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A SIMPLE DESIGN METHOD FOR EVALUATING THE ECONOMIC FEASIBILITY OF CONTROLLED VENTILATION

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This paper investigates the feasibility of controlling the outdoor air ventilation rate (OAVR) as a function of measured indoor air quality (IAQ). This control strategy is included in the recently approved revision to ASHRAE Standard 62 (1) as an alternative to the more conventional approach of a fixed minimum outdoor air ventilation rate.

A simple nomographic method has been developed to determine if IAQ monitoring and control is a preferable design choice when compared to a fixed OAVR. Results are presented giving payback period (or allowable monitoring and control system cost) as a function of degree days, design ventilation rate, and occupancy factors.

INTRODUCTION

The recently approved ASHRAE Standard 62 significantly increases the minimum outdoor air ventilation rates for most building applications (2). This change reflects the realization that lower OAVRs in conjunction with "tighter" building construction practices has led, in many cases, to unhealthy indoor air quality. The standard prescribes considerably higher OAVRs (expressed in liters/sec/person) for a wide range of applications. As an alternative to fixed OAVRs, Standard 62 allows for monitoring of IAQ and control of the OAVR to maintain a satisfactory environment.

Indoor air quality can be monitored using a variety of sensing technologies, including non-dispersive infrared sensors and heated semi-conductors. Sensor readings must be interpreted and used to adjust the outdoor air damper position and, when appropriate, the air handling unit operation. While this technology is still developing, sufficient products are commercially available to allow the designer the option of considering IAQ monitoring and control as a viable alternative to fixed OAVRs.

This paper presents a simple, nomographic method to determine whether IAQ monitoring and control is a feasible alternative for a given application. As with most nomographic solutions, the purpose is to provide a quick feasibility evaluation and is not intended to replace a detailed engineering analysis. If an IAQ monitoring and control system is indicated by the nomograph, a more detailed evaluation should be performed.

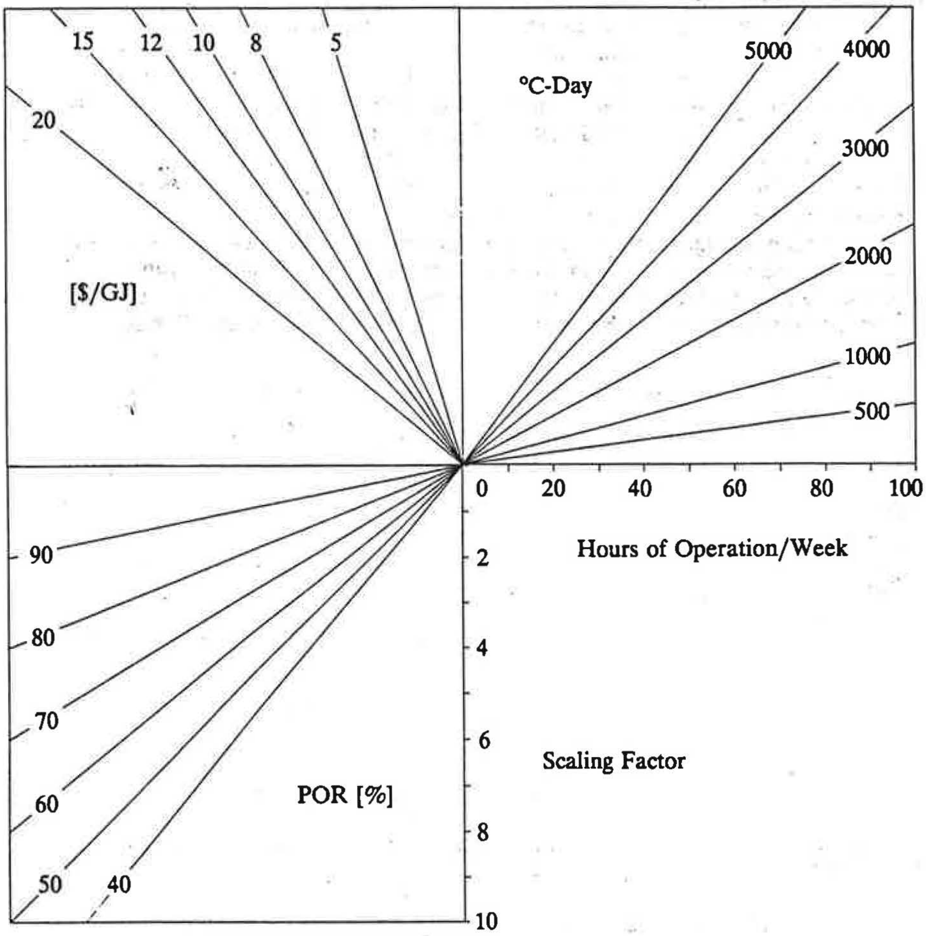
This method requires only minimal input. Data requirements include:

Weather: cooling and heating degree days

depend on the building application and the HVAC system characteristics. Construction of degree days from BIN data requires summation of the difference between the BIN and indoor temperatures times the hours in each BIN. Degree hours must then be converted to degree days. Equation (3) can then be used to determine the average energy cost.

Nomograph 1: Determination of the Scaling Factor

This nomograph is developed for a fixed OAVR of 100 liters/second. This simplification does not restrict the utility or range of the nomograph. Any OAVR can be evaluated but requires a simple concluding calculation. This simplification was used to yield a nomograph of greater clarity and accuracy than would have otherwise been possible.



Nomograph 1 Determination of the Scaling Factor

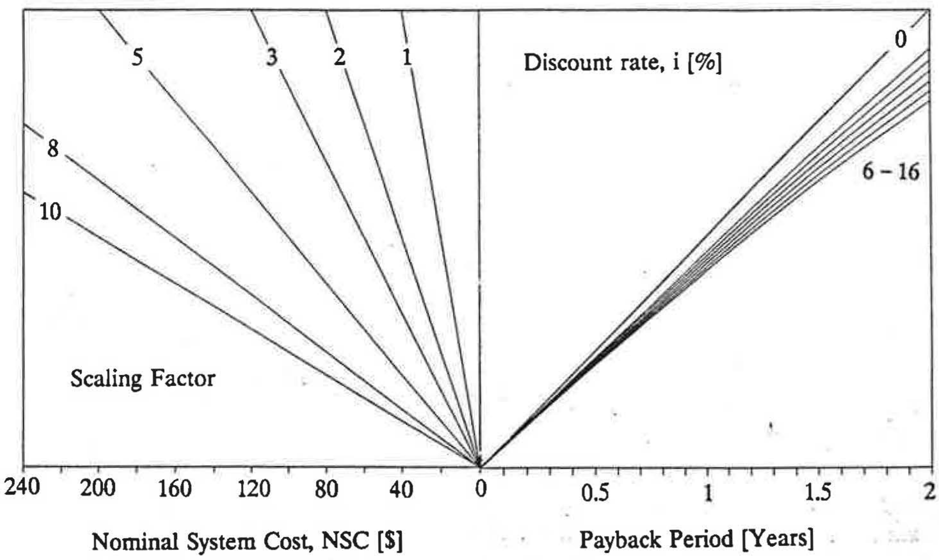
The upper right quadrant of the nomograph 1 determines the annual ventilation energy requirement for the fixed OAVR. The generation of this graph is based on the following equation:

Annual OAVR energy requirement = annualized OAVR x energy/unit OAVR
= [(volumetric flow rate)(density) (4)
x (hours of operation/yr)][(sp heat,c_p)(DD_t)]
= [(100 l/s)(3600 s/hr)(1 m^3/1000 l)(1.2252 kg/m^3)
x (hours of operation/week)(52 weeks/year)]
x [(1.0035 kJ/kg °C)(°C-day/yr)(1 yr/365 days)(1 MJ/1000 kJ)] [MJ/yr]

Enter this graph with the average hours of occupancy per week and construct a vertical line intersecting with the appropriate total degree days line. Move horizontally to the left into the upper left quadrant and intersect the average energy cost line for the facility. The value determined in this quadrant is the annual cost of ventilation (at the fixed OAVR) and is expressed by the following equation:

Annual energy cost = annual energy x cost/unit of energy
= [((MJ/yr)(1 GJ/1000 MJ)($/GJ)] [$/yr] (5)

From the point of intersection, construct a vertical line down into the lower left quadrant intersecting with the average partial occupancy rate (POR) for the facility. The POR represents the average level of occupancy of the facility compared to the design occupancy level. For example, a theater with a seating capacity of 100 persons but with normal ticket sales of 60 persons per performance would have a POR of 60%. A horizonal line is then constructed to the vertical axis where the "scaling factor" value is read. The scaling factor



Nomograph 2a Determination of Payback Period (0-2 Years)

is used to equate all ventilation savings to a single value and thus greatly simplify the determination of the payback period. Mathematically,

$$\text{Scaling factor} = \text{annual energy cost} \times (1\text{-POR})/(\text{scaling value}) \qquad (6)$$
$$= [(\$/\text{yr})(1\text{-POR}/100)/(\$ \text{ scaling value/yr})] \qquad [\text{Dimensionless}]$$

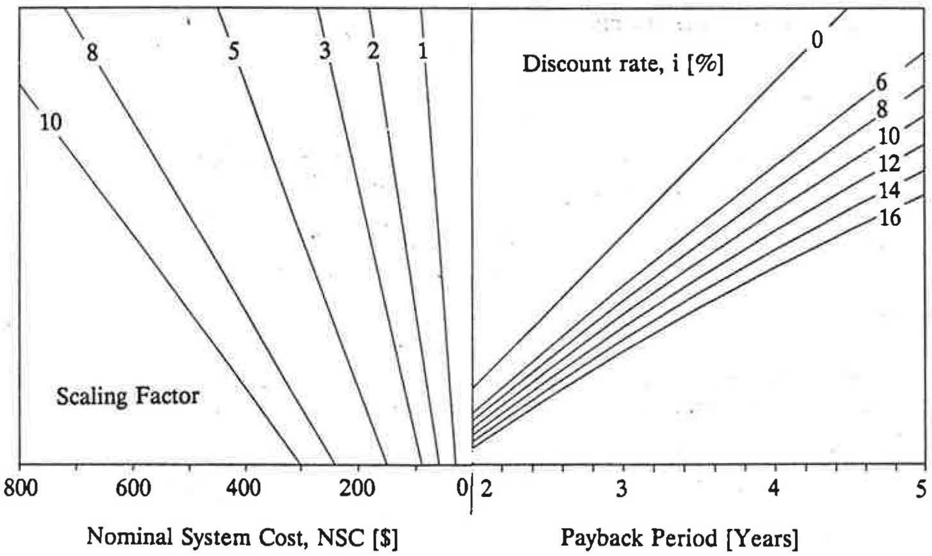
The scaling factor is carried forward for use in Nomograph 2.

Nomograph 2: Determination of Payback Period or Allowable IAQ Monitoring and Control System Cost

Two nomographs, 2a and 2b, are presented to allow for greater accuracy. Nomograph 2a covers payback periods from 0-2 years while nomograph 2b covers the periods from 2-5 years.

These nomographs can be read in either direction. By entering the right graph with an acceptable payback period, one can determine the allowable IAQ monitoring and control system cost which corresponds to the expected energy savings for that period. Conversely, if the system cost is known, the corresponding payback period can be readily obtained by reading the graph from the left to right.

Assume that the allowable system cost is desired. Enter nomograph 2 on the horizonal axis at the acceptable payback period, n, in years. Construct a vertical line which intersects with the discount rate, i, for the project. From this point construct a horizonal line into the left graph intersecting the line for the scaling factor obtained from nomograph 1. Then read



Nomograph 2b Determination of Payback Period (2-5 Years)

downward to obtain the nominal allowable system cost (NSC). The payback calculations are based on the equal series, present worth equation and are determined as follows:

$$\text{Allowable system cost} = \text{scaled value} \times (P/A,i,n)$$
$$= [\text{scaling value}][(1+i)^n-1]/[i(1+i)^n] \quad [\$] \qquad (7)$$

To determine the actual allowable system cost which corresponds to the design OAVR of the facility, use the following equation:

$$\text{Actual system cost (ASC)} = \text{nominal system cost (NSC)} \times \frac{\text{design OAVR (l/s)}}{100 \text{ (l/s)}} \qquad (8)$$

To determine the payback period for a proposed IAQ monitoring and control system, first calculate the nominal system cost:

$$NSC = \frac{ASC \times 100 \text{ (l/s)}}{\text{design OAVR (l/s)}} \quad [\$] \qquad (9)$$

Then enter the nomograph on the horizonal axis of the left graph working through the nomograph in a reverse fashion to obtain the corresponding payback period.

RESULTS

The results obtained by this method are limited by the ability to read the graphs accurately. The values obtained, however, are normally within 5% of the calculated value and are clearly suitable for preliminary design investigations. The limitations discussed in the introduction tend to overestimate the savings potential of an IAQ monitoring and control system. This tendency should be considered before pursuing a detailed evaluation, especially in those cases where the potential is marginal.

CONCLUSIONS

This simplified design procedure provides a straightforward and accurate method for determining the feasibility of incorporating an IAQ monitoring and control system into a facility. Application of this technology presents the opportunity to maintain a healthy indoor environment while simultaneously minimizing HVAC operating costs.

REFERENCES

(1) ASHRAE. 1989. ASHRAE Standard 62-1989. Ventilation for acceptable air quality. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

(2) ASHRAE. 1981. ASHRAE Standard 62-1981. Ventilation for acceptable air quality. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.