IEA ECBCS Annex 36: Retrofitting in Educational Buildings – Energy Concept Adviser for Technical Retrofit Measures

SUBTASK A

Overview of Retrofitting Measures

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Chapter 5

Solar control and cooling systems

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5.3. Cooling Systems

The control of the environmental conditions for educational facilities directly impacts the performance of the students and staff that occupy the space. One of the elements which control environmental conditions is the cooling (air conditioning) system selected. There are five categories of cooling systems with several variations within each. This section will highlight these five categories looking at appropriate climate zones to use, cost effectiveness, benefits, and operation and maintenance.

The five categories cooling to be described are:

a. Natural
b. Evaporative
c. Direct expansion
d. Chilled Water Plant
e. Geo-Exchange

Natural Cooling – There are two methods of providing natural cooling (ventilation): Cross and Stacked.

a. **Cross ventilation/cooling –** This method depends on the movement of air through the space to equalize the pressure. Wind, which blows against a wall or barrier is deflected around and above the barrier creating a higher pressure on the windward side of the building. The pressure on the leeward side of the building then has a lower pressure creating a suction and thus a pressure differential. When windows or other means of ventilation are opened, the outdoor air enters on the windward side moving to the lower pressure area. The movement across the teaching space, results in exhausting the internal air and cooling the space.

This method is very effective in mild climates and coastal climates. In coastal climates the need for a cooling system will almost be eliminated. This method does require an initial greater up front cost for operable windows which can range from 42 Euros to 62 Euros per classroom.

The benefits from using cross ventilation/cooling are:

1. In moderate climates meet most of the cooling load needs
2. Simple pay back for inclusion of this method from 8 to 10 years
3. Better indoor air quality
4. Simple to install and little maintenance
5. Give occupants a sense of individual control

b. Stack ventilation/cooling – This method depend on the difference in air densities to

Provide air movement in the teaching space. Two vents are needed for this method to work: One Close to the floor and the other high in the space. Warmed by internal loads (student/faculty, lights, and equipment) the indoor air rises. The warmer the air the less dense and it rises. This rising of the warmer air creates a vertical pressure gradient. The vent close to the system will allow the rising warmer air to escape and as it escapes it will draw in cooler air from the lower vent to replace it. Thus causing air movement and cooling of the space.

This method like the cross ventilation/cooling is very effective in mild and coastal climates. This method is especially effective in the winter when inside-outside temperature differential is at its maximum. And during mild weather conditions it can meet most of the cooling requirements. The benefits are the same as above as are the cost effectiveness.

Evaporative Cooling

Evaporative cooling is an alternative to air-conditioning with low energy costs because no compressor is needed, only a fan and a pump. This method is good for educational areas with high outside air ventilation requirements. Evaporative cooling can be either direct or indirect. Direct cooling involves the water being exposed to an air stream. This happens when water flows over a medium designed to maximize the surface area of water in contact with the air and air is cooled through evaporation. Effectiveness can be as high as 80 – 90%. Example: 26.7C air dry-blub with a 10C wetbulb, then the leaving air is cooled to 11.7C to 24.4C drybulb.
Indirect evaporative cooling is not as effective as direct, but adds no moisture to the air. Air passes over and through a cooling coil supplied with water from a remote cooling tower. This method is only 60% effective in reducing the dry blub temperature of the entering air to its wetblub temperature. When the direct method provides 22.2C to 23.3C air in the above example then indirect would only provide 25.6C air.
Initial installation costs are more than a typical AC unit the operating costs are significantly less. It is cost effective in warm and dry climates when higher indoor temperatures are acceptable during hot periods.

Direct Expansion Cooling

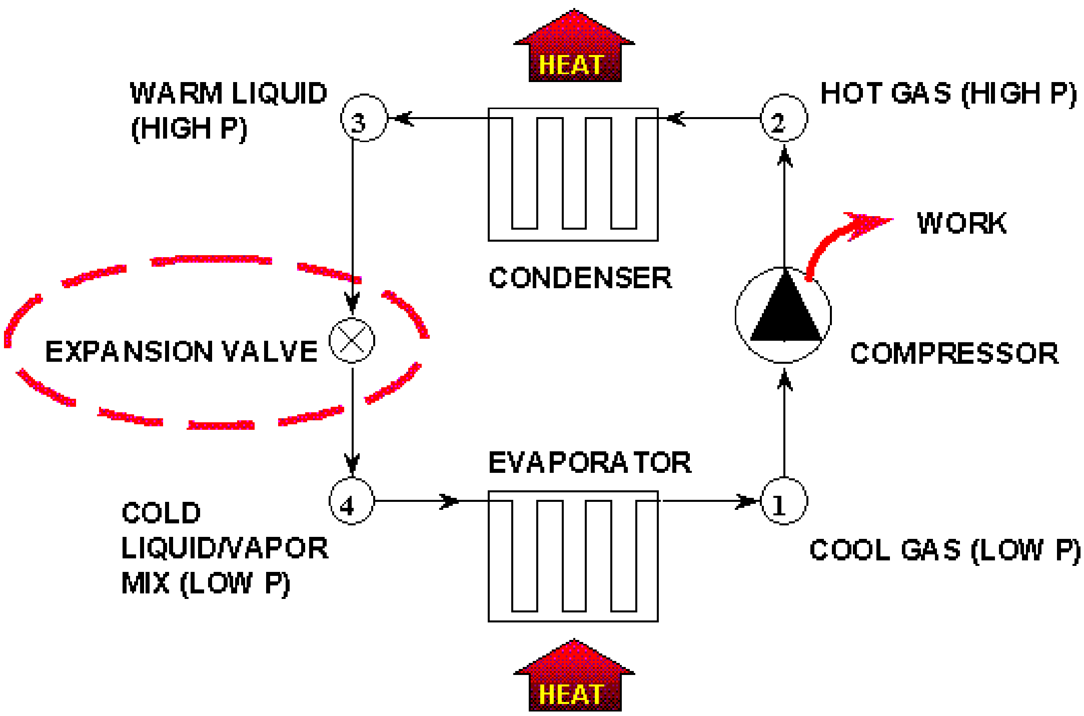

Fig. 5.2. The flow diagram of Direct Expansion Cooling cycle

Direct Expansion, or "DX", cooling uses the vapour compression refrigeration cycle in which a fluid called a refrigerant moves heat from one part of the cycle to another. The "cool" refrigerant is produced between states 3 and 4, after a large pressure drop (expansion) takes place. Typical devices used to produce the pressure drop include expansion valves, capillary tubes, and orifice plates. The cool refrigerant can then be used as a heat transfer medium in the evaporator to absorb heat where needed. In a normal DX unit this medium in air. DX systems are connected to Air Handling units for distribution of cooled air to specific zones of the educational facility these are know as split-systems.

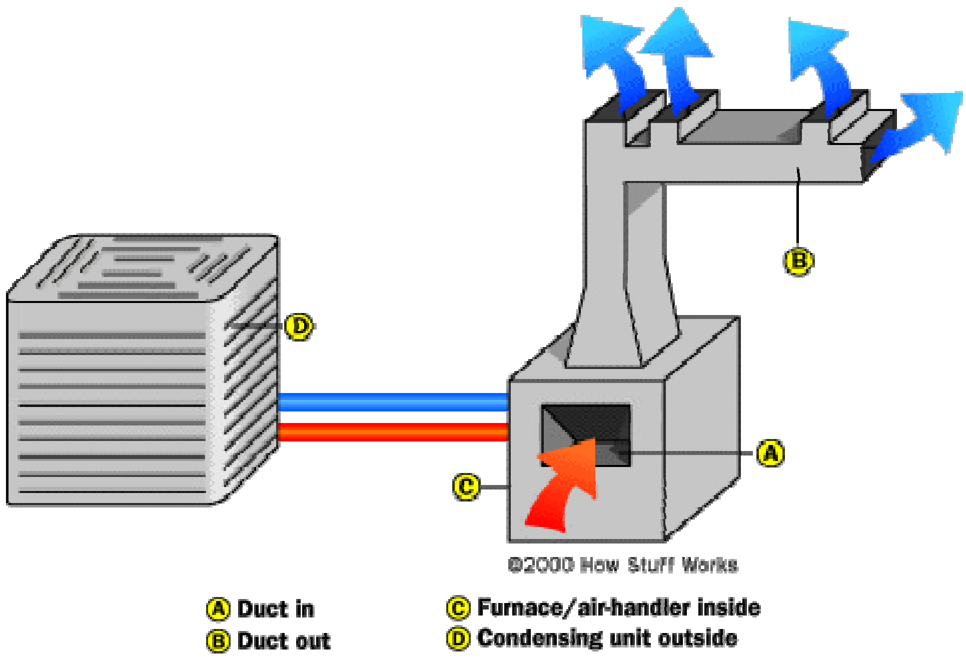

Fig. 5.3. A **split-system air conditioner** splits the hot side from the cold side of the system

The **cold side**, consisting of the expansion valve and the cold coil, is generally placed into a **air handler**. The air handler blows air through the coil and routes the air throughout the building using a series of ducts. The **hot side**, known as the **condensing unit**, lives outside the educational facility and in most cases on the roof. In other systems the medium will be a liquid which is normally a treated water.

Chilled-water System

In larger educational buildings and particularly in multi-story educational buildings, the split-system approach begins to run into problems. Either running the pipe between the condenser and the air handler exceeds distance limitations (runs that are too long start to cause lubrication difficulties in the compressor), or the amount of duct work and the length of ducts becomes unmanageable. At this point, it is time to think about a **chilled-water system**.

In a chilled-water system, the entire system lives in a mechanical room or behind the building. It cools water to between 40 and 45 F (4.4 and 7.2 C). This chilled water is then piped throughout the building and connected to air handlers as needed. There is no practical limit to the length of a chilled-water pipe if it is well-insulated.

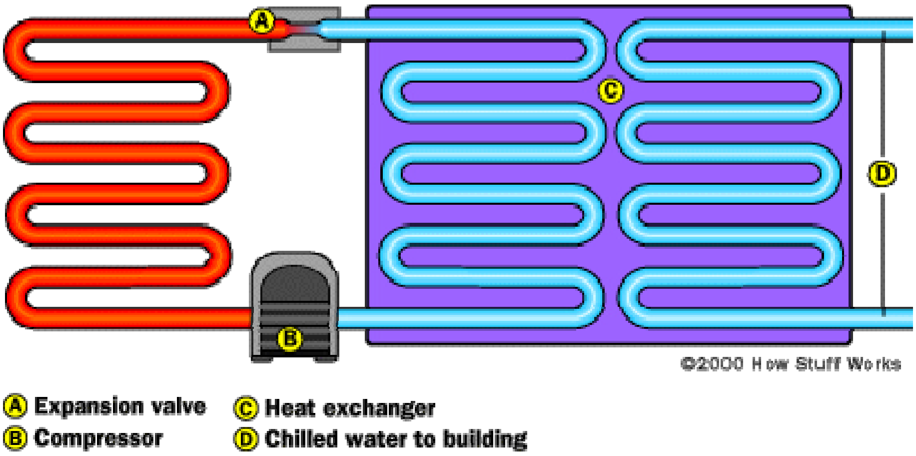

Fig. 5.4. Cooling Tower

You can see in this diagram that the air conditioner (on the left) is completely standard. The heat exchanger lets the cold Freon chill the water that runs throughout the building. To obtain maximum cooling capability of the Water in ©, a cooling tower is added in the flow of water in (D) to remove the heat gained while in the building and before it returns to © to be chilled again. Cooling towers fall into two configurations: Direct and Indirect. The direct one is when the fluid in D comes in direct contact with air in the cooling tower and is cooled. The other is indirect and the fluid is cooled by cascading water over the outside of the tubes. Air flow through the towers can be by either force draft (blown air through the tower) or induced draft (air pulled through the tower).

<u>Geo-Exchange</u>

The earth around an educational facility can serve as a heat and cooling source. These system are known by many names include geothermal, earth-coupled, ground-coupled, close-loop and water-coupled. They all use a fluid transported by a hydronic system through a Ground Source Heat Pump (GSHP) to either remove heat from the ground to the air in a space when heat is needed or to transfer the heat from a space to the ground when cooling is required using a refrigeration cycle.

Fig. 5.5. Typical Ground Source Heat Pumps for Varied Requirements

There are two types of geo exchange systems: Open-loop and Closed-loop. An open-loop system takes water directly from a well, lake, stream or other source and passes it directly through condenser loop GSHP. When cooling, the water is warmed as it passes through the condenser loop and the water is returned to the lake or stream or to another well. These systems have limited use. The system that is used the most is the closed loop system. This system circulates a fluid (usually containing a substance that prevents freezing in cold weather) through a subsurface loop of pipe to a heat pump. See illustration below.

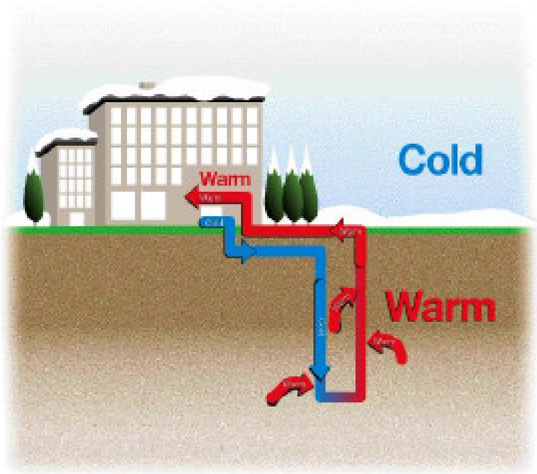

Fig. 5.6. Typical Geo Exchange Closed Loop Diagram

The subsurface loop typically consists of polyethylene pipe, which can be placed horizontally in a trench or vertically in a well. This pipe can also be placed in a pond or lake in coils to serve the same purpose. This thin-walled pipe is a heat exchanger, transferring heat to and from the earth. The earth temperature normally ranges from 10 to 15 (50 – 60 F) degrees C. The fluid inside the pipe circulates to the heat exchanger of an indoor heat pump where the exchange takes place with the refrigerant. The use of GSHP, allow for individual controls in the classrooms and allows for heating and cooling to occur at the same time in a educational building.
Cost of these system are normally more costly than a typical system from 10-15% but this first cost is offset by a 20-50% reduction in energy costs and a 30% reduction in maintenance costs. Payback for a typical Geo-exchange system ranges from 5 to 10 years. These systems can reduce peak energy demand and reduce the heat island effect, since waste heat is returned to the ground and not to the air.
All of the cooling systems described above are used in different configuration for installation in schools. The next section will describe air conditioning installations.

References:

[1]. PASCOOL Final report: Model development subgroup – Volume 2: Solar control. Editor S.Sciuto. Project coordinators: M. Santamouris and A. Argiriou. 1993.

[2]. Daylight Performance of Buildings. Edited by Fontoynont M. Published by James & James. 1999.

[3]. Properties of glazings for daylighting applications-Final report EEC-JOULE Sept. 1995.

[4]. Passive Solar Schools – A design Guide. Building Bulletin 79. Architects and Building Division. UK Department of Education. Published by HMSO London. 1994.

[5]. Horizontal study on passive cooling for buildings. EEC Building 2000. Final report. 1989.