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By- Rutgers, Norman
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The role that a good thermal environment plays in the educational process is discussed. Design implications arise from an analysis of the heating and ventilating principles as apply to vocational-technical facilities. The importance of integrating thermal components in the total design is emphasized. (JS)

THERMAL ENVIRONMENTS

Mr. Norman Rutgers
Director of Environmental Systems
Lennox Industries
Marshalltown, Iowa

I'd like to discuss just what we mean by good thermal environment, cut it apart and look at it from various angles. I think we have all attempted to force coordination of various facility components, various elements, into a school and as a result we've ended up with a final product that while it may have been reasonably good, we know it could have been a great deal better. Basically a good thermal environment for vocational-technical schools is very similar to the type of thermal environment we would like to have in any academic situation. There are, however, some specific areas where additional attention to thermal environment must be made.

Each new school presents its own special problems. The educational vacuum for high school students who could not, or did not choose, to go to college was very apparent. There is no reason in the world to believe that every high school graduate <u>should</u> go on to college; but we should give him the opportunity to continue his education in specific areas so he can make a greater contribution to the community and to himself. Also, we should look more toward the adult who wishes to increase his skills and upgrade himself. The vocational efforts in almost every community are directed not only to the 11th, 12th, 13th, and 14th grades, but also to interested adults of the community who wish to increase

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their own skills and abilities. There is a vocational technical facility in St. Paul, Minnesota, for example, which actually has 6000 students ranging from the ages of 19 to 60 years, demonstrating that this does meet a very definite need.

The United States will show an increase in students in the next few years from about 5 and 3/4 million to over 14 million. But we will deal effectively with this tidal wave of students only by providing the type of facilities that are required for their varying needs. To give you an idea of one recent trend in this country, in 1944, 66 million dollars was spent on vocational education. In the next twenty-year period, three hundred and thirty-three million dollars was spent for vocational-technical education. In 1965 it jumped to 620 million; In 1966 it was 730 million; and in 1967 the figure rose to 815 million dollars! If we take the 1966 figures and wonder where this money came from, out of the total of 730 million dollars, 215 million came from federal funds. The remaining 515 million came from state and local funds, which shows rather clearly that this is not a totally federally sponsored program. The federal money is normally met by matching funds or even by more than matching funds at which point it becomes very much a local problem with relatively modest federal support.

Special needs require early planning and I think others have touched on the necessity of getting into a planning program at a very early date. The Las Vegas School District *had been planning for a number of years before they started their first vocational-technical facility. Preliminary planning should involve not only educators, but representatives of local industry, the selected architect, trade unions, and local business and professional clubs. It's amazing how much you can grease the ways in eliminating later conflicts with unions, for example, if you include them in early plans. If people understand what the purpose of the program is on a prior basis, the thing moves along pretty smoothly. Too many schools have been planned and built in a hurry. Planning in a hurry will provide a very expensive type of facility and it will never quite fulfill its educational needs.*

The architect's role in designing the modern school is extremely important. My number one suggestion to any school board or any administrator would be to select the most progressive, the most up-to-date architect that can be found. Find the architect that is aware of the latest improvements and advancements in construction; an architect who is not afraid of a little innovation, provided, of course, that innovation has a purpose. If we continue to plan and build new schools based only on our past experience, we're merely going to repeat our former mistakes. If we're going to make mistakes, let's make original ones.

Without question the educational specifications become tremendously important. Without them, I don't think a good planning job can even be started. It won't cost the district, *in the long run, one bit more to hire a top-notch architect than it will to hire a poor architect. (I'm making the assumption there are "poor architects.") In fact, the poor architect can frequently cost the district considerably more than the full fees of a truly superior one.*

The term "learning environment" includes many important interrelated factors. One of the most critical, but the least understood, is that of thermal environment. Good thermal environment will provide an atmosphere in which the student is unaware of any physical discomforts. He is neither too warm, nor too cold. He doesn't have too much air moving over him, nor is he sitting in a stagnant pool of his own body conditions. It includes a lot more than just heating alone. Up until a few years ago, the only relationship to thermal environment was the question, "Do we have a heating system?" When we finish examining this question we will find that the heating system, while it is important, is certainly not the major factor contributing to a good thermal environment. There are other elements in every school situation that make heating a rather minimal consideration.

Let's take a look at all of the ingredients which make up a good thermal environment. We'll cover these one by one. Constant air circulation in any occupied area is very important. If you stop the air circulation, the air becomes stale; it grows stagnant and stuffy, and odors will collect. Just walk into a school that's approximately 15 to 20 years old that does not have good air circulation. Remember, it's that familiar old school with the gymnasium in the center, the principal's office on the right-hand side as you come in, and the classrooms fanning out around the gym. Open the front door and take a good deep breath. You can smell the sweat socks that have been in the lockers for the last ten years. That odor just seems to permeate the entire school; it hangs there and stays there. To repeat, air must be circulated. You have to pick up the odors, move them out, and bring in fresh air. If you do not have constant air circulation, the air will stratify. In other words, warm air will move up, collect and hang, the cold air will then drop down. Between the ceiling and the floor there can be as much as a 12 degree temperature difference. A student may be standing in a pool of cool air while his head is bathed in a considerably different temperature area, the combination of which can be most disconcerting, and certainly it does not contribute to a good learning environment.

If there is a lot of glass area, and many of these schools have been built this way, we very likely do not have good air circulation. We find that air will collect along the cold glass surface on a cold day of 25 or 30 degrees and will soon start cascading down the glass surface. As that air moves down the glass surface, it will pick up velocity; sometimes as high as 80 to 100 feet per minute. It will move across the floor, chilling feet as it does. In order to stop this cold movement we find that a vertical column of air should be introduced at the glass area. This will eliminate, or, to a large degree, minimize the problem.

In good air circulation, air is constantly mixed, but ideally on a gentle basis. There are some agreed upon requirements of air velocities in any space. About 50 feet per minute comes close to the acceptable maximum. If you get much below 15 feet per minute, air starts to stagnate. About 25 to 30 feet per minute would represent a reasonably good environment from an air circulation standpoint.

Air in academic spaces should be changed four to five times per hour. But now let's look at a vocational-technical facility. We have some areas in a vocational-technical facility which will require considerably higher frequency of air changes. When you get into your laboratories, you may want to exhaust virtually all of the air you're introducing into the space. If it's hot outside, you're bringing in higher temperature air. You have to cool it down to maintain a comfort level, demanding a greater capacity. The major point here is that you must consider the difference. In a welding shop, or an auto body shop there is an exhaust problem. You have to replace that air, so you have to have an air makeup provision introduced into the mechanical system.

Fresh, outside air needs to be filtered and treated before it is brought into the teaching space. We can clean air, of course; a problem that is linked very closely with the problem of air pollution that is becoming the number one topic in many communities. For a while we thought that California, and particularly Los Angeles, had a corner on air pollution. We find now by direct comparison that Los Angeles is not nearly as bad as parts of New York on certain days and unless we develop methods of filtering and cleaning air, we may merely be bringing in an outside problem and creating a new problem inside the classroom space which is equally as bad as it was before it got into the school.

Electronic air cleaning is moving ahead. We're seeing more and more of it being used. It's not cheap, but it is coming down in cost. Using charcoal filters proves an effective way of eliminating odors. These are mechanical methods featuring special devices which can be incorporated into the mechanical system. In older systems, a number of years back, we used to simply open windows for ventilation. This is no longer a sensible solution. Air conditioning virtually allows you to compact a building and by compacting you can save construction costs so you get a trade-off that makes real sense. When you did open windows in those old schools, of course, it was a direct invitation for all the airborne dust and dirt to come right in with the fresh, outside air. In newer school design, we find far fewer windows. If you noticed the Clark County vocational-technical school, there was very little glass. Glass was merely a vision strip which may lead some of you to think of me as being "anti-glass." I'm not at all anti-glass, but I hope to point out to you, if you use great expanses of glass, what you will have to do to counteract the negative thermal effect that that glass will cause. There are areas in between total glass and no glass at all that strike a more practical balance.

One thing about fresh air is that you must control it. This brings us to the subject of air temperature. The human body does not function too well at extreme air temperatures. Circulation is not the only requirement with which we must be concerned. Air really should not vary much more than a plus or minus 1 1/2 degrees from the control center. In some areas you will find a two degree plus or minus variation. In such cases, the body will begin to react to this much change and when it senses a change, it immediately sets up a process to offset it. The physiological relationships of man to his environment provide an extremely interesting study. This is one of the areas in which we are attempting to work with the Graduate School of Design at Harvard University. Body temperature adjustments take energy; it distracts a person from his studies and lowers his efficiency. The human body is also sensitive to the rate of temperature change. In other words, if you change the temperature in a room gradually, the body will adapt to it without too much straining, but if you bounce temperatures back and forth too drastically the body will react strongly to it.

Recent research also suggests that if 72 degrees is an optimum temperature at 11 o'clock, it is not necessarily true that 72 degrees is the optimum temperature for the same group of students at 2 o'clock. We think we might be on the verge of programming temperatures to arrive at ideal temperatures for the time of day following, say, a lunch period, and particularly programming temperatures in relationship to the academic courses or the studies that are going on. Very little is known about this at the moment, but since we are living in a computerized age, there is no reason in the world why we can't program for temperature changes as long as we know at what levels we should gauge it.

We should refer some to sound. We have, in the mechanical area, tried to reduce sound levels. On one occasion, we were able to get the mechanical sound level down to the point where the ballast in the fluorescent tubes was perceived as noisy and began to bother the people within the building. This was too much success. So now you reverse that trend and you come back up to a sound level which is compatible to the surroundings. A dead, quiet sound is actually most irritating. You need to have a level of sound but you have to plot the frequency of it against the pressure level of the sound.

Interestingly enough, heat is never added to the body. We never, even when we're in a heating situation, apply heat to the body. What we do, however, is regulate the heat loss from the body. Now, this is understandable when you think in terms of your body temperature being 98.6 degrees. Therefore, if I'm adding heat to the body, I've got to add heat at a higher temperature. My room, then, would have to be warmed to a level above 98 degrees before I could transfer heat from the room to the body. So when I maintain a 75 degree temperature, I am merely controlling the rate at which the body heat is being lost and when I allow the room temperature to drop down to 60 degrees, I begin to lose heat from the body at a faster rate, making me uncomfortable. I start to shiver simply because my body's physical processes are attempting to offset this increased heat loss. We heat the walls and the furniture, and all of the appointments. You're bringing them up to a temperature level and you're controlling the rate of heat loss from the body at the same time. Mechanical systems control the rate of heat loss merely by varying the ambient temperature surrounding the body. The closer the air temperature is to 98.6 degrees, the more difficult it becomes for the body to lose heat. This is apparent in the summertime. You feel stuffy. Your room starts to build up without air conditioning and your body cannot lose its heat, therefore your internal temperatures start to rise, just fractions of a degree, perhaps, but even so an extremely uncomfortable situation occurs.

Earlier we touched on air cleanliness and pollution. This is becoming more and more a major factor in mechanical design. Dirt and lint from clothes are all about us and the city air contains many contaminants. These contaminants are constantly being brought into the school itself. All such foreign matter should be removed from the air that the student breathes.

Today there is an additional area provided for in the plans of new schools designed to offer atomic fallout protection. This is a core area in which the students will congregate during a critical period. Of course, when you start to bring more students into a smaller area, you immediately change your thermal requirements. This requires shifting one's capacity from a total area into a confined area so that we increase the air volume to maintain the necessary minimum per student. Under a critical condition we extract the airborne radioactive particles from the air being brought in, as well as cool the air so that the temperature rise is controlled within the space. This can be accomplished without great additional cost, and has the added advantage in that it combines a school protection area with an essential community function. Certainly a lot more research must be done in this area and more people in the mechanical field should gain an interest in this research. Our basic tenet, however, still remains: air cannot be cleaned unless it is moved and circulated.

Let's look now at one of the biggest culprits in maintaining a level of comfort and that is the problem of heat gains. Our vocational technical facilities are being designed and used for year-round operation. Therefore, it is almost mandatory that we take a second look at the mechanical systems that go into a vocational technical facility. Let's pass over for now the summer months. We can all agree that in the summertime, in almost every American community, there will be temperature rises which require some form of mechanical treatment of the air to insure physical comfort. But in the winter, there are some very interesting heat gains that occur in a building where the outside temperature drops to zero.

Suppose there is a lot of glass area in a building.

Depending on the exposure, glass can add in excess of 240 b.t.u.'s of heat per square foot of glass. Relate this to the fact that in one ton of cooling there are 12,000 b.t.u.'s. Some simple arithmetic shows that a relatively small amount of glass area under some conditions of exposure can soon require a full ton of air conditioning to offset. Heat can build up in a hurry.

We have another problem that's related to this. Our lighting levels are going up sharply. Ten years ago our schools were designed to flood areas with about 70 foot candles. Today, 70 foot candles is at the lower level. We now recommend up to 100 foot candles and, if we would listen to the people in the lighting research, the watts per square foot would increase still more. Let me elaborate on this last reference. Today, for each square foot of building we typically have approximately 4 watts of electrical power. This is directly related to the heat input into a space since every watt of electrical power consumed will place 3.4 b.t.u.'s of heat into the area. We started out with 4 watts per square foot and we're now talking about lighting intensities going up to 100 foot candles from the old base of 70. In some instances, as much as 250 to 400 foot candles in lighting intensity is being recommended. While I am not a lighting expert, I can tell you that if we go from 4 watts to 6 watts per square foot, you're going to add a whale of a lot of heat to an area which will have to be countered with additional cooling capacity.

Take a conventional 900 square foot space at 4 watts per square foot, we have 3600 watts total. This would convert to about 12,000 b.t.u.'s, so we'll need a ton of cooling put in this room just to offset the heat from the lights. I'm merely pointing out what some of our problems might be. The maximum solar gain, plus the lights, plus the students themselves in a 900 square foot classroom can produce up to 60,000 b.t.u.'s. Now in those parts of the country where we occasionally have temperatures down to 25 degrees below zero, we would not need <u>any</u> heat in the classroom even on a zero degree day. We have enough heat from the lights, from the sun (if the sun is shining) and from the students to maintain an adequate balance. If you move up the outside temperature level to 10, 15, or 20 degrees above zero you are into a cooling, rather than a heating situation.

It's also an important problem to bring a building up to temperature in the morning so that it is comfortable when you go in. It's also a problem to maintain the building at night. But once you occupy the building and school is in session, the night heating situation may well disappear and be replaced almost instantly by a cooling one.

We'll consider a little about zoning before we get into the twilight period where we need some heating around the perimeter but at the same time some cooling on the inside. These are problems of control. The ingredients for a good thermal environmental system, then, are a supply of fresh air, with the air contaminants removed. If the air is at an abnormally low or high temperature, it has to be treated -- either heated or cooled. We have to have proper humidification, and finally we should constantly circulate this air.

Let's look for a time at why schools should be air conditioned. Rather than insist that schools be air conditioned, perhaps we should ask the question, "Why should schools be air conditioned?" This is what the voter is going to ask. And he is not going to take a statement and believe it. He's going to question closely this expense. First, most vocational technical schools are being planned for 12 months. If you're going to use that school during the summer period, air conditioning is certainly important. If the requirements that we have set forth have any validity at all, then I think that we should recall that even in the heating periods, air conditioning or cooling in some manner may be important.

We do have a communication problem and that centers on the reaction of the public to the term "air conditioning" and I wish we could find another term. There is a built-in resistance on the part of a good many people, who perhaps do not have air conditioning in their homes, because they feel that it is a terribly extravagant frill. At any rate, we have a public relations problem. As educators, as architects, as industrial people, we must school the public on the necessity of establishing a good thermal environment.

Let's look briefly at the various methods of air conditioning that can be accomplished in the school building and also examine their cost.

The system similar to the SCSD solution came out at *about $750 a ton. The mechanical costs for SCSD have been maintained at virtually the same level as they were 4 years ago when they were figured. The gas-fired, multi-zone, on-the-roof type has some obvious advantages. You put the system on the roof and generally speaking you do not lose any building space. You still need some space, of course, for incinerators, water heating, and so on. Reference here is only to the heating and cooling equipment. We could take the same equipment and put it inside a building which will require about 300 square feet for every 60 tons of cooling capacity. If we use a hot water system, and use a direct expansion coil, the price goes up some, as do also the spatial requirements. Space requirements do increase if you go to a hot water and chilled water system with a four-pipe distribution system.*

What is clear to the environmental specialist is that the school must be capable of changing thermally just as much as the physical spaces must lend themselves to change. A school without flexibility is obsolete the first day that students walk in the door. The traditional school has been a series of inflexible boxes which, among other things, contribute to some thermal difficulties.

Now let's consider the design of air conditioning for schools. Teaching methods evidently become obsolete faster than General Motors cars. We now need, for instance, the ability with audio-visual to darken the room and to lighten it. In the past when the budgets were drawn and air condition-

ing was merely added to the conventional design of the school, the School Board went carefully over the bid. The first thing that was cut out of the job was air conditioning. Nobody really thought about it as being a design problem. Frequently, air conditioning can become a design tool and this is the way we are beginning to use it. As such, the basic space requirements can be met at less cost. Let's see just what kind of savings we can get from proper design. Basically, if you can cut down on the perimeter construction of a school you're going to save money. In Atlanta, Georgia, the vocational technical school reduced its exterior walls by 2,593 lineal feet. By reducing that amount of lineal dimension, they saved more than a quarter of a million dollars on construction, or more than enough to cover air conditioning.

Some types of insulation can also reduce cooling requirements by one ton for every six classrooms or about $750. But more important than that, for every ton reduced, you reduce the operating cost. That continues for the entire life of the building. Again, insulation has a place. You can, of course, over-insulate. You have to trade off now the added cost of insulation against the reduction in cooling. If we can reduce the number of window frames and their installation, we can save for a normal-sized window about $50 to $60. Along with this, glass breakage can be a major problem in many of your more metropolitan areas and, glass must be covered with shades or drapes if you're going to employ audio-visual teaching. Again, I'm not against glass -- if you want to use it, fine, but bear in mind that glass effects your thermo-environmental system, and other factors, too.

Entrances that are faced away from the prevailing winds reduce the heat loss. But windows that are protected by shade trees will reduce solar gain. Also, if you can face windows to the north or to the east you will reduce the amount of solar gain that comes in through them. If the building has a narrow dimension and you can use that dimension on an east to west axis, you are better off than putting the long dimension facing the west where you get a greater sun gain.

We think a good thermal environment can reduce the number of doors. The door is a kind of traditional thing. We've always had them, but we need not always retain them. A door is not necessarily a means of entering. Frequently a door is a means of keeping people out. I think in any part of our educational facility we want to invite as many people into the facility as we possibly can.

In a good thermal environment we can also achieve savings if we go overhead, some pipe tunneling, and trenching. We can reduce equipment rooms, too, if this seems to be desirable for the school. In an equipment room that's reduced to $15 per square foot, for instance, you can save $7,500 to $12,000 on non-teaching space. These are things to at least consider. A good thermal environment should have outside air introduced into the building under controlled conditions. Now, the real value here, in addition to freshening the air, is that for temperatures down to 20 *to 30 degrees, I can use that air that's outside at that temperature and cool with it rather than start my compressors and use electrical power.*

What are the benefits of a good thermal environment? Well, with a good thermal environment, students learn more. This, I think, has been fairly well substantiated in reports available. Figures have shown that 23% of the elementary students improved their grades in a proper thermal environment compared to kids in an identical space adjacent to them. We are now undertaking a full year study on this kind of comparison. What about the thermal effect on teachers? I think here is one of the real indirect benefits because the recruitment of teachers can be a very difficult problem today. It has become very competitive and I'll bet that if you have an air conditioned school you will have more applicants for your good jobs than if you are trying to bring them into a non-air conditioned facility. Good thermal environment not only attracts good teachers, but allows the teacher to perform at a higher level of efficiency. It reduces his or her fatigue. It does all of the things for the teacher that we have been talking about for the student, and yet, it's just as important for teachers as it is for students.

A good thermal environmental system will allow windows to be closed and the air filtered, which will reduce cleaning within the building itself. This is quite significant. The glass reduction that air conditioning will allow will also reduce vandalism and glass breakage. We have found that for every dollar that you can save on maintenance and operational costs per year, you can afford to put about $8.00 more into your initial structure.

Many specifications are requiring maintenance and service contracts to be offered by the equipment manufacturers. SCSD required this. It is changing the structure of our company because we are going into the service and maintenance business on a national scale. Here is what it does. When you as the educator or as the architect specify that the manufacturer who is going to supply the equipment shall be responsible for that equipment for a minimum period of five years, with an option for an additional 15 years, the manufacturer who is putting the component parts into that product is going to look pretty carefully at each piece and each part because it's his baby should it prove faulty. He must pay for the replacement components and this insures a higher level of maintenance at a lower overall cost. Our maintenance costs are now running between 3 and 4 percent per year. It can go down from that point. That 3 and 4 percent figure is computed on the installed cost of the mechanical system. A service contract can be tailored to fit the local maintenance program. In other words, if a school district has extensive maintenance personnel, we can write a service contract merely to come in four times a year and do a total inspection and an on-site adjustment. The rest of the year the local district maintains the product. If you have a small school with no maintenance personnel, then you can buy a total maintenance program. I think you are going to find more and more emphasis on maintenance in the immediate future. Air conditioning is not a frill today, nor is it a luxury; rather, it has become just as important as the bricks, the blocks, the roof, and even the teachers. An air conditioned school will not give you a good educational program, but a good educational program will function better in a good thermal environment which, of course, would include air conditioning. With air conditioning, you'll also find other groups utilizing the facility more for evening meetings, and for important gatherings. The school library can do double duty in a small community by serving as a community library, as well. Round-the-clock utilization reflects back again to a sound thermal environment. With a flexible, adaptable thermal environment in your school you have laid the groundwork for an educational facility prepared to serve you and your community at an optimum level of efficiency.