无汞污染的水柱型大气压强计*

张 雄

（云南师范大学物理系，昆明 650092）

摘要 提出一种小尺寸(1.2m)的水柱型大气压强计，解决了生产和使用水银柱大气压强计时产生的汞污染环境问题。讨论水柱大气压强计的工作原理和使用方法，分析测量误差。简述应用中的若干问题。文中给出的压强计在海拔为0—3km、环境温度为6—40°C范围使用，测量结果的标准误差小于±0.9mmHg，能分辨±0.1mmHg的大气压强变化，适用于环境温度变化不大的室内大气压强测定。由于水的饱和蒸气压随环境温度有较大变化，从而导致了用水柱测大气压强的困难，文中报道了一种在一定环境温度范围内(6—40℃)解决这个问题的方法。

关键词 小尺寸水柱气压计，汞污染，水的饱和蒸气压，环境温度。

测量大气压强有多种方法和仪器[1]，1647年人类发明的水银柱大气压强计，为测量大气压强应用最为广泛的气压计。水银柱大气压强计在使用和制造过程中，产生的汞污染问题和环境保护问题一直困扰着人们。为了避免汞对环境的污染问题，早在17世纪就有人对水柱型大气压强计进行过研究，但都是在大尺寸范围内(整个水柱气压计长约14m)，因而未能使其进入实际应用阶段。

笔者研制了一种长约1.2m的水柱型大气压强计，这种气压计和水银柱气压计比较，具有测量精度高，造价低廉，测量大气压强范围不变等优点[2]，解决了长期以来水银柱大气压强计使用和生产时产生的汞污染环境问题。

1 实验原理和测量仪器

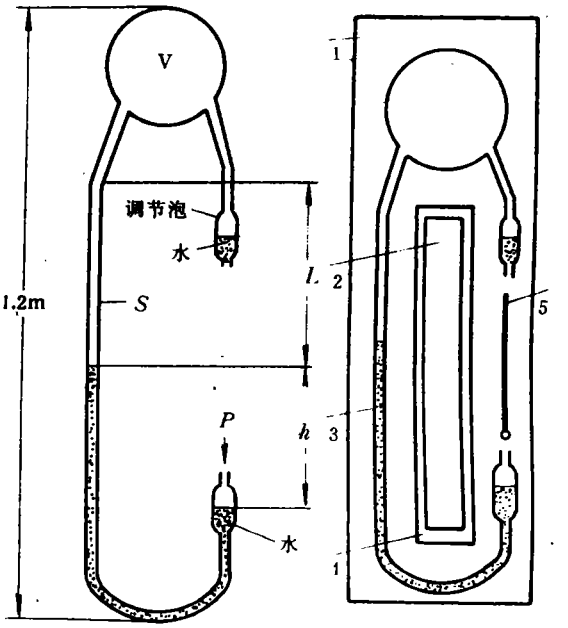
1.1 实验原理

根据有关的热力学理论，对图1(a)所示测量仪器，有：

$$P = P_V + P_\rho + P_g \qquad (1)$$

式中，P 为待测大气压强，P_V 为温度为 T 时水的饱和蒸气压，P_ρ 为高度为 h、密度为 ρ 的水柱在温度 T 时所产生的压强，P_g 为水柱上方容器 V 内永久气体的压强，由于容器 V 内的气体在制造仪器时被抽出了一部分，并且密封良好，所以近似做理想气体处理，则有：

$$P_g = \frac{NRT}{V + S \cdot L} = \frac{RT}{\frac{V}{N}(1 + \frac{S \cdot L}{V})} \qquad (2)$$



(a) 工作原理图　　(b) 结构示意图

图1 水柱气压计

1. 面板　2. $(T,h\text{-}P)(T\text{-}a_0)$参数表格　3. 水柱　4. 透明有机玻璃尺　5. 温度计

式中，R 是理想气体常数，S 为玻璃管的横截面积，L 为除体积 V 后水面到弯曲部分的长度，V 为球的体积和弯曲部分的玻璃管体积(包含调节泡水面上方的玻璃管体积)。设计仪器时可以将 V 取得很大，S 取得很小，从而保证$\frac{S \cdot L}{V}$小于

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10^{-4}，于是(2)式为：

$$P_g \doteq RT/(V/N) \quad (3)$$

当仪器的几何形状确定以后，球体积及相应的两弯曲部分的玻璃管体积 V 随之确定，尽管 L 在测量过程中会随着水柱高度的变化而增加或减小，但设计仪器时已经确保了 $\frac{S \cdot L}{V}$ 小于 10^{-4}，L 变化引入的误差与实际测量 P 的误差比较，可以忽略不计。体积 V 不变保证了 N 也不变($N=\frac{M}{\mu}$；M 表示 V 内气体的质量，μ 为它的克分子量)。如果令 $A=V/N$，将(3)式代入(1)式，有：

$$P = P_V + \rho gh + \frac{RT}{A} \quad (4)$$

或

$$A = \frac{V}{N} \doteq \frac{V}{N}(1 + \frac{S \cdot L}{V}) = \frac{RT}{P - P_V - \rho gh} \quad (5)$$

由于 $A=\frac{V}{N}(1+\frac{S \cdot L}{V})$，在环境温度给定时，确定出的 A 是一个仪器常数，一般 A 可以用多种方法直接得出。我们应用(5)式，通过用高精度的气压计测出大气压强 P 及相应的环境温度 T，查物理手册求出 P_V 及 ρg[3]，测出水柱的高度差 h，从而得到仪器常数 A。

由(4)式，如果令 $a_0 = P_V + \frac{RT}{A}$；$a_1 = \rho g$，则有 $P = a_0 + a_1 h$ (6)

(6)式就是水柱大气压强计的测量公式，为了方便求解(6)式中的系数 a_0、a_1，特给出温度间隔为 $\frac{1}{10}$℃的(T-P_V)表格。温度间隔为1℃的(T-ρ)表格，重力加速度 g 随海拔高度 H 变化的(H-g)表格。表中 T 的变化范围为6℃—40℃，H 的变化范围为0—3km，即水柱气压计仅能在这个环境条件下工作。体积 V 中的理想气体等效于"增加"了液体的密度和水柱的高度。

笔者设计的样机在校准以后，直接给出了不同温度 T 对应的系数 a_0(T-a_0)表格，不同温度 T 及不同海拔高度 H 下的系数 a_1k (T、H-a_1)表格，在测量中十分方便。此外，当 A 一定时，根据(6)式给出了不同温度和对应水柱差 h 下的(T、h-P)表格，只要测出水柱的高度差 h 和对应环境温度 T(用 $\frac{1}{10}$℃温度计)，能直接从(T、h-P)表格得出所测的大气压强。

水柱气压计灵敏度高，当大气压强 P 有微小变化时，水柱差 h 就会有明显变化，各地海拔不一样，P 必然随之改变，为了保证在海拔0—3km内适用，增设了调节泡，当仪器从工厂运到使用地点后，如果海拔变化800m以上，可以用注射器调节球体积 V 内的气体，使水柱对准调整位置(即水柱差 h 为50.00cm处)，在此情况下得出 A，应用(6)式就能进行测量。

1.2　测量仪器结构

仪器结构如图1(b)所示，仪器由玻璃吹制，工质用红色水柱，面版与水柱的色彩反差要大，水柱高度差用最小分格为1.0mm的宽有机玻璃直尺测量，环境温度用 $\frac{1}{10}$℃的温度计，吹制好的玻璃仪器和有机玻璃直尺、温度计都固定在面板上，仪器面板上端和调节泡处要开孔，让玻璃球V和调节泡有一半放入面板孔内，玻璃管能方便地固定在面板上，表格(T,h-P)及(T-a_0)等压放在有机玻璃直尺下，使其测量时能方便地得出大气压强。

1.3　仪器参数选取示例

根据(2)式，在设计仪器时，要使 $\frac{S \cdot L}{C} \ll 1$，取如下参数，玻璃管直径 $d_1=4.0$mm，测得水柱差部分直玻璃管最长 $L=1000.0$mm，则 $S \cdot L = \frac{\pi d_1^2}{4} \cdot L = 12560mm^3$，液面上除去管长 L 以后的体积为：$V=\frac{1}{6}\pi \cdot d_2^3 + S \cdot L_1 + S \cdot L_2$；式中，$d_2$ 为球直径，$d_2=160.0$mm，$L_1=100.0$mm，$L_2=100.0$mm 则 $V=2147173$mm^3，$\frac{S \cdot L}{V}=12560/2147173=0.005 \ll 1$。

1.4　仪器常数 A 结果示例

用最小分格 $\frac{1}{10}$℃的温度计测环境温度 T，用最小分格为1.0mm的直尺测 h，用福延式气压计测 P，由物理手册查表格(T-P_V)和(T-ρ)，昆明地区重力加速度 $g=9.787$cm·s^{-2}，笔者通过实际测量，由(5)式得样机的仪器常数：

$\bar{A}=33.26\pm0.21 dm^3 \cdot mole^{-1}$。

2 实验结果和误差讨论

测出的大气压强都经过修正才记录入表格，在每个环境温度下用水柱气压和福延式气压计对比重复测量10次，取平均值和计算标准误差后记录入表1。

修正误差时，福延气压计的平均值作了众所周知的温度修正，地方纬度修正。水柱气压计也做了相同修正，其所加的温度修正为：$H=H_t-(\beta+\alpha)H_t \cdot t$，$\beta$ 为水的体膨胀系数，α 为有机玻璃直尺的线膨胀系数，温度修正中，不考虑水的

表1 不同环境温度下的大气压强测量值

环境温度 (℃)	水柱气压计测大气压值 $P=a_0+a_1h$ (mmHg)	商品福廷气压计测大气压值 P' (mmHg)	相对误差 $E=\lvert\frac{P-P'}{P'}\rvert\times100\%$
5.00	610.0±0.3	612.5±0.1	0.3%
10.00	613.0±0.8	613.8±0.2	0.1%
15.00	612.0±0.5	612.7±0.1	0.1%
20.00	613.5±0.3	613.7±0.1	0.05%
30.00	612.5±0.5	610.5±0.5	0.3%
35.00	613.7±0.9	613.7±0.9	
40.00	613.5±0.9	615.5±0.8	0.3%

时间：1988年2月　　地点：昆明市云南师大物理楼实验室

饱和蒸汽压与温度变化的关系，此项在测量公式中 P_V 计算 a_0 时已考虑过。

温度、纬度、海拔高度、重力加速度等项引起的误差修正和传统的水银柱大气压强计所采用的误差修正方法完全一样，修正中仅需注意水银密度 $\rho_{水银}$ 和水密度 ρ 的差异。

由于应用水代替水银工质，密度的差异使其当大气压强变化1mmHg时，水柱高度变化13.00mm以上。因为测量工质的代换使仪器灵敏度提高了近10倍。

应用中，还有一个值得注意的问题，就是水的饱和蒸汽压 P_V 随环境温度 T 的变化，对测量结果的误差影响较大。T 在0—40℃范围内变化时，当 T 测量最大误差为±0.1℃时，引起 P_V 的最大测量误差为±0.3mmHg。所以使用水柱气压计时，环境温度 T 一定要用 $\frac{1}{10}$℃最小分格的温度计测定，以保证获得准确的系数 a_0、a_1。此外，当 T 从6℃增大到40℃时，P_V 将从7.01 mmHg增大到55.32mmHg，相对应的水柱差 h 减小约500mm长，这就限制了水柱气压计只能在一定范围的环境温度下使用[4]，笔者设计的样机 T 引起 ρ_V 的变化不能大于100mmHg，因为由(4)式和水柱气压计的外形尺寸得知，水柱差 h 的变化不能超过1000mm长，这也就是水柱气压计的不足，有待于进一步研究改进。

3 结束语

使用水柱气压计和水银柱福延式气压计在云南各地（海拔1500m—2200m范围）进行对比测量实验，两者最大相对误差小于1%，值得生产推广使用。水柱气压计测量大气压强时，除了测 h 外还要同时测出相对应的环境温度 T，使用起来不方便，还有待于研究改进。

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An anomalous phenomenon was discussed, in which it was found from a calculation of the allowable discharge levels of water pollutants in the Huainan reaches of the Huaihe River that there was a large flow of water with a small allowable capacity of pollutant discharge. A quantitative analysis for the causes of this problem was made, based on the mechanism of forming the capacity of the river to receive pollutants and on the equations for calculating the discharge of pollutants. Finally, the reaches of the Huaihe River in Huainan city were taken as an example to preliminarily study how can identify and determine the design flow of a river.

Key words: allowable discharge level, water pollutants, design flow.

Grey Systems Analysis of the Factors Affecting the Efficiency of Wastewater Treatment in Anearobic Reactors. Guo Jingsong, Long Tengrui (Dept. of Urban Construction, Chongqing Institute of Architecture and Engineering, Chongqing 630045): *Chin. J. Environ. Sci.*, **15**(4), 1994, pp. 62—65

The methods for grey systems analysis have been applied to studying the significance of each of major factors that would affect the efficiency of anearobic reactors in treating wastewater. The data from the experiments in an anearobic fluidized bed reactor were taken as an example to make a calculation analysis, resulting in a conclusion which was consistent with that based on a theoretical analysis. The results show that the use of a grey systems analysis for the factors affecting the efficiency of a biological reactor has the advantage of requiring relatively less data, as compared with other methods.

Key words: grey system, interference analysis, efficiency of wastewater treatment, anaerobic reactor, fluidized bed.

Accelerated Simplex Algorithm to Determine the Longitudinal Dispersion Coefficient in a River by Tracer Test. Zhang Jiangshan (Institute of Environmental Science, Fujian Normal University, Fuzhou 350007): *Chin. J. Environ. Sci.*, **15**(4), 1994, pp. 66—68

The accelerated simplex algorithm has been used to calculate the longitudinal dispersion coefficient in a river, as an example for which the Ynagkou reaches of the Futunxi River, a mainstream of the Minjiang River in Fujian province, was found to have a longitudinal dispersion coefficient D_2 of 2.62 m^2/s. The results show that the accelerated simplex algorithm was more effective to be used for evaluating the parameters for a nonlinear model than the nonlinear approach algorithm. This was simply because the accelerated simplex algorithm had a process of optimization in which it was not necessary to calculate the partial derivative of the goal function and was not limited by the complexity of a model so that it was easy to be calculated and widely applicable. This algorithm could be widely used to fit environmental and ecological models and to make parameters evaluation.

Key words: river water quality model, parameter estimation, longitudinal dispersion coefficient, accelerated simplex algorithm.

Effects of Fumigation with sulfur Dioxide, Nitrogen Dioxide, Ozone and Mixtures Thereof on Ethylene Emissions from Rice. Yu Fei et al. (Nanjing Institute of Environmental Sciences, NEPA, Nanjing 210042): *Chin. J. Environ. Sci.*, **15**(4), 1993, pp. 69—71

A study was carried out on the effects of fumigation with sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and mixtures thereof on the release of ethylene from rice plant being fumigated. It was found that the emission of ethylene as an internal hormone of plant increases when the crop rice is fumigated with SO_2, NO_2, O_3, or mixtures thereof. This can be considered as an indicator for the level of environmental pollution. If the O_3 level is constant, the emission of ethylene from rice is directly proportional to the levels of SO_2 and NO_2 in fumigating gases, where $O_3 + SO_2$ have a greater effect on the emission of ethylene from rice than $O_3 + NO_2$. If the total level of both SO_2 and NO_2 altogether is kept constant, an increased level of SO_2 can lead to a higher emission of ethylene than an increased level of NO_2. A fumigation with NO_2 at a concentration of 4 ppm for 2 hours has caused the leaves of rice to have bleached or yellow spots when ethylene and ethane are released at 7.70 and 2.30 $nl/g \cdot F \cdot W \cdot h$, respectively.

Key words: rice, sulfur dioxide, nitrogen dioxide, ozone, fumigation, ethylene, ethane, release.

Watercolumn Barometer without Mercury Contamination. Zhang Xiong (Dept. of Physics, Yunnan Normal University, Kunming 650092): *Chin. J. Environ. Sci.*, **15**(4), 1994, pp. 72—74

A miniatured (1.2 m long) watercolumn barometer has been developed to solve the environmental problem of mercury pollution resulted from the production and opreation of a mercury column barometer. The working principles, use methods and measurement errors of the watercolumn barometer were discussed and some aspects of its application were briefly described. This barometer can work well at 0— 3 km above sea level and at an ambient temperature in the range of 6— 40℃. The results from its measurement have a standard error of less than ± 0.9 mmHg and it can detecct a change in atmospheric pressure of ± 0.1 mmHg. This newly developed barometer is applicable to measure the atmospheric pressure in a room where there will be a less change in ambient temperature. A conventional watercolumn barometer is very difficult to be used to measure the atmospheric pressure because the pressure of saturated water vapor varies largely with a change in room temperature. The use of this new barometer can also solve this problem.

Key words: miniatured watercolumn barometer, mercury pollution, saturated water vapor pressure, ambient temperature.

Advances in Physical and Chemical Technologies for Decolorization of Dye Wastewater. Yu Gang, Yang Zhihua et al. (Dept. of Environ. Eng., Tsinghua University, Beijing 100084): *Chin. J. Environ. Sci.*, **15**(4), 1994, pp. 75—79

A review was made on the current status and development of physical and chemical technologies for decolorization of dye wastewater, including adsorption, coagulation and flocculation, chemical oxidation, ion exchange, ultrafiltration, and others.

Key words: dye wastewater, technology for decolorization, physical and chemical processes.

APPlications of Polymerase Chain Reaction to Environmental Microbiology. Hu Wenqi and Zhang Zhiguang (Department of Biology, Hunan Normal University, Changsha 410006): *Chin. J. Environ. Sci.*, **15**(4), 1994, pp. 80—83

Because of its high sensitivity, high specificity and simplicity, Polymerase Chain Reaction (PCR) has been widely used to detect pathogenic bacteria, indicator bacteria and viruses in environmental samples since its creation in 1985. A review was made on the fundamental priciples, methodology and current status of the applications of PCR to environmental microbiology.

Key words: polymerase chain reaction, environmental microbiology, detection application.

Role of Microbial Co- metabolism in the Biodegradation of Chlorinated Organic Compounds. Shen Dongsheng et al. (Dept. of Environ. Sci., Zhejiang University of Agriculture, Hangzhou 310029): *Chin. J. Environ. Sci.*, **15**(4), 1994, pp. 84—87

Biochemical mechanism of microbial co-metabolism, progress in its research, and its role in the biodegradation of chlorinated organic compounds were dealt with in this article. The prospect of microbial co-metabolism, a biological process which has not yet been fully understood, to be applied in the treatment of refractory compounds such as chlorinated organic compounds was also suggested.

Key words: co- metabolism, chlorinated organic compounds, biodegradation.