Contains a selected and annotated listing of source material concerning the thermal environment in school facilities. It is directed toward the school planner, architect, or administrator concerned with developing a more functional classroom environment. Topical coverage includes—(1) The Thermal Environment and Learning, (2) Physiological Factors in the Thermal Environment, (3) Heating-Ventilating and Air-Conditioning in the Classroom, and (4) Additional Considerations in Planning and Thermal Environment. (Author)
THERMAL ENVIRONMENT IN SCHOOL FACILITIES

A selected and annotated bibliography

Prepared by
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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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INTRODUCTION

Information contained in this selected bibliography concerning the Thermal Environment was annotated on the basis of accessibility of current material. Citations were selected on the basis of pertinence of information to the school environment, current publishing dates, quality of information and manner of presentation.

All documents were selected with the following point of view: "Will this source provide useful information to the school administration, architect, or planner concerned with developing a more functional classroom environment, physiologically more suited to student metabolisms and psychologically more comfortable to enhance learning efficiency."
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AVAILABILITY

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SECTION

1

THE THERMAL ENVIRONMENT AND LEARNING--

PHYSIOLOGICAL FACTORS AND THE CLASSROOM

Covers various physiological factors planners must consider in establishing optimum thermal environments for learning. Includes discussion of ideal air and body temperatures for various classroom activities.

Healthful, comfortable conditions in the school require more than maintenance of the proper temperature. Another factor is being recognized increasingly as vital to good health and comfort in the school -- relative humidity.


A listing of factors includes: (1) educational needs, (2) physiological needs, (3) special needs, (4) conditions of air for prevention of disease, (5) heating and ventilating systems, and (6) fuels.


The comfort of children depends not only upon the temperature and the air circulation, but also upon the relative humidity. High humidity of the atmosphere prevents the human body from ridding itself of heat through perspiration, and the individual feels uncomfortable. Low humidity has the opposite affect.


Characteristics of the human organism in general and the learning child in particular indicate three factors that must be taken into account in the design of the thermal environment in classrooms: (1) the child is different from the adult, (2) thermally induced stresses can alter the growth, development, and learning of children, (3) the child's problem-solving capacity is affected by the effective temperature of his classroom.


Discusses several areas of concern for those involved in designing the thermal environment: (1) the maturing child requires a different set of thermal standards than the
mature adult, (2) there must be an increased concern for controlling the thermal environment in all of its aspects (temperature, air movement, and humidity), and (3) rigid control of all thermal factors of the classroom in order to maintain internal body temperature levels consistent with various activities during the course of the day. Includes a bibliography.


Directed to school administrators, engineers, and architects concerning three phases of the thermal environment in schools: (1) a description of the human body as a heat machine, with emphasis on the thermal and physiological factors which result in different optimal conditions for various types of work, (2) an analysis of the environmental thermal factors, and (3) a description of special hygiene problems in the thermal environment.


This report serves two purposes: (1) it summarizes research done at the Iowa Center for Research, and (2) points out that as a minimum, school buildings should be equipped with the best ventilation equipment possible. Heating is not the major problem - ventilation is. A good thermal environment is as important as a good aesthetic environment.


Two points are discussed: (1) in controlling the thermal environment, body radiation of the occupants must be considered, and (2) teacher training programs should be initiated on the educational value of temperature control.


Describes research project investigating the effect of the thermal environment on learning between a group of elementary students in a model thermal environment and marginal thermal environment. Students in the optimum thermal environment performed generally at a higher level than those in the typical thermal environment.


Thermal comfort is not a luxury. It is a physical and mental requirement for effective use of a classroom. School discomfort means inattention, restlessness, poor behavior habits, and a minimum of ability to maintain sustained attention to any mental task. Emphasizes the need for air conditioning in today's schools.


Includes discussion of air temperature and body temperature for optimum comfort during task performance. Also discusses physiology of body temperature, humidity control, and ventilation. A final section describes mechanical systems available to the school architect.


Two similar classrooms were set up in the Lennox Living Laboratory, Des Moines, Iowa, one for experimental groups and one for control groups. Temperature, air circulation
and humidity can be controlled and measured in both rooms. The rooms are of similar size, layout and construction, the thermal environment being the only variable. The following questions were studied in this experimental schoolhouse: (1) is there a difference between boys' and girls' reported comfort? (2) is there a difference between boys' and girls' reported feelings of comfort in the same environment? (3) what is the effect of temperature and humidity on reported student comfort? (4) what is the actual operating time of the heating, cooling, and ventilating equipment when maintaining the ideal thermal environment? Results are given to these four questions.


Cooling rather than heating is the primary problem in all classrooms. Discusses: (1) the body as a heat producing machine, (2) oxygen requirements, and (3) excessive temperatures.


Reports on Lennox Research School studies on the thermal environment and learning. Compares learning, efficiency in good and poor thermal environments.


Includes: (1) influence of temperature of environment, (2) individuality in temperature, (3) physiological factors in temperature individuality, (4) pathological factors in temperatures, (5) hereditary factor in the rheumatism of children, (6) relations of height, weight, and age to temperature, (7) comparison of elementary school data with data obtained from upper middle class schools and older children, (8) comparison of absolute temperatures at each age in the public elementary schools and in middle class schools, (9) comparison of variabilities in temperature in the two types of schools.
PHYSIOLOGICAL FACTORS IN THE THERMAL ENVIRONMENT

Includes general physiological reactions to the thermal environment. Much work has been done in this area, however, most studies are limited in scope and few are directly related to the school environment. Citations in this section are included for their value as research documents and should provide additional clues to those interested in a more complete understanding of the thermal environment.

Discusses several areas of concern, including human physiological processes associated with the thermal environment and the effect these physiological adjustments may have on various human activities, specifically on work and mental task performance, on the learning process, and on human comfort.


Discusses: (1) wall temperatures and body radiation, (2) accuracy of skin temperature measurements, and (3) transmission of radiation through the skin.


Statistical comparison of comfort indices and actual comfort.


Survey and general review of existing literature. Contains 380 bibliographical entries. Comprehensive source for anyone interested in man and his environment. This is not only limited to the thermal environment.


A study of the perceptions of comfort and thermal change and corresponding physiologic adaptations.


   A study of optimal room temperatures as perceived by Japanese workers engaged in different tasks.


   A method for studying and determining optimum thermal environments in steady state situations.


   Best on man's thermal heat budget, including equations.


16. Texas Engineering Experiment Station. *Some General Considerations in the Natural Ventilation of Buildings.* College Station, Texas: The Texas A & M College System.

SECTION

3

HEATING-VENTILATING AND AIR-CONDITIONING
IN THE CLASSROOM

Discusses important heating, ventilating and air-conditioning factors in providing a healthy, clean and economical thermal environment for schools. Majority of sources indicate that air-conditioning is more important than heating and should be considered a necessity not a luxury.

*Progressive Architecture* devotes the entire issue to problems of air conditioning in architecture.


Emphasizes the role air conditioning plays in providing an ideal thermal environment for the classroom. Advantages include: (1) greater student enrollment in air conditioned schools, (2) higher degree of work output, (3) faculty and student body are more comfortable, and (4) maintenance costs are satisfactory.


In planning ahead for a twelve month school year, the school board for this rural high school adopted the architect's suggestion that the building be designed with air conditioning from the outset.


Presents several examples of air conditioned schools and architects discuss advantages and limitations of various mechanical systems.


Electric cable heats floor slabs in Chicago kindergartens. Slab surface is kept at 72 degrees by control device measuring slab temperature. Timer programs operating hours.


Describes first fully air conditioned school to be built in Missouri.

Architects fit air conditioning into the school construction budget by avoiding expensive perimeter walls.


Air in a classroom must be controlled for temperature, distribution, motion, cleanliness, humidity, purity, and odor. Authors discuss advantages and limitations of unit ventilation systems, central air systems, and radiant heating.


Classifies ten types of heating systems common to schools and sets forth each system's advantages and limitations. Each system is rated for installation and maintenance. Engineers provide editorial remarks for each system.


Describes air conditioning details for a 319,000 square foot high school in Mount Vernon, New York.


Compares two schools, one equipped with air conditioning and one without, in terms of cost maintenance and depreciation, educational outcomes, and incidence of physical illnesses and psychological problems among students. Two junior high schools were employed in the study, each meeting similar standards of area, enrollment, and cost of construction. They are located in Pinellas County, Florida. Preliminary findings are reported.

Comparison between two new schools in Florida; one air conditioned, the other non-air conditioned. Schools are evaluated for attendance, increased use of facilities by communities, and educational effectiveness. Results are not given.


Discusses optimum school building climate conditions. Points out that an uncomfortable thermal environment may be fatiguing and distracting to the student; therefore, maintenance of proper thermal environment is an important factor in making most productive use of teachers' time. Specifications are given.


Describes five basic types of mechanical systems and presents a criteria for selecting the appropriate system for your school's needs.


Presents a brief review of thermal environment research as well as a summary of various types of heating and ventilating systems for various school environments.


Discusses: (1) heating and ventilating objectives, (2) the heating system, (3) methods of ventilation, and (4) sanitary facilities in relation to school planning.

Discusses various planning considerations in creating a healthful school environment; includes discussion of heating and ventilation factors.


Discusses the flexibility and heating-cooling system must have in order to meet the changing needs of a typical classroom day.


Reports on a seminar held by the Better Heating and Cooling Council dealing with the thermal environment. Various architects and engineers give their candid views on some practical approaches to provide schools with better thermal environments.


General characteristics of common types of air conditioning systems are described. A brief discussion of factors to consider when choosing a particular system is provided.


The design of heating and ventilating plants for school buildings must be adapted to the building construction characteristics developed by the architects.


New 1,200 pupil Kimberly, Wisconsin High School utilizes a heat pump system to retrieve heat generated within the building by fluorescent lamps and occupants. In this way the school heats itself.

Air conditioning is considered to be the most critical factor in providing an optimum thermal environment for learning.


"Recent research revealing that the ventilation rate in a school may be reduced and consequently become more economical."


"An environmental control design in which the lighting provides more than enough heat energy for a building under critical outdoor winter temperatures is discussed."


"A comparative analysis of two questionnaires concerning the acceptance of air conditioning in public schools is discussed."


Author of this article states the case for air conditioned schools. Three factors are mentioned: (1) comfort standards demand air conditioning, (2) saving construction costs in many new buildings, (3) offer interesting architectural possibilities.


Thermal environment pages 175-190. Discusses various factors concerning the thermal environment in school planning, including: (1) when to heat and when to cool the classroom, (2) selecting the right type of fuel, (3) selecting the type of system, (4) checklist of
advantages and disadvantages of various types of heating-cooling systems, (5) air movement, and (6) air conditioning.


Deals with heating, cooling, and ventilation of the classroom as related to students' learning abilities. It is designed to assist school boards, administrators, architects, and engineers in understanding the beneficial effects of total climate control, and in evaluating the climate conditioning systems available to schools. Discussion includes: (1) the physiology of comfort, (2) comfort design; (3) climate control engineering, (4) climate control systems, and (5) the total electric concept.


Discusses the following factors: (1) optimum room temperature for various tasks, (2) air movement required for comfort, (3) heating and ventilating systems, (4) air conditioning should be considered if economically possible.


Includes discussion of: (1) results of Lennox "living laboratory" research on thermal environment and learning, (2) ventilation needs and benefits, (3) air conditioning as related to location and school design, and (4) future projections.


This thesis gives complete calculations, design, and specification of the heating, ventilating, and air conditioning system for a typical classroom in Madison, Wisconsin.


Discusses the following: (1) supply, (2) cost, (3) advantages, (4) efficiency, and (5) the "year-round" concept of gas. In conclusion, selection of heating and cooling systems and fuel to power it will affect the economy and budget of the school district for years to come. One must investigate claims closely, know all costs, study regulations, and check comparisons.


Briefly reviews research related to thermal environment and human comfort. Air conditioned environments increase work output and cut absenteeism.


May issue of *Nation's Schools* devotes 25 pages to various aspects concerning the thermal environment in school facilities.


Includes: (1) effect of conditions of the air on mental work, the condition being changed daily, (2) effect of
conditions of the air upon the rate of improvement of mental function, (3) effect of conditions of the air upon the accuracy of judgment, (4) effect of certain conditions of the air upon the choice of alternatives to mental work, and (5) summary and interpretations.


Describes an air conditioning system to meet the various needs of a school building. Discusses: (1) factors affecting design, (2) ventilation requirements, (3) heat gain calculations, (4) plant calculations, and (5) heat load calculations.


School planners may choose from four patterns of heating and ventilation: (1) a system combining heating and ventilating and cooling in the same ducts, (2) a unit ventilator system, using heating and ventilating and cooling units in one space, (3) a straight radiant panel system, and (4) radiant heating.


Presents design requirements for installation of an air conditioning system for the Engineering Building on the University of Wisconsin campus. Includes specifications and calculations.


A 1960 census revealed that 913 schools and college buildings were partially or completely air conditioned, substantially more new buildings were air conditioned in
1961. One major manufacturer reports that schools are its fifth largest market for large central air conditioning equipment, ranking ahead of department stores and apartment buildings. Author investigates motivations for increase in air conditioned schools.


Does air conditioning really improve the learning process is the question being answered by a definitive project of the Pinellas County, Florida, schools with two identical schools, one with and one without air conditioning. Progress report is given.


A number of factors, including economics and a demand for better environmental control, are tending to produce compactness in many new schools, with air conditioning its natural concomitant.


Twenty notable architects and educators discuss the pro's and con's of air conditioned schools. Topics covered include: (1) windowless classrooms, (2) interior courts, (3) changing educational requirements, and (4) flexibility.


Emphasizes the need for architect and school administrators to place the same value of concern on the thermal environment as has been placed on the lighting and sonic environments. Discusses many aspects of the thermal environment, including: (1) healthful aspects, (2) artificial vs. natural conditions, (3) heat gain and loss, (4) classroom ventilation, (5) fuel savings, (6) ideal thermal environment, and (7) economic factors.

There should be an integral relationship between engineering aspects of school construction and school architecture - a relationship in which the architectural approach should not only influence engineering but the engineering approach should also influence architecture at the design stage. A prime example of this process working itself out in practice is the advent of air conditioning in school facilities.


Discusses several aspects of thermal comfort controls designed and tested at Washburn Elementary School, Auburn, Maine, including: (1) air distribution, (2) night-time heating, (3) cooling, (4) solar heat gain, (5) dew-point controller, (6) skyshine, and (7) aluminum coated curtains.


"Basic to planning a coordinated mechanical air system is the relationship between window area and air change. Four factors must be considered in the design of classroom windows: (1) light, (2) heat, (3) air, and (4) aesthetics."
SECTION 4

ADDITIONAL CONSIDERATIONS IN PLANNING THE THERMAL ENVIRONMENT

Includes sources dealing with architectural orientation, solar screening devices, landscaping the site and the need for planning coordination.

Topics discussed: (1) solar energy data applicable to building design, (2) thermal effects of solar radiation on man, (3) solar effects on architecture, (4) solar effects on building costs, (5) solar shading and glass selection to reduce cooling demand, (6) design of windows, (7) designs of skylights, (8) design of electric illumination, (9) design of windows in Europe, and (10) design of windows in Sweden.


Architects use a ceramic block sunscreen to control the natural thermal environment. Overhangs and exterior plant materials are also used as a design element to control heat gains from the sun.


Discusses the role architectural orientation of school building to site plays in controlling the thermal environment. Architectural decisions made before the mechanical engineer goes to work may have a substantial bearing on whether a building will be comfortable at all, in either winter or summer.


Explains the operation and advantages of hydronic heating systems. This system is designed to do more than heat the air; it also automatically controls heat flow, as well as eliminate "hot spots," drafts, and undesirable or unwanted odors.

5. "Educational Planning Comes First," Nation's Schools, 63 (May, 1959), 94.

In planning a good thermal environment for a school, the architect and mechanical engineer must first know the needs of the school's educational program. What is the probable
length of the school year? What is the summer school registration, and what is the school's basic curriculum?


School board members should review and select temperature control systems by the following criteria: (1) comfort, (2) flexibility, (3) simplicity, and (4) economy.


Discusses various types of building materials and their value as insulators. Deals primarily with roof design and insulation.


Devotes entire issue to problems of thermal environmental control.


School administrators and architects should consider factors of microclimatology when selecting sites and building orientation. Emphasis is placed on the role landscaping can play in controlling the thermal environment as well as in beautifying the site.


Discusses heat and radiation transmission for glass and solid walls with respect to angles of incidence, orientation and various shading conditions. Performance of shading systems was measured and expressed by shading coefficients. Diagram showing shading coefficients was
then used to record the effects of various shading systems due to color, location, design, and materials.


Reviews and comments on school planning research found in current literature. Emphasizes the need for thorough planning in school design. Includes comprehensive bibliography on various aspects of school planning, including the thermal environment.