Water Level and Sediment Load Monitoring Systems – An Update

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ABSTRACT

This paper presents an update of the basic design and performance of a precision pneumatic water-level gage that is suitable for application in most severe environments. The key to the success of this pneumatic bubbler gage is the incorporation of an analog "traveling-wave" low-pass filter which pre-filters out the noises generated by wind waves and swells. It eliminates the high cost and error problems associated with a stilling well. The system satisfies the basic design requirement of ± 1mm resolution of water head. With multiple gage setup, the system can also be used to monitor the sediment load in rivers, estuaries and coastal waters. For applications where the water contains significant amount of suspended materials, one needs also to monitor the water column density so that the measured hydrostatic pressures may be converted into true water level reading. To do so, one can install at one location two bubbler gages. The sediment load monitoring system is intended for providing better measurements for sediment monitoring and control in river-basin management.

INTRODUCTION

The pneumatic bubbler gages are widely used in the U.S. for water level measurements by the National Oceanic and Atmospheric Administration (NOAA) in the coastal waters and by the U.S. Geological Survey (USGS) in the inland waters and estuaries. The bubbler gage is suitable for water level measurements along open coast or river with large water level ranges, in remote locations, and in harsh environments where other instruments cannot be easily deployed. In the past decade, we had field tested the gage in the U.S. coastal locations, at a UK tide Observatory station in Holyhead, and along Yangtze River in China. Presently, we are building 15 bubbler gages to be installed for water-level monitoring at Yangtze River hydrological stations. In the following, an update of these field tests and their performance will be given.

THEORY OF A PNEUMATIC TIDE GAGE

The detail of the basic theory for a pneumatic gage was given in Ling and Pao (1994), hence will not be repeated here. A pneumatic circuit diagram of our bubbler gage is schematically shown in Fig. 1. The key to the success of this pneumatic gage is the incorporation of an analog "traveling-wave" low pass

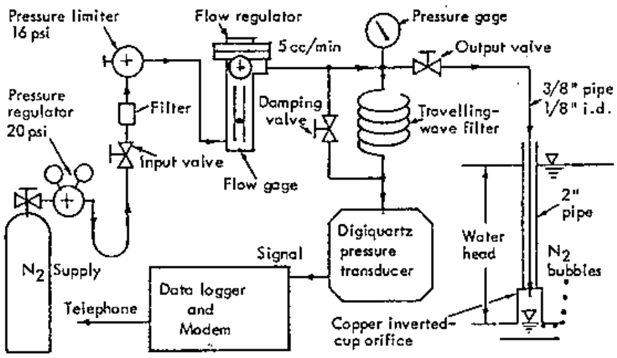


Fig. 1. Pneumatic bubbler tide gage circuit diagram

filter which pre-filters out the noises generated by wind waves and swells. Fig. 2 illustrates the effectiveness of the low-pass filter. The output from the bubbler gage without low-pass filter shows rather noisy signal with fluctuations slightly over one foot as shown in Fig. 2(a), while the output from our precision advanced bubbler gage equipped with the low-pass filter shows a virtually noise-free signal. Some other advanced tide gages, in use today, take reading once every second for 3 minutes and for the next 3 minutes process the average of the readings to represent the average of a 6-

minute data recording window. This technique is used by NOAA/National Ocean Service for their second-generation tide gages.

FIELD DATA

In the past decade, we had field tested our pneumatic bubbler gages in many locations around the world. A few sample data will be presented in the following.

Solomon Island, Maryland

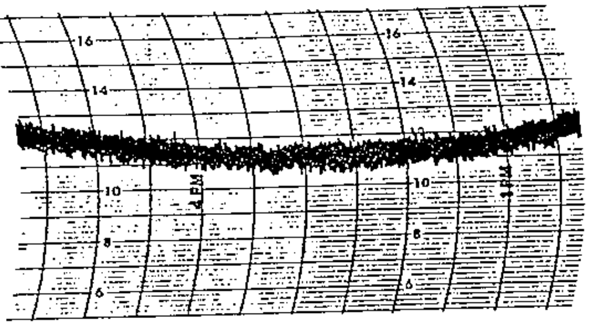
Fig. 3 shows the water level data recorded by the gage in 1995 at Solomon Island, Maryland near the Chesapeake Bay. The data was recorded every six minutes. It is noted that the reading is taking every second for a short period of 10 seconds. The reading shown is the average during the 10 seconds. Therefore, it is virtually equivalent to a reading at an instant which is different from the NOAA/NOS technique that averages over a period of 3 minutes. Since the location of the gage is at the mouth of Patuxent River into the Chesapeake Bay, the wave climate there is rather mild. However, the water level is influenced considerably by the local wind setup. There is a NOAA/NOS tide gage at the same station. A comparison of our data with NOS's data showed that, during the 6-day period, the root mean square difference between these two sets of data is 0.53 mm, with a maximum difference 14.3mm. Therefore, both data are of high quality and reliability.

Holy Head, UK

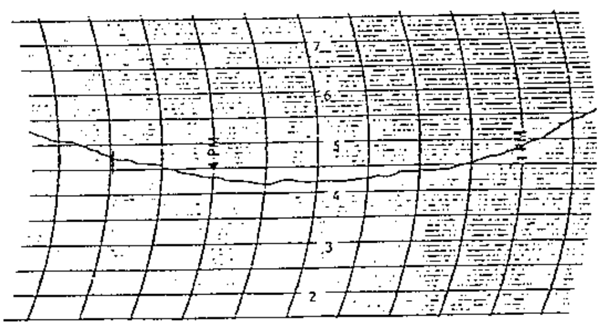
Fig. 4 shows the tide data at Holy Head station of U.K. Tide Observatory. The station is on the Atlantic coast of England. The maximum tidal range is over 5 m. The British Tide Observatory also adopted pneumatic bubbler gages, however, they data is obtained by continuously averaging over a period of 15 minutes. Hence any oceanic event with a period of less than 30 minutes, such as Tsunami, will probably affected by this averaging process.

CunTan Station, Yangtze River

Fig. 5 shows the water level data recorded at CunTan station a short distance downstream from Chongqing on Yangtze River. It is seen the water level rises rapidly during the 1998 great flood of Yangtze River. During June 23-24, 1998, the water level rises 5 meters in a 24-hour period, with a maximum rate of 3m



(a) Data from a bubbler gage without a low-pass filter



(b) Data from a bubbler gage with a low-pass filter

Fig. 2 Illustration of outputs for bubler gages with and without low-pass filter.

in 6 hours. This is equivalent to a rise rate of 50 cm per hour. Our bubbler gage is designed to handle this type of rapid water level rise.

SEDIMENT LOAD MONITORING

With multiple gage setup, the system can also be used to monitor the sediment load in rivers, estuaries and coastal waters. For applications where the fluid medium contains significant amount of suspended or dissolved materials, one needs also to monitor the water column density so that the measured hydrostatic pressures may be converted into true water level reading. To do so, one can install at one location two bubbler gages. The cup orifice of gage #2 is set at precisely say L=2.000m below that of gage #1. The average specific weight of the water column between the two orifuces can be expressed as

$$\gamma_c = (P_{02} - P_{01})/L \qquad (1)$$

where P_{01} and P_{02} are the respective presure readings of the two gages. Knowing γ_c, and the specific weights of pure water γ_w and sediment particles γ_s,

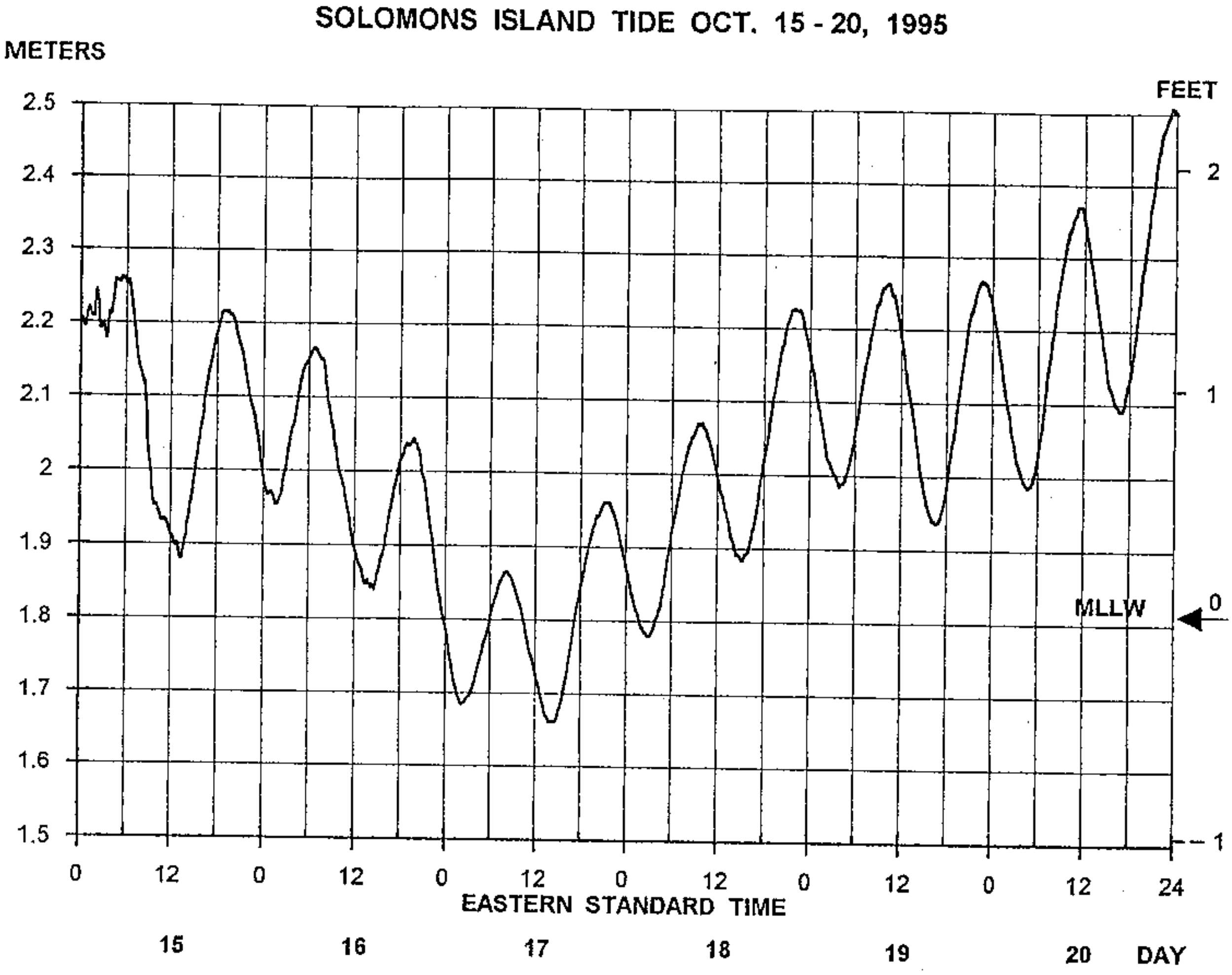


Fig. 3. Tide data recorded by High Precision pneumatic bubbler gage at Solomon Island.

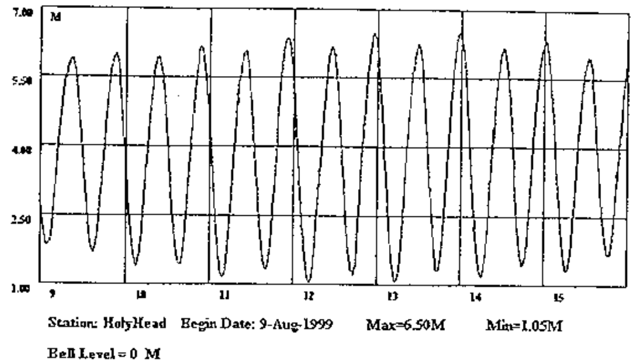


Fig. 4. Tide data recorded by High Precision bubbler gage at HolyHead station, UK Tide Observatory.

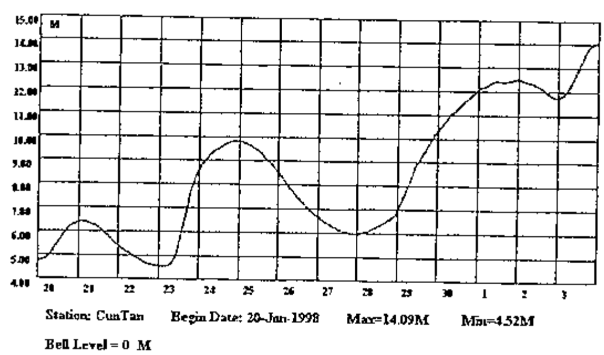


Fig. 5 Water level data recorded at CunTan station on Yangtze River.

one can obtain the information of sediment concentration as

$$Cs = (\gamma_c - \gamma_w)/(1 - \gamma_w/\gamma_s) \qquad (2)$$

It is seen that the resolution for field measurement of the term $(P_{02} - P_{01})/\gamma_w$ is $\pm$ 1mm. Thus the resolution for determining $\gamma_c/\gamma_w = (P_{02} - P_{01})/(\gamma_w L)$ is $\pm$ 1mm/2000mm, which is $\pm$ 0.0005. Such a resolution is quite adequate for field monitoring of sediment load. The reason that this technique can achieve a reasonably high accuracy for continuously monitoring sediment load in the field is due to the fact that the measurements of the water head are taken at a virtually noise-free manner, attributed to the effectiveness of the low-pass filter. The field continuous monitoring of sediment loads is a difficult task, in particular, in high sediment environment. Many rivers in Taiwan and China are known to have high sediment loads which are the main reason that many reservoirs are being silted up. Therefore, a reliable and accurate monitoring system of sediment loads is highly desirable.

Therefore, the present Precision bubbler tide gage is intended for providing more reliable information concerning the long term variation of the sea level, and for improving the precision of flood forecast and control. The sediment load monitoring system is intended for providing better field measurements for sediment monitoring and control in the river-basin management.

REFERENCE

Ling, S.C. and H.P. Pao, A precision water level and sediment monitoring system, Proc. First International Symposium on Hydraulic Measurement, IAHR, a keynote paper, Nov. 1994, Beijing, China.