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ABSTRACT

This review surveys documents and journal articles previously announced in RIE and CIJE that deal with climate control, integrated thermal and luminous systems, total energy systems, and current trends in school air conditioning. The literature cited indicates that selection of thermal systems must take into account longterm operating costs in addition to relative costs of available fuels. The review also notes that because of the national energy crisis, educators must examine the energy efficiency of each proposed system. A supplemental bibliography gives additional references, many of which are technically oriented and may be of more interest to the architect and the school engineer than to the administrator. Ten of the documents reviewed are available from the ERIC Document Reproduction Service. (Author)

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Thermal Environments

Alan M. Baas

> Evening classes, multifunction buildings, year-round air conditioning, the increased use of electronic teaching aids all add up to one indispensable fact: the energy requirements—for light and power, heating and cooling—of the modern educational institution are as different from those of the pre-1950 school as a programed teaching machine is from a McGuffey reader.
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> *Educational Facilities Laboratories (1967)*

Selection of heating and cooling systems for school facilities has traditionally been made in terms of the relative costs of available fuels—natural gas, oil, or electricity. Recently, school planners began considering the long-term operating costs required by different thermal systems. Today's technology makes available numerous systems capable of total and all-season climate control and flexible enough to meet the needs of the changing learning environment.

Integrated thermal and luminous systems permit design of compact schools that are cost-effective, especially in urban areas where land prices are rising rapidly. Many integrated systems employ sophisticated heat-recovery and transfer techniques to reclaim the "waste heat" generated by equipment, lights, and even the building inhabitants. Further economies are possible through use of "total energy" systems that provide on-site generation of a school's power needs.

Because of the national energy crisis, educators must not only examine the fuel and operating costs of climate control and power equipment, but they must also thoroughly evaluate the *energy efficiency* of the prospective system. One of the first direct statements about this new concern appears in an *American School & University* article by H. Harry Phipps (1973). The energy demands of the school plant will rise sharply as more schools are air-conditioned and made available for year-round instructional programs and extensive community use. He gives startling statistics about future energy costs for school buildings and urges educators—for both economic and ecological reasons—to perform a thorough energy systems analysis on each proposed facility:

> While the selection and design of more efficient systems is strictly an engineering function, the wholehearted support of school board members and members of the staff must be forthcoming to achieve the ultimate objectives. If you have not made an issue of the efficiency of energy systems to your architect and engineer, you cannot expect them to start the crusade on their own.

The literature in this review offers useful information about climate control, integrated thermal and luminous systems, total energy systems, and current trends in school air conditioning. A supplemental bibliography lists additional references, many of which are technically oriented and may be of more interest to the architect and school engineer than to the administrator.

Of the documents reviewed, ten are available through the ERIC Document Reproduction Service. Complete instructions for ordering are given at the end of the review.

CLIMATE CONTROL

An early publication by Harmon (1953) discusses organizing basic principles of environmental control to ensure efficient and successful student performance. In considering the nature of the human organism, how it regulates and maintains its body temperature, as well as those changes that occur under various forms of activity, three factors are relevant to classroom thermal design:

- The developing child differs from the adult and needs a different set of standards for controlling his thermal environment in the school.
- Thermally induced stress can alter the growth, development, and learning of children.
- The child's problem-solving capacity is affected by the effective temperature of his classroom.

To meet the thermal needs of school children, Harmon urges that classroom design combine knowledge of the control of heat, air movement, and humidity with knowledge of light, sound, structural materials, and teaching spaces.

An American Electric Power System ([1968]) report relates the effects of environment to basic elements in personal comfort and to the teaching-learning process. The role of climate and space conditioning in terms of sensory factors affecting the learning process influences guidelines for facilities design. A technical supplement to this publication (Perkins and Will, Architects [1968]) explains the beneficial effects of total climate control and helps administrators and architects evaluate climate conditioning systems available for schools. The supplement also examines physiological and design aspects of comfort, climate control systems and engineering, and the total electric concept.

Lane (n.d.) summarizes research on school thermal environments and reports on thermal research conducted at the Iowa Center for Research in School Administration. Results indicate that children do learn better under model thermal conditions. Teachers, accordingly, must become more aware of the thermal environment in their classrooms. Administrators, boards of education, and architects should pay careful attention to good thermal conditions in planning renovation or new construction. Research also suggests that large expanses of glass make it difficult to control the thermal environment.

A document published by the Ontario Department of Education (1971) describes various climate control systems and components, pointing out factors to be considered in selecting mechanical equipment. Introductory remarks relate the concept of thermal equilibrium to human metabolism and describe the interrelationships among human activity, thermal environment, and equipment costs. Charts and figures illustrate the publication's treatment of basic principles of ventilation and heat gain and loss.

Rutgers (1967) emphasizes the importance of integrating thermal components in the total design of a school facility. His discussion of the role a good thermal environment plays in the education process concentrates on specific thermal design implications of vocational-technical facilities.

A selected and annotated listing of source material concerning the thermal environment in school facilities is directed to school planners, architects, and administrators (Hartman 1968). Topics include thermal environment and learning, physiological factors in the thermal environment, heating-ventilating and air conditioning in the classroom, and additional considerations in planning the thermal environment.

Integrated Systems

Meckler (1967) recommends a systems approach to the integrated design of lighting, heating, and cooling components. The system conserves energy by making use of all available energy inputs. Utilization of heat generated from the system's own equipment and from the building's lighting units reduces the need for cooling and air-handling equipment. By employing the same equipment to provide heating and cooling, such a system also minimizes nonusable space. Illustrations and citations of laboratory tests supplement Meckler's material.

A General Electric Company (1966) report discusses the design, evaluation, and control of integrated systems utilizing the heating potential of lighting equipment. General principles cover heat transfer, heat from lamps and luminaires, and control of lighting heat. The document also describes several types of integrated systems and makes extensive use of photographs, illustrations, and charts to explain technical materials.

An integrated thermal and luminous environment is achieved in a compact California high school described by Bergquist (1966). The school, based on the open plan concept, incorporates every possible space for academic use. The building's principal source of heat derives from the body temperature of its inhabitants and from its lighting system. Use of a few electrical panels spotted in critical areas achieves temperature control without a central heating system.

TOTAL ENERGY SYSTEMS

The concept of "total energy" entails the installation of an on-site electrical generating system and the conversion of the system's "waste heat" into steam or hot water for use in heating, air conditioning, and domestic hot water. Such systems, the subject of much praise and criticism, have been commercially successful since 1960. Because the concept enters into direct competition with local utility companies, the Educational Facilities Laboratories, Inc. (EFL) sponsored and published (1967) a "third party" assessment of total energy implications for schools and colleges.

The EFL document reports that total energy systems require higher initial investment but also promise greater long-range operating economies. Examination of design alternatives for integrated lighting, heating, cooling, and power systems suggests the total energy approach may be the best solution for modern school energy needs. For a total energy installation to make economic sense, three criteria must be met:

> First, there should be the expectation of a high and fairly constant electric power demand over an extended portion of the day and over most of the year. Power generation equipment maintains its highest efficiency when operated at constant demand levels over long periods of time.
>
> Second, the building should function so that demands for heating or air conditioning will occur simultaneously with, and in relative proportion to, the demand for electricity. In this way, immediate use of waste-heat by-products is assured. This, in effect, presupposes air conditioning of the building for year-round use. If air conditioning is not even being considered, for climatic or other reasons, then a total energy system is almost certainly uneconomic since the only possible use for waste-heat by-products would occur during the heating season.
>
> Third, the gas or liquid fuel rates in the area should be low enough to compete with prevailing electric rates. . . . In cases where local electric rates are known to be well below the national average, and gas or oil rates known to be well above, total energy is bound to be a loser.

The survey presents two case studies, recommendations for conducting a feasibility survey, and guidelines for plant and equipment design. While future trends for total energy systems are not completely predictable, some problems and promises appear on the horizon. Nuclear power may make electricity cheap enough to render on-site generation of school power uneconomical in many cases. Power demands, however, will probably continue to outpace power supplies, and the total energy system can be expected to remain a viable solution for many schools.

The windowless, compact school design, according to Bair (1966), offers more efficient space utilization and lower operation costs for total energy systems. He points out, however, that windowless buildings reduce heat costs but also require increased lighting levels, air conditioning, and air treatment. In assessing the feasibility of installing a total energy unit, school planners should seek engineering consultation, should compare annual commercial energy costs with operation and maintenance costs of total energy units, and should consider the purchase of backup equipment for use in the event of a power failure.

A brief report by Hick (1965) discusses conditions and limitations involved in installation of total energy systems and identifies questions that must be resolved before commitment to this type of system. He also evaluates some factors related to the development and use of such systems:

- initial and ultimate size of plant
- type and source of fuel
- sophistication of the system's use of the specific fuel
- rate of change for energy requirements in total plant
- availability of technical personnel to operate the plant
- ability of organizations to employ and retain such technical personnel
- location of system and safety implications

AIR CONDITIONING

A pamphlet by the Educational Facilities Laboratories (1971) advocates use of air conditioning to improve educational productivity. Cited experiments substantiate the benefits of air conditioning in promoting learning. Several case studies demonstrate the necessity and economy of air conditioning for open-space and compact schools and for schools with year-round programs in operation.

Air conditioning is a vital element in the integrated climate control systems used in modern school construction. Noting the successful use of air conditioning in Toronto's systems building program, EFL observes:

> Systems-built schools, and even modern schools built via the conventional construction process, illustrate the interdependence of different building components in creating a good interior environment. In a noisy central city, it is pointless to spend money for acoustical ceilings, sound-damping partitions, and carpeting all precisely designed to control noise without also including the airconditioning that would allow windows to be closed in warm weather.

Given current trends in all-season and community use of school facilities, air conditioning is expected to figure significantly in future modernization and new construction programs.

Two articles in *Nation's Schools* describe benefits and options provided by air conditioning. In the first, Jarvis (1970) identifies several types of renovation "bonuses" educators should consider when installing air conditioning in existing structures. The construction work necessary for an air-conditioning system can facilitate cost-effective completion of other renovation tasks such as repainting, addition of acoustical insulation, and upgrading of other building systems (heating, plumbing, and electricity). By eliminating the need for windows, air conditioning permits buildings to be expanded by filling in a courtyard or adding to an existing wall. Older buildings, Jarvis observes, frequently have nonfunctional spaces that may be used for air-conditioning equipment, thereby providing further space economies.

In the same issue, Nack (1970) discusses two broad categories of air conditioning for new school construction: packaged or self-contained units and central plant systems. Comparison of first and long-term costs for each type of system suggests that the large central plant may often be most cost-effective. Administrators are cautioned that such a plant also requires a full-time maintenance engineer whose annual salary of twelve thousand dollars or more represents an additional operating expense. Nack concludes his article with a discussion of preliminary design considerations that must be included in construction of air-conditioned schools.

The advantages and disadvantages of five basic air-conditioning systems receive attention by Wilson (1963). He points out that air conditioning can improve teaching and learning efficiency, permit more effective use of educational facilities, and provide for more efficient use of space through compact school design.

To gather the documents in this review, Research in Education and Current Index to Journals in Education monthly catalogs were searched from January 1968 through January 1973, using as search terms these descriptors: **Air Conditioning, Controlled Environment, Human Engineering, Heating,** and **Thermal Environment.**

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RESEARCH HIGHLIGHTS

For both economic and ecological reasons educators should perform a thorough energy systems analysis for each proposed school building. *Phipps (1973)*

The developing child differs from the adult and needs a different set of standards for controlling his thermal environment in the school. *Harmon (1953)*

The school building can be designed so that the principal source of heat derives from the building's inhabitants and from its lighting system. *Bergquist (1966)*

Examination of design alternatives for integrated lighting, heating, cooling, and power systems suggests that the total energy approach may be the best solution for modern school energy needs. *Educational Facilities Laboratories, Inc. (1967)*

Given current trends to all-season and community use of school facilities, air conditioning is expected to become an important feature in renovation and new school construction programs. *Educational Facilities Laboratories, Inc. (1971)*

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