Journal of the Korean Society of Oceanography
Vol. 34, No. 4, pp. 200—206 December 1999

Development of a Time-selective Self-triggering Water Sampler and Its Application to *In-situ* Calibration of a Turbidity Sensor

JAE-YOULL JIN, KEUN CHOON HWANG, JIN SOON PARK,
KI DAI YUM AND JAE KYUNG OH[1]
Korea Ocean Research and Development Institute, Ansan P.O. Box 29, Seoul 425-600, Korea
[1]Department of Oceanography, Inha University, Inchon 402-751, Korea

Seawater sampling is the primary task for the study of the marine environmental parameters that require shipboard or laboratory experiments for their analyses, and is also required for the calibration of some instruments for *in situ* measurement. A new automatic bottle (AUTTLE) is developed for seawater sampling at any desired time and water depth by self-triggering. Both any type of single or assembled mooring for 15 days and manual actuation by using a remote messenger as existing instantaneous single point water samplers are possible. Its sampling capacity and the resolution of time setting are 2 liters and 1 second, respectively. The result of a field experiment with an optical backscattering sensor (OBS) and a total of 14 AUTTLEs for the *in situ* calibration of the OBS shows that the AUTTLE must improve our understanding on the behavior of the sand/mud mixtures in the environments with high waves and strong tides. The AUTTLE will serve as a valuable instrument in the various fields of oceanography, especially where synchronized seawater sampling at several sites is required and/or the information in storm period is important.

INTRODUCTION

From the viewpoint of measurement, marine environmental parameters may be divided into two categories: the first group is for *in-situ* measurable parameters with relevant probes, and the second for the parameters requiring laboratory or shipboard experiments for the quantitative analyses. Physical parameters including water elevation, current speed and direction, wave characteristics, temperature and salinity belong to the former group. While most biological and chemical parameters to the latter, although some parameters such as dissolved oxygen, ammonia can also be measured *in situ* with the instruments.

The instruments for *in situ* measurement should be calibrated with reliable accuracy before mooring or deploying. The calibration coefficients between some parameters and the relevant instruments largely vary according to the measuring site and time due to the sensing mechanism of their probes. The representative is the electronic instrument for the monitoring of suspended sediment concentration (SSC). Thus, the OBS, the transmissometer, and the acoustic backscatter sensor (ABS) should be calibrated *in situ* to ensure that a time series for true SSC can be obtained (Sternberg *et al.*, 1986; Hay and Sheng, 1992; Maa *et al.*, 1992; Black and Rosenberg, 1994).

For the study on the behavior of the second group parameters, seawater sampling is the primary task for the experiments. Various types of instantaneous water samplers including the Van Dorn, the Nansen, the Niskin bottles and the Rosette have been used for seawater sampling. These samplers basically work on the same principle: they collect and retain water by closing and sealing the lids at each end of the sampler by a remote messenger or the electric signal from the deck command unit (Rosa *et al.*, 1994). The prerequisite for seawater sampling with these samplers is the mild sea condition in which vessel cruising is possible. However, in cases of some parameters such as SSC and pollutant concentration from the contaminated bed, the value in storm period is much more important than that in mild season. Thus, to understand the behavior of these parameters more comprehensively, it is required to develop a mooring type self-triggering bottle that can provide the information in storm period.

This paper describes a new time-selective and self-triggering water sampler developed for automatic seawater sampling at a desired water depth and time, and its field application conducted for the *in situ* calibration of an OBS.

DEVELOPMENT OF THE AUTTLE

With the basic concept that *in situ* solenoid driving can take the place of manual dropping of a messenger or sending electric signal from a boat, the AUTTLE was designed as a simple combination of a Niskin bottle and two electronic circuit boards. The one is for time control and the other for high power generation (Fig.1, 2). The bottle and the circuit cylinder were made of PVC and Monomer Cast Nylon, respectively. The bottle length is 460 mm and its sampling capacity is 2 liters. The operation procedure of the AUTTLE consists of time control, high power generation, and triggering by driving the solenoid molded on the bottle with epoxy (Fig. 3). The AUTTLE can be moored or deployed for 15 days with two 9-volt alkaline batteries, and the resolution of time setting is 1 second. There are three switches for the setting and checking. The first switch is for powering on the AUTTLE. After powering on and setting desired triggering time, the second is switched on to start time counting and display the remaining time to trigger through the LED panels. The third switch is to power off the LED panels for reducing their power consumption. In order to check whether the time counter operates well, the third should be switched on.

The prototype circuit board was modified for reducing the diameter of the circuit cylinder to minimize the disturbance of ambient flow (Fig. 2). After testing the performance of a revised AUTTLE, a total of 26 AUTTLEs were constructed and have been successfully tested several times in a flume (Fig. 4). Although the test for determining the limit of mooring depth has not been extensively conducted, it was proved by a pressure chamber test that the circuit cylinder is safe against water intrusion at the water depth of 200 m.

IN-SITU CALIBRATION OF AN OBS WITH AUTTLES

General limitation in using the OBS

The output unit of most electronic instruments for SSC monitoring is digitized voltage that is converted from analogue data of light or acoustic signal intensity. Thus, as mentioned above, all the instruments should be reliably calibrated in order to provide real SSC expressed as mg/l for the study of sedimentary processes. Furthermore, in case of some multi-parameter instruments using formazin turbidity units (FTU) or nephelometric turbidity units (NTU), two kinds of calibration should be conducted: the one is between voltage and FTU or NTU, the other is between FTU or NTU and mg/l.

Since Downing *et al.* (1981) developed, the OBS has been the most widely used for SSC monitoring because of its relatively low price. However, the OBS has several error-generating causes (D&A Inst. Co., 1991). The most critical error is due to the variation of its gain (volts per mg/l) with the size of suspended particulate matter (SPM). The changing in the slope sign of the calibration curve due to the blocking of infrared radiation also causes a serious error in the quantitative study of high concentrated suspension (D&A Inst. Co., 1991; Kineke and Sternberg, 1992).

The gain of an OBS has inverse relationship with the size of SPM, and can vary by a factor of 200. Therefore, the output voltage in a muddy suspension is higher than that in a sandy suspension, although they are equal in the concentration. Jin *et al.* (1999) have found out that the slope of the regression line obtained by *in situ* measuring of surface SSC with an OBS and seawater sampling with a bucket changes according to measuring site and sea state (Fig. 5).

Considering this inevitable limitation of the OBS due to its gain characteristic, the SSC monitoring with an OBS must be associated with reliable calibration. Downing and Beach (1988) and KORDI (1999) constructed apparatuses for the laboratory calibration of the OBS with bottom sediments. In a macrotidal regime with sand/mud mixtures, however, the OBS calibration with bottom sediments is not appropriate because the sand fraction in the suspension can largely vary with tidal phase. Sternberg *et al.* (1986) and Black and Rosenberg (1994) used pumping units for the *in-situ* calibration of the OBS. However, they cautioned to give special consideration to variations in mixture facies during an experiment based on the fact that the accuracy of SSC by pumping depends on the effect of grain inertia on the pump trapping efficiency.

Field test of the AUTTLE for an OBS calibration

To test the performance of the AUTTLE for the *in-situ* calibration of an OBS, a field experiment was carried out in Youngkwang area (Fig. 6) that belongs to low-macrotidal regime according to the classification of Hayes (1979). The mean spring and mean neap tidal ranges are about 5.4 m and 2.2 m, respec-

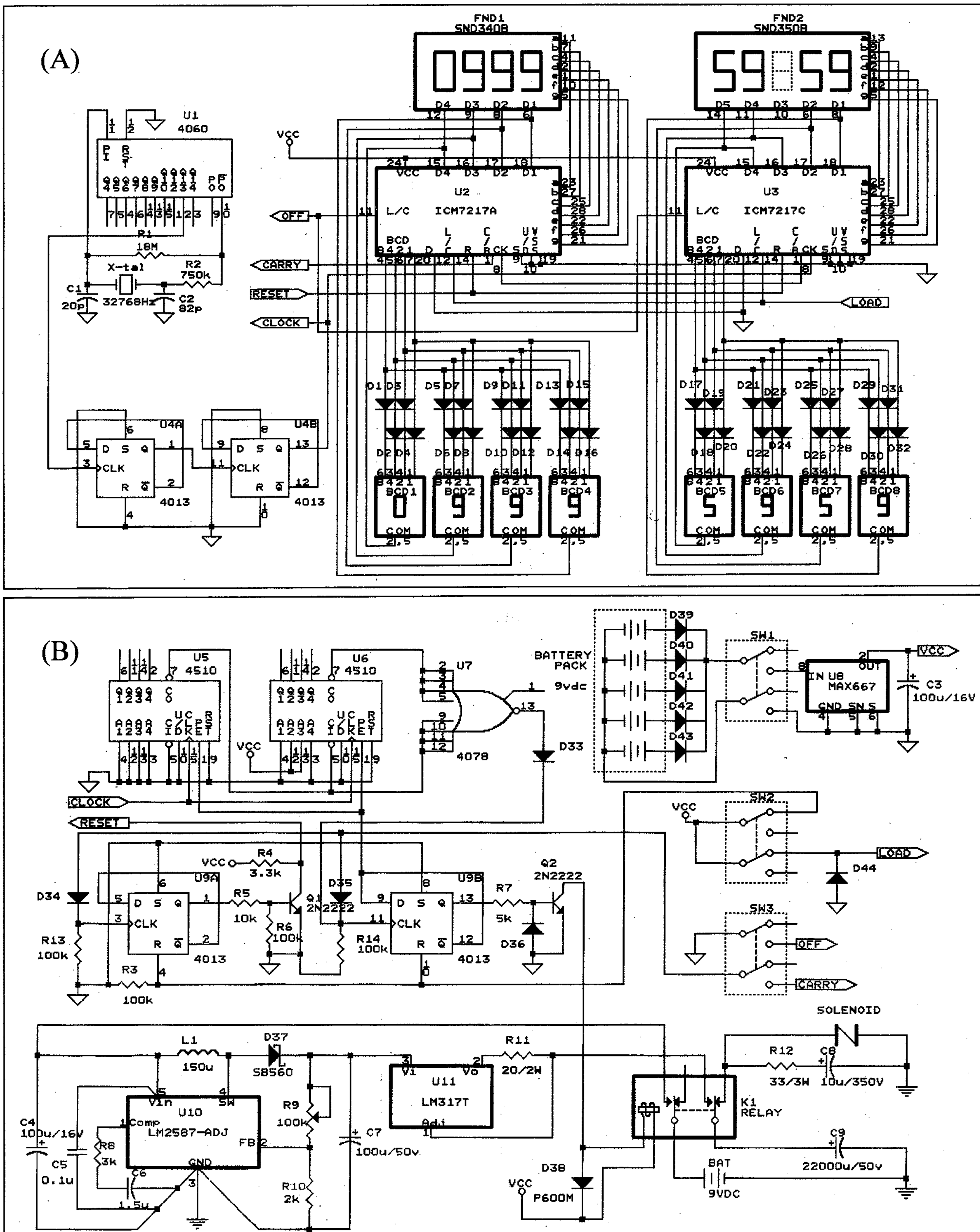

Fig. 1. The electric circuits of the AUTTLE for **(A)** its time control and **(B)** high power generation.

tively. The mode directions of incoming waves in summer and winter seasons are W (18%) and WNW (61%), respectively. The occurrence frequency of the significant wave heights beyond 0.8 m is only 2%

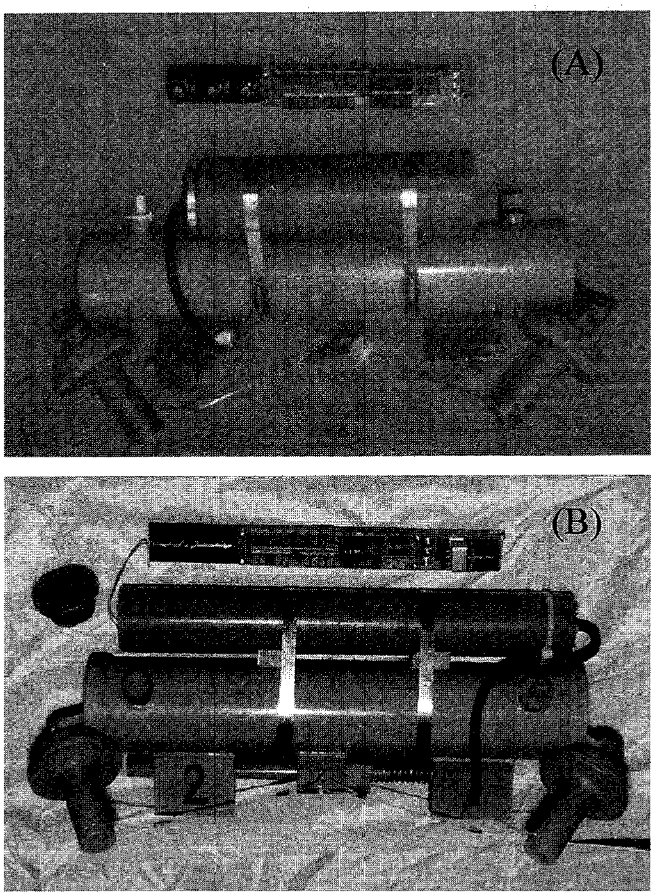

Fig. 2. **(A)** Prototype and **(B)** revised individual AUTTLE.

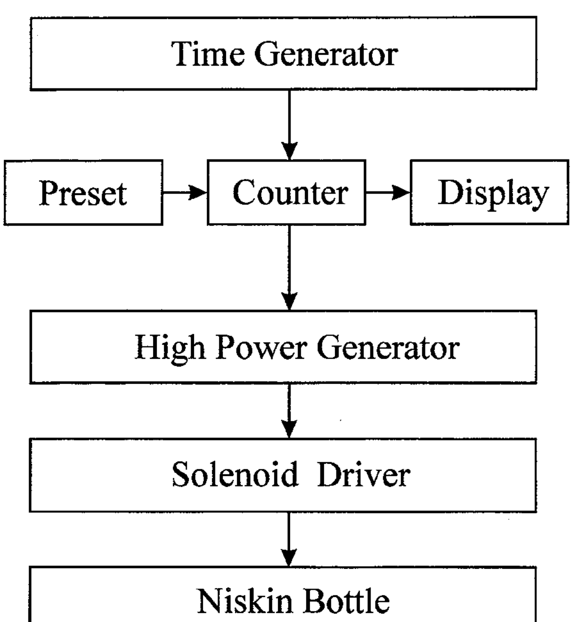

Fig. 3. Block diagram the operational procedure of the AUTTLE.

in summer, while 31.3% in winter due to strong winter monsoon (KEPCO, 1994).

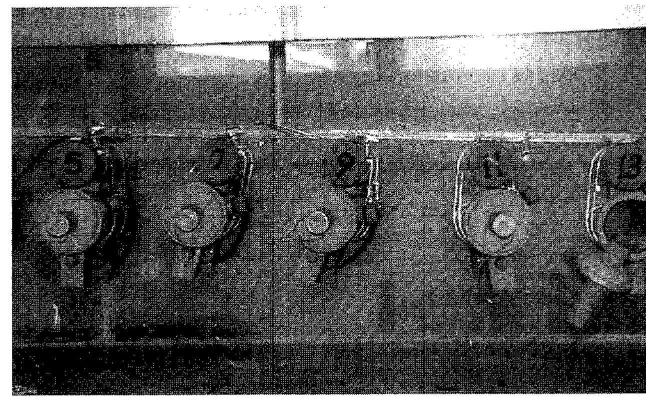

Fig. 4. Flume test of the AUTTLEs.

A total of 14 AUTTLEs were horizontally moored with a multi-parameter water quality monitor, 6000UPG of YSI Inc. of USA of which the OBS output is NTU (Fig. 7). The OBS sensor of the 6000UPG at 1 m above the AUTTLEs has a self-cleaning wiper to prevent biofouling. Its measuring interval was 5 minutes. To cover one tidal cycle, the suspension was sampled at one-hour interval from 16:05 December 12, 1998. Just beside the mooring site, additionally, a wave and tide gauge, Aanderaa WTR9, was deployed with 30-minute measuring interval. The designed mooring height of the AUTTLEs above the bed was 1 m, however, it was found by a diver's checking that the height reduced to about 0.6 m due to the sinking of the weight into the soft bed. Actually, another multi-parameter monitor, Aanderaa RCM9, was also moored. However, it failed to obtain proper data because its OBS breakdown during the mooring caused the problems in the electronic circuit. Furthermore, the second and the last AUTTLEs were not triggered due to setting mistake.

As shown in Table 1 and Fig. 8, the overall temporal variation of the OBS turbidity seems to agree with the real SSC from the AUTTLEs. However, the real SSC increased at 20:05 December 12 and 0:05 December 13, while the OBS turbidity did not increased at these times. This discrepancy seems to be due to the difference in the mooring height above the bed. That is, it may be interpreted as that the resuspended bottom sediments by strong flood and ebb currents were sampled by the AUTTLEs at 0.6 m above the bed, while could not reach to the OBS at 1.6 m above the bed.

It is worthy of notice that the sand content in the sampled suspension varies with the maximum factor of 800, although it was neap period and wave effect was negligible. This variation indicates that the OBS

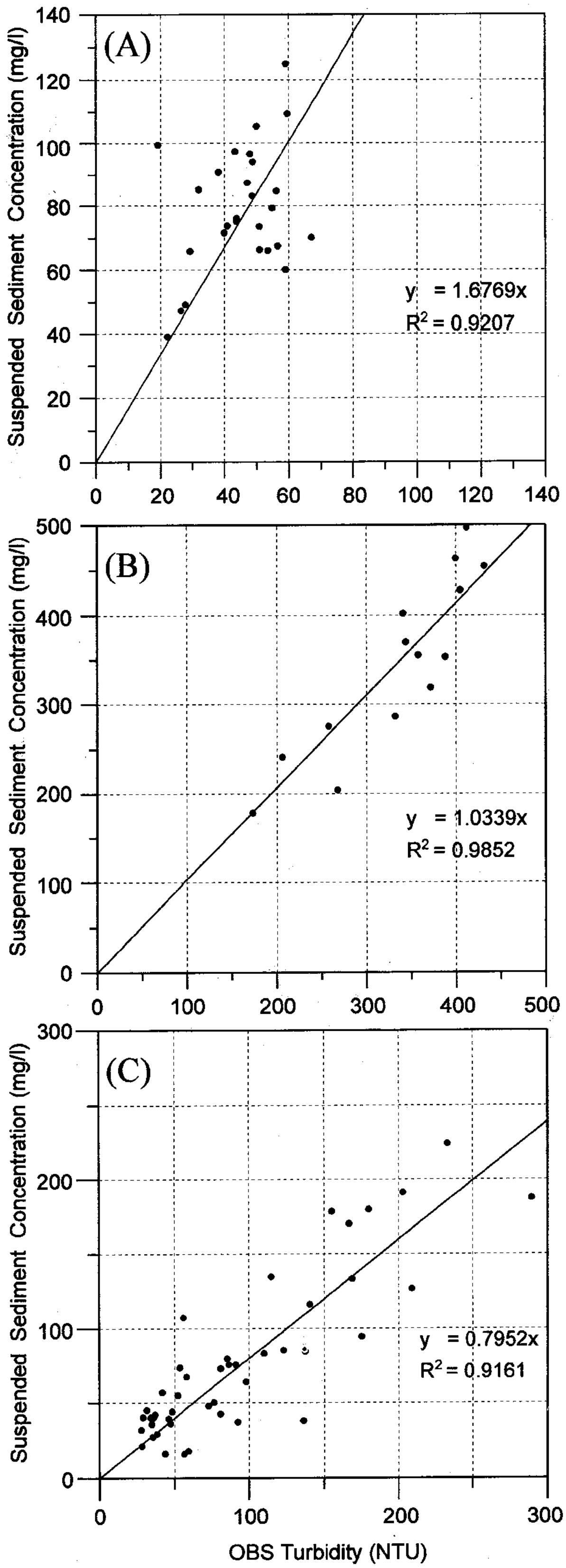

Fig. 5. Change in the slope of the regression line according to sites and sea condition: (**A**) Inchon area in mild spring tide, (**B**) Youngkwang area in relatively rough spring tide, (**C**) Youngkwang area for mild two weeks.

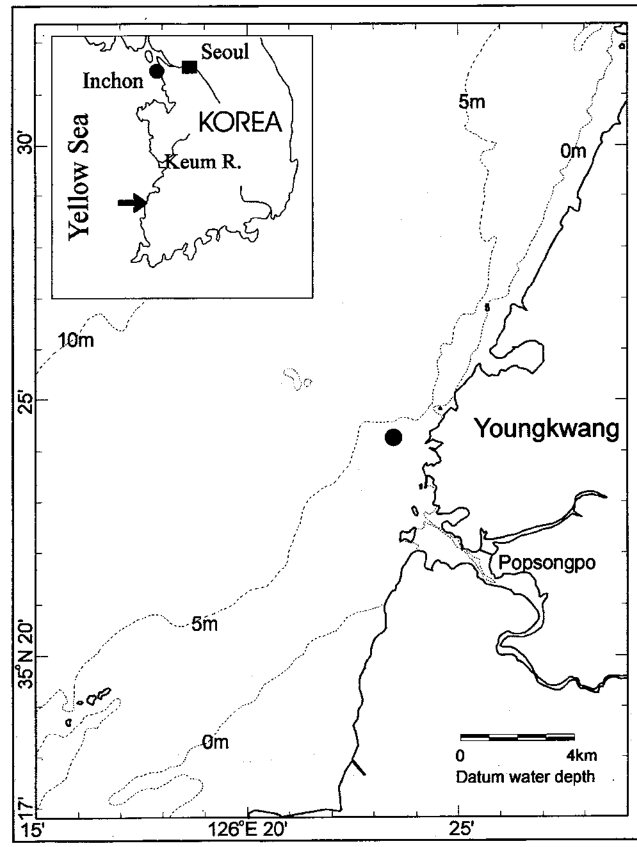

Fig. 6. Location map of the field experiment.

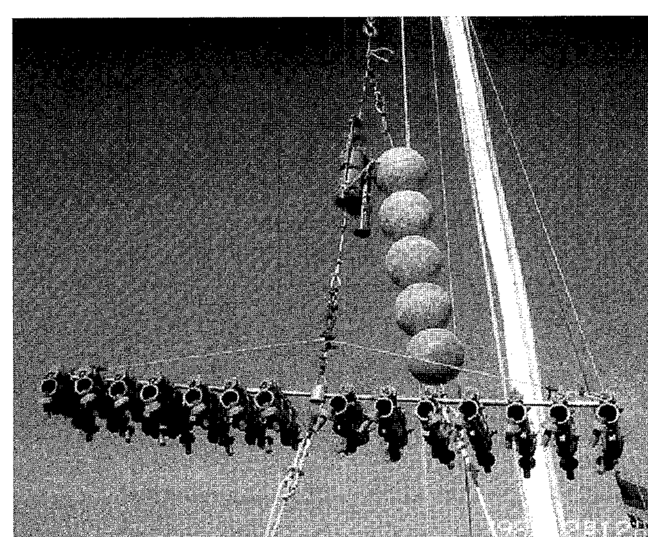

Fig. 7. Mooring configuration of 14 AUTTLEs, RCM9 and 6000UPG.

calibration with bottom sediments is not appropriate in this area.

The regression line between the real SSC by filtering the seawater sampled with the AUTTLEs and the OBS turbidity in NTU from the 6000UPG is shown in Fig. 9. Because of the difference in the

Table 1. Results of field experiment.

No.	Date & Time	SSC from AUTTLE (mg/l)			OBS (NTU)
		Sand	Mud	Total	
1	12/12/98 16:05	7.83	296.51	304.34	196.60
2	17:05				
3	18:05	3.52	164.89	168.41	77.20
4	19:05	4.24	144.49	148.73	55.10
5	20:05	0.63	196.72	197.35	45.20
6	21:05	3.22	129.43	132.65	49.80
7	22:05	2.61	149.61	152.21	58.10
8	23:05	0.93	140.67	141.59	60.40
9	12/13/98 0:05	2.75	188.63	191.38	39.40
10	1:05	0.71	105.13	105.84	35.40
11	2:05	0.40	132.92	133.32	92.60
12	3:05	0.01	144.30	144.31	93.00
13	4:05	0.16	141.60	141.76	106.30
14	5:05				

mooring height of the AUTTLE and the OBS, the determination coefficient is relatively lower than those in Fig. 5.

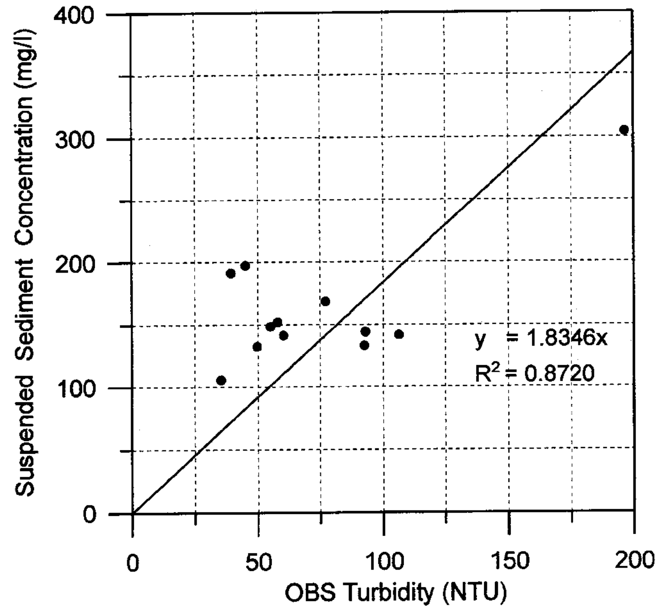

Fig. 9. Correlation between the real SSC from the AUTTLEs and OBS turbidity.

DISCUSSION

In various fields of oceanography, the automatic seawater sampler of mooring type can serve as a valuable instrument. Its advantage will be highlighted in studying the parameters of which the values in storm period are very important. Synchronized seawater sampling at several sites by mooring these samplers must cost-effectively improve the data quality in various fields, especially in the calibration of satellite data.

By simple combining two electric circuits to a Niskin bottle, a new self-triggering bottle, the AUTTLE, was developed and its performance was confirmed through flume and field tests. The AUTTLE can also be actuated manually as existing instantaneous water samplers.

In the study of sedimentary processes, it is the primary task to measure the SSC in storm period that is much higher than that in mild period. For the prediction of the change in sedimentary facies due to the various types of coastal development, the vari-

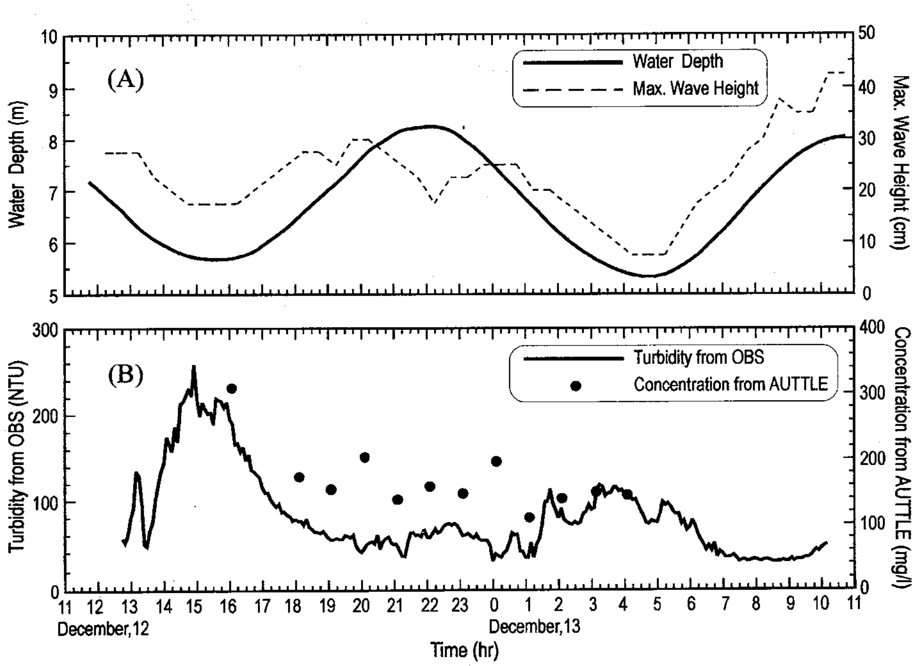

Fig. 8. Temporal variations of **(A)** water level and maximum wave height, and **(B)** the OBS turbidity and the real SSC from the AUTTLEs at the test site.

ation of the grain composition in suspension should be quantitatively understood. The results of a field experiment with the AUTTLEs for an OBS calibration showed that the AUTTLE could be largely helpful in studying dynamic sedimentology.

However, the AUTTLE still has some problems under being improved. The LED panel for the display of time counting will be changed with LCD for reducing power consumption. And the electronic circuit is being simplified in order that only one circuit board is enough for its function.

ACKNOWLEDGEMENTS

This study was partially supported by the Korea Ocean Research and Development Institute under Grant No. PE-98707-2.The authors are grateful to Y. K. Kim, W. D. Baek, H. J. Song and Y. C. Kim for their help in constructing, and laboratory/field testing the AUTTLE.

REFERENCES

Black, K.P. and M.A. Rosenberg, 1994. Suspended sand measurements in a turbulent environment: field comparison of optical and pump sampling techniques. *Coast. Eng.*, **24:** 137 – 150.

D&A Instrument Company, 1991. Instruction manual of OBS-1 & 3, 41 pp.

Downing, J.P. and R.A. Beach, 1988. Laboratory apparatus for calibrating optical suspended solid sensors. *Mar. Geol.*, **86:** 243 – 249.

Downing, J.P., R.W. Sternberg and C.R.B. Lister, 1981. New instrumentation for the investigation of sediment suspension process in the shallow marine environment. *Mar. Geol.*, **42:** 19 – 34.

Hay, A.E. and J. Sheng, 1992. Vertical profiles of suspended sand concentration and size from multifrequency acoustic backscatter. *J. Geophys. Res.*, **97:** 15661 – 15678.

Hayes, M.O., 1979. Barrier island morphology as a function of tidal and wave regime. In: Barrier Island, edited by Leatherman, S.P., Academic Press, New York, pp. 1 – 27.

Jin, J.-Y., D.-Y. Lee, J.S. Park, K.S. Park and K.D. Yum, 1999. Monitoring of suspended sediment concentration using vessels and remote sensing. In: Coastal and Estuarine Fine Sediment Transport: Processes and Applications, edited by Mehta, A.J., Elsevier Science Ltd., in printing.

Kineke, G.C. and R.W. Sternberg, 1992. Measurements of high concentration suspended sediments using the optical backscatterance sensor. *Mar. Geol.*, **108:** 253 – 258.

Korea Electric Power Company, 1994. A study on the reduction of thermal discharge effects around neclear power plants-1st interim report (Youngkwang). Rep. No. 92 – 802, 336 pp (in Korean with English Summary).

Korea Ocean Research and Development Institute, 1999. Sediment dynamics within bottom boundary layer: Observation and prediction technology. The Ministry of Environment, Korea, 308 pp (in Korean with English Summary).

Maa, J.P.-Y., J. Xu and M. Victor, 1992. Notes on the performance of an optical backscatter sensor for cohesive sediments. *Mar. Geol.*, **104:** 215 – 218.

Rosa, F., J. Bloesch and D.E. Rathke, 1994. Sampling the settling and suspended particulate matter. In: Handbook of techniques for aquatic sediments sampling, Chapter 5, edited by Mudroch, A. and S.D. MacKnight, Lewis Publisher, Boca Raton, 236 pp.

Sternberg, R.W., R.V. Johnson, II, D.A. Cacchione and D.E. Drake, 1986. An instrument system for monitoring suspended sediment in the benthic boundary layer. *Mar. Geol.*, **71:** 187 – 199.

Manuscript received January 13, 1999
Revision accepted September 20, 1999