THE COST OF INCREASED VENTILATION AIR

by

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ABSTRACT

The present American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standard 62-1981 "Ventilation for Acceptable Indoor Air Quality" is being revised. The recommended ventilation rate will be increased four-fold from 2.5 l/s/person to 10.0 l/s/person. The immediate response to this proposal is that the energy consumption and costs will parallel this increase and rise dramatically. It is the intent of this paper to provide a better understanding of the actual effect of the changes to the ASHRAE standard.

The Introduction describes the reasoning behind the proposed changes to the ASHRAE standard and the method by which the authors have evaluated the effects of the changes.

Part 1 presents the Building Simulation Data and the design parameters used to analyze the effect of the proposed increase in the minimum outside air ventilation rate. These include the building construction, building air systems, weather data, building simulation program background and calculation methods.

Part 2 explains the results obtained from performing an analysis for each building system by increasing the minimum outside air ventilation rate 4-fold from 2.5 l/s/person to I 01/s/person.

The interpretation pays particular attention to the effect economizers have on the energy consumption of building air systems. This issue provides a key to the understanding of the whole ventilation issue.

Part 3 discusses the results, the factors which affect the results and explains the eff ect economizers have on the ventilation system and the energy consumed.

INTRODUCTION

A phenomenon known as the sick building syndrome is occurring in our buildings. Present concerns, regarding indoor air quality in commercial buildings, has prompted research into the causes and possible solutions for poor indoor air quality.

Six probable causes of poor indoor air quality are:

1) Tighter building construction reducing air infiltration.
2) Natural ventilation has all but been eliminated by design.
3) Outside air ventilation rates have been reduced.
4) Off-gassing by various synthetic materials into the space.
5) Inadequate air diffusion and circulation in the space.
6) Poor maintenance and operating methods of the mechanical systems.

Increased employee health problems, such as; headaches, dizziness, nausea and, therefore, increased sick leave are attributable to poor indoor air quality.

Several proposed solutions to these problems include:

1) Increase natural and forced ventilation through the building.
2) Tighter material specifications on building materials and furnishings.
3) Improved indoor air diffusion and circulation rates in the space.
4) Improve the maintenance and the operation procedures for mechanical systems.

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) is in the process of revising its Standard 62-1981 "Ventilation for Acceptable Indoor Air Quality".

The revised standard will:

1) Increase the minimum outside air intake rate by a factor of four. (From 2.5 to 10.0 l/s/person).

2) Define effective air diffusion and circulation as a design criteria.

This revised standard should provide the necessary mechanical needs to overcome poor indoor air quality. However, this action carries the issue full circle back to the question of energy cost and conservation. The question is, "What effect will the new ASHRAE standard 62-1981R have on building energy consumption?"

To fully analyze and understand the effect of the changes, an in depth computer simulation was performed. The simulation analyzed a building under varying ventilation rates, weather conditions and mechanical systems. In total 4 cities and 8 building systems were analyzed.

PART 1: BUILDING SIMULATION DATA

The Building Simulation Data found in this section is used to provide an understanding of the analysis methods used in the simulation.

The building simulated was a hypothetical structure which can be found in most North American cities. The design is rather arbitrary but an attempt has been made to typify the design parameters. The only changes made in the various models were weather, ventilation rate and the control of the economizer.

BUILDING DATA

We attempted to construct a typical building by setting typical values for design and construction.

Table 1 following displays the actual design criteria used in regards to building loading.

Table 2 describes the physical characteristics chosen.

Table 1

DESIGN DATA	
Indoor Temperature	22°C (All Year)
Indoor Humidity	40% RH
Internal Load - People	15 m^2/Person
- Lights	15 W/m^2
- Equipment	100W/Person
Infiltration	0.3 Air Changes/Hour
Schedule	Mon. - Fri. 6 am - 6 pm

Table 2

BUILDING DATA-CONSTRUCTION	
Storeys-	10.+ Underground Floor
Glass-	Double Pane
	U = 0.55, GF. = 0.39
	Internal Shades
	40% of Wall Area
Wall-	Medium Weight -
	RSI = 2.1 m^2-K/W
	Neutral Colour
Roof-	Built-up
	Medium Weight
	RSI = 2.1 m^2-K/W
	Medium Colour
Area -	Per Floor - 930 m^2
	Floor to Floor - 4.0 m

BUILDING SYSTEMS

The HVAC systems compared, represent the systems which are likely to be encountered in a majority of buildings. The systems chosen include the following:

1) Constant Volume with Reheat
2) Multizone
3) Pure Variable Air Volume
4) Variable Air Volume with Reheat

In all cases, perimeter baseboard heating was designated.

A comparison was also made between using a non-integrated economizer and an integrated economizer for each of the systems.

A non-integrated economizer system compares the outside air temperature and discharge temperature. Based on this comparison, the dampers are positioned to mix return air and outside air to provide a mixed air temperature equal to the required discharge temperature. When the outside air temperature is equal to the discharge temperature, the outside air dampers will be 100% open. When the outside air temperature is greater, the dampers return to their minimum position.

In the case of the integrated economizer, the outside air damper remains at 100% open until the outside temperature equals the return air temperature. When the outside air temperature is above the discharge temperature set point, a combination of outside air cooling and mechanical cooling is used to provide the necessary cooling.

In the case of humid environments, like Toronto and Vancouver, an enthalpy controlled economizer was used in the simulation instead of a dry-bulb control.

CONSTANT VOLUME WITH REHEAT

The constant volume reheat (CVR) system uses a central fan to provide a constant volume of conditioned air to each zone or space. Heating coils in the supply ducts at each zone are controlled by individual zone thermostats to provide reheat in order to maintain zone temperatures.

MULTIZONE

The multizone (MZ) system uses a central two deck blow-thru air handler to provide a constant volume of variable temperature air to each zone. Dampers downstream of the deck coils are controlled by the zone thermostat to modulate the flow of air over the coils in the hot and cold deck. The mixing of hot and cold air streams provides supply air at a temperature sufficient to maintain the zone temperature at the proper thermostat setting. The hot and cold deck coil outlet temperatures are maintained at their design values. A dual duct system operates similarly in that it mixes hot and cold air to maintain comfort conditions.

VARIABLE AIR VOLUME

The variable air volume (VAV) system uses a central supply fan to provide a variable volume of conditioned air to zone terminals. Thermostatically controlled terminal dampers regulate supply air flow to maintain each zone at the required setpoint temperature. The heat for the space is provided by perimeter radiation. The ventilation air is tempered by the internal heat loads in the building. The minimum air flow setting is low and is assumed to be equal to the minimum outside air required or 10% of the total system air flow rate.

VARIABLE AIR VOLUME WITH REHEAT

The VAV system with reheat (VAR) operates in a similar manner to the "pure" VAV system. It differs in that terminal dampers close only to a specified minimum position. Beyond this point a constant volume of air is provided to the zone.

To prevent over-cooling, terminal coils provide reheat as necessary to maintain each zone at the required setpoint temperature. The minimum airflow rate can now be higher.

WEATHER DATA

The weather sites chosen for the building simulations are considered representative of the various Canadian climate regions. The cities chosen are Vancouver, Calgary, Edmonton and Toronto. The long term, 30 year average for 1958-1987 was used in the HAP program. Hourly average dry bulb/wet bulb temperatures for each month were used.

It is recognized that the profile of the computer generated weather data is not exactly the same as the actual recorded conditions. Figure 1 below shows the two profiles for Calgary. Similarly, there are similar variances in the other centres.

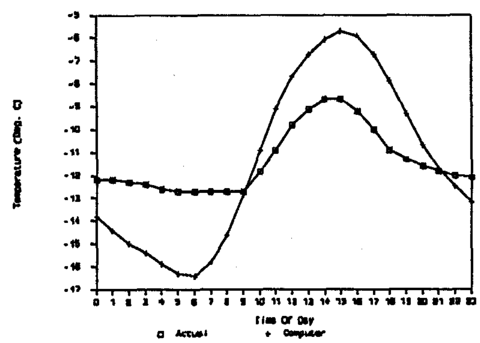

Figure 1
Calgary Weather

The use of the 30 year average temperature should eliminate, to a great extent, the errors normally found in computer generated average weather conditions.

HOURLY ANALYSIS PROGRAM (HAP)

The computer program used in the simulation is as the Carrier Corporation's, "Hourly Analysis Program".

There are basically two proven methods of analysis for Building Systems - These are:

1. Hourly Analysis
   In this program type the average temperature for each hour of the day on a monthly basis is used for analysis.

2. Modified Bin Temperature
   The number of hours per year that a given range of temperatures occur in a month are used in the analysis.

Both of these programs are used by the writers in their work. In this analysis the Hourly Analysis method was chosen for the following reasons:

1. The occupied and unoccupied times and the temperatures which occur during these times is critical to the analysis. The bin temperature method does not fully address this factor.

2. The weather office records the daily hourly temperatures which can be averaged for a month.

FUNDAMENTAL TERMS

A building is a complex thermal-mechanical system consisting of a large number of interacting components. The HAP program is divided and organized into six categories as shown in Figure 2. The arrangement signifies the order in which the building input occurs beginning with the elements and finishing with the building.

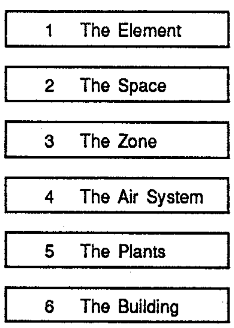

Figure 2
Hierarchy of Basic Components (Carrier 1986)

Each item is explained in detail in the following paragraphs.

1. **The Element** is the component of the building associated with heat gain or loss. These include such items as walls, windows, roofs, lighting, people and appliances. An element is described by its characteristics which affect heat transfer.

2. **The Space** is a region of the building comprised of one or more elements.

3. **The Zone** is a group of one or more spaces having a single thermostatic control. On its simplest level, a zone contains a single space with its own thermostat. It is common, however, for a group of spaces to be served by a single thermostat.

4. **The Air System** is the equipment and controls used to provide conditioned air to a region of a building. An air system serves one or more zones.

5. **Plants** are the equipment used to provide or extract heat through heat exchangers.

6. **The Building** is a structure containing one or more energy consuming systems. The building is the unit for which energy and operating cost totals are computed.

CALCULATION METHODS

Upon completion of building data inputs, each building system was simulated using the appropriate weather data. The ventilation rates were varied from 2.5 to 10.0 l/s/person in increments of 2.5 l/s/person.

PART 2: INTERPRETATION OF RESULTS

The immediate response to the idea of increased ventilation rates in building heating/cooling systems is that the heating and cooling costs will also increase. However, there are several factors which affect the outcome of such a statement. The factors which are dealt with in this section are building location, (hence weather), building mechanical systems and accessory devices, particularly economizer systems.

CALGARY

Calgary is known for its fluctuating weather conditions. (As was evident during the 1988 Calgary Winter Olympics). Results obtained for Calgary, however, are based on the long term average weather which negates extreme occurrences. For this reason, some results will not be indicative of these extreme occurrences.

PLANT ENERGY REQUIREMENTS-CALGARY

Results obtained using the HAP building simulation program represent the plants monthly and yearly cooling and heating energy requirements. Some interesting facts come to light when one studies the output from the computer runs. Tables 3 - 6 following show the energy requirements for the 8 systems in Calgary.

Table 3 Constant Volume Reheat

Flow Rate	Non-Integrated Economizer		Integrated Economizer	
l/s/person	Heating MWh	Cooling MWh	Heating MWh	Cooling MWh
2.5	2525	181	2525	58
5.0	2525	175	2525	58
7.5	2525	170	2525	58
10.0	2525	165	2525	58

Table 4 Multizone

Flow Rate	Non-Integrated Economizer		Integrated Economizer	
l/s/person	Heating MWh	Cooling MWh	Heating MWh	Cooling MWh
2.5	2127	127	2226	53
5.0	2127	122	2226	53
7.5	2127	119	2226	53
10.0	2127	116	2226	53

Table 5 Variable Air Volume

Flow Rate	Non-Integrated Economizer		Integrated Economizer	
l/s/person	Heating MWh	Cooling MWh	Heating MWh	Cooling MWh
2.5	741	143	741	54
5.0	741	135	741	54
7.5	748	128	748	54
10.0	755	122	755	54

Table 6 Variable Air Volume With Reheat

Flow Rate	Non-Integrated Economizer		Integrated Economizer	
l/s/person	Heating MWh	Cooling MWh	Heating MWh	Cooling MWh
2.5	779	143	776	54
5.0	779	135	776	54
7.5	787	128	784	54
10.0	794	122	790	54

CONSTANT VOLUME REHEAT

The CVR system with a non-integrated economizer shows a decrease in the cooling energy requirements when the minimum ventilation rates are increased. When the economizer set point of 13°C is exceeded, the increased ventilation reduces the cooling energy requirements.

In contrast, the CVR system with an integrated dry bulb economizer has cooling requirements which remain constant. In the case of Calgary's average weather, the highest dry bulb temperature never exceeds the return air temperature and therefore the minimum ventilation increase is not a factor.

The heating inputs for the CVR system with either economizer do not increase as the ventilation rate increases. The outside air required to cool the return air to 13°C is greater than 10 l/s/person; the heating cost remains constant.

MULTIZONE

The cooling plant inputs for the MZ system with a non-integrated economizer reacts in a similar manner as the CVR system in that the cooling energy requirements decrease as the ventilation rate increases.

The cooling plant inputs for the MZ system with an integrated economizer demonstrates the same relationship as the CVR system with integrated economizer.

For the MZ system with either economizer, the increased ventilation rate does not increase heating energy. As with the CVR system, the outside air requirements to maintain a 13 deg C mixed air temperature is always greater than each of the minimum ventilation rates.

VARIABLE AIR VOLUME

The cooling energy requirements for the VAV system with non-integrated economizer also follows the same logic as laid out for the CVR system. Above 13°C, the minimum ventilation rates reduce the cooling energy needs when the outside air is cooler than the return.

Comparatively, this same system with an integrated economizer has overall reduced cooling energy needs. However, like the constant volume systems, there is no increased cooling with an increase in the ventilation rates.

The heating requirements for the VAV system with non-integrated or integrated economizer do not follow the same pattern as the two constant volume systems. The variable volume system requires a much lower supply air volume to satisfy the building loads. As a result, the economizer operation, which requires a proportional amount of outside air to maintain the mixed air temperature, is overridden at certain minimum ventilation rates. For this reason, there are some heating requirement increases when the minimum ventilation rate increases in the months of December, January and February.

VARIABLE AIR VOLUME WITH REHEAT

Similarly, the VAV system with reheat requires relatively the same plant, cooling & heating energy inputs as the VAV system in both the integrated and non-integrated economizer cases.

The interpretations for the Calgary building are representative of what occurs in the other chosen sites at Edmonton, Toronto and Vancouver with some minor differences.

EDMONTON

The same explanations for Calgary's heating energy and cooling profiles also applies to Edmonton. The main difference is the total energy consumption. The weather profile is on the average, colder than Calgary.

TORONTO

In the case of Toronto, the total energy requirements are less but as a result of the extremely higher humidity conditions, the difference between the integrated economizer case and non-integrated economizer case is not as dramatic as in the drier prairie provinces.

VANCOUVER

Vancouver has an extremely mild climate and the energy requirements for both heating and cooling are less. Similarly in Toronto, the high humidity conditions also affect the two economizer cases.

PART 3: SUMMARY DISCUSSION

The results obtained by the computer simulations are only relevant to this hypothetical building. We believe that this is typical of many existing buildings. The relative energy consumption for this building and the climates examined indicate that with increased ventilation rates:

* The annual energy use for heating increases by up to 5.8%
* The annual energy use for cooling decreases by up to 14.2%
* The overall building energy drops by up to 2.1%

The cooling and heating consumptions are dependent on many factors. Some areas which have an effect on how ventilation air affects energy include:

1) Outside air damper leakage rates.
2) Building stack effect related to infiltration and exfiltration.
3) Building characteristics. ie. size, construction, etc.
4) Percentage glass.
5) Volume to surface area ratio.
6) Internal loads. ie. computers, photocopiers, etc.

Most systems are equipped with economizers and for a majority of the occupied hours, the building is requiring net cooling and the economizer is functioning. The conversion of non-integrated economizers to integrated economizers will affect overall energy saving. Therefore the cost of increasing the ventilation rate will be nullified in all systems. The quantity of air required to provide cooling is typically much beyond the minimum rates recommended. The minimum ventilation rates become a factor only at very extreme outside air temperatures. These extremes occur for a very few hours in a year.

Finally, most system designs typically incorporate a 10% minimum ventilation rates. For the majority of buildings, this translates into a ventilation rate which is often two to three times the present minimum recommended rate of 2.5 l/s/person.

The integrated economizer insures that we are bringing in additional outside air year around. This will provide the best possible indoor air quality.

For these reasons, the proposed changes to the ASHRAE standard 62-1981 "Ventilation for Acceptable Indoor Air Quality" is not going to significantly affect the energy consumed.