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USES, ADVANTAGES AND LIMITATIONS OF EVAPORATIVE COOLERS

Assoc. Prof. Dr. Osama Mohammed Elmardi Suleiman Khayal
Department of Mechanical Engineering
Nile Valley University, Atbara, River Nile, Sudan

Assoc. Prof. Dr. Elhassan Bashier Elagab
Department of Electrical and Electronic Engineering
Nile Valley University, Atbara, River Nile, Sudan

Abstract— **the benefits and advantages of an evaporative cooler, also known as swamp cooler, air cooler, or desert cooler include inexpensive price and lower energy consumption, as well as easier and inexpensive installation and maintenance, when compared to traditional air conditioners; and suitability for use in dry and arid climates, especially during hot and dry weather conditions.**
On the other hand, the disadvantages of an evaporative cooler center primarily on the negative impacts of too much humidification. These disadvantages translate further to more specific limitations and drawbacks. For example, using an evaporative cooler for prolonged period of time or under a hot and humid weather increase health-related risks such as respiratory distress, as well as the susceptibility of wood-based, paper-based, and electronic products.
Evaporative cooling has both advantages and disadvantages, and the choice rests with the individual Homeowner. Therefore, the consumers should investigate all the alternatives and then make the right decision based on technical specifications, cost preference, lifestyle and individual priorities.

Keywords— **Components, advantages, limitations, evaporative cooler, maintenance**

I. INTRODUCTION

Most world population residing in hot regions have traditionally regarded evaporative cooling as a good way to keep cool in the summer. Before the advent of residential air-conditioning it was the only mechanical means available to make home interiors livable in the hot, dry, desert summers. Evaporative coolers function well except for the few weeks of the summer "monsoon" season with its accompanying elevated humidity and thus decreased cooler efficiency. These cooling systems are economical in terms of energy usage. During the energy crunches of the last four decades, evaporative cooler use was promoted as one means to control household utility bills. However, little thought was given to cooler water consumption. With rapidly increasing population, warm temperatures, and limited water supply, evaporative cooler water usage can no longer be ignored.

With conservation as the cornerstone of the Groundwater Management Act, researchers at The University of Arizona Office of Arid Lands Studies developed in the mid-1980s a W-Index or index of residential water efficiency. The index was proposed as a device to evaluate residential water savings and as a management tool to motivate water-saving practices [1]. The researchers noted that for home cooling, the highest index rating is received for having no evaporative cooler, the alternative being air-conditioning which although using more energy, uses practically no on-site water. This advice flies in the face of all the energy-conservation practices supported by utility companies, industry and educational institutions and leads to confusion with mixed messages to consumers.

In arid and semi-arid regions consumers have learned that air conditioning uses three to five times as much electricity to cool their homes as evaporative cooling. They know how much their utility bills rise in the summer months. Some have added evaporative cooling for use during the hot, dry summer months and switch to air conditioning during the "monsoon" season.

Others have changed over completely to evaporative cooling, reducing their cooling utility bills. Yet evaporative cooling consumes significant amounts of water, and water is a precious and increasingly costly commodity in most of the universe.

How much water does an evaporative cooler use. Data for evaporative cooler water use are scarce since little research on this topic has been undertaken, and many factors, from household composition to location of the cooler, influence cooler water use. In Cool Houses for Desert Suburbs, Jeffrey Cook, a Phoenix architect, estimates that a 4500 CFM (cubic foot per minute) cooler, under certain weather conditions, uses 200 gallons of water per day [2]**.**

On the other hand, in a television interview in Tucson in September 1990, a Tucson Water Company employee stated that an evaporative cooler could be able to cool a 1,500 square foot home uses approximately four gallons of water per hour or 96 gallons per day, an estimate 50 percent lower than

Cook's. Further, the Arizona Department of Water Resources estimates that a typical Tucson household cooler uses a year-round average of 16 gallons per day [3]. These projections of water use convert to annual water costs in Tucson ranging from about $16 to $97 for a 26-week cooling season.

A research study was initiated by the Office of Arid Lands Studies at the University of Arizona and the Water Services Department at The City of Phoenix with funding from the Arizona Department of Water Resources. This study monitored evaporative coolers at 46 homes in Phoenix. The preliminary data from this study indicates that water usage of an evaporative cooler in Phoenix was about 7.6 gallons for each hour that the cooler was operated (4.4 gallons per hour for systems without bleed-off and 10.4 gallons per hour for systems with bleed-off) [4].

II. MAJOR COMPONENTS AND FUNCTIONS OF EVAPORATIVE COOLERS

A. Major Parts of an Evaporative Cooler

The typical evaporative cooler consists of eight major parts: housing (metal or fiberglass), a blower, recirculating water pump, water reservoir, float valve, pads, water distribution lines, and electric motor.

B. Work Principle of an Evaporative Cooler

The cooling process works on the principle of evaporation of moisture. The fan of the cooler draws outside air through pads soaked with water. The evaporation of the water lowers the temperature of the air passing through the wet pads of the cooler. This cooled air is blown through an opening into the building.

The movement of the cooled air is directed by the homeowner by means of ducts to appropriate areas around the home and exhausted from partially opened windows, doors or ceiling ducts.

C. Ways to Use Evaporative Coolers

There are three ways to use evaporative cooling: (1) as the sole cooling system, (2) as a second alternative cooling system to refrigeration (air conditioning, heat pump), and (3) as a "dual" or "combined" system with a refrigeration system.

One advantage to having both systems is that you get the better of two worlds - evaporative cooling during the dry months in spring and fall, and refrigeration in the hot summer months when the temperature and humidity are higher.

Despite the convenience of the combined system, there are drawbacks. For example, considerable air movement is required for comfort with evaporative cooling. Refrigeration ducts are often too small for this and result in insufficient air flow and more noise. Also from the utility standpoint, the use of both systems results in an enhancement of the peaking problem for both water and power suppliers and, therefore, contribute to the need for additional capacity of these systems which are poorly utilized in off-peak demand periods.

For systems using shared ductwork, dampers must be installed to separate the two units. Without dampers, refrigerated air will escape to the outside through the evaporative cooler and, conversely, moist air from the evaporative cooler will enter and corrode the refrigeration unit. Many systems have dampers that are automatic. They should be checked annually for correct operation.

Care must be used when operating the evaporative cooler and refrigeration unit alternately. The refrigeration system will work much harder than normal since it has to remove the moisture brought into the house by the evaporative cooler. Moisture from the cooler will condense on the refrigerant coil and increase electrical costs appreciably; therefore, one should not directly precool air to be refrigerated [5]. Figs. 1 and 2 below show two types of cooling pad elements.

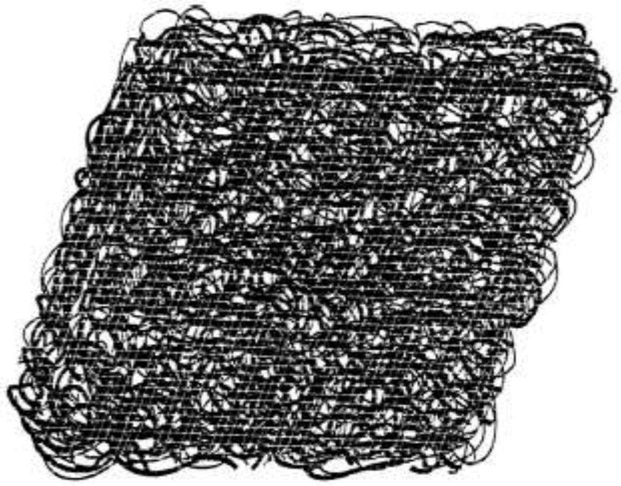

Fig. 1 Aspen wood fiber pad

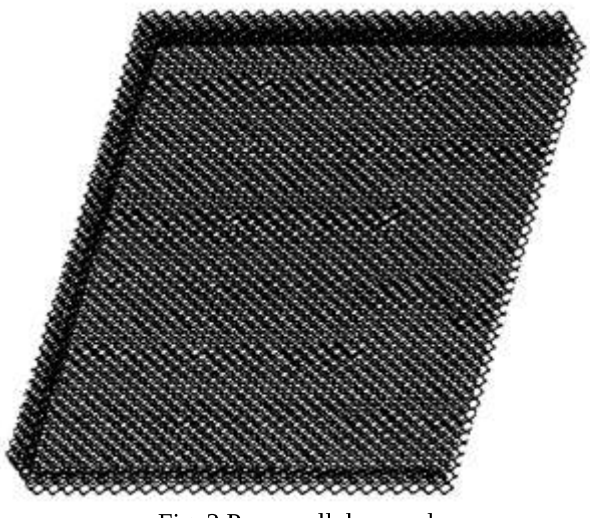

Fig. 2 Paper cellulose pad

D. Placement of Coolers on Buildings

Evaporative coolers can be classified according to the position of the cooler in relation to the building. Generally, there are three types: (a) down-draft (roof mounted), (b) side-draft (typically eave or window mounted), and (c) up-draft (ground mounted).

Roof mounted, down-draft coolers (a) are sometimes preferred since they can usually be more readily connected to duct systems and are out of the way on the roof. However, eave mounted (b) or ground mounted (c) units can be more easily and safely serviced since the person doing the maintenance does not have to use a ladder to inspect or repair the system. Figs. 3 and 4.

E. Use of Water by Coolers

The use of water by coolers is generally dependent on their size, air movement and relative humidity of the air. Therefore, all things being equal, a 4500 CFM cooler uses less water than a 6000 CFM cooler. Research is showing that some units appear to more efficiently evaporate water and, thus, produce more cooling per unit of water use [6].

F. Selection of the Right Size of Coolers

A simple formula can help you decide. First, you'll need to determine your home's cubic footage. Multiply the square footage (length by width) of the floor area by the ceiling height and divide by two. For example, a 1600 square foot home multiplied by a ceiling height of eight feet is 12,800 cubic feet, divided by two is 6400. An evaporative cooler with a CFM number closest to 6400 should be adequate for your home. CFM are usually clearly marked on the front of the cooler. Consult with your cooler supplier about cooler size. Too large or too small coolers are wasteful of both water and energy and will not provide the comfort or efficient use of resources you are seeking for your home.

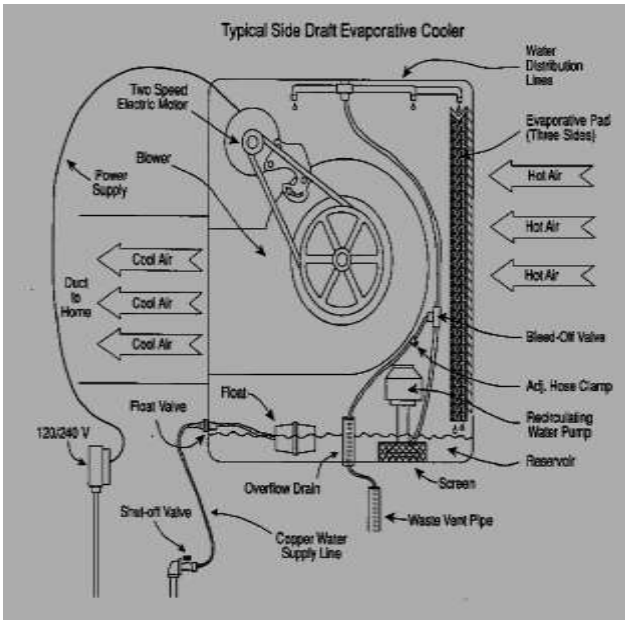

Fig. 3 Typical side draft evaporative cooler

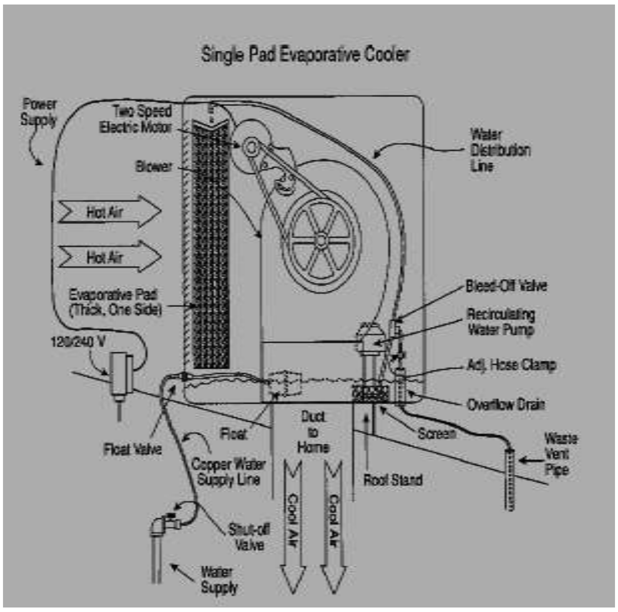

Fig. 4 Single pad evaporative cooler

G. The Advantage of a Two-Speed Cooler System

The advantage of a two-speed system is that low speed can be used at night when exterior temperatures drop or on days when temperatures are not excessive. Low speed could also be used during the day when family members are working. When family members return home, high speed would quickly lower the temperature. Coolers usually run more quietly at low speed and provide about 66 percent of the airflow of high speed. They also use about 30 percent of the energy needed to run the cooler at high speed, thus reducing operating costs. Many individuals believe it is more economical overall to leave the coolers off when the building is not occupied.

H. Use of Water When Operating the Cooler System At Low Speed

The amount of cooling generated by an evaporative cooler is a function of the amount of evaporation that occurs in the unit. Increased dry air movement over the wet cooler pads will increase the amount of evaporation and produce more cool air. At the same time, decreased air movement will decrease the amount of water used for cooling, while the bleed-off rate will remain the same.

I. Maintenance of Evaporative Coolers

A cooler should be inspected monthly and serviced as needed during operation. The owner's manual should be read to determine if more frequent servicing is required. Before starting any maintenance operations, read all operating and maintenance instructions and observe all cautions and warnings. During these maintenance inspections all parts should be inspected for wear or damage. Belt tension and water level in the reservoir should be checked. Since cooling efficiency

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is determined by how much water is evaporated, it is important to see that the pads receive a uniform wetting and be thoroughly wet at all times to provide the most cooling. Dry spots will greatly decrease cooling efficiency. The Arizona Department of Commerce Energy Office publishes a pamphlet that describes in detail cooler maintenance procedures [7].

J. Advantage of Using Thermostat

A thermostat can be set to start the cooler when a certain temperature, for example 80 degrees, is reached in the home. When the cooler is not operating, it is using neither water nor energy. Thermostats cost from $30.00 - $45.00. Timers can also be used to start the cooler and begin the cooling of the home prior to the arrival of the family. The use of 2 function thermostats starts the wetting of the cooler pads prior to air movement and thus prevents the blowing of dry air into the residence.

K. Recommended Types of Pads

Cooler pads (sometimes called media) come in several alternatives. University of Arizona agriculture engineers have long recommended aspen wood fiber pads. They are encased in chemically treated cheesecloth to absorb more water, and they offer the least amount of resistance to air flow through the cooler. Aspen wood pads can be used for an entire cooling season. Although aspen wood pads are efficient in distributing cooled air, they may also produce debris in the water reservoir, increasing cooler maintenance. Some cooler manufacturers recommend a cellulose fiber media or pad for use with their equipment. The media is said to be uniform throughout, to provide consistent cooling performance and to last for several seasons. They are superior to spun aluminum and plastic pads available at hardware or do-it-yourself stores or supermarkets. These are less expensive initially than aspen wood but may need to be changed several times in one cooling season.

The newer single pad coolers require a much thicker pad. This type of pad is more expensive than
the traditional aspen wood fiber pad but is designed to last for several years if the cooler is operated in compliance with the owner's manual.

L. Effect of Minerals in Hard Water in the Operation of Evaporative Coolers

Mineral deposits and scale build-up caused by hard water can cause rust and corrosion in metal coolers. Some estimates are that this rust and corrosion can shorten a cooler's life by 50 percent. Further, scale build-up on cooler pads can cause uneven distribution of water, leading to "hot spots" on the pads and reduced cooling because of reduced air flow. Some manufacturers recommend installing a "bleed-off" valve to the recirculating water line. A bleed-off valve is installed in the recirculating line and is typically connected to a drain line or directed to irrigate turf areas or other landscaping. This results in draining part of the recirculating water, reducing buildup of hard water minerals. Bleed-off valves are controversial because it is estimated that they increase cooler water usage from 10 to 50 percent. Data from the Phoenix cooler study indicates that bleed-off systems use an average of about 8,650 gallons during the cooling season [6]. Horticulture specialists discourage collecting bleed-off water for irrigating plants. The high concentration of minerals in the water may kill or damage plants [8]. The high salt content also can result in the sealing of soils, especially soils with a high clay content, thus preventing moisture penetration. Some plant species such as Bermuda and salt grass can tolerate the high salt content water [9]. Bill Witschi, the Water Systems Manager at the University of Arizona, suggests that bleed-off should be about 1/3 makeup water. The rate could be lowered if no scale is observed forming on the cooler pads [10].

M. Increasing Cooler Life

Thorough cleaning of the cooler is suggested to remove mineral deposits and scale build-up at least once during the cooling season. Additives to the water supply also are available to help reduce scale build-up. Chemicals will not reduce scale build-up but they can increase the solubility of calcium and other minerals, thus allowing a lower bleed-off rate, or they can combine with the calcium and produce a softer scale that is easier to remove. Some cooler manufacturers do not recommend their use because they may damage the protective coating on the cooler. Caution should also be exercised about what chemicals are used because these can be blown into the home during the normal operation of the cooler [11]. Ask your cooler supplier. However, you may have to replace the cooler sooner than you would if you used a bleed-off valve.

N. Circulating Air without Water

With cool air in the evening and nighttime hours, the cooler fan can be run with dry pads. This brings cool air into the home and circulates it without using water. Ceiling and/or oscillating fans used in occupied rooms can help circulate the air for increased comfort. If cooler pads have been allowed to dry out, either through non-use or by circulating air only, it is advisable to run the pump and saturate the pads thoroughly before running the cooler fan. This ensures that cooler air begins to circulate sooner and reduces the introduction of dust and pollen into the home.

If you switch to air conditioning during the "monsoon" season and then switch back to the evaporative cooler as the relative humidity decreases at the end of the rainy season, remember that standing water in the cooler pan is a stagnant pool. This water can become a good place for the growth of bacteria, even the bacteria that causes Legionnaire's Disease. For safety it is best to drain the cooler if it will not be used for several days. Alternatively, the water in the cooler pan can be treated with chlorine for at least 30 minutes before turning the cooler back on.

O. Using Softened Water to Operate Evaporative Coolers
The sodium added to water by water softening will accumulate on the cooler pads and will become concentrated in the water reservoir. Softened water also may increase the need for pad maintenance and the rate of rusting of metal cooler parts.

P. Function of Ceiling Vents
Ceiling vents or open windows are required to permit the exhaustion of the air blown into the home by the blower. Unlike refrigeration systems which recycle air within the home, coolers blow large volumes of cooled outside air into the living areas, and this air needs to be vented from the home. Ceiling vents make it possible to keep windows and doors closed while the cooler is running. This is helpful for security. These prefabricated exhaust ducts are installed in the ceiling in several rooms of the home. These exhaust air into the attic which must have an adequate amount of vents. UL tested ducts that automatically close in case of fire are available from cooler equipment suppliers. The venting of house air into the attic will also reduce the air temperature in the attic and thus the amount of heat gain in the living area of the home.
Homeowners could also benefit from window stops, available from most hardware stores for almost all types of windows. With stops in place, windows cannot be opened beyond a certain point chosen by the homeowner, usually 6 to 8 inches. They are easy to install, very inexpensive, and discourage entry. Plants with many spines and thorns, such as cactus and other desert species, can also be planted near windows to enhance security.

Q. Cost of Operating an Evaporative Cooler
Studies have indicated that the average annual cooling energy usage for a 1,600 square foot home is approximately 6,000 kilowatt hours for refrigeration and 1,500 kilowatt hours for evaporative cooling.
If electricity costs were 0.15 Sudanese pounds per kilowatt hour (a sample cost), the average annual cost would be 900.00 Sudanese pounds for a refrigeration system versus 225.00 Sudanese pounds for evaporative cooling. However, the cost of water must be added to the electricity cost for evaporative cooling, but it is too small to be added, therefore it can be neglected.

R. Reasons for Covering Coolers during Winter Season
A cooler cover can provide protection for the cooler from rain, dust, and wind, and this helps to extend the life of the unit.

III. ADVANTAGES AND LIMITATIONS OF EVAPORATIVE COOLERS

Like any other space heating or cooling system, evaporative coolers have advantages and disadvantages. Listed below are points consumers should weigh carefully in deciding how to cool their homes for summer comfort while trying to conserve water and energy, not only for the present but for future generations.

A. Advantages of Evaporative Coolers
1. Coolers are economical to operate, using one-third the energy of refrigerated air-conditioning.
2. Installing a new evaporative cooling system adequate for a 1,500-square-foot home costs about $700. For the same home, installing a new air-conditioning system, using existing duct work, costs about $2,500.
3. Most cooler maintenance and repairs can be accomplished by the homeowner.
4. Most cooler replacement parts (pads, belts, etc.) are nominal in cost when compared to air-conditioning system replacement parts.
5. Coolers bring fresh, cooled, outside air into the home.
6. Coolers provide a healthy environment for plants.

A. Limitations of Evaporative Coolers
1. Coolers use on-site water, a non-renewable resource in some parts of the world, for cooling.
2. Coolers are aesthetically unattractive if not maintained and overflow of concentrated salts from the cooler can damage roofs.
3. Air velocity when operating on high speed may cause annoying noise.
4. Open windows to exhaust air may be a security hazard. This can be overcome by installing ceiling vents. Adequate attic ventilation is necessary for ceiling vents to function properly.
5. Cooled air may bring dust and pollen into the home causing discomfort for allergy sufferers. Growth of microorganisms such as molds on the cooler pads may cause allergy problems in sensitive individuals.
6. Coolers require regular maintenance, difficult if the cooler is roof-mounted.

IV. THINGS TO CONSIDER BEFORE DECIDING TO BUY AN EVAPORATIVE COOLER

The first is cost. Get at least three estimates from reliable cooling suppliers or contractors in your community, and don’t forget to include the hidden costs, like installation, maintenance, and operational costs of utilities (electricity and water).
Perhaps the greatest advantage of evaporative cooling is the low cost: about one-third as much as refrigeration. The costs for operating a system will depend on the size and number of units, and how homeowners choose to run the evaporative cooler or refrigeration unit and the overall thermal properties of the home (insulation, thermal mass, amount of window area, orientation of the structure).
The next consideration is comfort. Evaporative cooling cannot keep every home comfortable all the time. A typical desert home will not be able to achieve temperatures in what is usually considered the comfort range on days when the humidity is high. Performance can be maximized, however, if all the windows are shaded from direct sunlight, the walls are properly insulated, and protected from direct sunlight,

especially on the east and west sides or passive solar concepts were used in the construction of the home. Keep in mind that air movement, not just air temperature, contributes to comfort: 82 feels like 75 in a moderate breeze. The basic principle of evaporative cooling is simple and in the past the typical coolers were very simple devices. More recently, however, many variations and innovative concepts are being applied to cooler design and construction to achieve cooling efficiency. Therefore, before deciding what type of cooling, air conditioner or heat pump you wish to purchase, shop by comparing their differences, comfort, capital and operating cost. For evaporative coolers compare purchasing and operating costs, pads, construction materials (metal versus fiberglass or stainless steel).

V. CONCLUSIONS

Some of the notable advantages of an evaporative cooler over a traditional air conditioning unit include a more affordable price and lower energy consumption.

The simplicity of an evaporative cooler or swamp cooler when compared to an air conditioner also translates to cheaper installation and maintenance costs. It does not have a compressor and operation revolves chiefly around a fan and a water pump. There are also no special working fluids, especially refrigerants.

Remember that an evaporative reduces air temperature through humidification or more particularly, by increasing the moisture level in the air. Hence, an evaporative cooler works best in areas with dry and arid or desert climates such as the Middle East, North Africa, West Australia, and the American Southwest. This is the reason why an evaporative cooler is also known as a desert cooler.

The aforementioned advantages translate to several specific benefits including improving comfort and decreasing static electricity problems. There are also some health benefits as well. Dry weather dries out the lining of the nose and throat, thus resulting in respiratory distress. It is also important to note that low humidity can damage wooden furniture and can shrink paper-based products such as books and artworks.

The limitations of an evaporative cooler could be summarized in: It cannot lower the ambient temperature as much as a vapor-compression or refrigerant-based air conditioning units. In other words, it is not as effective and as efficient as air conditioners in terms of cooling capacity; an evaporative cooler cannot provide similar thermal comfort. In fact, because it increases humidity in the air, it can actually increase discomfort. There is also a need to use this electric appliance alongside exhaust ducts or open windows, or in the open air to maximize its efficiency; in areas with high relative humidity or during hot and humid weather, using this electronic appliance can increase thermal discomfort [12] – [23].

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