Table 1. Expected results for operating various cooling systems for a 1,500-square-foot area under non-monsoon summer conditions (temperature = 100°F, relative humidity= 10%) and monsoon summer conditions (temperature = 90°F, relative humidity = 50%). Includes maximum temperature reductions (↓Temp) and relative humidity increase (↑RH), energy use, water use during operation and for electric energy generation, hourly operating cost (assuming continuous operation), and unit purchase cost (installation not included).

Tucson Summer Climate	Non-Monsoon Conditions 100°F; 10% RH				Monsoon Conditions 90°F; 50%			
Application	Indoor Cooling*		Outdoor/Ag Cooling†		Indoor Cooling–		Outdoor/Ag Cooling§	
Cooling System	Swamp	A/C	Outdoor Mist	High-Press Fog	Swamp	A/C	Outdoor Mist	High-Press Fog
Max Temp ↓ (°F)	- 20°F	- 40°F	- 35°F	- 40°F	- 10°F	- 40°F	- 15°F	- 20°F
Max RH ↑ (%)	+ 40%	+ 0%	+ 80%	+ 90%	+ 30%	- 30%	+ 40%	+ 50%
Energy Use								
Energy Use (kWh/hr)	0.6	14	1.3	2.5	0.6	14	1.3	2.5
Water Use								
Operation (gal/hr)	7.5	0	45	17	3.8	0	11	5
Electricity Generation** (gal/hr)	0.3	7.0	0.7	1.3	0.3	7.0	0.7	1.3
Total (gal/hr)	7.8	7.0	45.7	18.3	4.2	7.0	11.7	6.3
Energy Cost†† ($/hr)	$0.05	$1.12	$0.10	$0.20	$0.05	$1.12	$0.10	$0.20
Water Cost— ($/hr)	$0.08	$0.0	$0.48	$0.18	$0.04	$0.0	$0.12	$0.05
Unit Cost ($)	$525	$2500	$150	$2000	$525	$2500	$150	$2000

* Indoor cooling systems designed for a 1500-square-ft home.
† Outdoor/Agricultural cooling systems designed for a 1500-square-foot outdoor or agricultural area.
‡ Indoor cooling systems designed for a 1500-square-ft home.
§ Outdoor/Agricultural cooling systems designed for a 1500-square-foot outdoor or agricultural area.
** Water is required to generate electricity. In Tucson, the majority of electricity is generated with coal, which uses 0.5 gallons of water per kWh electricity produced.
†† Hourly operating cost is based on electricity price of 8¢/kWh.
— Water costs assume $0.01/gallon water use for system operation.

References:

Chatterjee, A., M. Lenart. 2007. Cooling systems affect resources, climate, and health. Southwest Climate Outlook. Sept. 2007.

Davis Energy Group. 2004. Advanced evaporative cooling white paper. Prepared for the California Energy Commission. P500-04-016-A1.

Karpiscak, M., M.H. Marion. 1994. Evaporative cooler water use. Arizona Cooperative Extension. http://ag.arizona.edu/pubs/consumer/az9145.pdf

Naughton's, Personal communication with salesman, provided information regarding swamp coolers and AC's.

Sabeh, N.C. 2007. Evaluating and minimizing water use by greenhouse evaporative cooling systems in a semi-arid climate. Dissertation. University of Arizona. Controlled Environment Agriculture Center.

Wikipedia. Evaporative cooler systems. http://en.wikipedia.org/wiki/Evaporative_cooler

ADVANTAGES AND DISADVANTAGES

1. Forcing Air through a Wet Pad

+ Fans ensure evaporation occurs
+ Can control amount of cooling with fans
+ All water is evaporated (no losses)
- Cooling is not uniform ‡ Lowest temperatures near the wet pad
- Need electric power for fans

2. Forcing Water into Dry Air

+ Can cool occupied space more uniformly
+ Low energy use because wind provides air exchange
- Low wind speeds will restrict evaporation
- Need a pump (energy) to boost water pressure
- When evaporation is poor ‡ inefficient water use, wet people, plants, floors, etc.

FACTS AND FIGURES

Increasing airflow (cfm) has a diminishing return on temperature reduction, but always uses more water and energy, and increases capital and operation costs.

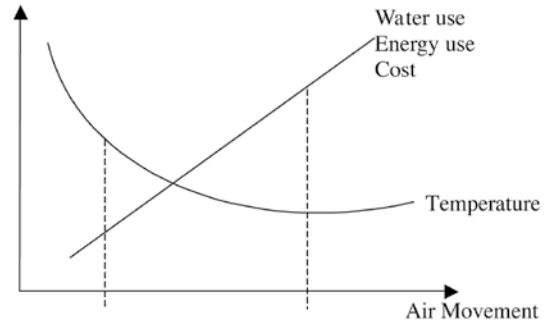


Figure 1. Operational diagram of a common household swamp cooler. Courtesy of wikipedia.

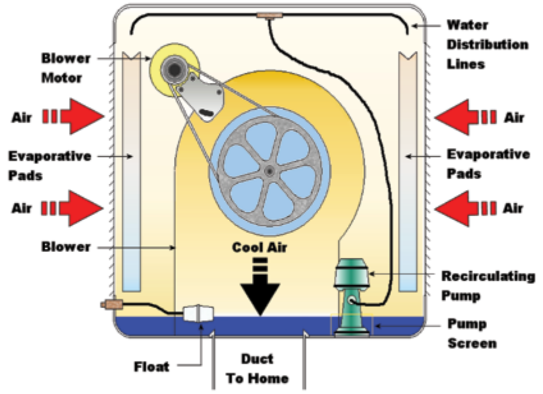
Partnered with:
Cooperative Extension

Funded by:
U.S. Dept of Interior, Bureau of Reclamation

ARIZONA COOPERATIVE EXTENSION
COLLEGE OF AGRICULTURE AND LIFE SCIENCES

Evaporative Cooling In Semi-arid Climates

How homeowners and horticulture/agriculture users can improve performance and save water



AZ1444 05/08

The University of Arizona
College of Agriculture and Life Sciences
Tucson, Arizona 85721

Gene Giacomelli
Director, Controlled Environment Agriculture Program

Nadia Sabeh
Graduate Student - Controlled Environment Agriculture Program

Contact:
Gene Giacomelli
giacomel@ag.arizona.edu

This Information has been reviewed by University Faculty.
cals.arizona.edu/pubs/water/az1444.pdf

WHAT IS EVAPORATIVE COOLING?

Definition:

Evaporating water to reduce air temperature and increase air humidity. This process occurs when heat in the air is transferred to the water, causing it to evaporate.

Examples:

- Sweating/Perspiring
- "Swamp Coolers"
- Outdoor Misters

Reasons to Use Evaporative Cooling:

- Uses less energy than air-conditioning systems
- Alleviates health problems associated with dry air and "sick building syndrome"
- Reduces water and heat stress on plants and animals

Applications:

- In-home cooling
- Outdoor cooling
- Horticulture
- Controlled Environment Agriculture (greenhouses and animal housing)

FORCING AIR THROUGH A WET PAD

Principles of Operation

- Outside air pulled through wet media (pad), usually by a fan
- Water on pad evaporates
- Cooled and humidified air enters the occupied area

Residential Application

"Swamp Coolers"

"Swamp coolers" are commonly used for residential cooling. Swamp coolers house the wet pad, fan and water distribution lines all within a single box. The fan pulls outside air through the wet pad and blows the cooled air into the home. Swamp coolers are usually placed on the roof, with air moving down across the wet media. They may also be located on the outside wall and delivered horizontally into the home.

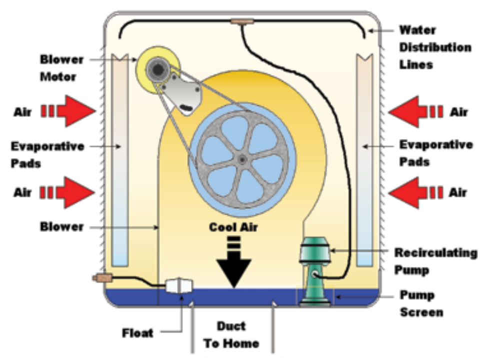


Figure 1. Operational diagram of a common household swamp cooler. Courtesy of wikipedia.

Horticulture/Agriculture Application

Pad-and-Fan Systems

Pad-and-fan systems are commonly used for cooling plants inside greenhouses (nurseries, residential and commercial vegetable or flower production, etc). Exhaust fans pull outside air through a wet pad, bringing cooled and humidified air into the greenhouse. Typically, the wet pad and fans are located on opposing walls so that the evaporatively cooled air is pulled from one end of the structure to the other.

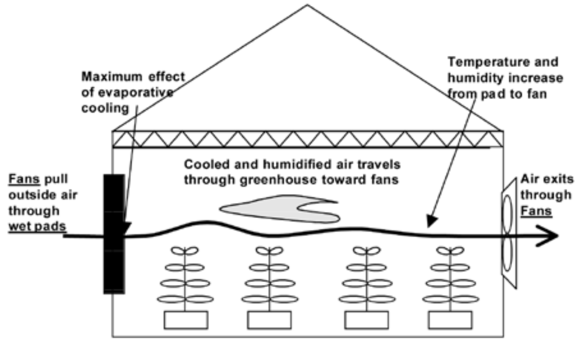


Figure 2. Operating fundamentals of the pad-and-fan cooling system used in a greenhouse.

Improving Performance:

Performance can be enhanced with greater system control and regular maintenance

- Use a two-speed (or variable-speed) fan to control airflow and limit water use
- Use temperature control (eg. thermostat) to operate the fan and/or water delivery system
- Inspect and maintain the system monthly to maximize operating efficiency
  - – Pad ➡ remove dirt and debris from delivery system and water reservoir
  - – Fan ➡ check and optimize belt tension, blade condition, and louvers

Saving Water:

Improving performance will help save water, including:

- Use multi-speed fan to control airflow ➡ lower air speeds use less water
- Use temperature control to operate fan ➡ operate only when needed
- Inspect and maintain system ➡ more efficient evaporation, no leaks

FORCING WATER INTO DRY AIR

Principles of Operation

- Small water droplets are sprayed directly into air
- Droplets evaporate in the air
- Air is cooled and humidified within the occupied area

Residential Application

Outdoor Misters

Outdoor misters are commonly used for commercial patio dining, residential patios, and amusement park areas. Mist lines are located overhead, where water is sprayed through low-pressure nozzles (25 PSI) into the air above the occupied area. Water droplets can be evaporated in the air or off of surfaces, such as people's skin. For evaporation in the air, cooled air falls downward or is carried by the wind. The most effective cooling, though, occurs when water droplets evaporate from people's skin because heat is transferred directly from the skin to the water.

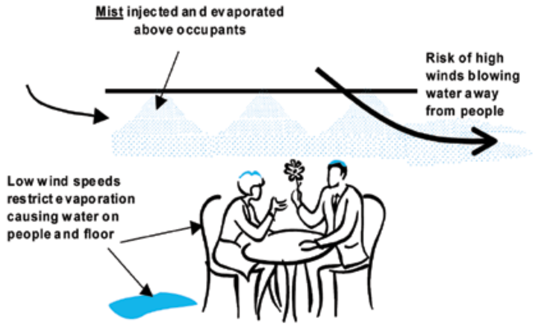


Figure 3. Operation of an outdoor misting system.

Horticulture/Agriculture Application

High-Pressure Foggers

High-pressure fog systems are used primarily for agricultural and horticultural production of plants (greenhouses and animal housing). They can be used as outdoor misters but are more expensive to purchase and operate. Fog droplets are much smaller than mist, allowing water to evaporate more quickly and offer better cooling. Wind or fans may be utilized to introduce fresh air for continued evaporation.

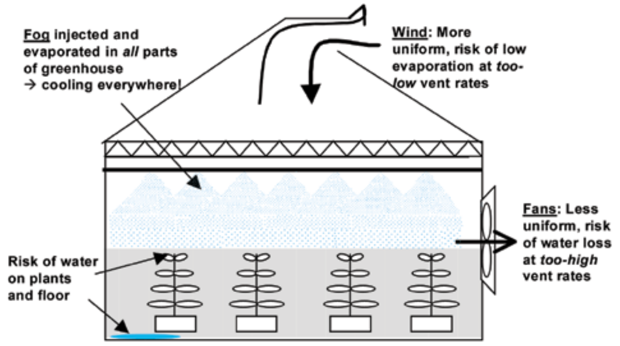


Figure 4. Operating fundamentals of high-pressure-fog system used in a greenhouse.

Improving Performance:

Performance can be enhanced with greater system control and regular maintenance

- Place nozzles so predominant winds will blow droplets toward occupied area
- Point nozzles into wind stream ➡ more water droplets will evaporate away from occupied area, and only the cooled air will be carried into that area
- Use high-pressure fog nozzles to improve evaporation
- Inspect and maintain the system to maximize operating efficiency
  - – Nozzles ➡ remove salts and residues by soaking in cleaning agent
  - – Filters ➡ replace after 90 days of regular operation

Saving Water:

Improve performance will help save water, including:

- Place nozzles so wind blows cooled air toward occupants, not in other directions