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Paper 2

INDOOR AIR QUALITY IN "BUILDINGS OF THE YEAR". MAX PRODUCTIVITY - MINIMUM OF COMPLAINTS

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ABSTRACT

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

If air quality is improved by increasing air volume, the energy demand will increase - and extended initial costs will rise.

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 which is related to allergy and respiratory disorders. Evidence available from research and official statistics indicate that complaints about the indoor climate are clearly related to well-being and productivity in our places of work (1).

1. Introduction.

For more than 25 years air consultancy has been focused on low investment cost in addition to the question of energy consumption. After the oil embargo in the mid 1970's, several energy conservation efforts have had a negative impact on the indoor air quality (IAQ). This very unfortunate situation is about to be changed.

Major companies take a different attitude regarding employees, and have become more concerned about their comfort, productivity and health. These companies ask what we - as planners - can do to provide a new building, with a secure indoor environment, a minimum of contaminants, and sufficient amount of well filtered outdoor air.

One of these companies is Norsk Hydro who decided to build a 22000 sq. meter building in Bergen for the administration of the Oseberg oilfield in the North sea. They started in 1985 with an evaluation of architects and ended up with a paid

competition between five very qualified architectural companies in Norway.

As HVAC-consultants for Hydro, our company was responsible primarily for capital costs and minimizing energy consumption. We made the complete specifications for technical installations (HVAC) and supervised detail engineering done by the winning contractor based on the winning architect's sketches. This approach was completely new in Norway, and the result as far as indoor environment was very good.

Even during the construction of the Norsk Hydro Administration Building in the mid-eighties, new technology in the field of indoor environment was widely expanded. This new technology will enable the next two buildings that Norsk Hydro has scheduled for construction to be built in an even more cost effective manner regarding total costs over the lifetime of the building than the first building. This will result in substantial savings when one considers that personnel costs represent close to 90 percent of the total costs.

2. Indoor Climate

The consequences of energy technology for indoor climate have not received much attention. New developments in energy technology and the use of new materials in buildings have, to a greater extent than previously, created buildings with indoor climate problems (SBS). Simultaneously, health, comfort 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 health, comfort, and productivity of employees.*

The problems around indoor climate can now be documented by means of questionnaires in which people give their opinion about their situation. Common complaints are:

- *Draughts.*
- *Dust or dry air.*
- *Humming and noise from ventilators, etc.*

** SBS - Sick Building Syndrome*

- *Heavy air, headaches, nausea, dry throats, fatigue and smarting eyes.*
- *Too cold or too warm.*

Many individual cases also point towards conditions being worse in buildings having lower ventilation rates than in others. The minimum requirements of the Building Codes today do not contain adequate consideration of:

- *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 (MMMF).*
- *Fall-out from panelled ceilings (MMMF) & dust.*
- *Textile fibres from clothing.*
- *Dust in the duct network.*
- *Etc.*

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

3. Energy requirements in office buildings.

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. A new office building for Statoil in Stavanger (330.000 sq.feet) has only used energy for NOK 100.000,- during the first year of operation.

Despite this, we often see that modern office buildings have large total energy requirements, perhaps just as large as previously. We also see that energy requirements, to a greater extent than previously, must be met by electricity. The explanation for this is that buildings are now filled with equipment needing to be powered by electricity, such as computer equipment, printing and copying, and general office equipment. Large

data processing centres and communication centres are also common. All these produce excess heat which needs cooling through the air conditioning system - which also requires electricity.

It seems that the reduced energy requirement per device is insufficient to outweigh the great increase in the number of devices being installed in our buildings. Additionally, improvement in the efficiency of light fixtures seems to be proceeding much more slowly than expected.

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 (2). Figure 1 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 time, we have, as just mentioned, a great need for electric power to run equipment - including fans and pumps.

Fig. 1

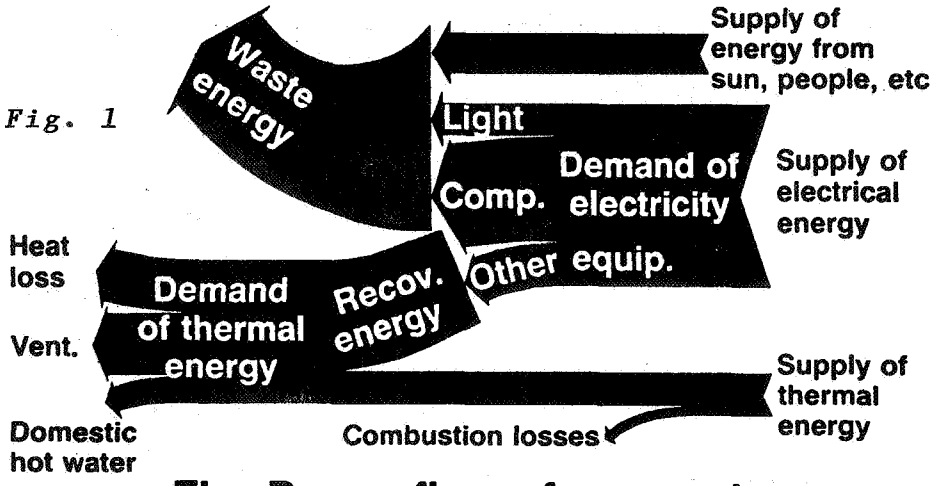


Fig: Power flow of energy in an office building

If the excess heat from operating equipment, 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 (1).

To put this into a more tangible form, we have looked at a building planned for Statoil in Trondheim, Norway. This building has a gross floor space of approximately 25000 sq. meter and will meet the needs of approximately 750 people. We will assume that the building has a present day standard regarding choice of materials, and that smoking is permitted. A separate EDP department requires 300 kW of energy to operate the data processing equipment.

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

Figure 2 shows the energy requirements per square meter of this building, with the three different demands on air quality (3).

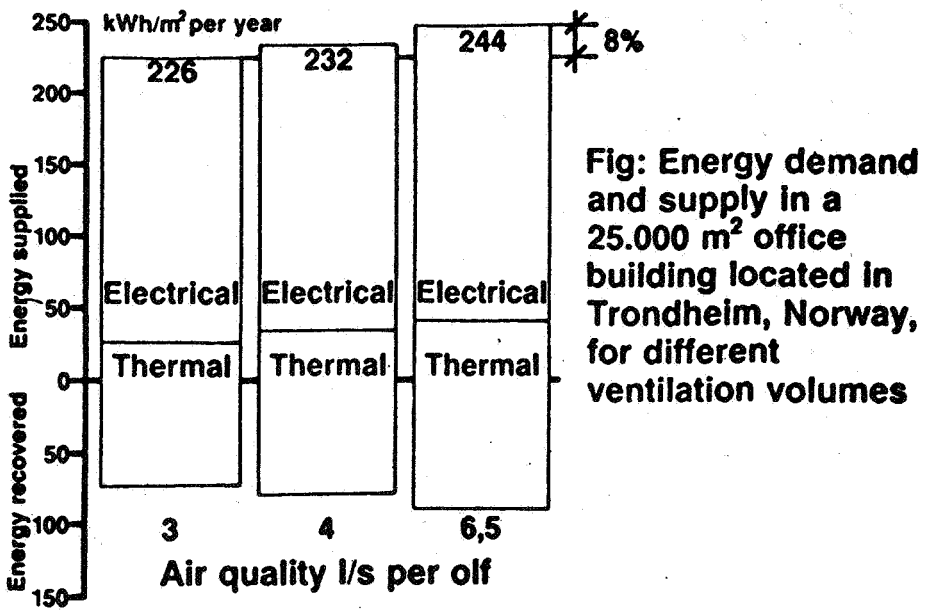


Fig: Energy demand and supply in a 25.000 m² office building located in Trondheim, Norway, for different ventilation volumes

We see that the need for electric power for lighting, operating equipment, etc., is greater than the need for thermal energy for air conditioning. Furthermore, exploiting possibilities

for recovering heat from electrical equipment, the sun, etc., will significantly reduce the actual demand for thermal energy.

If we want to improve the air quality in this building by increasing the air flow from approximately 7.2 up to 15.6 cubic meters per square meter per hour, we see that it results in only marginal increases in total energy consumption. To reduce the expected number of complaints from 35% to 20% requires an increase from 226 to 244 kilowatt hours per square meter per year, or about 8%. (Professor P.O. Fanger) (3).

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

An 8% increase in energy consumption means in this case that operating costs will increase by approximately 315 Norwegian kroner (48 US$) per year for each employee - which is negligible.

4. *Performance and Well-being.*

As regards environmental questions, pollution of the external environment is the theme that politicans 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 (4).

At present time there seems to be a change in attitude towards this in Scandinavia. More and more people make the point that the indoor environment is also important for public health. Professional building owners have long since realized that investment in a good indoor climate is an investment in the well-being of employees and in increased productivity (5). In October this year FIABCI Common Market Committee will arrange their study days in Stavanger, and the main topics are energy consumption and indoor air quality and their inpact on the value of real estate.*

** FIABCI - FEDERATION INTERNATIONALE DES PROFESSIONS IMMOBILIERS*

Our Statoil project does not attempt to carry out a broad investigation of the relationship between air quality and productivity. Such a study would demand too many resources. We nevertheless believe that the information available from official statistics and related research projects can prove such a connection (6).

5. What are total costs?

The annual costs of a building consist of depreciation on invested capital costs plus operational costs (Fig. 3). 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.

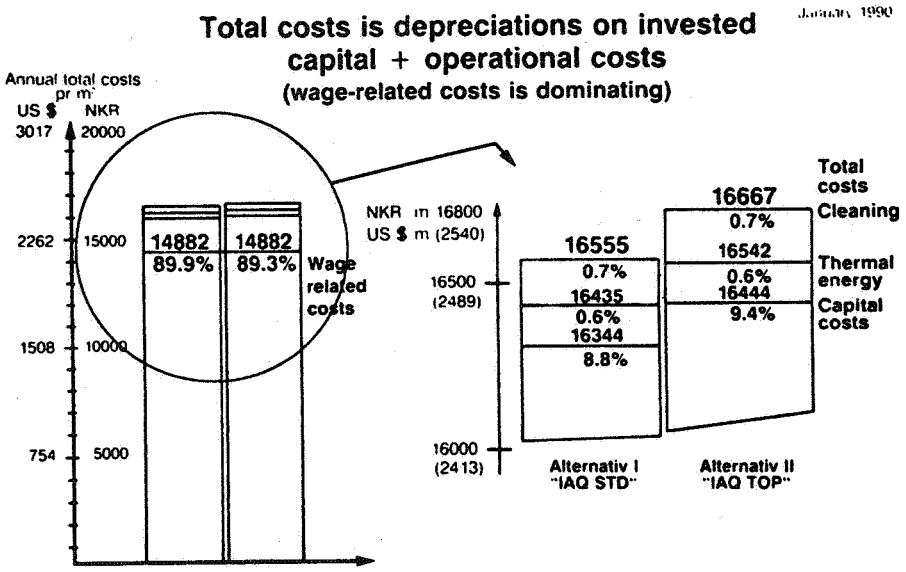
The annual costs are often evaluated per square meter floor space. Obviously the costs should be kept as low as possible.

Annual costs are then related to the building instead of to the employees working in the building.

Costs like these are related to the building itself and running the building. But why do we put up an office building in the first place? Of course it is because we have work to be done, and this can be done in a less expensive way if the temperature feels comfortable and the productivity is high. A good indoor environment is one of the most important factors to improve the efficiency of any staff. This is elementary - but do we act like this in our building industry? Do the building owners act like this? I am afraid not, and therefore I have started to bring up an extended expression for total cost. Total cost must be related to the sum of wage-related and building costs. This is shown in the Oseberg complex in Bergen (Norsk Hydro) where personnel related costs per square meter is NOK 14.882,- in the left columns (Fig. 3).

The total costs for what I call Indoor Air Quality Standard (IAQ Std) 7.5 cubic meters per square meter per hour, is NOK 16.555,-. If we raise the standard to 15 cubic meter per square meter per hour and take precautions with selec-

tion of materials, building procedures, cleaning procedures etc., the costs will rise to NOK 16.667,- and the difference is mainly in investment costs: 9.4 - 8.8 = 6%. The personnel related costs dominate totally.



6. *Are the buildings for the owner or for the tenants?*

When we receive a commission as consulting engineers, the main task normally is to provide buildings with low total costs for planning, construction and maintenance of the building, which are primariely:

- *Investment costs.*
- *Energy costs.*
- *Maintenance of buildings (MOB).*
- *Cleaning.*

The above costs are just about 10% of the total picture because wage-related costs dominate after the building is occupied. Total cost is depreciation on invested capital plus operational costs. Instead of talking about the building itself, we should concentrate on the tenants which should have as close to an optimal indoor environment as possible. This environment is a multiple of the

following factors ("Seven Sisters") which overlap each other:

- *Thermal environment (humens heat balance).*
- *Atmospheric environment (contaminants and VOC's).*
- *Acoustic environment (hearing, sound, noise).*
- *Actinic environment (lightning, radon and electromagnetic radiation).*
- *Mechanical environment (feeling, pain, accidents etc.).*
- *Psychosocial environment (relationships between people).*
- *Aesthetics (what's good for our senses- eyes, smell, ears, taste, feeling and balance).*

In "buildings of the year" - three office buildings under construction - we have made specifications and drawings especially for the tenants - and the owners have accepted all new information we have provided for the combination of the "Seven Sisters" above:

- *Choice of materials with low emissions in any part of the buildings.*
- *Air condition systems of the very best design.*
- *Specifications for full temperature control year around (20 - 24oC)*
- *15 m3 filtered air per square meter per hour in offices.*
- *Displacement ventilation in some offices and dilution in others - max. air velocity 12 cm per second.*
- *The best filtration (EU7 or 8) of outside air.*
- *High quality cleaning.*
    - *After the building is tightened.*
    - *Before laying carpets.*
    - *Before closing suspended ceilings.*
    - *Before moving into the buildings.*
    - *Good cleaning procedures during the buildings lifetime.*
    - *High quality carpets, curtains and furniture.*
    - *Central vacuum cleaning systems.*

Qualified personnel are contracted to overlook building procedures under the construction period, and in addition to be consultants for HVAC installations, have a special responsibility for the total indoor environment.

7. Conclusions.

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

- Architects and planners must be made conscious of the need to minimize the pollution load indoors.

- All offices and EDP equipment in our buildings produce a heat surplus which can be exploited for heating. The air conditioning systems 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 requirements in such buildings.

- To be able to upgrade the air quality we can hardly avoid increasing the air volume compared with the small volumes that have been made desirable due to the energy conservation drive. IAQ top means about 15 cubic meter filtered air per sq. meter per hour.

- An optimal air quality is believed to be a factor in increasing productivity. Regarding the thermal indoor climate, a 5-10% reduction in productivity has been shown to occur with only small variations from the optimal climate. Moreover, we know that of the registered cases of illness, 25% are related to eyes, nose and the respiratory system. We believe 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 including 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 in general. 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*

- *Total cost is dominated by wage-related costs, and investments and energy costs are negligible compared to that.*

- *It is always cheaper in the long run to make the right decisions before making any drawing.*

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