



# Evapotranspiration Model

---

## Application Note

*Rev. October 2008*

## Introduction

This application note is intended to help explain the evapotranspiration process and the use of the Evapotranspiration Model program in the Argus system for scheduling outdoor irrigation. For detailed information on setting up and using the Evapotranspiration Model, please refer to the Evapotranspiration Model Operator Manual.



---

**Note:** The Evapotranspiration Model program is intended for predicting water loss from **unsheltered outdoor crops**. The results can be accumulated in **Irrigation Schedules** for automatically adjusting the frequency and/or duration of crop irrigation. For indoor crops, where wind is not a factor and the evapotranspiration losses are different due to a protected environment, it is generally easier to simply use accumulated light as a means of predicting irrigation demand. Light accumulation can also be used successfully for outdoor crops. However, a properly configured evapotranspiration model should (in theory) be more accurate since many more variables are considered. The Argus system also provides other strategies for irrigating crops including feedback control using soil moisture sensors or weight scales, manual operation, and time clock watering. Please refer to the **Irrigation Programs** manual for more details.

---

## What is Evapotranspiration?

Evapotranspiration or ET refers to two processes that deplete water from the root zone: **Evaporation** and **Transpiration**.

### Evaporation

Evaporation is the process by which liquid water from the soil and plant surfaces is transformed into water vapor. The rate of evaporation is influenced by many factors including the air temperature, air movement, radiation heating, moisture content of the air, air pressure, and many others.

### Transpiration

Transpiration is the movement and eventual evaporation of water from inside the plant to the outside of leaves, stems, and other plant parts. Water is absorbed at the roots by osmosis, and any dissolved mineral nutrients travel with it through the xylem. Water exits the plant through specialized plant cells called the stomata. These cells open allowing the diffusion of carbon dioxide gas from the air into the fluids within the plant where it is transported to the cells for photosynthesis. Transpiration also cools plants since the evaporation of water requires heat energy. It also enables the mass flow of mineral nutrients and water from roots to replace the water that is lost through evaporation from the plant surfaces. While doing this, plants must constantly maintain the correct turgidity or water pressure within the cells in order to help support soft plant tissues and structures. Otherwise wilting will result.

The amount of water taken in and transpired by a plant depends on its size, the health of the root system, the availability of water in the soil, and the ability for water to evaporate from leaf surfaces. As a result, the transpiration rate is influenced by many of the same factors that affect evaporation in general.

Whenever we apply irrigation water, we are replacing the water that has been lost through evapotranspiration.

## Measuring Evapotranspiration

To determine evapotranspiration by test means you need to measure the combined amount of water lost to soil evaporation in the root zone and the evaporation from plant surfaces. The device for achieving this is called a weighing lysimeter. It is simply a scale that measures the combined weight of the soil or planting media and the test plants. As water is lost due to evapotranspiration the soil/plant combination becomes lighter. Whenever water is added through rainfall, dew, or irrigation, the scale registers an increase in weight.

Although some compensation is required to take into account the increased dry weight of the plant as it grows, this system can be a very accurate way to monitor evapotranspiration and the effects of weather and irrigation. It is somewhat superior to sensors that only measure soil moisture since losses from the plant are also taken into account. However, it is not often practical to use lysimeters in commercial situations. The test plants and media must be representative of the entire crop, and any problems such as local insect infestations or disease in the test group may produce unrepresentative results.

Despite the difficulty of using lysimeters in commercial situations, direct measurement of net evapotranspiration (ET) has been extremely useful in research applications focused on modeling and quantifying the factors that affect ET. Many crop simulations and models have evolved that can estimate the rate of ET with relatively high accuracy. Because they measure the influences rather than the plants themselves, these models are immune to the problems of representative sampling that plague direct measurement alternatives.

## Evapotranspiration Modeling

To the extent that the various factors that determine the rate of evapotranspiration can be understood and quantified, it is possible to mathematically predict the rate of evapotranspiration for a given crop. Using lysimeters and other measuring devices, scientists have been able to calculate the relative effects of temperature, light, wind, humidity and a host of other factors. Much of the work has been done with grasses since it is a relatively easy crop to produce in uniform stands. Despite this, models based on grass can be adapted for use with other crops by simply adjusting the gain of the predicted ET calculation. Often this can be achieved through trial and error (successive approximation) methods.

# The Argus Evapotranspiration Model program

Although many models have been developed, Argus has selected a calculation method based on the Penman-Monteith equations as described and recommended by the **Food and Agriculture Organization of the United Nations**.

A complete description can be found in the publication “**Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56**”. This document provides an excellent description of evapotranspiration and the many factors that influence it.

As of this printing, the complete document can be found at:

<http://www.fao.org/docrep/X0490E/X0490E00.htm>

The Argus Evapotranspiration Model program uses commonly measured inputs such as outdoor wind speed, temperature, humidity, and light to calculate the current rate of evapotranspiration. Other, less critical values such as atmospheric pressure can be measured, or a declared value can be entered.

Program Type: Evapotranspiration Model	Program Name: <u>Evapotranspiration Example</u>
Wind Speed	Results:
Temperature	<u>Crop Adjustment</u>
Humidity	ETc 1: 0.3651635 mm ETo Hour
Light	ETC 2: 0.3469053 mm ETo Hour
Atmospheric Pressure	ETC 3: 0.3140406 mm ETo Hour
Psychrometric Constant (gamma)	ETC 4: 0.2811759 mm ETo Hour
Mean Saturation Vapour Pressure (es)	ETC 5: 0.1825818 mm ETo Hour
Slope of Saturation Vapour Pressure Curve (Delta)	ETC 6: 0.3249955 mm ETo Hour
Actual Vapour Pressure	ETC 7: 0.3286472 mm ETo Hour
Solar Calculations	ETC 8: 0.3651635 mm ETo Hour
Extraterrestrial Radiation for Daily Periods (Ra)	ETC 9: 0.3651635 mm ETo Hour
Clear-Sky Solar Radiation	ETC 10: 0.3651635 mm ETo Hour
Net Shortwave Radiation	
Net Longwave Radiation	
Net Radiation	
Solar Flux Density	
Evapotranspiration	
Installation and Service	

Although the calculations are quite complex, you can easily use the model without understanding the mathematics used to predict evapotranspiration. Let's say you have several blocks of containerized nursery stock to irrigate. In each irrigation block the factors that contribute to rate of evapotranspiration such as the current temperature, light levels, wind speeds etc. will be nearly identical. However, the actual amount of evapotranspiration occurring in each block may be quite different due to differences in species, stage of growth, rooting media, spacing, and container size.

The Evapotranspiration Model program produces a common estimate of the current ET rate. You can then tune this value to match the water requirements of each irrigated block by using a compensation factor that closely matches the actual rate of evapotranspiration for each irrigation block.

This compensation factor can be determined through successive approximation (trial and error). The compensated value is then accumulated and used to trigger waterings in irrigation decisions.

For example, using one of the 10 compensation settings in each Evapotranspiration program, you could set up an Irrigation Accumulation Decision that will accumulate the current compensated evapotranspiration (ETc) until a specified threshold is reached. Once the threshold is achieved, a watering takes place and the accumulated value is reset.

By observing the crop and adjusting the compensation value, irrigation events can be timed to accurately match the observed rate of drying for each block. For instance, if the decision seems to be triggering waterings too soon, the compensation factor can be reduced. Similarly, if the crop appears to be in need of watering before the Irrigation Decision has triggered a watering, the compensation value can be increased until the program is reliably watering the crop at the correct rate and interval. Provisions are also available for subtracting from accumulated values to allow for rainfall.

Once tuned, an evapotranspiration calculation can serve as the basis for triggering waterings, or as a check against other irrigation scheduling strategies. You can also use it in more complex strategies where a combination of timed or sensor-based waterings are required.

## Further Reading

You can find more information in the **Evaporation Model - Operator Manual**. Please contact Argus for details.



ARGUS CONTROL SYSTEMS LTD.  
1281 Johnston Road  
White Rock, British Columbia  
Canada V4B 3Y9

<b>Telephone:</b>	(604) 538-3531 or (604) 536-9100
<b>Toll Free Sales:</b>	(800) 667-2090 (North America)
<b>Toll Free Service:</b>	(888) 667-2091 (North America)
<b>Fax:</b>	(604) 538-4728
<b>E-mail:</b>	<a href="mailto:argus@arguscontrols.com">argus@arguscontrols.com</a>
<b>Web Site:</b>	<a href="http://www.arguscontrols.com">www.arguscontrols.com</a>

Information in this document is subject to change without notice.  
© Copyright 2008 Argus Control Systems Ltd. Printed in Canada  
Argus is a registered trademark of Argus Control Systems Ltd.