United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory
Research Triangle Park, NC 27711

Research and Development

EPA/600/SR-92/125 December 1992

EPA

Project Summary

HVAC Systems in the Current Stock of U.S. K-12 Schools

Jerald D. Parker

This report summarizes information on the types of heating, ventilating, and air-conditioning (HVAC) systems commonly found in U. S. school buildings and the effect that the operation of these systems has on indoor radon levels. The report describes the ability of various HVAC systems to pressurize and ventilate classroom spaces, how they operate, and how they are controlled. Some information is given to compare systems as to energy usage, cost, and their ability to maintain stable levels of static pressure in classrooms and/or to adequately ventilate the spaces.

Previous studies of school buildings have shown that radon levels can be reduced by depressurization and ventilation of soil under slabs, but this method is not readily applicable to all such buildings. The HVAC systems have also been shown to have an impact on radon levels through pressurization and ventilation of classroom spaces.

Not all HVAC systems can provide pressurization since some have no provision for the makeup air to replace the exfiltration losses always created by positive room pressure. The level of pressure attainable in a space depends upon fan characteristics, duct design, room leakiness, and the method of control of fans and dampers. Return fans and relief dampers play an important role in some systems, and exhaust fans always work against maintaining positive room pressures.

There appear to be no well defined trends in the types of HVAC systems involved in current school building construction and modification. Some systems using reheat and/or mixing have been prohibited or their use discouraged by local codes and regulations because they waste energy. Capital costs appear to vary more with locale and quality of construction than with the type of system installed.

The unit ventilator (UV) has been the most popular system in U.S. schools but its noise and operating limitations have reduced its popularity in recent years relative to central systems. UVs can provide limited pressurization and dilution through outdoor air intake but the fan must be operating for it to be effective.

The two-fan, dual-duct variable air volume (VAV) system appears to be an excellent choice for relatively low operating costs in future construction and should be capable of pressurization and ventilation. All HVAC systems will have significantly increased utility costs if they are operated long hours during unoccupied periods and/or if they are modified to maintain higher static pressure levels in classrooms. This is particularly true for U.S. school buildings, many of which are not tightly constructed (i.e., they have high passive rates of outdoor air exchange through the building envelope).

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The U.S. Environmental Protection Agency (EPA) has studied ways to reduce radon levels in schools since 1987. Some of these studies are described in the proceedings of the 1991 International Symposium on Radon and Radon Reduction Technology. Radon mitigation research to date has emphasized reduction of radon levels through the use of active subslab depressurization (ASD). Although ASD has proved successful in a number of schools, it is not applicable in all school buildings. As a result, reduction of radon levels with HVAC systems needs to be investigated as an alternative approach to radon mitigation, particularly in schools alternative approach to radon mitigation, particularly in schools with moderately elevated radon levels (4 to 20 pCi/L). One recent study concludes that one of the most significant factors contributing to elevated levels of radon in schools and influencing the mitigation approach is the design and operation of the HVAC system, and that complexities of large building HVAC systems, present problems not previously encountered in house mitigation.

A report on an EPA school evaluation program (SEP), involving site studies in 26 schools in 8 regions in the U.S., states that an HVAC system approach was the preferred radon reduction technique over soil depressurization in 23 of the 26 schools evaluated. The reason given was that many of the schools did not meet current standards for school ventilation, and that radon levels were low enough that meeting ventilation standards would likely solve the radon problem. A wide variety of ventilation systems were found in the SEP schools, and many of these systems were not designed or operated properly.

Researchers at EPA desired to better understand the various types of HVAC systems that exist in kindergarten through twelfth grade (K-12) schools throughout the U. S. This report fills the need for a reference document that identifies the various HVAC systems that one should expect to find in U. S. schools, the ability of these systems to pressurize and ventilate, strategies used to control pressurization and ventilation, and modifications (and their effects on pressurization and ventilation control) that might have been made by owners to conserve energy.

HVAC System Prevalence/ Characteristics

Data regarding types and numbers of HVAC systems presently installed in U. S. schools was not readily available. Data from a 1979 report give the distribution of U. S. school building heating and air-conditioning (HAC) systems. These data are described and shown graphically in the full report. Most of the school buildings described by the data are likely still in use, some with modifications to their HVAC systems. Recent construction probably has led to trends different from those of the 1979 study.

Calls and inquiries to school administrators and staff and to consulting engineers revealed no newer quantitative data but did show clearly that a very wide variety of HVAC systems are in use in U. S. schools. While most school systems operate within guidelines of state and federal regulation, they are generally free to select their own architects and engineers and the designs and policies followed in building construction are locally controlled. The types of systems might depend more upon age, size of plant, and local economics and wage scales that upon geography or even climate, although cooling systems do appear to be more common in the warmer southern states than in states with cooler or milder summers. They are also more common in schools used year-round.

Air conditioning (cooling) very often has more elaborate ventilation and control systems than where only heating is utilized. Some types of heating systems, such as radiant systems, have no controlled ventilation as part of the system and depend entirely upon radiation or free convection to transfer heat to the controlled space and depend on infiltration for ventilation.

School boards and administrators are becoming more concerned with indoor air quality problems and hopefully will benefit from the current attention being given to environmentally sound design. There is a boom in construction and refurbishing of schools in many parts of the country, with the national level being its highest since the 1950s. The estimate of the F. W. Dodge Group of McGraw-Hill for 1990 is that elementary and high school construction spending is at an all-time high of $10.7 billion and is expected to continue at near this level throughout the decade.

A very large part of the current construction projects involve overhauls of existing buildings, most of which were built during the 1950s and 1960s and which generally were of low-cost construction. Many school buildings have undergone modification, some with only quick fixes attempting to reduce energy consumption. Many school buildings have HVAC systems that need significant repairs. Thus it is a good time to be promoting good design for improvement of indoor air quality.

Regarding future trends, the requirements of local building codes will be strongly influenced by ASHRAE Standard 90.1-1989, *Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings*, and ASHRAE Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*. These standards and the desire of school boards to have both low initial and operating costs in their buildings will probably cause certain types of systems (e.g., reheat and dual-duct, constant flow) to no longer be built. No single type of system seems to be the obvious best choice for all schools. The following is from the 1991 Applications Handbook:

"No trends in educational facility design as related to heating, ventilating, and air-conditioning systems are evident. In smaller single-building facilities, centralized systems are often applied. These systems include unit ventilator, rooftop and single and multizone-type units. Central station equipment, especially variable volume systems, continues to have wide application in larger facilities; water-to-air heat pumps have also been used."

The single most significant factor considered in this study is the air distribution system of a school building and whether that system has provision for outdoor air. Schools which have no air distribution systems, for example ones with only radiant heating or schools with exhaust only ventilation, cannot (without modification) pressurize the space for reduction of radon levels. Modification for radon abatement would require the addition of an air distribution system, properly designed to be compatible with the existing comfort system or to totally replace it.

Some existing school HVAC systems have air circulation but no controlled provision for outdoor air. Some systems with outdoor air have been modified to minimize (or eliminate) outdoor air to save on energy costs, and in some systems outdoor air dampers no longer operate properly due to poor maintenance. Every one of the 26 schools in the EPA SEP study was reported to have at least one ventilation problem.

Pressurization of a building occurs when the amount of outdoor air introduced into the building exceeds the amount of air removed by exhaust systems. The excess air (air not exhausted by fans) is forced out of the building through leaks in the building shell (e.g., floor cracks, around windows and exterior doors). This leakage of air from inside the building to the outdoors is referred to as exfiltration. Air exfiltration always occurs under a positive pressure condition. Therefore any system without controlled outdoor air must be

modified to provide that feature if room pressurization is to be ensured. It should be obvious that dilution of room air by ventilation cannot occur without the intake of outdoor air. Room pressurization is always accompanied by some dilution due to the required introduction of outdoor air.

After a brief introduction of pertinent HVAC terms, the full report describes the basic central air system and uses it as the basis for comments on the different types of systems existing in schools.

*U.S. Government Printing Office: 1993 — 750-071/60173

J.D. Parker is with Oklahoma Christian University, Oklahoma City, OK 73136.
Timothy M. Dyess is the EPA Project Officer (see below).
The complete report, entitled "HVAC Systems in the Current Stock of U.S. K-12 Schools," (Order No. PB92-218338/AS; Cost: $19.50 subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Official Business
Penalty for Private Use $300

EPA/600/SR-92/125

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35