Soil Plant Water Seed

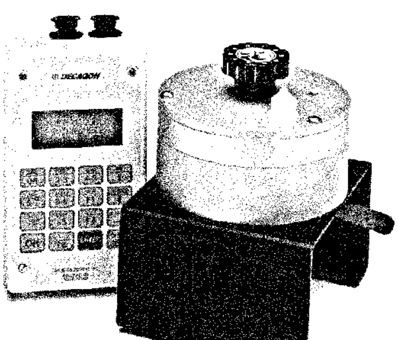
SOILS NEWS

Volume 3, Issue 1 ISSN#1077-5915

Measuring Soil Water Potential — One Hundred Years of Progress

Gaylon S. Campbell

People have measured the water content of soils and other porous materials for a very long time, and the ideas surrounding that measurement are easily understood. Water potential is a more recent concept, and, in spite of its importance, is still not well understood by many soil and plant scientists. The main component of the soil water potential, the matric or capillary potential, was first described by Edgar Buckingham almost 100 years ago. Buckingham recognized that gradients in water potential are the driving forces for water movement in soil, and that components of the total potential could be balanced against each other. He made the first attempts to determine the relationship between water content and water potential in soils by balancing the matric potential against the gravitational potential in vertical soil columns which he stood in containers of water. He was correct in assuming that the matric potential would equal the negative of the gravitational potential (which he computed from the height above the free water surface) once the columns were at equilibrium. He could not have known then that equilibrium would have taken many decades.



Tru Psi water potential thermocouple psychrometer 15-year precursor to the faster WP4 PotentiaMeter.

More than a decade passed before significant progress was made beyond Buckingham's experiments. In the 1920's and 1930's two lines of research produced the main tools used by soil physicists for water potential measurements for the next 70 years. L. A. Richards, working in the laboratory of Willard Gardner at Utah State University, and later at the U. S. Salinity Laboratory, developed the idea of using a semi-permeable porous ceramic to balance a pressure potential against a matric potential. At equilibrium the matric potential could be determined from the balancing pressure potential. The tensiometer and the pressure plate apparatus both came from this

New WP4 Dew Point PotentiaMeter now introduced by Decagon.

continued next page

Decagon 1999 Trade Shows:

American Society of Agricultural Engineers
July 18-22, Toronto, Ontario, Canada

American Societv of Plant Physiologists
July 24-29, Baltimore, Maryland

Ecological Society of America
August 8- 12, Spokane, Washington

Society of American Foresters
September 11-15, Portland, Oregon

American Society of Agronomy
October 31-November 4 Salt Lake City, Utah

Inside

Measuring Soil Water Potential — 100 Years of Progress

Continued from page one.

work. At about this same time George Bouyoucos at Michigan State University equilibrated gypsum blocks with soil and measured the water content of the gypsum to determine water potential. He measured the change in water content by measuring the electrical resistance of the gypsum block.

Again a decade or more passed before there was significant additional progress. In the late 50's two scientists, L. A. Richards in the U. S. and John Monteith in Britain published papers describing a thermocouple psychrometer for measuring the water potential of soil samples. Those early devices were eventually developed into the Tru Psi thermocouple psychrometer system sold by Decagon for the past 15 years. They were also the precursors to the new WP4 Dew Point PotentiaMeter now being introduced by Decagon.

WP4 PotentiaMeter, a laboratory-grade instrument, makes water potential measurements easier than ever.

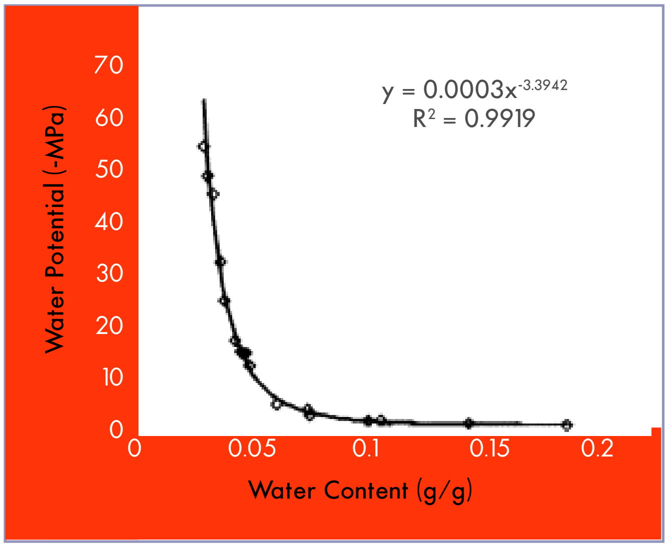
Somewhat later, in the early 70's, Claude Phene and Stephen Rawlins, of the U. S. Salinity Laboratory, invented an improved matric potential sensor. The principle of operation of the sensor was similar to that of the Bouyoucos block, but they used a porous ceramic for the standard matrix, and used heat dissipation to determine its water content. These changes eliminated problems with dissolution and solute sensitivity that plagued gypsum block sensors. Both the ceramic and thermal sensor were improved upon by C. Calissendorff and myself at the Washington State University soil physics laboratory. These sensors are part of the ThermoLink system for field measurement of matric potential.

The development of accurate and reliable sensors has been a difficult and time consuming activity, but the dream of a century of soil physicists is finally near reality. The WP4 can measure the water potential of any sample between 0 and -40 MPa (saturated to air dry) in less than 5 minutes, with an accuracy of 0.1 MPa or better. This provides a host of opportunities to researchers ranging from rapid and accurate moisture characteristics over the entire plant growth range to studies of seed zone moisture in arid environments. Matric potential sensors with the ThermoLink can be used for *in situ* water potential measurements. Their range is -0.01 to -100 MPa. The response is approximately proportional to the logarithm of the water potential (linear with pF), so readings in the wet range have a resolution approximately equal to a tensiometer; readings in the mid range have a resolution comparable to a thermocouple psychrometer, and in the dry range the sensors respond to changes in atmospheric humidity. The sensors therefore offer a convenient, reliable and trouble-free method of monitoring water potential in the field.

ThermoLink eliminated problems with dissolution and solute sensitivity that plagued gypsum block sensors.

Generating a Soil Moisture Characteristic

Bryan Wacker



Sample Moisture Release Curve for Walla Walla Silt Loam
This line is power law fit to the data.

A MOISTURE RELEASE curve, or soil moisture characteristic relates the water potential of a particular soil to its water content. This information is important for describing water storage in soil and water availability to plants, and for predicting water and contaminant transport in soil.

A moisture characteristic is obtained by measuring the water potential and water content of a set of soil samples over a range of water contents. The following procedure can be used to generate a moisture characteristic using a WP4.
(see cover article)

The soil moisture characteristic is hysteretic. At a given water potential, samples which reached that water potential by wetting will have lower water content than those which reached it by drying. The procedure described here is for a wetting characteristic.

Procedure

1. Weigh out six 10g samples of air-dry soil.

2. Add 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0g of water respectively to the samples.

3. Mix each sample thoroughly and seal each one with a watertight cover. Let them stand overnight.

4. Measure the water potential of each sample with the WP4, then weigh each sample immediately.

5. Place each sample in the drying oven with the lid off. Leave them in the oven for 24 hours at 105 degrees Celsius. Remove the samples from the oven, replace the covers, and wait until cool.

6. Weigh each sample again. Also determine the tare weight of the sample container. Compute the water content with the formula shown below.

7. The resulting data can be plotted as shown. *(above left)*

8. The above procedure can be repeated with smaller increments of water content to better define parts of the moisture characteristic of your particular application. ■ ■

Data chart.

w - (g/g)	(MPa)
0.027	-49
0.029	-44
0.031	-40.8
0.034	-28.8
0.035	-22
0.0396	-15
0.0419	-13.1
0.0422	-12.7
0.0434	-12.8
0.0453	-10.6
0.056	-3.75
0.068	-2.75
0.0685	-1.97
0.092	-1.05
0.097	-1.08
0.131	-0.2
0.17	-0.11
0.175	0

Formula.

$$w\,(g/g) = \frac{(\text{weight of wet soil + tare}) - (\text{weight of dry soil + tare})}{(\text{weight of dry soil + tare}) - (\text{tare})}$$

Thermal Runaway

Testing thermal resistivity—a measure of the soil's ability to carry heat away from cables.

The cables, like any other piece of electrical equipment, risk failure upon reaching a certain temperature.

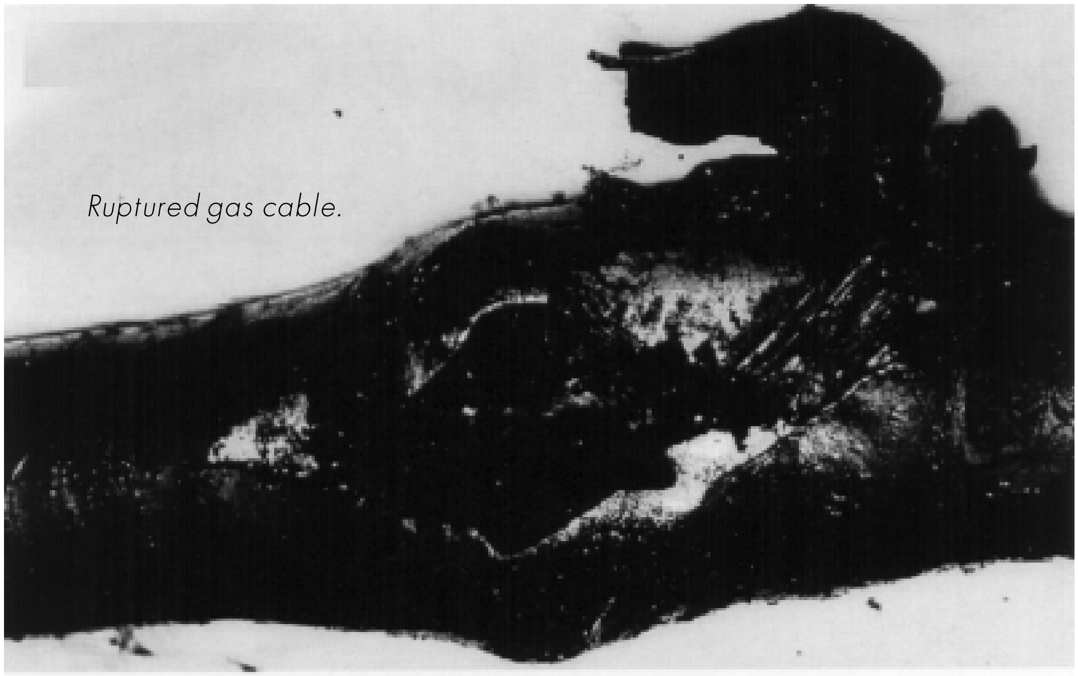
From Reuters/Variety
March 3, 1998
By Matthew Brockett

WELLINGTON, March 3 (Reuters) - Irish rock band U2 came to the aid of power-hungry Auckland as a giant cargo plane for concert equipment was diverted to fly in generators to relieve a 12-day power outage in February 1998.

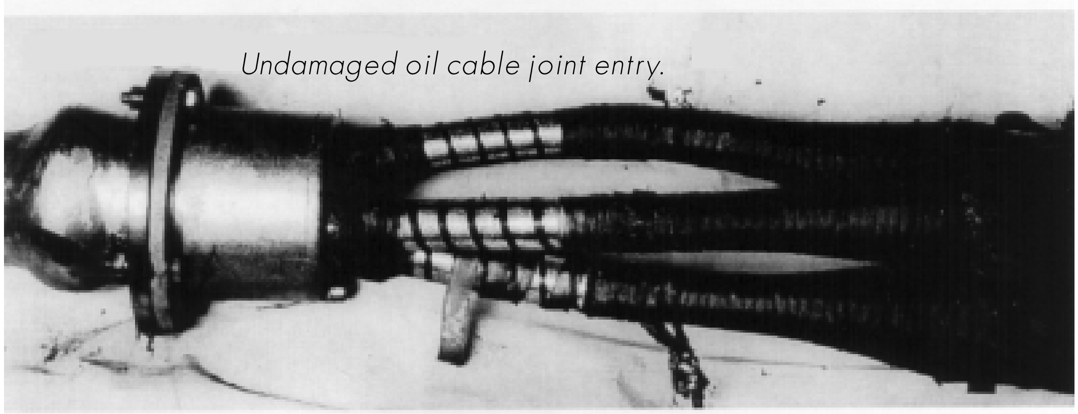
The use of the band's plane was one of very few victories for Mercury during 12 days which it has described as "the weeks from hell."

Central Auckland was plunged into darkness on February 20 when the last of Mercury's four main power cables into the city failed. The 110,000-volt cables started to collapse in January.

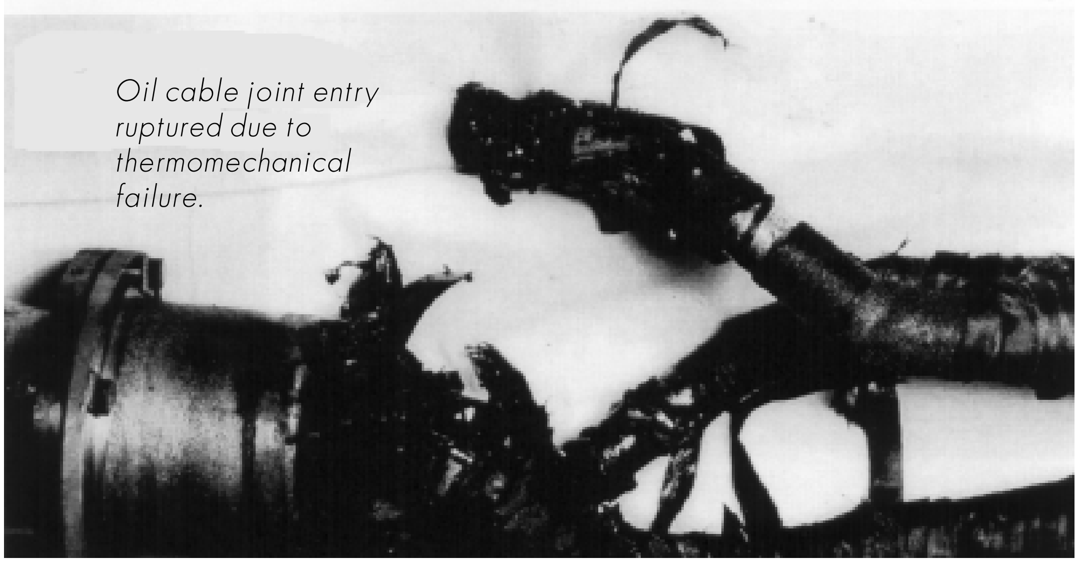
The source of the failure was thermal runaway in the buried cables carrying power to Auckland. Thermal runaway is becoming increasingly common



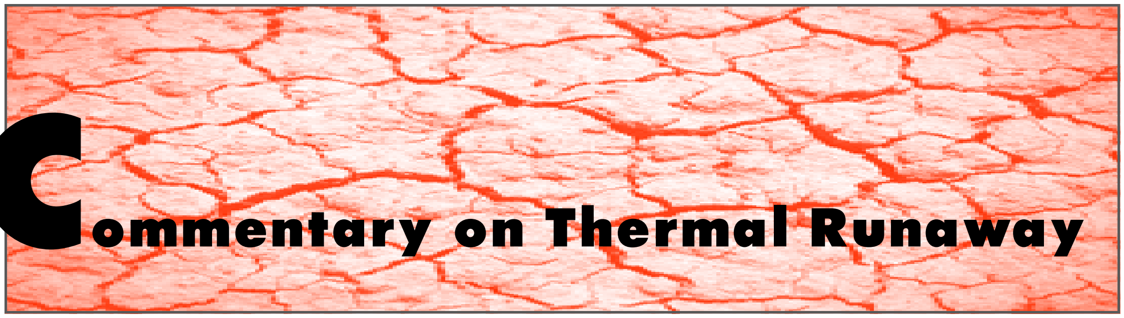
Ruptured gas cable.



Undamaged oil cable joint entry.



Oil cable joint entry ruptured due to thermomechanical failure.



Commentary on Thermal Runaway

throughout the world, as public power companies are privatized and infrastructure is pushed to the limits of its capacity in order to maximize profits. The results of miscalculations are disastrous. While Decagon can't stop thermal runaway problems, we can help.

Thermal runaway can occur in underground power cables. Because the cables carry current, they generate heat. The heat is dissipated to the soil surrounding the cable. The soil/cable system is designed so that, for the current normally carried by the cable and the thermal properties of the soil in which it is placed, the temperature of the cable will remain within safe limits. Thermal runaway results when the design conditions are exceeded, either by passing too much current through the cable, or allowing the soil to dry around the cable, thus decreasing its thermal conductivity. Once the cable starts to heat, a positive feedback condition starts (similar to a microphone and amplifier in a public address system feeding back on itself). When a temperature gradient exists in soil, water tends to move from regions of high temperature to regions of low temperature. As the cable heats, the moisture around the cable is driven away, leaving the cable in dry soil. The thermal conductivity of dry soil is only about 1/5 that of wet soil, so the cable temperature has to rise substantially in order to dissipate the heat it is producing. This increased temperature dries an even thicker layer of soil around the cable, which results in even more temperature rise at the cable. The positive feedback produces a runaway condition where the cable temperatures become high enough to cause catastrophic cable failure, as is shown in the pictures.

How can Decagon help?

We can't control the current that power companies chose to send through a cable, but we can supply engineers with measurements of soil thermal properties. This will allow the engineers to compute safe limits for power dissipation in the cables. The Thermolink, with the thermal properties probe, measures thermal conductivity, thermal diffusivity, and specific heat of a soil in less than two minutes. Thermal resistivity, which is often used in these calculations in place of thermal conductivity, is just the reciprocal of the conductivity. It is probably too late to start these measurements and calculations after the lights go out, but we hope future disasters like the power outage in Auckland can be averted by better measurements of soil thermal properties and more careful design of soil/cable systems which take these properties into account.

■ Figures released by the National Institute of Water and Atmospheric Research showed February was Auckland's hottest month since 1868.

SOILS NEWS

Teaching Soil Hydraulic Conductivity with a Mini Disk Infiltrometer

To: soils@decagon.com
Subject: Mini Disk Infiltrometer

I am teaching a soils and hydrology course at the University of Georgia, and one of the lab-techs showed me your Mini Disk Infiltrometer. I used it in my lab, and the students were astounded. No other device has sparked as much interest as this one. I find it is a great teaching tool. Is there some way I can purchase a number of these?

Best Regards. Todd Rasmussen Associate Professor of Hydrology
trasmuss@uga.edu

Infiltrometers have been used in a wide variety of teaching applications, and are ideal for student use. Labs on infiltration fit in general soils courses, as well as in soil physics, geotechnical engineering, irrigation and drainage, and turf courses. An infiltrometer, along with a soil column, can be used to teach concepts of infiltration, redistribution, and field capacity, as well as effects of initial moisture, crusts, texture, density, and structure on infiltration. The infiltrometer provides a convenient means of applying measured quantities of water to the soil surface, so it can also be used in solute transport and breakthrough experiments. Since the soil surface is not saturated (water is supplied under a small suction) flow in macropores is avoided, so results are repeatable.

Mini Disk Infiltrometers are good for student laboratory or for infiltration experiments in a specific site, on crusts, etc. Call now to order your infiltrometer and ask for a free application note.

Visit our website:
www.decagon.com/soils/

Soils Physics Instruments
DECAGON
950 NE Nelson Court
Pullman, Washington
99163
509-332-2756
fax: 509-332-5158
soils@decagon.com