400 W as compared to only half of this amount for the mode of operation with no cooling during the night. The great advantage with so-called "floating" temperatures is this explained.

By the item "Q-mass" is shown the heat that has passed through the exterior wall - as levelled out over the whole day and night. As the wall is heated by the sun, an increase of heat is obtained - this is however of little importance (appr. 10 W as compared to the heat leakage from the sun through the window of appr. 300 W).

Week-ends and holidays

With possibilities to air the rooms, the room temperature could normally be kept at an acceptable level without having to resort to cooling as the fans are assumed to be operating also during week-ends. During for instance a sunny Saturday when the outdoor temperature is $20 \pm 5^{\circ}C$, the room temperature of rooms facing the south rises from 23 to $28^{\circ}C$ during the day, and of rooms facing the north from 23 to $26,5^{\circ}C$. When making the calculations we have presumed that the airing summertime of the rooms corresponds to 1,5 renewals of the air per hour.

During heat waves, the building could probably be "prepared" for usage during the week-ends, by lowering the temperature level on Fridays. The temperature increase could then be kept within the limits given above during Saturdays without having to start the cooling plants outside normal office hours. In this manner the high extra costs that are now debited for the operation could be reduced.

Energy requirements

We have given account of a calculation for an ordinary room facing the south. Several calculations of this kind have been made based upon different assumptions with the purpose of examining the function and thermo dynamics of the building. We have then summarized the energy requirements for cooling, heating and fan operation, based upon the calculation results and information on climatic data. As mentioned above, we present the result for the "average" room.

Tabel 3 shows the difference in energy consumption that our calculations give between the present mode of operation and the suggested one. The -sign signifies reduced energy consumption and the +sign signifies increased energy consumption.

We assume that during the winter the unintentional ventilation as an average increases by 0.25 renewals of the air/h on account of the openable windows.

In order to make this base for the calculation more understandable we provide the following example based on the average room and average temperature during the cold season.

Airing during the winter season is assumed to mean about one change of fresh air per hour. If for example in the average room the window is left open for one hour per 24 hours each day during cold season 60 kWh per annum are consumed.

Table 3 on page 19 has been calculated for 120 kWh per annum for desired ventilation in the winter. This means for example that for each room is assumed airing for 2 hours per day or that every fourth room has a window open for airing during the entirely office hours each day. According to our opinion this assumption is on the high side and includes also energy consumption due to leaks through leakeness.

Another few examples may be illuminating for what may happen.

Increased energy consumption (as compared with table 3) if every 15 window is left open during night time due to neglect will be about 95 kWh per annum.

Reduced energy consumption if the staff air every third room for one hour each day and one window in thirty is left open during the night due to neglect will be about 50 kWh per annum.

Summarily it may be established that farily considerable changes in the assumptions concerning frequency of airing and a number of forgotten open windows do not cause such dramatic changes in the consumption of energy that the final results are completely distorted.

Tabel 3 Difference in energy consumption for the "average" room between the present mode of operation and the suggested one.

Measure	Energy kWh/year	Cost AS/kWh	Cost AS/year (jan. -82)
Fan operation			
- reduced flow of air in the wintertime	- 60	1,80	- 108
- reduced flow of air	- 30	1,65	- 50
- increased operating time summertime	+ 30	1,40	+ 42
Heating			
- discontinued post-heating summer	- 60	0,80	- 48
- increased unintentional ventilation winter	+ 120	0,80	+ 96
Cooling			
- reduced cooling on account of floating control	- 400	1,05	- 420
Reduced energy	- 400	Reduced cost ca	490 AS/year

The following comments should accompany the table. The reduced flow of air reduces the fan operation in the wintertime. This reduction is neutralized during the summer as the operating time then is longer. The discontinued central cooling of the air is of great importance. In the first place, the energy consumption for cooling is very reduced, and in the second place, the need of post-heating in the summertime disappears.

To sum up, it is apparent that the fan energy consumption and the cooling energy consumption decrease. The heat energy gains is however counteracted. The heat consumption will increase on account of unintentional ventilation winter time which we assume will depends on open windows and less efficient weatherproofing.

In all, the energy consumption decreases by 400 kWh per room and year which corresponds to the cost 490 AS/annually. These savings can be made at the cost of having to accept that the room temperature during 3 or 4 days anually rises to 27 - 28°C.

Air temperatures near a façade exposed to the sun

When there is no wind blowing and the sun shines continuously, the surface of the façade gets hot and occasions a hot upward air stream. In extreme cases, the temperature of the surface of the façade could theoretically be 25° higher than the environs. The speed of the air current increases by the altitude. At for instance 100 m, the maximum speed within the boundary layer will be ca 5 m/sec and the thickness of the boundary layer ca 2 m.

The layer is consequently broken down already at low wind speeds. It might be interesting to know how the air that leaks into the room will affect the temperatures that we have discussed previously.

Taking into consideration that the air speed at the desks must not be too high, the individual will limit the leakage air flow with his sliding shutter. We assume that this air flow will not exceed 50 m^3/h during normal working hours. If we make the reasonable assumption that the temperature of the leakage air is 6° higher than the temperature of the air in the room it will give a heat contribution of 100 W to the room. The figure 6°C is reasonable as the air layer closest to the façade is constantly being mixed with air with outdoor temperature.

The effect 100 W to the room is insignificant as compared to the ca 1,000 W which is provided by the sun radiation through the windows. The cooler of the window unit in the room has extra capacity which can cope with the additional heat contribution of 100 W even at the reduced flow of air that we assume. At the very rare occasions when the wind speed is nearly 0 at 100 m, the air close to the façade could however be heated to 20° above the temperature of the air in the room. However, we think that the staff will probably close the windows at these rare occasions when there could be some discomfort.

4.4 Technical aspects on introducing openable windows

One aspect which is important in tall buildings and which we particulary examined is the risk that there should be so-called chimney effects in the building which is apparently now very weatherproof. There have also been questions if the ventilation system should become unbalanced.

We think the risk for "chimney" effects should not be too difficult to eliminate. These effects are found mainly in connection with the staircases of each building (4 staircases per building). The proofing between the floor plans and these staircases are not sufficient.

The draught preventing strips will have to be adjusted and exchanged for almost all doors facing the staircases (appr. 650 doors). This will not effect the fire ventilation system. We only speak of those doors already equipped with preventing strips but not enough efficient.

We find there is but little risk of the ventilation system becoming unbalanced. The drop of pressure between the duc system and the room, which drop is mainly in the window units, is big enough to keep the supply air volume steady. This can be changed by reducing the air flow in one system.

Possible discomfort caused by draught in the corridors will as previously stated hardly occur.

5 COSTS

5.1 Costs of investments

In this case, it will not be possible to calculate in a neutral manner the costs of investment starting from cost statistics based upon experience, as can always be done in the case of new buildings. We have therefore contacted some possible suppliers/subcontractors to get preliminary offers of 10 trial windows as well as 5,000 windows including all costs for installations, travel, daily allowances, etc. A 5-year guarantee must also be included. We have so far received 6 replies.

The price that we have received, except one, relate to sliding windows; they are however of varying type. The offers are based upon broken thermal bridges and unbroken thermal bridges.

The price for 10 trial windows varies from ca AS 10,000 to AS 15,000 per window. For the delivery of 5,000 windows, prices from AS 6,000 to 8,500 are offered.

As mentioned above, the doors to the stair wells must be adjusted and made draught-proof. If this job is carried out on contract, we estimate the cost for it at AS 300,000 - 350,000. We however think it would be suitable to use staff from the Building Management for this job, if there is time enough. The cost for materials used would be some AS 40,000.

To this should be added costs for projecting the purchasing basic documents, for evaluating the offers and tests, administration etc. The extent of the job has to be discussed with the Building Management.

The setting of the air treatment and heating plants should best be made by the Building Management Staff. We have not attempted to assess the amount of time this setting would take;however we have in table 5 page 23 made a rough estimate based on our experience from similar buildings.

5.2 Annual costs

We have attempted a cost benefit analysis in this part.

We have considered as costs the investment in windows, draught-proofing of doors to the stair wells; adjusting and setting the ventilation plant; adjustment of heating system; increased maintenance for windows (change of sealing strips, etc).

The "benefits" consist in the energy saving which has been described in part 4, and which in all amounts to 400 kWh/ year for the "average" room.

We have assumed that for energy costs and maintenance costs, the annual increase in costs is 15 %. As agreed with Mr Eiblhuber no cost for capital is included.

The result of the cost/benefit analysis are given in tabel 4. The cost savings that originate in the reduced consumption of energy can give a depreciation period of some 7 - 10 years.

Table 5 Cost/benefit analysis

COSTS

Investments	Investment/1 000 AS
5 000 windows	24 000 - 40 500
Adjustment doors and some shafts	400 - 450
Adjustment ventilation	600 - 1 000
Adjustment heating	1 000 - 1 500
Administration	300 - 750
Investment total	26 300 - 44 200

Annual costs	Annual costs/benefits AS
Adjustment windows, weatherships 1 hour 1 000 windows/year	150 000
Adjustment draught-excluder doors	50 000
Increased heating energy from p 19 5 000 x 96	480 000
Increased fan operating time from p 19 5 000 x 42	210 000
Annual cost total	890 000 AS

BENEFITS

Reduced cooling energy from p 19 5 000 x 420	2 100 000
Reduced fan energy from p 19 5 000 x 158	790 000
Reduced heating energy from p 19 5 000 x 48	240 000
Annual benefits total	3 130 000

BENFITS NET

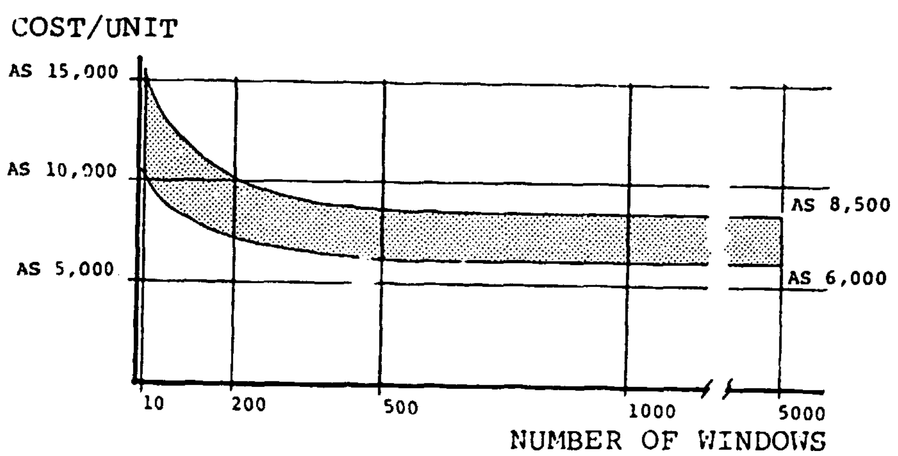
Benefits net will be 3.130.000 - 890.000 = 2.240.000 AS. Benefits net accumulated if the annual increase in costs is 15% are shown in the following table.

Number of years	Benefits net accumulated 1000 AS
3	7.770
5	15.100
7	24.800
10	45.400
15	107.100

CONCLUSION

Total investmens is 26.300 - 44.200 (1000 AS)

If no capital cost is included and the annual increase in costs is 15% the depreciation period will be 7 - 10 years.



6 PERFORMANCE - SCHEDULE

It should be obvious from the above that it is not really possible in a study of this kind to point to all consequences nor to produce all facts needed for the final decision of such a large investment and also such a large intervention in the building as an installation of ca 5,000 openable windows would be.

Our team has therefore examined alternative plans for performance which contain full-scale tests to varying degrees.

As one alternative, we would suggest that a technical test is made, based upon 10 trial windows - of two different constructions if possible -, during a period which should at least to some extent also contain wintry weather. This test could provide answers to problems with for instance proofing, thermal bridges and possible icing in extreme weather conditions, and other similar technical aspects. It will then also be possible to make objective observations of how the flow of air in the rooms is affected.

Another test could also be made, being more of a survey of the behaviour and reactions. This kind of test should have the same limitation in height and floor area as a central air treatment plant. The test should examine the reactions of the staff to the altered mode of operation with less rigid temperature requirements above all in the summertime and how these alterations are coped with as it will then be possible to open the windows to let in fresh air. The number of windows needed for this kind of test would be appr. 220 if the test is carried out in two different office towers.

We have separated the stages of the performance plan thus:

- projecting, including a survey of all premises in question where windows will be changed
- contacts with suppliers and manufacturers, drawing up the basic documents for purchasing, which should be based upon a summarized description of the construction and also the terms to be applied to the contract work
- analysis to tenders
- evaluation of tenders, visit to factories (if necessary), and purchase of 10 or 220 trial windows with option on the total contract work. Consequently, roughly all negotiations needed for purchasing all 5,000 windows are carried through on this stage. It shall also contain the possibility to break the agreement if the test window from the planned manufacturer does not come up to the expectations

- manufacture and installation of test window

- test period

- tests are evaluated, the agreement is changed if necessary, and the decision to carry through the contract work is taken

- manufacture of windows

- installation of windows; this tage is to some extent parallel to the manufacture of windows as the number of windows to be changed is very great and it will not be possible to install them all at the same time.

If the tests are limited to cover only technical tests of some ten windows (alt. 1), our estimate is that the performance - that is, the installation of 5000 windows - could be finished by the summer of 1984.

If the test period with 220 windows is also included (alt. 2) in order to examine the staff's reactions to the new situation, then the completion will be prolonged by 4 months. We then assume that the first test period could be somewhat shortened.

The alternative we suggest however (alt. 3) is one test period with 220 windows. The installation could be finished by the end of the summer, 2 months later than altl. 1. This alternative 3 would be possible with a careful and serious evaluation of tenders (including studies of prototypes).

The performance plan here briefly described has been compiled in the schedule (alt. 1 and alt. 3) in annex 2.

7 SUMMARY - RECOMMENDATION

As we pointed our by way of introduction, this examination indicated that it is possible to equip the VIC with openable windows in a practical as well as a tolerable economic manner.

We would like to sum up the recommendations of our team in the following points:

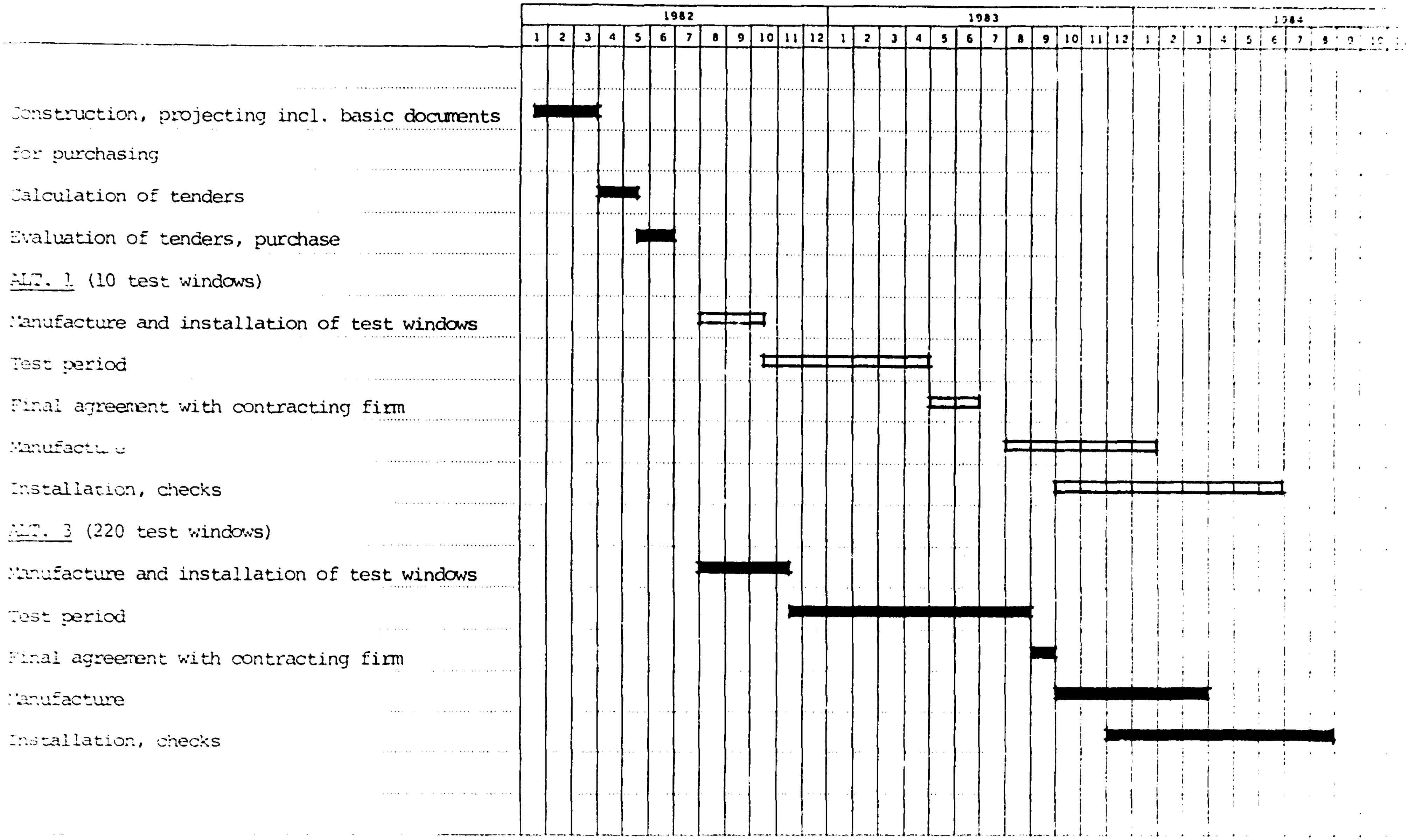
- side sliding windows should be chosen as window construction alternative. The alternative with bottom-hinged window should however not be rejected until the costs have finally been examined,
- the decision of carrying-through should be based upon at least one full-scale test. We suggest a test of some 220 windows where both technical aspects as well as behaviour and other reactions are studied,
- the current temperature requirements should be less rigid and consequently the accepted temperature in the summer be raised by 2°C
- the capacity of the realtively compact building to absorb and give heat, its thermo-dynamics, should be made use of by introducing "floating" adjustments of the temperature.

The energy analysis shows that by using be suggested mode of operation, it is possible to save appr. 400 kWh/year for the "average" room, which corresponds to 2000 MWh/year for the whole VIC. The corresponding saving in costs is AS 2 240 000/year. We assess the total investment for 5000 windows to AS 26.300.000 - 44.200.000. For 220 test windows the investment would be 1.200.000 - 2.000.000 AS. If no capital cost is included and the annual increase in costs is 15 % the depreciation period will be 7 - 10 years.

THE NATIONAL BOARD OF PUBLIC BUILDING
Technical Division

TIME - SCHEDULE

Annex 2



Engelbrekt Isfält *

Wärmespeicherungswirkung in Gebäuden

Die thermische Speicherwirkung in Gebäuden spielt bei der Dimensionierung luft- und klimatechnischer Anlagen eine entscheidende Rolle. Die Vorgänge sind nur schwer einer rechnerischen Behandlung zugängig. In der vorliegenden Untersuchung werden Berechnungen vorgestellt, die am Lehrstuhl für Heizung und Lüftung der Königlich Technischen Hochschule Stockholm durchgeführt wurden. Der Einfluß der Wärmespeichereffekte auf das Raumklima wird an einigen Beispielen erläutert.

Heat Storage Effect in Buildings

The thermal storage effect in buildings is of decisive importance for the sizing of air and climatic installations. The processes can only be assessed with some difficulty by calculations. In the following investigation calculations are put forward which were performed at the Department or Heating and Ventilating at the Royal Technical University of Stockholm. The influence of the storage effect on the climate of the space is explained by giving examples.

Effet de l'accumulation de chaleur dans les immeubles

L'effet d'accumulation thermique dans les immeubles joue un rôle déterminant dans le calcul des installations de ventilation et de conditionnement. Les procédés sont seulement accessibles à l'aide d'un traitement par le calcul. On présente, dans l'étude dont il est question, des calculs qui ont été effectués par la chaire de chauffage et de ventilation à l'école supérieure technique royale de Stockholm. L'influence des effets de l'accumulation de chaleur sur le climat ambiant est expliquée à l'aide de quelques exemples.

Das Klima in Gebäuden wird von vielen Faktoren beeinflußt, deren Zusammenspiel von äußerster Vielfalt ist. Die Erfahrung von Jahrhunderten hatte zu Gebäuden geführt, die gut an das jeweilige Klima angepaßt waren. Die in letzter Zeit notwendig gewordenen Rationalisierungsmaßnahmen führten jedoch zu Konstruktionen, wo diese Erfahrungswerte nicht mehr ausgenutzt werden konnten. Hierdurch sind Schwierigkeiten aufgetreten, besonders bei zu hohen Innentemperaturen, ausgelöst durch Wärmeperioden. Viele Rückschläge in dieser Hinsicht haben es notwendig gemacht, Gegenmaßnahmen in Form von verbesserter Lüftung, oft mit Kühlung, zu treffen. Wegen der Kompliziertheit und aufgrund der fehlenden Dimensionierungserfahrungen, ist es häufig zu Überdimensionierungen von Klimaanlagen gekommen. Erst die Ausschöpfung aller Hilfsmöglichkeiten, die der Computer bietet, hat es inzwischen ermöglicht, die Einwirkung verschiedener Fakten auf das Raumklima bis ins Detail zu analysieren. Das Ergebnis ist in diesem Artikel durch einige Beispiele dargestellt.

Die Berechnungen, die hier dargestellt sind, wurden mit Hilfe der modernen Data-Technik an der Königlich-Technischen Hochschule Stockholm, Lehrstuhl für Heizung und Lüftung, durchgeführt. Die Arbeit wird durch staatliche Unterstützung gefördert.

Die Forschung begann vor ca. 15 Jahren, also zu einem Zeitpunkt, da man begann, sich für die immer höher steigenden Innentemperaturen zu interessieren. Alle unnötigen Approximativen sollten möglichst vermieden werden. Herr Dr. *Gösta Brown* stellte seinerzeit die theoretischen Berechnungsunterlagen auf [1, 2].

Der langwellige Strahlungsaustausch zwischen Raumflächen ist mit dem Gesetz von *Stefan Bolzmann* — T 4-Gesetz — errechnet. Berechnet ist auch die Verteilung der kurzwelligen Sonnenstrahlung mit Rücksicht auf die Reflexionsfähigkeit der verschiedenen Flächen.

Konvektive Wärmeübergangszahlen sind aus den herrschenden Temperaturverhältnissen errechnet. Sie sind verschieden für Decken, Fußböden und vertikale Flächen. Die Wärmeleitung in Wänden und Decken ist mit Hilfe der Differentialgleichung von *Fourier* numerisch behandelt. In den Berechnungsunterlagen sind eine Reihe von Begriffen relevant mathematisch beschrieben und mit der Wirklichkeit in Einklang gebracht, z. B. Fassaden, Fenster, Beleuchtungsquellen, Heizkörper etc. Die mathematische Behandlung und maschinelle Bearbeitung der sehr umfassenden Berechnungsunterlagen wurde der damalige *Matematikmaskinnämnden* (Ausschuß für Mathematikmaschinen), der in großen Teilen des internationalen Computergebietes eine gute Position hatte, zu Rate gezogen. Fragen von rein mathematischem Charakter wurden von professionellen Mathematikern untersucht. Für die Programmierung und maschinelle Bearbeitung war seinerzeit Herr Dr. *Axel Bring* zuständig. Er hatte zu der Zeit durch seine Arbeit mit Wetterprognosen direkte Erfahrungen von gleichartigen Problemen, nämlich große Systeme von nicht-linearen Differenzgleichungen. Die Angestellten sind jetzt auf die Industrie und Universität verteilt. Eine kleine Gruppe, in der sich auch Herr Dr. *Axel Bring* befand, grundete die Firma A. B. Data-System. Diese Firma baute selbst den Computer „TRASK", der im Institut für Atomphysik in Stockholm installiert und später vom Institut erworben wurde. Später baute die Firma A. B. Data-System einen neuen Computer: „TRASK 2". Die Firma hat in den letzten Jahren mit sehr avancierten Aufträgen gearbeitet, besonders hervorzuheben sind einige Kompilatoren u. a. SAAB:s ALGOL-GENIUS sowie eine optimale Spezialplanung für die gesamte Produktion der LKAB (Staatliche Schwedische Erzgruben Gesellschaft) pp.

Durch Herrn Dr. *Brings* Einsatz erhielten die Programme von Herrn Dr. *Brown* eine Ausführung, die in vielen Punkten Ideen vorzeigt, welche noch heute oft als datatechnische Neuheiten lanciert werden. Das von Anfang an sehr ambitiös geplante System hat sich durch Jahre hindurch ständig erweitert und entwickelt, und zwar in der Zusammenarbeit zwischen Data-System und dem Lehrstuhl für Heizung und Lüftung an der Königlich-Technischen Hochschule in Stockholm. Der ursprüngliche Programmverfasser ist als Verantwortlicher für das Projekt geblieben. Die Vorteile, die dadurch entstanden sind, versteht jeder, der mit Computerfragen zu tun hat. Mehrere Computer-Programme für Wärme- und Kälteberechnungen werden an verschiedenen Orten der Welt entwickelt. Doch oft ersetzt man die Differenzberechnungen mit Formeln, die durch Vereinfachungen zum Ergebnis führen. Auch die Wärmeübertragung von Raumflächen wird oft mit vereinfachten Methoden berechnet. Der Gebrauch solcher Programme muß sehr kritisch gehandhabt werden, da die Ergebnisse nur unter gewissen und begrenzten Voraussetzungen zuverlässig sind [3]. Ein Vergleich der Ergebnisse verschiedener Programme, was den Kühlbedarf für den gleichen Fall betrifft, wurde auf Veranlassung der REHVA durchgeführt. Das Ergebnis zeigte fast katastrophale Unterschiede zwischen den einzelnen Berechnungsmethoden [4].

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dieser Hinsicht erhält man, wenn die Ventilatoren während der Nacht arbeiten. Eine Voraussetzung für eine sichere Temperatursenkung, damit ein verträgliches Innenklima geschaffen wird, ist, daß die Wärmeübe.führungen zwischen der zugeführten Außenluft und Decke effektiver gemacht werden. Dieses kann durch richtig aufgeteilte Kanäle in der Decke erfolgen, die mit Außenluft durchströmt werden.

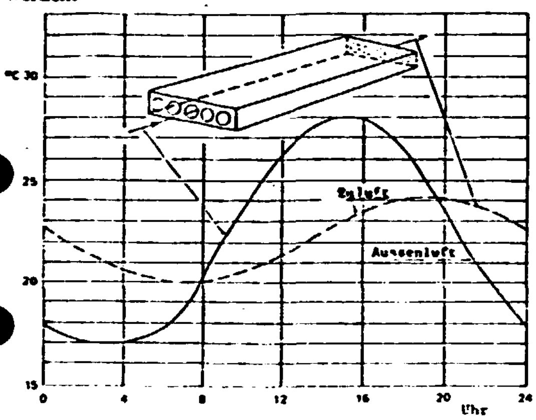

Bild 7 Temperaturverläufe beim Transport der Luft durch Betonkanäle der Hohldecke

Abb. 7 zeigt schematisch, wie die Außenlufttemperatur-Variationen durch das Passieren der Kanäle verändert werden. Die Kurven werden seitlich verschoben und die Schwingungen stark gedämpft. Wenn keine Wärme zu den Oberflächen der Decken durchdringt, haben die Schwingungen den gleichen Mittelwert, d. h. die Außentemperatur = Tages-Mittelwert. Die Temperatur der Decke wird am Tage unter der Raumlufttemperatur liegen. Die Steigerung der Raumtemperatur wird gehemmt. Außerdem ist die Zuluft nach dem Passieren der Kanäle größtenteils während der Arbeitszeit kälter als die Außenluft, was auch dazu beiträgt, die Raumtemperatur auf einem guten Niveau zuhalten.

Abb. 8 und 9 illustrieren den Unterschied der Temperaturverhältnisse in einer warmen Periode, wo die Zuluft zum Raum auf traditionelle Weise erfolgt und durch vorhergenannte Kanaldecken. Die Voraussetzungen sind aus nachstehender Aufstellung ersichtlich:

Raummaß:	
Breite:	3 x 1,2 m (3 Module)
Tiefe	5,0 m
Höhe:	2,6 m
Fensterfläche:	1 x 3 m²
Sonnenschutz:	Rollos zwischen Doppelfenstern
Wände:	
Außenwand:	leicht k = 0,4 W/m² °C
Innenwände:	Gipsplatten auf Riegeln
Unterdecke:	Bei der herkömmlichen Ausführung 3 cm Isolierwolle
Luftmenge:	100 m³/h Module Tag und Nacht
Personenwärme:	350 W von 8.00 Uhr — 17.00 Uhr
Sonnenstrahlung:	Juli, Süden, klares Wetter.

Das herkömmliche Zuluftsystem, ohne Kühlung, ergibt (Abb. 8) eine Raumtemperatur, die während der Arbeitszeit über 25 °C und während 3 Stunden über 29 °C liegt. Raumtemperatur ist hier definiert als der Mittelwert der Lufttemperatur und der Deckenfläche.

Durch die Zufuhr von Außenluft in die Hohldecke (siehe Abb. 9) liegt die Raumtemperatur während 4 Stunden der Arbeitszeit unter 25 °C, und der max. Wert übersteigt keine 26,5 °C. Nachdem die Berechnungen für eine außergewöhnliche Wärmeperiode mit der max. Außenlufttemperatur von max. 28 °C gilt (Frequenz in Stockholm zwei- bis dreimal jährlich), sind dieses Werte, die man ohne Zweifel akzeptieren kann. Eine Kältemaschine ist in diesem Fall nicht zu empfehlen.

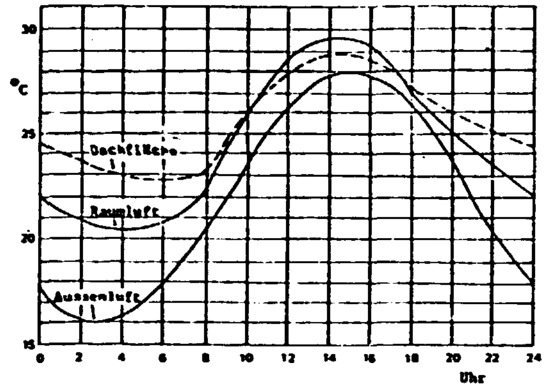

Bild 8 Temperaturverläufe beim Transport der Luft im konventionellen System

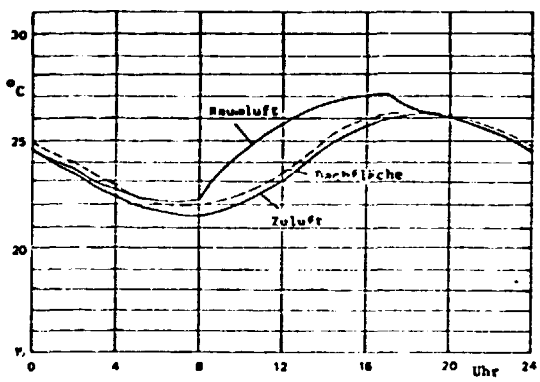

Bild 9 Temperaturverläufe beim Transport der Luft durch Betonkanäle der Hohldecke

Die beschriebene Methode, die thermische Träge der Decken für eine Klimatisierung in zukünftigen Gebäuden auszunutzen, wird an Modellen (in Naturgröße) in Stockholm am Lehrstuhl für Heizung und Klimatechnik an der Königlich-Technischen Hochschule durchgeführt. Für die Berechnungen wurde eine spezielle Version des Computer-Programmes von Herrn Dr. *Brown* entwickelt. Fragen verschiedener Faktoren, wie Luftmenge, Wärmeübergangszahl, Kanäle in Decken und deren Placierung, Isolierung usw. in bezug auf verschiedene Fälle, werden weiterhin erprobt. Das Projekt wird von einer selbständigen Techniker-Gruppe, die vom schwedischen Ausschuß für technische Entwicklung unterstützt wird, betrieben. Mitglieder der Gruppe sind u. a. tekn. Lic. *L. O. Andersson*, civ. ing. *Axel Rosell* und der Verfasser. Eine Firma aus dem Bereich der Heizungs- und Klimatechnik setzt sich dafür ein, daß diese Methode zur praktischen Anwendung kommt.

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Einfluß von vereinfachter Fenstercharakteristik

In Abb. 1 wird gezeigt, was eine Vereinfachung der Berechnung eines Fensters bedeutet:
Die Kurven geben den Kühlbedarf eines Raumes an, der über ein Thermostat gesteuert, 22 °C anzeigt. Die gleichen Voraussetzungen gelten fur beide Kurven:

Abmessungen des Raumes:	
Breite:	3,6 m
Tiefe:	5,0 m
Höhe:	2,6 m
Fenstergröße:	4,6 m²
Wände:	
Außenwand:	10 cm Isolierwolle auf Riegel mit leichter Außen- und Innenbekleidung
Innenwand:	10 cm Beton
Decken:	Hohlbeton, Gewicht 325 kg/m²
Außentemperatur:	22 ± 6 °C
Sonneneinstrahlung:	Stockholm, Juli, Süden, klares Wetter

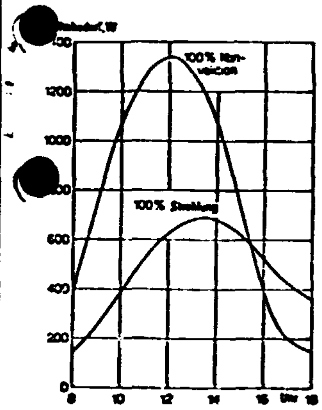

Bild 1 Der Kältebedarf am Tage in einem Raum mit konstanter Lufttemperatur, berechnet teils unter der Voraussetzung, daß alle Sonnenwärme durch Konvektion zur Raumluft und teils daß alle Sonnenwärme durch Strahlung den Raumflächen zugeführt wird

Die umliegenden Räume sind in ihrer Konstruktion und Abmessung gleichartig. Das Fenster reduziert einfallende Sonnenwärme mit 50%. Die Berechnungen gelten für ein periodisches Geschehen. Der einzigste Unterschied bei den Berechnungen liegt darin, daß dem Raum Sonnenwärme zugeführt wird. Die obere Kurve zeigt den Kühlbedarf, wenn alle Sonnenwärme konvektiv zur Raumluft übergeht, h. sie gelangt direkt — ohne jegliche Verzögerung — r Raumluft. Das Thermostat erfordert unmittelbar Kälte. Die untere Kurve zeigt den Fall, daß alle Sonnenwärme durch Strahlung auf die Raumfläche überführt wird, vorausgesetzt: alle Flächen haben die gleiche Farbe. Durch die Trägheit der Wände werden diese langsam erwärmt. Die ärmemenge, die der Luft zugeführt wird, wird gehemmt d gedämmt. Der durch den Thermostat erforderte Kältebedarf wird in diesem Fall um ca. 50% reduziert. Dieses Beispiel zeigt, welche Fehler bei Vereinfachung von Berechnungen — in diesem Fall die Schematisierung von dem Einfall der Sonnenwärme in einem Raum — auftreten können. Im „Kühllastberechnungsprojekt" sind die Fenstereigenschaften eingehend untersucht. Durch diese Arbeit entstanden detaillierte Unterlagen, die es ermöglichten, korrekte Berechnungen von Raumtemperaturen sowie Wärme- und Kältebedarf durchzuführen [5].

Schwere oder leichte Konstruktionen

In der Abbildung 2 wird dargestellt, wie sich die thermischen Eigenschaften eines Gebäudes beim Übergang von schweren zu leichten Konstruktionen verändern. Es ist schwierig, dem Vergleich gerecht zu werden, da die Dämmung nicht nur von der 24stündigen Periode abhängig ist, sondern auch von längeren Perioden mit und ohne Sonnenschein [6]. Bei diesem Beispiel wurde eine Warmwetterperiode zugrunde gelegt, der eine Kaltwetterperiode vorausging. Bei Beginn der Berechnung (0.00 Uhr 1. 24Stunden-Periode) zeigt die Gesamtkonstruktion eine Temperatur von 20 °C. Hierdurch läßt sich der Einschwingungsverlauf in beiden Alternativen vergleichen. (Oftmals läßt man die Berechnungen fortschreiten bis zur vollkommenen Einschwingung.) Der Luftaustausch beträgt 3,5 m³ Außenluft/m² Bodenfläche/h. Dieses entspricht einem Luftaustausch, den man ma. als Selbstabzug erreichen kann. Die klimatischen Voraussetzungen sowie die Wärmeentwicklungen gehen aus dem Diagramm Nr. 3 hervor. Es stellt die Raumluft-Temperatur während der 3. 24Stunden-Periode für schwere und leichte Konstruktionen dar. Im übrigen gelten gemeinsam:

Tabelle 1

Raumabmessungen:	Breite	= 5,0 m
	Tiefe	= 5,0 m
	Fenster	= 6,0 m²
Sonnenschutz:	Lamellenstore zwischen Doppelfenstern heruntergezogen in der Zeit von 12.00 Uhr mittags bis 8.00 Uhr nächstfolgenden Morgen.	
Nicht übereinstimmende Daten:		
Schwere Konstruktion:		
Raumhöhe:	3,5 m	
Außenwand:	2 Ziegelsteine	
Innenwand:	1 Ziegelstein	
Decke:	20 cm Beton	
Leichte Konstruktion:		
Raumhöhe:	2,5 m	
Außenwand:	6 mm Eternit und 10 cm Isolierwolle sowie 13 mm Gips auf Riegeln	
Decke:	20 cm Beton + Luftschicht + 3 cm Isolierwolle	

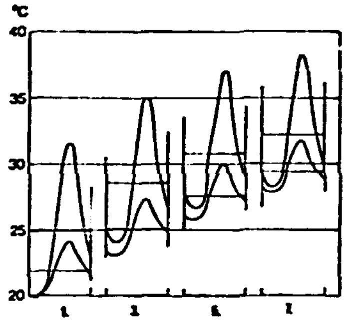

Bild 2 Temperatursteigerung der Raumluft während einer Wärmeperiode, mit schwerer und leichter Konstruktion

In der Abb. 2 sieht man, daß der 1. 24stündige Mittelwert der Raumluft steigt. Bei den leichten Konstruktionen bis 4,9 °C. Die höchste Temperatur liegt ca. 6,7 °C über dem 24stündigen Mittelwert. Entsprechende Werte der schweren Konstruktionen betragen 1,9 °C resp. 2,3 °C. Die Temperaturen steigen noch nach 7 Tagen an. Die Tages-Durchschnittstemperaturanstiege ebben erst nach 14 Tagen ab. Hierdurch führt es auch bei den schweren Konstruktionen zu erhöhten Innen-Temperaturen. Diese Punkte stimmen nicht mit den Erfahrungen überein! — Die Erklärung hierfür ist zu finden in nicht zu lange andauernden, zusammenhängenden Wärmeperioden dieser Art. Durch Lüftungen während der kühleren Tagesperioden können die Temperaturen oftmals reduziert werden, was in diesem Vergleich jedoch keine Berücksichtigung fand. Außerdem sollte nur mit einer Personenbelastung von 5 Tagen pro Woche gerechnet werden. Die Ursachen dafür, daß sich diese leichte Konstruktion langsam einpendelt, besteht darin, daß der Luftumsatz sehr gering ist. Die Kräfte, die den Verlauf steuern, sind zu schwach. Die Decken sind schwer und außerdem einseitig des Raumes isoliert. Dieses führt zu einem langsamen Temperaturanstieg, doch auch zu einer schwächeren Dämpfung der Tagesvariationen. Dieses Beispiel gibt ein klares Bild über die Größenordnung der vorangegangenen Akkumulierungseffekte bei dem Übergang zu leichten Konstruktionen.

Heat balance for a room facing south

	3 o´clock a.m. mode of operat.		11 o´clock a.m. mode of operat.		8 o´clock a.m. mode of operat.		day and night mode of operat.	
	present	sugg´d	present	sugg´d	present	sugg´d	present	sugg´d
H_c	0		-601	-695	0	0	-194	-250
Q_{vent}	0	-94	-272	+32	0	-18	-125	-15
Q_{leak}	0	-107	0	+10	0	-36	0	-33
H_{int}	0	0	+281	+281	0	0	+101	+101
Q_{mass}	+73	+275	-204	-398	+4	+73	+13	+9
Q_{sun}	0	0	+1054	+1061	0	0	+300	+302
Q_{trans}	-73	-74	-260	-292	-4	-25	-96	-114
t_l	20,0	20,0	27,5	27,5	26,3	26,3	25,0	25,0
t_i	-	21,0	15,0	28,5	-	27,3	15,0	26,0
t_r	26,2	25,4	24,0	27,0	26,9	28,1	26,5	26,3
G_i	0	76	108	76	0	76	108	76
G_l	0	70	0	70	0	70	0	70

Symbols:

H_c	after cooling effect of window-unit, W
Q_{vent}	heat evacuated by ventilating air, W
Q_{leak}	heat evacuated by leakage air, W
H_{int}	heat contribution from individuals and illumination, W
Q_{mass}	heat to/from walls, floors and roofs, W
Q_{sun}	solar heat through windows, W
Q_{trans}	heat transmitted through windows
t_l	temperature of outdoor air, °C
t_i	temperature of intake air
t_r	temperature of air in room
G_i	intake air flow, kg/h
G_l	leakage air flow, kg/h

SOME FIGURES
OF THIS DOCUMENT
ARE TOO LARGE
FOR MICROFICHING
AND WILL NOT
BE PHOTOGRAPHED.