Revisiting the Fully Automated Double-ring Infiltrometer Using Open-source Electronics

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American Geophysical Union Fall Meeting
December 2012

H11I-1294

ABSTRACT

The double-ring infiltrometer (DRI) is commonly used for measuring soil hydraulic conductivity. However, constant-head DRI tests typically involve the use of Mariotte tubes, which can be problematic to set-up, and time-consuming to maintain and monitor during infiltration tests.

Maheshwari (1996) developed a method for eliminating Mariotte tubes for constant-head tests using a computer-controlled combination of water-level indicators and solenoids to maintain a near-constant head in the DRI. A pressure transducer mounted on a depth-to-volume calibrated tank measures the water delivery rates during the test and data are saved on a hard drive or floppy disk.

Here we use an inexpensive combination of pressure transducers, microcontroller, and open-source electronics that eliminate the need for Mariotte tubes. The system automates DRI water delivery and data recording for both constant- and falling-head infiltration tests. The user has the option of choosing water supplied to the DRI via gravity feed or by a pressurized/pumped system. An LCD screen enables user interface and observation of data for quality analysis in the field. The digital data are stored on a micro-SD card in standard column format for future retrieval and easy importing into conventional processing and plotting software. We show the results of infiltrometer tests using the automated system and a conventional Mariotte tube system conducted over test beds of uniform soils.

INTRODUCTION

The DRI is commonly used for measuring soil infiltration rates. Two open cylinders, one inside the other, are driven into the ground and partially filled with water. The outer ring prevents inner ring lateral-flow and promotes one-dimensional, vertical plug flow beneath the inner ring. The DRI can be operated under constant head and falling head conditions. In the constant head technique, the volume of water added to maintain a constant level in the inner ring is measured as a function of time. In the falling head technique, the decreasing water level in the inner ring is measured as a function of time. In both techniques, the water level in the outer ring is maintained at the same level as that of the inner ring.

Water delivered into the DRI may be provided by:
- Mariotte tubes
- float-valve system
- manually pouring a known volume of water

Issue: Manually delivering water and recording reading water levels are time consuming and may at times lead to errors in reading.

Efforts on automation (past work):
(1) Constant Head - used depth sensor, solenoid valves, water level sensors, 12V car battery, laptop computer, and software (Maheshwari, 1996)
(2) Falling Head - partial automation using pressure transducer and data logger for inner ring and manually refilling the outer ring (Arriaga et al., 2010)

Project objective: Construct a fuly automated DRI (auto-DRI), for both constant head and falling head test methods, using open source electronics.

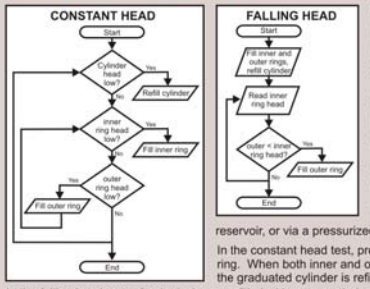
MATERIALS / DESIGN

System functions:
1) Infiltration procedure:
   - Constant Head
   - Falling Head
2) Water supply:
   - Reservoir/Pump
   - Gravity feed
   - Water supply system
3) Sensor type:
   - Pressure transducer
   - Water level switches (float)
4) Pressure transducers:
   - slope calibration
   - high/low water level
6) Battery voltage
7) Low water warning
8) Data saved on SD-card
9) Date/time
10) Stop watch
11) Backlight

Pressure transducer: +/- 1mm
Power: 12V DC, 5A
Max infiltration rate: 300 mm/hr (1.5L/min)

The Parallax Propeller microcontroller was used for this project. An adjustable power supply regulates the 12V car battery supply down to 7.5V. Open source Propeller Object Exchange (OBX) codes were used to interface with the DS1307 clock, peripheral devices (LCD, keypad, and SD card), and the 12-bit ADC. Input signals are taken from the pressure transducer and/or water level sensors. Head conditions in the inner and outer rings, graduated cylinder, and reservoir, water levels are controlled using solenoid valves and Bilge pump using transistor switches.

AUTO-DRI FLOW CHART

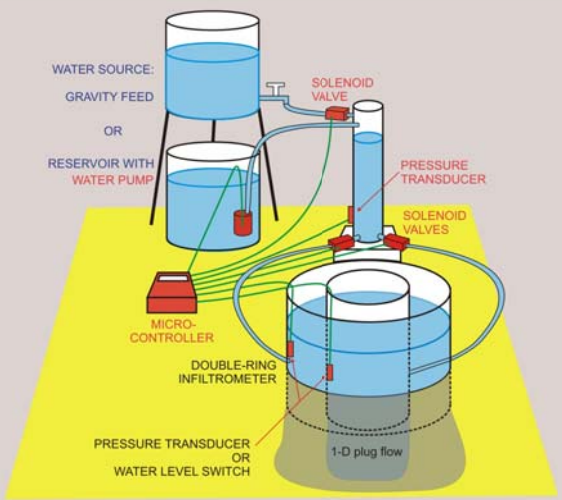


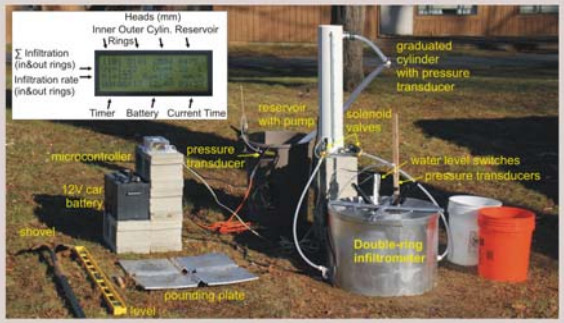
Water levels are measured using pressure transducers for 1) the inner and 2) outer rings of the DRI, 3) graduated cylinder for delivering water to the DRI, and 4) a reservoir. Water level switches may also be used for fixing the water level in a constant head test. When the water level in the inner or outer rings drops by ~5 mm from the set height, the time and volume of water delivered to the DRI from the graduated cylinder are recorded by the microcontroller and saved to an SD card. The graduated cylinder is refilled bypumping water from a reservoir, or via a pressurized/gravity feed system.

In the constant head test, precedence is given to filling the inner ring. When both inner and outer rings are to their desired levels, the graduated cylinder is refilled.

In the falling head test, after both rings are filled with water to their desired level, the water level in the inner is allowed to drop. Due to lateral flow, water in the outer ring infiltrates faster than in the inner ring. A solenoid valve switches on and water from the cylinder fills the outer ring to the same level as that of the inner ring.

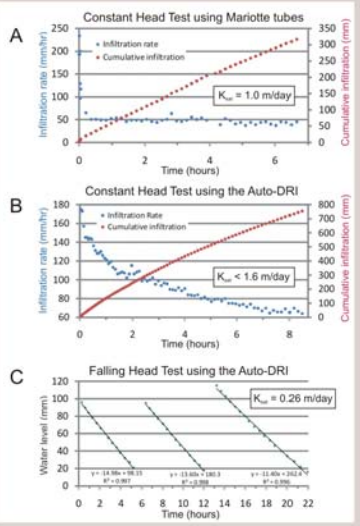
FIELD SETUP





FIELD DATA EXAMPLES

Examples of constant head infiltration tests conducted on soils underlain by glacial sediments using (A) Mariotte tubes and (B) the auto-DRI. (C) Example of falling head infiltration test performed using the auto-DRI. Results indicate satisfactory performance of the auto-DRI and overall achievement of the project goals.



ACKNOWLEDGMENTS

This work was supported by the U.S. Environmental Protection Agency under contract EP11D000055, and the USGS Toxic Substances Hydrology and Groundwater Resources Programs. Any use of trade, product, or firm names is for description purpose only and does not imply endorsement by the U.S. Government. Although this work was reviewed by the EPA and approved for publication, it may not necessarily reflect official EPA policy.

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