Measurements on Space Shuttle Hermes

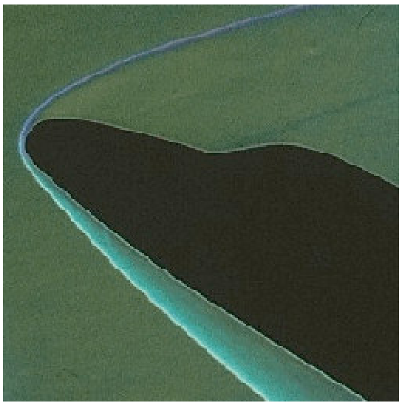
Heat Flux Detection by MCT Coaxial Thermocouple

In 1985, we were commissioned by the shock wave laboratory of RWTH Aachen University to investigate the aerodynamics and heat input into the model of the European space shuttle "Hermes" during the re-entry phase. For this purpose we had a hypersonic wind tunnel at our disposal, which allowed a maximum of Mach 30 for about 20 microseconds. The model had a length of approx. 30 cm.

In addition to being equipped with numerous pressure sensors, heat flow sensors should be fitted above all on the underside and at critical points such as the fuselage nose and the leading edges of the wings. The equipment with pressure probes based on the very high-frequency PVDF sensors just developed by Müller und Platte, a forerunner of today's M60-3 model, as well as Kistler sensors could be easily solved.
However, we had no solution for temperature sensors that were able to measure reliably within the very short measuring window of 20 microseconds.
On the one hand, the usual filigree thermocouples were not fast enough and, on the other hand, they would not have survived any tests.

Our development approach resulted in a very small thin-film thermometer, see our MTFT, which, with a very thin layer of nickel, achieves a rise time of 10 microseconds with simultaneous high temperature resolution. Since this thin film element was also very sensitive, however, it can only be used in non-critical areas such as on the top of the wings. The ceramic body has low heat conduction only, so that during the short measuring time there is no danger that the rear end of the thin film element will also heat up. Thus, to calculate the heat flow into the thin film element, the equation for half infinite bodies can be applied.

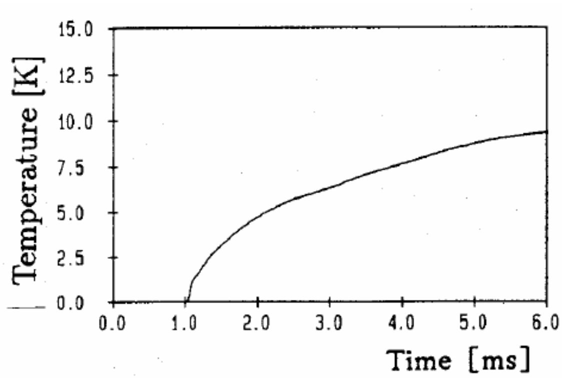
A solution for the critical points as well as the underside of the wings and fuselage was still missing. So we went back to the thermocouples. The aim was to minimize the ground of the thermocouple while maintaining robustness.

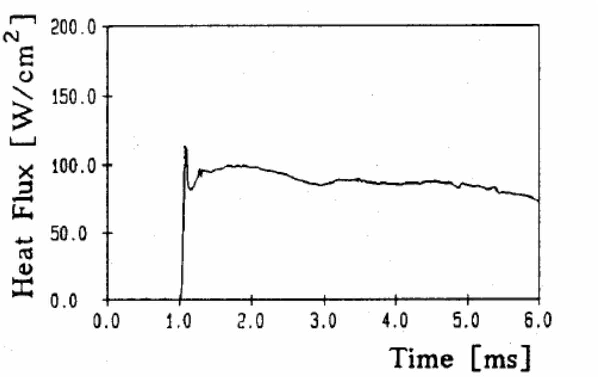


So we built a coaxial thermocouple. The metals were bonded with ceramic adhesive to insulate them from each other. By grinding the front side with sandpaper of grain size 150 to 240, the fine metal chips were pressed into the insulator and formed an almost mass-free bridge. The response time was 3 microseconds. This approach also had the great advantage that the thermocouple could take any shape and thus be ground seamlessly into the surface of e.g. wing noses. With its robustness even in critical positions, it could easily survive Mach 30 at approx. 3000°C. The MCT thermocouple is almost indestructible. If the resistance between the two poles becomes too high after the test because the chips are corroded, the sensor only needs to be regrinded until the resistance between the poles is again around 30 ohms.

The MCT thermocouples have also been designed sufficiently long so that the rear end of the thermocouple does not heat up immediately during the measurement. This takes approx. 40 ms under the above conditions. Thus, from the dynamic surface temperature changes during the measurement, which were at approx. 60 K, the heat flow into the model could again be calculated using the equation of semi-infinite bodies. Maximum values for these tests were 20 MW/cm².

Today, these thermocouples are still used for experiments of this and similar types. Their application spectrum covers all short-term applications, be it hypersonic tests, explosion tests or other short-term measurements of a single event. As long as the measurement does not take longer than approx. 100 ms, depending on the temperature, the heat flow as a function of time can always be determined from the surface temperature distribution.





We strongly recommend making use for these calculations of our "Heat Flux Calculator" program HFC, which calculates the conversion of sensor signals into temperatures as well as heat flows.