PAP-296

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MAY 1962 EDITION
GSA GEN. REG. NO. 27

PAP-2

UNITED STATES GOVERNMENT

Memorandum

Memorandum

TO : Chief, Hydraulic Structures Branch

Denver, Colorado
DATE: October 2, 1973

THROUGH: Chief, Hydraulics Branch

FROM : R. A. Dodge

SUBJECT : Laboratory test of 4-foot Metritape for monitoring water surface elevation for Snyder Aqueduct - 20-foot Metritape Tests and Some Letters Attached

INTRODUCTION

Purpose

The purpose of the laboratory studies was to provide data to help design branches determine the feasibility of using Metritape water surface elevation sensors manufactured by Metritape, Inc., as an alternative for floats in monitoring and controlling Snyder Aqueduct.

Background

Description of Sensor and Electronic Unit. - The sensor includes a thin shorting strip covered on the back, edges, and partially on the front near the edges by an electrically insulating jacket. Resistance wire is wrapped around the partially insulated strip in a helix fashion under slight tension to bridge away from the shorting strip. A flexible outer protective jacket seals the unit from liquid or granular materials. Pressure on the jacket pushes against the wire to overcome the spring action and electrically short the wire. The remaining resistance above the last shorted contact can be related to water surface elevation. The outer protective cover pumps air in and out of the sensor as water falls and rises. Therefore, a silica-gel chamber is provided for absorbing water vapor from the air to prevent condensation in the sensor.

The company sells an electronic unit to be used with the sensor. The unit provides a high and low water level alarm, a 1 to 100 direct reading needle dial, and voltage output terminals.

Meeting with Designers. - Difficulties have been experienced in the use of floats for monitoring water surface elevation. The designers needed an alternative for float-controlled mechanisms and indicated that the device satisfy the following requirements:

(1) Linear over a 40° to 60° F range
(2) Measure over a 30-foot range of water surface elevation
(3) Have an electrical output

During a meeting of August 7 with designers and researchers, the Denver sales representative for Metritape demonstrated a 4-foot Metritape to the group. The designers requested the loan of a 20-foot Metritape for testing by the Hydraulics Branch. The demonstrator 4-foot Metritape and electronic unit was left with the Hydraulics Branch while the representative checked on the possible loan.

Further Information Furnished by the Company. - By telephone call, the representative provided the following information to questions asked during the meeting and to help in performing the laboratory tests:

1. Metritapes have been in use in water with some failures due to mishandling.

2. Difficulties with algae growth were experienced in Narrangansett Bay. However, blocking out light corrected the problem.

3. Growths such as barnacles have been removed from Mylar plastic with weak acid solutions.

4. The company was not willing to loan us a 20-foot sensor for testing but offered to sell one for about $350.

5. The Corp of Engineers is using a Metritape in a special channel for river stage monitoring, Kansas City, Missouri.

6. The tensile strength of the stainless steel shorting strip of the sensor is 6,000 psi.

7. Using No. 14 (AWG), 13.6 (ohms/mile) wire, the output signal can be transmitted 4 miles. The change of resistance of the wire with temperatures is 0.4 ohm/1,000 ft/1° F, between 77° F to 149° F.

8. The sensor is made of tightly wound Nichrome resistance wire around a partially insulated stainless steel shorting strip.

9. Current to sensor under 5-volts direct current is 5 milliamps.

10. The electronic package provided by the company to be used with the sensor produces a constant current to the sensor.

11. The resistance of the sensor is 30 (ohms/foot) for 1/2-inch spaced spiral.

Test Program

Since the company would not loan us a 20-foot Metritape, it was decided that tests should be conducted with the demonstrator 4-foot sensor and electronic unit.

SUMMARY OF RESULTS PERTINENT TO APPLICATION

1. Although the electronic unit for the Metritape would not zero or span adjust the output, we were able to test the sensor by separate ohm measurements.

2. No progressive deterioration and/or leakage into the Metritape was noted during 40 days of installation in the laboratory.

3. Five minutes were required for resistance readings to become within ± 0.5 of an ohm of final ohm reading in response to 0.2-foot step changes of water surface.

4. Ohm readings with respect to water surface elevation are plotted in Figure 1.

5. The straight line envelopes labeled A, B, C, and D in Figure 1 are plotted at 30 (ohms/foot).

6. The A-line, Figure 1, represents the low values of resistance that the data tend to approach when the water surface around the tape is static for 1 to 2 days.

7. The B-line is the low ohm limit during tests where the water surface has ripples and waves up to 0.1 foot during the change and with no reading taken less than 5 minutes after a water surface has been changed.

8. The B-line also represents most data taken in sequence for a quietly lowered water surface. For example, see the dotted line curve with down arrows in Figure 1.

9. The <u>C-line</u> is the envelope of high ohm readings taken when the water surface is rising at rates greater than 0.05 (foot/min) without attempting to prevent small water surface waves or vibration of the Metritape.

10. The <u>D-line</u> is the maximum high ohm reading envelope that the data tended to approach when special care was taken to prevent surface waves and vibrations of the Metritape. The water was allowed to rise at 0.03 to 0.05 (ft/min).

11. Based on these studies the Metritape would be expected to monitor the water surface to within a (0.2 ft) band where there are vibrations, ripples, and waves helping to set electrical contact.

12. When the water surface can very slowly rise (0.03 to 0.05 foot/min) and also remains very still for 1 or 2 days, the tape can be expected to monitor the water surface only to within a 0.4 foot band.

13. No temperature sensitivity of the Metritape was noted during the laboratory tests with room temperatures covering the range 75° to 91° F and the well water temperature covering the range of 60° to 75° F.

LABORATORY TESTS

Inspection

Since the Metritape has been used as a demonstrator, it was inspected for signs of damage and/or leakage. There were two superficial fingernail-like indentions in the plastic diaphragm. The sensor had a slight bow of about 1/4 inch, 9 inches from the bottom. No other obvious damage was noted.

Laboratory Installation

After the inspection the Metritape was installed in an 18-inch-diameter well with a vernier-hook gage to measure water surface elevations. The water level in the well could be varied by interconnection to another well of the same size, by a drain, or by hose from the city water supply. A multifunction meter was used to measure the resistance of the Metritape and the voltage output of the electronic unit supplied by the company with the tape.

General Laboratory Conditions During Tests

During the laboratory tests temperature of the water in the well varied from about 61° to 75° F. The temperature range of the ambient air around the Metritape above the water surface or the active part of the sensor varied from 75° to 91° F. The Metritape was immersed over the range of water depth 0.2 to 2.0 feet for about 40 days. No sign of leakage through the protective covering was indicated by the moisture indicating crystals in the silica-gel dessicant chamber.

Preliminary Tests

Time Response Check. - The resistance response time of the sensor was checked for step changes or almost instantaneous changes of water surface elevation. Steps of about 0.2 foot were created in the well. Resistance readings settled to within $\pm$0.5 ohm of the final values in 5 minutes. Thus, no resistance readings were recorded until 5 minutes after water surface elevation changes.

Electronic Output Unit. - Early in the investigation, testing showed that the electronic unit produced a voltage output that went from about -700 mv at 0.2 foot of water to about +300 mv at 2.0 feet of water with about ±100 mv scatter at any water level. The output voltage would not respond to attempts to adjust the zero or span potentiometers. The Denver representative arranged to have a manufacturer's representative of Metritape, Inc., Concord, Massachusetts, call the laboratories. The manufacturer's representative said the output was not operating properly and that earlier models used lead-coated contacts on the circuit cards and that we should pull the cards and reconnect them to improve contact. This procedure was tried but did not help.

During the preliminary test, ohm readings were obtained when the sensor was not connected to the electronic unit. Currents to the sensor were calculated from the separate ohm and voltage readings on the sensor when connected to the electronic unit. They were very nearly constant to 19.6 ma over the range of water surface elevation tested. Using this current value, the ±100-mv scatter for the voltage data when the sensor was hooked up to the electronic unit, an ohm scatter was calculated that was commensurate with the measured scatter of separate ohm readings. Measuring separate voltage and ohm readings was time consuming because the electronic unit had to be turned off, the sensor disconnected, and then carefully connected to the function meter. Failure of the electronics did not preclude testing the Metritape for linearity and repeatability of ohm readings with respect to water surface elevation when disconnected from the electronic unit. Further tests concentrated on ohm reading versus water surface because the designers would use the Metritape sensor as an alternative to floats for monitoring water surface elevations.

Resistance of Sensor with Respect to Water Surface Elevation

All resistance data are shown plotted in Figure 1. Data envelopes are drawn in at slopes of 30 (ohms/foot).

The A-line represents the limit that ohm readings tended to approach when the water surface was left at one elevation for a long time, say over a weekend. These low readings were obtained whether or not the evaporation loss (about 0.008 ft/day) was replaced before taking an ohm reading. The D-line represents the upper limit that ohm readings tended to approach when allowing the water to creep slowly upward at 0.03 to 0.05 foot/min. However, removing the hook of the vernier gage out of the water would trigger a reduction of resistance reading from 1 to 5 ohms. Because the volume of the hook represented an unmeasurably small change in water elevation, it was concluded that vibration of the support frame and/or water ripples caused the resistance reduction. Disturbing the water surface with 0.1-foot waves in the well forced ohm readings to approach the B-line.

The B-line also represents the line that resistance data tended to follow for a falling water surface sequence. The dotted line with down arrows in Figure 1 is an example of this case. However, there was much greater variance from linearity for data obtained in an upward sequence. Combination of these two results suggests that the data scatter may be caused by the spring characteristics of the flexible covering and the Nichrome wire. Their combined spring action aids in breaking the shorting contact and opposes the making of contact.

The C-line represents the upper envelope of data taken in an upward sequence of water surface elevation changes when no special precautions are taken to prevent vibrations, ripples, waves, or rate of water surface rise greater than 0.05 ft/min.

These results indicate that the Metritape can monitor water surface elevation to within a 0.4-foot band where there are no vibrations, ripples, and waves helping to set electrical shorting contact and when the water surface does not remain static for long periods of time, 1 to 2 days, Figure 1 (A and D lines). This case could occur with a Metritape in a highly throttled stilling well combined with long periods of time with water at a constant level. When there are waves, ripples, and vibrations around the Metritape and water rises greater than 0.05 ft/min then the water surface can be monitored to within 0.2-foot band, Figure 1 (B and C-lines).

R A Dodge

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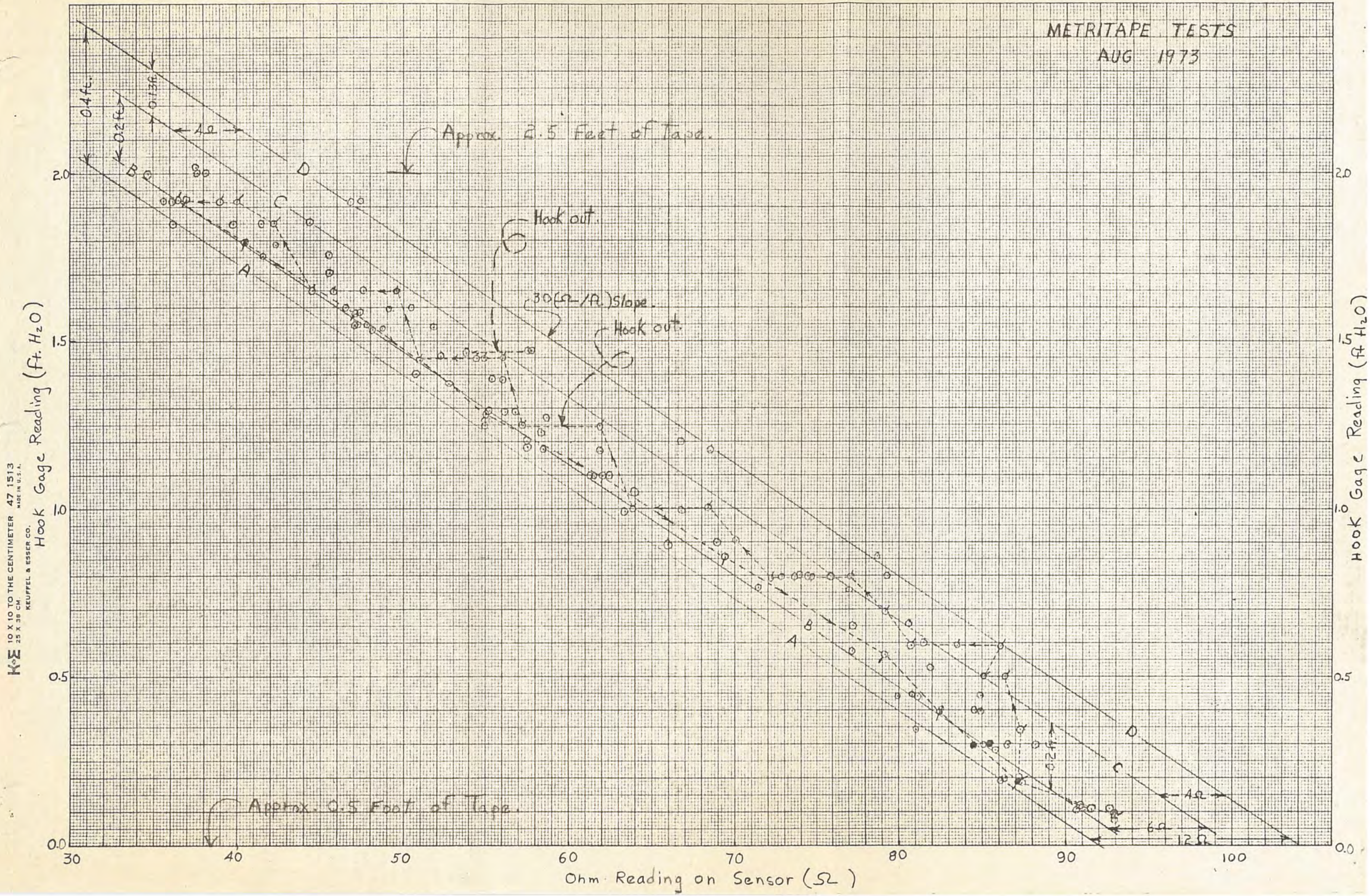
Figure 1


METRITAPE TESTS
AUG 1973
Hook Gage Reading (ft. H_2O)
Ohm Reading on Sensor (Ω)
Approx. 2.5 Feet of Tape.
Approx. 0.5 Foot of Tape.
Hook out.
Hook out.
30 (Ω/ft.) Slope.
0.4 ft.
0.2 ft.
0.13 ft.
4 Ω
6 Ω
12 Ω
A
B
C
D
K+E 10 X 10 TO THE CENTIMETER 47 1513
25 X 38 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

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(12-61)
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Memorandum

Denver, Colorado
November 12, 1973

Chief, Hydraulic Structures Branch

Chief, Hydraulics Branch

R. A. Dodge

Testing of 20-foot Metritape sensor for possible use in monitoring and controlling water surface elevation in Altus-Snyder aqueduct systems
(see my memorandum of October 2, 1973 on 4-foot sensor results)

Purpose

Laboratory tests were continued to compare the resistance characteristics of the 4-foot Metritape previously studied with those of a 20-foot tape.

Background

The results of the previous tests most pertinent to the designers and the automation team were:

1. The 4-foot Metritape monitored the water surface to within a 0.2-foot band when there were vibrations, ripples, and waves helping to set electrical contact.

2. When the water surface can very slowly rise (0.3 to 0.05 foot/min) and also remains very still for 1 or 2 days, the 4-foot Metritape monitored water surface within a 0.4-foot band.

Representatives of Metritape, Inc., after discussion of the test results, suggested that some of the data spread was the result of using the 4-foot sensor in the bottom 2.5 feet where end effects would be severe. The company offered the loan of a 20-foot Metritape to assist in defining the resistance characteristics.

The loan was accepted, and representatives of the Structures and Electrical Branches through the automation team, asked for additional tests with the 20-foot Metritape sensor. They expressed particular interest in the hysteresis and repeatability of resistance readings within 1 to 6 feet of the top and bottom of the sensor.

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Further Information Furnished by the Company

Information furnished with the 20-foot tape that may be of interest to designers and installers follows:

1. Metritapes can be coiled in minimum 5-foot-diameter circles between points of storage and installation.

2. Tapes should neither be coiled nor uncoiled when temperatures are less than 65° F.

3. Tapes should be stored in straight position, preferably at uniform temperatures greater than 65° F and away from point sources of heat.

4. When tapes are straight and temperatures are less than 65° F, then they should be handled in a straight position by three or four persons.

Metritape, Inc., also provided calibration data for two 16-foot tapes being used by The Public Service Company of Colorado. One of these calibrations shows a 9-ohm maximum deviation from the best fit line at distance of 3 feet from the top of the tape. The average deviation for the full length of tape is about 3 ohms. These deviations are equivalent, on the basis of 30 ohms/foot, to 0.3 and 0.1 foot of water, respectively. The second calibration has maximum deviations of about 7 ohms (0.23 foot of water) at 3 and 5 feet from the top of the tape. The average deviation for the full length is about 3 ohms (0.1 foot of water.)

Tests with 20-foot Metritape

The 20-foot Metritape was installed in a 4-inch-diameter aluminum pipe provided with a manometer to measure the level in feet of water on a white face tape (0.01-foot gradations). The water level in the pipe was varied by connection to the city water supply and a valve drain. A different multimeter was used for measuring the resistance change of the 20-foot tape than was used for testing the 4-foot tape.

The tape resistance and 4-inch pipe water levels measured during the tests of 20-foot Metritape are plotted in the enclosed graph. The two lines in the graph enclose most of the data.

The resistance values were taken 5 minutes after water surface changes for both rapid and tranquil cases. The range of data between the lines varies from 15 ohms at the 3-foot elevation to 11 ohms at the 17-foot elevation. The equivalent ranges in terms of feet of water are 0.50 and 0.35 foot, respectively.

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Tranquil changes of water surface elevation in the upward direction tend to cause ohm values to approach the upper line. Lightly striking the 4-inch pipe to produce vibrations tended to cause the ohm values to approach the lower line.

Data plotted in solid triangles were taken in downward sequence with rapid changes of water surface elevation. The data plotted as "X's" are for an upward sequence of rapid changes. No particular effort was made to vibrate the pipe during either of these sequences.

Comparison of Different Length Metritapes

The 4-foot Metritape data showed an envelope data range of 12 ohms from 0.5 foot to 2.5 foot from the bottom end of the tape. Since deviation can be expected on both sides of a best fit curve, the 16-foot tapes (data supplied from Public Service Company) can be considered to have an envelope range of 18 ohms. The 20-foot Metritape graph indicates a tapered envelope range that averages about 13 ohms; thus, 15 ohms could be considered about the average extreme data range for the three sizes of Metritapes. Based on 30 ohms/foot, this ohm range is equivalent to 0.5 foot of water.

R. A. Dodge

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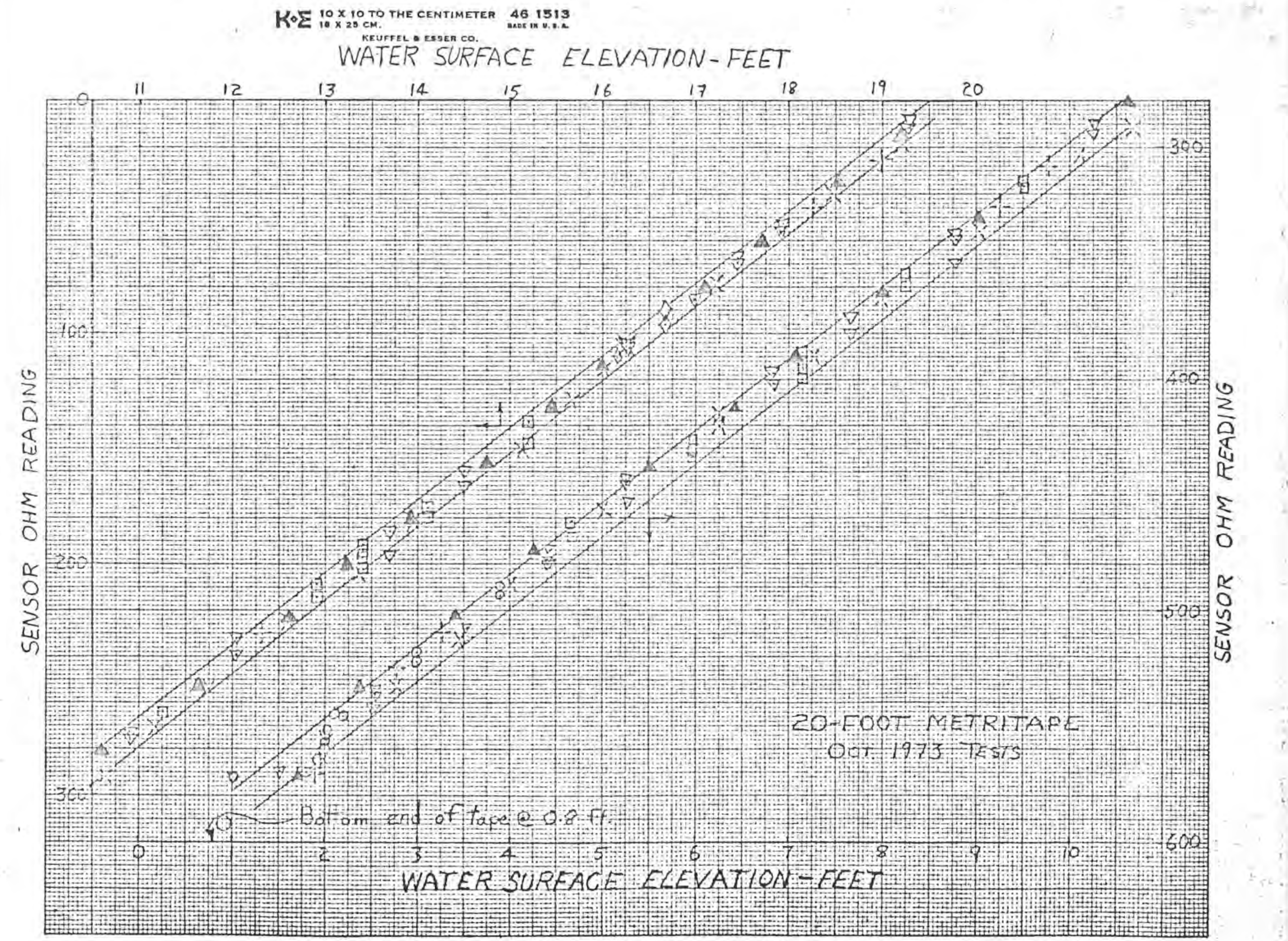
K•E 10 X 10 TO THE CENTIMETER 46 1513
18 X 25 CM.
MADE IN U.S.A.
KEUFFEL & ESSER CO.
WATER SURFACE ELEVATION-FEET
SENSOR OHM READING
20-FOOT METRITAPE
Oct 1973 Tests
Bottom end of tape @ 0.8 Ft.
WATER SURFACE ELEVATION-FEET
SENSOR OHM READING

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JAN - 4 1974

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Davis and Davis
Manufacturer's Agents
Post Office Box 9027
Denver, CO 80209

Gentlemen:

We greatly appreciate the loan of the 4-foot and 20-foot Metritapes and the help that Messrs. Bunch and Grant provided during our laboratory testing.

The 4-foot Metritape was installed in an 18-inch-diameter well with a vernier-hook gage to measure water surface elevations. The water level in the well could be varied by interconnection to another well of the same size, by a drain, or by a hose from the city water supply. A precision digital meter was used to measure the resistance of the Metritape and the voltage output of the electronic unit supplied by the company with the tape.

During the laboratory tests, temperature of the water in the well varied from about 61° to 75° F. The temperature range of the ambient air around the Metritape above the water surface or the active part of the sensor varied from 75° to 91° F. The 4-foot Metritape was immersed over the range of water surface elevations 0.2 to 2.0 feet above the 6-inch depth suggested by the company for a minimum zero.

The following are the results of our tests with the 4-foot Metritape of interest to you:

1. The electronic unit for the Metritape would not zero or span adjust the output. However, we tested the sensor by taking separate resistance measurements.

2. No deterioration and/or leakage into the Metritape was noted during 40 days of installation in the laboratory.

3. Five minutes were required for resistance readings to become within ±0.5 of an ohm of final ohm reading in response to 0.2-foot step changes of water surface.

4. Ohm readings with respect to water surface elevation are plotted in the enclosed Figure 1.

5. The straight line envelopes labeled A, B, C, and D in Figure 1 are plotted at 30 ohms/foot.

6. The A-line represents the low values of resistance that the data tend to approach when the water surface around the tape is static for 1 to 2 days.

7. The B-line is the low ohm limit during tests where the water surface has ripples and waves up to 0.1 foot during the change and with no reading taken less than 5 minutes after a water surface has been changed.

8. The B-line also represents most data taken in sequence for a quietly lowered water surface. For example, see the dotted line curve with down arrows.

9. The C-line is the envelope of high ohm readings taken when the water surface is rising at rates greater than 0.05 foot/minute without attempting to prevent small water surface waves or vibration of the Metritape.

10. The D-line is the maximum high ohm reading envelope that the data tended to approach when special care was taken to prevent surface waves and vibrations of the Metritape. The water was allowed to rise at 0.03 to 0.05 foot/minute.

11. Based on these studies, the Metritape would be expected to monitor the water surface to within a 0.2-foot band where there are vibrations, ripples, and waves helping to set electrical contact.

12. When the water surface can very slowly rise at 0.03 to 0.05 foot/minute and also remains very still for 1 or 2 days, the tape can be expected to monitor the water surface only to within a 0.4-foot band.

13. No temperature sensitivity of the Metritape was noted during the laboratory tests.

The 20-foot Metritape was installed in a 4-inch-diameter aluminum pipe provided with a manometer to measure the level in feet of water on a white face tape 0.01-foot gradations. The water level in the pipe was varied by connection to the city water supply and a valve drain. A digital multimeter was used for measuring the resistance change of the 20-foot tape. The resistance values were taken 5 minutes after the water surface was changed for both rapid and tranquil changes.

The following are the results of our tests with the 20-foot Metritape:

1. The tape resistance and 4-inch-pipe water levels measured during the tests of 20-foot Metritape are plotted in the enclosed Figure 2. The two lines in the graph enclose most of the data.

2. The range of data between the lines varies from 15 ohms at the 3-foot elevation to 11 ohms at the 17-foot elevation. The equivalent ranges in terms of feet of water are 0.50 and 0.36 foot, respectively.

The information contained in this letter report regarding commercial products or firms may not be used for advertising or promotional purposes and is not to be construed as an endorsement of any product or firm by the Bureau of Reclamation.

Very truly yours,

F. M. Holloway

FOR Howard J. Cohan, Chief
Division of General Research

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Metritape, Inc.
77 Commonwealth Avenue
West Concord, MA 01742

Gentlemen:

We greatly appreciate the loan of the 4-foot and 20-foot Metritapes and the help that Messrs. Bunch and Grant provided during our laboratory testing.

The 4-foot Metritape was installed in an 18-inch-diameter well with a vernier-hook gage to measure water surface elevations. The water level in the well could be varied by interconnection to another well of the same size, by a drain, or by a hose from the city water supply. A precision digital meter was used to measure the resistance of the Metritape and the voltage output of the electronic unit supplied by the company with the tape.

During the laboratory tests, temperature of the water in the well varied from about 61° to 75° F. The temperature range of the ambient air around the Metritape above the water surface or the active part of the sensor varied from 75° to 91° F. The 4-foot Metritape was immersed over the range of water surface elevations 0.2 to 2.0 feet above the 6-inch depth suggested by the company for a minimum zero.

The following are the results of our tests with the 4-foot Metritape of interest to you:

1. The electronic unit for the Metritape would not zero or span adjust the output. However, we tested the sensor by taking separate resistance measurements.

2. No deterioration and/or leakage into the Metritape was noted during 40 days of installation in the laboratory.

3. Five minutes were required for resistance readings to become within ±0.5 of an ohm of final ohm reading in response to 0.2-foot step changes of water surface.

4. Ohm readings with respect to water surface elevation are plotted in the enclosed Figure 1.

5. The straight line envelopes labeled A, B, C, and D in Figure 1 are plotted at 30 ohms/foot.

6. The A-line represents the low values of resistance that the data tend to approach when the water surface around the tape is static for 1 to 2 days.

7. The B-line is the low ohm limit during tests where the water surface has ripples and waves up to 0.1 foot during the change and with no reading taken less than 5 minutes after a water surface has been changed.

8. The B-line also represents most data taken in sequence for a quietly lowered water surface. For example, see the dotted line curve with down arrows.

9. The C-line is the envelope of high ohm readings taken when the water surface is rising at rates greater than 0.05 foot/minute without attempting to prevent small water surface waves or vibration of the Metritape.

10. The D-line is the maximum high ohm reading envelope that the data tended to approach when special care was taken to prevent surface waves and vibrations of the Metritape. The water was allowed to rise at 0.03 to 0.05 foot/minute.

11. Based on these studies, the Metritape would be expected to monitor the water surface to within a 0.2-foot band where there are vibrations, ripples, and waves helping to set electrical contact.

12. When the water surface can very slowly rise at 0.03 to 0.05 foot/minute and also remains very still for 1 or 2 days, the tape can be expected to monitor the water surface only to within a 0.4-foot band.

13. No temperature sensitivity of the Metritape was noted during the laboratory tests.

The 20-foot Metritape was installed in a 4-inch-diameter aluminum pipe provided with a manometer to measure the level in feet of water on a white face tape 0.01-foot gradations. The water level in the pipe was varied by connection to the city water supply and a valve drain. A digital multimeter was used for measuring the resistance change of the 20-foot tape. The resistance values were taken 5 minutes after the water surface was changed for both rapid and tranquil changes.

The following are the results of our tests with the 20-foot Metritape:

1. The tape resistance and 4-inch-pipe water levels measured during the tests of 20-foot Metritape are plotted in the enclosed Figure 2. The two lines in the graph enclose most of the data.

2. The range of data between the lines varies from 15 ohms at the 3-foot elevation to 11 ohms at the 17-foot elevation. The equivalent ranges in terms of feet of water are 0.50 and 0.36 foot, respectively.

The information contained in this letter report regarding commercial products or firms may not be used for advertising or promotional purposes and is not to be construed as an endorsement of any product or firm by the Bureau of Reclamation.

Very truly yours,

F. M. Holdaway

FOR Howard J. Cohan, Chief
Division of General Research

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Metritape, Inc.
77 Commonwealth Avenue
West Concord, MA 01742

Gentlemen:

Thank you for the additional data and brochures on Metritape systems for monitoring and measuring water surface elevation sent with your letter of January 24, 1974.

Unfortunately the Metritapes that you loaned us for testing did not show consistent or precise enough operation to satisfy our design requirements for fully automatic pump operation on municipal and industrial water supply systems. Pump starts and stops are governed by calculated volumes, thus water level sensing must be highly consistent. However, our test results do not preclude their use by the USBR for other possible applications having less stringent design requirements.

Enclosed are sketches of the test arrangements that we used for both sizes of Metritapes. For each size we used the silica cells with the long coiled tubing attached. Mr. Carl Bunch checked the air breather used with the 20-foot Metritape before final packing. He now has both tapes that you loaned to us.

During our tests the settling time seemed to be mostly related to slowly changing water surface elevation in the upward direction and pausing after small changes of water level. The settling time cited in our letter of January 4, Item 3, should have been stated as a maximum.

We were unable to relate your chart data to the accuracy sheet. The recordings appear to be nonlinear but no units were available to determine the deviation. Also we could not find data on an independent measure of water surface with respect to the output of the Metritapes.

Thank you for the loan of the two Metritapes and the additional information.

Very truly yours,

FOR Howard J. Cohan, Chief
Division of General Research

Enclosures

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Post Office Box 9027
Denver, CO 80209

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