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DEVELOPMENT, FABRICATION AND TESTING OF AN ADVANCED AUTOMATED TIDE GAUGE

FINAL REPORT

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Prepared for

Central Weather Bureau
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ABSTRACT

Majority of tide stations are in remote locations with severe environmental conditions. The coastal waters around Taiwan are subject to typhoon invasions and hence storm surges. The tide gauges of bubbler type are uniquely suitable for installation in such harsh oceanic and atmospheric environments. Earlier, we have performed in-depth theoretical and experimental studies on the bubbler gauge. Now, through advanced technologies we are bringing out the full capability of such gauges. Most of the original objectives of this project have essentially been achieved. It was to (a) incorporate our earlier in-depth study into the design and fabrication of a highly accurate, reliable, automated tide gauge suitable for use in the coastal waters of Taiwan, (b) develop a joint cooperative effort so that this new technology can be transferred for future use in Taiwan, (c) meet the needs of Central Weather Bureau for accurate water level measurements of storm surges during typhoon invasions, (d) thoroughly test and calibrate the gauge in the laboratory before field installation, and (e) provide technical and training services to insure proper installation and optimum operation of the new tide gauge.

1. INTRODUCTION

The pneumatic bubbler gauges are widely used in the U.S.A. for water level measurements by the National Oceanic and Atmospheric Administration (MOA) in the coastal waters and by U.S. Geological Survey (USCG) in the inland waters and estuaries. Basically, it consists of a long tube, a gas (typically nitrogen) supply, and an analog or a digital pressure recorder. While in operation, a small amount of gas is fed into the tube to keep it dry at all time. Excess gas is bubbled away very slowly at the submerged end of the tube. The pressure in the tube then represents the hydrostatic pressure of the water level, which can be detected at a remote location on land, safe from adverse sea or river environment. Since all the electronic components are located on shore, there are minimal environmental and fouling problems. The bubbler tide gauge is suitable for water level measurement along open coast, in remote locations, and in harsh environments where other instruments cannot be easily deployed. However, existing bubbler gauge suffers from several operational problems such as (a) clogging of dampening valve, (b) gas leakage, (c) gas line flooding, (d) errors due to improper orifice design, (e) recorder's chart speed variation and (f) inaccuracy arising from severe noise due to background wind-waves and ocean swells (see FIG(a)). Furthermore, the analog output is not compatible with present and future data processing requirements. Recently, in-depth theoretical and experimental analyses of the bubbler gage were performed by Lin and Pao[Ref #1]. Further improvement and upgrading of the tide gauge were carried out in the past several years. It should be noted that the upgrade of the tide gauges was carried out in three phases: (1) study of the fundamental mechanics, (2) improvement of existing hardware, and (3) capability enhancement. Each improvement and enhancement were designed in modular form such that it could provide maximum flexibility in implementation and adequate opportunity for system debugging. Now, through advanced technologies we are bringing out the full capability of the gauge.

The key innovation is the development of an effective low-pass traveling-wave filter for the pressure waves in the tube. With proper design, the filter dampens out the noises above a selected cut-off frequency. The remarkable improvement is shown in Fig. 1(b) where the background noise of wind-waves has been effectively filtered out. Other deficiencies of the existing bubbler gauge were also corrected through proper design, improved fittings and proper fabrication procedures.

The upgraded bubbler gauge has been further improved very recently by interfacing with a small digital data acquisition device so that the unit can read and store the data digitally every four minutes (or any specified interval). It is portable and convenient to transport for field use. The digital data acquisition unit can easily be transferred to any PC computer for further processing and analysis. The data can also be transmitted by a near real-time telemetry technique.

The objectives of this development project are to: (a) incorporate our earlier in-depth theoretical and experimental analyses into the design and fabrication of a highly accurate, reliable, automated tide gauge for use in the coastal waters of Taiwan island, (b) develop a joint cooperative effort só that this new technology can be transferred for use in Taiwan, (c) meet the needs of Central Weather Bureau for accurate water level measurements of storm surges during typhoon invasions, and (d) provide technical and training services to insure proper and optimum use of the new tide gage.

2. NOISE ATTENUATION

2.1 Concerns

High frequency noises, mostly due to wind waves and disturbances such as ship traffics, often degrade the data quality and render the data processing task rather difficult.

Existing bubbler gauges use a needle valve as noise dampening device. However, in order to be effective, the valve has to be adjusted to a very fine closure. This often causes valve clogging and subsequently requires maintenance operations.

2.2 The Principle of Low-Pass Filter - Theoretical Background

The principle of the low-pass filter was based on the theoretical and experimental study by Ling and Pao [Ref #1] of a long pneumatic pipe line. The present problem involves the propagation of very low frequency pressure waves in a long tube with small bore. Pressure fluctuation due to waves, swells, surges, and tides covers a range of wave periods T from 2s to 45,000s. The resultant oscillatory breathing flow developed in the tube is generally within the laminar flow range, hence the oscillatory flow profile in the tube is governed by the α parameter

$$\alpha = D/2(\nu T/2\pi)^{1/2} \qquad (1)$$

where D is the diameter of the tube, and ν the kinematic viscosity of gas. For the present problem, it can be shown that α is smaller than 1. Hence, the flow profiles are always fully developed and parabolic in form. Consequently, the frictional stress in the tube is essentially in phase with the flow [Ref #2]. Due to the relatively large amplitudes of waves under high sea-states, the kinematic viscosity of gas in the tube can no longer be considered as constant. It should vary with the mass density of gas ρ, and thus also with the pressure P. Since the flow resistance in the tube is an odd function of P, any oscillatory pressures in the tube can contribute to a mass positive pressure error. The conservation of momentum within a Δx element of the tube with uniform cross-sectional area A can be expressed as

$$\frac{\Delta x}{\Delta t}[q_x(t)-q_x(t-\Delta t)]+\frac{q(t)}{2}[U(t)_{x+\Delta x}-U(t)_{x-\Delta x}]+\frac{32\mu\Delta x}{D^2\rho(P_x)}q_x(t)=-\frac{A}{2}[P(t)_{x+\Delta x}-P(t)_{x-\Delta x}], \quad (2)$$

where t is the time, $q=A\rho U$ the mass flow rate, U the mean sectional velocity of gas flow, and μ the viscosity of the gas. The first term of Eq. 2 is the local rate of change of momentum in the Δx element. The second term is the convected momentum into the element. Due to uniform tube diameter and very long pressure waves, this term is very small with respect to the other terms. Hence, for this problem it may be deleted from the equation. The third term is the frictional force on the element due to laminar flow, and the last term represents the external pressure forces. The conservation of mass in the tube element can be expressed as

$$2A\Delta x\frac{\Delta\rho}{\Delta t}+[q(t)_{x+\Delta x}-q(t)_{x-\Delta x}]=0. \quad (3)$$

That is, the rate of change of the mass inside the tube element is equal to the net mass flow into the element. Due to both the long period of pressure wave and small tube size, the equation of state for the gas can be taken to be isothermal and expressed as

$$\Delta\rho/\Delta P=\rho_a/P_a\ , \quad (4)$$

where the subscript a represents the value at standard atmospheric conditions. Substituting $\Delta\rho$ of Eq.4 into Eq.3, we have

$$-\frac{P_a}{2\rho_a\Delta x A}[q(t)_{x+\Delta x}-q(t)_{x-\Delta x}]\Delta t=P_x(t)-P_x(t-\Delta t). \quad (5)$$

We further define the following nondimensional variables and parameters as:
$n=x/\Delta x$, $N=\ell/\Delta x$, $\Delta\tau=\Delta t/T$, $\bar{P}=P/|P_w|$,

$$\frac{\rho(P_x)}{\rho_a}=\frac{(P_a+P_s)}{P_a}\left[1+\frac{P_x(t)}{P_a+P_s}\right], \qquad Q=\frac{128\mu\ell P_a}{\pi|P_w|D^4\rho_a(P_a+P_s)}q\ ,$$

$$S=T\frac{(P_a+P_s)D^2}{32\mu\ell^2}\ , \text{ and } \qquad E=\frac{\rho_a}{P_a}\left[\frac{(P_a+P_s)D^2}{32\mu\ell}\right]^2,$$

where P_s is the mean hydrostatic pressure of the gauge, $|P_w|$ is the modulus of the input wave pressure, and ℓ is the total length of the tube. Finally Eqs. 2 and 5 can be expressed in the normalized forms as

$$\frac{E}{NS\Delta\tau}[Q_n(\tau)-Q_n(\tau-\Delta\tau)]+\frac{Q_n(\tau)}{N\left[1+\frac{|P_w|\bar{P}_n(\tau)}{P_a+P_s}\right]}=-\frac{1}{2}\left[\bar{P}_{n+1}(\tau)-\bar{P}_{n-1}(\tau)\right], \quad (6)$$

and

$$-\frac{NS\Delta\tau}{2}[Q_{n+1}(\tau)-Q_{n-1}(\tau)]=\bar{P}_n(\tau)-\bar{P}_n(\tau-\Delta\tau)\ . \quad (7)$$

Boundary conditions for the problem are the input pressure $P_w\sin 2\pi\tau$ at the inlet and closed tube at the output end.

The numerical solutions for Eqs.6 and 7 are given in Figs. 2,3, and 4. In Fig.2 the normalized attenuation of the output pressure $\bar{P}_o = |P_o/P_w|$ is plotted as functions of the normalized wave period S and system characteristic parameter E. Note that for S>3, the signal attenuation is minimal, while signal cutoff is very sharp at S<0.1. The E parameter only affects small period waves. To obtain good high frequency cutoff characteristic, it is necessary to make E<0.002. The general wave and swell periods cover a period band of 2s to 15s. Hence, it is desirable to place the 5s period wave at S=0.05 in order to obtain a good signal attenuation for these waves. Since the tide has a mean period of 45,000s, the corresponding S value is 450. From Fig.2, one notes that there will be no attenuation for the tide signal, and the corresponding phase lag ø is only -0.4^o. Hence, the system will provide accurate tide data. Fig.3 gives the normalized breathing mass flux Q_i at the inlet and its phase angle θ with respect to the input pressure P_w. This information is needed for the design of a larger diameter breathing cylinder to be attached to the inlet end of the tube. Note that Q_i decreases as 1/S for S>3. Since the net breathing mass or volume per period is proportional to SQ_i, the breathing volume per period is a constant and maximum for S>3. Hence, to prevent flooding of the pneumatic tubing, the volume of the breathing cylinder should be made larger than the maximum breathing volume of the tube plus the breathing volume of the breathing cylinder itself. For S>3, the net breathing volume per period will decrease and vary as $S^{1/2}$. It can be shown that the breathing effect can contribute to a mean negative pressure error. Figure 4 shows the normalized mean pressure error $P_e/|P_w|$ due to tube friction. It is plotted as functions of S and E parameters. For S<1 the error is a maximum and essentially a constant. Since the tube breathing effect generally contributes to a negative mean pressure error, while frictional effect contributes to a mean positive error, these errors can be made to cancel each other with a proper diameter for the breathing cylinder. The above analytical results have been verified experimentally.

From the results presented in Figs. 2 to 4, it is seen that the complex operating characteristics of a pneumatic transmission line is fully parameterized. From the present data, one can readily obtain the optimum design for a specific tide gauge; and many undesirable manual adjustments and correction factors for the gauge are thus eliminated. This has, in fact, paved the way for the automation of the tide gauge in this project.

2.3 Hardware Implementation

The results of mathematical model simulation led to the development of an effective low-pass filter, which is analogous to the traveling wave filter in modern radio and television sets. With proper design, the filter will dampen out the noises above a selected cut-off frequency. In the gauge hardware this was implemented by a coil of micro-bore plastic tubing.

3. NEW TIDE GAUGE

Based on the results of theoretical and experimental investigations, a completely new bubbler tide gauge has been designed and fabricated in this project. The new gauge is equipped with a high-precision pressure transducer, a properly designed filter coil, a leakage-free tubing system, and an automated data acquisition and control unit. Thus, the gauge is completely automated and compatible with many standard digital data-acquisition systems.

The general layout of the new tide gauge is shown graphically in Appendix A - Drawing No. GT-001. A schematic diagram showing the detail of the layout of the tide gauge is also given in Fig.5. A picture of the front control panel of the tide gauge is shown in Fig.6. The operating procedures for the control knobs are given in Appendix B - I. Tide Gauge Operating Procedures. These procedures are also posted on the inside of the cabinet door. The pneumatic control system is shown in Drawing No. GT-002 of Appendix A.

The data recording system as shown in Fig.7 can read and store data digitally. It is portable and convenient to transport for field use. The technical details are shown in Drawing No. GT-003 in Appendix A. A picture of the prototype of the new automated tide gauge is shown in Fig.8 in both open and closed positions. It is seen that the size of the new tide gauge in closed position is about the size of an attache briefcase.

The digital data in SQLOG module can easily be transferred to any PC computer for further processing and analysis. The detailed procedures of data transfer are given in Appendix B - III. Data Transfer.

4. LABORATORY TESTING

Laboratory tests of the new prototype tide gauge were carried out during the period from May 17 to June 10, 1991, using our unique tide simulator. The simulator, as shown in Fig.9, can give a water level fluctuation with a period of 12 hours. The tide gauge has been checked with respect to accuracy, stability, and reliability. It has performed almost flawlessly during the period of testing. This new tide gauge has passed our rigorous laboratory test.

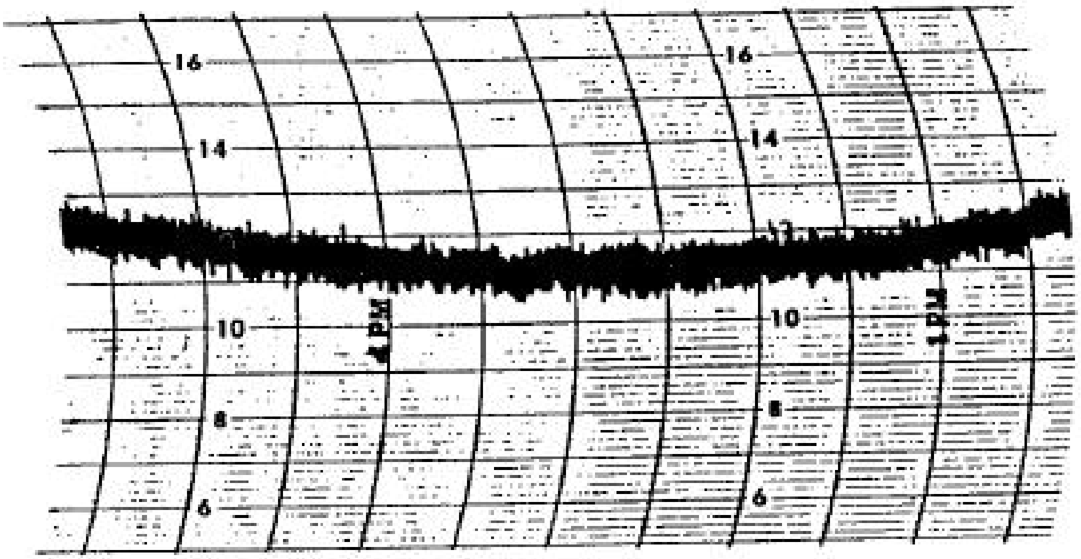
5. FIELD INSTALLATION OF GAS OUTLET ORIFICE

A copper cup which will be used as a gas outlet orifice has been designed and fabricated. It was so designed that the positive pressure error contributed by the frictional effect is essentially cancelled by the negative pressure error contributed by the tube breathing effect. A drawing showing the details of field installation for the gas outlet orifice is shown in Fig.10. The installation of the new tide gauge and training of local technical personnel is scheduled to take place in the last two weeks of June.

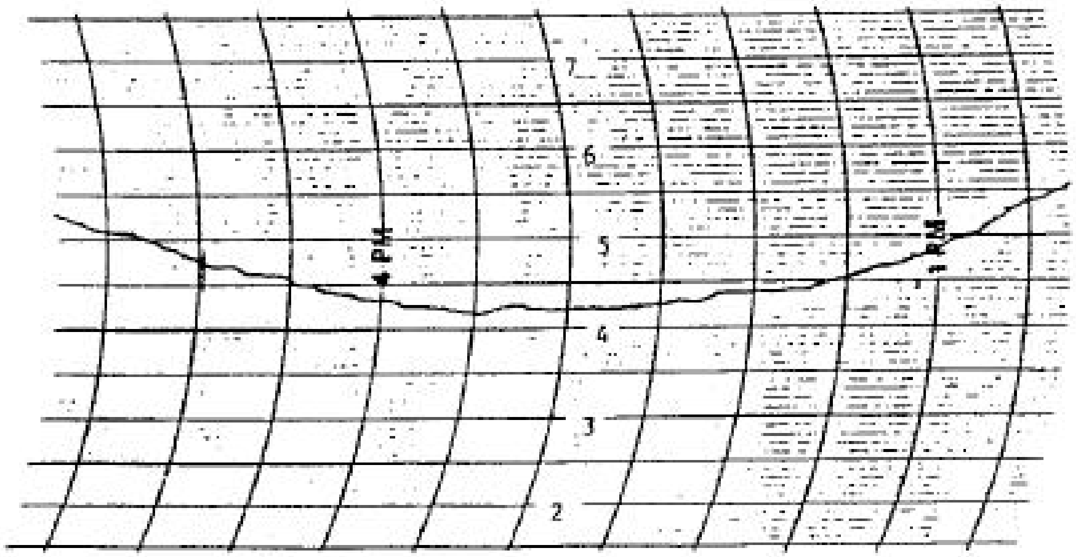
REFERENCES

1. Ling S. C. and Pao, H. P. (1984). "Mechanics of A Pneumatic Tide Gage," Proc. Fifth Engineering Mechanics Div. Specialty Conference, ASCE, A.P. Boresi and K.P. Chang (Ed.), pp 807-810.

2. Schlichting, H. (1968). Boundary Layer Theory, McGrow-Hill, N.Y., pp419-421.



(a) Output from existing gage



(b) Output from upgraded gage

Figure 1 . Comparison of analog outputs between existing and upgraded bubbler gage

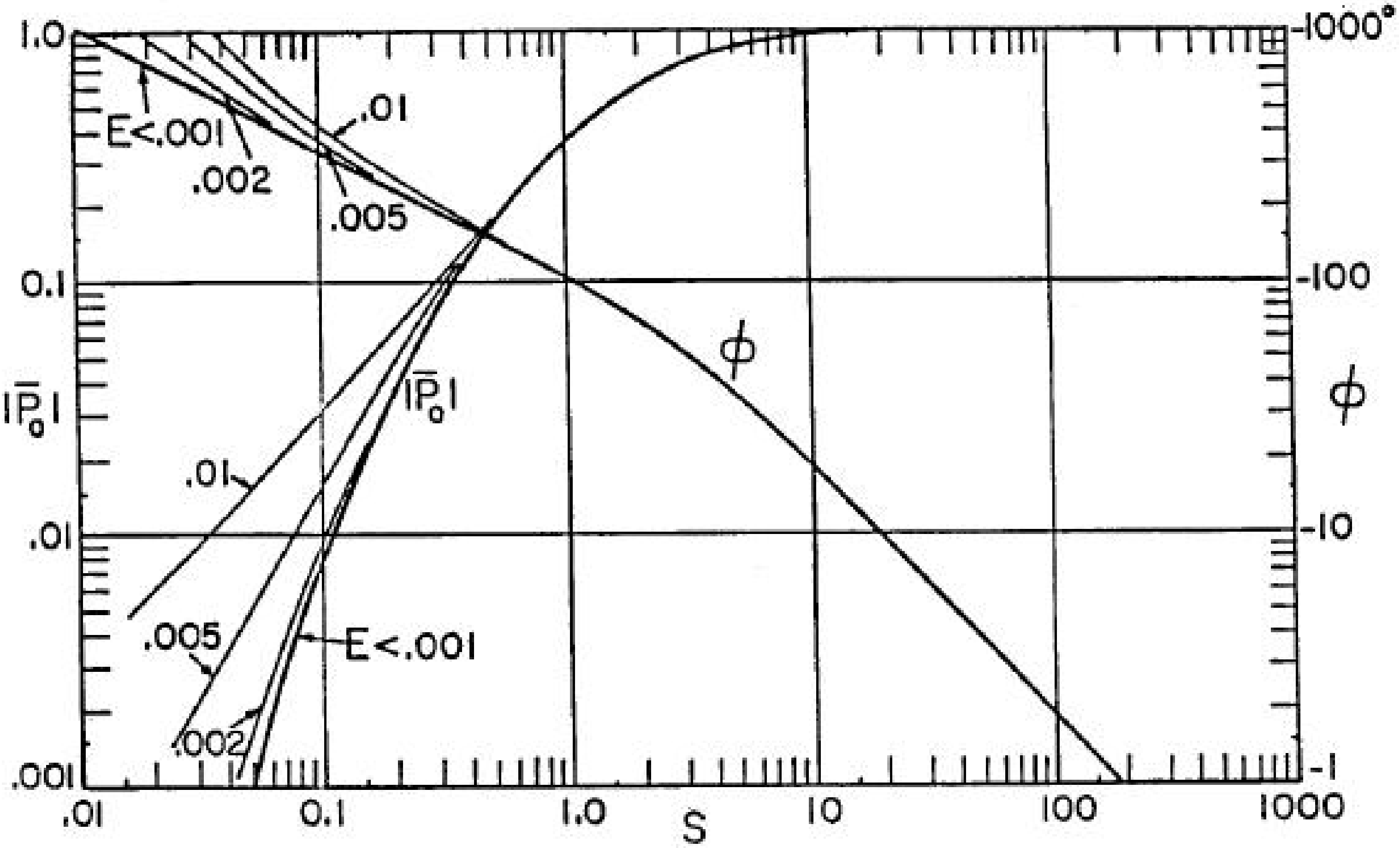


Figure 2. Normalized pressure response plot.

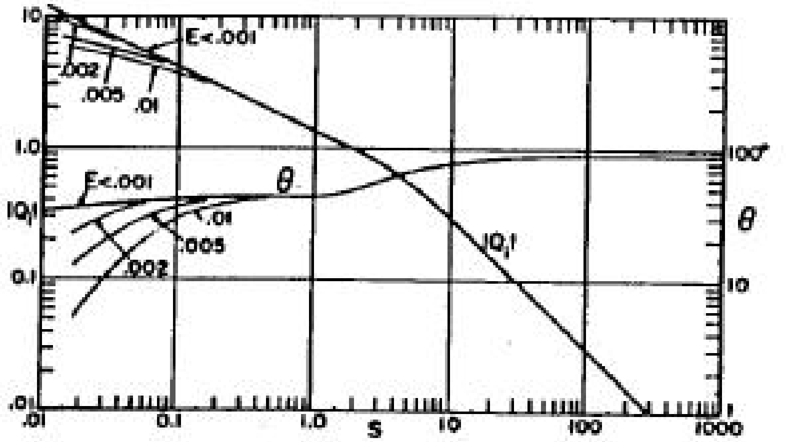


Fig. 3. Normalized breathing mass flow Q_i vs. S and E parameters.

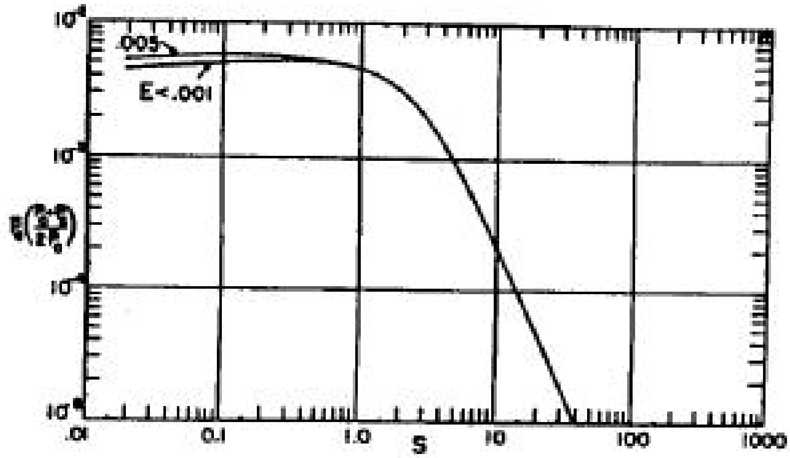


Fig. 4. Normalized mean pressure error due to pipe friction $\overline{P}_e$ vs. S and E parameters.

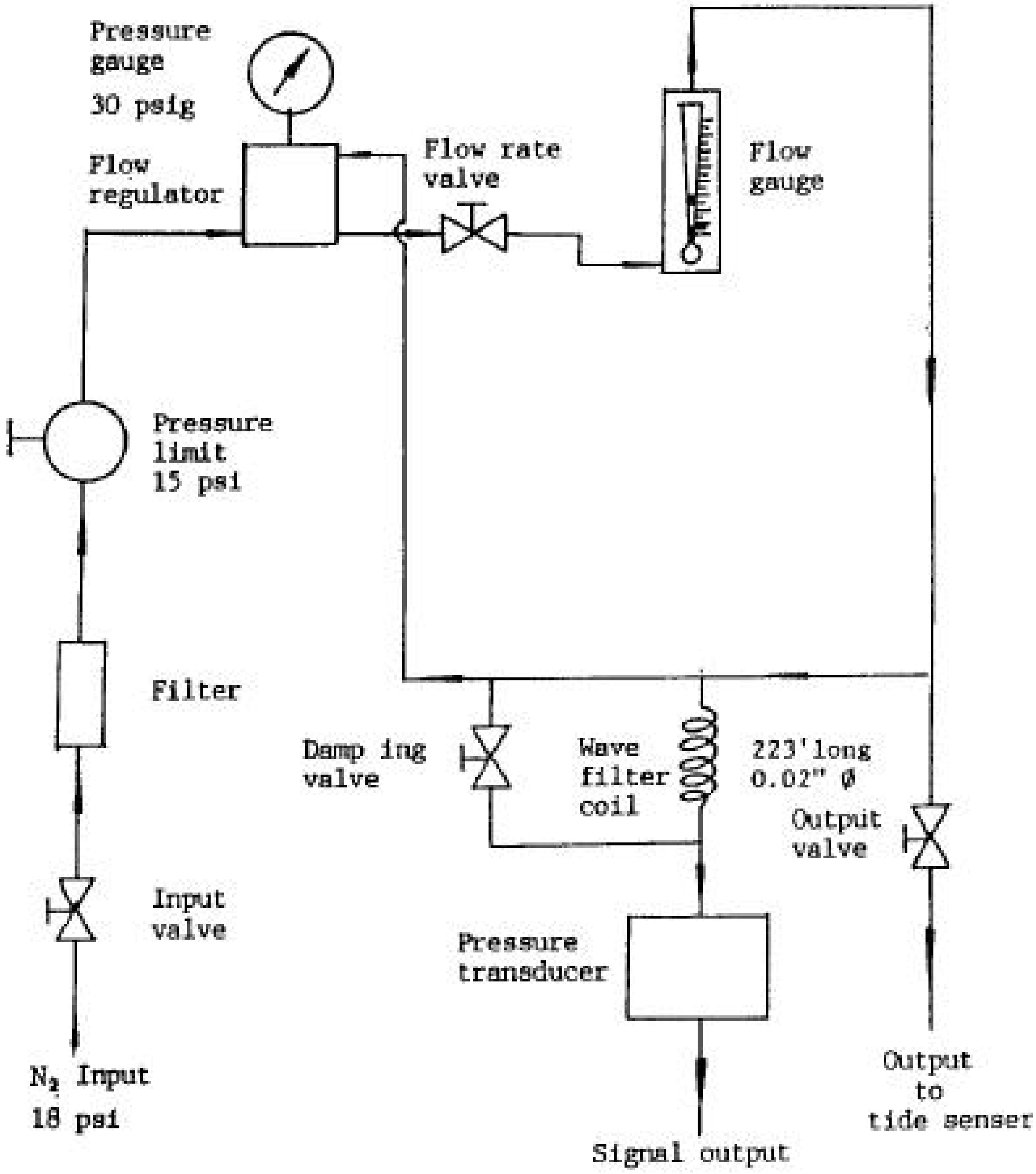


Figure 5. Schematic diagram showing detailed layout of the tide gauge.

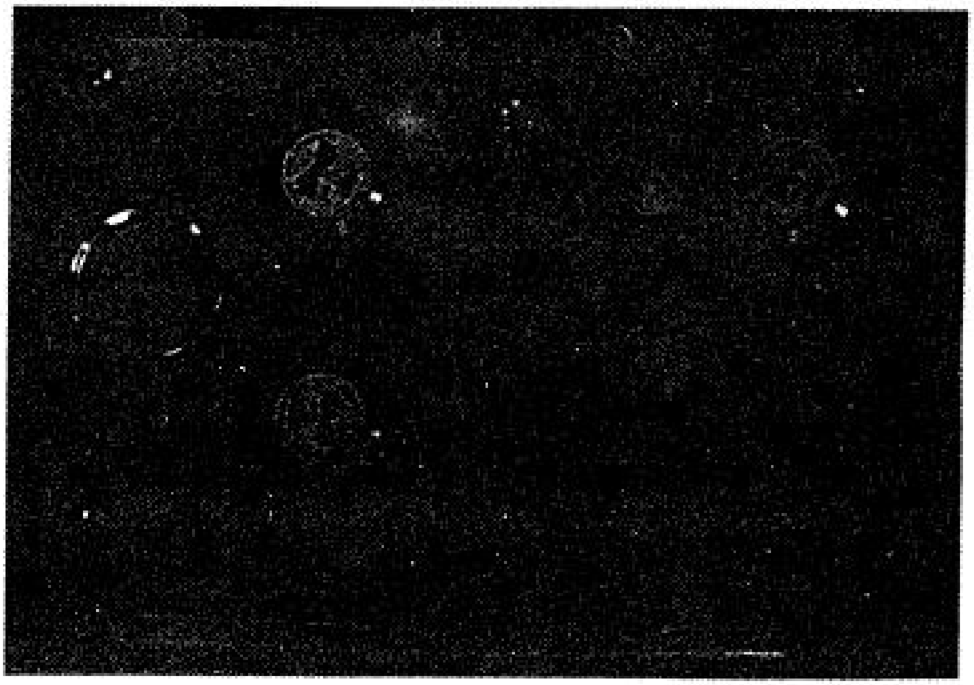


Figure 6. Front control panel of tide gauge.

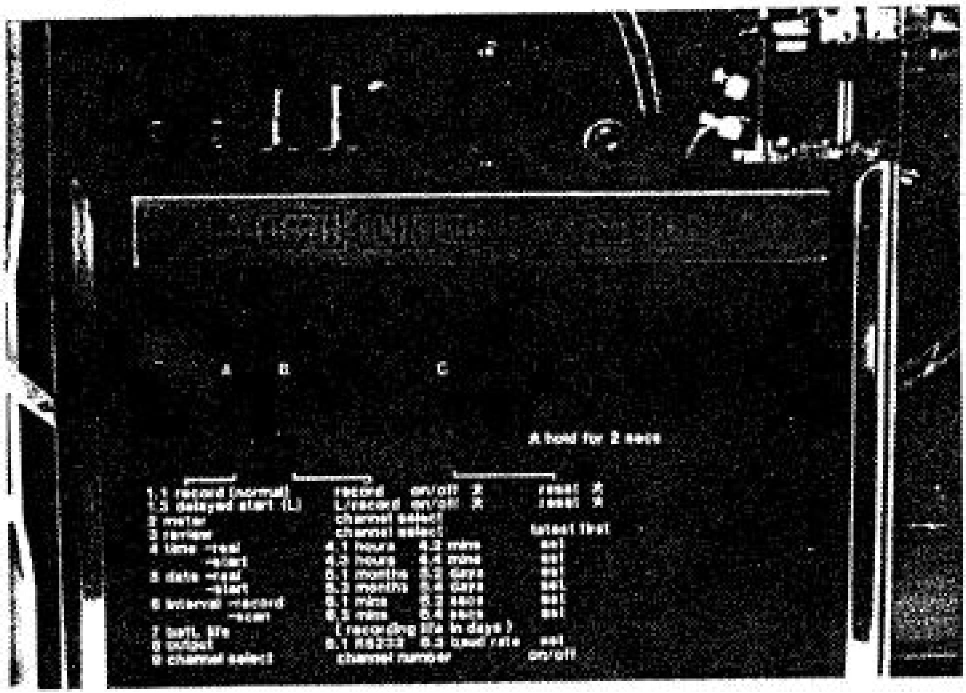
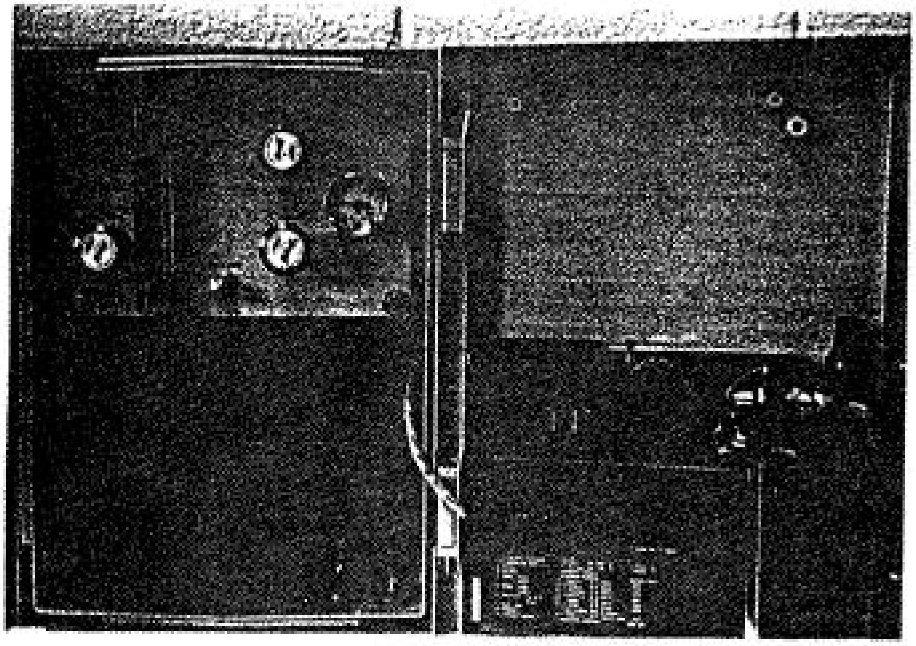


Figure 7. Data recording system.

(a)



(b)

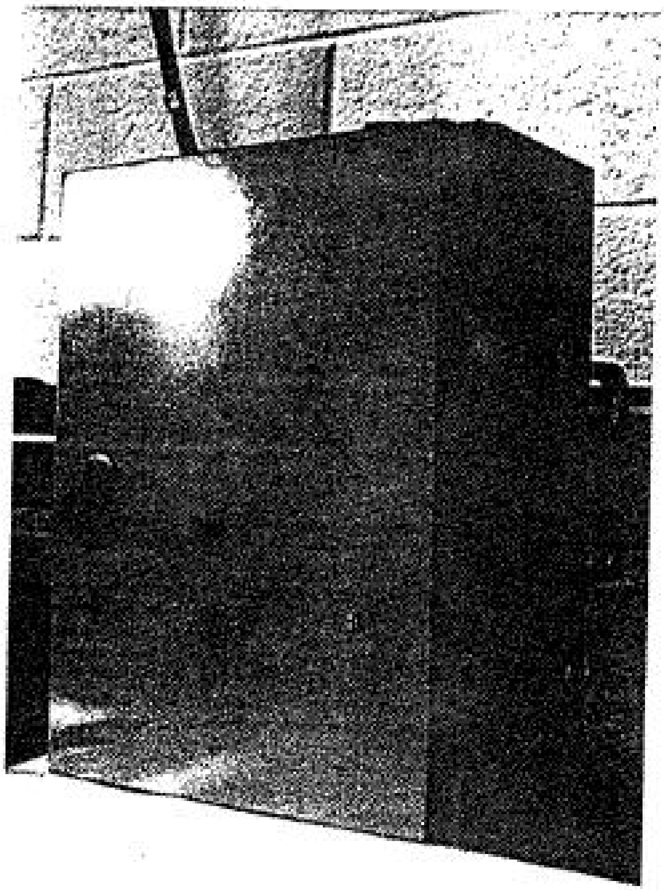
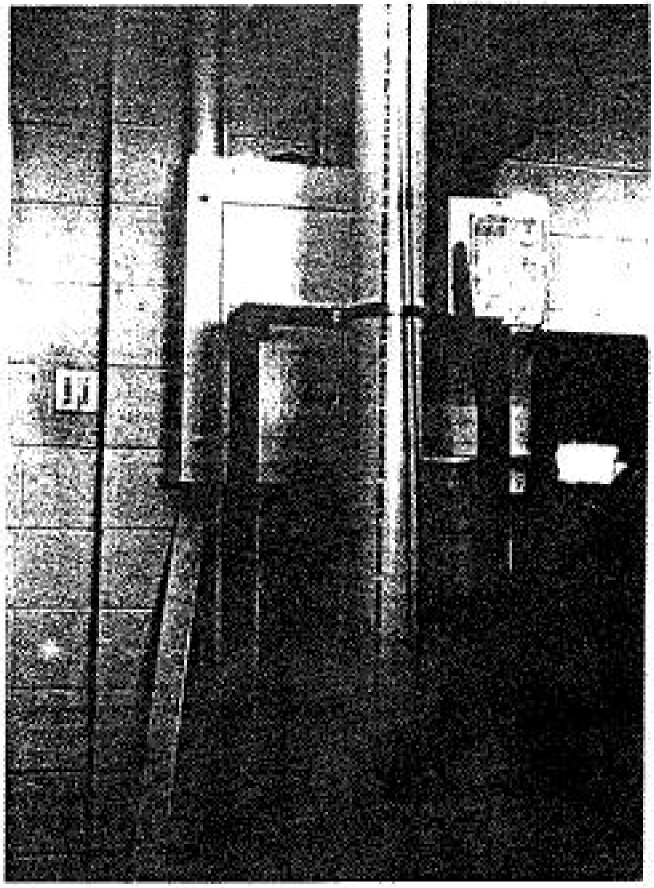


Figure 8. A picture of the prototype of the new automated tide gauge. (a) Open position; (b) Closed position.



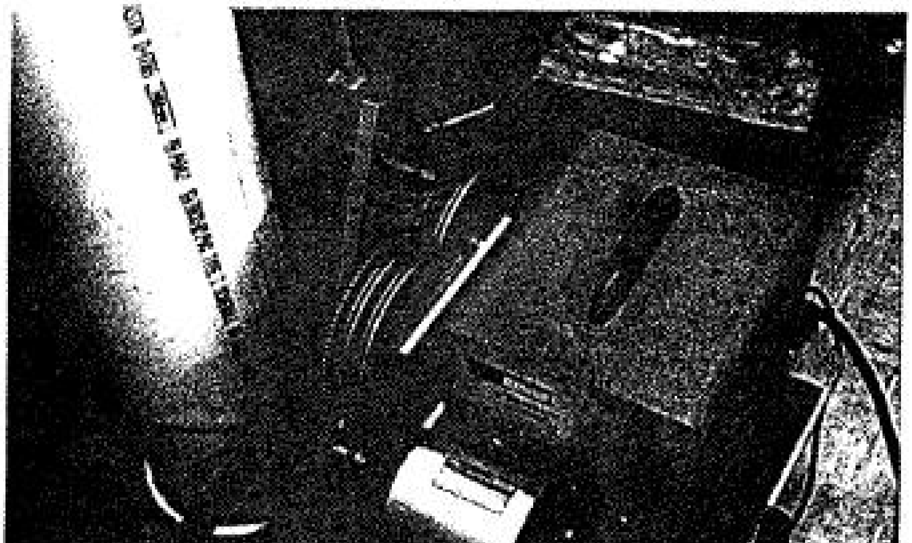


Figure 9. Laboratory tide simulator.

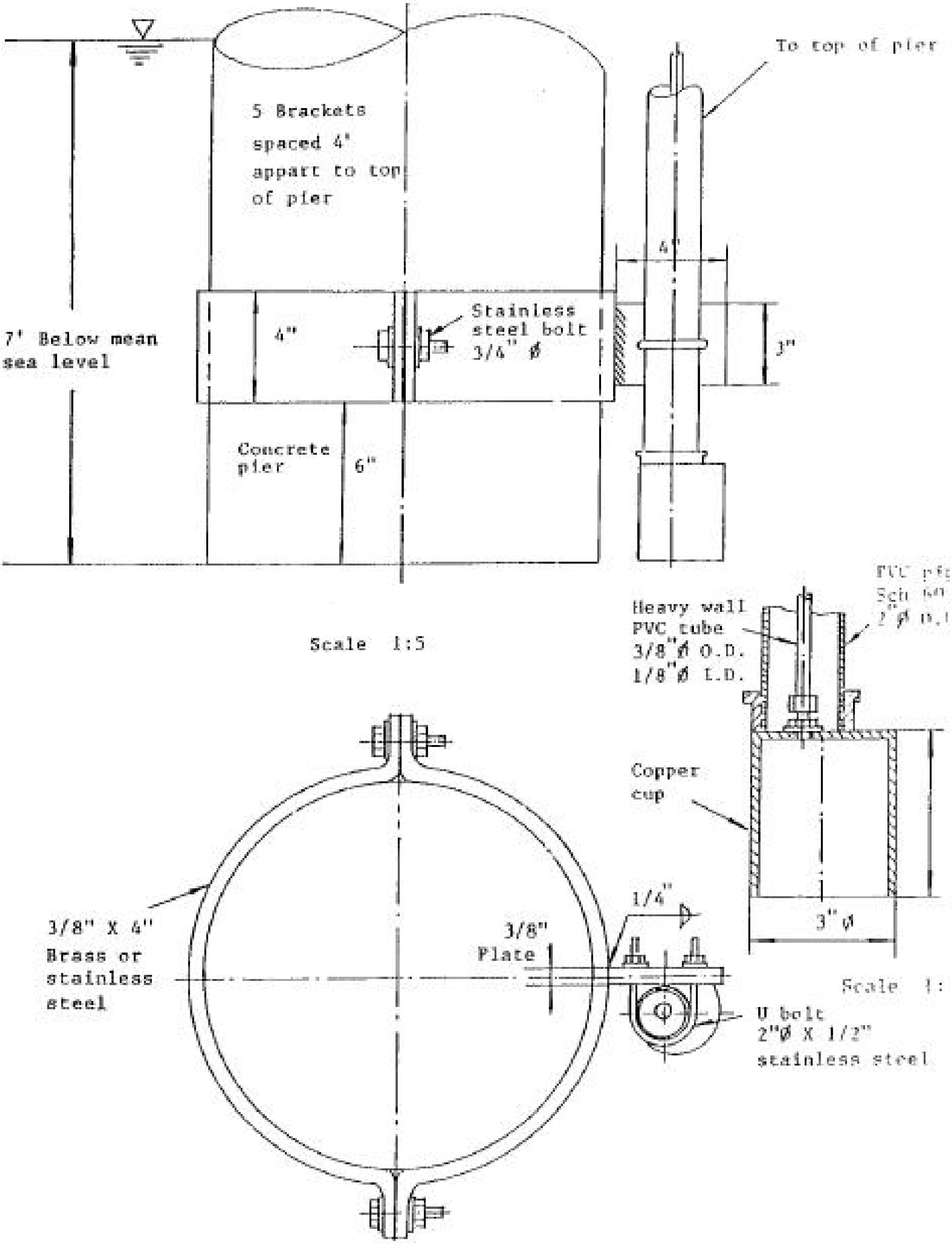
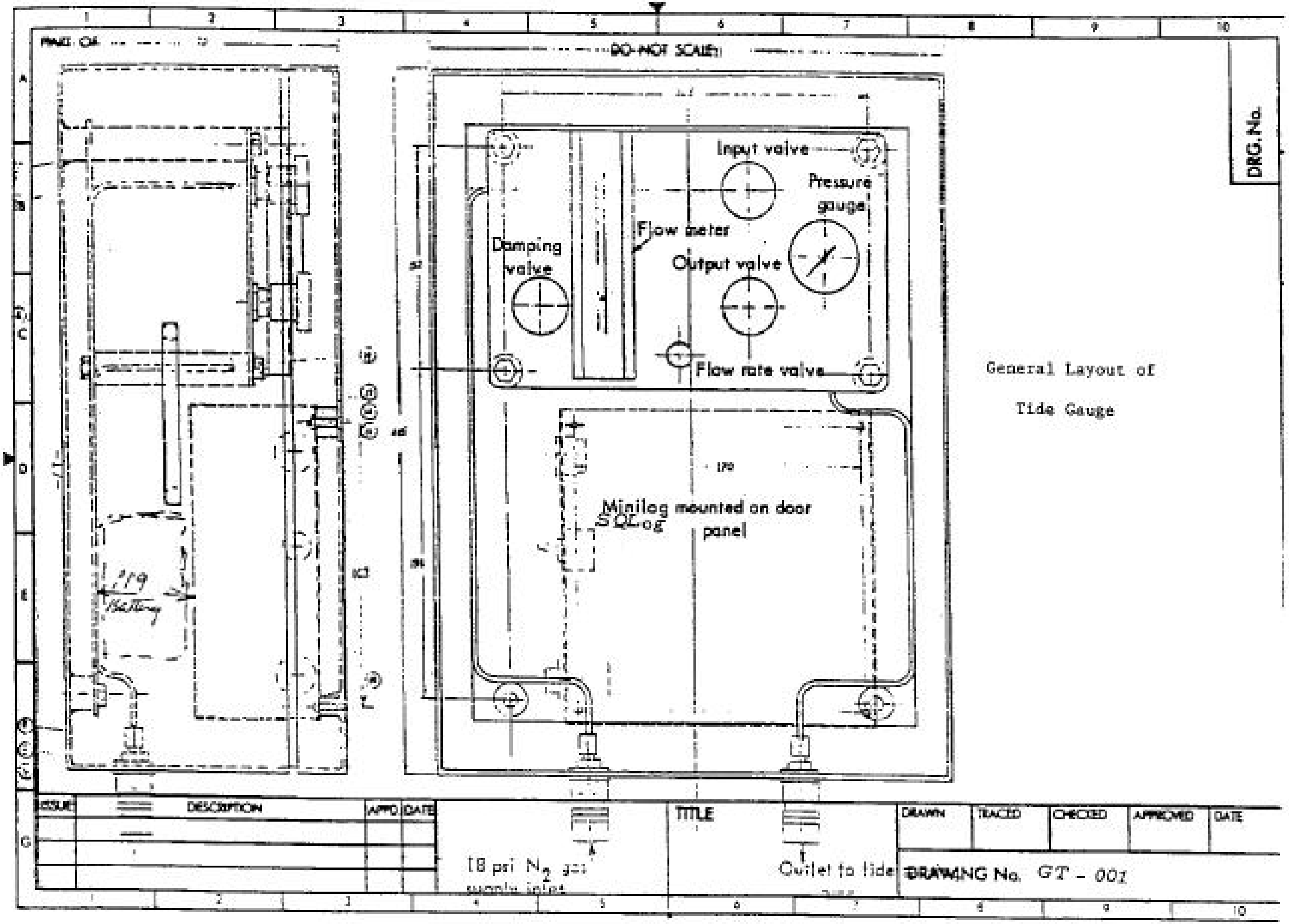
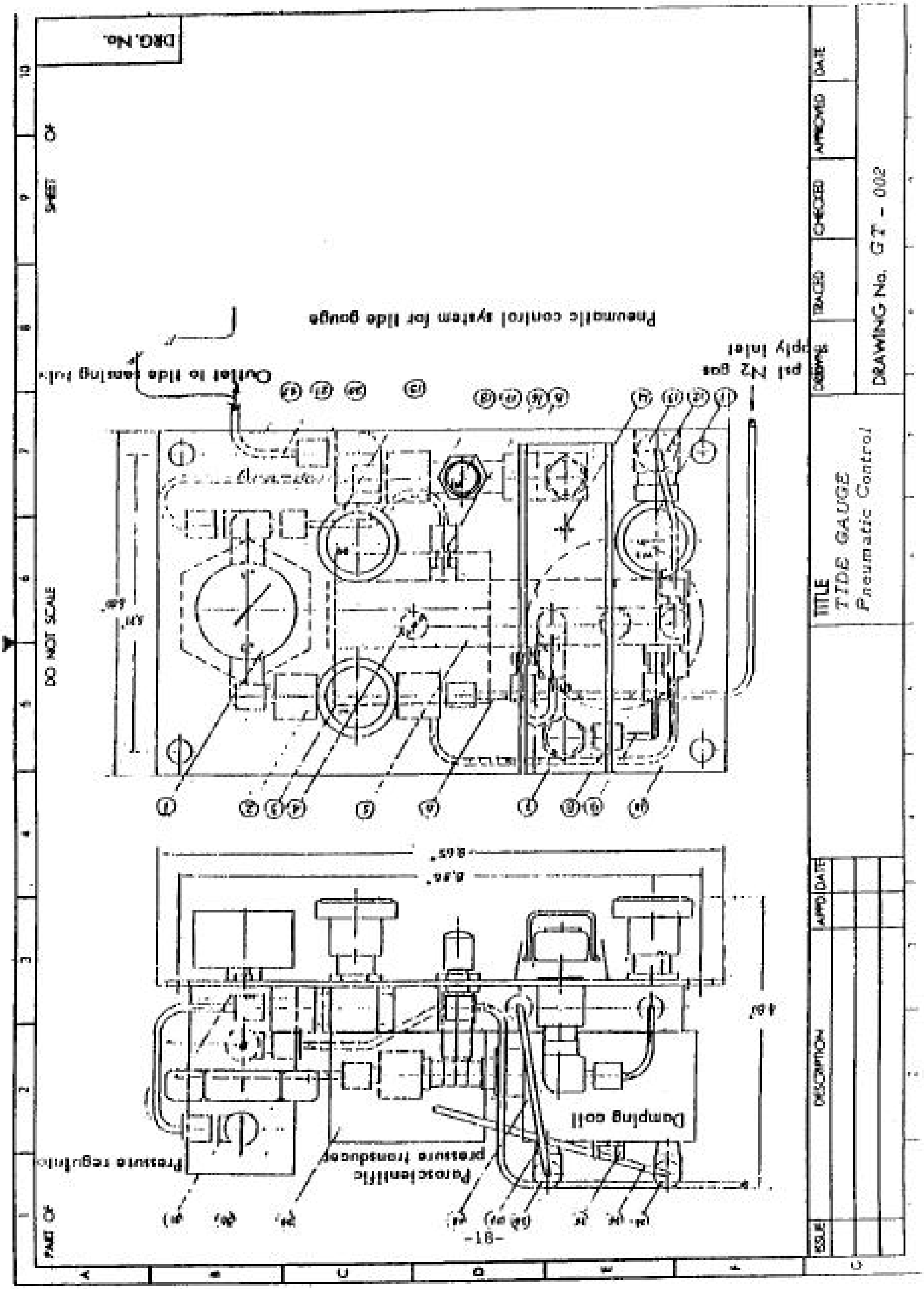


Figure 10. Drawing of bubbler tide gauge gas outlet orifice installation at a concrete piling (assuming 1-ft diameter).

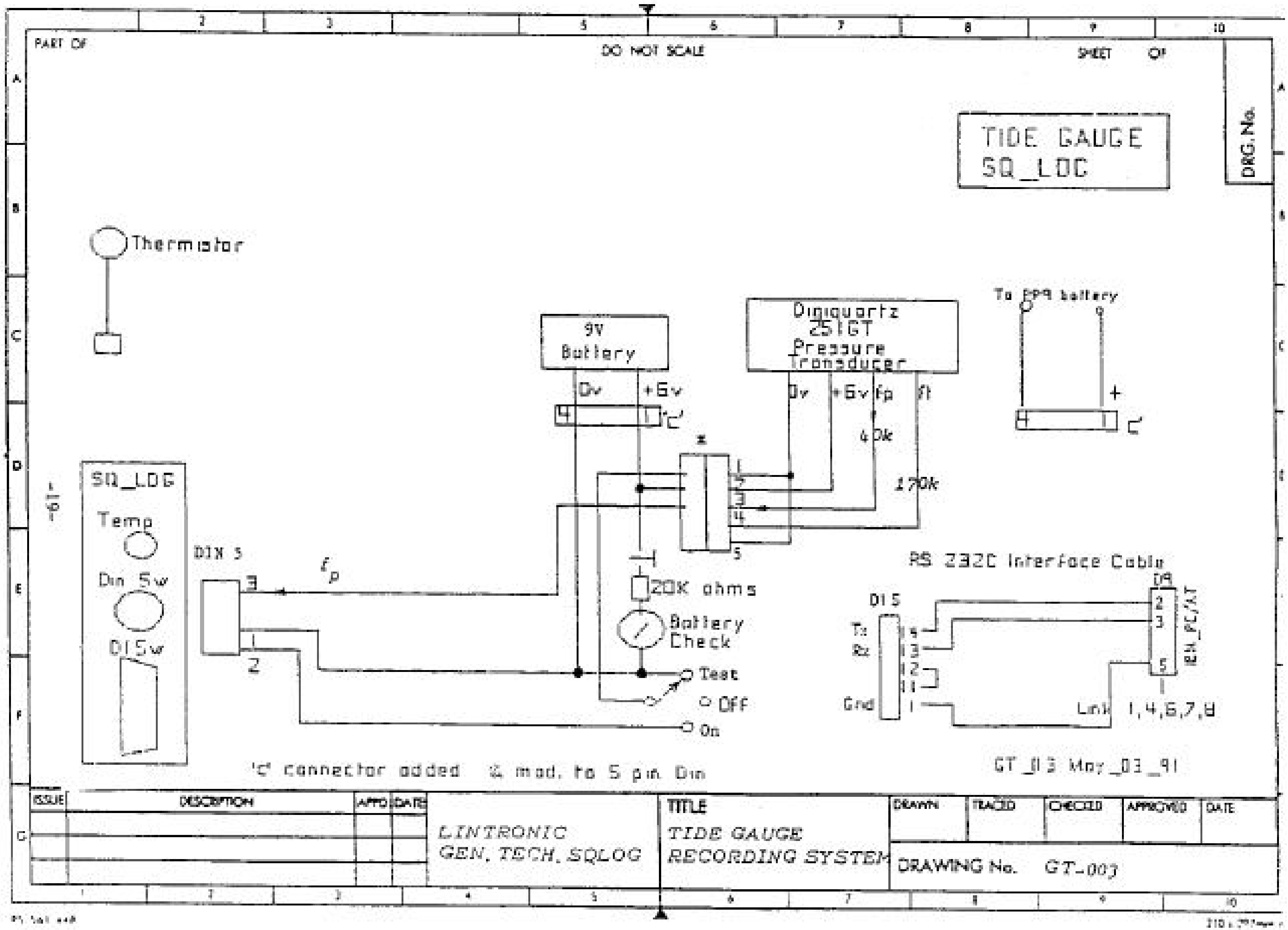
APPENDIX A

TECHNICAL DRAWINGS


DO NOT SCALE
Input valve
Pressure gauge
Flow meter
Damping valve
Output valve
Flow rate valve
Minilog mounted on door panel
SQLog
179
Battery
General Layout of Tide Gauge
DRG. No.
ISSUE
DESCRIPTION
APP'D
DATE
TITLE
DRAWN
TRACED
CHECKED
APPROVED
DATE
DRAWING No. GT - 001
18 psi N_2 gas supply inlet
Outlet to tide



DRG. No.
SHEET
OF
DO NOT SCALE
PART OF
Pneumatic control system for tide gauge
Damping coil
Paroscientific pressure transducer
-18-
DRAWN
TRACED
CHECKED
APPROVED
DATE
TITLE
TIDE GAUGE
Pneumatic Control
DRAWING No. GT - 002
ISSUE
DESCRIPTION
APP'D
DATE


PART OF
DO NOT SCALE
SHEET OF
DRG. No.
TIDE GAUGE
SQ_LOG
Thermistor
9V
Battery
0v
+6v
'C'
Digiquartz
251GT
Pressure
Transducer
0v
+6v
fp
ft
40k
170k
To PP9 battery
+
C'
SQ_LOG
Temp
Din 5w
D15w
DIN 5
fp
20K ohms
Battery
Check
Test
Off
On
RS 232C Interface Cable
D9
D15
Tx
Rx
Gnd
IBM_PC/AT
Link 1,4,6,7,8
GT_03 May_03_91
'C' connector added & mod. to 5 pin Din
ISSUE
DESCRIPTION
APPD
DATE
LINTRONIC
GEN, TECH, SQLOG
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TIDE GAUGE
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DRAWING No. GT-003

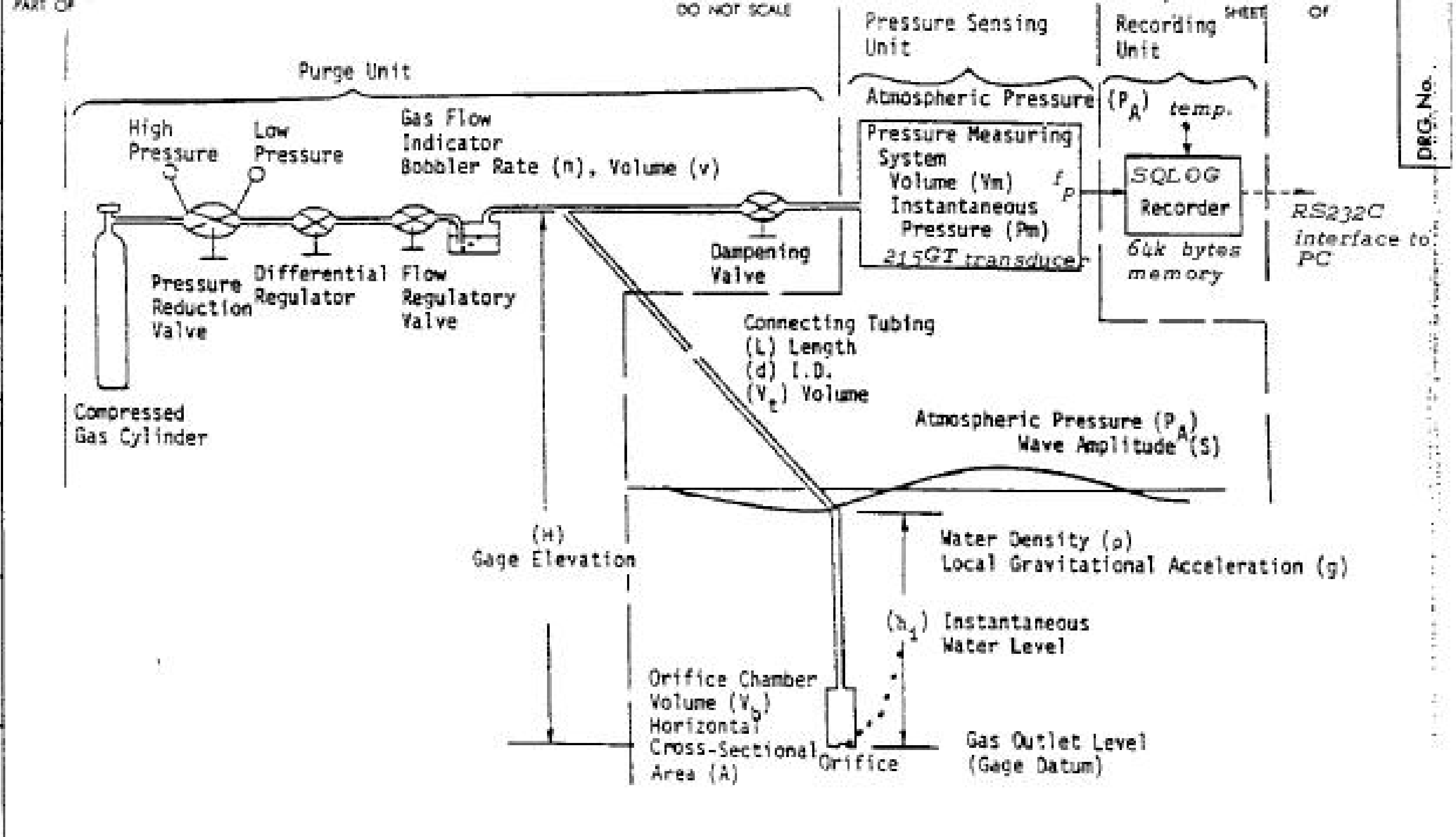

Figure 1 Schematic diagram of bubbler gage and its principle system parameters (3)

ISSUE	DESCRIPTION	APPD	DATE	TITLE	DRAWN	TRACED	CHECKED	APPROVED	DATE
				TIDE GAUGE RECORDING SYSTEM	DRAWING No. GT-005				

PART OF — DO NOT SCALE — SHEET — OF — DRG. No.

— 20 —

APPENDIX B

USER'S MANUAL

STARTING PROCEDURES

1. Check that the quick connectors of the input and output hoses to the tide gage are seated properly.
2. Check that all valves with green knobs are closed clockwise, then open all one turn counter clockwise.
3. At the N_2 gas supply-tank, open the main gas supply valve and slowly adjust the pressure regulating valve until the output pressure gage reads 18 psi.
4. At the tide gage, adjust the flow-rate control valve for a gas flow-rate of 30 to 40 cc/min as indicated by the flow gage.
5. Note that the pressure gage on the panel will start to indicate a rising pressure in the system and settle slowly in 5 minutes to a reading of approximately 3 psi, representing a water head of 2 meters. This indicates proper operation. If the pressure continued to rise quickly beyond 10 psi, close the input valve quickly. This would mean either the output line is plugged or the output valve is closed. If the output line is plugged, the condition should be corrected before resume operation.
6. If the above operation is normal, proceed to reduce the flow rate to a value of 5 cc/min as indicated by the red arrow-mark on the flow gage.
7. Close the damping valve clockwise. Be sure that under operation, this valve is always closed for filtering out all unwanted signals from the waves and pass only the tide signals.
8. If there are waves in the ocean, the pressure-gage needle will oscillate with the waves indicating a proper operation for the tide gage. Start data recording. If the needle does not oscillate with the waves, it could mean a partially plugged transmission line. The problem should be resolved before resume operation.

CLOSE DOWN PROCEDURES

1. For both a long or short close down, it is best to keep a minimum flow of N_2 gas through the system all the time to prevent marine growth inside the transmission tubing. Failure to do this will require the replacement of the whole transmission line before a new start up. A partially plugged line can cause serious error in the tide recordings.

REGULAR SERVICES

1. Both the 9 volts alkaline batteries for the pressure gage and the Salogger should be replaced with new ones every two months of continued operation, or if battery checks show battery in low conditions. It is best to keep a written record on the tide gage for the date of battery change. Watch carefully for correct polarity when installing new batteries. Use only high quality alkaline batteries.
2. Check the 18 psi input N_2 gas supply pressure and the 5 cc/min flow rate at the tide gage. Adjust if necessary.
3. Check the high pressure gage on the N_2 gas tank for sufficient gas supply. A fully charged 3 cubic foot tank should provide one year of continued service.
4. The copper cup orifice placed in the sea should be inspected and cleaned by a diver at least once a year for marine growth. Clean more often, if marine activities are high at the site.

CONTROL/DISPLAY PANEL - 216GT TIDE GAUGE & TEMPERATURE SQLOGGER

	BUTTON A functions select	BUTTON B modes select	BUTTON C set/reset	Remarks
1.1	record [normal].....	record - on/off *	reset *	* hold for 2 secs to start record'g
1.3	delayed start [L]...	L/record-on/off *	reset *	recording starts as set to 4.3,4.4 5.3, 5.4
2.	meter................ [display]	channel select		ch.1= temperature ch.2= 10 - second pulse counts
3.	review.............. [display]	channel select	latest data displayed first- then continue to roll back	
4.	time - real......	4.1. hours 4.2. mins	set	real- time clock
	- start.....	4.3. hours 4.4. mins	set	- delayed start
5.	date - real......	5.1. months 5.2. days	set	month and date
	- start.....	5.3. months 5.4. days	set	- delayed start
6.	interval-record..	6.1. mins 6.2. secs	set	record interval
	-scan....	6.3. mins 6.4. secs	set	[scan interval]
7.	battery life..................................			recording life in days
8.	output...........	8.1. RS232............	[refer to SQLOTUS data transfer to pc @ 4800 baud for detail]	
		8.3. baud rate	set	must be 4800 for compatibility
9.	[channel select]...	[channel number]	N/A	This is now used for functions: H, L and P
H.	base value.......	H.1. 10e5	set	ms digit
		H.2. 10e4 H.3. 10e3	set	2nd & 3rd digits
L.	base value.......	L.1. 10e2 L.2. 10e1	set	4th & 5th digits
		L.3. 10e0	set	ls digit
P.	calibration.....	P.1. 10e3 P.2. 10e2	set	ms 2 digits
	[4 digits]	P.3. 10e1 P.4. 10e0	set	ls 2 digits [display chan.-2 in tide-height]

Base value is settable up to 999999

```
                   (msd) H1 ___!!!!!!___ L3
          (Function H) H2 ____!!!!____ L2 (Function L)
                       H3 _____!!_____ L1 (msd)
```

Following function 8 is function H. So after function 8, if button A is pressed once, function H is selected. This function together with function L allow setting of base value up to 999999. Select the digit to be adjusted using button B. The digit will then flash. Change the digit using button C.

Pressing Button A after function H will select function L. Select the digit to be adjusted using button B. The digit will then flash. Change the digit using button C.

Pressing Button A after function L will select function P. Set the digits as for function H and L.

The input is sampled over 10 seconds and the total number of pulses counted. The SQLOG then computes the absolute difference between the Base value and the total count. This figure is then multiplied by the calibration value (set in function P) and divided by 10000. The result is displayed in function 2. If the result is greater than 10000, a decimal point is inserted after the thousands digit.

Recorded Value = ABS(Total Count - Base Value)

$$\text{Displayed Value} = \frac{\text{ABS(Total Count-Base Value)} \times \text{Calibration Value}}{10000}$$

Recorded values are displayed in function 3 using the displayed value formula.

Example: Procedures in setting up SQLOG to record temperature from thermistor probe (Ch.1) and pulse counts fp (Ch.2) from 215GT pressure transducer.

To Setup SQLOG to record temp and fp at 4 minutes interval and to use the delayed start facility,proceed as follows:-
Assuming real time is 8:35 and real date is Jun_20_1991 and recording (using delayed start) to start at 9:00 on Jun_20_1991

1. Stop recording (if record appears under function 1, press button B to cancel it.)

2. Download stored data if necessary before reset SQLOG.

3. To set real time
Press button A and select function 4
Note 4.1 and 4.2 refer to real time
Press button B for 4.1. Hours digit will flash. Use button C to set to 8
Press button B for 4.2. Mins digit will flash. Use button C to set to 35

4. Note 4.3 and 4.4 refer to delayed start time
Press button B for 4.3. Hours digit will flash. Use button C to set to 9
Press button B for 4.4. Mins digit will flash. Use button C to set to 00

5. To set real date and delayed date
Note 5.1 and 5.2 refer to real date
Press button A and select function 5
Press button B for 5.1. Months digit will flash. Use button C to set to 6
Press button B for 5.2. Days digit will flash. Use button C to set to 20
Press button B for 5.3. Months digit will flash. Use button C to set to 6
Press button B for 5.4. Days digit will flash. Use button C to set to 20

6. To set record interval
Press button A and select function 6
Press button B for 6.1. Mins digit will flash. Use button C to set to 4
Press button B for 6.2. Secs digit will flash. Use button C to set to 00

7. To enable delayed start
Press and release button A (several times) until f1.3 appears
Press button B then

f	set		
1.3	record	L	appears

At the starting time L (for late) and set will go off and record comes on.

1. CONTROL & DISPLAY PANEL - SQLOG

1.1 Control buttons

Button A selects the recorder functions in column 1 on the front of the instrument.

Button B & C have different effects according to the function selected by the button A, and these are shown in columns 2 and 3 on the front of the instrument.

1.2 Display

The left hand digit indicates function selected. Above it is the letter f (for function). The next (second) digit has two separate uses. In functions 2 and 3 it shows which channel has been selected and in this case the letters ch come on above it (for channel). In functions 4 to 8 it is used to indicate a sub-function. Up to four digits can be shown in the right hand block. These are used to display incoming and recorded readings and for other purposes as described in the next section, 'Using the Meter/Logger'

Units of measurement appear at the right of the display. The appropriate one appears with every reading displayed.

Also on the display are the words record, reset and ready.

These are used as follows:

record shows that a recording run is in progress with reading being taken at the preset interval.

reset shows that the memory has been cleared and you can start a new recording run.

If neither record nor reset are on while the display is operating and Function 1 selected then the memory already contains a completed recording run. If this run is required it must be played back to a computer or reviewed on the LCD display before the recorder is reset. Then another recording can be started.

ready comes on to show that a computer is connected and the Meter/Logger is ready to send its readings out at the request of the computer.

2. Using the SQLOG - Meter/Logger

2.1 On/Off switch

When switched off the recorder retains recorded data in its memory with the lowest possible power consumption. To switch off, select function 1 using button A, wait for the display to go off and then move the slide switch to the off position. (Note that the clock is switched off so time and date will need resetting).

2.2 Switching-on

Switch on using the slide switch on the back plate of the unit.

2.3 Selecting function required

To bring the display on, hold down button A until f1.1 appears at the left hand end of the display. If you press button A again within 2 seconds the function will immediately switch to the next one as shown at the start of each row printed on the case and repeated pressing within 2 seconds will cause it to cycle through all its functions. If you allow more than 2 seconds between one press and the next there will be a delay of up to 1 second before the instrument responds. If the Meter/Logger is left in function 1 for 10 seconds the display is automatically switched off.

2.4 Function 1 - Record

Function 1 record is provided with 1.1 record and 1.3 delayed start.

To make an instantaneous start recording

Use button A to select record f1.1.

Hold button C until reset appears on the display.(If reset is already on, omit this operation). (Note that buttons B and C only have any effect while the display is on).

Hold button B down until record appears and the display shows the current value of channel 1. If the switches are now left, the display goes off after two seconds and the Meter/Logger records at the selected interval. Every 20 seconds the display comes on showing the last recorded value of channel 1 and record.

While recording, the Meter/Logger can be used as a meter to show the current reading (see Function 2 above), and the recordings already made can be displayed in sequence (see Function 3 below) and battery life check. None of these will affect the recording process. During a recording run it is not possible to send data to the computer, nor alter the recording interval, nor reset the clock.

To find out how many recordings have already been stored, use button A to select function 1. The display shows the number of stored readings followed after 1 second by the last recorded value of channel 1. On reaching 10,000 readings, the number is rounded down and displayed as 10.0 etc. If the memory is already full, the display will show the number of readings stored, but not the value of channel 1 and record will not come on.

2.5 To stop recording

Use button A to select f1.1.

Hold button B down until record goes off. The display shows the number of readings stored in the memory.

2.6 Function 1.3 - Delayed start

The time and date for the delayed start should be set as in functions f4.3, 4.4 and 5.3, 5.4

To put the SQLOG into the delayed start recording mode, use button A to select 1.3 and button B to obtain L (for late) on the display . At the starting time L will go off and record comes on. The SQLOG now behaves as if set to record using f1.1.

The figure for the month in the start time is restricted to not more than 3 months ahead of the real time. This limits the maximum period that the start time can be set ahead to between 3 and 4 months depending on the day in the month of the real and start times. This is done to prevent a setting error in the date or time resulting in almost a year's delay when only a short delay was intended. If an unacceptable start time is set the display shows E when button B is pressed in funtion 1.3.

Note :
Delayed start rationalizes the number of recordings with respect to a preferred start time. Thus, if recording started at say 00:00 Hour with interval set to 5 minutes, the number of recordings for one day will be 288.
(see 5. Data Transfer - SQLOTUS)

3. Set Time and Date

3.1 Function 4 - Time

Real time Use button A to select f4. The display now shows the real time in hours and minutes. To alter, use button B to select 4.1 hours (up to 24 hours) or 4.2 mins. (Note that if SQLOG is recording, or set in f1.3 for delayed start recording, record will come on and the time cannot be altered). The value of whichever is chosen flashes and can be increased by repeated operation of button C. Hold down button C to increase the value rapidly if the required setting is a long way off.

Start time On SQLOG with the delayed start time facility, start time is shown and adjusted in 4.3 and 4.4. It is set in the same way as real time.
Once a recording run is reset the start time automatically reverts to real time and follows it. It has to be adjusted before a new delayed start run is made.

3.2 Function 5 - Date

Real date Use button A to select f5. The display shows real month and day. It is set in a similar way to setting the clock (see Function 4).(Note that if SQLOG is recording, or set in f1.3 for delayed start recording, record will come on and the date cannot be altered).

Start date.The start date is shown and adjusted in 5.3 and 5.4. It is also set in a similar way to setting the clock.

Once a recording run is reset, the start date automatically reverts to real date and follows it. It should be adjusted (if necessary) before a new delayed start run is made.

3.3 Function 6 - To set the interval between recordings

Use button A to select f6. The display shows the interval in minutes and seconds. It reads up to 99 minutes, 59 seconds and is reset in a similar way to setting the clock (see Function 4).

(Note that if zero interval is selected, recording are actually taken at 100 minute intervals).

4. Display

4.1 Function 2 - Use as a meter

The display can be used to show the current value of the input from any channel. This can be done during a recording run without affecting the recordings.

Use button A to select f2.

Use button B to select channel number to be displayed.

The channel number and ch will appear in the second position on the LCD, e.g. ch2. Reading of the selected channel will appear on the right hand side of the display.

The displayed value is updated every second. When the display is no longer wanted, use button A to switch to function 1. If this is not done, battery life will be reduced.

4.2 Function 3 - To review recorded readings on the display

All stored readings can be reviewed at the rate of 1/sec, even while recording is taking place.

To review readings starting with the oldest, select f3 using button A. Select channel number to be viewed using button B.

The oldest reading is displayed first, followed by the others. Finally the last reading is displayed until a new function is selected.

To review readings starting with the newest, select f3 using button A. Select channel number to be viewed using button B. Then press button C. Readings will be displayed as described above, but starting with the newest.

Interrupting the review. If you do not need to see all the readings you can press button B at any time to display readings from a different channel. Readings from the new channel will start with the oldest unless button C is pressed after button B.

4.3 Function 7 - To display battery life

Use button A to select f7. The display gives a guide to how many days recording time (when used in Function 1) are left in the battery with enough charge at the end of the run to play back the contents of the memory to a computer. The display works by measuring the battery output voltage. This fluctuate a little with temperature and load so the indication can go up as well as down.

As the power required to drive the display and the output to the computer is very much higher than needed just for recording, the number of days recording time available can go down quite quickly in functions other than Function 1.

For this reason the SQLOG should always be returned to Function 1 when the other functions are not being used.
= =

5. SQLOTUS Data Transfer

5.1 Function 8 - To send recorded data to a computer

Use button A to select f8.

RS232 serial I/O: Use button B to select 8.3 and check that the baud rate displayed is (4800).
If necessary, using button C to alter the baud rate.

Connect the computer and load the data Transfer program.

When ready to run use button B to select 8.1 for RS232 serial.

When ready is displayed, run the computer. During transmission, 232 is displayed, and ready goes off.

Transmission must not be interrupted for more than 2 seconds as, after this time, the recorder is powered down automatically.

See 5.2 SQLOG DATA TRANSFER for further detail.

5. SQLOTUS DATA TRANSFER

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5.2 Function 8 output to PC:

1. Stop Recording
   Press button A for f1.1. Press button B until record disappears.
2. Connect RS232C Interface cable to the PC. Refer to Drawing No. GT-03 for converting D25 to D9 if necessary.
3. SQLOG may be removed from the cabinet for remote processing.

Boot up IBM PC as normal.
When A> appears, remove MS-DOS diskette (5.25 in).
Insert Transfer program diskette in Drive A.

For LOTUS 123
Type SQLOTUS -P288 <enter> (For 1 day of 5-minute recordings)
(see Delayed start f1.3 and f4.3 f4.4 f5.3 and f5.4)
or
Type SQLOTUS <enter> (For all recorded readings)

The program will be LOADED and RUN.
Enter Name for Data File : -...............

Check that function 8.3 is set to 4800 baud
Check ready in f 8.1 (ready will appear if RS232C cable is connected between SQLOG & the PC)

Press SPACE-BAR to transfer data. Press ESC to exit at any time

Get Run from File (message will appear on screen)

Enter year - (type 1991 or as appropriate)

Writing Lotus File (message will appear on screen)

Please type the character to use as decimal point

You entered '.' - Please confirm (Y or N)

Writing Data to xx.L01 (message will appear on screen)

Lotus File completed. Press SPACE-BAR

Note all the files are written to default drive.
To write them to another disk, put the disk to be used in one drive and the program diskette in the other. i.e drive B for the data and A for the program then type:
A:>B: B:>A:SQLOTUS

6. Battery

The Meter/Logger is supplied with a battery already fitted and connected. When replacement is necessary it is accessible under the black cover on the back of the instrument. Use a PP3 size Alkaline battery, such as Duracell MN1604. If the wrong type of battery is used, the indicated battery life (see under Function7) will be incorrect.

To change the battery without losing stored readings, select function 1, wait for the display to go off and then move the slide to the off position. Disconnect the battery and replace as quickly as possible. If the batteries are exchanged within eight seconds, the stored readings will be preserved. The readings will be lost, however, if the battery is connected with the wrong polarity (the circuits are protected, but the memory contents will be lost).

7. Conditions of use

The Meter/Logger can be used in ambient temperatures between -30 and +65 degC with humidity up to 95% (non-condensing).

8. Cleaning the case

Grease and dirt can be removed from the case with a non-toxic carbon tetrachloride based cleaning fluid such as 'Arklone'

How to transfer data from SQLOG to PC and convert the raw data to tide heights:

1. Installation:

There are five files in the floppy disk:

TIDE.BAT	(a batch file)
SQLOTUS.EXE	(transfer data from SQLOG to PC)
TIDEH.EXE	(convert raw data to tide height)
DENSITY.DAT	(data file containing value of seawater density)
TIDE.DOC	(this file written in Macrosoft's Word)

Copy all the five files into the hard disk. You may want to create a directory for these files. To create a directory called TIDE, for example, type

md tide <Enter>

at DOS command line, where <Enter> means pressing the Enter key. Then you can change to that directory by typing

cd tide <Enter>.

2. Data converting:

After copying the five files into directory TIDE, you can transfer data from the SQLOG to the PC. The data transferred, however, are dates, times, temperatures and pressure related raw data, which should be converted to the tide heights. We offer all necessary means to get the job done. For the end user, it's quite simple -- just type

tide <Enter>

at the DOS command line. The batch file TIDE.BAT executes two programs SQLOTUS and TIDEH sequentially. SQLOTUS transfers data from SQLOG to the PC storing in several files (2000 records maximum in each file) with the extension of L01, L02, L03... and so on, and TIDEH converts the raw data to tide heights and writes them into a single file with truly LOTUS 1-2-3 compatible format and file extension of PRN.

When SQLOTUS is executed, you are expected to specify a filename to the program for the file containing the data transferred. When TIDEH is executed, you have to specify the same filename again at the program prompt. TIDEH reads data from that file, converts them, and writes them into a newly created file having the same filename with the extension of 'PRN'

For example, if you specify a filename TIDEJUL for program SQLOTUS, then you type it again for program TIDEH. TIDEH opens files TIDEJUL.L01, TIDEJUL.L02..., processes the data, and writes the results into a file called TIDEJUL.PRN. When you process the data in LOTUS 1-2-3 later on, to load the file you can omit the extension by typing TIDEJUL only, because the extension PRN is LOTUS 1-2-3's default. So when batch file TIDE is finished, there are several data files created, the files contain the raw data having whatever filename you specified, and the other contains useful tide data having the same filename except the extension being changed to PRN. It's your responsibility to delete or remove the raw data files to save the valuable disk space. It's recommended that you do the housekeeping once a month.

If you transfer the data from SQLOG to PC once a month, the data file could be a bit large. In order to make the job done smoothly for a laptop PC or even for a notebook PC with small amount of memory, program TIDEH processes data in batches: each time it reads 1000 records of datum(that is one batch) from the raw data file into the PC's memory, then calculates and writes the results into the PRN file. Then it reads another batch of datum from the raw data file starting from the point it just stopped into the same memory location(the old data being wiped out) and processes them and so on, until it reaches the end of the raw data file.

Because the density of seawater varies, program TIDEH offers a way to let the user modify the value when it's necessary. The file DENSITY.DAT on the distributed disk contains the default density value of 1022 Kg/Cubic Meter. Before the conversion starts, TIDEH display the current density value on the screen and ask the user if the value needs to be changed. The display may look like this:

```
Density of the seawater = 1022 (Kg/Cubic Meter)
Want to change it (Y/N)?
```

You can decide to change the value or not. If the value is all right just press the 'N' or 'n' key, then the process starts using the default value. If for some reason you want to change the value, hit 'Y' or 'y' key, then the next prompt appears:

```
New value of seawater density (Kg/Cubic Meter) =
```

type the correct value of the seawater density and press the <Enter> key, then the program uses the new value to convert the data. The new value is also stored in the file DENSITY.DAT automatically and the next time you running the program, this value will be the default value appearing on the screen. In this way, you don't have to type in the seawater density value each time you run the program, it becomes necessary only if you want to change it.

When all the conversion is finished, TIDEH tells you how many records of datum being written into a PRN file and waits for you to press a key to exit from it.

APPENDIX A. TECHNICAL DRAWINGS

GT-001 General Layout of Tide Gauge
GT-002 Tide Gauge Pneumatic Control
GT-003 Tide Gauge Recording System

APPENDIX B. USER'S MANUAL

I. Tide Gauge Operating Procedures
II. SQLOG Recording Unit
III. Data Transfer

APPENDIX C. PERSONNEL

H. P. Pao , Principal Investigator
S. C. Ling Co-Principal Investigator
Alan Chen, Research Engineer
Zhili Yu, Research Engineer