Dynagage™ Sap Flow Sensors

Trunk gages and stem flow gages.

SGB16 sap flow sensor with weather shield attached.

Microsensors (left to right) SGA5, SGA3, SGA2.

Dynagage Summary

The Dynagage Sap Flow Sensors are the latest technology for measuring the sap flow, and thus the water consumption of plants. These energy balance sensors measure the amount of heat carried by the sap which is converted into real-time sap flow in grams or kilograms per hour. The sensors are non-intrusive and not harmful since the plants are heated up 1ºC to 5ºC typically. The principles of heat balance sensors are scientifically proven and references exist for most major crops and many tree species. Unlike other methods, Dynagages require no calibration since sap flux is directly determined by the energy balance and rates of heat convection by the sap flow.

The need for this new technology is great because it is an affordable and practical way to measure the water use by plants of agricultural, economic and ecological importance. Plants in greenhouses, nurseries or in natural environments can be measured with the same ease.

Dynamax introduced the first sap flow sensor prototypes in 1988 and today offers a full range of sensors from 2 mm up to 150 mm.

Microsensors 2 to 5 mm

The Dynagage Microsensors measure transpiration by small diameter crops, cereals, seedlings or floricultural species. Petiole and peduncle sap flow measurements are now possible.

Features

- **Durable acrylic shell, patented hinged clam-shell design**
- **Flexible inner core conforms to stem shape**
- **Very low power 0.07 W**

Stem Gages 9 to 32 mm

Features

- **Direct transpiration measurement**
- **Strap-on sensor collar**
- **Non-invasive and flexible**
- **Constant heat-energy balance**
- **Real-time monitoring and recording**
- **1 year warranty**

Benefits

- **Absolute measurement and no calibration required**
- **Reusable and portable**
- **Harmless and conforms to plant size**
- **Reliable and proven method**
- **Measures absolute mass-flow**
- **Helps correct decision making**

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Dynagage™ Specifications

Trunk Gages 32 to 125 mm

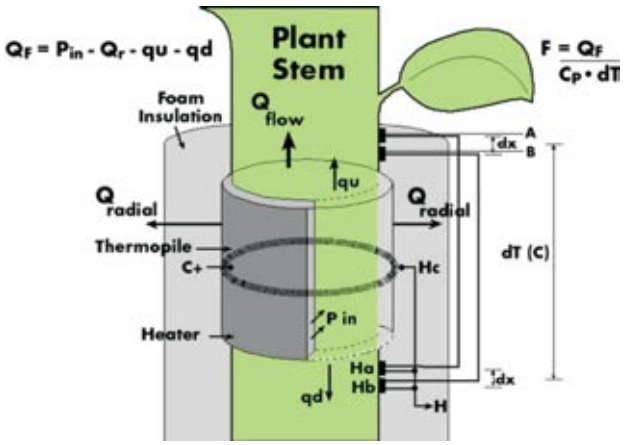
Trunk gages are unique tools for the measurement of sap flow in trees. A myriad of applications are solved by knowing tree water usage. Trunk flow gages have advanced designs that combine all temperature signals into three signal outputs and a heater voltage sensing output compatible with all other Dynagage signal connections.

Trunk gages have four or eight pairs of differential temperature sensors spaced around the circumference of the trunk, as shown in the chart below. This advanced design ensures that flow rates that vary around the circumference are accurately monitored and averaged into one reading. Up to 18 radial heat flux sensing thermocouples are also spaced evenly around the circumference to ensure that radial heat is accurately monitored.

With the capability to monitor sap flow in tree branches, important canopy studies can be performed. Water conductivity and tree transpiration may be partitioned into the flow rates related to the canopy level.

Dynagage Summary

Model No.	Diameter Min. (mm)	Diameter Max. (mm)	Ht. (mm)	Input Volts	Typical Power (w)	No TC Pairs	TCGap dx (mm)
Microsensors							
SGA2-WS	2.1	3.5	35	2.3	.05	1	0
SGA3-WS	2.7	4	35	2.3	.05	1	0
SGA5-WS	5	7	35	4.0	.08	2	3
Stem gages							
SGB9-WS	8	12	70	4.0	.10	2	4
SGA10-WS	9	13	70	4.0	.10	2	4
SGA13-WS	12	16	70	4.0	.15	2	4
SGB16-WS	15	19	70	4.5	.20	2	5
SGB19-WS	18	23	130	4.5	.30	2	5
SGB25-WS	24	32	110	4.5	.50	2	7
Trunk gages							
SGB35-WS	32	45	255	6.0	.90	4	10
SGB50-WS	45	65	305	6.0	1.4	8	10
SGA70-WS	65	90	410	6.0	1.6	8	13
SGA100-WS	100	125	460	8.5	4.0	8	15
SGA150-WS	150	165	900	9	13	8	20



Tree-trunk gages applied to rain forest research inside the Biosphere II dome in Oracle, Arizona. Picture by permission of Biosphere II.

Energy Balance Equations

The energy balance is:

$P_{in} = Q_r + Q_v + Q_f$ (W) (1)

$P_{in} = V^2/R(W)$ from Ohm's law

Vertical conduction components are:

$Q_v = Q_u + Q_d$ (2)

$Q_u = K_{ST} A \, dTd/dx$

$Q_d = K_{ST} A \, dTd/dx$

Kst = stem thermal conductivity (W/m x °K)
A = stem area (m^2)
dTu/dx = temperature gradient (°C/m)
dx = thermocouple junction spacing (m)

$Q_r = K_{sh} \times CH$ (3)

K_{sh} = sheath conductance (W/mV)

K_{sh} is determined by solving equation (1) during zero-flow, $Q_f = 0$:

$K_{sh} = (P_{in} - Q_v)/CH$ (W/mV) (4)

CH = radial-heat thermopile voltage (mV)

Finally:

$F = (P_{in} - Q_v - Q_r)/Cp \times dT$ (g/s) (5)

Cp = spec ific heat of water (J/g x °C)
dT = temperature increase of sap (°C)
dT = (AH = BH) /2 (°C)

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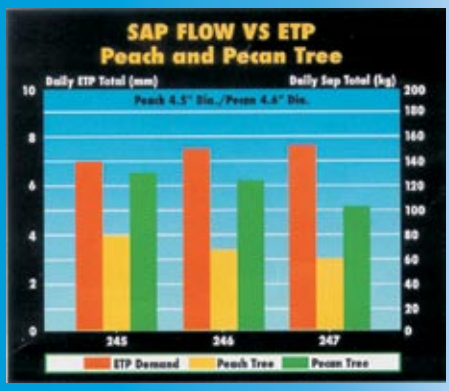
Dynagage™ Applications

SGA5 microsensor, with weather shield, monitors okra plant transpiration.

Comparing peach tree hourly transpiration to evapotranspiration demand computed from Penman-Van Bavel modeling software and Dynamet Weather Station.



Peach and pecan tree accumulated daily water consumption declines 25 and 20% under limited water availability as ETP demand increases.

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Dynagage Applications

Agricultural Engineer
Agricultural Consultant
Botanist
Citrus Grower
Crop Science
Crop Physiology
Entemology
Extension Service
Farm Industry
Fertilizer Evaluation
Genetic Engineering
Global Climate Change
Greenhouse Control
Forestry Planning
Horticulture
Hydrology
Irrigation Systems
Orchard Monitor
Ornamentals
Plant Physiologist
Phytoremediation
Pollution Studies
Pomology
Reforestation
River Water Authority
Seed Genetics
Tree Farm
Weed Science
Water Conservation
Xeriscape Plant Selection

Dynagage sensors work well with most of the worlds major crops and trees. Vines, shrubs, natural vegetation, and ornamentals can also be monitored with the Dynagage Sap Flow System.

Species Monitored by Dynagage

Crops	Tree	Other
Cucumber	Almond	Coffee
Cotton	Apple	Grape
Corn	Avocado	Kiwi
Sorghum	Bald Cypress	Ligustrum
Soybean	Douglas Fir	Mesquite
Sugarcane	Eucalyptus	Potato
Sunflower	Ficus	Rose
Sweet Potato	Kumquat	
Tomato	Mangosteen	
Wheat	Oak	
	Orange	
	Pecan	
	Pine - Xmas Tree	
	Pine - Lobolly	
	Poplar	
	Red Cedar	
	Tangerine	

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NEW EXO-Skin™ Sap Flow Sensor

Patent Pending 13/155,369

EXO Sensor showing the different layers of insulation and shielding that comes with each sensor.

Lower Cost
Same Accuracy
Less Maintenance
-Intl. Pat. Pending

Benefits

- **Easy installation**
- **Expandable Velstretch® attachment**
- **Sealed electronics**

Features

Flexible sensor skin for
- **Odd plant stems - shapes**
- **Growth**

New innovative features
- **New water shedding layer**
- **Wicks out water vapor**
- **Insulation and shielding provided**

Applications

- **Crops**
- **Understory**
- **Vines**
- **Trees**
- **Vegetables**
- **Research AND Commercial Monitoring**

After 20 years of experience and a worldwide experience with sap flow sensor manufacturing and design, the Dynamax team brings you the latest innovations and sap flow sensor construction advancements. With continuous customer feedback over the years, and through several years of research, we solved many of the commercial and research needs for a more plant friendly and user-friendly sap flow sensor. We improved the longevity, reliability and accuracy with commercial irrigation applications in mind.

The new EXO-Skin Dynagage is based on tried and proven energy balance technology for sap flow measurement. The Dynagage has been the world leader in sensor shipments since 1990. Thousands of sensors have been fielded for research in agriculture, plant physiology, water relations, crop science and numerous ecological, hydrology and engineering studies. With the advent of sap flow monitoring in commercial vineyard applications, and the introduction of Low– Cost Sap flow systems, the Flow4 and Probe12, our customers needed an easier plant connection and a more economical sensor. Customers explained their needs for innovation and we designed the EXO-Skin sensor to solve some of the recurring issues with the well-respected Dynagage, the one piece integrated sap flow sensor.

Ordering Information

Each sensor is supplied with foam body and donuts, reflective bubble shield and a raincoat weather shield.

SGEX-9 - 9 mm EXO-Skin Sap flow sensor
SGEX-10 - 10 mm EXO-Skin Sap flow sensor
SGEX-13 - 13 mm EXO-Skin Sap flow sensor
SGEX-16 - 16 mm EXO-Skin Sap flow sensor
SGEX-19 - 19 mm EXO-Skin Sap flow sensor
SGEX-25 - 25 mm EXO-Skin Sap flow sensor

Accessories

Cable Kit for Loggers
EXOC-25 - Logger cable kit for Flow32 and CSI, EPIG-3 and EXQC-25 extension
AVRD - Controlled dual-adjustable regulator, 1.5 - 10 V, 2.5 A output
EPIG-3 - Logger pigtail - with voltage divider (3 ft.) to CPC Female
FL32-1K-SW - Flow32 logger software for CSI CR1000 loggers (requires Loggernet or PC400)
AM16/32 - 16 channel multiplexer to input 8 sensors to CSI logger

Individual extension cables for Flow32 (9 pin circular locking connectors sealed)

EXQC-25	25 ft. (7.6 m) Extension quick connect cable
EXQC-50	50 ft. (15 m) Extension quick connect cable
EXQC-75	75 ft. (22.8 m) Extension quick connect cable
EXQC-100	100 ft. (30.5 m) Extension quick connect cable

Eight EXQC-25's will convert a Flow32 to use any (8) EXO-Skin sensors to connect with 9 pin circular locking connectors.

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NEW EXO-Skin™ Sap Flow Sensor

Improvements – New Solutions Provided

EXO-Skin is a simpler construction of the insulation body, separating a sealable electronic body from the insulation. The Exoskeleton approach consists of the heater and heat-sensing electronics prepared in one layered wrapping.

- Makes sensors more flexible and easier to install especially in non-uniform stems
- Manufacture the separate body with sealed electronics with low cost material.

EXO-Skin uses a stretch Velcro wrapping to secure the body to the plant. We apply a stretch Velcro (Velstretch®) wrapping in a spiral around the circumference to secure electronics to the plant.

- Reduce maintenance and installation issues required to accommodate growth
- Secure the sensor yet not constrict the stem growth
- Provides easier installation and maintenance
- Velstretch® is made of a breathable, porous nylon and Lycra® spandex
- Collects moisture and conducts water from the stem and sensor area

The EXO-Skin package includes a waterproof membrane cloth wrapped over the sensor insulation surrounding the electronics and heater-electronic exo-skeleton. The membrane cloth is made of Teflon impregnated synthetic fabric that is permeable to water vapor but impermeable to water drops.

- Blocks incoming water, and maximizes water vapor extraction from the stem and sensor area. Allow longer term, full season measurements on some plants.
- Reduces microbial damage to the plant and the sensor body, as well as prevent corrosion to electronics.
- The membrane surrounds the sensor and insulation wrap. The rain coat blocks rainwater, and extracts water vapor to the surrounding ambient, while reducing condensation build-up inside the sensor.

EXO-Skin sensors come with a flexible reflective sheath. The material is consists of two 96% reflective layers of flexible film bonded to two internal layers of heavy gauge polyethylene bubbles. This layer is required to block radiant heat, which is well known to cause errors in sap flow sensing applications.

- The “bubble shield” makes a reflective radiant barrier.
- Provides a conductive barrier.

EXO-Skin sensors have longer, easier to reach, lead wires with sealed (water tight) locking connectors. Gold plated pins prevent corrosion and conduct noise-free reliable signals to the data logger.

The EXO-Skin sensor internal thermocouple wiring is similar to Dynagage SHB sap flow sensors.

- No changes or reduction in accuracy using a proven stem heat balance (SHB) method
- Compatible with existing loggers, from high end Flow32 to low-cost loggers.
- All EXO-Skin sensors wires are coated with water proofing to provide long-term all-weather performance.
- With annual maintenance, lifetime expectations are 3- 5 years. All sensors are guaranteed for 1 year.

Velstretch® Wrapping

Waterproof Membrane Cloth

Reflective Shield

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EXO-Skin™ Specifications

The EXO-Skin on an irregular shaped grape vine.

Finished installation on the grape vine.

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Mechanical Specifications

Model	Plant Diameter (mm)	Min Dia. (mm)	Max Dia. (mm)	Min Installed Length (Axial) (mm)	Typ. Installed Length-Shield & Insulation (Axial) (mm)
SGEX-9	9	8	10	70	150-350
SGEX-10	10	9.5	13	70	170-360
SGEX-13	13	12	16	80	190-380
SGEX-16	16	15	19	90	210-400
SGEX-19	19	18	23	100	240-450
SGEX-25	25	25	29	120	280-500

Electrical Specifications

Model	Heater (Ohms)	Typical Voltage (dc)	Max Voltage	Typical Power (W)	Max Power (W)
SGEX-9	120	4.0	5.0	.13	.21
SGEX-10	140	4.5	5.0	.15	.18
SGEX-13	120	4.5	5.0	.17	.21
SGEX-16	100	4.5	5.0	.20	.25
SGEX-19	60	4.5	5.0	.34	.42
SGEX-25	42	4.5	5.0	.48	.60

Environmental Specifications

	Min (°C)	Max (°C)	
Operating Temp	0	50	Below freezing plants and sensor will not have / respond to transpiration.
Installation Temp	15	35	At temps below min, EXO skin is brittle, may sustain damage during installation.
Storage Temp	0	60	Store clean and dry, away from direct heat.

Wrap & Protection Specifications

		EXO-Skin Sensor Size					
	Color	**9**	**10**	**13**	**16**	**19**	**25**
Velstretch® (length in cm)	Black	60	65	75	90	110	170
Insulation Close Cell Foam (length in cm)	Black	15	17	19	21	24	28
Rain Coat Membrane (length in cm)	White	24	25	28	30	34	35
Reflective Radiant Barrier (length in cm)	Alum.	35	36	38	40	45	50

** all specifications are subject to change without notice*

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