28. HEAT-FLOW OPERATIONS AT HOLES 35.0 AND 35.1

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INTRODUCTION

During the planning for Leg 5, the JOIDES Heat Flow Panel proposed that an attempt be made to obtain measurements of the *in situ* sediment temperature gradient using instrumentation which was being developed for this purpose. Basically, this instrumentation consisted of a sensing thermistor mounted on an extender rod so that it projected several decimeters ahead of the drill-bit. The upper end of the extender rod was fastened to an instrument package seated in the bottom of a normal core barrel which was raised and lowered by the coring wire. Although in its final configuration the instrument will be self-contained, the Leg 5 operations were conducted with a modified system in which thermistor resistance was converted to a frequency at the bottom-hole instrument and this frequency was telemetered to the surface via the logging cable. In the logging shack on deck the signal was monitored on an oscilloscope, and the basic data recording was in the form of counts which may be converted to temperature by the use of calibration tables prepared by the Heat Flow Panel.

Although the use of the logging wire introduced several problems, which, however, do not affect the final self-contained instrument, an initial attempt was scheduled for Site 35. In addition to an estimate of the temperature gradient in the sediment, it was hoped that further insight would be provided into the problems imposed by the non-stationary platform.

OPERATIONS

On 29 April at Site 35, with the drill-bit already in place at the sea floor, the instrument was lowered by the logging cable. Stops for measurements were made at intermediate depths of 1000, 2000 and 3000 meters in the pipe before the instrument was lowered into the sediment at the bottom of the hole. Throughout the lowering process, the oscilloscope monitor indicated that the signal was very noisy and the counter in the logging shack recorded a broad spread of counts. Because of the noise, the probe was left in the bottom of the hole for fifteen minutes. At the end of the recording period, as the probe was being retracted through the drill-bit, an abrupt jump in the count indicated damage to the instrument; and, the down-hole power was shut off. Upon return to the drilling deck, the probe was found to be broken and the extender rod had been bent. Further examination indicated that a major repair was required at the point where the logging cable connected to the adaptor cable for the instrument. Because of the time required for this repair, the coring of the sediment section was commenced at Hole 35.0, following which, the ship moved to Hole 35.1 for another attempt to obtain a temperature profile.

Upon arrival at Hole 35.1 on 4 May, the logging cable was reconnected with a better balance of the conductors used to transmit the signal from the instrument to the counter. This, together with the securing of radio transmission during the operations, resulted in almost complete suppression of the noise that had been so prominent at the previous station. As part of the routine of checkout and operation of the equipment during lowering, stops were made routinely to measure the temperature at depths in the pipe of 1000, 2000 and 3000 meters. These data (Table 1), in addition to providing a comparison with the seawater temperatures at comparable depths outside the pipe, are an indication of the lack of noise and provide some estimate of the precision of the system when measuring a constant temperature.

On the first lowering, an attempt was made to obtain a temperature at a point just deep enough in the sediment to keep the drill string stable. To accomplish this, the bit was held several meters above the bottom until the instrument was seated. Then, the drill string was lowered into the bottom and held steady for a five minute recording period. Sea conditions were moderate during the operation and shipboard consensus was that the drill-bit and temperature probe were probably stable and at about 10 to 20 meters below the sediment-water interface. Figure 1 is a plot of the temperatures (converted from the counts) for the five minutes of record. The record is marked by intermittent high temperature jumps with reasonably rapid recovery (see particularly the record after two minutes), and there is clear indication of a slow temperature increase with time.

For the second lowering the bit was advanced to 36 meters below the first depth. The recording period was started as the instrument was being lowered through the drill-bit into the underlying sediment. Only three minutes of recording were completed before an abrupt jump in the count indicated damage to the probe. These data are not presented in plotted form because

TABLE 1
Temperatures Measured at Intermediate Depths in the Pipe at Hole 35.1

	1000 meters	2000 meters	3000 meters
First Lowering	n = 12 T = 3.32°C s = 0.000°C	n = 10 T = 1.85°C s = 0.010°C	n = 10 T = 1.63°C s = 0.010°C
Second Lowering	n = 10 T = 3.23°C s = 0.010°C	n = 11 T = 1.80°C s = 0.012°C	n = 12 T = 1.58°C s = 0.013°C
Third Lowering	n = 11 T = 3.36°C s = 0.000°C	n = 12 T = 1.83°C s = 0.010°C	n = 11 T = 1.57°C s = 0.010°C

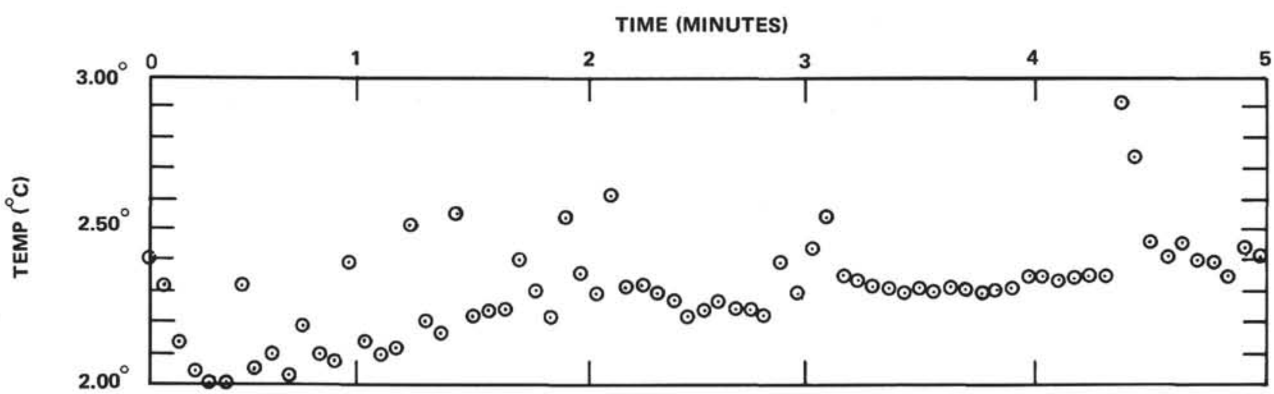

Figure 1. *Temperature-time plot for first lowering at Hole 35.1.*

the record was very short, and there is some question as to whether or not the probe was actually in the underlying sediment or only in some bottom-hole slurry and still inside the drill-bit.

The third lowering was made after an additional advance of 57 meters. Sea conditions were deteriorating and the probe was left in the sediment for an eleven minute recording period. The record is the noisiest of the three, and is marred by many intermittent "high-temperature" spikes. Figure 2 is a portion of the record which appears to have the least scatter and is least marred by the above-mentioned spikes.

Upon recovery from the third lowering, the instrument was damaged and this, together with the rapidly worsening weather, forced cancellation of further attempts.

TEMPERATURE MEASUREMENTS

The principal instrumental uncertainty in the temperature determination is the significance of the "high-temperature" spikes that appear on all records and which were particularly obvious on the third lowering. The magnitude of the temperature increase indicated by the spikes is completely unrealistic in many cases (several tenths of a degree or more), and recovery is frequently almost instantaneous. Examination of even the limited records shown in Figures 1 and 2 indicates that the sudden departures from a relatively smooth temperature-time curve are invariably toward high temperature values. It is probable that many of these sudden departures are not real but are a result of the telemetry from the instrument through the logging cable to the counter. Since the counter is triggered only when signal amplitude reaches an appropriate level, any loss of amplitude in the signal reaching the counter can cause missed counts and consequent interpretation as higher temperatures. Such a loss in amplitude was observed intermittently at the oscilloscope monitor in the logging shack.

The records for each of the lowerings have been passed through a filter which suppresses the effect of the high temperature spikes and, although still not steady, the filtered records are considerably less ambiguous than the unfiltered data. A plot of the filtered record for the first lowering is presented in Figure 3, for comparison with Figure 1. From the filtered data, temperature estimates have been made for each of the three lowerings (Table 2).

HEAT FLOW

Even after a temperature estimate has been accepted, the question of its meaning and its use as part of a heat flow determination is still unanswered. There is no way to be certain that the probe was in undisturbed sediment or whether it was held steady during the period of measurement. However, consideration of the environmental conditions (principally sea state and wind), the drilling operation logs, and analysis of the records

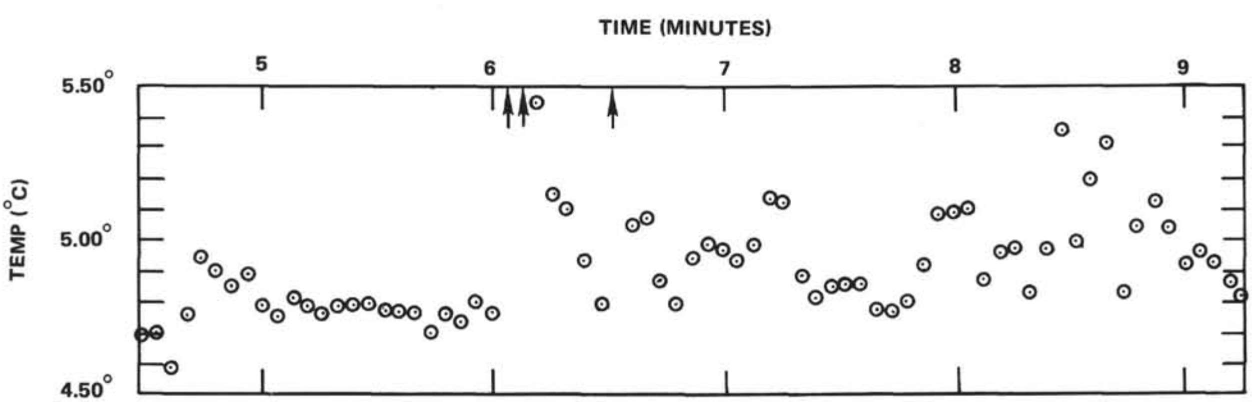

Figure 2. *Temperature-time plot for third lowering at Hole 35.1.*

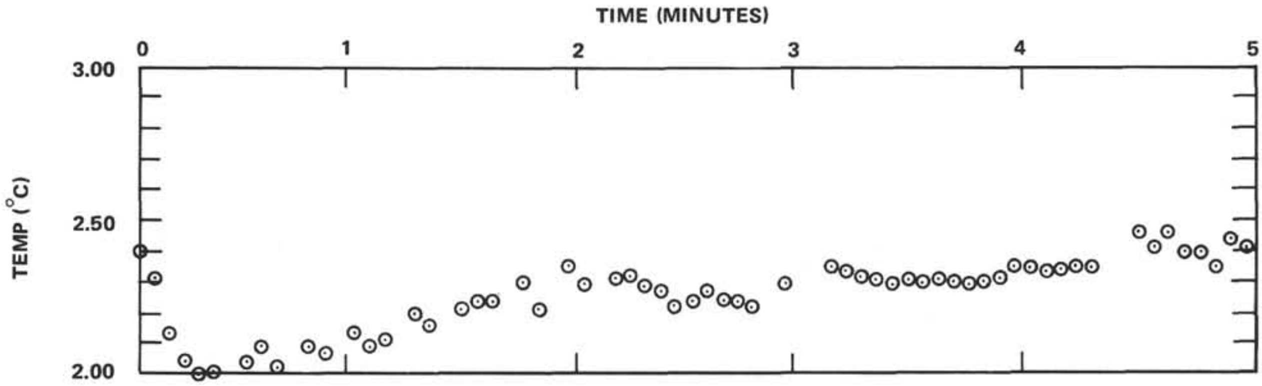

Figure 3. *Temperature-time plot of filtered record for first lowering at Hole 35.1.*

TABLE 2
Temperature Estimates at Hole 35.1

First Lowering	Second Lowering	Third Lowering
0 - 1 minutes	0 - 1 minutes	5 - 6 minutes
n = 10	n = 14	n = 13
$\overline{T}$ = 2.11°C	$\overline{T}$ = 3.02°C	$\overline{T}$ = 4.76°C
s = 0.132°C	s = 0.074°C	s = 0.024°C
1 - 2 minutes	1 - 2 minutes	6 - 7 minutes
n = 7	n = 14	n = 10
$\overline{T}$ = 2.19°C	$\overline{T}$ = 3.10°C	$\overline{T}$ = 5.01°C
s = 0.073°C	s = 0.026°C	s = 0.197°C
2 - 3 minutes	2 - 3 minutes	7 - 8 minutes
n = 11	n = 8	n = 9
$\overline{T}$ = 2.26°C	$\overline{T}$ = 3.10°C	$\overline{T}$ = 4.83°C
s = 0.034°C	s = 0.000°C	s = 0.056°C
3 - 4 minutes	no record	8 - 9 minutes
n = 14		n = 8
$\overline{T}$ = 2.32°C		$\overline{T}$ = 4.94°C
s = 0.021°C		s = 0.102°C
4 - 5 minutes	no record	9 - 10 minutes
n = 10		n = 8
$\overline{T}$ = 2.38°C		$\overline{T}$ = 4.94°C
s = 0.053°C		s = 0.110°C

themselves does permit some qualitative evaluation to be made. On this basis, the record from the initial lowering is probably the best one both for measurement in undisturbed sediment and for stability during the recording period. As mentioned above, the second lowering may not have been in undisturbed sediment and may well have measured a temperature of slurry or sediment which was still inside the bottom of the drill pipe. The final lowering was accomplished under heavier sea conditions and, although the probe was probably in sediment below the drill-bit, even the filtered record indicates irregularities in the temperature-time plot which are interpreted as indications of movement of the probe during the record.

Any estimate of heat flow based on these data is conditioned by the many uncertainties already discussed. Using the two best temperature estimates (2.3°C for the first lowering and 4.8°C for the third) and the 96-meter separation indicated by the drill string advance, the temperature gradient is 0.27×10^{-3} °C cm^{-1}, which is quite low. Projecting this gradient to the sediment-seawater interface (and assuming a temperature of not more than 1.6°C which was the 3000-meter water temperature) places the first measurement at 26 meters and the third at 119 meters. Thermal conductivities determined for this depth range at Hole 35.1 are 3.3×10^{-3} cal/°C cm sec at 45 meters, 4.7×10^{-3} cal/°C cm sec at 87 meters, and 5.7×10^{-3} cal°/C cm sec at 99 meters. The estimated heat flow based on these data is 1.3×10^{-6} cal/cm^2 sec.