RESULTS OF QUALIFICATION TESTS ON WATER-LEVEL SENSING INSTRUMENTS, 1986

By Randolph R. Holland and Donald H. Rapp

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ABSTRACT

The U.S. Geological Survey's Hydrologic Instrumentation Facility at the Stennis Space Center, Mississippi, conducts qualification tests on water-level sensing instruments. Instrument systems, which meet or exceed the Survey's minimum performance requirements, are placed on a Qualified Products List.

During 1986, qualification tests were conducted on four instrument systems. Three of the four systems met minimum performance requirements and have been added to the Qualified Products List. During preliminary tests, the fourth system did not perform according to manufacturer's specifications and was returned without further testing.

This report presents to users of hydrologic instruments and U.S. Geological Survey procurement personnel a Qualified Products List of water-level sensing instruments, updated to include the three systems that met minimum performance requirements during 1986 testing. This report provides information concerning test procedures and, for each of the three qualifying systems, summaries of test data, results, and brief system descriptions.

INTRODUCTION

The U.S. Geological Survey conducts a nationwide program of water-resources surveys, investigations, and research. Over the years, the need for streamflow and ground-water-level information has led the Survey to establish thousands of gaging stations on rivers, canals, streams, lakes, and reservoirs, and observation-well sites. The most common methods of automatically measuring water-surface elevation or stage are floats and manometers. Stage is sensed, for automatic recording, either by a float in a stilling well or by a gas-purge system that transmits the pressure head of water in a stream to a manometer. The latter system, which does not require a stilling well, is known as a bubble gage (Rantz and others, 1982).

Hydrologic-instrumentation manufacturers have developed a variety of new systems to sense and record the water-level data. During 1986, four systems, one model of each, were tested at the Hydrologic Instrumentation Facility (HIF) at the Stennis Space Center, Mississippi. The test purpose was to determine if each system could meet the Survey's minimum performance requirements for the collection of water-level data (Buchanan and Somers, 1968; Kennedy, 1983; and Rapp, 1982).

Under the Qualified Products List (QPL) program, water-level-sensing systems are tested by the HIF. Systems that pass the qualification tests are placed on the Survey's QPL.

The Federal Acquisition Regulations (General Services Administration, 1984) allow Federal agencies to require manufacturers to have their products tested and qualified for QPL before these manufacturers may submit bids in response to a solicitation for bids by the agencies. The QPL can be used as a guide by the Survey's field offices when purchasing systems not available from the HIF.

A glossary is included in this report to aid in understanding the terminology used in the report.

Purpose and Scope

This report describes the qualifying systems and presents a summary of the data collected during the qualification testing. The report also provides an updated Survey QPL that includes water-level-sensing systems that passed QPL test requirements during 1986. A list of instrument features is presented for each of the systems. The report describes performance-qualification test procedures and test-data summaries. No recommendations are made as to the best instrument system for any given application. The report does, however, provide pertinent information and test results, which will assist the instrument user in selecting a system that best meets the requirements of a particular site or the data needed.

Acknowledgments

The authors acknowledge the cooperation of the manufacturers who provided their instruments for the qualification tests.

DESCRIPTION OF INSTRUMENT SYSTEMS TESTED AND SPECIAL INSTALLATION REQUIREMENTS

One model of each instrument system was tested. These instruments are available from the manufacturers listed alphabetically by company name in table 1 and by classification in annex I. A comparison of major system features is given in table 1. Note that the Aanderaa Instruments, Inc.,[1] 2847 water-level sensor and the In-Situ, Inc., pressure transducers can be ordered with required cable lengths.

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[1] Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 1.--Comparison of instrument systems

Selected instrument features	Instrument company and model name and number			
	Aanderaa Instruments, Inc. 2847 Water-level system	Fluid Data Systems WaterGage HY 60 FT H20	In-Situ, Inc. Hermit SE 1000B Pressure transducers	
			10 lb/in^2	100 lb/in^2
Station type (see annex II)	special	daily	special	special
System error as tested, in feet	-0.09 to 0.2	-0.01 to 0.03	-0.10 to 0.07	-0.47 to 0.61
Sensor type gas-purge manometer (M) submersible pressure transducer (SPT)	SPT	M	SPT	SPT
Maximum sensor or orifice distance to recorder, in feet	328	1600	450	450
Recommended range in stage, in feet	32.81	60	23.14	[1]115.67
Affected by sediment	yes	yes	yes	yes
Shelter required	yes	yes	yes	yes
Power requirement, in volts	6.5 to 10 dc (external) lithium battery	±12 dc or 120 ac	12 to 18 dc (external) or lithium battery (internal)	12 to 18 dc (external) or lithium battery (internal)

Table 1.--Comparison of instrument systems (continued)

Selected instrument features	Instrument company and model name and number			
	Aanderaa Instruments, Inc. 2847 Water-level system	Fluid Data Systems WaterGage HY 60 FT H20	In-Situ, Inc. Hermit SE 1000B Pressure transducers	
			10 lb/in^2	100 lb/in^2 [1]
Instrument total weight, in pounds	15	30	30	30
Instrument size (without sensors and cables or tubing)	[2]A	[2]B	A	A
Operating range in air, in degrees Celsius	-40 to 65	-40 to 65	-40 to 65	-40 to 65
Internal data memory	no	no	yes	yes
Data output to	[3]RS-232C [5]PDC 4	[4]ADR (rotating shaft)	RS-232C	RS-232C

[1]The 100 lb/in^2 pressure transducer was tested over a 50 lb/in^2 pressure range because of the testing facility limitations.
[2]Instrument package size and weight for A is smaller than 18 inches long by 12 inches wide by 18 inches high and no single component weighs more than 25 pounds. Instrument package size and weight for B is larger than size A, but smaller than 36 inches long by 18 inches wide by 36 inches high, and complete system weighs less than 50 pounds.
[3]The Electronics Industry Association's (EIA) recommended standard, defining the electrical characteristics and physical specifications for serial transmission.
[4]Analog-to-digital recorder, records water-level data on paper-punch tape from the rotating float pulley shaft.
[5]Communications interface connector for sending or receiving 10-bit binary serial pulse-width code.

Aanderaa Instruments, Inc., Water-Level System Model 2847

The Aanderaa water-level system, model 2847, is composed of four components: submersible 2847 water-level sensor, atmospheric-pressure compensating unit, solid-state electronic 3010 plug-in board, and 2978 lithium battery pack. The 2847 water-level sensor, 3010 plug-in board, and 2978 battery pack are shown in figure 1. The water-level sensor is shown with the atmospheric-pressure compensating unit in figure 2.

The 2847 water-level sensor is a strain-gage, submersible pressure transducer with a range of 32.808 feet (10 meters). The effects of temperature on the sensor are corrected by the heating of the silicon sensor chip to 37 ^{o}C prior to taking a reading. A compensating unit, connected to the water-level sensor by a heavy-duty, armored cable, corrects for changes in atmospheric pressure. The compensating unit and the housing for the water-level sensor are constructed of anodized aluminum. The net weight of the water-level sensor, with compensating unit, is approximately 8 pounds. The qualification-operating temperature range of the 2847 water-level sensor is from -5 to 50 ^{o}C. A calibration equation that linearizes the data obtained from each 2847 water-level sensor is provided with that sensor. The input into the calibration equation is the instrument output value, a count number, obtained from the 3010 plug-in board when the RS-232C interface or PDC 4 interface connectors are used. The output from the calibration equation is the linearized pressure reading in bars, international unit for pressure.

The 3010 plug-in board is housed in an 11- by 6- by 1-inch box constructed of anodized aluminum and weighing approximately 3 pounds. Solid-state electronic components for the 3010 plug-in board are molded in epoxy. The qualification-operating temperature range of the 2847 water-level system, minus the 2847 water-level sensor, is from -40 to 65 ^{o}C. The output of the 3010 board is an RS-232C or PDC 4 connector (or port). This unit can read up to 12 model 2847 sensors, with 10-bit resolution, at a sampling interval selected from 10 intervals between 0.5 and 180 minutes. The number of channels and the sample interval is selected by use of rotary switches. Continuous and remote start operations are supported. In the remote start operation, a single measuring cycle is performed upon the reception of a remote triggering signal. The continuous operation is a nonstop, repeating, measuring cycle. The 3010 board does not record the pressure reading but transfers the analog-to-digital (A/D) conversion count number in ASCII (defined in Glossary) form to the RS-232C port or in 10-bit binary code to the PDC 4 port. The ASCII output from the 3010 board can be sent to a commercially available reader and (or) recorder with a RS-232C port to display and (or) record the count number. The 10-bit binary code can be sent to the Aanderaa 2990 data-storage unit or Aanderaa's VHF transmitter through the PDC 4 port. The count number is converted to the pressure reading in bars by using the calibration equation.

The external 2978 lithium battery pack, which powers the 3010 board and the 2847 sensor, is connected to the 3010 plug-in board by a port connection. Average operating current drain, not including sensor(s), is 4.5 milliamps. The 2847 water-level-sensing system uses a positive ground reference.

The 3010 plug-in board, 2978 battery pack, and the atmospheric-pressure compensating unit should be installed in a weather-protected shelter for long-term installation. The 2847 water-level-sensor is either suspended underwater down a well, stilling well, or fastened to an underwater fixture.

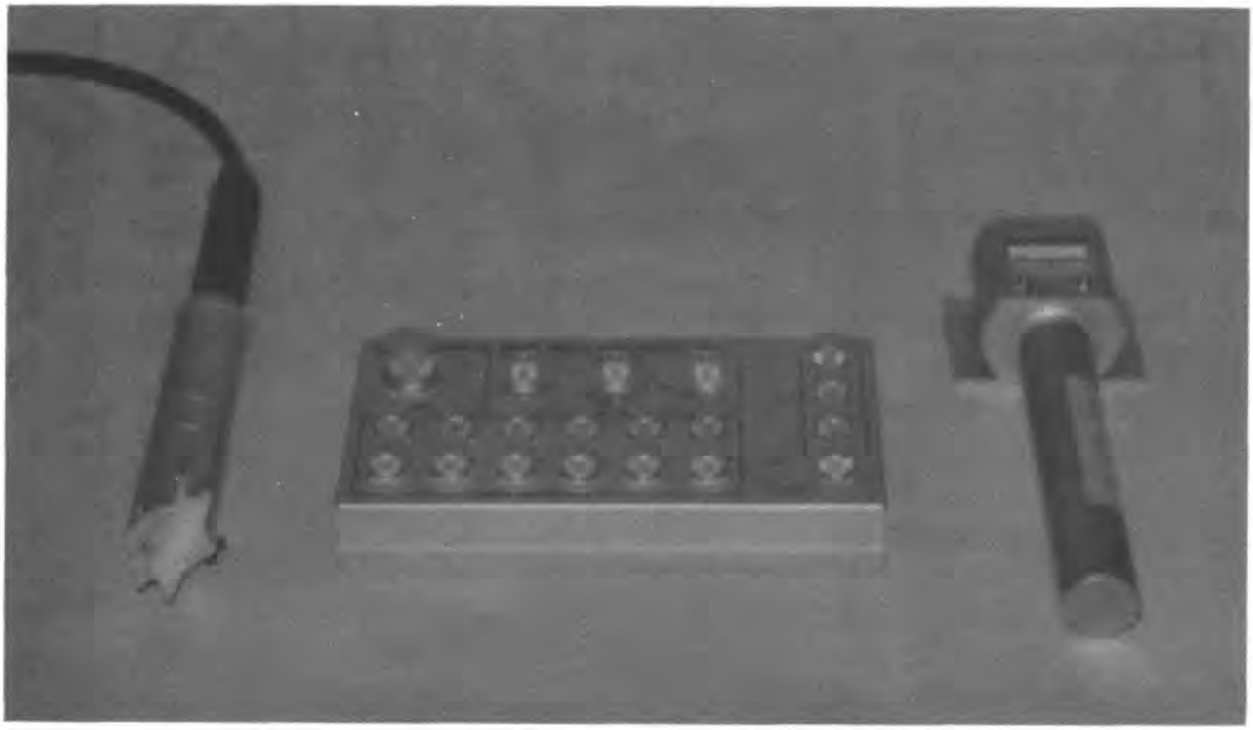

Figure 1.--The Aanderaa Instruments, Inc., model 2847 water-level system.
Left: The 2847 water-level sensor
Center: The 3010 plug-in board
Right: The 2978 battery pack.

Figure 2.--The Aanderaa Instruments, Inc., model 2847 water-level sensor with atmospheric-pressure compensating unit.

Fluid Data Systems WaterGage Model HY 60 FT H20

The WaterGage is an electromechanical device that senses pressure. The WaterGage is shown in figure 3, and some of the chain-and-sprocket drive assemblies used with the WaterGage are shown in figure 4.

A gas-purge system transmits the pressure head of water over an orifice, which is submerged in the stream. To measure this pressure head, the WaterGage uses a bellows and a balance beam with a moving weight. Null-balancing is accomplished by a servo-controlled motor. A source of regulated gas pressure, a sight-feed bubbler chamber, a flow regulator, and a bubble or gas transmission tube with an orifice are required.

The instrument chassis and beam are constructed of anodized aluminum and the cover is made from Lexan[1] plastic and walnut wood. The instrument weight is approximately 30 pounds. The WaterGage has a mechanical-digital display. The unit is powered using two external 12-volt dc batteries supplying ±12 volts, or by 120 volts ac converted to ±12 volts dc from a wall mount transformer. The current drawn is typically 5 to 8 milliamps. Environmental temperature qualification range is from -40 to 65 ^{o}C.

The instrument can be modified to cover a number of ranges in water-level stage. Ranges from 0 to 10, 50, and 60 feet were used for the qualification tests. The manufacturer furnishes instruments for use with higher ranges.

An analog-to-digital recorder (ADR), a paper-punch recorder, a potentiometer with a recorder, or a graphic recorder can be used to record water-level data from the shaft output. Data accuracy can be affected by vibrations transmitted to the instrument when data are recorded. The instrument rebalances itself quickly, and the sensitivity to small changes can be reduced by proper adjustments. Either the shelters or the instrument shelf should be isolated from vibration sources, such as highway and railroad traffic.

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1 Lexan is a registered trademark of General Electric Company.

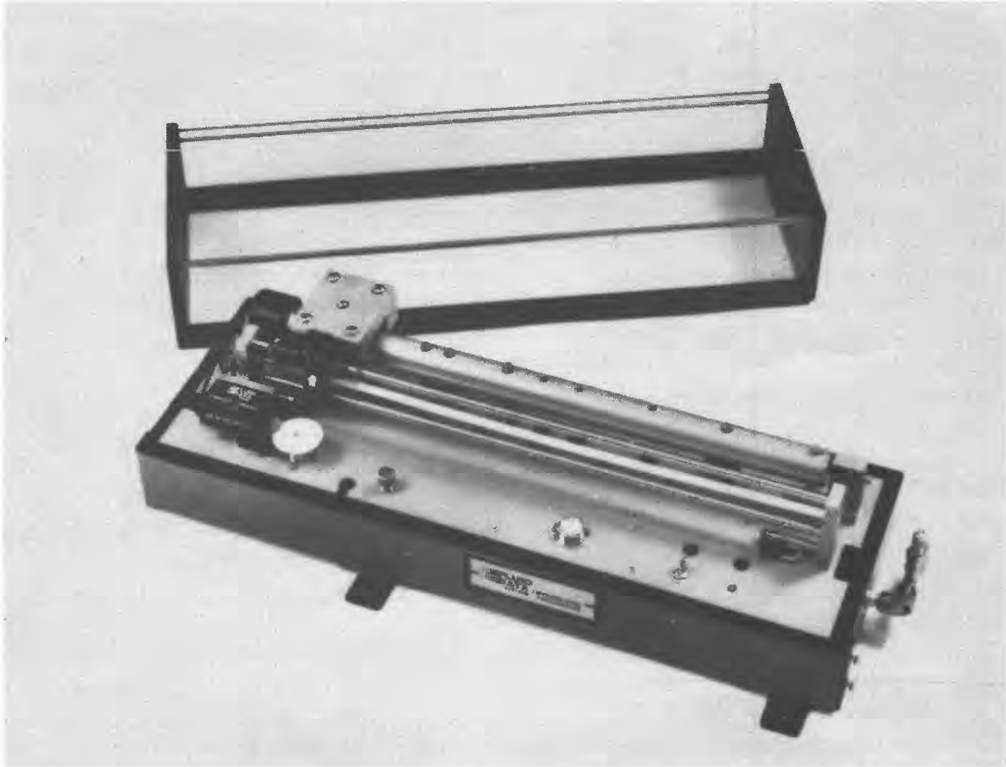

Figure 3.--The Fluid Data Systems WaterGage model HY 60 FT H2O.

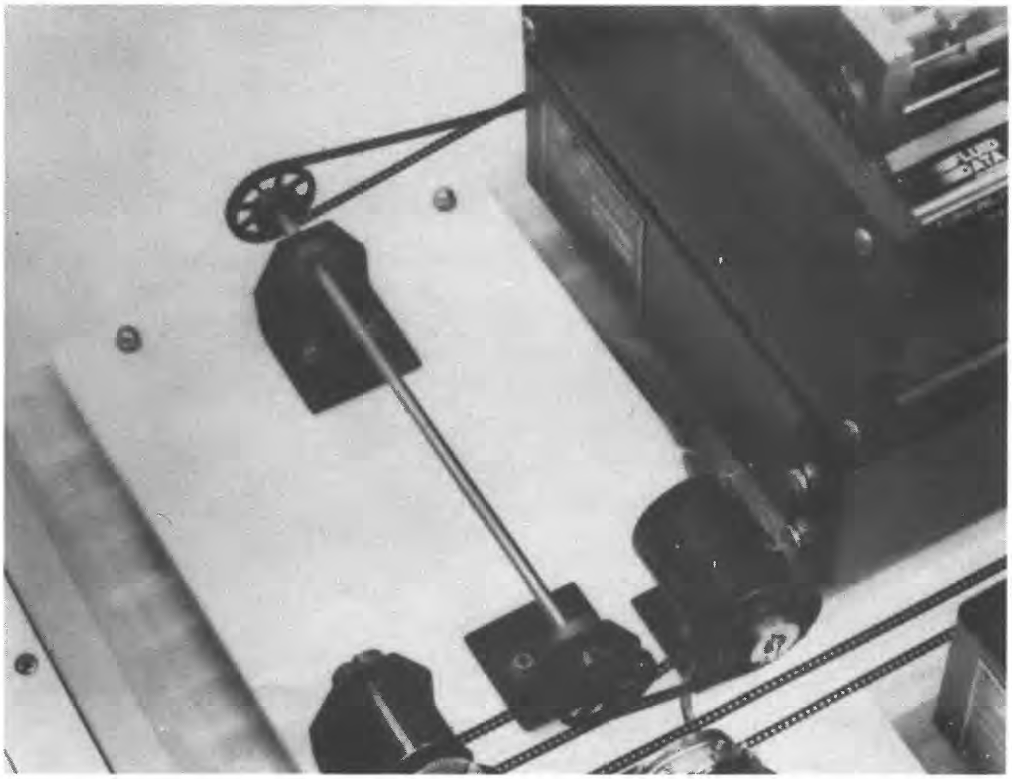

Figure 4.--Some of the chain-and-sprocket drive assemblies used with the Fluid Data Systems WaterGage Model HY 60 FT H2O.

In-Situ, Inc., Hermit Environmental Data Logger Model SE 1000B
And Associated Pressure Transducers

The Hermit environmental data logger is a solid-state electronic device that uses one or two strain-gage, submersible pressure transducers to sense water pressure. The Hermit and transducers are shown in figures 5 and 6. The Hermit's dimensions are 7 by 11 by 9 inches and its weight is approximately 12 pounds. The Hermit has internal lithium batteries but can be powered externally by using a 12-volt battery. Current drawn from an external battery is typically 20 milliamps, with 350 milliamps maximum. The Hermit qualification temperature range is from -40 to 65 ^{o}C. The pressure transducer qualification temperature range is from -5 to 50 ^{o}C.

The Hermit records water-pressure data in pounds-per-square-inch units in solid-state memory. These data recordings can be observed on a liquid-crystal display (LCD). The data-sampling rate is programmable from 1 minute to 99 hours. Logarithmic sampling (decreasing sampling rate with time) from every 0.2 seconds in the first 2 seconds of elapsed time to every 500 minutes after the first week is also supported. Setting up the Hermit for each sensor and recording data is done under software control by the user entering the required information at each prompt observed on the LCD display. An RS-232C interface is used for printer or computer communications.

Two pressure transducers can be connected to the Hermit for recording multiple water pressures. The two pressure sensors, qualified for use with the Hermit, are the 10 lb/in^2 and the 100 lb/in^2 pressure transducers. The pressure-transducer cables are coated for environmental protection and placed on spools.

Alarm contacts are provided with the unit for conditionally powering external equipment. Contact voltage rating is 30-volts ac or dc maximum and the current contact rating is 1 amp maximum.

The Hermit data logger and the pressure-transducer spool(s) should be installed in a weather-protected shelter for long-term installation. The pressure transducer(s) is suspended underwater down a well, a stilling well, or is fastened to an underwater fixture.

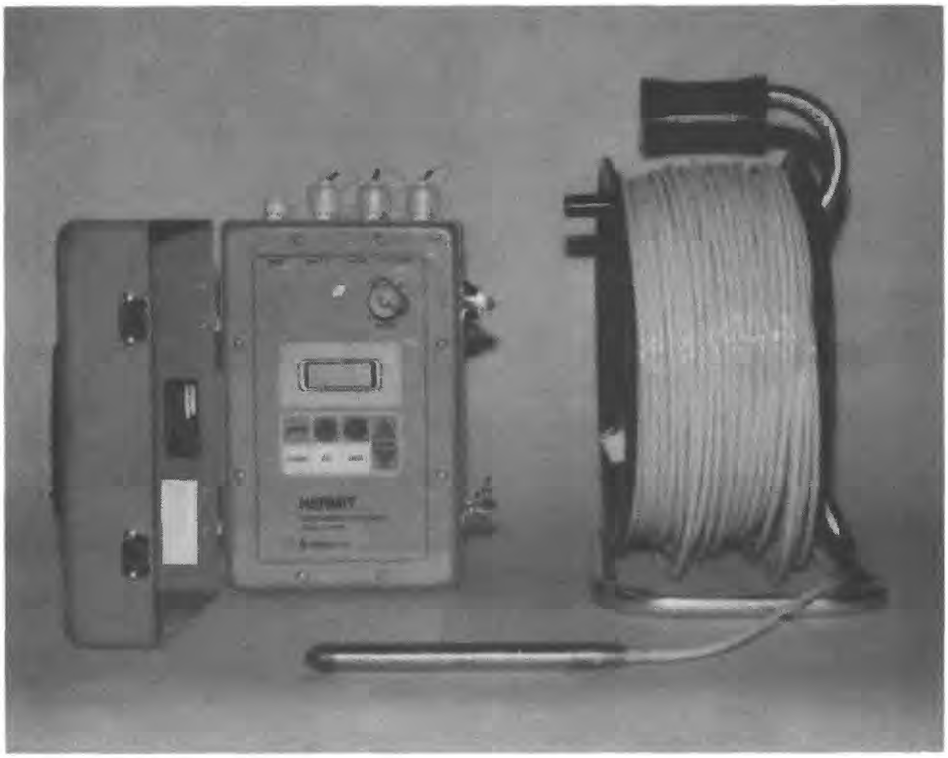

Figure 5.--The In-Situ, Inc., Hermit environmental data logger model SE 1000B and a pressure transducer.

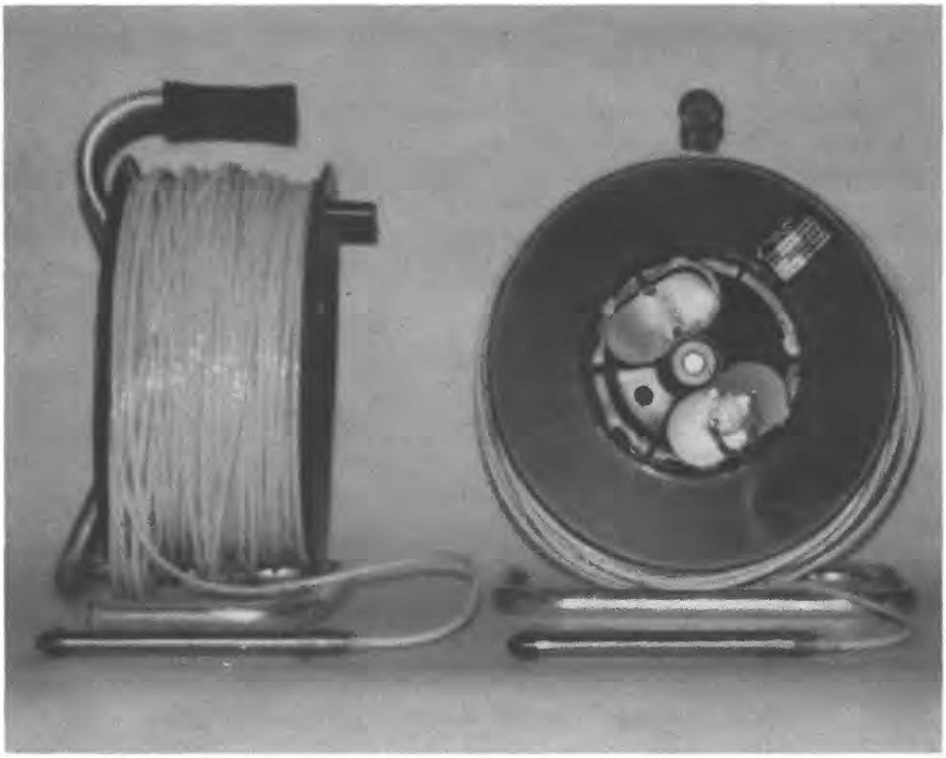

Figure 6.--Two In-Situ, Inc., pressure transducers and their spools used with the Hermit environmental data logger model SE 1000B.

TEST PROCEDURES

The laboratory qualification tests were conducted by the HIF's Test and Evaluation Section, using one model of each candidate system. Upon delivery from the manufacturer, each system was unpacked, inspected for shipping damage, and set up in the laboratory according to the manufacturer's instructions. To assure that each instrument system was tested under the same conditions, all tests were run indoors under controlled conditions, which simulated average and extreme field conditions.

The first test on each system was made at prevailing room temperature and humidity conditions. This was a bench test to familiarize personnel with system operation and to test instrument output at a constant input level. Auxiliary laboratory instruments, printers, and recorders for the tests were connected to each system during this period. The power consumption and stability of each system's output was monitored.

The calibration of each instrument was checked in the second test, using procedures appropriate for that type of system.

Environmental tests were run to establish the system performance under simulated field conditions. The instrument packages were placed in the environmental test chamber, and the tests were run under controlled temperature and humidity conditions.

The last test was a calibration check for drift in each instrument's output over the qualification testing period.

TEST RESULTS

The data were collected under the conditions described in the preceding section. Representative samples of test results are summarized graphically in figures 7 through 19 and numerically in tables 2 through 5 for the three instrument systems that passed the qualification tests. The system that failed to qualify was returned to the manufacturer. This system will be retested at the manufacturer's option and the results published in a future report.

Representative samples of calibration data for the instrument systems that qualified are presented in tables 2 through 5. The graphs shown in figures 7 through 9 are a summary of the temperature test results on the pressure transducers qualified for use with their respective instrument system. Note that the HIF-I-1 specification (Rapp, 1982) for the temperature range of submersible type sensor(s) is from -5 to 50 ^{o}C. Figure 10 is a graphical representation of the WaterGage calibration data presented in table 3. The plots shown in figures 11 through 16 are information on drift and output stability for each of the pressure transducers that qualified.

In the environmental chamber, the instrument systems were subjected to a wide range of temperature and humidity conditions. During this time a constant-pressure head was applied to each system, with all pressure transducers at room temperature. Results of this test for the qualifying systems are presented in figures 17 through 19.

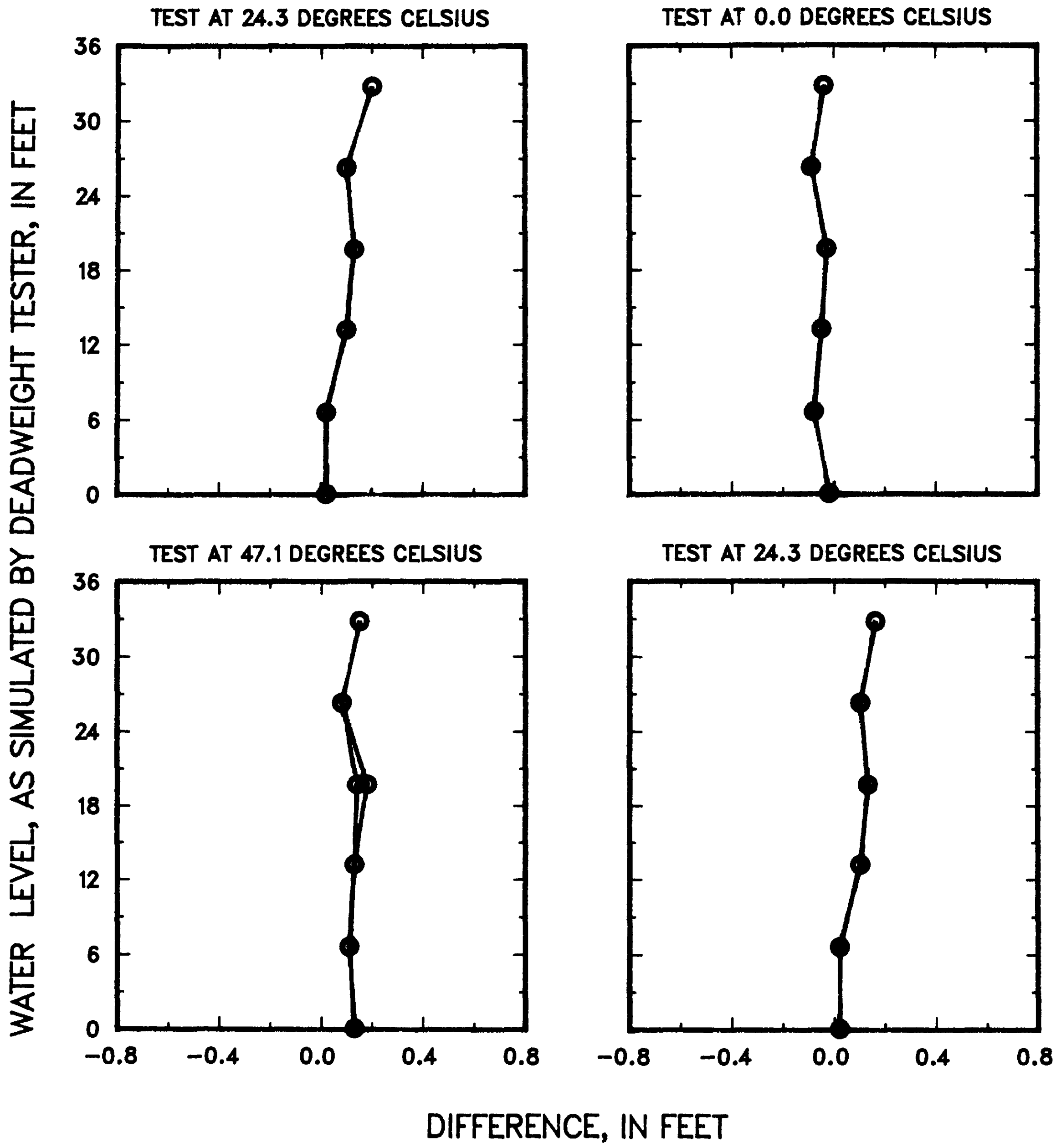

Figure 7.--Temperature effects on the Aanderaa Instruments, Inc., model 2847 water-level sensor. Difference is the instrument reading, converted to feet, minus the actual depth applied from the deadweight tester. During the temperature tests, the 2847 water-level system, minus the sensor, was at room temperature (25.0 ±5 °C) and was used to monitor the sensor output. The temperature test in the upper left-hand corner was performed first and the temperature test in the lower right-hand corner was performed last. At each of the test temperatures, increasing and then decreasing pressures from 0 to 32.75 ft were applied to define the instrument's hysteresis (defined in Glossary) characteristic.

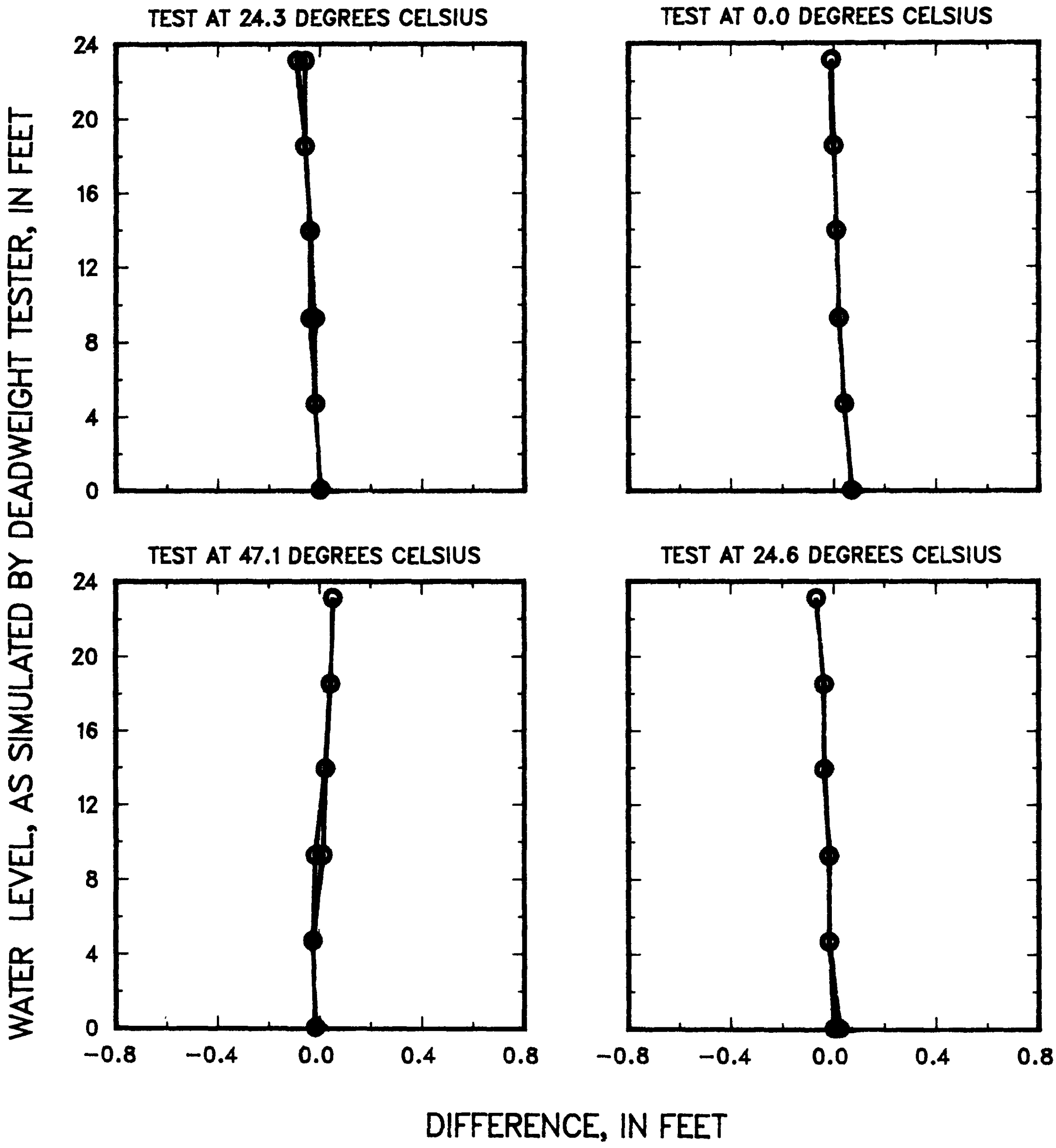

Figure 8.--Temperature effects on the In-Situ, Inc., 10 lb/in^2 pressure transducer. Difference is the instrument reading, converted to feet, minus the actual depth applied from the deadweight tester. During these temperature tests, the Hermit SE 1000B was at room temperature (25.0 $\pm$5 ^{o}C) and was used to monitor the output of the 10 lb/in^2 pressure transducer. The temperature test in the upper left-hand corner was performed first and the temperature test in the lower right-hand corner was performed last. At each of the test temperatures, increasing 0 to 23.083 ft and then decreasing 23.083 to 0 ft pressures were applied to define the instrument's hysteresis (defined in Glossary) characteristic.

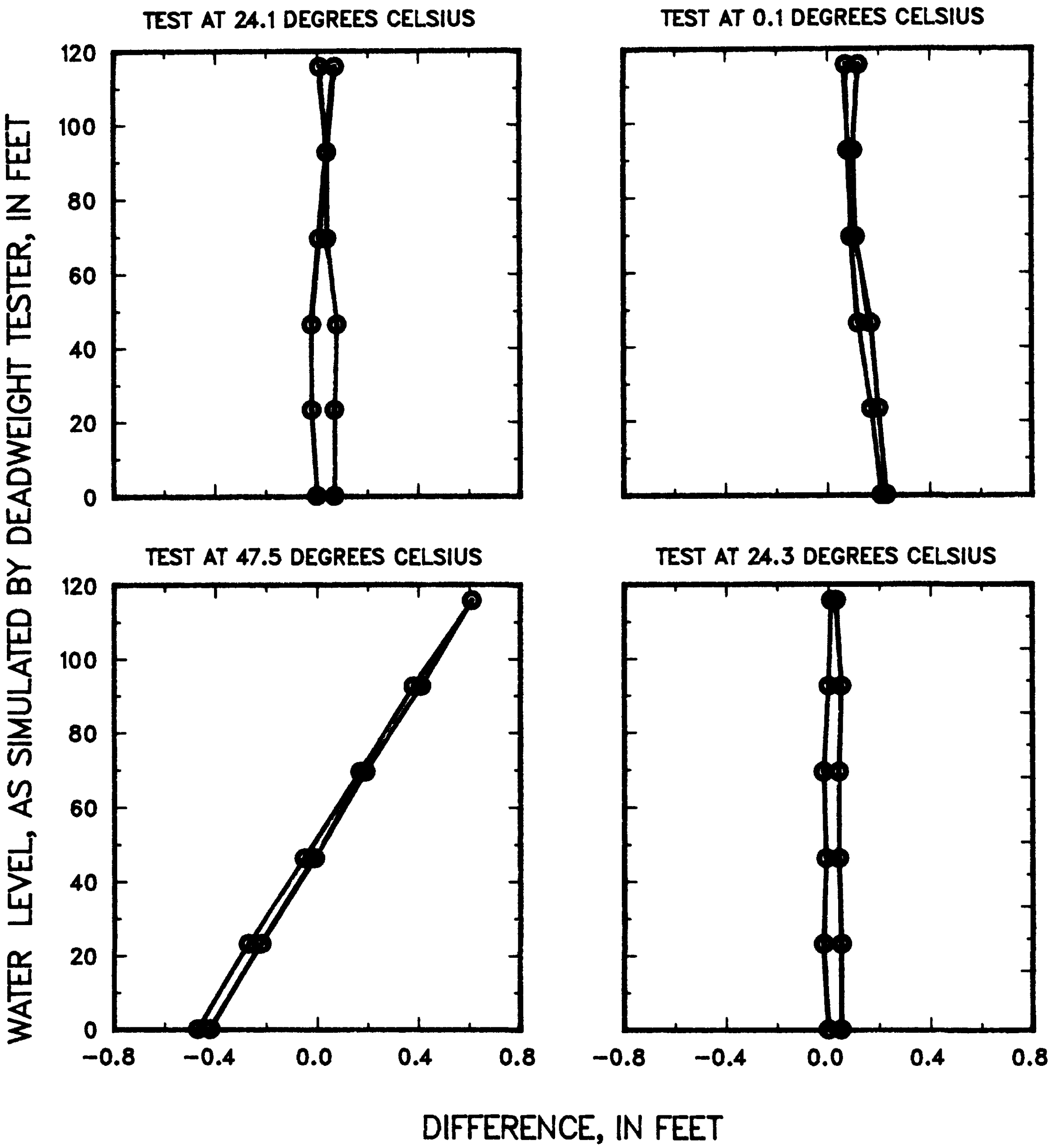

Figure 9.--Temperature effects on the In-Situ, Inc., 100 lb/in^2 pressure transducer. Difference is the instrument reading, converted to feet, minus the actual depth applied from the deadweight tester. During these temperature tests, the Hermit SE 1000B was at room temperature (25.0 ±5 °C) and was used to monitor the output of the 100 lb/in^2 pressure transducer. The temperature test in the upper left-hand corner was performed first and the temperature test in the lower right-hand corner was performed last. At each of the test temperatures, increasing 0 to 115.667 ft and then decreasing 115.667 to 0 ft pressures were applied to define the instrument's hysteresis (defined in Glossary) characteristic. At the test temperature of 47.5 °C, the pressure transducer was tested outside the manufacturer's temperature-compensated range but within the operational temperature range of the pressure transducer.

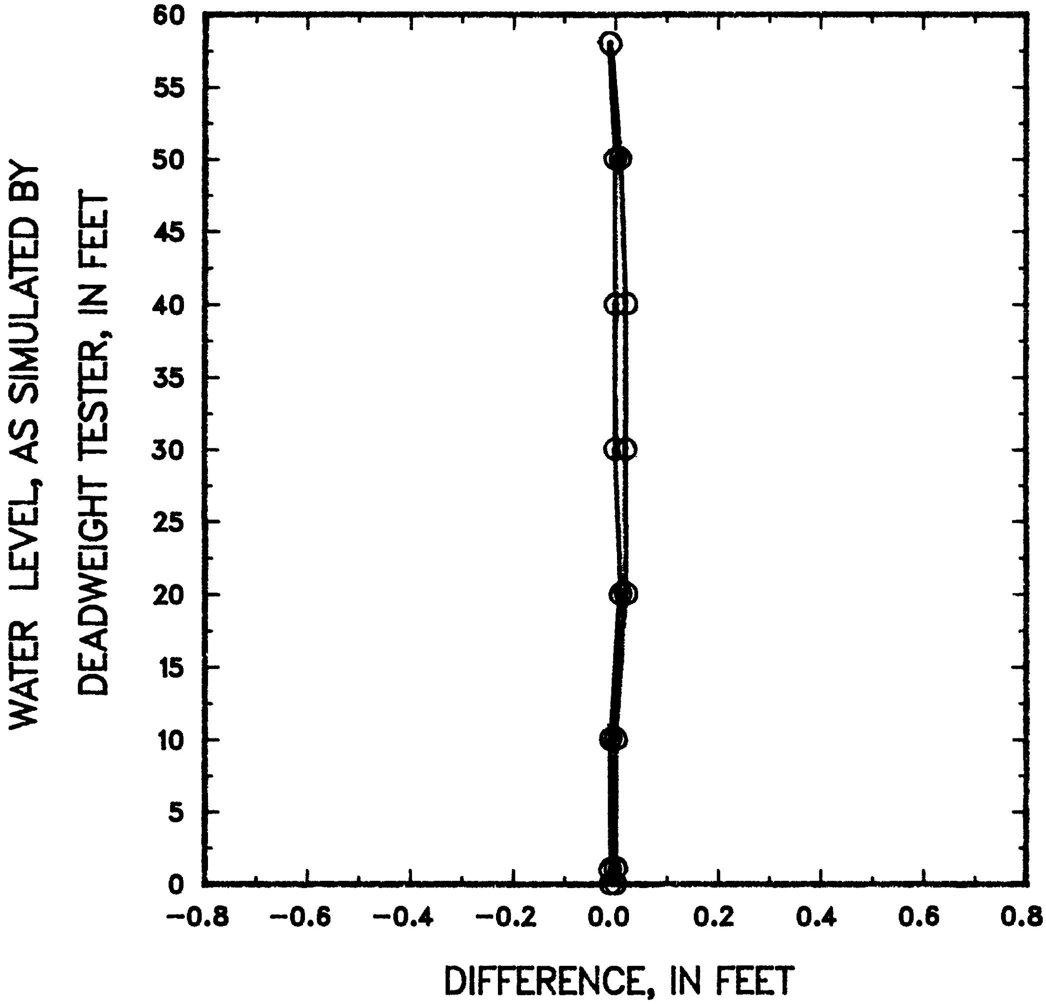

Figure 10.--The Fluid Data Systems WaterGage room-temperature calibration data graph. Difference is the instrument reading, in feet, minus the actual depth applied from the deadweight tester. Room temperature was 24.0 ±1 °C. At each of the test temperatures, increasing 0 to 58 ft and then decreasing 58 to 0 ft pressures were applied to define the instrument's hysteresis (defined in Glossary) characteristic.

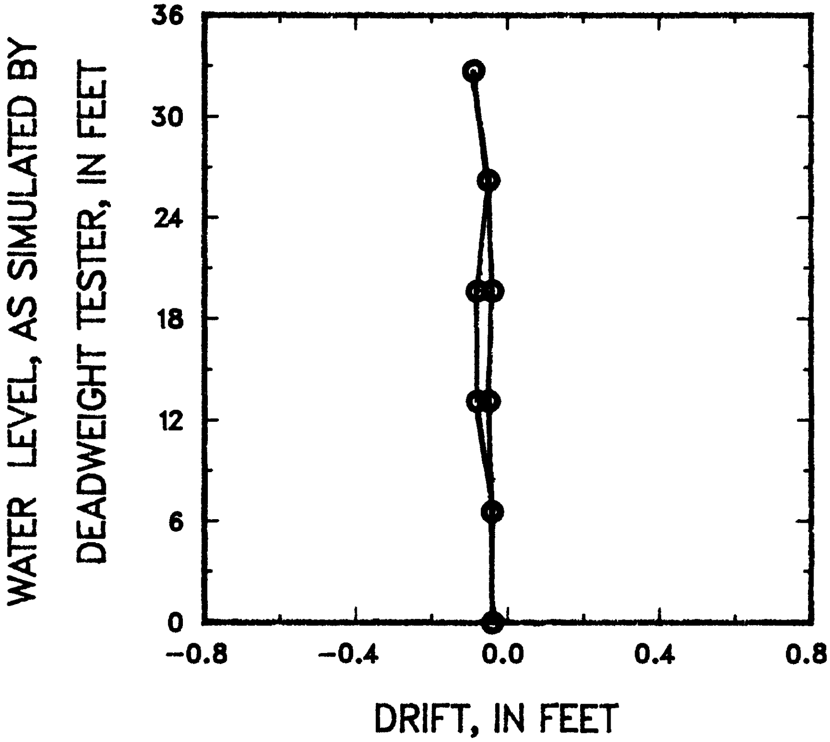

Figure 11.--Drift of the Aanderaa Instruments, Inc., model 2847 water-level system over the qualification testing period. Drift, an indication of the long-term system stability, was the observed change in the instrument output at room temperature (23.6 ±2 °C) over a 64-day period. Increasing and then decreasing pressures were applied.

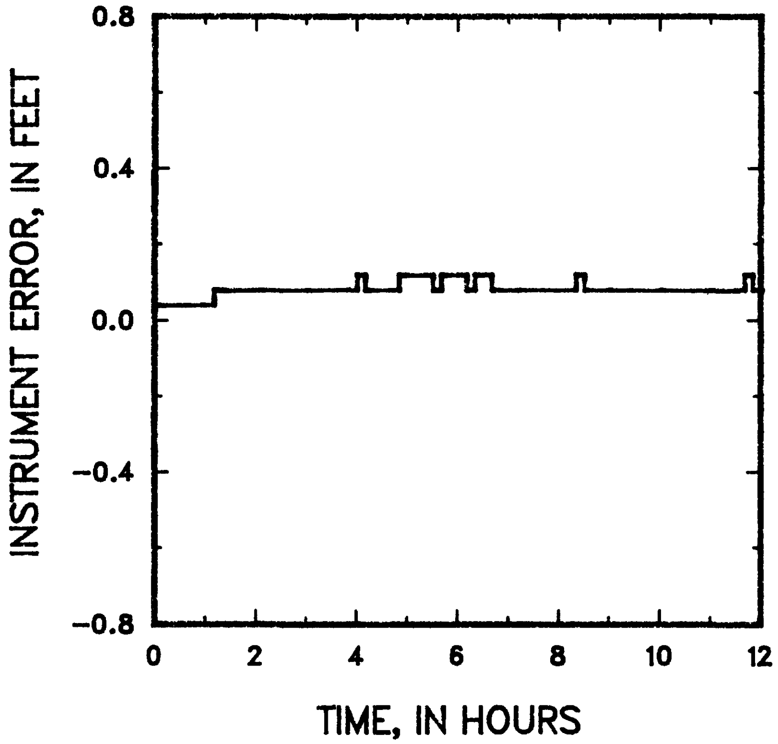

Figure 12.--Output stability of the Aanderaa Instruments, Inc., model 2847 water-level system over a 12-hour period. This qualification test was performed at 24.4 ±2 °C. To determine output stability, a constant pressure of 16.417 ft was applied from the deadweight tester. The instrument reading was recorded over a 12-hour period and the observed instrument error was computed. The starting observed instrument error is included in the graph.

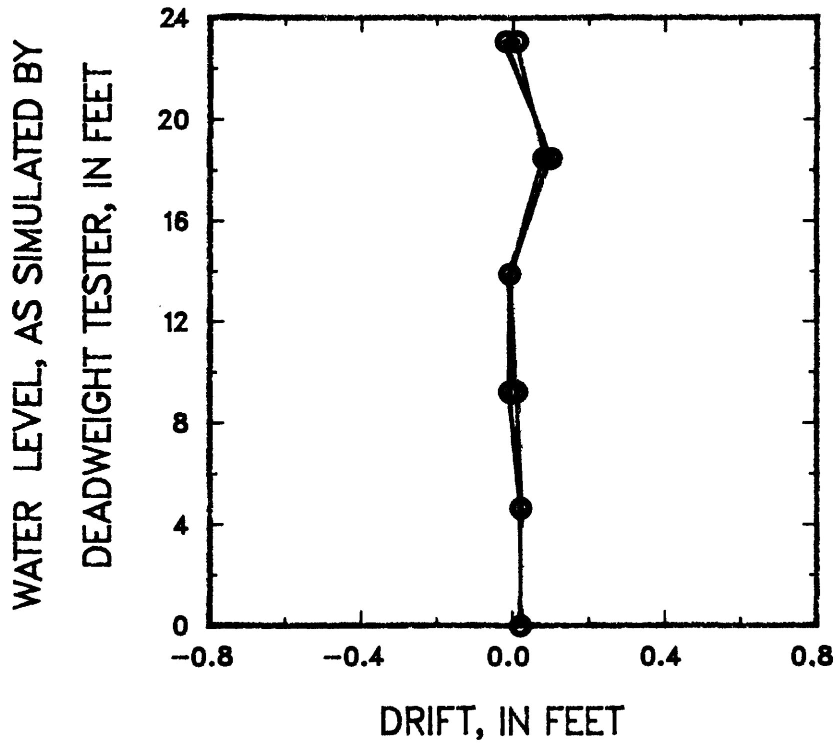

Figure 13.--Drift of the In-Situ, Inc., Hermit SE 1000B with a 10 lb/in^2 pressure transducer over the qualification testing period. Drift is the observed difference in the instrument output at room temperature (22.7 ±2 °C) over a 44-day period. Increasing and then decreasing pressures were applied.

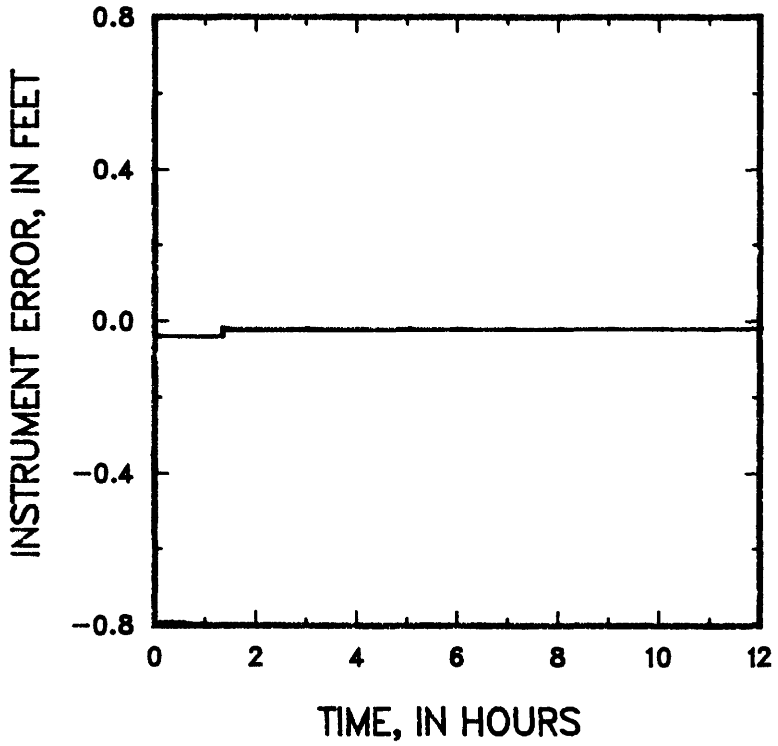

Figure 14.--Output stability of the In-Situ, Inc., Hermit SE 1000B with a 10 lb/in^2 pressure transducer over a 12-hour period. This qualification test was performed at 23.0 ±3 °C. To determine output stability, a constant pressure of 11.583 ft was applied from the deadweight tester. The instrument reading was recorded over a 12-hour period and the observed instrument error was computed. The starting observed instrument error is included in the graph.

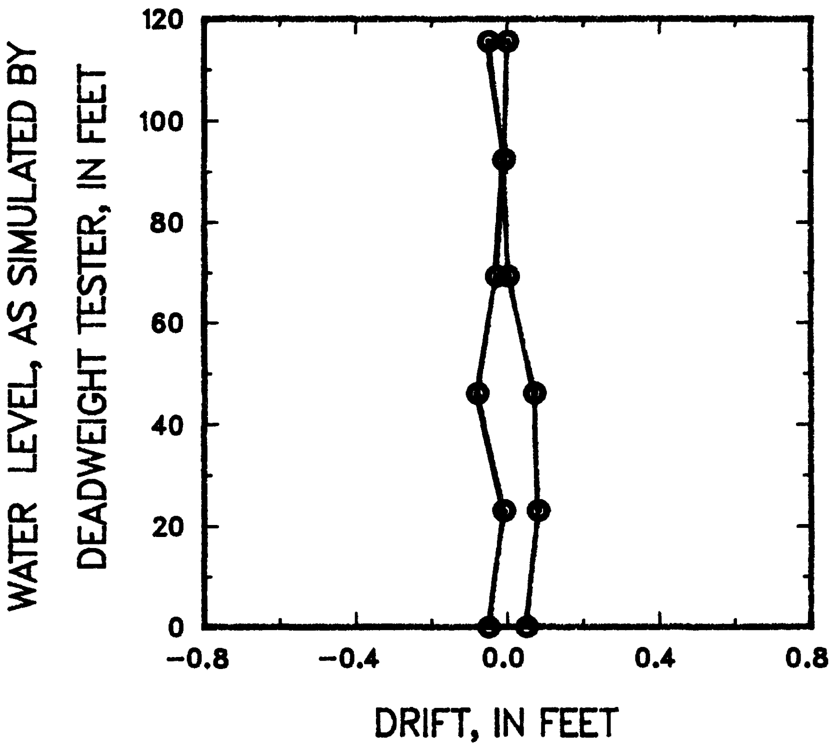

Figure 15.--Drift of the In-Situ, Inc., Hermit SE 1000B with a 100 lb/in^2 pressure transducer over the qualification testing period. Drift is the observed difference in the instrument output at room temperature (22.9 ± 2 ^{o}C) over a 41-day period. Increasing and then decreasing pressures were applied.

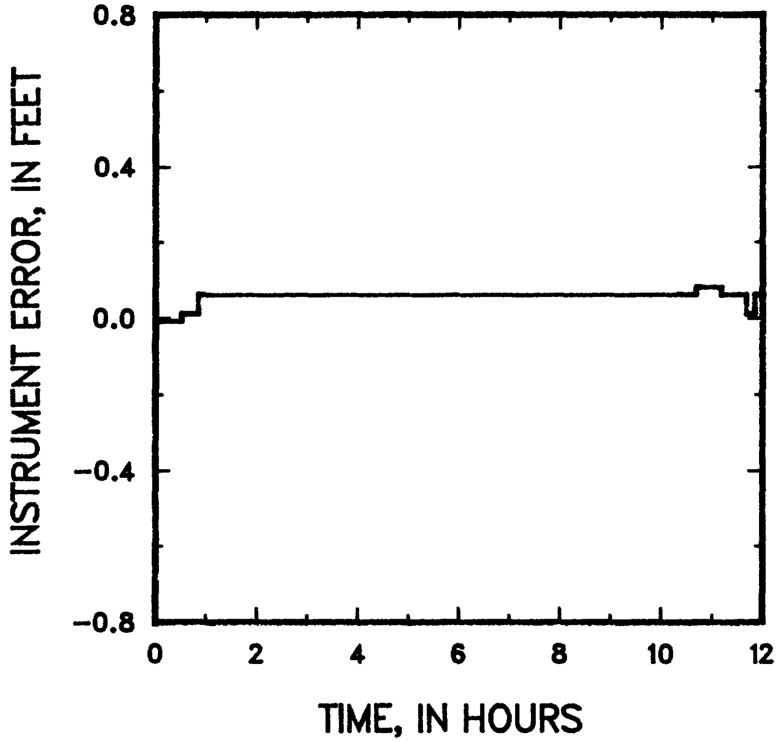

Figure 16.--Output stability of the In-Situ, Inc., Hermit SE 1000B with a 100 lb/in^2 pressure transducer over a 12-hour period. This qualification test was performed at 21.5 ±2 ^{o}C. To determine output stability, a constant pressure of 23.167 ft was applied from the deadweight tester. The instrument reading was recorded over a 12-hour period and the observed instrument error was computed. The starting observed instrument error is included in the graph.

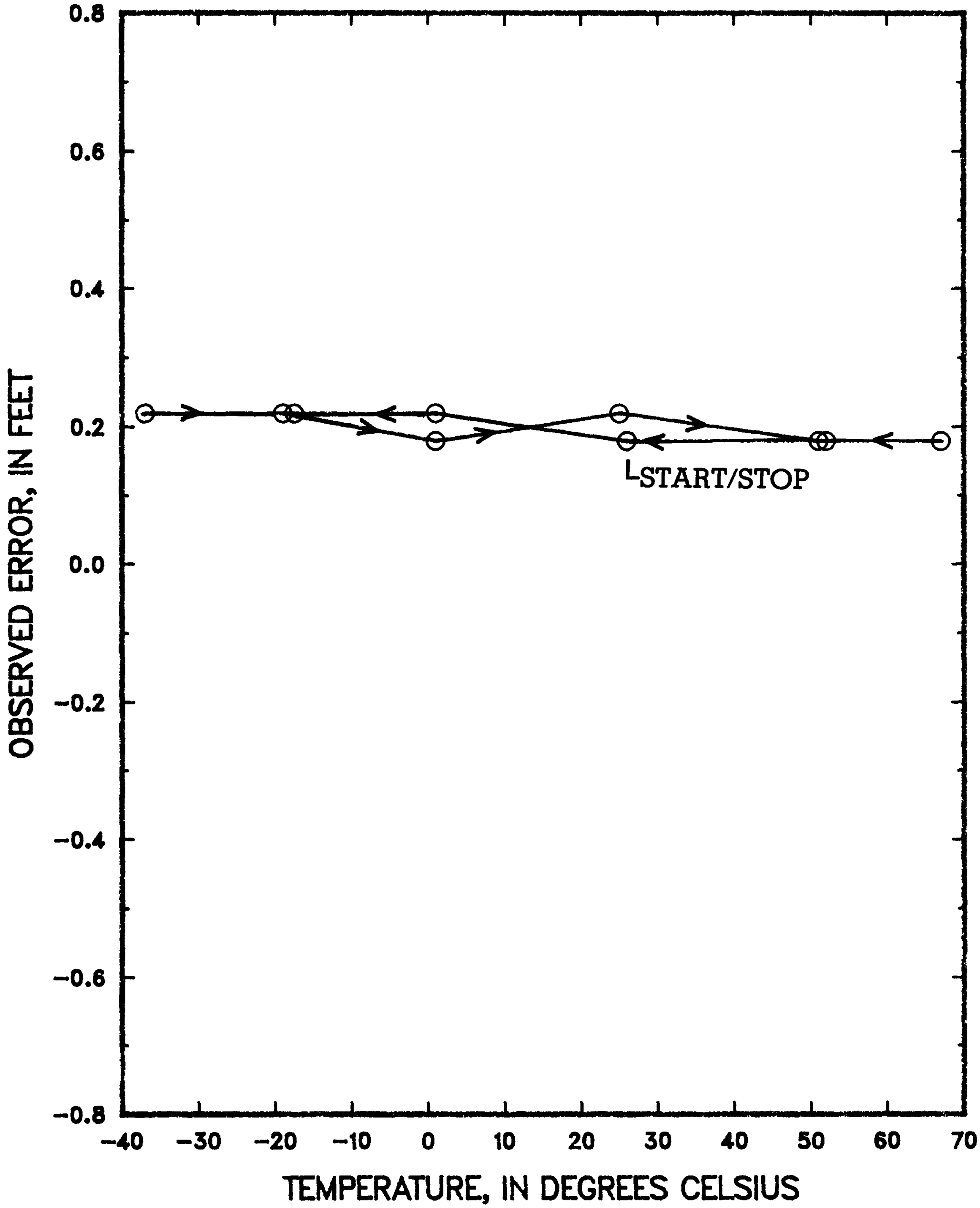

Figure 17.--The observed error of the Aanderaa Instruments, Inc., model 2847 water-level system, minus the 2847 water-level sensor, over the qualification temperature range. During this environmental qualification test, the 2847 water-level sensor was at 25.0 ±5 °C and a constant pressure of 23.083 ft was applied from the deadweight tester. The starting observed error is included in the observed error over the qualification temperature range.

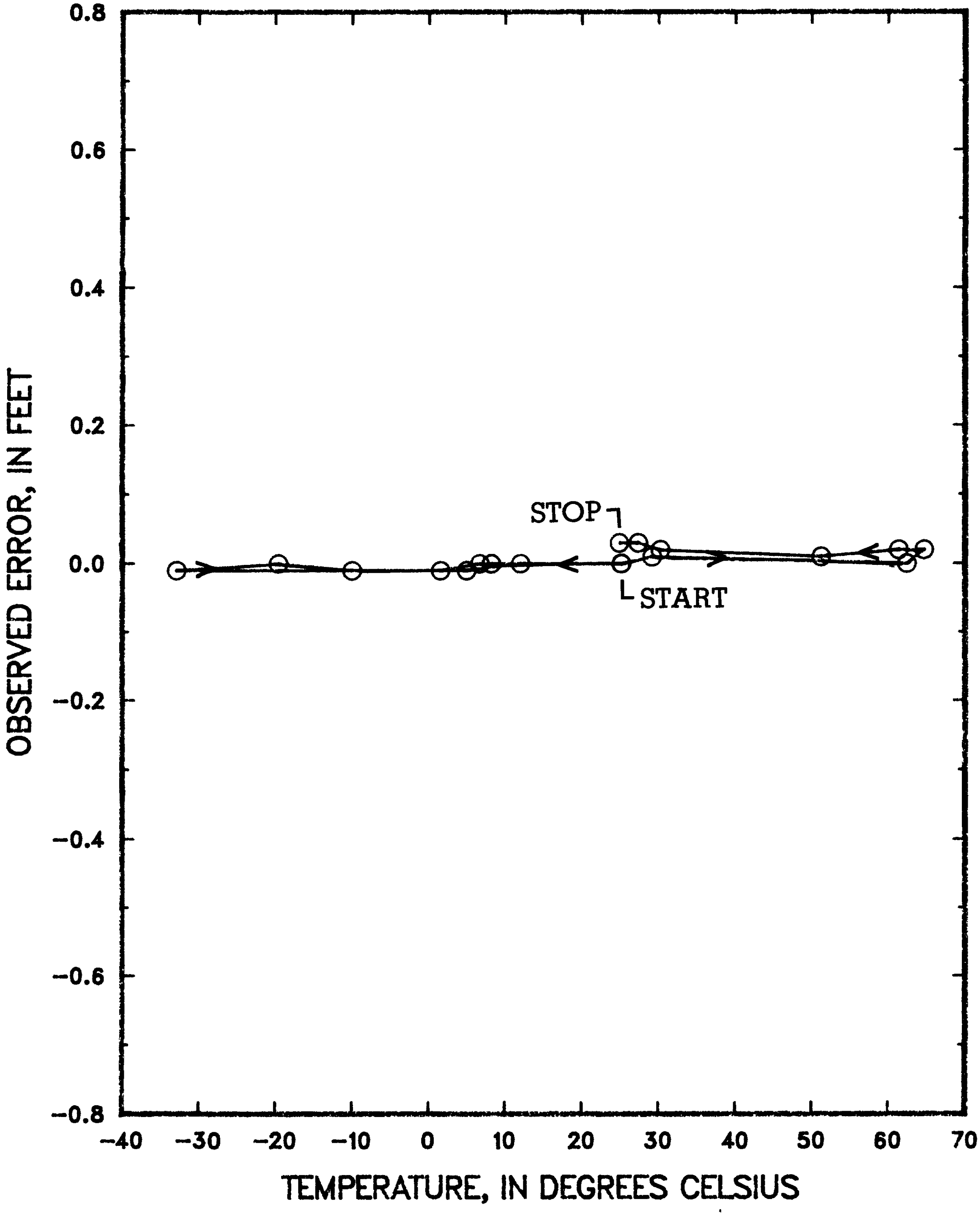

Figure 18.--The observed error of the Fluid Data Systems WaterGage Model HY 60 FT H20 over the qualification temperature range. During this environmental qualification test, a constant pressure of 5.000 ft was applied from the dead-weight tester.

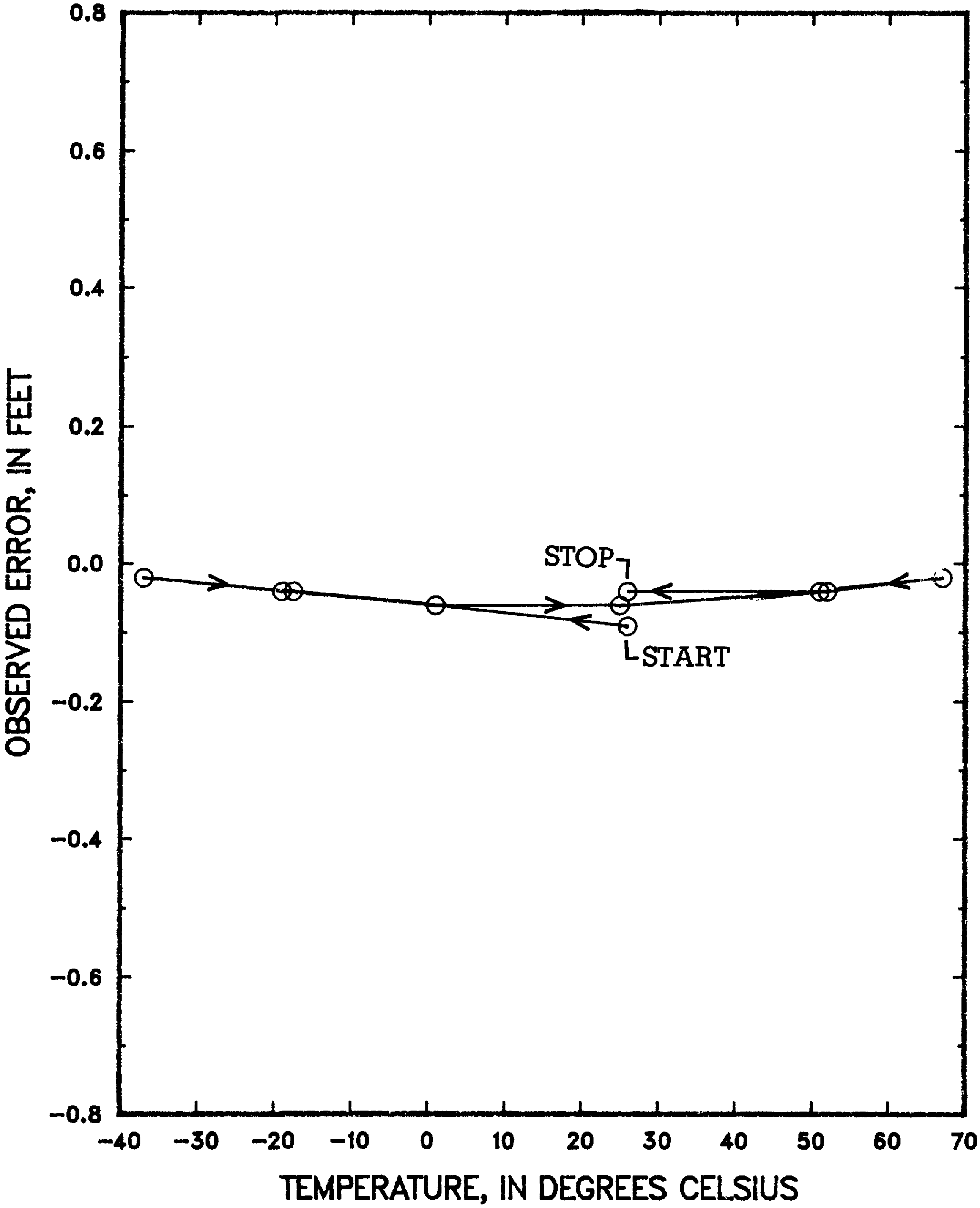

Figure 19.--The observed error of the In-Situ, Inc., Hermit SE 1000B over the qualification temperature range. During this environmental qualification test, the 10 lb/in^2 pressure transducer was at 25.0 ±5 °C and a constant pressure of 23.083 ft was applied from the deadweight tester. The starting observed error is included in the observed error over the qualification temperature range.

Table 2.--Data analysis on Aanderaa Instruments, Inc., model 2847 water-level system

(Calibration test was performed at 24.3 ±0.5 °C using the Aanderaa Instruments, Inc., 2847 water-level sensor serial No. 56, 3010 plug-in board, 2978 battery pack, atmosphere-pressure compensating unit, and a minicomputer. The instrument readings were converted to bars using the manufacturer's equation

$$\text{Pressure (bar)} = A + BN + CN^2 + DN^3,$$

where N is the observed count,

A equals -5.61058×10^{-4},

B equals 1.131×10^{-3},

C equals -2.26702×10^{-8}, and

D equals 1.54219×10^{-11}.

The bar reading was then converted to feet using the conversion factor 33.5492 feet per bar at 24.3 °C.)

[1]Deadweight tester (feet)	Instrument Reading observed (count)	Instrument Reading converted (feet)	[2]Difference (feet)	Percent difference (percent)
0.000	1.00	0.02	0.02	--
6.583	175.00	6.60	0.02	0.3
13.167	352.00	13.27	0.10	0.8
19.667	526.00	19.80	0.13	0.7
26.250	700.00	26.35	0.10	0.4
32.750	875.00	32.95	0.20	0.6
32.750	875.00	32.95	0.20	0.6
26.250	700.00	26.35	0.10	0.4
19.667	526.00	19.80	0.13	0.7
13.167	352.00	13.27	0.10	0.8
6.583	175.00	6.60	0.02	0.3
0.000	1.00	0.02	0.02	--

The number of digits listed under each column for all tables does not imply that each digit is significant for a particular reading, but that several readings within the column do have this number of significant digits.

[1] Defined in glossary.
[2] Difference equals converted reading minus deadweight-tester reading.

Table 3.--Data analysis on Fluid Data Systems WaterGage model HY 60 FT H20

(Calibration test was performed at 24.0 ±1 °C using the WaterGage serial No. 850701.)

Deadweight tester (feet)	Instrument reading (feet)	[1]Difference (feet)	Percent difference (percent)
0.000	0.00	0.00	--
1.000	1.00	0.00	0.0
10.000	10.00	0.00	0.0
20.000	20.02	0.02	0.1
30.000	30.02	0.02	0.1
40.000	40.02	0.02	0.0
50.000	50.01	0.01	0.0
58.000	57.99	-0.01	0.0
50.000	50.00	0.00	0.0
40.000	40.00	0.00	0.0
30.000	30.00	0.00	0.0
20.000	20.01	0.01	0.0
10.000	9.99	-0.01	-0.1
1.000	0.99	-0.01	-1.0
0.000	-0.01	-0.01	--

[1] Difference equals reading minus deadweight-tester reading.

Table 4.--Data analysis on In-Situ, Inc., Hermit SE 1000B with a 10 lb/in^2 pressure transducer

(Calibration test was performed at 24.3 ±0.5 °C using the Hermit SE 1000B and pressure transducer serial No. 1932. The instrument readings were converted to feet using the conversion factor 2.3131 feet per lb/in^2 at 24.3 °C.)

Deadweight tester (feet)	Instrument Reading observed (lb/in^2)	Instrument Reading converted (feet)	[1]Difference (feet)	Percent difference (percent)
0.000	0.00	0.00	0.00	--
4.667	2.01	4.65	-0.02	-0.4
9.250	3.98	9.21	-0.04	-0.4
13.917	6.00	13.88	-0.04	-0.3
18.500	7.97	18.44	-0.06	-0.3
23.083	9.94	22.99	-0.09	-0.4
23.083	9.95	23.02	-0.06	-0.3
18.500	7.97	18.44	-0.06	-0.3
13.917	6.00	13.88	-0.04	-0.3
9.250	3.99	9.23	-0.02	-0.2
4.667	2.01	4.65	-0.02	-0.4
0.000	0.00	0.00	-0.00	--

[1] Difference equals converted reading minus deadweight-tester reading.

Table 5.--Data analysis on In-Situ, Inc., Hermit SE 1000B with a 100 lb/in^2 pressure transducer

(Calibration test was performed at 24.2 ±0.5 °C using the Hermit SE 1000B and pressure transducer serial No. 1844. The instrument readings were converted to feet using the conversion factor 2.3129 feet per lb/in^2 at 24.1 °C.)

Deadweight tester (feet)	Instrument Reading observed (lb/in^2)	Instrument Reading converted (feet)	Difference[1] (feet)	Percent difference (percent)
0.000	0.00	0.00	0.00	--
23.167	10.01	23.15	-0.02	-0.1
46.250	19.99	46.23	-0.02	0.0
69.417	30.02	69.43	0.01	0.0
92.500	40.01	92.54	0.04	0.0
115.667	50.02	115.69	0.02	0.0
115.667	50.04	115.74	0.07	0.1
92.500	40.01	92.54	0.04	0.0
69.417	30.03	69.46	0.04	0.1
46.250	20.03	46.33	0.08	0.2
23.167	10.05	23.24	0.07	0.3
0.000	0.03	0.07	0.07	--

[1] Difference equals converted reading minus deadweight-tester reading.

CONCLUSIONS

Three of the four instrument systems tested met the Survey's minimum performance requirements. The Aanderaa Instruments, Inc., model 2847 water-level system and the In-Situ, Inc., Hermit model SE 1000B with associated pressure transducers qualified for the special-case stations, where lower accuracy is acceptable. The Fluid Data Systems WaterGage model HY 60 FT H20 qualified for the daily discharge stations, where higher accuracy is required. These three systems are on the Survey's updated Qualified Products List for water-level-sensing instrumentation systems. HIF-I-1 specifications were used as the standard to determine system qualifications.

This report provides individual characteristics and test results to assist users in selecting a particular system or systems that best fits a specified set of field conditions.

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GLOSSARY

ADR.--Analog-to-digital recorder, records water-level data on paper-punch tape from the rotating float pulley shaft.

ASCII.--American Standard Code for Information Interchange uses serial communications protocol, an 8-bit character code for communication to computers.

Bars.--International unit for pressure equal to 10^5 pascals, or 10^5 newtons per square meter, or 10^6 dynes per square centimeter.

Daily discharge station.--A daily discharge station is a site where no more than a 0.05-percent error of full scale is allowed.

Deadweight tester.--A pressure standard for calibrating pressure transducers in which known pneumatic pressures are generated by means of freely balanced (dead) weights loaded on a calibrated ball.

Error.--Error in stage output is defined as the difference between the water-surface height measured by the water-level sensing system and the simultaneously measured true water-surface height above a given datum.

Hysteresis.--A characteristic where the descending device response for a given decreasing applied input does not match the ascending device response for a given increasing applied input.

Instrument package size and weight.--The requirements to house the instrument system including any of the required interface hardware, nitrogen gas tanks, pressure system, power supply, and batteries are classified as follows:

A. Smaller than 18 inches long by 12 inches wide by 18 inches high and no single component weighs more than 25 pounds.
B. Larger than size A, but smaller than 36 inches long by 18 inches wide by 36 inches high, and complete system weighs less than 50 pounds.
C. Larger than size B, but smaller than 4.0 feet long by 3.0 feet wide by 8.0 feet high, and complete system weighs less than 75 pounds.
D. Larger than size C and (or) weighs more than 75 pounds.

Note: The weight listed in items A through D above excludes the weight of a nitrogen gas tank in cases where a tank is required.

PDC 4.--Communications interface connector for sending or receiving 10-bit binary serial pulse-width code.

RS-232C.--The Electronics Industry Association's (EIA) recommended standard, defining the electrical characteristics and physical specifications for serial transmission.

Special-case station.--A special-case station is a site where a 0.5-percent error of full scale is acceptable.

ANNEX I--QUALIFIED PRODUCTS LIST OF WATER-LEVEL SENSING INSTRUMENTS, 1986

Daily Discharge Stations

Type: Encoder, Shaft (Electronic)
Golden River Encoder, Model Number 502
Golden River Corporation, 7672 Standish Place, Rockville, MD 20855

Type: Manometer (Mechanical)
[1]WaterGage, Model Numbers HY 10 FT H20 to 50 FT H20
[1]WaterGage, Model Number HY 60 H20
Fluid Data Systems, 7370 Opportunity Road, San Diego, CA 92111

Type: Manometer (Mercury)
STACOM Manometer
Built by an instrument company for HIF Warehouse.

Type: Transducer, Pressure (Submersible)
ISCO, Model Number 2500
ISCO, Inc., Environmental Division, 531 Westgage Blvd., Lincoln, NB 68501

Special-Case Stations

Type: Acoustic (Contact)
Sarasota Upward Looking
Sarasota Automation, Inc., 1500 N. Washington Blvd., Sarasota, FL 33577

Type: Transducer, Pressure (Nonsubmersible)
Tavis Insulated Transducer, Model Number SPCL
Tavis Corporation, 3636 Highway 49, Mariposa, CA 95338

[2]Type: Transducer, Pressure (Submersible)
[2]Aanderaa Instruments, Inc., Water-Level Sensor 2847, Battery Pack 2978 and Sensor Plug-in Board 3010
Aanderaa Instruments, Inc., 30 F Commerce Way, Woburn, MA 01801

[2]Type: Transducer, Pressure (Submersible)
[2]Hermit Environmental Data Logger, Model SE 1000B and associated 10 and 100 lb/in^2 Pressure Transducers
In-Situ, Inc., 210 South Third Street, P.O. Box I, Laramie, WY 82070-0920

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[1]New addition to the daily discharge station category QPL, December 1986; previously qualified for special-case station category.

[2]New addition to the special-case station category QPL, December 1986.

ANNEX II--SYSTEM ACCURACY FOR DAILY DISCHARGE AND SPECIAL-CASE STATIONS

Systems accuracy for daily discharge and special-case stations to meet minimum performance requirements are taken from specification report (Rapp, 1982).

Daily Discharge Stations

Range in stage (feet)	Maximum allowable error (feet)
0 to 10	±0.005
0 to 20	±0.010
0 to 35	±0.018
0 to 50	±0.025
0 to 100	±0.050
0 to 200	±0.100
greater than 200	±0.100

Allowable full-scale error is 0.050 percent for all ranges less than 200 feet, except for shaft encoders. The maximum allowable error for shaft encoders is ±0.005 feet of the indicated reading.

Special-Case Stations

Range in stage (feet)	Maximum allowable error (feet)
0 to 10	±0.050
0 to 20	±0.100
0 to 35	±0.180
0 to 50	±0.250
0 to 100	±0.500
0 to 200	±1.000
greater than 200	±1.000

Allowable full-scale error is 0.50 percent for all ranges less than 200 feet, except for shaft encoders. The maximum allowable error for shaft encoders is ±0.05 feet of the indicated reading.

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