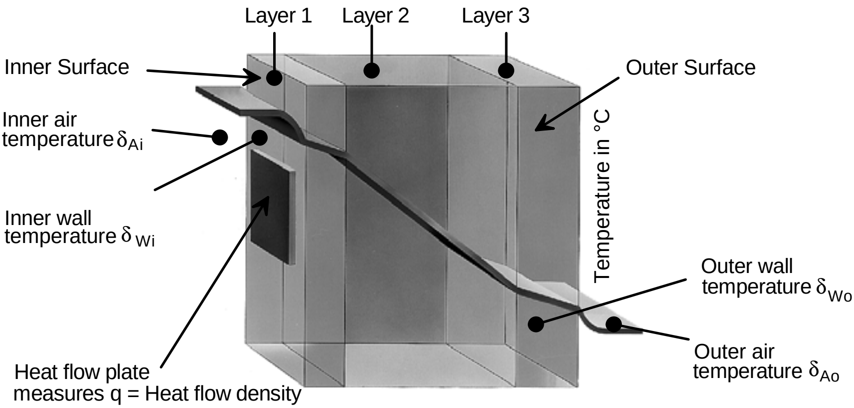
3.2 Sensors for Applications in Building Physics

3.2.1 Basic Principles of Heat Flow Measurements

At heat flow measurements on brickwork the heat transfer coefficient and the heat transition coefficient (k value) are determined. Two air temperature sensors and two wall surface temperature sensors and one heat flow plate are required for calculating the heat flow density q.

Presentation of the Temperature Behaviour



Depending on the installation of the temperature sensors the quotient q/T1-T0 equals the heat transfer coefficient α, the heat conductivity coefficient Λ or the heat transition coefficient k:

Heat transfer coefficient $$\alpha_i = \frac{\text{Heat flow density q}}{\text{Inner wall temperature } T_{Wi} - \text{Inner air temperature } T_{Ai}}$$

Heat transfer coefficient $$\alpha_a = \frac{\text{Heat flow density q}}{\text{Outer wall temperature } T_{Wo} - \text{Outer air temperature } T_{Ao}}$$

Heat conductivity coefficient $$\Lambda = \frac{\text{Heat flow density q}}{\text{Inner wall temperature } T_{Wi} - \text{Outer wall temperature } T_{Wo}}$$

Heat transition coefficient:

Experimental k value $$k = \frac{\text{Heat flow density q}}{\text{Inner air temperature } T_{Ai} - \text{Outer air temperature } T_{Ao}}$$

DIN k value $$k = \frac{1}{1/\alpha_i + 1/\Lambda + 1/\alpha_o}$$

DIN 4108:
$\alpha_i = 8.1$ W/m²K and
$\alpha_o = 23.3$ W/m²K
$1/\alpha_i + 1/\alpha_o = 0.16578$

Measuring Principle of the Heat Flow Plates

Heat flow plates consist of a meander of many opposing thermocouples that are embedded in a substrate.

If the heat flow plate is placed on the measuring point under test it acts as a thermal resistance that obstructs the heat flow. A temperature gradient proportional to the density of the heat flow develops over the thickness of the plate. With thick substrates the plates are structured so that a sufficient shell zone exists, besides the meander, which helps to prevent a lateral circulation of the heat flow. The heat flows always refer to the surface covered by the meander and they form the average value for this surface.

Calibration Value

With heat flow measurements the individual calibration value [W/m²mV] of the heat flow plates must be considered to obtain the correct value of the heat flow in W/m², when the plate provides 1mV as output.

The calibration value of ALMEMO® heat flow plates FQ A0xx has already been factory-set and stored in the ALMEMO® connector so that ALMEMO® instruments can immediately indicate the current heat flow density in W/m². However, the scaling for the calibration value can also be performed according to the following table.

Heat flow [W/m²]	**Calibr. val.** [W/m²mV]	**Meas. range**	**Factor**	**Exp.**
0.0 to 2000.0	1.0 to 20.0	260 mV	0.100-2.000	1
0.0 to 2000.0	10.0 to 200.0	26 mV	0.100-2.000	2

Attaching the Sensors

The **heat flow plates** must be attached so that a homogenous contact between the bottom surface and the measuring point is ensured, e.g.:

- Sticking by using double-sided PVC or fabric tape. Do not use paper tape because the heat flow plate may not be able to be removed easily later.
- Covering the bottom surface with heat-conducting paste and attaching the heat flow plate with adhesive tape or a mechanical fixture at the margin of the plate.

Temperature Sensor

One surface temperature sensor and one air temperature sensor is required to determine the heat transfer coefficient and two surface temperature sensors are required to determine the heat conductivity coefficient.

Suitable for measuring **surface temperature**s is e.g. the surface thermocouple FT 9683-2 with connecting cable ZTA 683-AK. Ensure that the thermocouple is correctly polarized : The positive pole (marked red) is connected to the green wire of the NiCr-Ni compensation line. Also suitable, alternatively, are bare thermo-wire sensors FTA390-1 welded to the tip. The sensors are attached using (double-sided) adhesive tape directly beside the heat flow plate and connected to the measuring instrument. Also suitable for measuring **air temperature** are bare thermo-wire sensors FTA390-1 welded to the tip. The measuring tip must be set up at a distance of at least 10 cm above the heat flow plate.

Please note that all connecting cables of the thermocouples must be composed of the corresponding thermo wire or a compensation line.

Arrangement and Programming of the Sensors

Sensor	**MPt**	**Range**	**Size**	**Description**
NiCr-Ni sensor	$M00_1$:	NiCr	T0	Temperature T0 in °C
NiCr-Ni sensor	$M01_1$:	NiCr	T1	Temperature T1 in °C
	$M01_2$:	DiFF	T1-T0	Difference T1- T0 in °C
				Averaging mode CONT or CYCL
			M(T1-T0)	Average of T1-T0
Heat flow plate	$M02_1$:	mV 2	q	Heat flow in W/m^2
				Averaging mode CONT or CYCL
			M(q)	Average of heat flow
	$M02_2$:	q:dt	M(q)/M(T1-T0)	Heat flow/Temperature difference

Determining the Coefficient Heat flow/Temperature difference

The measuring channel $M02_2$ allows, in combination with the measuring range "q:dt", the calculation of the quotient from the average value of the heat flow of $M02_1$ and the average value of the temperature difference of $M01_2$=$M01_1$-$M00_1$. The type of averaging (continuous or cyclic) is programmed with the channels $M01_1$ and $M02_2$. As there can be large phase deviations between the temperature difference and the heat flow, it is recommended to perform the averaging over long periods and to check that the temperature differences do not become too small.

3.2.2 Thermal Conductivity Measurement with Insertion Probe

Application and Description:

The special range SB 2290-L allows the ALMEMO® 2290-4 instrument to perform a fast and easy determination of thermal conductivities of heat relief materials and fine bulk goods during their production, storage and processing, as well as during measurements of materials that have already been installed, e.g. for the sanitation of buildings. The device is used with the heatable thermal conductivity probe FP A437-1, which feeds a constant heat flow into the test material until a balance is established between thermal energy being passed into and thermal energy dissipating from the material. The resulting overtemperature is a dimension for the thermal conductivity λ of the material that is directly indicated in W/m•K after the measurement is complete. The additional measuring range ´Lamb´ is available for the evaluation of the signal. During the manual programming the measuring range will be indicated by the abbreviation `LAMb` at the end, between `q:dt` and `P104`.

Measuring Range:

Meas. range thermal conductivity λ:	0.025 ... 0.250 W/m•K
Resolution:	0.001 W/m•K
Indication in the display:	`LAMb`
Presentation in the printout:	`Lamb`
Interface command:	`B81`

Thermal Conductivity Probe:

Order number:	FP A437-1		
Meas. element:	Pt100 sensor		
Diameter:	1.5 mm		
Connector programming:			

1st channel:	meas. range:	Pt100-2 0.01K	`P204`
		comment:	`´*L  ´`
2nd channel:	meas. range:	thermal conductivity	`LAMb`

The function values Limit Value High, Zero Point Correction, Slope (Gain) Correction, Base Value and Factor are occupied by the calibration values of the thermal conductivity probe and are, therefore, no longer available for the user (locking level 7).

Device Programming:

Measuring cycle: 00:00:10 s

☞ The measuring cycle is set automatically as soon as the thermal conductivity probe is plugged into socket M0. If the probe is disconnected and the device is switched off and then back on again, the measuring cycle previously set will be reactivated.

Measuring Process:

- Connect the thermal conductivity probe FPA437-1 to socket M0 on device 2290-4.
- Insert thermal conductivity probe FPA437-1 into the body under test.
- By means of key **M▲** select channel M0 (temperature).
- Wait until temperature compensation has been completed.
- Press the **START/STOP** key; the **START** arrow should light up; the temperature reading rises.
- In channel M2 a cycle counter is displayed running from 59 to 0 (= 10 min).
- After 10 minutes the device stops automatically and the **START** arrow goes out again.
- By means of key **M▲** change to channel M2 and read the thermal conductivity λ in W/mK.
- The meas. process can be stopped at anytime by operating the key **START/STOP**.
- In case of repeated measurements, it is absolutely necessary to either wait for the cool down period or re-insert the probe at another location.

Important Notes:

☞ Minimum insertion depth 60 mm.
Minimum coverage 15 mm.
Do not use for measurements within test materials that have a high thermal gradient.

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