**Evaluation of the Electronic Bubbler Gas Monitoring System for High Flow in the
BaBar Detector**

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ABSTRACT

Evaluation of the Electronic Bubbler Gas Monitoring System for High Flow in the BaBar Detector. ANGELA LITTLE (Seattle Pacific University, Seattle, WA, 98119)
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We evaluated the gas monitoring system in the Instrumented Flux Return (IFR) portion of the BaBar detector at the Stanford Linear Accelerator Center (SLAC) to determine its suitability for flows greater than 80 cc/min. Future modifications to the IFR involve particle detectors with a higher gas flow rate than currently in use. Therefore, the bubbler system was tested to determine if it can handle high flow rates. Flow rates between 80 and 240 cc/min were analyzed through short term calibration and long term stability tests. The bubbler system was found to be reliable for flow rates between 80 and 160 cc/min. For flow rates between 200 and 240 cc/min, electronic instabilities known as baseline spikes caused a 10-20% error in the bubble rate. An upgrade would be recommended for use of the bubbler system at these flow rates. Since the planned changes in the IFR will require a maximum flow of 150 cc/min, the bubbler system can sufficiently handle the new gas flow rates.

INTRODUCTION

The BaBar collaboration at the Stanford Linear Accelerator Center (SLAC) is currently in the process of upgrading the Instrumented Flux Return (IFR) portion of their detector. The Resistive Plate Chambers (RPC's) currently installed on the central or barrel portion of the detector will be replaced, starting in 2004, with Limited Streamer Tubes (LST's). To operate properly, both systems require a specialized gas mixture flowing through them [1]. However, the flow rate required by the new LST's is approximately three times the flow rate that is currently supplied to the RPC's. In addition, the RPC's located on each end of the detector will have an increased gas flow rate to improve their function. A portion of the existing gas system was evaluated to determine whether or not it can operate effectively at higher flow rates.

Gas flowing from each RPC is currently measured by an electronic digital bubbler system. The flow from each RPC is determined by allowing the gas to bubble up through a fluid and then counting the number of bubbles per second. The existing system has been extensively tested at flow rates in the range of 20 to 80 cc/min. Our purpose is to evaluate whether the digital bubbler system can function properly when the flow rate is increased to between 80 and 240 cc/min.

Short duration calibration tests were run by increasing the flow from 80 to 240 cc/min in 20 cc/min increments. Flow rates and the corresponding two-minute average bubble rate counts were recorded in a computer file for later analysis. In addition, the electronic signal from each channel was examined on an oscilloscope to determine if the bubble counts were being affected by system noise or instabilities introduced by the high

flow rates. As well, since previous studies have indicated that the bubbler system is sensitive to significant changes in temperature, the temperature of the test apparatus was controlled and continually monitored during each test.

In addition to the short duration calibration tests, it was necessary to determine the long term stability of the digital bubblers at higher flows. Four hour stability tests were performed at flow rates between 80 and 240 cc/min. Two-minute average bubble rate data was collected every 10 minutes during these tests. The temperature of the test apparatus was also controlled and monitored during each test.

MATERIALS AND METHODS

Description of Electronic Bubbler

Each digital bubbler can monitor the flow from up to 16 individual RPC's. However, it was not possible to test all 16 channels as only four flow meters were available to provide flows in the desired range. Compressed air flowed through two pressure regulators and into the four flow meters to achieve an adjustable flow rate with a maximum output of 250 cc/min for each channel. Compressed air was used rather than the typical Argon gas mixture used in the RPC's. The tubes from the meters were connected directly to the four channels used on the electronic bubbler.

The bubbler apparatus (Fig. 5) consisted of an aluminum chamber filled with 38 cc's of Dow Corning 704 Diffusion Pump fluid and a small amount (approximately 30:1) of mineral oil. The electronic bubbler system in the IFR currently uses 28 cc's of this fluid mixture. The increased amount of fluid was chosen because previous studies have indicated that a higher amount of oil in the chamber improves electronic stability.

As the compressed air flows through the four channels and into the oil-filled apparatus, bubbles are created. Photogates installed inside give an electronic read-out of the bubble rate. More specifically, bubbles created by the compressed air in the oil pass through the photogate and disrupt the photons emitted by the infrared LED from hitting the phototransistor (Fig.1). A voltage gain is then read out into the Discriminator Circuit (Fig. 2). The idea of using photogates to measure the bubble rate was originally proposed by a group from Princeton University in 1998 [2], and a similar system is installed on the Belle detector in Japan.

An example of the bubble rate signal as read out at a testpoint is shown in Figure 3. The first spike in the signal is due to the top of the bubble passing through the photogate. The voltage drop in the middle of the signal correlates to the middle of the bubble passing through the photogate, which allows more photons to pass through to the phototransistor. This will be referred to as the “valley” of the photogate output signal (V_{out}). Lastly, the second voltage spike comes from the trailing edge of the bubble. As long as V_{out} is greater than the threshold voltage of 1.1V, the discriminator circuit generates a square wave TTL signal. It is important to note that the valleys of the V_{out} signal need to be adjusted higher than the threshold voltage otherwise they will produce false bubble counts. Since the voltage signal needed to be converted from TTL to a negative MECL signal, the MC10124P converter chip was used. The MECL signal was read out by the DAQ and the bubble rate was then readout to on a local computer for future analysis.

The photogate circuit has a testpoint at C that can be read out on the front panel of the bubbler itself. The testpoint was connected to an oscilloscope to monitor the signal

for any electronic instabilities that might occur. In addition, different flow rates resulted in different V_{out} 's from the photogate. A means of adjusting this voltage was implemented through the front panel. It had a screw connected to the variable resistor in the photogate circuit through which V_{out} could be adjusted.

Calibration and Stability Test Description

To run calibration tests, the temperature was brought up to roughly 31.0° C and kept within a two-degree range for the duration of the test. Temperature was monitored through a temperature sensor mounted onto the electronic bubbler and read out through the BaBar DAQ on a local computer. The valleys of the V_{out} signal were adjusted to 1.5 V at 120 cc/min. The flow from the meters was set at 80 cc/min and a two-minute long test was taken to determine the bubble rate. The test was repeated up to a 240 cc/min flow in increments of 20 cc/min. As the flow was increased, the signal was adjusted to remain similar to that shown in Fig. 3. Both temperature and time were recorded in addition to the bubble rate. Five separate calibration tests were run.

To run stability tests, the temperature was again stabilized to 31.0° C and kept within a two-degree range. V_{out} was set to around 1.5 V at each specific flow. Flow rates of 80, 100, 160, 200, and 240 cc/min were each tested. Tests consisted of four hour long runs in which a two-minute test of the bubble rate was taken every ten minutes. Before each test was taken, V_{out} was monitored for each of the four channels on the oscilloscope to check for any electronic instability. The meter readings were also checked at this time to determine if there had been any fluctuation in the compressed air flow. If the meter readings had changed or become unstable, they were adjusted before the next test was taken.

RESULTS

One channel of data had to be thrown out for analysis purposes since one meter became unstable during testing. Figure 7 shows the combined data from the five calibration tests. The graph of flow rate vs. bubble rate is linear to a good approximation between flow rates of 80 and 240 cc/min.

Figure 8 compares the stability data from each of the five tests. Ideally, the stability graph for each flow should be a straight line. A chi-squared fit was used to determine how close the actual graph came to a straight line. Table 1 shows the result of the chi-squared fit. A0 is essentially the average bubble rate, while A1 is the slope and would be zero if the graph were in fact a horizontal flat line. The chi-squared value is given as an estimate of the reliability of the fit. Bubble rate fluctuations of 0.2 counts/sec or less were likely due to instabilities in the compressed air and the experimental set-up.

Some electronic instabilities were observed that caused error in the bubble rate at specific flows. Instabilities thirty minutes in duration in which the signal jumped up roughly one volt were observed at the 80 and 160 cc/min flow rates. At 80 cc/min, this signal jump did not create any error. However, at 160 cc/min, the signal jump allowed more baseline spikes to cross the threshold voltage, creating an error in the bubble rate. Instabilities in which the signal periodically jumped up for shorter periods of time (<5s) were observed at a flow rate of 240 cc/min. No electronic instabilities were observed in which the signal jumped down.

While not yet confirmed, we believe signal jumps to be a result of small bubbles in the oil attaching themselves to the photogate. This would explain the fact that the

signal jumps were only temporary. As the small bubble later detached from the photogate, the signal would again become normal.

Baseline spikes (Fig. 4) were the primary electronic instability that created error in the bubble count. These spikes occurred much more frequently at higher flows and led to a greater spread in the bubble rate data for each point. Table 1 shows the progression of baseline spikes greater than 1.0 V as the flow rate was increased. At lower flows (80-100 cc/min), there were little to no baseline spikes. However, at rates such as 240 cc/min, the bubble rate was affected by close to 20%.

DISCUSSION AND CONCLUSION

To gauge whether or not the electronic bubbler system is acceptable for use at high flow rates, it must first be determined if there is a limit for the bubble rate that the system is able to read. As the flow rate is increased, the bubble rate should never remain the same. If this were to occur, the bubbler system would have a maximum readable bubble rate. Since the calibration graph (Fig. 7) stays roughly linear with a positive slope, the system does not appear to have a maximum bubble rate between the flow rates of 80 and 240 cc/min.

Flow rates lower than 80 cc/min have been extensively tested, and it has been determined that the calibration graph for flows between 20 and 100 cc/min has a slope almost twice as large as the slope for flows between 80 and 240 cc/min (Fig. 8). This decrease in slope as flow rate increases is undesirable since it makes the bubbler less efficient at discriminating between different flow rates. However, between 80 and 240

cc/min, the system has enough difference in bubble rate to distinguish properly between different flow rates.

Most importantly, however, is the stability of the bubbler system for long periods of time. If there are too many electronic instabilities, a false bubble rate will be generated and the bubbler system will become useless. Between flow rates of 80 and 160 cc/min, the system fluctuates about 0.3 cc/min, which is close to within the error created by our experimental set-up. Table 3 also shows that the bubble rate begins fluctuating more in the range of 200 cc/min-240 cc/min. At 240 cc/min, the greatest fluctuation in bubble rate is 1.301 counts/sec. While this is more than lower flow rates, this only corresponds to a maximum error of 9.25% in the flow rate. The bubbler system functions adequately under the stability test since fluctuations in the bubble rate lead only to very low error.

Electronic instabilities known as baseline spikes were detrimental to the bubbler system. At times, these spikes would cross the threshold voltage of 1.1V, creating false bubble counts (Table 2). At flows between 80 and 160 cc/min, the error due to baseline spikes is negligible. However, for flow rates upwards of 200 cc/min, the bubble rate becomes affected by about 10-20%. Thus, a system upgrade would be recommended for these flows.

A working hypothesis for the cause of the baseline spikes involves foaming from the oil inside the apparatus. We observed more small bubbles passing through the photogates at higher flows. While this hypothesis has not yet been confirmed, these small bubbles could have created an output voltage from the photogate that would disrupt a clear baseline signal.

Since the new LST system will operate at around 90-135 cc/min, the bubbler system can easily handle the change from the lower flowing RPC's. Furthermore, the highest flows planned in the near future for remaining RPC's is 100 cc/min. This is also well within the acceptable operating range that the bubbler system can handle. Therefore, for the near future IFR applications, the electronic bubblers are an efficient gas flow monitoring system.

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REFERENCES

- [1] Harrison, P.F. and Quinn, H.R, eds. *The BaBar Physics Book*. Stanford Linear Accelerator Center. SLAC Report 504. 1998.
- [2] Ahart, M., et al. “Flow Control and Measurement for RPC Gases”. Princeton University. KEK Belle Note #135. July 1998.

TABLES

Flow Rate (cc/min)	A0	A1	CHISQUARE
80	8.0319	-2.1953E-05	0.4932
100	8.9773	4.6082E-04	0.7226*
160	11.154	-1.2683E-04	0.7692*
200	12.741	1.0493E-04	0.5544
240	13.899	1.0720E-03	0.5251

Table 1. Stability Test Linear Fit Data. *Higher Chi-square values are due to systematic errors related to sudden changes in flow rate and are not indicative of greater fluctuation.

Flow Rate (cc/min)	Baseline Spikes > 1.1 V (#/bubble signal)
80	n/a
100	n/a
120	1/60 – n/a
140	1/60 – n/a
160	1/20 – 1/100
180	1/20 – 1/40
200	1/10 – 1/25
220	1/10 – 1/15
240	1/6 – 1/10

Table 2. Average baseline spikes > 1.1 V during calibration tests. Both the high and low values are given.

Flow Rate (cc/min)	Absolute Value of Maximum Bubble Rate Fluctuation (count/sec)	Maximum % Error in Flow Rate
80	0.3319	4.12%
100	0.3227	3.56%
160	0.446	4.01%
200	0.659	5.16%
240	1.301	9.25%

Table 3. Maximum bubble rate fluctuation from stability graph and relation to % error in flow rate.

FIGURES

Figure 1. Photogate Circuit.

*Some aspects of circuit diagrams are from
<http://www.hiviz.com/tools/triggers/makeown.htm#pg>

Figure 2. Discriminator LM339N Circuit.

Figure 3. Normal signal from photogate output.

Figure 4. Signal from Photogate Output at 240 cc/min. Baseline spikes are circled.

Figure 5. Front pannel of Digital Bubbler System mounted on a rack.

Figure 6.

Figure 7.

Figure 8.