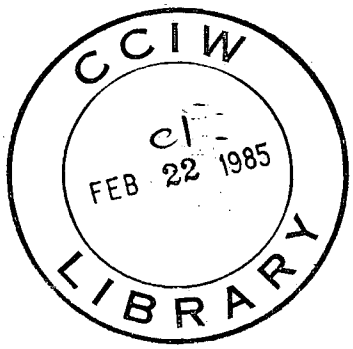
HYDRAULICS DIVISION
TECHNICAL NOTE



DATE: November 1984 **REPORT NO:** 84-30

TITLE: Evaluation Report of Guildline Model 9450 Digital Thermometer, Serial No. 51888, EDR No. 252460.

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REASON FOR REPORT: Requested by L.R. Peer, Calibration Lab Supervisor, with regard to future automated temperature measurements by Hydraulics Division personnel.

STUDY FILE NO: Study 84-362

1.0 INTRODUCTION

The Guildline Model 9540 digital thermometer is an accurate, relatively low cost instrument with full computer interface capabilities. The Hydraulics Division has recently purchased two of these devices for frazil ice studies, which were subsequently modified with extended probe cables by MANTEC. An acceptance check and evaluation of the thermometers was carried out by the calibration laboratory, and the results are published in the following note.

2.0 ACCURACY

Specification:

Range:	-40°C to +180°C
Resolution:	0.001°C
Limits of Error:	
24 hours	@ 23°C ± 1°C
	± 0.010°C
90 days	@ 23°C ± 5°C
	± 0.015°C
1 year	@ 23°C ± 5°C
	± 0.030°C

Total guaranteed performance is worst case. It assumes all contributing errors are maximum and occur at the same time and in the same direction. Contributing errors include calibration uncertainty which is referred to flowing water at the rate of 1 m/sec, repeatability, stability, temperature coefficient, linearizaton, plus sensor and electronics drift and probe self heating.

Calibration Results: the results are presented in Table 1.

3.0 FRONT PANEL CONTROLS

Sample Switch: OK

Continuous Switch: OK

Degrees Celsius/Degrees Fahrenheit: OK

Filter Off: Time between readings approx. 1 second (both display and analogue output)

Filter On: Time between readings approximately 1 second. Thermometer integrates the reading over the last 10 temperature measurements (approx. 10 sec.). The average is continually updated, dropping the 10th last reading and adding the most recent.

Analogue Output: As specified

Note: See conclusion for further discussion

4.0 IEEE488 INTERFACE

Procedure: Short test programs were written using the HP9825 as the controller.

Results: All remote functions OK. The bus address was set at 3.

5.0 TEMPERATURE COEFFICIENT

Specification: $\leq \pm$ 0.0005 °C/°C

Working Temperature Environment: 0 to 50°C

Maximum Temperature Coefficient: 50(0.0005) = 0.025°C.

Procedure:

1) The thermometer chassis was placed in a temperature controlled furnace with the probe external to the furnace.

2) The temperature in the furnace was raised to 50°C and held there so that the internal electronics would stabilize at that point.
3) The probe was placed in a stable ice bath at 0°C as measured by the Guildline Model 9500 temperature bridge.
4) The furnace temperature was then lowered to 0°C while maintaining the external probe at a constant temperature.
5) The reading of the thermometer was recorded both as displayed and with an HP 7100B chart recorder monitoring the analogue output.

Results:

The results are presented in Table 2. The data was confirmed by the chart record of the analogue output.

6.0 REPEATABILITY

Specification: ±2 least significant digits (±2m°C)

Procedure:

1) Stable temperature baths of 0°C and +40°C were prepared (confirmed by the Guildline 9500 bridge).
2) The probe of the 9540 was placed in the ice bath at 0°C and the display reading recorded.
3) The probe was then placed in the oil bath at 40°C and the reading again noted.
4) The probe was then cleaned (to prevent contamination), re-inserted in the ice bath, and the corresponding reading was taken.

Results:

Actual Temperature: (Guildline Bridge) (°C)	Display Temperature: (Guildline 9540) (°C)
0.001	0.003
40.018	40.020
0.002	0.003

7.0 TIME CONSTANT

Specification: 5 seconds

Procedure:

1) Stable temperature baths were prepared at 0°C and at 40°C, as in 6.0 above.
2) The probe of the 9540 was stabilized at 0°C.
3) The probe was then plunged into the 40°C bath, while monitoring the analogue output of the thermometer with an HP 7100B chart recorder, until the output stabilized at 40°C.

Results:

The time constant recorded in the above experiment was 7.5 seconds to reach 63% of the maximum temperature with the probe inserted directly in the bath. The test was repeated, except that the probe was wiped with a hand towel prior to insertion in the hot oil. This yielded a time constant of 6.25 seconds for the thermometer to reach 63% of the maximum temperature of 40°C. These response times were approximately doubled, at 14 seconds and 13 seconds respectively, for the thermometer to

attain 90% of the final temperature. In both cases, the filter was in the OFF position. The thermometer's response time increases with the filter ON, as there is a delay between the displayed reading and the actual probe temperature.

8.0 LINE VOLTAGE VARIATION

Specification: 95 to 130 VAC

Procedure:

1) A stable temperature bath was prepared (verified by the Guildline Model 9500 temperature bridge).
2) The 9540 thermometer probe was placed in the bath, and the line voltage to the 9540 chassis was varied, using a variac, over the voltage range specified.
3) The line voltage to the 9540 was monitored using a Fluke 8050A digital multi-meter, and an HP 7100B chart recorder was used to display the analogue output of the thermometer as the line voltage changed.

Results:

The results are recorded in Table 3. The chart recorder trace obtained during the test confirmed those results.

9.0 CONCLUSIONS

This evaluation confirms that the Guildline Model 9540 does meet or surpass the specifications presented in the operating manual, with the exception of time constant. The accuracy of the thermometer was well within specification, as could be expected with the "worst-case" criteria used to determine these figures. No "tweaking" of the

instrument was required, as shown in the calibration results in Table 1. The front panel controls and IEEE488 interface performed as expected. The temperature coefficient was exceeded while the temperature of the chassis was in a transient state, but was well within specification once the electronics had adjusted to the different environment, as shown in Table 2.

The repeatability of the instrument was excellent, with no variation in reading after the probe had undergone a 40°C hysteresis, as shown on page 4. The time constant for a 40°C change was not close to the 5 seconds mentioned in the operating manual, although this figure is not specified over a fixed range of temperature. Certainly the thermometer will respond quickly to small variations in temperture, as repeated use of the instrument in the calibration laboratory has demonstrated. Changes in the power supply voltage had no effect on the thermometer reading, as shown in Table 3, and stable operation of this device can be expected over a wide range of line voltages.

The integrating filter feature of the Model 9540 cannot be overlooked. When large temperature variations are being measured, with a relatively quick rate of temperature change, then the filter should definitely be OFF to avoid errors due to the integration delay. However, when sensitive temperature measurements are contemplated, the filter is best left ON to provide a stable display and fully realize the 0.001°C resolution of the instrument. Calibration lab testing of the thermometer with the probe placed in a stable bath, and the filter OFF, results in an irregular display which "jumps" about ±5 m°C. (worst case) around a relatively constant bath temperature, known to have a short term stability of less than 1 m°C. Activating the filter promptly removes these "noisy" readings, and yields an averaged figure which more closely reflects the actual bath temperature. With the filter OFF, the Model 9540 thermometer has basically a 0.01 °C resolution, in that the varying least significant digit is not reliable nor, more importantly, repeatable. Regardless of whether the filter is ON or OFF, however, the best 24 hour accuracy specification remains ±0.010 °C as quoted by the manufacturer.

There was one disturbing effect noticed during the testing of the 9540, specifically with the analogue output when used in the "x100" mode. A digital-to-analogue converter is used in the instrument to obtain this feature, and as the thermometer reaches certain temperatures, there are abrupt DC voltage changes at the output. Initially the problem was discovered as the most significant digit of the display changed (e.g., 19.999 to 20.000°C). At this point, a large 5V DC "spike" occurred, and then reset to the original DC level once the digit had stabilized. Since the "x100" mode gives an overall sensitivity of 5V/°C, a 5V level change represents a significant shift in the analogue output.

The calibration lab contacted Guildline Instruments Ltd. in Smiths Falls, Ontario, about this problem in the analogue output of the Model 9540. Guildline was unaware that this problem existed, and they stated at that time they would investigate using their own facilties and a current production model. On October 23, 1984, Dwaine Brown at Guildline returned our call concerning the spikes in the analogue output. He informed us that a software problem existed in the current version of the ROM employed in the 9540 digital thermomemter, and that he had solved the problem and would send us a new, "burned in" version of the software for inhouse replacement of the IC. Mr. Brown stated that the new software would eliminate the 5 VDC "spike" that occurred whenever the most significant digit of the display changed, as mentioned above.

On January 15, 1985, the Model 9540 was re-evaluated with the new software installed, and repeated tests confirmed that there were no abrupt changes in the analogue output as the "tens" digit of the display changed. It is recommended that any digital data be collected through the IEEE interface, since this would avoid an analogue temperature to digital conversion, a subsequent digital to analogue output conversion, and finally an analogue to digital interface with a computer.

10.0 REFERENCES

Operating and Technical Manuals, Guildline Instruments Ltd. for the Model 9540 thermometer.

TABLE 1. Calibration Results

Actual Bath Temperature (°C)	Displayed Temperature (°C)	
0.002	0.003	- no adjustment necessary
37.001	37.001	- no adjustment necessary
19.992	19.997	- mid-point check (24 hrs. later)
0.002	0.000	- zero check (24 hrs. later)

TABLE 2. Temperature Coefficient Results

Time	Actual Bath Temperature (°C)	Displayed Temperature (°C)	Furnace Temperature (°C)
15:00	0.001	0.013	50
15:05	0.001	0.013	50
15:10	0.001	0.013	50
15:15	0.001	0.015	set at 0
15:20	0.001	0.011	25
15:25	0.001	-0.003	0
15:30	0.001	0.005	0
15:35	0.001	0.011	0
15:40	0.001	0.015	0
15:45	0.001	0.017	0
15:50	0.001	0.021	0
15:55	0.001	0.021	0
16:00	0.001	0.021	0

TABLE 3. Line Voltage Variation Results

Line Voltage (VAC)	Actual Bath Temperature (°C)	Displayed Temperature (°C)
115	40.013	40.006
110	40.015	40.006
105	40.015	40.006
100	40.015	40.006
95	40.014	40.006
90	40.014	40.006
95	40.015	40.006
100	40.014	40.006
105	40.016	40.006
110	40.016	40.006
115	40.016	40.006
120	40.016	40.006
125	40.016	40.006
130	40.015	40.006
135	40.016	40.006
130	40.017	40.006
125	40.017	40.006
120	40.018	40.006
115	40.018	40.006