Excessive infiltration and ventilation air

An examination of six areas that need development

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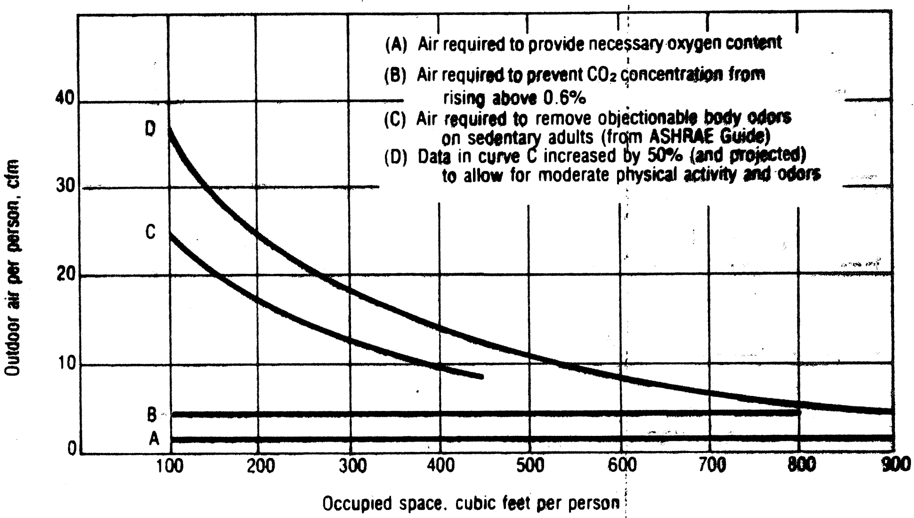

1 Ventilation requirements related to cubic feet of occupied space per person.

Discontinuing the practice of specifying and using excessive quantities of ventilation air could result in significant reductions in energy usage as well as in the first cost of heating and cooling systems. For example, each 1000 cfm reduction of outdoor air (in a 6000 degree-day area) represents a savings of about 3 tons in cooling equipment and 80 MBtuh in heating equipment. With a heat pump system, this could cause an annual operating cost reduction of approximately 30,000 KWH and an incremental equipment cost saving of about $2500. Comparable savings can be realized with fuel burning heating systems and motor driven cooling systems, depending on the type of system and seasonal operating efficiency.

Unfortunately, to take full advantage of such savings, several practices and procedures discussed in this article must have universal acceptance. It will be seen from the discussion to follow on each of the components listed that the suggestions are not new or revolutionary. In fact, they have been used quite successfully in a number of installations to obtain practical and economical systems.[1]

• *Standards for minimum ventilation requirements*–The unanswered question has been, and still is, what constitutes excessive ventilation air; or stating it another way, what are minimum ventilation requirements?

[1] *Superscript numerals refer to references at end of article.*

ASHRAE in the past has related ventilation air requirements for human occupancy in general office areas to the occupied space per person and to the activities to be assumed.[2] These outdoor air requirements, based on the minimum odor-free air required to remove objectionable body odors as shown in Fig. 1, Curve C, were established in 1936 under laboratory conditions for the heating season. These recommended quantities vary from 8 cfm per person when occupying a volume of 400 cu ft to 25 cfm per person with 100 cu ft of space. In connection with the cooling cycle, the *ASHRAE Guide and Data Book* also recommends outdoor ventilation air quantities of 15 cfm per person with a minimum of 10 cfm for general office area with some smoking. For private offices with no smoking, the values increase to 25 cfm per person, and with considerable smoking, to 30 cfm or 0.25 cfm per sq ft of floor area, whichever is greater.[3,4]

It is interesting to note that the above outdoor ventilation air requirements specified by ASHRAE are not governed by oxygen requirements or the carbon dioxide liberated, which for normal activities are about 1.3 and 3.7 cfm per person respectively; (Curves A and B, Fig. 1) but instead, they are governed by the odors rising from occupancy, living habits, and related factors. The idea being that reduction or control of these odors can generally be accomplished by the introduction of outdoor or purified air in sufficient quanitites to dilute the odor concentration to a nonobjectionable level.

The acceptable ventilation air quantities are listed in the latest ASHRAE *Standards for Natural and Mechanical Ventilation*.[5] The quantities specified for general office space and similar areas in commercial and institutional buildings are substantially the same as established in 1936 and used during the intervening years. The important difference is that the meaning of the term, ventilation air, has changed. It no longer refers exclusively to outdoor air. The latest recommended definition is "an outside (outdoor) air supply plus any recirculated air that has been treated to maintain the desired quality of air within a designated space."[6]

This new definition calls for a certain quality of air. This quality is regulated by means of a *Table of Maximum Allowable Contaminant Concentrations for Ventilation Air,* which has been established by the National Air Pollution Control Administration and made a part of the ASHRAE standards. This regulation permits reducing outdoor air quantity to 15 percent of the specified ventilation requirements. In no case, however, "shall the outdoor air quantity be less than 5 cfm per person."

• *Uniformity in federal statutes, local and state ordinances, and among consulting engineers*–The outdoor ventilation air requirements for air conditioning systems found in local codes and ordinances throughout the United States vary quite widely. They range from 10 cfm per person to 2 cfm per sq ft of floor area, depending on the city and geographic area under consideration and on the type of space involved. The code in one large Midwestern city, for example, specifies that 33⅓ percent of the total air circulation must be outdoor air.

In fact, a number of consulting engineers base their ventilation air requirements (when not particularly specified by codes or ordinances) on a certain percentage of the total air circulation. Such a quantity is justified in their opinion to assure proper dilution of the odors and at the same time furnish sufficient makeup air for the exhaust systems throughout the building. Needless to say, such high rates result in a considerable waste of energy.

The main difficulty facing the air conditioning industry is to get an agreement in all these local codes to permit the use of the minimum amount of ventilation air. Undoubtedly, the best way this can be accomplished expeditiously is by federal statute.

• *Basic system design and operation with minimum outdoor ventilation requirements*–Special consideration must be given to the air conditioning systems in order to effectively use the minimum outdoor ventilation quantities. Systems for the larger multistory commercial or institutional buildings, for example, frequently employ medium or high pressure induction units, using 100 percent outdoor primary air. Such designs may result in ventilation quantities in excess of the minimum required for health and safety with a corresponding increase in energy consumption.

There are several other designs that are more suitable for lower ventilation rates when energy conservation is a prime consideration. One possibility is to use recirculation air instead of outdoor primary air with the induction units. Other possibilities are to use fan-coil units or self-contained conditioners as terminal units.

The selection of the outdoor ventilation air quantities and the design of the air conditioning unit will in turn affect the design of the exhaust system. For the 100 percent outdoor primary air induction units, an equal portion of the recirculated air (to compensate for the outdoor ventilation air) must be exhausted from the building usually through hallways, kitchen, lavatories, etc. For other air conditioning designs, the ventilation air and exhaust systems, for other than the office and other occupied areas, can be grouped together and operated independently of the main system.

It is frequently feasible in such designs to deliver the air directly from outdoors to the space involved. For example, in the case of kitchens or chemical laboratories and the like, vented hoods mounted directly over heat and odor producing equipment can be a practical solution. The hoods can often contain both the unheated supply air and exhaust air circuits. An acceptable hood design must have an effective method for entraining and exhausting the pollutents from localized areas with a minimum consumption of room air. Careless and over libreal designs of hoods will result in excessive ventilation quantities with corresponding high initial and operating costs.

These air conditioning designs are applicable and practical for new buildings still in the planning stage. Similar adjustments, revisions, and alterations, however, can be made to numerous systems in existing buildings to materially reduce the ventilation air rate. In these cases, it is not usually practical to replace the air conditioning units, but major changes can often be made in the distribution system.

In connection with the ventilation air systems, a factor always present is the difficulty of checking to see if the design quantities are being used in the day-to-day operation. It is possible for the manager or operating engineer to adjust the ventilation air controls and dampers to give quantities below that specified, or on the other hand, it could be considerably in excess of the specifications and not discovered because of the safety factor generally used in sizing equipment. This applies particularly to existing installations and to systems that have been altered and/or modified. Until positive procedures are developed and followed to determine the ventilation air actually being used, the estimated energy saving on a national basis can be very misleading.

• *Purification equipment has attractive possibilities*–Actually, the direct use of even minimum quantities of outdoor air may be unacceptable because of the objectionable, irritable, and toxic odors and other pollutents caused by a high percentage of hydrogen sulphide, smog, and other chemical effluents from industrial processes and other such chemical byproducts often found in the atmosphere.

It is because of this possibility that use of physical or chemical odor removing equipment has such an appeal. It has been found for instance, that an absorbing material such as activated charcoal together with an efficient mechanical air filter or electronic filter is quite effective in removing tobacco smoke and other such odor causing substances as well as particulates. Using such units along with a minimum amount of outdoor air in a year 'round system (to satisfy the oxygen and carbon dioxide requirements) can be very practical and will frequently show an attractive saving in both the first and operating costs over a system striving for dilution of the odors by using larger quantities of outdoor air.

• *Residential applications require different considerations*–The discussion so far has been concerned primarily with commercial and institutional buildings. Heating and cooling systems for residences and other such dwelling units do not as a rule provide for the introduction of a predetermined amount of ventilation air into occupied space. Outdoor air infiltration through cracks and openings is usually considered more than sufficient to satisfy the health and safety living requirements of a normal household. In fact, the problem has usually been to reduce the leakage to an acceptable level.

The instantaneous infiltration can vary with the type of construction, the design of the windows, the wind velocity, occupancy, type of heating system, number of appliances being used, and with the operation of the kitchen and bathroom exhaust fans as well as the clothes dryer. It was found that the infiltration measurements in two research houses varied from 0.12 to 1.34 air changes per hour, depending on the operating conditions.[7]

In electric heated residences with full insulation, double windows and doors, which are considered criteria of tight construction, an average value of ½ to ¾ air changes per hour is often assumed for design conditions. In fossil fuel systems, the amount can be much greater because air for combustion and flue drafts exhausts are involved.

Numerous field tests have been made to measure the infiltration to verify the above conculsions. As a consequence, the same practices used in the early thirties are still being followed in arriving at a quantity of outdoor air for heat loss and heat gain calculations.

Table 1—Items needed to realize energy reductions by using minimum ventilation air quantities.

- Standards for different operating conditions that are based on authentic data and recommended minimum ventilation air quantities to satisfy all safety and health requirements.
- Uniformity in federal statutes and local and state ordinance.
- Fundamental system designs based on sound engineering principles to take full advantage of the recommended requirements.
- Acceptable procedure for using purfication equipment.
- Residential installations need recommended infiltration rates.
- Research and development to obtain factual data that can serve as a guide for establishing minimum ventilation rates for health and safety of the occupants.

The latest ASHRAE standards[8] for single unit dwellings recommend 7 to 10 cfm per human occupant with 200 sq ft of floor area. This is equivalent to about ½ air change per hour. Until now, infiltration has not been considered a major contributing factor. With national attention being directed to energy conservation, however, additional efforts must be made to obtain more realistic values.

• *Research and development necessary*–Additional research is needed to establish factual minimum quanitites of outdoor ventilation air for the health and safety of the occupants under various operating conditions for both residential and commercial applications. Such action is mandatory to obtain full agreement by the existing local codes and ordinances throughout the country. Many of these standards have been in existence for 35 years or more, and revisions will be slow in coming without substantiation of the recommendations, even though the energy conservation may be considerable.

A recent advancement in this direction is the establishment of Quality Standards of Ventilation Air.[9] This permits filter equipment and efficient adsorption or other odor and gas removal equipment to be employed to purify the air. Thus the ventilation air can consist mostly of recirculated air with only a relatively small portion of outdoor air required to supply oxygen requirements and take care of the liberated carbon dioxide. In fact, purification of recirculation air as a substitute for outdoor air offers a most promising means of energy conservation. Exploration and development of various equipment designs and procedures are needed to obtain the required air quality and at the same time realize a practical means of obtaining maximum energy conservation during both the heating and cooling cycles.

Air purification systems are applicable in both existing and new buildings. Actually, an attractive potential for immediate energy reduction is realizable in existing commercial and industrial buildings.

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