INSTRUCTION MANUAL

67 Dynagage Processing Instruction

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67 DYNAGAGE PROCESSING INSTRUCTION

1.0 FUNCTION

The Dynagage Processing Instruction, P67, is used in conjunction with a Dynamax, Inc. Dynagage stem flow gage. P67 calculates the sap flow rate within a plant stem by using an energy balance equation and inputs from a Dynagage. It eliminates the long list of program instructions previously necessary for calculating sap flow when using the standard instruction set (see Appendix A for details).

Briefly, the energy input into the stem is a known quantity (Q_h), conductive radial and vertical energy losses are calculated (Q_r and Q_v, respectively), and the residual energy is assumed lost through sap flow (Q_f). Therefore,

$$Q_f = Q_h - (Q_r + Q_v).$$

By measuring the temperature of the sap before and after heating (dT equals temperature after heating minus temperature before heating), and by taking into account how much energy it takes to heat water (4.186 joules g^{-1} H_2O °C^{-1}), the flow rate can be calculated.

Accumulated flow can be calculated using datalogger Instruction P72.

2.0 INSTRUCTION DETAILS

P67	Dynagage Sap-Flow Instruction
01:0000	Begin Input Location
02:0.000	K_{sh} (W/mV)
03:0.000	Heater Resistance (ohm)
04:0.000	Stem Area (sq cm)
05:0.000	Thermal Conductivity (W/m*K)
06:0.000	Thermocouple Gap (cm)
07:0.000	Low-flow cutoff temperature (C)
08:0.000	High-flow cutoff velocity (cm/s)
09:00	Output (0=Short, 1=Long)
10:0000	Destination Input Location
11:0.000	Multiplier
12:0.000	Offset

2.1 INPUT VOLTAGES

Parameter 1. Four voltages must be stored sequentially beginning with the Input Loc option stated in Parameter 1.

INPUT LOCATION
Loc 1: Ch - Thermopile (mV)
Loc 2: Ah - Upper TC (mV)
Loc 3: BH - Lower TC (mV)
Loc 4: Voltage Input

These voltages are measured using Instruction 2. Voltages for locations 1-3 are measured on the 5 mV slow range with the 21X or the 2.5 mV slow range with the CR10. The voltage for location 4 is measured on the 5000 mV slow range with the 21X or the 2500 mV slow range with the CR10.

2.2 CONSTANTS

Parameters 2 thru 6 are constants that must be entered for each Dynagage.

Parameter 2. K_{sh}(W mV^{-1}), a constant required to relate the thermopile output proportionally to the radial heat transfer.

Parameter 3. The heater resistance (ohms), measured with an Ohm meter.

Parameter 4. The cross sectional area of the stem (cm^2).

Parameter 5. Thermal conductivity (W m^{-1} K^{-1}). This number is generally 0.54 W m^{-1} K^{-1} for herbaceous plants or 0.42 W m^{-1} K^{-1} for woody plants.

Parameter 6. Thermocouple gap (cm), the distance between the thermocouples in the Dynagage, measured in cm. This value is determined by Dynamax and is found in the Dynagage documentation.

2.3 FILTERS

Two predictable conditions may occur when the output from the Dynagage is not valid. In these cases, the output must be "filtered" so only reasonable flow rates are processed. These conditions are very low flow rates and high flow rates, both of which cause dT to approach zero. The values generally placed in Parameters 7 and 8 are 0.5 °C and 0.042 cm s^{-1}, respectively. These values should be used unless conditions determined by the user indicate otherwise.

<u>Parameter 7</u>. Low-flow filter (0.5°C). This filter has two phases: The first phase <u>sets the reported flow rate (F) to zero</u> if Q_f is greater than or equal to 0 and less than 20% of Q_h, and if dT is less than 0.5°C. That is:

IF $0 <= Q_f < 20\% \ Q_h$
AND IF dT < 0.5°C
THEN F = 0 g h^{-1}.

Explanation of phase 1: When there is a zero flow rate in a very small stem, dT approaches zero. In this situation, F will be highly exaggerated if a minor residual Q_f also exists, disrupting the accuracy of the flow accumulator. To avoid this, F is set to zero. Phase 1 also filters out possible negative flow rates resulting from negative dT readings that may occur in small stems at night.

Phase 2 sets the reported flow rate to -0.036 g h_{-1}. This flag alerts the user to the possible need of adjusting K_{sh}. K_{sh} may not be perfectly set, and it is possible that a large negative flow will occur, which could adversely affect the flow accumulator. The small negative number (-0.036) will not adversely affect the flow accumulator.

<u>Parameter 8</u>. High Flow Filter (0.042 cm s^{-1}). This filter sets F equal to a calculated theoretical maximum flow (F_{max}) if F is greater than F_{max}. That is, where F_{max} equals the theoretical maximum velocity (V_{max}), multiplied by the cross sectional area of the stem ($F_{max} = V_{max} * A$):

IF $F > F_{max}$
THEN $F = F_{max}$

This filter is used to protect the integrity of the flow accumulator when the gage capacity to measure F has been exceeded. When F is exceptionally high, nearly all of the heat is absorbed by the sap. As F continues to increase, dT approaches zero asymptotically. As dT becomes infinitesimal, previously insignificant thermal noise from radiation or other sources can cause a major exaggeration of F. The value 0.042 cm s^{-1} for V_{max} was determined by Dynamax to be a typical maximum. At the users option, V_{max} (Parameter 8) can be increased or decreased when the species under study is verified to be accurately measured.

2.4 INSTRUCTION OUTPUT

<u>Parameter 9</u>. Zero gives the short output, and 1 gives the long output. W = Watts, g = grams, h = hours, mV = millivolts.

Short Output	Long Output
Sapflow (g h_{-1})	Sapflow (g h_{-1})
K_{shapp} (W mV_{-1})	K_{shapp} (W mV_{-1})
	dT (°C)
	power input (W)
	Q_v (Vertical Flux, W)
	Q_r (Radial Flux, W)
	Q_f (Sapflow Flux, W)

2.4.1 Sapflow (g h_{-1}).

The calculated sap flow rate. If total sapflow is desired, Output Processing Instruction 72 must be used in conjunction with Instruction 67.

2.4.2 Q_f and dT.

See Instruction.

2.4.3 Q_r, K_{sh}, K_{shapp}.

Q_r, radial energy loss, is the loss of energy through the cork and foam sheath on the sensor. K_{sh}, the thermal conductivity constant, is used to calculate Q_r. Since Q_r can be a large percentage of the total energy loss, K_{sh} must be determined accurately as outlined in the Dynagage manual. The essence of the procedure is to record K_{sh} (the second output of Instruction 67, K_{shapp}) when there is no stem flow. This value is then placed in Instruction 67, Parameter 2, K_{sh} (W mV^{-1}). K_{shapp} and K_{sh} (W mV^{-1}) have no effect on each other in Instruction 67. K_{sh} must be determined for each installation.

2.4.4 Power Input (W).

Power input or Q_h is calculated from the input voltage and heater resistance: $Q^h = V/R$.

2.4.5 Q_v (W).

Q_v, or vertical energy loss, is the loss of energy through the wood at the ends of the sensor not associated with the heating of the sap.

Appendix A

Instruction P67 Processing

Loc = input location assuming input locations 1, 2, 3, and 4 are used.

Par = Instruction P67 parameter.

P_{in} = (Loc 4)*(Loc 4)/(Par 3)

Q_v = (((Loc 3)-(Loc 2))/(4.0*(Par 6)))*(Par 4)*(Par 5)

Q_r = (Loc 1)*(Par 2)

$Q_f = P_{in} - Q_v - Q_r$

K_{shapp} = (P_{in} - Q_v)/(Loc 1)

dT = ((Loc 2+Loc 3)/2.0)*25.0

Sapflow = Q_f/(dT*4.186)

If Par 7 µ 0.0 then go to XXXXXX

If Q_f < (0.2*P_{in}) and If dT < Par 7, then Sapflow = 0.0

If Q_f < (0.2*P_{in}) and If Q_f < 0.0, then Sapflow = - 0.00001

XXXXXX

If Par 8 µ 0.0 then go to YYYYYY

F_{max} = (Par 8)*(Par 4)

If Sapflow > F_{max}, the Sapflow = F_{max}

YYYYYY

Sapflow = (Sapflow*(Par 11))+(Par 12)

Transfer to Input Locations beginning with Parameter 10, either short output or long output, depending on Parameter 9.

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