TRANSVERSE FLOWMETER

The Transverse Flowmeter (PFL TRANS) measures the flow of groundwater across a drillhole (Figure 1). The equipment used in the transverse flow measurements confines a test section (across which flows are measured) inside the drillhole. The test section is a 0.4 m long part of the drillhole. The test section is confined by packers and it is also divided into two parts by two longitudinal packers. The parts are connected through a flow sensor. The flow direction in the flow sensor can be either positive or negative.

Flow along the drillhole is directed through the test section by means of a bypass pipe and is discharged at the upper or lower end of the probe.

The flow rate is measured by thermal techniques as in the Difference Flowmeter (PFL DIFF). The angular position of the probe is detected by a position sensor.

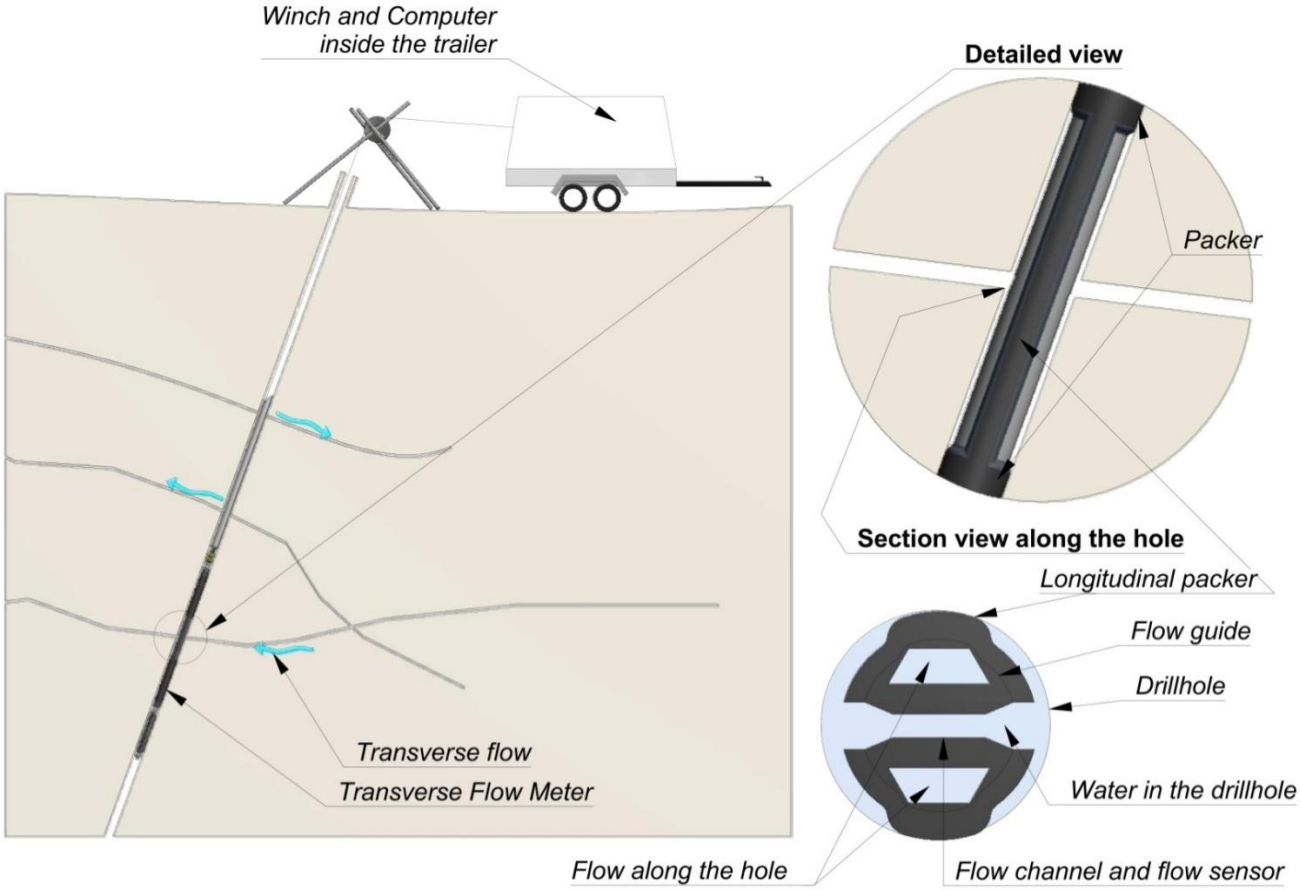

Figure 1. *Schematic of the probe used in the PFL TRANS.*

After transferring the probe to a new position (a new depth and/or a new direction), a single flow measurement is conducted before inflating the packers. After the first flow measurement is complete the packers are inflated and a series of flow measurements is initiated. The inflation of the packers is usually visible in the results. A waiting period (normally about 15 minutes) is allowed to elapse after each flow measurement at the same position. The aim is to repeat measurements at the same position until a steady state condition is achieved.

In addition to flow measurements, the PFL TRANS probe can also measure:

- The single point resistance (SPR) of the drillhole wall (grounding resistance). The electrode used for SPR measurements is located between the uppermost rubber sealing disks as in PFL DIFF and it is used for the high-resolution depth determination of fractures and geological structures. It is an essential tool in deep drillholes for finding a predetermined target fracture.
- The drillhole water temperature.
- The position of the probe. The sensor includes a magnetometer, accelerometer and gyroscope, all a three component devices.
- Hydraulic head of the measurement section can be measured using a plastic tube.

Usually a single target fracture is measured using several probe orientations. The consistency of the flow measurements can be evaluated by comparing the results to a theoretical model. The simplified model used here assumes a planar, constant flow. The effect of the probe orientation is illustrated in Figure 3. When the measuring channel is parallel to the flow field the flowmeter gives the maximum response. As the probe is turned, the measured flow decreases and is zero when the probe is perpendicular to the flow field. The form of the flow pattern is such that the maximum is wide but the minimum is narrow.

In reality the situation is more complicated. The drillhole draws the flows towards itself in such a way that the detected flow in the drillhole is double to that far from the drillhole (for even fractures). This effect makes the flow pattern even wider near the maximum. The fracture aperture (fracture width) may vary in natural fractures which can make the flow pattern complicated. The packer itself has an effect to flow pattern. An example of field result is presented in Figure 4

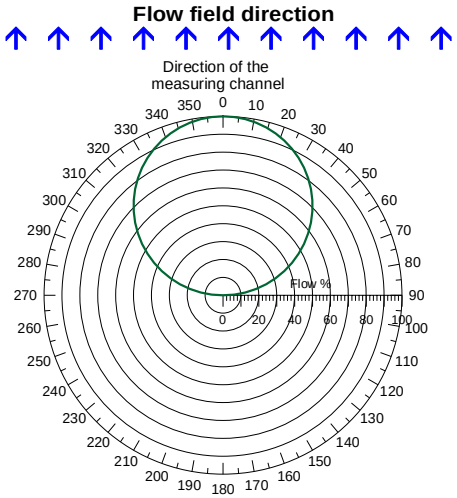

Figure 3. *Flow pattern with different probe orientations.*

Table 1. *Equipment and features.*

Part/Feature	Description
Flowmeter	PFL TRANS probe
Measurable drillhole diameters	76 mm
Length of test section	0.4 m
Method of flow measurement	Thermal pulse and thermal dilution
Additional measurements:	Temperature, Single point resistance, Magnetic field, Water pressure, Air Pressure, Packer pressure, Hydraulic head of measurement section
Winch:	Mount Sopris Wna 10, 0.55 kW, conductors, Gerhard-Owen cable head
Depth determination	Based on a digital distance counter
Logging computer:	PC (Windows XP)
Software	Based on MS Visual Basic
Total power consumption:	1.5 - 2.5 kW depending on the type of pump employed

Table 2. *Range and accuracy of sensors.*

Sensor	Range	Accuracy
Flow	3 – 1 000 mL/h	± 10% curr.value
Temperature (central thermistor)	0 – 50 °C	0.1 °C
Temperature difference (between outer thermistors)	-2 – +2 °C	0.0001 °C
Magnetic field	-2 – +2 G*	± 2% full-scale
Single point resistance (SPR)	5 – 500 000 Ω	± 10% curr.value
Groundwater level sensor	0 – 0.1 MPa	± 1% full-scale
Packer pressure	0 – 1.6 MPa	± 1% full-scale
Air pressure	800 – 1060 hPa	± 5 hPa

*1 G = 10^{-4} T

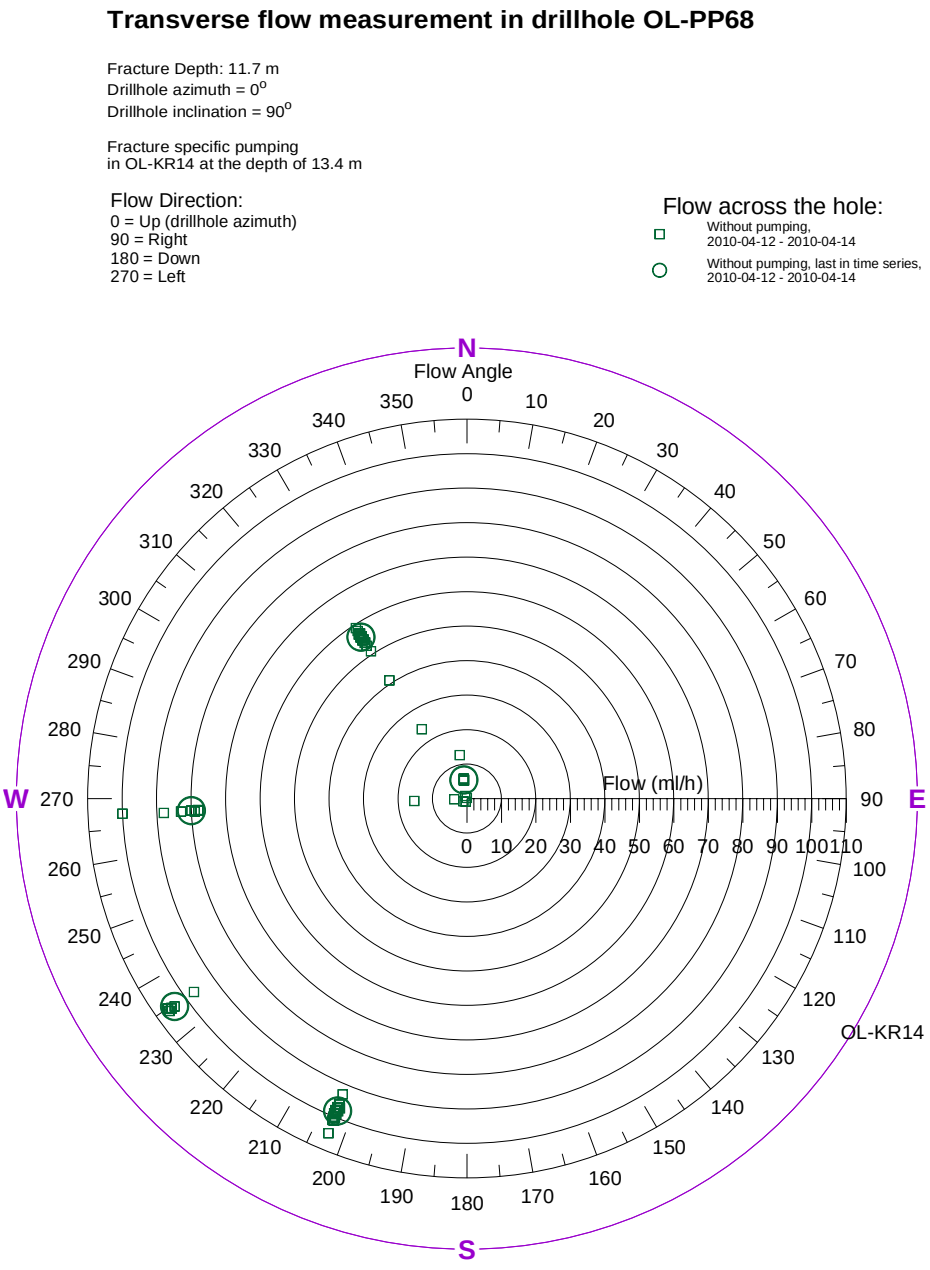

Figure 4. *A measured TRANS result in a vertical borehole. The flow is probably caused by a tunnel nearby*

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