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Climate Conditioning for the Learning Environment.

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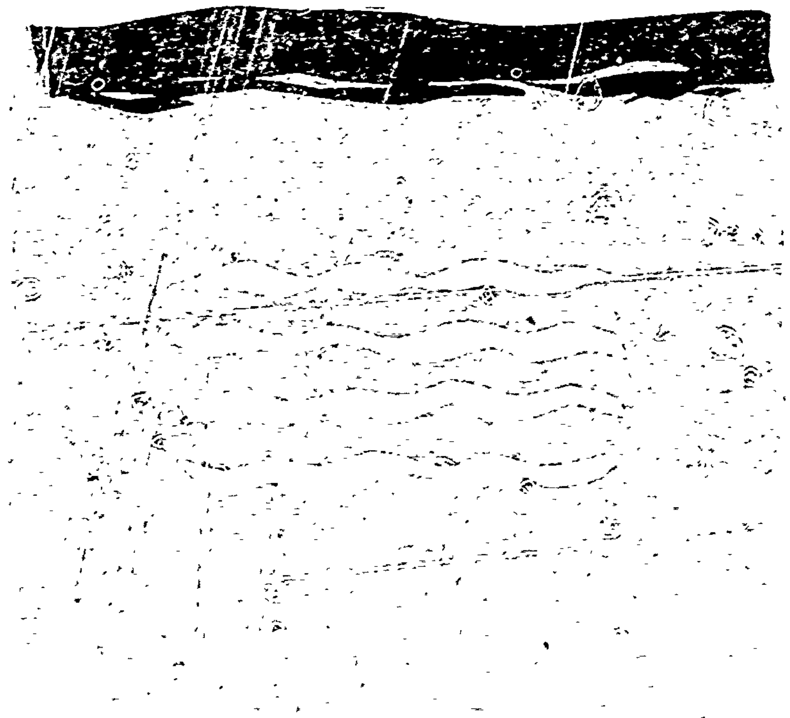
Discusses heating, cooling, and ventilation for the classroom in relationship to students' learning abilities. It is designed to assist school boards, administrators, architects and engineers in understanding the beneficial effects of total climate control, and in evaluating the climate conditioning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



CLIMATE CONDITIONING

for the learning environment

This booklet, entitled "Climate Conditioning," has been prepared by The Perkins & Will Partnership, architects, at the request of the American Electric Power System Companies.

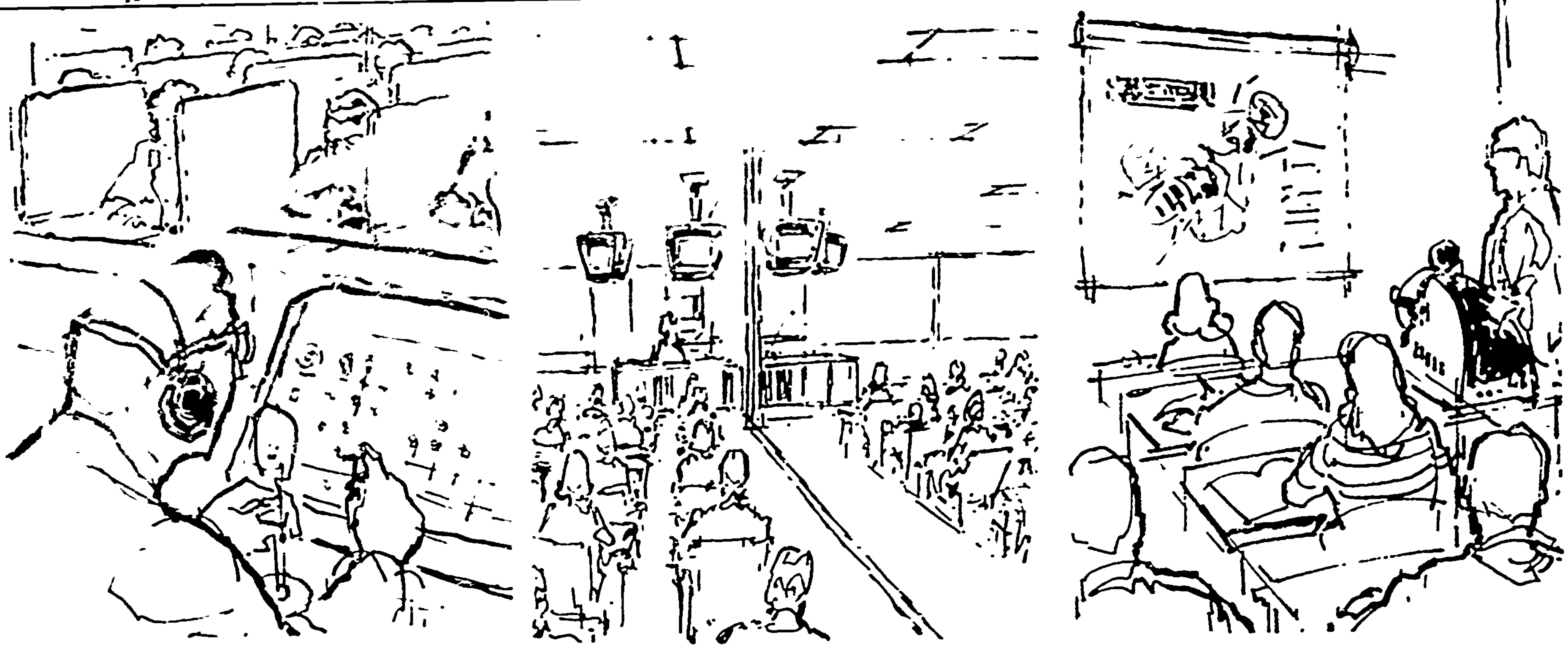
Published as a technical supplement to "The Learning Environment," this report deals with heating, cooling and ventilation as related to students' learning abilities. It is designed to assist school boards, administrators, architects and engineers in understanding the beneficial effects of total climate control, and in evaluating the climate conditioning systems available for schools.

CLIMATE CONDITIONING

for the learning environment

by THE PERKINS & WILL PARTNERSHIP

for THE AMERICAN ELECTRIC POWER SYSTEM (AEP)



Winter heating of all types of buildings has always been an undeniable necessity in most geographic areas of this country. Only in recent years have we come to realize that year-round climate conditioning—including summer cooling—affords us comfort, not just for comfort itself, but for the economic and social benefits of greater efficiency, higher productivity, and better health.

There is abundant proof that students and teachers perform far better in school rooms where temperature and air quality are controlled to suit the particular learning task in which they are engaged. For example, recent studies demonstrated that typing students working at 68° F accurately completed 15 per cent more work than students working at 75° F. Similar tests on reading (which involves less exertion) showed that students achieved the highest marks in rooms maintained at 75° F.

Many such investigations have illustrated dramatically the direct relationship that exists between climate-conditioned school environment and measurably superior learning achievement. Thus many more schools today are climate controlled to achieve the optimum learning environment.

THE PHYSIOLOGY OF COMFORT

Why do we feel too cool or too warm? It's simply that our bodies are losing heat either faster than they should, or not rapidly enough. There is a normal rate at which we must lose excess body heat in order to feel comfortable. This rate is affected by our physical activity, and the temperature and relative humidity of surrounding air. On a hot, humid day, or when we exercise violently, we cannot lose body heat as fast as it is created. Conversely, when we are sitting still in a cool room, or near cold windows or outside walls, our body loses heat too rapidly. In both cases we experience discomfort.

Relative humidity is important to comfort. Outdoors, summer moisture reduces the body's ability to dissipate heat by evaporating perspiration. Dry winter air accelerates evaporation, increasing our discomfort. Then, too, air filled with dust, pollens, smoke and other impurities can cause serious discomfort, and even kitchen or chemistry laboratory odors can impair one's efficiency.

A fully occupied classroom will rather quickly become unpleasantly stuffy, and students will become drowsy and inattentive if the air is not changed frequently or properly conditioned.

COMFORT DESIGN

Mechanical Functions

From an understanding of these physiological reasons for comfort, engineers have derived a set of principles which are basic to the design of climate conditioning systems. A fully climate-controlled school will contain equipment that performs the following essential functions:

1. *Temperature Control*—Regulating temperatures to suit the type of physical activity carried on in each building space—ranging, for example, from about 60°F in the gymnasium to 75°F in the library. In addition, the system should be capable of easy change from heating to cooling because the heat given off by the people in the room, plus that produced by the sun, the lighting and other power-using equipment, may quickly become excessive even during relatively cool weather.

2. *Ventilation*—Exchanging fresh air for stale air.

3. *Filtering*—Removing dust, soot and pollens.

4. *Humidity Control*—Taking excess moisture from room air during cooling cycles, and adding moisture when needed.

5. *Quiet, Draft-free air circulation*—Delivering air as quietly and as imperceptibly as possible.

Architectural Functions

The mechanical elements are the basic, though not the only considerations for the entire job of climate-control. The orientation, plan arrangement, design of the building and the materials used can contribute to the quality of comfort achieved, and to the economy.

Here are some recent findings by leading architects:

1. Less roof and exterior wall exposure in a compact, multi-story building will cost less to heat and cool than a sprawling, one-story arrangement of equal area and cubage.

2. Classroom windows facing east or west receive excessive heat from the sun. Although this fact assists heating in cold weather, the cooling problem is generally greater. As a general rule, it is preferable to face the majority of rooms north or south.

3. "Windowless" buildings are entirely practical: they save on first cost, maintenance and heat loss, and are free of outside dust, smoke, odors and noise. A few small windows should be introduced, however, to avoid that "closed-in" feeling.

4. Wide roof overhangs, solar screens, glass block and similar devices to control sunlight are no longer essential. Cleaner, simpler, far less expensive designs are now possible with uniform, high-level electric illumination.

5. Adequate insulation of roofs and exterior walls reduce both heat loss and heat gain far more than is generally supposed. Even double glazing adds measurably to more economical climate control.

CLIMATE CONTROL ENGINEERING

Energy Sources

To create heating or cooling mechanically, energy must be expended by burning fossil fuels—coal, oil or gas—or by the use of electricity. One of the factors in choosing among the four energy sources is the relative cost at the point of use. Coal, oil and gas for public use have become more expensive in recent years. Electrical energy costs, however, have decreased or remained relatively constant.

Two other major factors must be carefully balanced with the energy cost in selecting the right climate control system for a particular school: initial construction and equipment, and long-term operation and maintenance costs. Electric heating, for example, can, in a great many instances, be demonstrated to be the most economical, because boiler space, a chimney, and pipe trenches are unnecessary; equipment is simpler, smaller and more automatic; and a single electrical distribution system can serve all heating, power and lighting requirements. Thus lower capital and maintenance costs can be the deciding factor.

Heating and Cooling Generators

Whether coal, oil, gas, or electricity is the source of energy, the heart of a climate conditioning system is the means of providing heating and cooling. For heating this may be a warm air furnace, a hot water or steam boiler, or separate electric resistance units. A refrigeration machine is the source of cooling. A heat pump can produce both heating and cooling.

Furnaces and Boilers—either those burning fossil fuels, or using electric energy—transfer heat to a distribution medium—air, water, or steam—by which heat is delivered to all parts of the building as needed. In the case of electric energy, heat transfer from resistance elements is essentially 100 per cent efficient, since all of the energy is converted into useful heat. The fossil fuels lose a great deal of heat energy up the chimney in the process of combustion.

Electric Resistance Heating has the noteworthy advantage of being usable directly in individual rooms, thus eliminating ducts or pipes, and the loss of heat from air, water or steam in transit from a central furnace or boiler.

This type of heating may be installed as cable in the floor or ceiling to produce radiant heat, or in the form of baseboard or wall-type convectors. It may also be the heat source in an individual room unit ventilator which, with a small refrigerating unit, will do the entire job of climate conditioning in the room.

Refrigeration Machines and the Heat Pump

People commonly think of the refrigeration machine in an air conditioning system as a device exclusively for cooling. Because of the way it operates, it may also be used for heating. Such a unit is essentially a heat transfer machine, using compression and expansion of a refrigerant to move heat from one area to another. The act of producing cold is naturally accompanied by the generation of heat. During the cooling season, unwanted heat is discharged outside of the building. During the remainder of the year both the heat produced and the cooling can be used, because there are times when different learning spaces of the building will require heating and cooling simultaneously. When both the heating and cooling capabilities of the refrigeration machine are used, it is known as a "heat pump."

An interesting thing about the heat pump is that, on the average, only about two units of input energy are required to obtain five units of output heating energy. The other three units are either transferred from indoor areas that have excess heat, or from another source such as outside air. Thus each two units of electrical energy purchased will make available five units or more of heating energy.

CLIMATE CONTROL SYSTEMS

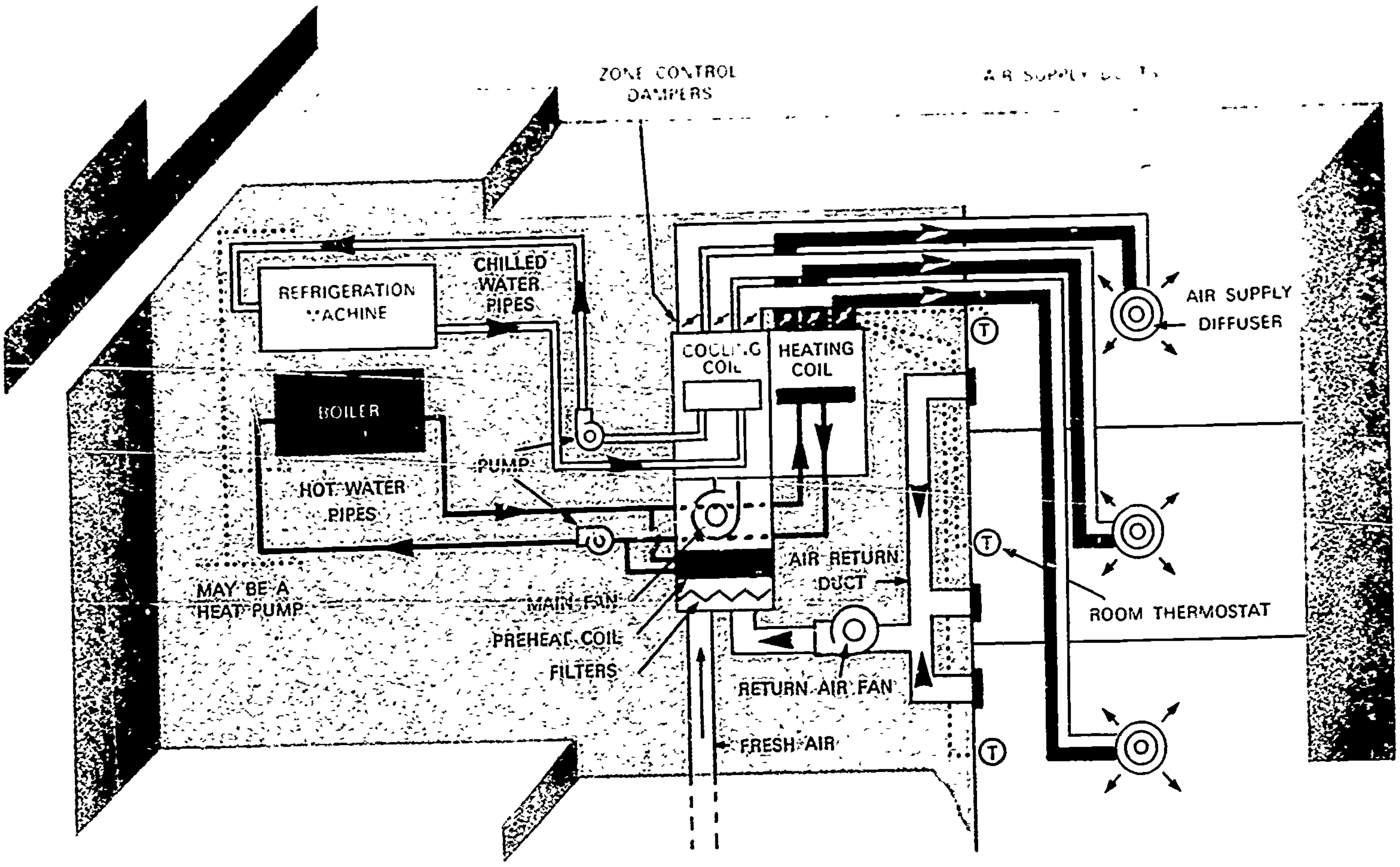
Up to this point, only the basic elements of climate conditioning have been discussed—energy sources and the means of translating that energy into usable heating and cooling. A comprehensive system, designed to perform all of the functions required in a completely climate-controlled school, must include the following components:

1. A distribution network to carry heated or cooled air or water from the central generating equipment to all parts of the building. In the case of a total-electric system, the network may consist solely of the wiring by which energy is transported for direct use in the rooms.
2. Fans or pumps to force the heating and cooling media through the distribution network, and fans to bring in fresh air, remove stale air, and create the necessary circulation in each space.
3. A system of filters for air cleaning.
4. A control system that automatically regulates the temperature to suit the activities in each room.
5. A system which will remove or add moisture, maintaining relative humidity at proper levels at all times of the year.

Equipment to perform these functions is available in great variety, and there are numerous ways in which it can be combined to create partial or complete systems.

This study will not attempt to survey and rate the entire field of equipment and the almost innumerable combinations and refinements thereof. Five systems, ranging from the self-contained, single-room package unit to the very elaborate double-duct, high-velocity, constant volume system, have been selected for review because they are representative of the equipment best suited to the requirements of a typical school.

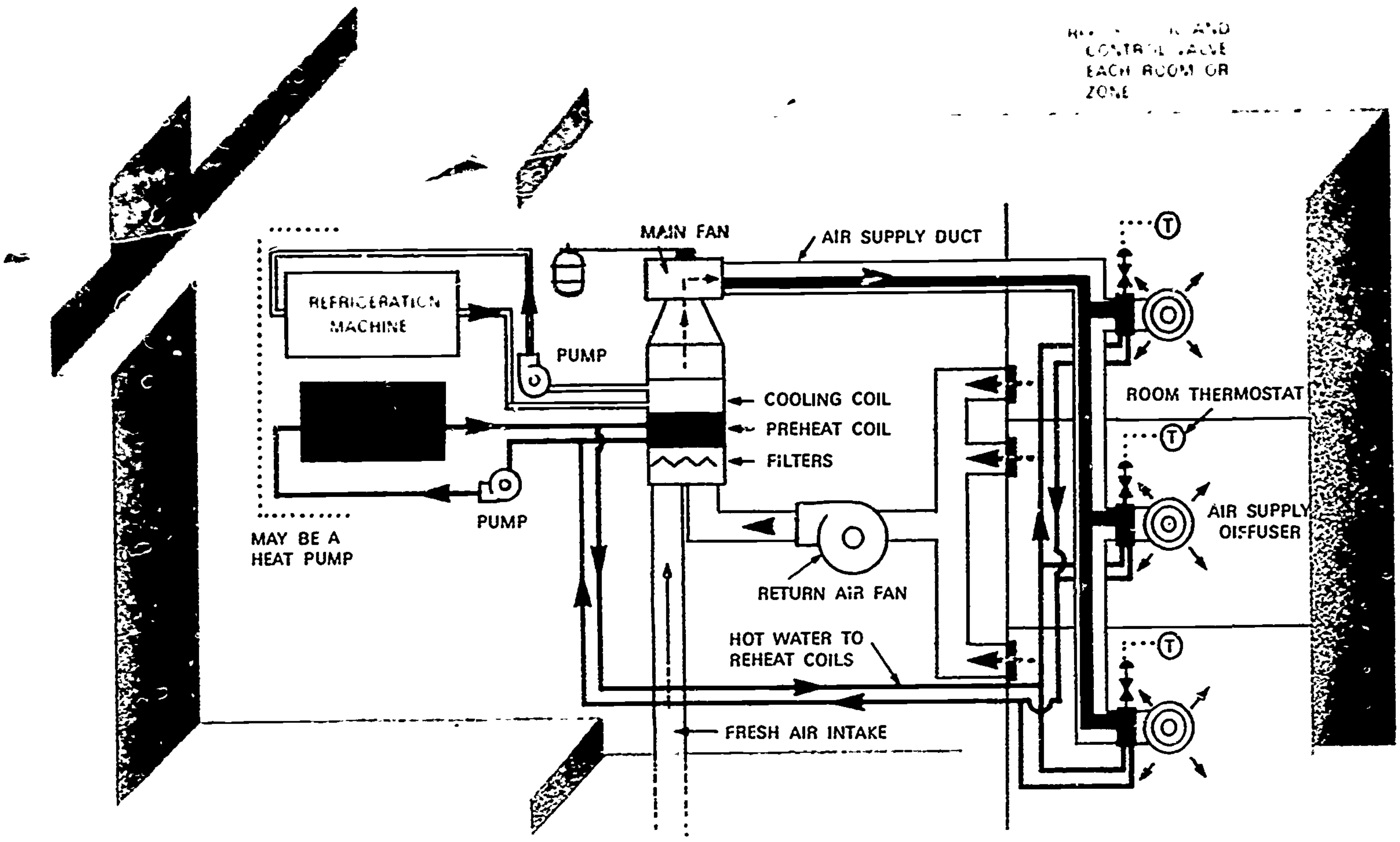
First, each of these five systems can provide the factors of climate control previously described: they can both heat and cool, ventilate, dehumidify, filter, and supply air without drafts throughout the school. Second, they can be controlled to meet the conditions required in each and every space in the building, readily adjusting to varying activities, number of occupants and outdoor temperatures. Third, they fall within the average of the range of original cost, operating energy cost, and ease of maintenance.



SINGLE-DUCT, NORMAL-VELOCITY, MULTI-ZONE SYSTEM

Operation:	Conditioned air distributed through ducts to individual spaces or zones from central air handling equipment.
Heating and Cooling Sources:	Central hot water or steam boiler and refrigeration machine, or may be a heat pump.
Distribution:	Main central fan forces air through heating and cooling coils. Conditioned air is supplied to each space in zone by individual ducts. Return air fan recirculates part of air supply. Amount of required fresh air taken in from outside is variable up to 100%.
Temperature Control:	Room thermostats maintain mixture of warm and cool air at required temperature. One zone may be heated while another is being cooled.
Humidity Control:	Humidity is naturally reduced during cooling operation. Must be added during heating.
Filtering:	Filter system cleans fresh and recirculated air before it passes through main fan.

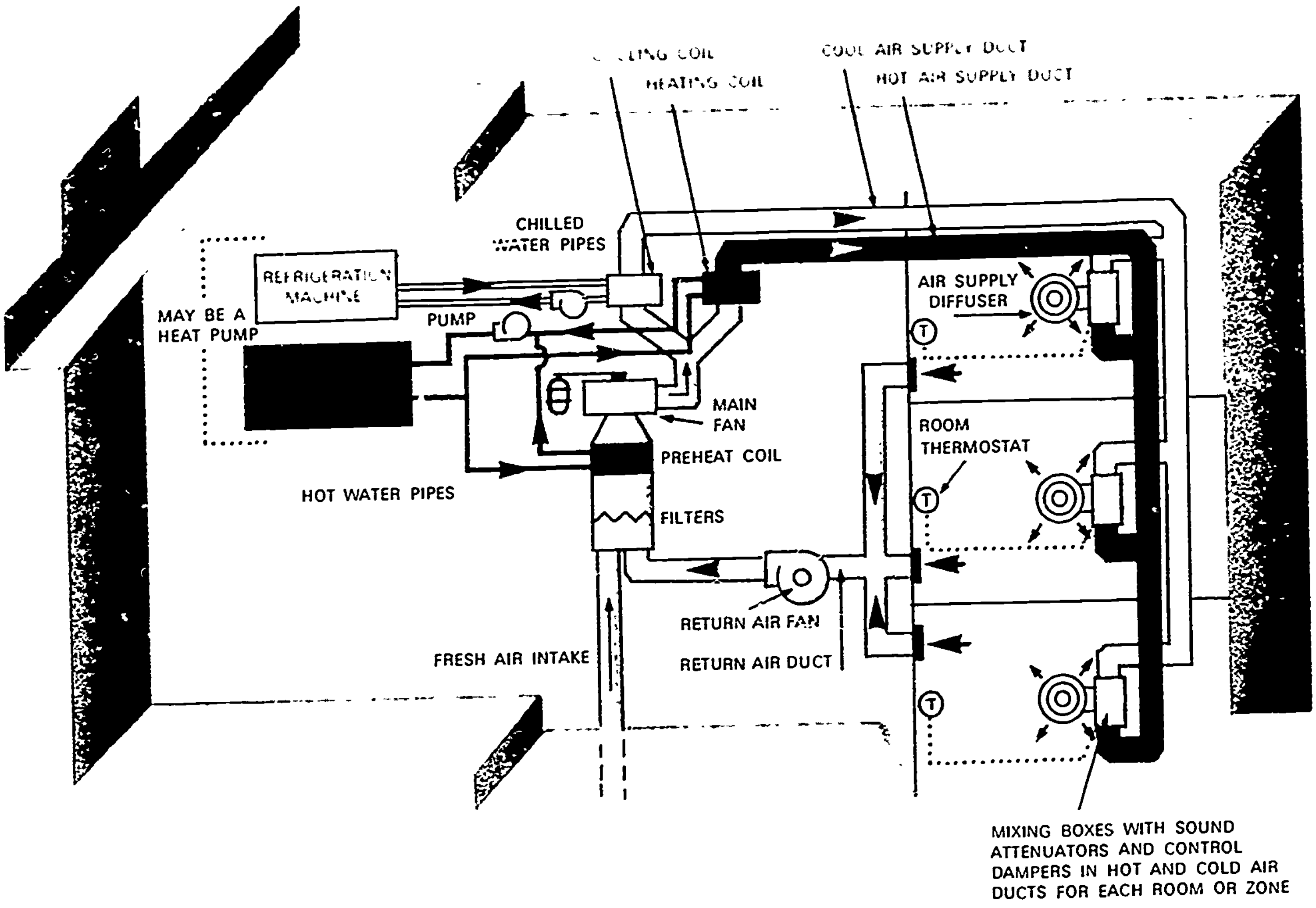
This type of system is applicable to small compact schools, because of comparative low initial cost and energy cost. All climate conditioning functions can be included and handled efficiently. Maintenance is facilitated, because all equipment (except thermostats) is in a central space.



SINGLE-DUCT, NORMAL-VELOCITY SYSTEM WITH REHEAT

Operation:	Conditioned air distributed through ducts to individual spaces or zones with precise temperature adjustment at point of delivery.
Heating and Cooling Sources:	Hot water or steam boiler and refrigeration machine, or a heat pump.
Distribution:	Main central fan forces fresh and/or recirculated air through preheat and cooling coils. Reheat coil in supply duct to each space provides exact room air temperature. Return air fan recirculates part of air supplied. Fresh air intake can be sized for 100% capacity.
Temperature Control:	Room thermostat regulates temperature of reheat coil for final tempering of centrally conditioned air.
Humidity Control:	Humidity is naturally reduced during the cooling operation. Centrally-added moisture, reheated in supply ducts, affords positive control.
Filtering:	Intake and recirculated air are filtered ahead of main fan.

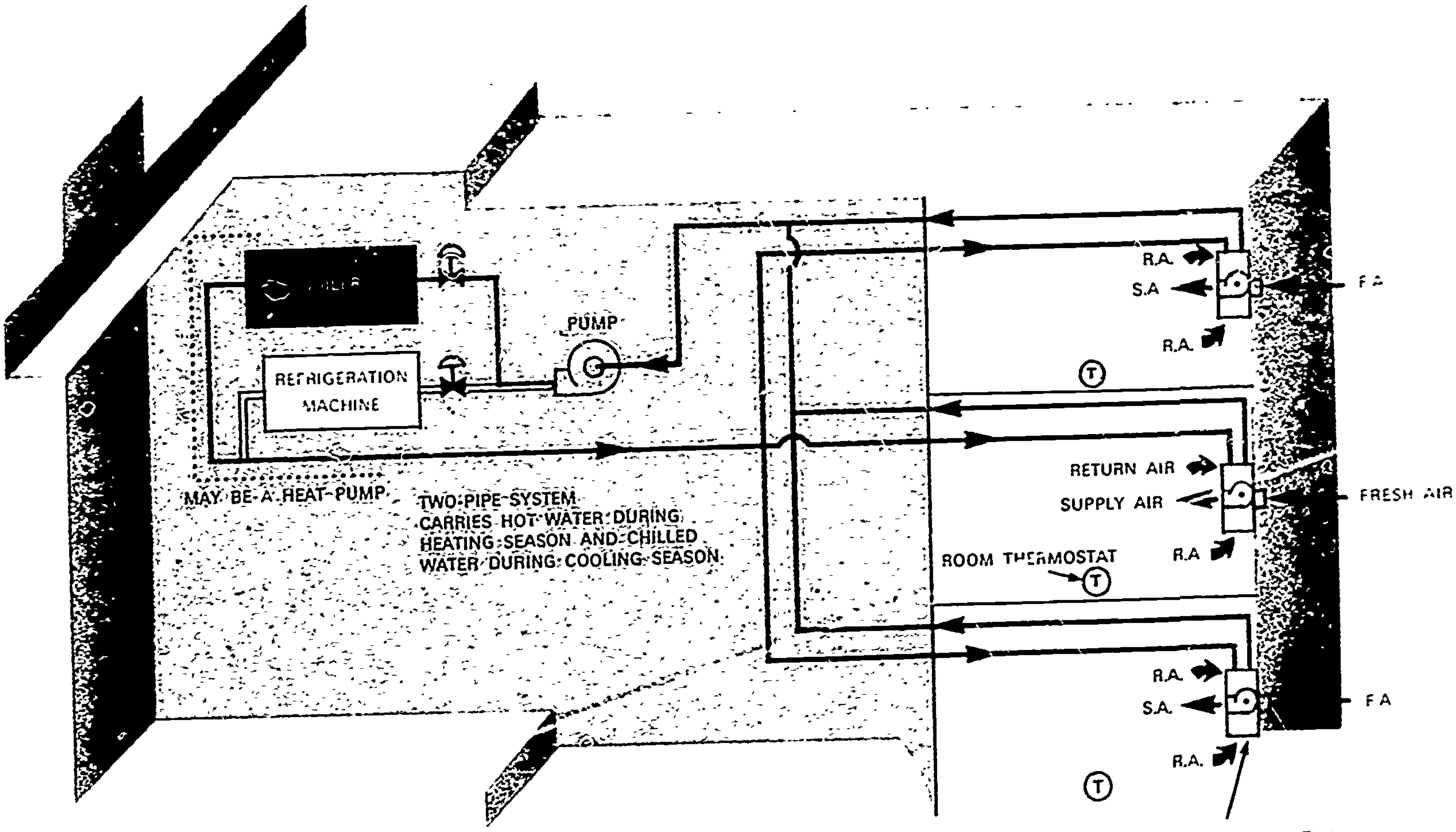
Superior performance in all climate conditioning functions makes this a highly-rated system for compact schools. Initial costs are higher, because of added piping and reheat coils. Maintenance and operating costs are likewise greater due to the number of controls, plus increase in fan power.



DOUBLE-DUCT SYSTEMS

Operation:	All-air systems in which heated and cooled air are delivered at either high- or low-velocity through separate ducts, and combined in mixing boxes at each room to achieve the proper temperature.
Heating and Cooling Sources:	Central hot water or steam boiler and refrigeration machine, or a heat pump.
Distribution:	Hot and chilled water is circulated through a coil in the heating and cooling duct respectively. A central fan forces air through both ducts to the mixing box at each room. Fresh and return air are proportioned as required for the total system.
Temperature Control:	Room thermostat regulates amount of hot and cooled air entering mixing box, and thence, the room.
Humidity Control:	Overall building control, achieved centrally.
Filtering:	In main fan.

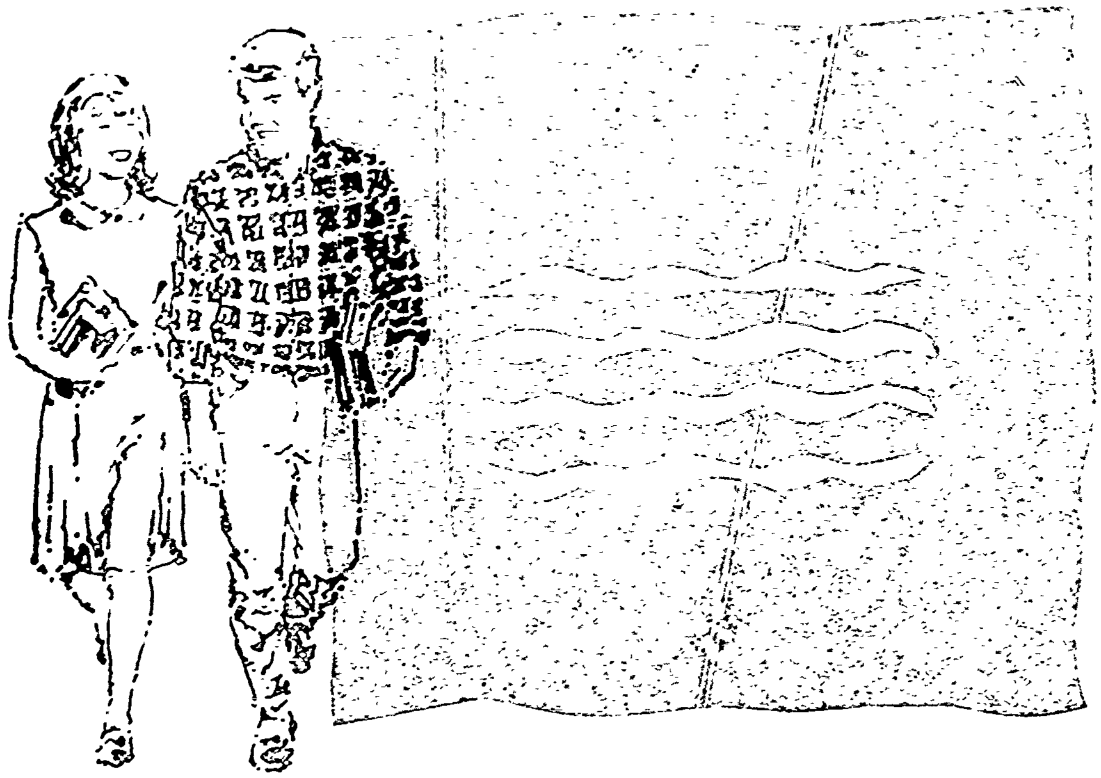
The double-duct type of system is the most sophisticated, and most costly to install and operate, because of the greater amount of duct work and number of isolated controls, and higher fan power required. All climate-conditioning functions are highly rated. Heating or cooling may be done simultaneously in different rooms or parts of the building.



ROOM UNIT VENTILATORS WITH CENTRAL HEATING AND COOLING

Operation:	Individual room units containing heating and cooling elements, and air circulating fan.
Heating and Cooling Sources:	Central hot water boiler, (or electric resistance heating element in each unit ventilator) a central refrigeration machine, or a heat pump.
Distribution:	Hot or chilled water from central plant circulates in a piping system to each unit ventilator. (Piping is still required for chilled water if electric resistance heating elements are used.) Fan in unit recirculates room air and adds required fresh air.
Temperature Control:	Thermostat in room regulates temperature of heating-cooling coil and fresh air quantity.
Humidity Control:	High relative humidity is lowered naturally during cooling cycle. Adding moisture during heating increases system cost, because of water piping and injection system which must be installed throughout building.
Filtering:	Each unit contains its own set of filters.

An excellent system for spread-out schools and for additions. Low initial cost and operating energy cost. Rapid response to room requirements for heat or cooling. Location under windows counteracts cold or heat from glass. Extensive duct system is unnecessary.



THE TOTAL-ELECTRIC CONCEPT

It should be clear from the foregoing discussion that electrical energy is required in the functioning of any climate-conditioning system. Electric power is needed to operate fuel, water and condensate return pumps, air supply and exhaust fans, and temperature control systems. Fossil fuels can be replaced by electrical power as the source of heat energy in warm air furnaces, or in steam or water boilers. Therefore, the question may very well be asked—Isn't there a climate-conditioning system which uses only electricity, with no dependence on complex water, steam or air distribution?

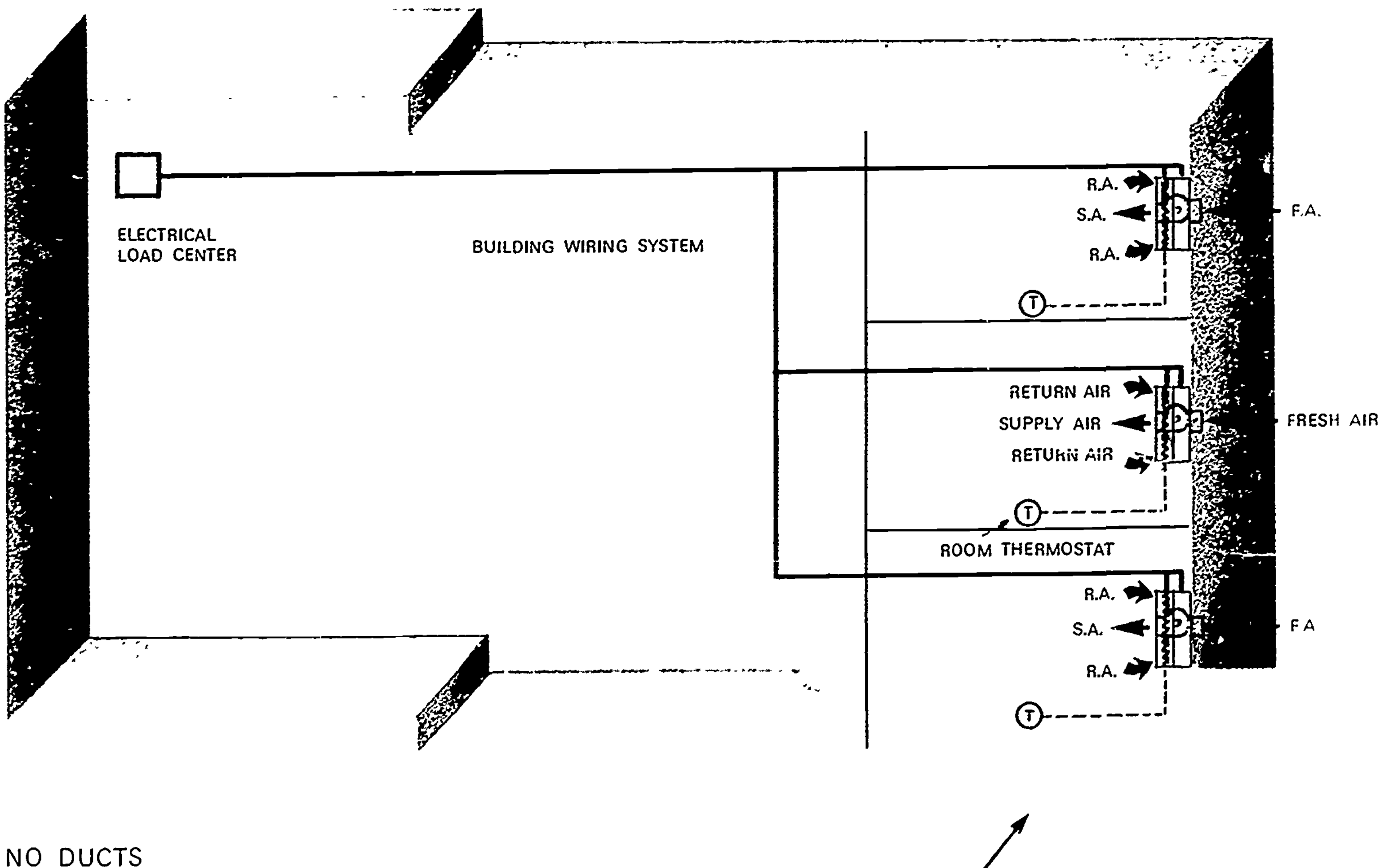
The answer, of course, is that electricity can be appropriately and effectively used as the sole source of energy for any of the four complete climate-conditioning systems just described. However, the room unit conditioner system, illustrated on the following page, is particularly attractive for an all-electric school, because of its favorable initial cost and flexibility. The diagram of this type of system has been drawn to point out graphically some of the major construction advantages inherent in total-electric installations, the most significant of which are these:

- No boiler, hence no chimney.
- No fuel storage required.
- No boiler room.
- No central water chiller. Each unit conditioner contains its own cooling unit.
- No main air-handling unit.
- Space required for mechanical equipment is reduced or eliminated.
- No heating or cooling water piping, therefore no need for pipe trenches.
- No ducts throughout the building. Less space required above ceilings. (Reduces building volume.)
- Single distribution system carries electrical energy for both power and lighting.
- Building additions are most easily made.

ROOM UNIT CONDITIONERS—TOTAL ELECTRIC

Operation:	Unit conditioners in each room provide all heating, cooling and ventilation required.
Heating and Cooling Sources:	Each unit conditioner contains an electric resistance heating element and a direct expansion cooling unit, or a heat pump.
Distribution:	The only total building distribution is the electric wiring system. Air circulation and ventilation are by the unit conditioner fan.
Temperature Control:	The room thermostat controls directly the function of the unit conditioner. Immediate change from heating to cooling.
Humidity Control:	Occurs naturally with cooling. Moisture must be added during heating, when needed.
Filtering:	Each unit ventilator contains filters.

Ideal for open-plan schools, and especially for remodeling and additions, because of the ease with which power for both heating and cooling, and for lighting and equipment can be extended. Localized control of every teaching space—dependably and economically.



NO DUCTS

NO PIPES

NO CHIMNEY

ROOM UNITS CONTAIN ELECTRIC RESISTANCE HEATING ELEMENT, DIRECT EXPANSION COOLING UNIT AND AIR CIRCULATING FAN AND FILTER

THE TOTAL-ELECTRIC CONCEPT

Conclusions

The objectives of this report have been to assist school boards, administrators, architects, and engineers in understanding the beneficial effects and in evaluating the systems for Total Climate Conditioning.

In addition to the construction economies in a Total-Electric installation, the overall long range gains are equally impressive:

Flexibility:	Heating and cooling exactly when and where needed, with each space conditioned immediately for the activity involved.
Safety:	No flames, no fumes.
Quiet:	No combustion noise and vibration.
Cleanliness:	No combustion smoke and fumes.
Simplicity:	Fewer large pieces of equipment to maintain and adjust.
Economy:	Automatic operation. No need for an operating staff. Longer equipment life.

Neither first cost nor energy cost alone can tell the whole story. Only with a comprehensive evaluation of *all* the differences and features, of the systems, measured against the total budget, as well as the quality of environment provided, can we pinpoint the true value of an energy or a system. Such considerations will lead to the inevitable confirmation of electricity not only as the essential, but in fact, as the superior source of energy for creating the learning environment which every Board of Education and School Administrator is seeking for their students.

This is of paramount importance, for time is youth's most valuable asset. We must insure that the priceless learning years are spent most productively.

We simply cannot plan in terms of less than the best Learning Environment.