Thermal Dissipation Sap Velocity

- Principle of Measurement
- Specifications
- System overview
- Features & Benefits
- Installation Procedures and tips
- Applications

TDP - How Does it Work

- Probe consists of two needles
  - One incorporating a (-) Reference T-Type Thermocouple
  - One incorporating a (+) T-Type Thermocouple & Heater

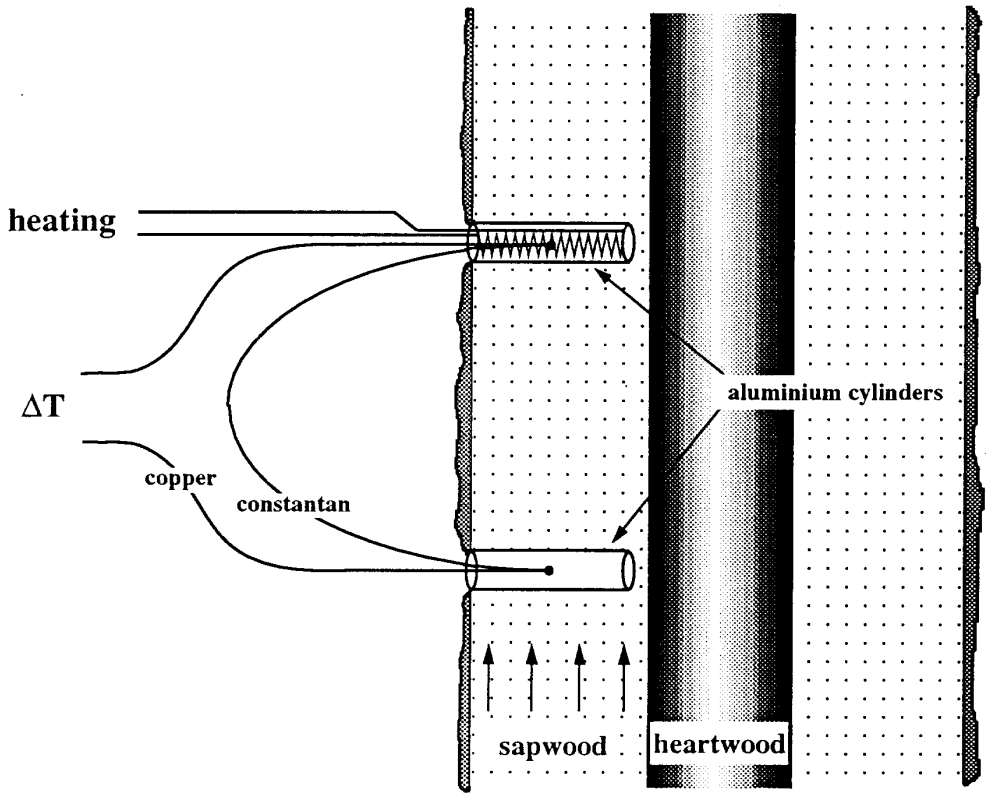
- Heated upper needle temperature is compared to lower ambient temperature needle (dT)
  - Maximum dT occurs when the needle is hottest = No Flow
  - Minimum dT occurs when the needle is coolest = High Flow

- dTM - Maximum dT is recorded and averaged pre-dawn = the zero flow set point.

Original Granier Design

Dynamax Improvements

- Smaller Needles
- Internally mounted heater
- Teflon Coated Probes



TDP - Measurement Principle

- **Calculate Dimensionless Variable K**

$$K=(dTm - dT)/dT$$

- **Calculate Velocity V**

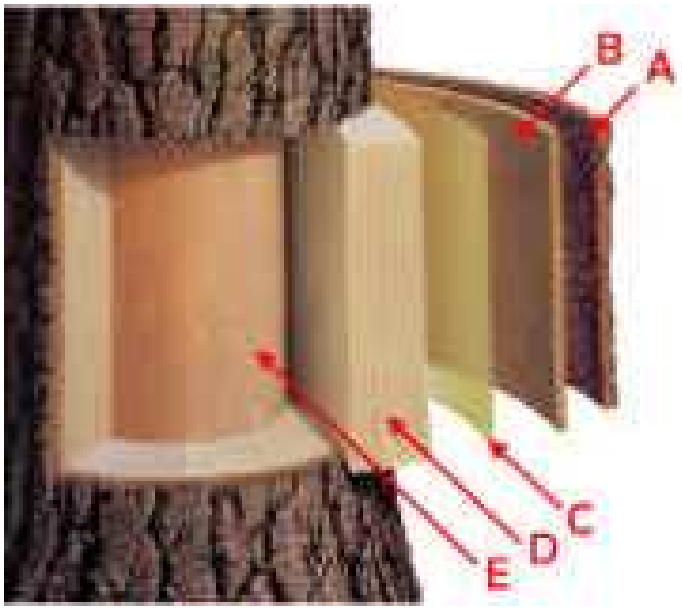
$$V= 0.000119 * K \wedge 1.231 \ \ (m/s)$$

- **Calculate Area of Sapwood & multiply to obtain volume flow**

$$Sapflow = A * V$$

Sapwood Area

(A) Outer Bark
(B) Inner Bark
(C) Cambium Layer
(D) Sapwood
(E) Heartwood



- **Only the Sapwood conducts water**
- **Only the sapwood needs to be measured.**
- **Maritime Pine (*Pinus pinaster*) – Sapwood thickness = 40-80mm**

Sapwood Area Calculations

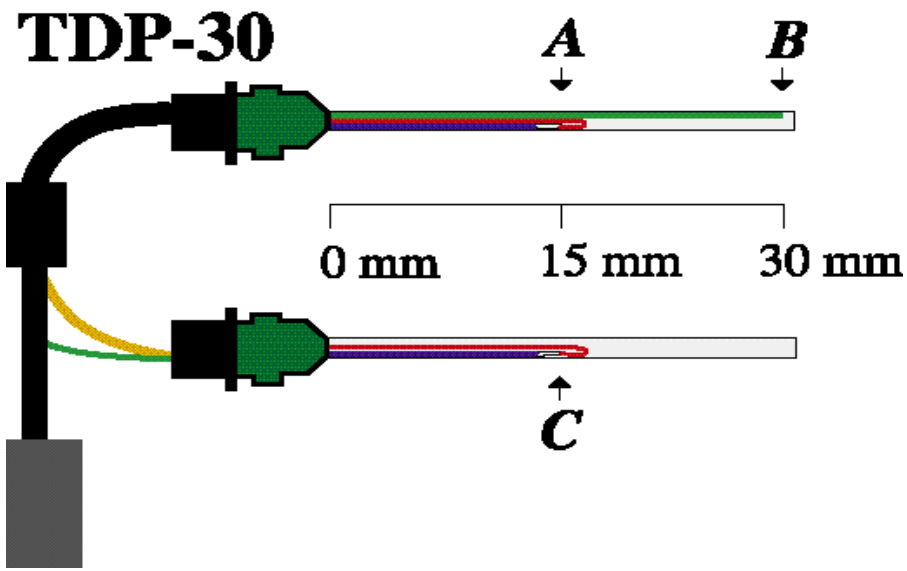
- **Sapwood Area must be calculated to Compute Sapflow**

- **The method used by Grainer**
  - **Destructive sample & physically measure**
    - **Stem cores from a sample of trees**
    - **Measure DBH**
    - **Calculate the tree circumference S_T**
    - **Establish Statistical relationship**

$$S_A = -0.0039 + 0.59\ S_T$$

TDP-30 Probe Specifications

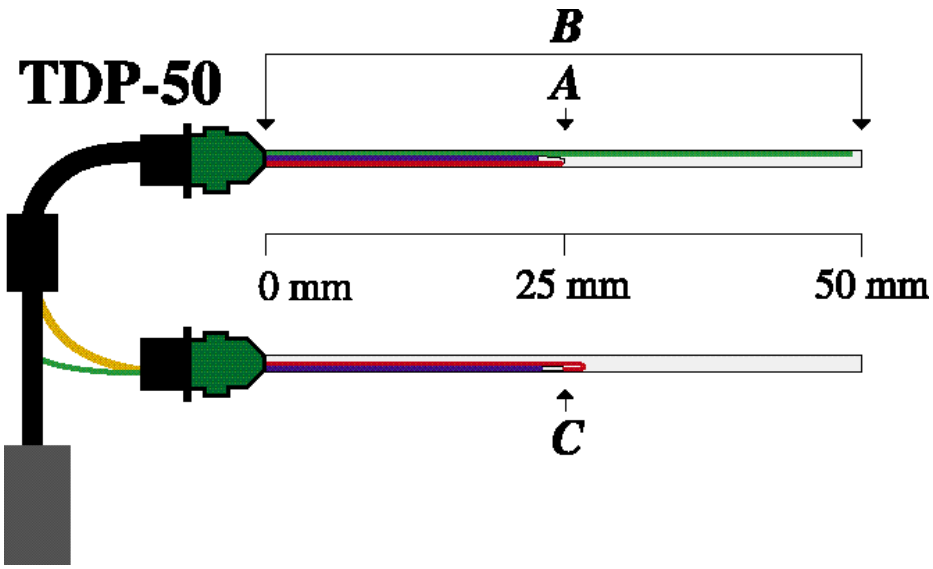
Model	TDP-30
Length	30mm
Diameter	1.2 mm
T-Type T/C's	1 ea
Probe Spacing	40 mm
Power	0.15 to 0.2 w
Cable Standard	10ft/ 5 cond
Heater Resistance	45 Ohms
Operating Volts	3.0 V @~8°C
Signal Out	40 uV/°C



A- Thermocouple #1
B- Heater
C-Reference Thermocouple

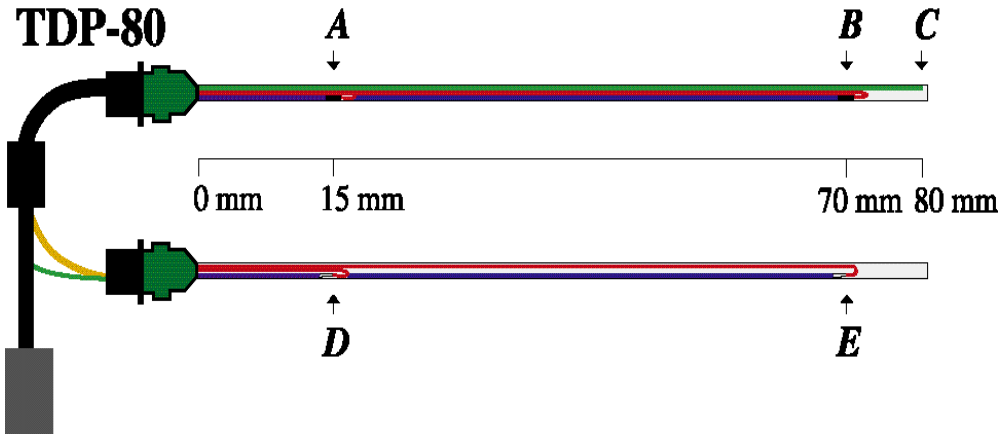
TDP-50 Probe Specifications

Model	TDP-50
Length	50mm
Diameter	1.65 mm
T-Type T/C's	1 ea
Probe Spacing	40 mm
Power	0.32 to 0.38 w
Cable Standard	10ft/ 5 cond
Heater Resistance	77 Ohms
Operating Volts	5.0 V @~8°C
Signal Out	40 uV/°C



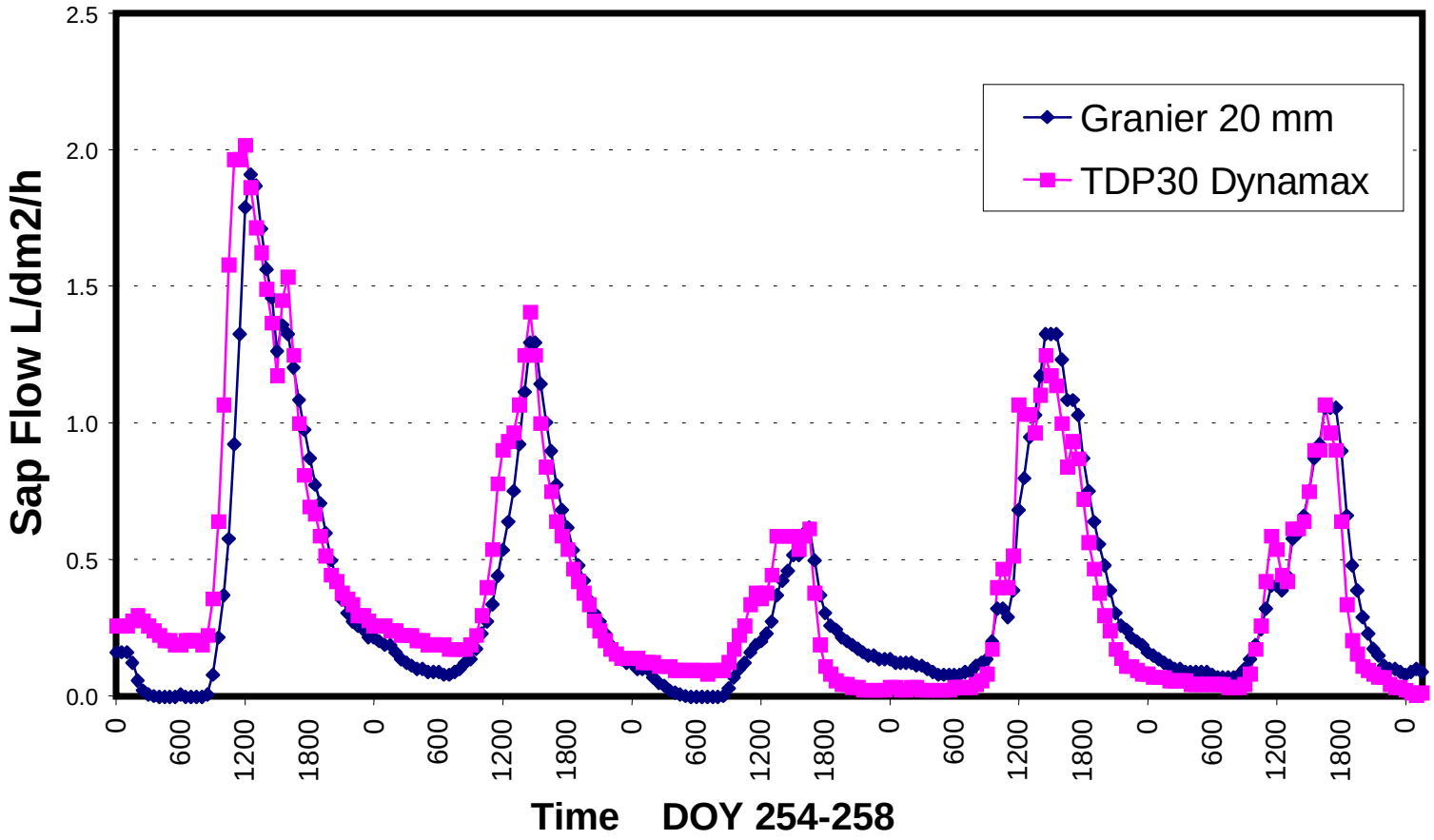
TDP-80 Probe Specifications

Model	TDP-80
Length	80 mm
Diameter	1.65 mm
T-Type T/C's	2 ea
Probe Spacing	40 mm
Power	0.4 to 0.5 w
Cable Standard	10ft/ 7 cond
Heater Resistance	100 Ohms
Operating Volts	7.5 V @~8°C
Signal Out	40 uV/°C



A- Thermocouple #1
B- Thermocouple #2
C- Heater
D- Reference Thermocouple
E- Reference Thermocouple

Sap Flow Calculation - Conifer



Specifications Summary

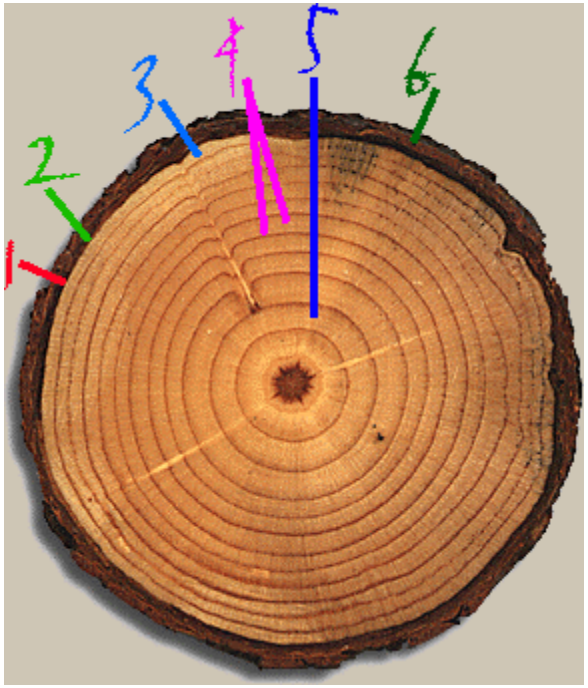
- **Free flexible cable between needles of the sensor specifically designed to improve installation and removal of probes.**

- ***Sensors constructed using solid or epoxy encapsulation methods causes sensor damage during removal. Non-reusable.***

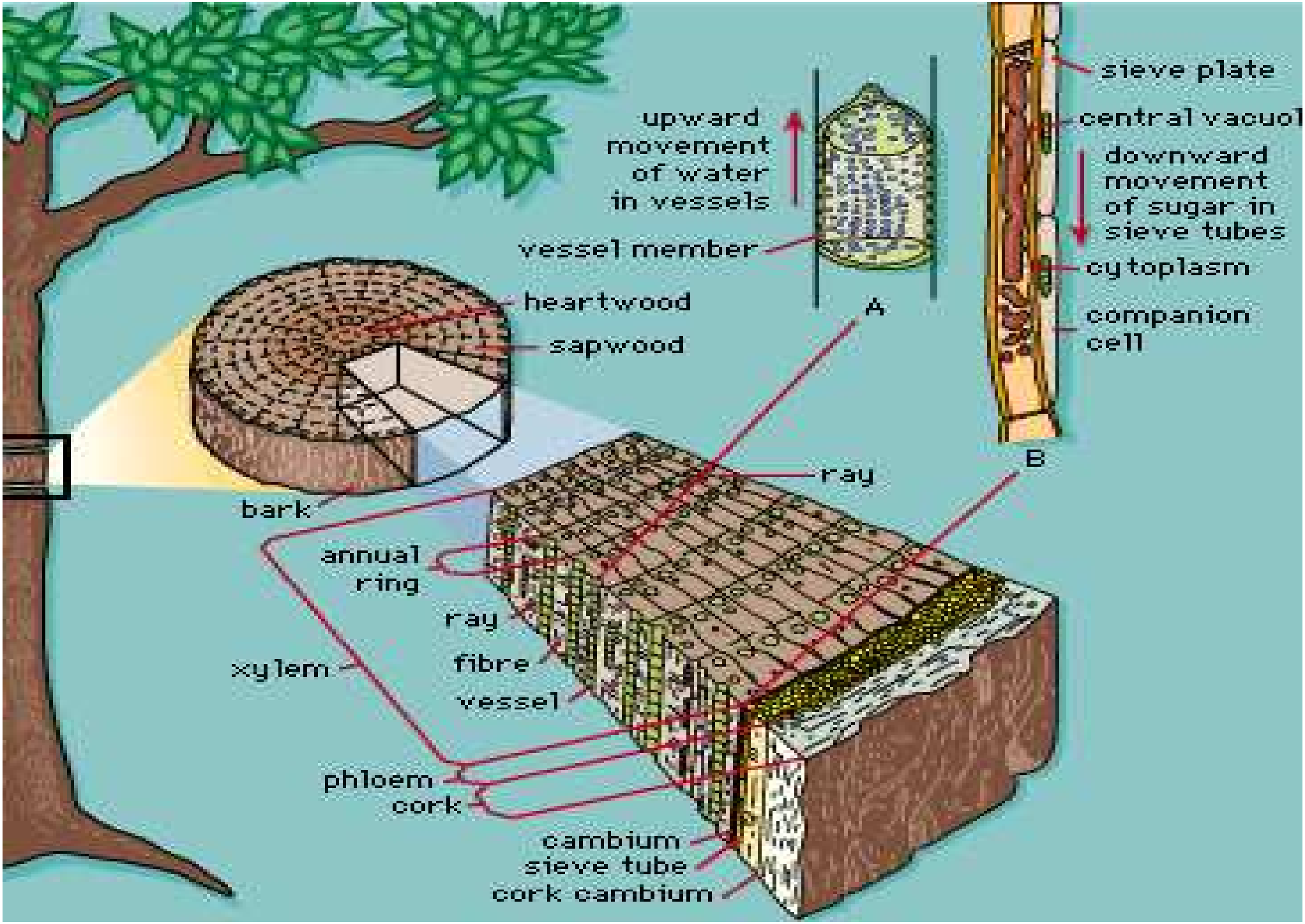
- **Modified Hypodermic syringe minimizes probe diameter**

- ***Grainer concluded the smaller diameter of DYNAMAX design is pivotal to improved responsiveness of DYNAMAX TDP probes over his original prototype.***

How Many Sensors Not How Long!



- Uniform Growth Conditions
- Non-uniform Growth Conditions


upward
movement
of water
in vessels
vessel member
A
heartwood
sapwood
bark
annual
ring
ray
xylem
fibre
vessel
phloem
cork
cambium
sieve tube
cork cambium
ray
sieve plate
central vacuol
downward
movement
of sugar in
sieve tubes
cytoplasm
companion
cell
B

TDP-30 Species Compatibility

(1) Ring-porous Species

- **Large Early wood vessels to small Late wood**

(2) Thin xylem

(3) Pinus & Oak Species

- ***Pinus radiata* - Monterey Pine**
- ***Pinus caribaea* - Caribbean Pine**
- ***Quercus petraea* – Sessile Oak**

TDP-50 Species Compatibility

(1) Ring-porous Species
(2) Mature trees with with medium Sapwood

- ***Pinus strobus*** **- Eastern White Pine**
- ***Juglans nigra*** **- Black Walnut**
- ***Toona australis*** **– Red Cedar**
- ***Pseudotsuga menziesii*** **– Douglas Fir**

TDP-80 Species Compatibility

(1) Diffuse-porous Species

- **No differentiation between early wood & late wood**

(2) Plants with > 30% Sapwood

- ***Populus Deltoides*** **- Cottonwood**
- ***Acer rubrum*** **- Red Maple**
- ***Eucalyptus regnans*** **– Mountain Ash**
- ***Phytolacca dioca*** **- Ombu Tree**
- ***Mangifera Indica*** **– Mango Tree**

TDP Sensors

Features

- INRA research (Granier) design
- Verified & supported math
- Two needles epoxy sealed
- Teflon coated probes
- International License
- Multiple probe size
- One differential channel
- Low voltage operation

Benefits

- Continuous Sap Velocity
- Simple data calculation/analysis
- Durable, Reusable Design
- Real-Time Data Acquisition
- Monitor multiple trees
- Monitor large trees
- Universal logger compatibility
- Easy voltage regulation

TDP Probe Installation

Installation Procedure

1. **Prepare the Probe Site:**
   - **Select a height 1-2 meters above the ground**
   - **Remove old rough bark to cambium layer**
2. **Drill Holes:**
   - **Place the Drilling Jig flat on the prepared surface**
   - **Drill a hole with the smallest drill bit**
   - **Enlarge the hole with the larger drill bit (if Required)**
3. **Install Probes:**
   - **Insert the heater in the top hole & the reference in the bottom**
   - **Insert needles slowly and gradually**
   - **Tape cables to the tree for support**

Insulation & Sensor Removal

- **Insulation:**
  - **Install a water proof seal around the needles**
  - **Secure Foam Quarter spheres around probes**
  - **Install thermal insulation using reflective foam Bubble Wrap**
- **Probe Removal:**
  - **Do NOT pull on the base of the needle**
  - **Never use Claw hammers or other long Levers**
  - **Always use the supplied nail removing Pry-bar**
  - **Address the cannula with the pry-bar then, using moderate force withdraw the probes gradually.**

Applications

- Forestry Research
- Commercial Forestry
- Transpiration Research
- Phytoremediation
- Carbon Sequestration

Forestry Research

- **Stand Transpiration for projection of Biomass production**
- **Effects of thinning on tree water use**
- **Species Water Use requirements for new plantations on marginal land**

Commercial Forestry

- **Effectiveness of regeneration techniques after harvesting.**

- **Growth rate modeling for harvesting projections**

Transpiration Research

- Whole tree water use
- Transpiration correlation to photosynthesis, light, soil & water
- Spatial variations in xylem sap flux density
- Irrigation efficiencies of mature citrus trees
- Drought tolerance of tree species

Phytoremediation

- **Hydraulic containment of contaminated groundwater.**
  - **Groundwater level reduction**
  - **Tree stores contaminants**
- **Calculation of water removal rate**
  - **Net Stand transpiration rate**
  - **Determine current removal rate**
  - **Project future removal rate**

Carbon Credits Trading

- **Carbon Sequestration**
  - **New research to determine species carbon accumulation or storage rates and capacities.**
  - **Used for future environmental trading**
  - **Offset CO_2 emissions**