RESUME

Une partie prépondérente des ressources utilisées au bilan énergétique combustible de l'énergie revient aux charbons dont ne sont pas ou presque pas utilisés pour la combustion dans les chaudières énergétiques suivant les méthodes classiques. L'utilisation des combustibles solides à faible capacité calorifique est etroitement liée au problème d'aprovisionnement en énergie du monde entier, tendisqui une nécessité de développement poussé et de mise en ouvre s'impose. Les freins principaux de l'utilisation de ces combustibles sont les problèmes techniques et écologiques qui sont provoqués par la capacité baissant de réaction du combustible d'une part et par la teneur élevée des cendres, de la sulfure et de l'humidité, de l'autre.

Il existe plusieurs approches aux recherches de procédés nouveaux qui utilisent avec plus d'efficacité la matière première énergétique à faible capacité calorifique.

Les circuits technologiques utilisant le traitement calorifique préalable, la gazification, le soufflage d'oxygène, le lit fluidisé ouvrent les percpectives avantageuses devant la combustion des combustible de basse qualité.

Les recherches théoriques et expérimentales menées par L'Institut énergétique sont orientées sur une technique nouvelle de combustion de ces combustibles aux CTE compte tenu des impératifs écologiques modernes.

La première installation industielle et expérimentale qui comprend un fourneau à air-liquide au lit bouillant circulant de 120 t/heure doit être mise en service à la CTE Dobrotvorsk et 1989.

Actuellement dans notre Institut on élabore les circuits technologiques de combustion à haute température des combustibles en question et on procède à l'extraction des cendres liqufiés et à l'utilisation des installations à gaz-vapeur avec le fourneau préalables (préfourneau) à soufflage d'oxygène. On travaille une technique où le peu de déchets sera utilisé pour la fabrication des matériaux de construction, des alliages de métaux et autres marchandises.

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DIVISION 2 Énergie et environnement
Energy and the Environment

Session 2.3 Mesures de protection de l'environnement: rôle de la technologie
Environmental Problems Control — The Role of Technology

2.3.10

ENERGY CONSEQUENCES OF UPGRADING INDOOR AIR QUALITY

LES CONSEQUENCES SUR L'ENERGIE EN CAS D'AMELIORATION DE LA QUALITE DE L'AIR INTERIEUR

by

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1. BACKGROUND AND DESCRIPTION OF THE SITUATION
CONTEXTE ET DESCRIPTION DE LA SITUATION

Energy technology

Following the oil embargo during the '70's, energy and conservation of energy have understandably been offered considerable attention. Some good results have been achieved as regards limiting the great increase in requirements for new energy which there was reason to fear. Energy technology has become a field of its own embracing energy production, energy supply, energy consumption and energy conservation.

The pattern of energy consumption in modern office buildings has also altered. Improved insulation standards, reduced infiltration, heat recovery, etc., have reduced heat loss. Increasing use of EDP equipment, equipment for handling paper, telefaxes, and the like, has affected work procedures in the buildings and increased the internal heat load. Exploitation of passive solar heat and increased use of glass are also popular. All this has led to an increased amount of surplus energy in the buildings and a relative turn towards electricity as the source of energy. Information about this is of considerable importance for planning expansion in energy supply, including the potential for district heating.

Energy technology chiefly focuses on technical approaches. The heating system, thermal station, ventilation plant, and so on, become in themselves the dominant aspect since these, as technical devices, need to function as well as possible. Energy conservation is also to a major degree focused on these strictly technical systems.

Indoor climate

The consequences of energy technology for the indoor climate have not received as much attention. New developments in energy technology and the use of new materials in buildings have, to a greater extent than earlier, created buildings with indoor climate problems (Sick Building Syndrome). Simultaneously, health, well-being and productivity have become factors to which greater attention is attached during debates about developments in society. When calculating the annual costs of a building it is therefore not only economy that counts, but also the value of well-being, health and productivity.

The problem of the indoor climate can now be documented by means of inquiries in which people give their opinion about the situation. Key words mentioned are:

- draughts
- dust or dry air
- humming and noise from ventilators, etc.
- heavy air, headaches, nausea, dry throats, tiredness and smarting eyes
- too cold or too warm

Many individual cases also point towards conditions being worse in buildings having small volumes of ventilation than in others. The minimum requirements of the building regulations do not today contain adequate reserve capacity for:

- processes in the building (the work function itself)
- cleaning (including cleaning agents)
- copying equipment
- computers, terminals and printers
- degassing from furniture and fittings
- textile fibres
- floor adhesives
- other "hairy" surfaces
- rock-wool fibres
- fall-out from pannelled ceilings
- textile fibres from staff
- dust in the duct network
- etc.

These factors represent pollution in excess of that human beings themselves produce. Importance must be attached to the sum of the pollution when the ventilation volume and the principles concerning ventilation are being determined.

Hypotheses

The situation described above has led to a research project being initiated in Norway based on the following working hypotheses:

1. The present-day indoor climate in Norwegian office buildings must be improved.
2. Such an improvement will best be attained by changing the materials used and upgrading the air standard.
3. Modern office buildings contain considerable surplus energy, enough to heat the extra ventilation air.
4. The value of well-being and health must be included in a concept of total annual costs. Increased investment on upgrading the indoor climate results in the lowest annual costs totally.

Hypothesis 1 has already been confirmed by the massive frequency of complaints from a large number of buildings, forming some of the background for the research and development project.

2. HOW DO WE DEFINE AIR QUALITY? COMMENT DEFINIR QUALITE DE L'AIR ?

Can air quality be measured?

Everyone who has tried to measure air quality, both in the laboratory and in actual buildings, has had difficulty in identifying the substances in the air which correlate with people's notions of good or bad air quality. Perhaps this is related to the existence of thousands of chemical compounds in the air, most of them in extremely small concentrations?

Firstly, it is very difficult to measure such low concentrations, and, secondly, we have no knowledge of how the human being reacts to each substance or to combinations of several substances.

This is the chief reason why Professor P.O. Fanger [1] points out that man's sense of smell is the best "instrument" for judging air quality. He has therefore evolved a principle for determining the necessary volume of air, which exploits man's ability to judge air quality. This can be readily compared with sampling in the food industry, wine-tasting, and the like.

<u>"Olf" - a new unit for indoor pollution</u>

The human being has traditionally been looked upon as the chief source of pollution in office buildings. Pioneering research by Pettenkofer [2] and Yaglou [3] is based on this, and it is expressed by the amount of air often being quoted as the amount introduced per person. Pollution from human beings is well studied and familiar, and can therefore be used as a reference. Fanger [1] has consequently introduced the <u>olf</u> unit (from the Latin "olfactus" = sense of smell), which is the emission rate of air pollution from a standard person (Fig. 1).

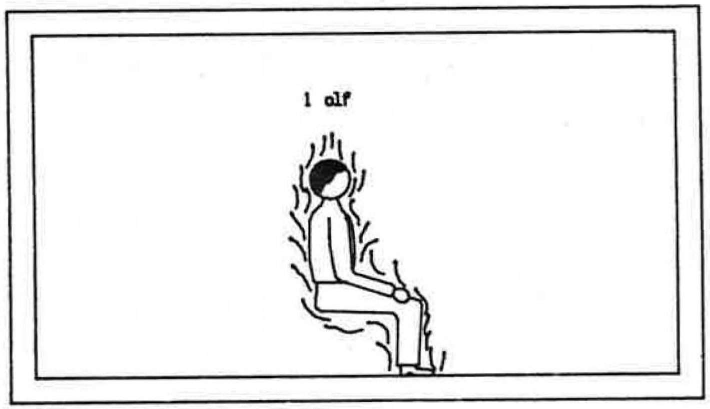

Fig. 1: ONE olf IS THE POLLUTION FROM A STANDARD PERSON (1)

Any other pollution source can be expressed as equal to the pollution from a certain number of standard persons (olf), since it will lead to the same dissatisfaction with air quality under otherwise equal conditions.

The olf-values for some sources of pollution are:

Sedentary person	1 olf
Active person	8 olf
Smoker, whilst smoking	25 olf
Smoker, on average	6 olf
Materials in an office	0-0.5 olf/m²

<u>Volume of ventilation per olf</u>

Since sense of smell is the "measuring instrument" used for judging air pollution, groups of people will have to be established who are trained to use their good sense of smell to determine olf values from different sources of pollution.

These "smell-detection panels" (or smelling bodies!) will also be able to determine the degree of satisfaction with air quality in a room with given volumes of ventilation. Fanger has taken such a group of people round to different buildings. The statistical result of this study is shown in figure 2.

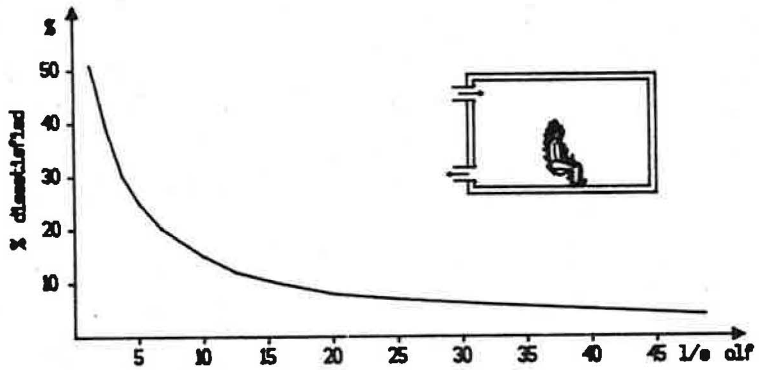

Fig. 2: DISSATISFACTION WHEN USING ONE olf AT DIFFERENT VENTILATION VOLUMES

A common ventilation volume used nowadays is 3 l/s per olf. This will give as much as 35 % evaluation of non-satisfactory air quality. If the number of dissatisfied persons is to be reduced to 5 % the air volume will need to be increased to as much as 15 l/s per olf.

Even the ventilation plant pollutes

The visit of the "smell-detection panel" to many and diverse buildings has also revealed that the ventilation plant itself pollutes! This has emerged through carrying out smelling tests in the same building, with and without operation of the ventilation plant. Figure 3 shows an average olf load in a limited number of investigated buildings.

QUANTIFIED POLLUTION SOURCES

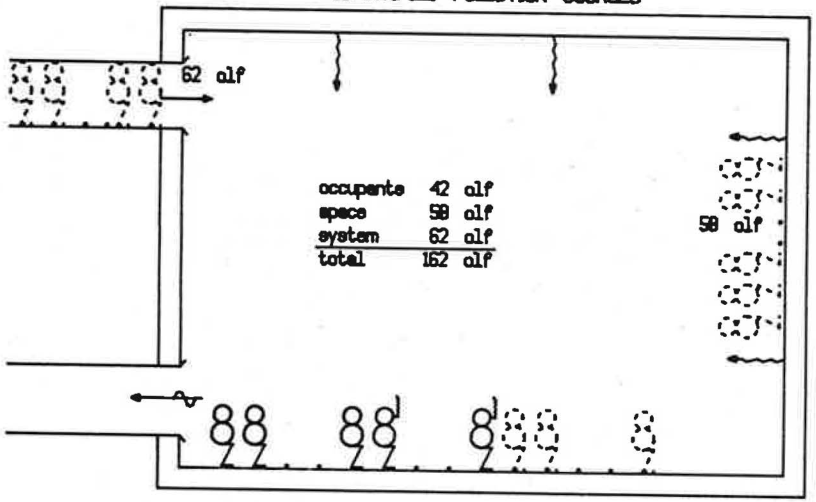

Fig. 3: MEAN VALUES OF POLLUTION SOURCES QUANTIFIED IN TWENTY OFFICES AND ASSEMBLY HALLS IN COPENHAGEN <1>

This frightening picture shows that there is a challenge for the HVAC industry to design and operate ventilation plants in such a way that they do not adversely affect the indoor climate.

At the same time it offers a challenge to the architect in that he must select materials and methods that liberate the smallest possible amounts of pollution into the indoor air. In Scandinavia, the notion of "low-olf buildings" has appeared as an objective.

This means that the building has a pollution load of 0.2 olf/m². Present-day buildings in which smoking is permitted have a load of perhaps 0.7 olf/m². Good air quality can therefore not be attained by only increasing air volume; pollution must also be reduced.

3. ENERGY REQUIREMENTS IN OFFICE BUILDINGS
LE BESOIN D'ENERGIE DANS DES IMMEUBLES DE BUREAUX

The energy required for heating modern office buildings has been reduced in recent years. This is because the need for energy conservation has resulted in buildings with improved insulation, triple glazing, improved air infiltration, and reduced ventilation volumes.

Despite this, we often see that modern office buildings have large total energy requirements, perhaps just as large as previously. We also see that the energy requirements, to a greater extent than previously, must be met by electricity. The explanation for this is that the buildings are now filled with equipment needing to be powered by electricity, such as computer equipment, printing and copying equipment, and general office equipment. Large data processing centres and communication centres are also common. All this produces excess heat which needs cooling off through the air-conditioning system - which also requires electricity.

It seems that the reduced energy requirement per device, which we nonetheless have experienced, is insufficient to outweigh the great increase in the numbers being installed in our buildings. Improvement in efficiency of light fittings seems, in addition, to be proceeding much more slowly than expected.

A low energy consumption in modern office buildings is therefore only possible if the air-conditioning system is designed in such a way that transferred heat can be exploited to cover heat losses. Figure 4 shows the "energy flow" in a modern building. Heat loss, ventilation loss and domestic hot water requirements determine the thermal energy requirement. At the same

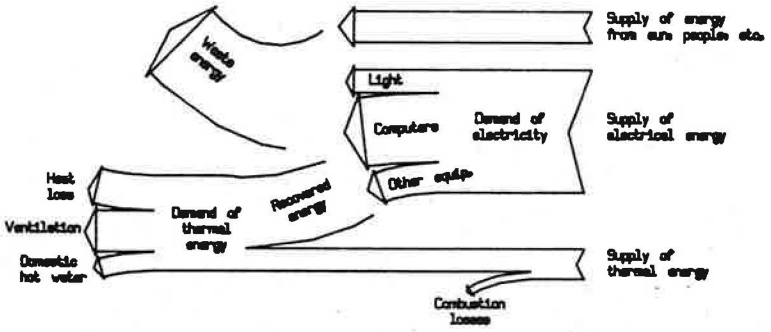

Fig. 4 POWER FLOW OF ENERGY IN AN OFFICE BUILDING.

time, we have, as just mentioned, a great need for electric power to run equipment. If the heat excess from operating the equipment, and from the sun and human beings, can be recovered and used to meet the thermal energy requirements, then the necessary input of thermal energy will be merely a balancing item. This "superfluity" of thermal energy in our office buildings offers us possibilities for upgrading the indoor climate without specially significant consequences for energy consumption.

Energy requirements in an actual building

To put this into a more tangible form, we have looked at a building planned for an oil company in Norway. The building has a gross floor space of ca. 25,000 m² and is to cover the needs of ca. 750 office jobs. We will assume that the building has present-day standard as regards choice of materials, and that smoking is permitted. This represents a pollution load of ca. 0.7 olf per m² in the work-place space. A separate EDP department attached to the concern requires 300 kW of energy to operate the data processing equipment.

The building has a combined cooling unit which cools EDP machines, cold ceilings in the offices and ventilation air in the summer. The excess heat is transferred to a heating system based on water. This energy can thereby be exploited to meet a substantial portion of the thermal requirements.

We will first calculate the energy requirement of such a building having a ventilation volume in the office space corresponding to 3 l/s per olf (2 l/s per m²), which is

a very common figure today. Figure 2 shows that we can expect 35 % to complain about the air quality.

Subsequently, we will calculate the energy requirement if the air volume is increased to 4 l/s per olf and 6.5 l/s per olf. In the last case, we can expect ca. 20 % to complain about the air quality.

Energy requirements per m²

Figure 5 shows the energy requirements per m² of this building, with the three different demands on air quality.

We see that the need for electric power for lighting, operating equipment, etc., is greater than the need for

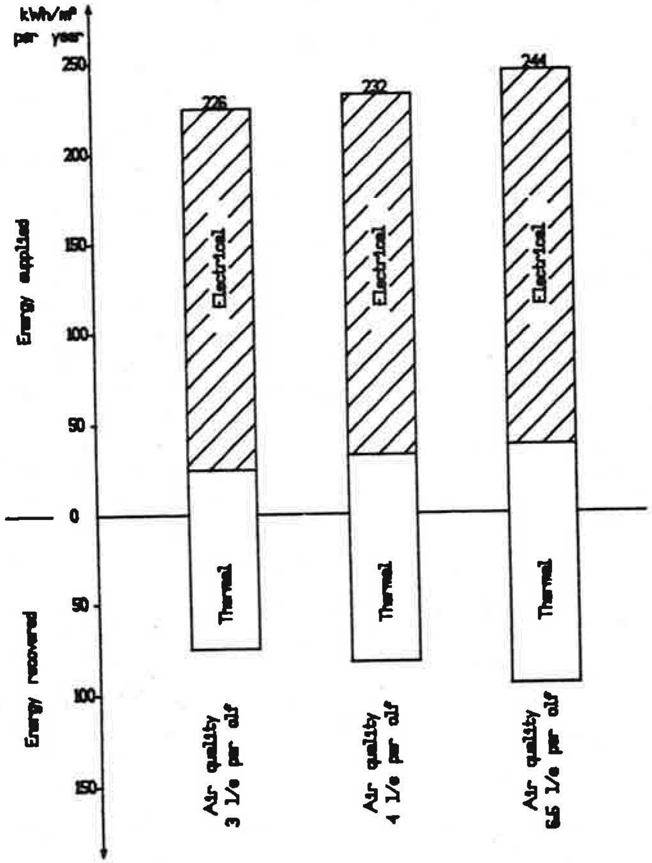

Fig. 5 ENERGY DEMAND AND SUPPLY IN A 25,000 m² OFFICE BUILDING LOCATED IN TRONDHEIM, NORWAY, FOR DIFFERENT VENTILATION VOLUMES.

thermal energy for air conditioning. Furthermore, exploiting possibilities for recovering heat from electrical equipment, the sun, etc., will significantly reduce the actual supply of thermal energy.

If we want to improve the air quality in this building by increasing the air volume, we see that it results in only marginal increases in total energy consumption. To reduce the expected number of complaints from 35 % to 20 % calls for an increase from 226 to 244 kWh/m² per year, or ca. 8 %.

This calculation confirms hypothesis 3, that there is largely excess energy present in modern office buildings. When we, nonetheless, have some increase in energy consumption with increase in air volume this is largely related to increased energy for operating fans.

Financial consequences of increased ventilation

An 8 % increase in energy consumption means in this case that operating costs will increase by ca. NOK 315 per year for each employee.

The consequences for investments are apparently larger. A doubling of the air volume, which is what we are talking about here, means an increase of investment of ca. NOK 15,000 per employee. With a real interest rate of 6 % per annum and depreciation over 15 years this will mean NOK 1500 per year for each employee.

With an air volume of 4 l/s per olf the figures for increased energy consumption and capital costs increase by about 1/3.

4. PERFORMANCE AND WELL-BEING PRESTATION ET PROSPERITE

Status

As regards environmental questions, pollution of the external environment - air and water - is the theme politicians and the media are preoccupied with. The fact that people are mostly indoors is rarely pointed out. The reason seems to be that we have not considered it a health hazard to be indoors in homes and places of work, except for a few industrial work-places.

Nowadays, there seems to be a change in attitude towards this in Scandinavia. More and more people make the point that the internal environment is also important for public health. Professional building owners have long-since realized that investment in a good indoor climate

is investment in the well-being of employees and in increased productivity [4].

In our project we do not aim to carry out a broad investigation of the relationship between air quality and productivity. Such a study would demand too many resources. We nonetheless believe that information available from official statistics and related research projects can illustrate such a connection [5] and [6].

The effect on health of an adverse indoor climate

Problems related to indoor climate seem largely to arise from the irritating effect of impurities on the skin and the mucous membranes of the eyes and respiratory passages. The irritation is chiefly felt as a sensation of "dry air" and results from the combined effect of irritants (impurities) in the internal environment. Smell plays an important role in our conception of our surroundings, and may be a stress factor. Formaldehyde is a common irritant gas indoors because of building materials and smoking. In addition to eye irritation, changes in the mucous membrane of the nose have been demonstrated with high formaldehyde concentrations.

Hyper-reactivity may result from irritation of mucous membranes, and is increased by infections, which in their turn reduce resistance to infections and increase risks for developing allergies. Epidemological data suggest that internal climatic conditions may be important causes of a large proportion of proneness to allergy and respiratory ailments and diseases. There seems, therefore, to be a very large preventative potential in improving these conditions, on health grounds and therefore also economically. In view of the data available, it is not unreasonable to assume that say half the respiratory ailments and diseases in our population can to a greater or lesser degree be ascribed to shortcomings in the indoor environment.

Several studies, particularly where damp is involved, have also revealed considerable tiredness and occurrence of headaches. This should lead to the question of whether the central nervous system is also affected, or whether it is a form of allergic reaction.

Rock-wool fibre from construction materials and insulation is another suspected cause of irritations. Other significant health effects from such fibres than itching and irritation have not so far been revealed, but major studies dealing with this are underway.

Official statistics show an increase in the occurrence of asthma and acute respiratory infections in the

Norwegian population. There is reason to believe that much of this increase results from the influence of the indoor climate, some think close on half.

Productivity

How heat and cold indoors affect the achievement capabilities of the human being has been studied in detail by Wyon [7] through controlled laboratory investigations using test persons.

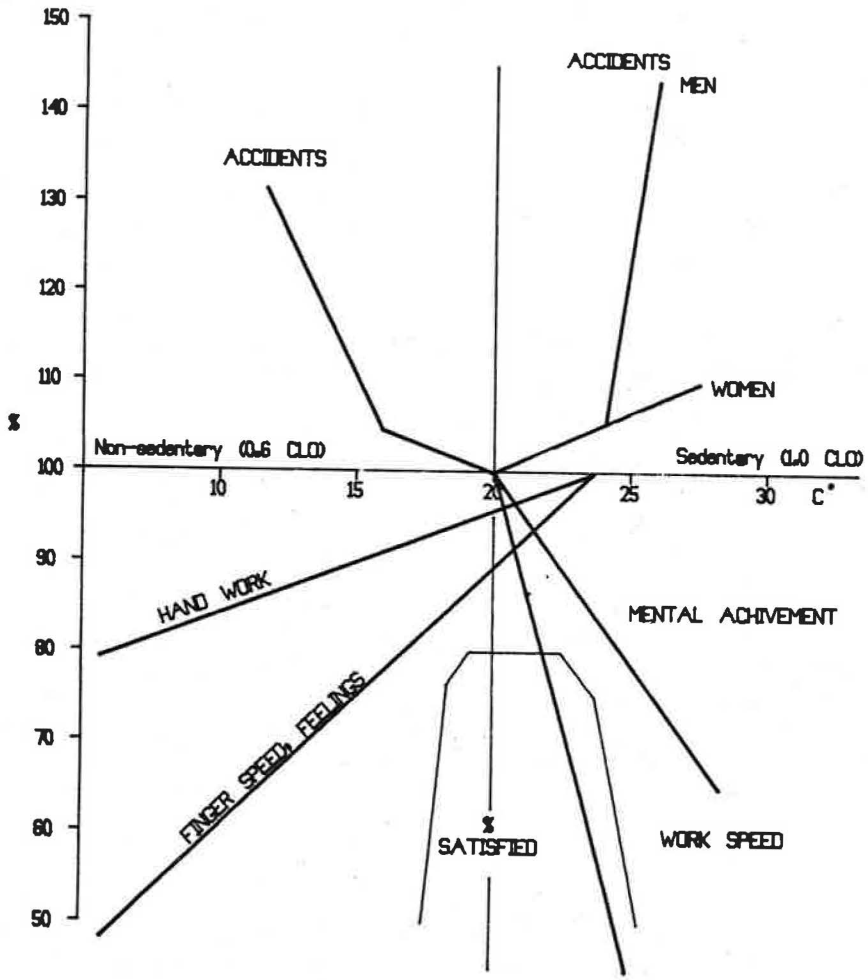

Fig. 6: INDOOR CLIMATE, ACCIDENTS, WORK EFFICIENCY AND COMPLAINTS (simplified) Dr. David Wyon

Wyon has shown that finger temperature is significant for productivity. It is therefore important to be aware of the factors affecting this temperature. When it is cold, the hands quickly become cooler because blood circulation to periferal parts of the body is reduced. This will rapidly reduce ability to work efficiently with the hands, or perform similar tasks (see Fig. 6). It is not only room temperature that affects finger temperature, but also movement and clothing.

Figure 6 also shows accident proneness and mental performance at various air temperatures.

Wyon has also examined the interaction between thermal stress and other stress factors such as noise and light. Relationships with air quality have not, however, been investigated.

Nevertheless, there is reason to believe that stress caused by poor air quality will also result in reduced levels of achievement. Figure 6 shows that extremely small departures from an optimal indoor climate will quickly reduce productivity by 5-10 % for some individuals.

Official statistics [8] show that the average number of days with reduced activity because of illness during the year is 31 for men and 46 for women. Moreover, we know that ca. 1/4 results from diseases of the eye, ear and respiratory system. This also suggests that there is room for improvement

5. PROPOSALS FOR REMEDIAL MEASURES [5] PROPOSITIONS DE MESURES CURATIVES

To solve the problems of poor air quality by merely increasing the air volume is scarcely technically and economically acceptable. We must therefore first do whatever is possible to reduce the pollution. The aim must be to achieve "low-olf buildings". We will now propose some measures which can help to attain this objective.

Smoking

Smoking often leads to the most serious pollution of the indoor climate. In practice, smoking will demand such large requirements for air that it is impossible to dilute the air to an acceptable level. With a consumption of 1-2 cigarettes an hour, a smoker will pollute the air as much as 6 persons who do not smoke.

If smoking indoors is to be permitted it must take place in separate smoking rooms with separate ventilating systems.

Buildings, interior and fittings

Evaporation and pollution from construction materials and interior walls, floors, ceilings and so on, may result from many factors:

- In new buildings, evaporation can take place from hardening materials including paints, adhesives, wallboards, etc. This can lead to a need for increased ventilation in an initial phase, perhaps ½-1 year after occupation? The half-life for evaporation may vary from weeks to 3-4 months. This can be partially countered by knowledge about and sensible use of construction materials. For example, damp wallboards may give off formaldehyde, drying adhesive and paint release solvents or fission products from plastics and hardeners.

- Not cleaning the building before it is brought into use, particularly in places which users cannot see. The building must therefore be thoroughly cleaned before being taken into use.

- The accumulative or storage effect of pollution in the materials. This increases with increasing size of surfaces and is especially large on "hairy" surfaces, being a strong argument against using carpetted floors.

- The negative effects of carpetted floors are made still worse by dampness, condensation (cold floors), and heavy wear and poor cleaning.

- Good everyday cleaning and regular thorough cleaning reduce the problems of indoor climate. The interior must be easy to keep clean.

- Vacuuming may pollute the air with large quantities of fine particles. This can be improved by installing a central vacuum-cleaning system. It is theoretically possible to filter the air, but vacuum cleaners with "allergy filters" have so far not been adequately tested.

- Photocopying machines, paper-shredding equipment and other frequently used machines handling paper should be situated in separate exhaust zones. Use of impact paper can lead to problems because of liberation of chemical exhaust steam.

- Paper dust and pollution can be prevented by having enclosed shelving and files, and by having these extending to the ceiling, thus avoiding unnecessary dust-traps.

- More investigation should be carried out to learn whether use of lowered pannelled ceilings leads to problems with the indoor climate as a result of large areas of horizontal surface in a room being inaccessible for cleaning. If this is confirmed, lowered ceilings should be avoided.

Ventilation installations

Ventilation installations must be kept clean. Pollution from these can be caused by:

- Not cleaning the building before it is taken into use. It must be insisted that ducts are degreased, and that they are delivered to the site with caps on the ends to be removed prior to fitting.

- Deposition of dust and other pollutants in the installations. Recirculated air must not be permitted.

- Induction units permit local recirculation in the room and often lead to reduced air quality, both because dust is recirculated and because substantial quantities of impurities can quickly build up in the unit itself. Additional problems can occur when cooling takes place resulting in condensation in the unit and thereby favourable conditions for mites, fungi and bacteria to develop when food in the form of impurities in the unit is already present. Induction units must therefore be avoided.

- Hygroscopical, rotating, heat recovery units also recover water-soluble impurities. All rotating heat recovery devices recover cooking fumes. There is still some uncertainty whether they also recover other impurities, but it is clear that also non-hygroscopical heat recovery units become hygroscopical and recover impurities when their surfaces become contaminated. They must therefore be easily accessible for inspection and cleaning.

- Heat recovery units must be installed in such a way that leakages and excess pressure do not occur from the used air side. The installations must be checked for leakages both on delivery and during subsequent follow-up.

- Poorly located inlet openings can result in large numbers of insects entering the air inlet plant. This leads to unacceptable air quality and risk of development of allergy and asthma.

- Dampness in the plant readily leads to undesirable biological activity, and humidifcation should generally be avoided. If humidification takes place in the plant, technology must be used which safeguards against this sort of development. Intermediate storage of water can promote biological development. Even though this water is subsequently boiled in a steam humidifier, the organic material produced in the intermediate storage tank may lead to undesirable effects. Intermediate storage tanks should therefore not be used. There is also a risk of condensation precipitation in the ducts with corresponding consequences there, too.

- Use of contaminated materials in the ventilation installation must be avoided. When sound absorbers and the like, made of fibre glass and rock wool, are being installed it must be ensured that the plant is cleaned after fitting and that material is used that is guaranteed against fibre loss. This applies to internal surfaces from the air inlet through to and including the supply valves.

- The installations must be accessible for inspection and cleaning. This must be written into the contract, and be verified on acceptance.

6. ANNUAL COSTS AND OPTIMAL INDOOR CLIMATE
FRAIS ANNUELS ET CLIMAT INTERIEUR OPTIMAL

The annual costs of a building consist of capital costs and administrative, operating and maintenance costs. When a new building is being planned it has become more and more common to use annual costs as a decision-making tool. The reason for this is that the costs during the operating phase increase relatively, particularly labour and power costs. The annual costs are often evaluated per m² floor space. Obviously the costs should be as low as possible.

Employees at the centre of the stage

All modern businesses stress that the staff are their most important resource, and the most significant production factor. Therefore it is surely only natural that investments and operating costs which are related to the well-being and health of the employees are viewed in relation to productivity and annual costs.

What is the value of improved productivity?

It is difficult to give an unambiguous answer to this question with regard to office workers. One angle of approach may be to examine wage-related costs.

In figure 7 the value of improved productivity is shown in percentages for different wage levels.

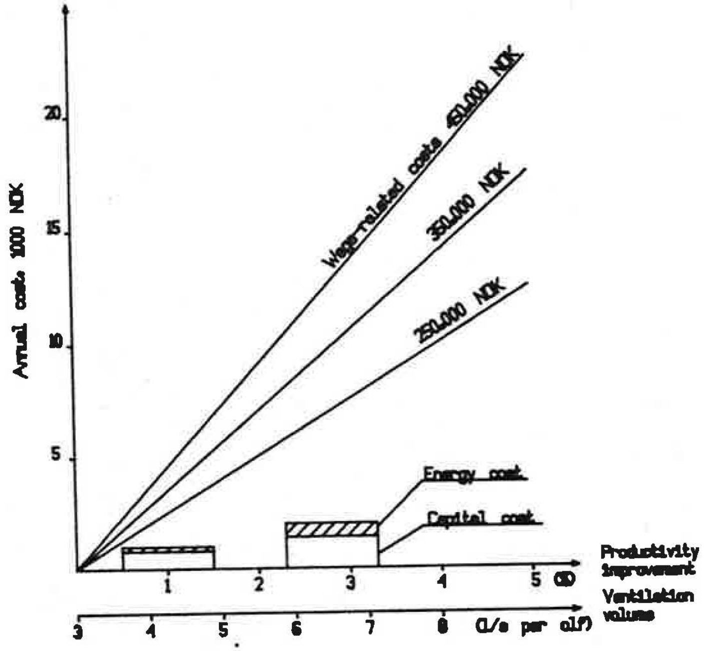

Fig. 7: PRODUCTIVITY IMPROVEMENT VERSUS COST OF UPGRADING INDOOR AIR QUALITY TROUGH INCREASING THE VENTILATION VOLUME.

Can the indoor climate influence productivity?

We believe we have strong indications that this is so. The best figures relate to the connection between performance and thermal indoor climate (see Chap. 4). Apart from this we must resort more to assumptions and assessments of the influence the complainer has on productivity, and whether the number of days absent through illness can be reduced.

However, we who have contact with users on matters concerning indoor climate see that much effort and time is spent discussing and thinking about the indoor climate, if that is not as it should be. In extreme cases, we have seen health authorities threatening to close buildings whose indoor climate has obviously been the cause of people's absence through illness (Sick Building Syndrome).

It is therefore not unreasonable to assume that an improvement in air quality indoors can help promote a productivity improvement of up to 3 %.

Is there an optimal air quality?

In figure 7, we have included a scale for air quality, measured in air volume per olf. An improvement in air quality from 3 to 6 l/s per olf will, according to this, result in productivity improving by up to 3 %.

In the same figure, we have included bars showing increased capital costs and energy costs when air quality is upgraded by increasing air volume (Chap. 3). Increased energy costs account for only a small portion of this total increase.

It is likely that some of these relationships may differ somewhat. But the margins seems to be so large that the main conclusion is clear:
It is very profitable to upgrade air quality.

How do we upgrade air quality?

A good principle for HVAC engineers has always been to eliminate the source first, and then dilute. The same applies here. The correct approach must be to carry out measures to reduce the sources of pollution in our buildings (Chap. 5), but it is also necessary to increase air volumes.

The short-term objective must be to obtain fewer than 20 % complaints about the indoor climate from users, as opposed to 35 % today.

7. CONCLUSIONS
CONCLUSIONS

By means of a current research project in Norway, we aim to find out how to upgrade the air quality indoors, and at the same time the consequences of doing so. The need for such upgrading is recognized through the ever increasing numbers of complaints from users concerning modern office buildings.

Even though the research is at an early stage and more information needs to be collected and systematized, we can draw the following conclusions:

- All substances and materials, fittings and equipment must, in addition to the human being, be looked upon as sources of pollution.

- We need methods for characterizing indoor air quality. Training groups of people to use their nose to judge air quality seems to be a useful way to go.

- All architects and planners must be made conscious of the need to minimize the pollution load.

- All office and EDP equipment in our office buildings produce a heat surplus which can be exploited for heating. The air-conditioning system must be designed in such a way that heat recovery is possible. This, however, leads to a move towards using more electricity and less thermal energy for meeting the energy requirement in such buildings.

- To be able to upgrade the air quality we can scarcely avoid increasing the air volume compared with the small volumes that have been made desirable due to the energy conservation drive.

- An optimal air quality is thought to be capable of increasing productivity. As regards the thermal indoor climate, a 5-10 % reduction in productivity has been shown to occur with only small departures from an optimal climate. Moreover, we know that of registered cases of illness, ca. 1/4 are related to eyes, noses and the respiratory system. We assume that productivity can be readily increased by up to 3 % by improving the air quality.

- Even a productivity improvement of only 1 % would more than cover the increased costs of upgrading the indoor air quality. These increased costs include energy costs and capital costs.

- Increased energy consumption as a result of upgrading the air quality may be up to 8 %. This has little financial significance for the individual employer or owner-builder.

- Any increase in energy consumption is undesirable from the viewpoint of society at large. A marginal increase for upgrading the air quality must, nevertheless, be looked upon from the viewpoint that demands for energy conservation have for a long time taken place at the expense of air quality.

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Abstract

Sustained efforts to conserve energy during the last 15 years have taken place at the expense of the indoor climate. Ventilation air volume has been reduced to a minimum. Use of new materials, substances and equipment which emit gases, vapours, fibre and other pollutants to the indoor air are an additional reason for the increasing frequency of complaints about the indoor climate.

We are generally able to maintain control over the thermal indoor climate, but it is necessary to upgrade the indoor air quality. To achieve this, architects and other planners must be made conscious of the need to reduce the pollution load, at the same time as the ventilation volume must be increased.

In Scandinavia, "smell-detection panels" (i.e. groups of people trained to detect smells) are now being used to judge the air quality in buildings, according to a pre-determined scale. The "olf" is a unit corresponding to the pollution from one person. Pollution emitted from equipment, materials, carpets, etc., is classified according to the same scale. A relationship exists between the volume of ventilation per olf and the number of satisfied people.

If air quality is improved by increasing air volume, the energy demand will increase. For an office building that is being planned it has been calculated that doubling the air volume will result in an 8 % increase. This is less than expected because the heat surplus from EDP-equipment, etc., can be utilized by means of an efficient air-conditioning system.

Adverse effects on health, caused by poor air quality, have been recorded. These include irritation of the skin and mucuous membranes, fatigue and headaches. Such conditions are also of significance for ill-health related to allergy and respiratory disorders. Evidence is available from research and official statistics indicating that complaints about the indoor climate are clearly related to well-being and productivity in our places of work.

We have calculated the value of increased productivity in relation to the energy costs and capital costs of upgrading the air quality. A productivity increase of only 1 % has been found to more than cover these costs. We claim that a potential productivity improvement of at least 3 % can be attained by improving air quality. The conclusion is that upgrading indoor air quality is profitable.

Any increase in energy consumption is unwelcome from the viewpoint of society, but in this case it must be seen as a reaction against some energy-conserving efforts which for a long time have been practised at the expense of air quality.

Résumé

Les efforts continuels pour l'épargne d'énergie durant la dernière quinzaine d'années sont allés aux frais du climat intérieur. A cause de ceci, le volume d'air de ventilation a été réduit au minimum. L'usage de nouveaux matériaux, matières et équipement qui répandent des gaz, des vapeurs, des fibres et d'autres souillures à l'air intérieur a également causé une augmentation de la fréquence des plaintes concernant le climat intérieur.

En général, nous avons le climat intérieur thermique sous contrôle, mais il est nécessaire d'améliorer la qualité de l'air à l'intérieur. Ceci doit se faire en rendant les

architectes et d'autres faiseurs de projets conscient en ce qui concerne la réduction de la quantité de souillure, en même temps que le volume de ventilation doivent augmenter.

En Scandinavie, on s'est servi de "panels sentants" (des groupes de personnes qualifiées à détecter des odeurs) qui jugent de la qualité de l'air dans des bâtiments d'après une échelle élaborée. L'unité "olf" correspond à la pollution par une personne. Des souillures par l'équipement, les matériaux, les tapis, etc. sont caractérisés d'après la même échelle. Il y a des rapports entre le volume de ventilation par olf et le nombre de mécontents.

Si la qualité de l'air est améliorée en augmentant le volume d'air, le besoin d'énergie augmentera. Pour un immeuble de bureaux planifié, on a calculé 8 % d'augmentation en redoublant le volume d'air. Ceci est moins qu'attendu, parce que l'excédent de chaleur de l'équipement électronique etc. est exploité par un système de conditionnement de l'air efficace.

On a enregistré des effets sur la santé comme des irritations de la peau et des membranes muqueuses, de la fatigue et du mal de tête à cause d'une mauvaise qualité de l'air. Des conditions pareils sont également d'importance pour les mals liés à l'allergie et aux maladies des voies respiratoires. On peut présenter plusieurs résultats de recherches scientifiques et des statistiques officielles indiquant que des plaintes sur le climat intérieur aient distinctement de l'importance pour la prospérité et la productivité à nos lieux de travail.

Nous avons calculé la valeur de la productivité augmentée en proportion de l'amélioration de la qualité de l'air. On constate que déjà moins de 1 % d'augmentation de productivité couvrera ces frais. Nous prétendons que le potentiel d'amélioration de productivité par une meilleure qualité de l'air est au moins de 3 %. La conclusion : une amélioration de la qualité de l'air à l'intérieur est lucratif.

Chaque augmentation de la consommation d'énergie est peu désirable d'un point de vue social, mais doit ici être considéré comme une réaction contre les initiatives d'épargne d'énergie qui ont longtemps été aux frais de la qualité de l'air.

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DIVISION 2 Énergie et environnement
Energy and the Environment

Session 2.3 Mesures de protection de l'environnement: rôle de la technologie
Environmental Problems Control — The Role of Technology

2.3.11

- THE BENEFICIAL EFFECTS OF ENERGY SAVINGS ON ENVIRONMENT

- LES EFFETS FAVORABLES DE L'EPARGNE D'ENERGIE SUR L'ENVIRONMENT

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INTRODUCTION

The utilization of the natural energy resources always involves a more or less important impact on the environment.

This impact takes on different forms and entities according to the resource used and the final use made of it, but in any case it may be stated that it always causes change in the environment.

The evolution of human society, especially in the last 100 years, has led to an enormous increase in the consumption of energy resources.