Design and Commissioning of an Energy Efficient Air Distribution System in a University Hospital

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Energy efficiency was a significant by-condition in the design work of the New Block (23,700 m²; 255,100 ft²) of the University Hospital in the city of Linköping in Sweden. The block is made up of several interconnecting buildings of between two to four floors, and contains the Heart Centre, the Ear Centre and the Clinic for Infectious Diseases. The principal aim of the design work was to decrease the electrical energy end-uses for air distribution, cooling and lighting (electronic ballasts, occupancy sensors). Over 1,300 windows with very low U-values contributed to the decrease in the heat energy use. The building was occupied and commissioned during the spring and summer of 1995.

A pre-study was made of approximately half the air distribution system. i.e. air handling units as well as the duct system. The air flow rate of this half was assumed to be 30 m³/s (63,500 cfm); constant round the clock. The marginal profitability from the base case through three more energy-efficient designs was calculated, assuming a depreciation time of 15 years, an electrical energy price of SEK 0.30 (US¢ 4-5) per kWh, and 15% minimum allowed marginal internal rate of return. The fan energy use was expressed through an energy performance ratio, i.e. the Specific Fan Power *SFP* [kW/(m³/s); 0.472 W/cfm]. The gradual steps which decreased *SFP* from 4.0 kW/(m³/s) to 3.0, 2.0 and 1.5 were all found to be profitable, leading to a more detailed design with the goal of obtaining $SFP \approx 1.5$ kW/(m³/s). During the commissioning in late summer 1995, the *SFP* was measured for the actual air distribution system. For the two largest air handling units (custom built), the measured *SFP* was 1.86 kW/(m³/s) and 1.63 kW/(m³/s), respectively. The reasons for this increase compared with the pre-study were mainly due to more efficient filters being installed on the return air side of all air handling units. Furthermore, the filter class had been increased one step on the supply air side of the air handling unit with the highest measured *SFP* and the dual-duct mixing boxes needed higher static pressures than stated in the manufacturer's data.

INTRODUCTION

Background

In the Swedish national energy efficiency programme a vital part is played by the technical procurement of energy efficient technologies and products based on the purchasers' demands. The programme is administered by the Department of Energy Efficiency, DOEE at the Swedish National Board for Industrial and Technical Development, NUTEK. The aims of the programme are (1) to achieve a faster market introduction for the current, most energy efficient technologies and products, (2) to encourage development of more energy efficient technologies and products. One way to achieve a market pull is for DOEE/NUTEK to form groups of purchasers around various themes, e.g. electronic ballasts, windows, air handling units, etc. Another way is for DOEE/NUTEK to make an agreement with influential purchasers, such as a group of County Councils (which owns nearly all Swedish hospitals), resulting in rather limited financial support for investments in energy efficient technologies and products. A prerequisite is that all technologies and products used fulfil DOEE/NUTEK's specifications in the actual area. The investment subsidy is SEK 1.50 (US$ 0.21) per conserved annual kWh, or a maximum of 50% of the marginal investment. The owner of the University Hospital in the city of Linköping, County Council Properties of Östergötland (Landstingsfastigheter Östergötland), has had such an agreement since 1990.

Scope

This paper describes some of the analysis, design and commissioning work around the recent extension of the University Hospital at Linköping. Energy efficiency played a significant role as a by-condition in this work, as the building owner (1) had a recent agreement with DOEE/NUTEK to implement energy efficient technologies and products in their buildings, and (2) had a general interest in energy efficiency and in reducing the operation costs of their buildings. In the middle of the 1980's life cycle cost analyses (including calculations of energy costs in present-day terms) were made compulsory for all building investments under the jurisdiction of the County Council of Östergötland.

EXTENSION OF THE UNIVERSITY HOSPITAL AT LINKÖPING

General Description

The campus of the University Hospital at Linköping contains buildings erected from the late 1800's to today. In the mid 1970's the County Hospital as it was called then was transformed into a University Hospital at the same time as a major new university was established in Linköping. A significant part of this transformation was the erection of a large high-rise Central Block on the hospital campus. During the late 1980's parts of the medical and surgical wards in the Central Block, as well as in older buildings, had outgrown the available space and plans were made for a larger extension. At the end of 1990 it was decided to erect a New Block containing a Heart Centre (cardiology and thorax surgery, and intensive care wards), an Ear Centre (surgery and wards) and the Clinic for Infectious Diseases (wards only).

The New Block was deliberately designed to contrast with the high-rise modernistic Central Block, which is located close by. The architectural characteristics "multiplicity, concord and variation" were paramount. The New Block is made up of several interconnecting buildings of two to fours floors. This building layout results in a number of closed and semiclosed courtyards giving the possibility of interesting views and good daylighting. The New Block's net floor area is 22,400 m² (241,120 ft²) resulting in a gross floor area of 23,700 m² (255,110 ft²), and the heated volume is 91,700 m³ (3,240,280 ft³). Figure 1 shows a view of the New Block from the south.

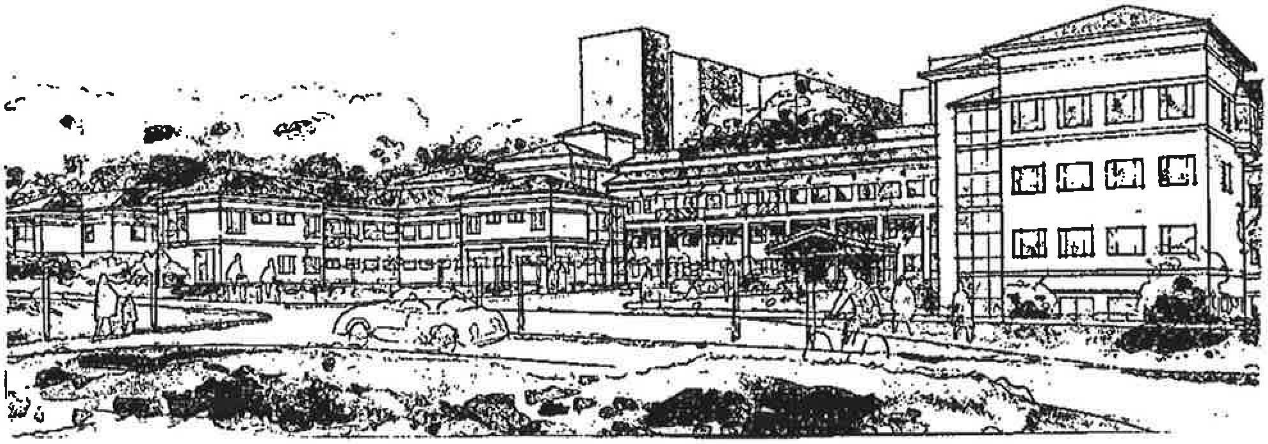
Energy efficiency played a significant part in the analysis and design work. Life cycle cost analyses (present value calculations) were carried out on all parts of the building (walls, windows, roofs, lighting system, HVAC system, etc.). The present value analyses included: the original investment, any necessary reinvestments during the assumed life time of 30 years, maintenance and operation costs, of which energy costs made up a substantial part.

The lighting system was carefully designed to achieve the desired lighting levels in the "right areas" and was realised with high frequency fluorescent lighting as well as with compact fluorescent lamps. These measures reduced the average installed lighting power density from 16 W/m² (1.5 W/ft²) to 10 W/m² (0.93 W/ft²). Occupancy sensors were installed in office rooms, toilets, storerooms, etc., which were assumed to decrease the operating time from 3,700 h/year to 1,500 h/year and thereby decrease the average lighting power density to just over 6 W/m² (0.58 W/ft²). The total investment for the lighting system was 455 SEK/m² (~USD 5.60 per ft²), of which the marginal investment for the energy conservation measures was 185 SEK/m² (~USD 5.60 per ft²). The calculated marginal pay back period for these measures was 9.1 years, assuming an electrical energy price of SEK 0.50 (US¢ 7.1) per kWh. Much care has also been spent on the design of the electrical wire systems to reduce electric-magnetic fields and avoiding creeping currents, etc.

More than 1,300 energy efficient windows were also installed in the New Block. These windows have a U-value around 0.8 W/m²,K (~0.14 Btu/h, ft²,°F) including glass and frame, which can be compared with standard three pane windows with a U-value around 2 W/m²,K (~0.35 Btu/h, ft²,°F). The additional investment for these windows was 140 SEK/m² floor area (~USD 1.75 per ft²) and the payback period for the change of windows was 10 to 20 years depending on the balance temperature of the premises, assuming a district heating price of SEK 0.30 (US¢ 4.3) per kWh.

All cooling in the New Block is carried out by a water based system which provides cooling for the HVAC systems, as well as for heat generating medical equipment, etc. The same is true for the old Central Block after recent refurbishments. The cold water is delivered from a central cooling plant to the whole hospital campus. Due to the extension of the New Block and the retrofit to the Central Block, the capacity of the cooling plant had to be increased during the winter of 1994/95. As the existing refrigerant water chillers used R12 they also had to be retrofitted or exchanged since this refrigerant is not allowed to be refilled after 1 January 1995 in Sweden. The old chillers had nearly reached the end of their technical lifetime and it was decided to install three new refrigerant chillers, each with four compressor circuits. Originally all of these were to have use R22, but it was later decided to convert two compressors circuits on each chiller to R290 (propane). Due to the risk of explosion when using propane the electrical system in the chillers' room had to have extra protection and with breakers placed in a separate room. This measure did not incur any extra investment, as the electrical system in the chillers' room had to be changed anyway. Neither did the conversion of the compressor circuits (new throttle valves) bring about any extra investment worth mentioning. The coefficient of performance is nearly the same for propane as for R22 but the condenser heat power is somewhat decreased for propane compared to R22. Preliminary results from long-time monitoring of the cooling plant indicated a somewhat more energy efficient operation with propane than with R22. When selecting the new refrigerant ammonia (R717) was also considered, however use of ammonia chillers should impose an

Figure 1. View of the New Block of the University Hospital at Linköping From the South. The Modernistic Central Block from the 1970s Is Seen in the Background



Source: Hedenström (1994) 124.

extra investment of about 25-30% compared to chillers using R22 or propane.

AIR DISTRIBUTION SYSTEM

General Requirements

A Variable Air Volume (VAV) central ventilation system was selected, due to the varying times of use of the different premises in the New Block. Thus, the air flow rate variation is a result of the operation of timer-controlled dampers. The different premises also had varying requirements on the supply air temperature which led to the selection of a dual-duct system with one warm duct and two cold ducts. It should be possible to connect the warm duct and one of the two cold ducts to each mixing box (group of rooms). One cold duct delivers air at a temperature of 15°C (59°F) all year round (priority cooling), whereas the other cold duct delivers air at a temperature of 15°C only, when the ambient temperature is lower than this value (non-priority cooling) since this duct has no cooling coil. The choice of priority or non-priority cooling depends on the type of premises, and it also results in different energy costs for the tenants.

Since ventilation air is needed all round the clock, a reasonably low electrical energy use for operating the fans was also an important by-condition in the design work. The marginal profitability for decreasing the fan energy use was analysed in a pre-study. Two main objectives were laid down for the design work (1) the function of the ventilation system should be reliable at the same time the system is general and flexible, and (2) the annual energy use of the fans should be reasonably low. These objectives led to the decision of the following general requirements:

- Outdoor air flow rates should be set according to the requirements on the indoor air quality and the need for cooling the premises. Once set, the air flow rates are not allowed to be decreased during the design process to obtain a low fan energy use;
- Supply air filters of class EU6 (70% ASHRAE dust spot efficiency); No re-circulation of return air, instead applying the usual Swedish solution:
- Rotary air-to-air heat exchangers with temperature efficiency > 70% (only sensible heat);
- Cooling coil design conditions: 25°C (77°F) dry bulb temperature, 50% relative humidity (65°F wet bulb temperature), supply air dry bulb temperature 15°C (59°F);
- Noise generation from mechanical rooms to duct system < 55 dB(A);
- Pressure drops over air terminals ≥ 50 Pa (≥0.2 in.w.g.);
- To avoid high pressure drops in horizontal ducts on the floors due to the widespread building layout, the vertical shafts were placed fairly close and connected via large ducts in the attics;

- To be able to meet future increased air flow rates, fairly large circular ducts should be used horizontally on each floor as well as vertically in the shafts (Ø400, Ø315 and Ø250; Ø16", Ø12" and Ø10");

- To enable three distinct vertical zones for ventilation ducts, warm and cold water pipes and electrical wire ladders, fairly high floor-ceiling heights should be used. The types of installations should if possible also be separated from each other in a horizontal direction. Due to this layout, the ducts can be straight and therefore the necessity for any 4.45° elbows to counteract obstructions from pipes or wire ladders that might occur during the construction phase.

Pre-study

The pre-study (Bentzel 1992) was restricted to one of the large mechanical rooms in the New Block, serving about half the floor area, i.e. 11,000 m^2 (118,410 ft^2). The air flow rate was selected as 30 m^3/s (63,560 cfm), i.e. 2.7 (L/s)/m^2 (0.54 cfm/ft^2), and kept constant round the clock. This was due to the fact that at this early stage ventilation schedules for the different premises could not be estimated.

Just in time for the pre-study a new make of dual-duct mixing boxes was introduced onto the Swedish market, requiring only about 100 Pa (0.40 in.w.g.) static pressure. This meant that the pressure requirements of the duct system would be only 200-300 Pa (0.8-1.2 in.w.g.), depending mainly on how the layout of the horizontal ducts was solved. Consequently, the main part of the pre-study work concentrated on the air handling units. Early on in the pre-study, it was decided to investigate the possibilities to selected a few large custom built air handling units, instead of several smaller standard pre-fabricated units. These large custom built air handling units were standard design for large air flow rates around 1970, but due to leaky walls (up to 15-30%) of some makes this technology later fell out of favour. However, around 1990 tight walls, originally intended for clean rooms, were available at an acceptable price.

The electrical energy efficiency of the air distribution system was characterised by the Specific Fan Power, *SFP*. This energy performance ratio is defined as the ratio between the total electrical power of all the fans in the air distribution system and the supply or the return air flow rate, whichever is the largest. According to Scandinavian guidelines R2 (SCANVAC 1992), the design air flow rate should be used for Constant Air Volume (CAV) systems and 80% of the design air flow rate should be used for VAV systems. Since the air flow rate in this case was assumed constant, the *SFP* directly reflects the annual energy use of the fans. Table 1 specifies the maximum allowed *SFP* in the four classes, including one electrical efficient sub-class, according to R2.

***Table 1.** Specific Fan Power Classes for CAV Systems at Design Air Flow Rate According to SCANVAC R2*

Specific Fan Power SFP	Remark
≤4.0 kW/(m^3/s) (1.89 W/cfm)	Maximum allowed
≤2.5 kW/(m^3/s) (1.18 W/cfm)	
≤1.5 kW/(m^3/s) (0.71 W/cfm)	
≤1.0 kW/(m^3/s) (0.47 W/cfm)	Energy efficiency sub-class (future goal)

Source: SCANVAC 1992, 15 & 16

The requirements from DOEE/NUTEK are that an air distribution system must fulfil $SFP \leq 1.5$ kW/(m^3/s) if any investment subsidies are to be given to a building owner with which DOEE/NUTEK has an agreement. The values in Table 1 can be compared with the prescriptive criteria according to ASHRAE/IES Standard 90.1-1989 (ASHRAE 1990) at design air flow rate:

- $SFP \leq 1.69$ kW/(m^3/s) (0.8 W/cfm) for CAV systems;

- $SFP \leq 2.65$ kW/(m^3/s) (1.25 W/cfm) for VAV systems.

When comparing American conditions, it must be remembered that in Sweden no re-circulation of return air is used in ventilation and air-conditioning systems. Instead air-to-air heat recovery equipment is used, which normally increases the *SFP* by 0.2-0.5 kW/(m^3/s) (0.09-0.24 W/cfm).

For the New Block the marginal profitability was investigated for four different system solutions designed to fulfil different levels of *SFP* at the design air flow rate. Table 2 specifies these different system solutions. The last system solution in Table 2 with two large centrifugal fans with an impeller with backward curved blades leads to less noise generation and thereby smaller noise attenuaters and smaller pressure drops in the air handling unit.

The original design of the mechanical room was estimated to accommodate an air handling unit with $SFP \approx 2.5$ kW/(m^3/s). Consequently, the mechanical room had to be

Table 2. Investigated System Solutions in the Pre-Study for the New Block

SFP kW/(m³/s) (W/cfm)	Face Velocity m/s (fpm)	Centrifugal Fans with Backward Curved Blades- Numbers and Size	Duct System Static Pressure Pa (in.w.g.)	Numbers of Large Rotary Air-to-Air Heat Exchangers
4.0 (1.89)	2.8 (551)	1 small fan	300 (1.2)	2
3.0 (1.42)	2.8 (551)	1 large fan	300 (1.2)	2
2.0 (0.94)	2.0 (394)	1 large fan	200 (0.8)	3
1.5 (0.71)	2.0 (394)	2 large fan	200 (0.8)	3

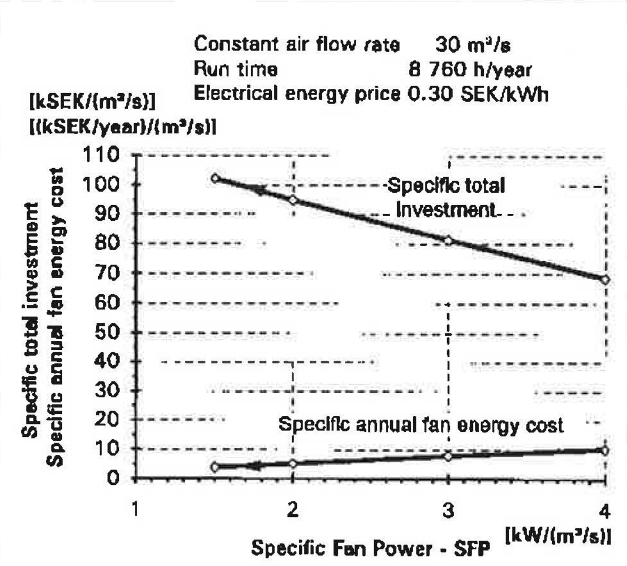
Source: Bentzler 1992, 7

extended to accommodate the two solutions with the lowest *SFP*. Since the mechanical rooms were placed in spacious attics the increased building cost was limited. To calculate the marginal profitability of the decreased *SFP*, a depreciation time of 15 years was assumed. The minimum acceptable marginal internal rate of return was 15%. The electrical energy price was assumed to be fairly low at SEK 0.30 (US¢ 4-5) per kWh with no future real price increase. The investment costs do not include proprietor costs and VAT and refer to March 1992. Figure 2 shows the increased specific total investment and the consequently reduced specific annual cost for operation of the fans.

As seen in Figure 2 the specific investment increases from around 81,000 SEK/(m³/s) (USD 6.50 per cfm) at *SFP* of 3.0 kW/(m³/s), which is fairly normal in Sweden, to around 102,000 SEK/(m³/s) (USD 8.20 per cfm) at the low *SFP* of 1.5 kW/(m³/s). If expressed per floor area the investment for the air distribution system is increased from 190 SEK/m² (USD 3.00 per ft²) to 280 SEK/m² (USD 4.42 per ft²). This can be compared with the investment of all the building services systems which is about 850 SEK/m² (USD 13.40 per ft²).

Figure 3 shows the marginal internal rate of return for each step down to *SFP* = 1.5 kW/(m³/s). As seen all steps have a larger marginal internal rate of return than the required 15% and it is therefore profitable to decrease the *SFP* down to the lowest level investigated. However, the last step has a marginal profitability that just fulfils the required marginal rate of return. This means that a relatively small increase in the investment cost may make this step unprofitable.

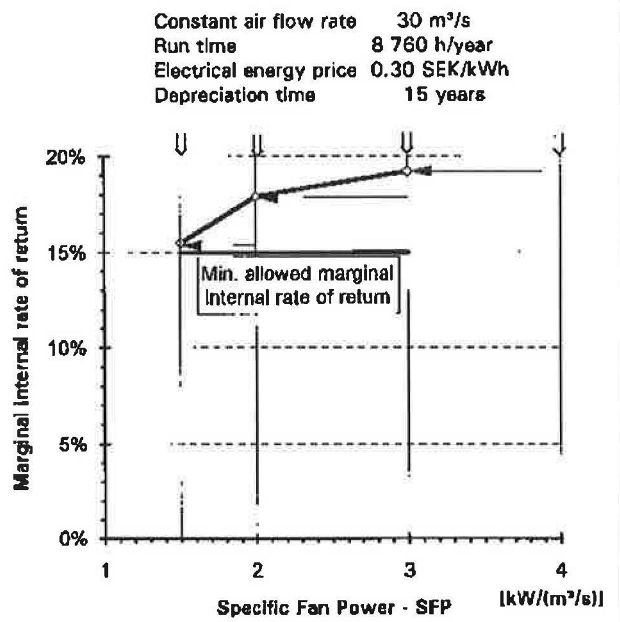
Figure 2. *Specific Total Investment and Specific Annual Fan Energy Cost for the Air Distribution System Solutions Studied in the Pre-study. 1 SEK ≈ USD 0.17*



Note: Based on Bentzel (1992) 9

Note that the air flow rate is very large and that the fans run round the clock. Consequently, the results from this pre-study of a hospital can not be applied, for example, on office buildings where the air flow rates are much smaller (typically 5-10 m³/s; 10,600-21,200 cfm) and the fans' running time is 2,000-3,000 hours per year.

Figure 3. Marginal Internal Rate of Return for the Air Distribution System Solutions Studied in the Pre-study



Note: Based on Bentzel (1992) 9

Based on the results of the pre-study, it was decided to use mainly custom built air handling units and make a detailed design of the air distribution system with the goal to be reached, if possible, $SFP \approx 1.5$ kW/(m³/s).

Design and Construction

The construction work of the New Block started in January 1993 and it was completed in February/March 1995. The commissioning work then started and the tenants moved in gradually until the building was fully occupied and commissioned in September 1995.

During the detailed design stage it was decided to use five air handling units for the New Block. Several changes were made from the pre-study, mainly in relation to the fan type and an increased need for air filtration.

The two largest air handling units (CA1 & CA3) serve areas with general ventilation needs, are custom built and have three air-to-air rotary heat exchangers each. They also have vane-axial fans with a patented anti-stall ring which give stable operation regardless of air flow rates and pressure rises. The air flow rate is controlled by variable pitch control. The supply air filter class is EU7 (85% ASHRAE dust spot efficiency) and EU6 (70% dust spot efficiency), respectively. The return air filter class is EU6.

The three smaller air handling units serve special premises (CA2—thorax surgery, CA4—clinic for infectious diseases, CA 5—ear surgery), are prefabricated and have coil heat recovery loops to avoid any cross contamination from the return air to the supply air. They also have large centrifugal fans with an impeller with backward curved blades. The fans are direct-driven via shaft couplings and the air flow rate is controlled by frequency inverter adjustable speed drives (ASDs). The filter class is EU6 for both the supply air and the return air. For the two air handling units serving surgery premises, filters of the class EU8 (90% dust spot efficiency) are located in the supply air ceilings of the operating theatres.

The centrifugal fans proposed in the pre-study were changed to vane-axial fans for the air handling units CA1 and CA3 due to the large air flow rates and rather low pressure rises required. However, vane-axial fans generate higher noise levels than centrifugal fans under the same conditions. Due to this, larger noise attenuaters had to be used than were originally planned for the two air handling units. These somewhat higher pressure drops are balanced by the slightly higher efficiencies of the vane-axial fans (particularly at part load air flow rates).

In the other three air handling units the centrifugal fans proposed in the pre-study were kept, but the efficiency was increased somewhat (particularly at part load air flow rates) as all fans are direct-driven via shaft couplings. The standard V-belt drive between the motor and the fan, as well as the standard two-speed inlet-vane control of the air flow rate, were exchanged for a frequency inverter adjustable speed drive (ASD). One ASD was selected for each fan motor.

It was also decided to increase the air filtration. For CA1 the supply air class was increased to EU7. On the return air, where the pre-study had no filters, it was decided to install filters of the class EU6 to protect the air-to-air heat exchangers in all air handling units. This increased air filtration led to higher pressure drops and a higher Specific Fan Power, *SFP*. However, to ensure that all filter surfaces were fully used, and thereby minimising the pressure drops, the filter bags were stretched by connecting them to wires running parallel to the filter banks in all air handling units.

One prerequisite to obtain the low Specific Fan Power, *SFP* specified for the New Block was that the designed pressure drops in the duct system must not be exceeded in the actual system. Consequently, the ducts must be constructed according to the drawings and no extra pressure drops added due to unplanned extra elbows, etc. The ventilation contractor took the legal responsibility for the duct pressure drop calculations from the HVAC design engineer and had to guarantee that the maximum designed pressure drops would not be exceeded in the actual system. This was a novel approach for Swedish condition and worked well whilst, in general, the duct system became a good piece of work.

Commissioning

The commissioning work covered a period of six months from February to September 1995. During this period the tenants moved in gradually. The main part of the commissioning was co-ordinated functional testing of the different building services and control systems. In these testings the building owner's controller was in charge and all contractors involved in a particular system participated, as well as the consulting engineers in question.

With regard to the air distribution system many problems were encountered with the frequency inverter ASDs. As an example, the fans in CA2 serving the thorax surgery operation theatres stopped a couple of times during operations due to maladjusted ASDs. This led to an expensive installation of switchover cables to enable the building management system to run the fans, regardless of whether the ASDs are working properly or not. Typically the frequency inverter ASDs used are general purpose drives and a large amount of values has to be set to reach the desired operation. The knowledge of how to set these values properly is currently limited in the Swedish construction and HVAC industry. This is because the technology is new in these applications. A general impression is that many of the values could be pre-set by the producer and that there is a communication gap between the HVAC/electrical/control engineering consultants and the contractors/producers. To minimise the generation of harmonics from the frequency inverter ASDs, extra filters also had to be installed during the commissioning. Due to the new all-European Electric Magnetic Compatibility (EMC) Directive, this should not be needed in the future, provided that the proper compatibility class is specified. All electrical equipment sold in Europe after 1 January 1996 must comply to this EMC Directive. It specifies, for different compatibility classes what levels of different types of disturbances the equipment must endure, as well as what levels the equipment are allowed to generate. The compliance must be shown by measurements in an authorised laboratory.

Measurements of the Specific Fan Power, *SFP* of two air handling units, CA1 and CA3 were also included in the commissioning process (Saand 1995). Table 3 summarizes the results of these measurements. The Swedish HVAC construction instructions allow for $\pm 15\%$ divergence of the measured air flow rate from that designed, including measurement errors. The air flow rate as well as the electricity supplied to the fans were measured through the measuring points of the central energy management system. The measurement error on the *SFP* was estimated to be about 8%.

Table 3 shows that the goal of $SFP \approx 1.5$ kW/(m^3/s) has almost been reached. For CA3 the goal was exactly reached if the measurement errors are assumed to be on the "right side." The increase in the measured *SFP* compared with the values obtained in the pre-study can partly be explained by the following design differences: (CA3) Increased filter class on the supply air, filters on the return air, slightly oversized motors (decreasing one motor size, i.e. to 30 kW, should increase the part load ratio from 70% to 87%); (CA3) Filters on the return air. In addition, it has been found during the commissioning that the dual-duct mixing boxes require a higher static pressure than stated in the manufacturer's data. The extra pressure is about 50 Pa (0.2 in.w.g.) which means an increase of about 50% on top of the manufacturer's data.

CONCLUSIONS

For large air distribution systems with long run times it is profitable, as well as practically possible to achieve a Specific Fan Power, *SFP* just above 1.5 kW/(m^3/s) for Swedish conditions. To achieve this goal the following steps must be taken:

- Keep the pressure drops low in the duct system, in particular, the number of duct fittings should be kept as low as possible. All unplanned extra elbows which allow the ducts to pass any possible obstructions that might occur during the construction process, must be avoided. If possible let the ventilation contractor take over the legal responsibility so that the designed duct system pressure drops are not exceeded in the executed system;

- Select reasonably low face velocities in the air handling units, around 2 m/s (400 fpm). For large air flows this is best achieved by the use of custom built air handling units where the area of each air conditioning part can be optimised;

- Design the interface between the air handling unit (fans) and the duct system in such a way that the system effect pressure drops will be as low as possible due to space restrictions;

- Select the most efficient fans and drive systems. Normally these are, (1) for large VAV systems vane-axial fans with variable pitch control, and for (2) smaller VAV systems direct-driven centrifugal fans with an impeller with backward curved blades. The direct-driven fans are usually equipped with frequency inverter adjustable speed drives. Much care must be put into the installation of the frequency inverters to avoid harmonics and other electrical-magnetical disturbances. Because DOEE/NUTEK in 1995 had a technical procurement competition for VAV air handling units for

Table 3. Measurements of the Specific Fan Power, SFP of the Two Largest Air Handling Units in the New Block of the University Hospital at Linköping

Air Handling Unit	Design Air Flow Rate (Max.) [m^3/s (cfm)]	Measured Air Flow Rate [m^3/s(cfm)]	Name Plate Motor Power [kW]	Measured Motor Power [kW]	SFP [kW/(m^3/s)] [(W/cfm)]
CA1 Supply air	28.15 (59,640)	28.09 (59,510)	37	26.3	
CA1 Return air	28.14 (59,610)	27.87 (59,050)	37	25.8	
CA1 - Total					1.86 (0.88)
CA3 Supply air	9.91 (21,000)	9.79 (20,740)	11	8.6	
CA3 Return air	9.83 (20,820)	10.07 (21,340)	11	7.8	
CA3 - Total					1.63 (0.77)

Source: Saand 1995, 1

schools, this issue has attracted a large amount of interest from property owners, as well as producers in Sweden. One result of this technical procurement competition is that adjustable speed drive frequency inverters can now be delivered with the greater part of the parameters preset from the producer.

- In the commissioning process, naturally, the Specific Fan Power, *SFP*, i.e. the maximum air flow rates and fan powers, should be measured. Any difference between the measured and designed *SFP* should be investigated, and if possible, something done about it, even if it is only used as experience for the next project.

ACKNOWLEDGEMENTS

This work was sponsored by the Department of Energy Efficiency at the Swedish National Board for Industrial and Technical Development (DOEE/NUTEK), and the Swedish Council for Building Research (BFR).

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