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HFP-2293 Heat-Pulse Flow Meter Probe

Calculate Hydraulic Parameters from Open Borehole Logs

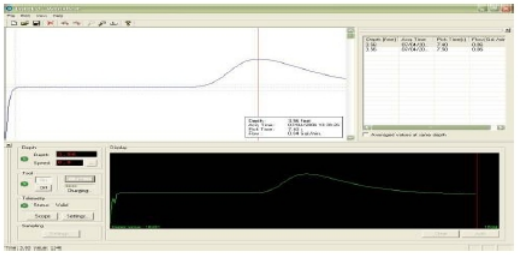
Theory of Operation

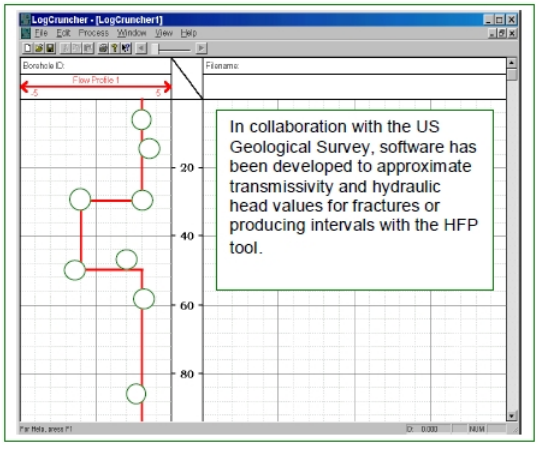
The tool is lowered into the borehole via a cable attached to a winch. When the tool is in position to take a flow measurement the trigger assembly button is pressed. This sends a pulse down the center conductor which when detected by circuitry in the probe, fires the heat grid and signals the surface monitoring equipment and software to begin a flow measurement cycle. The grid heats ambient fluids and if there is up or down flow in the well, this heated fluid mass is detected at thermistor sensors (2 cm from grid) allowing the time (and flow rate) through a known x-sectional area to be recorded by an amplifier.

The output of this amplifier is then converted to a frequency. This frequency is then driven up the cable line and monitored by the surface equipment. When the tool is pulsed by the surface system, the tool immediately begins to charge the capacitors that produce the voltage for the heat grid in preparation for the next measurement cycle. A complete flow measurement is made when the time is accurately measured from when the heat grid is fired to when a peak temperature change, carried by the flow, is detected by either the upper or lower sensor.

Software

MSHeat is the Windows acquisition software for the HFP-2293. This software is compatible with Matrix systems. Individual heat-flow waveforms can be saved, and text files with depth and flow rate can be imported into **WellCAD** for a histogram-type presentation.





In collaboration with the US Geological Survey, software has been developed to approximate transmissivity and hydraulic head values for fractures or producing intervals with the HFP tool.

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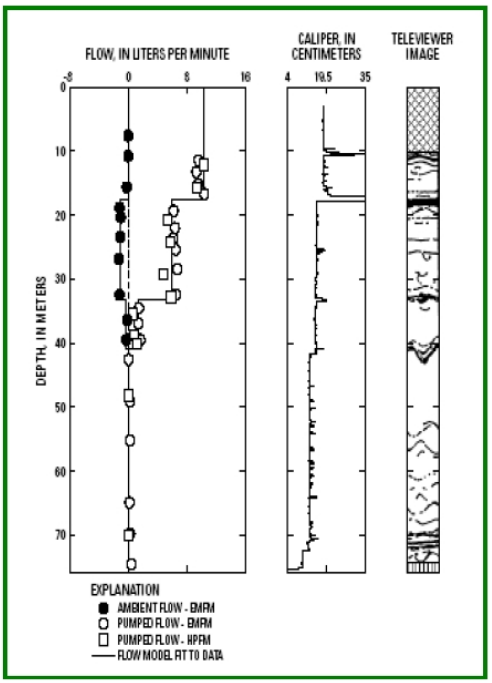
Specifications:

- Measuring Range:
  - 0.113. liters/minute to 3.785 liters/minute
  - (0.03 gallons/minute to 1.0 gallons/minute)
  - 0.046. meters/minute. to 3.962 meters/minute
  - (0.15 feet/minute to 13 feet/minute)
- Resolution:. 5%
- Accuracy: 5% (Mid-Range) to 15% (Extremes)
- Dimensions:
  - Length:. 122 cm (48 inches)
  - Diameter:. 4.1 cm (1.63 inches)
  - Weight:. 5.5 kg (12 lbs)



A typical example from a bedrock well with three fracture zones (Paillet, 2004) gives the transmissivity and depth to water level in each of the zones. The figure shows the original flow data and the model prediction as a synthetic flow log generated by the model. When model output matches the measured flow for both conditions, the results represents a unique solution for the two variables (transmissivity and water level) as a "solution" to the two flow data sets (ambient and pumping/injection). The solid line in the figure is the model fit to the data. The results show the depth to water that would be found by isolating each fracture with packers. The fact that the two deeper fractures have the same water level is strong circumstantial evidence that they are connected to each other in the vicinity of the borehole.

Flow Zone (depth in meters)	Transmissivity (m^2/Sec)	Zone Hydraulic Head Meters below top of casing)
16.8	2.0×10^{-5}	5.95
32.0	4.0×10^{-5}	6.85
39.8	1.3×10^{-5}	6.85

References:

Paillet, F. L., 1998, Flow modeling and permeability estimation using borehole flow logs in heterogeneous fractured formations: Water Resources Research, v. 34, no. 5, p. 997-1010.

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Paillet, F. L., 2001, Hydraulic head applications of flow logs in the study of heterogeneous aquifers: Ground Water, v. 39, no. 5, p. 667-675.

Paillet, F. L., 2004, Borehole flowmeter applications in irregular and large diameter boreholes, Journal of Applied Geophysics, vol. 55, p. 39-60.

Paillet, F.L., Senay, Y., Mukhopadhyay, A., and Szekely, F., 2000, Flowmetering of drainage wells in Kuwait City, Kuwait: J. of Hydrology, v. 234, p. 208-227.

Williams, J.H., and Paillet, F.L., 2002, Using flowmeter pulse tests to define hydraulic connections in the subsurface – a fractured shale example: Journal of Hydrology, v. 265, p. 100-117

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