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Inconsistency in gravimetric sampling pumps and cyclones

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ABSTRACT: The elimination of the incidence of silicosis in employees in industries such as mining and pottery is an ongoing international initiative. After many decades of industrial activity in these industries and many dollars spent on preventative measures, silicosis is still occurring. The exposure-prevention measures taken so far have certainly improved the working environment dust concentrations; however, the illness is still regularly diagnosed in workers. More funding is needed for interventions to improve working conditions. Many aspects of dust prevention and suppression will be researched and exposure assessment methodologies and equipment will need to be reviewed for the purposes of improvements in effectiveness. This paper presents results from laboratory tests carried out on gravimetric sampling pumps and cyclones. It highlights the erratic flow produced by gravimetric pumps of three different manufacturers who claim their respective pumps are equipped with flow stabilisers. The standard BS EN 1232:1997 is used as a basis for the tests. A method, albeit impractical for fieldwork, is shown for the elimination of the pulsation in the flow. This method serves to prove the method and protocol used in this study. The pressure loss caused air-flow resistance of cyclones is measured. The air inlet aperture size of cyclones is measured. The large discrepancy in the two criteria between individual cyclones is shown. The paper concludes that all the pumps tested failed the prescribed limits of BS EN 1232:1997 regarding the pulsation of the gravimetric sampling flow. The difference in flow characteristics of the cyclones, together with the erratic flow produced by the pumps, throws into question the accuracy of the exposure assessments. It is suggested that substantial resources be channelled towards solving these flow problems in parallel with measures taken to reduce exposure. In principle, the accurate assessment of exposure and dust concentration levels is a prerequisite for effective management of the problem of silicosis.

1 Introduction

An international initiative to eliminate the incidence of silicosis in mine workers and in other silica-related industries has been initiated and is a brave, commendable step.

The accurate measurement of exposure levels is essential for the management of the incidence of silicosis. If accurate measurement of dust concentration in air is not possible then the evaluation of exposure or remedial action efficacy cannot be carried out with confidence.

Two of the crucial components used for measuring are the gravimetric sampling pump and the cyclone. The flow of air through the cyclone is of utmost importance for accurately establishing which fraction of the dust to which employees are exposed is actually respirable. The flow rate and also the consistency of the flow are important. Inconsistent flow through the cyclone will result in unpredictable results.

Improved electronic instrumentation makes the rapid and accurate measurement of the air-flow-rate possible. Flow measuring instruments capable of measuring at a frequency of 1000 readings per second were used for this project.

Gravimetric sampling pumps from three different suppliers were examined in the study. All three suppliers claim that their pumps are fitted with flow stabilizers. When compared to the requirement of BS EN 1232:1997 all three grossly exceeded the maximum allowable pulsation of 10% of the average.

Cyclones of a type generally used in the mining industries in South Africa were tested. The pressure loss of the air passing through the cyclones was measured with an electronic micro-manometer. The results show a vast difference in pressure loss, which indicates differences in construction dimensions of the cyclones.

2 Laboratory Equipment Used

2.1 Flow Meter

The flow meter used is shown in Figure 1. The design of the instrument is based on the hot wire principle. A valid NIST certificate of calibration was available for the flow meter. Flow readings were taken from the flow meter with a computer through an RS232 interface and the Microsoft HyperTerminal communication software. The readings were taken at 1000 per second.

Three identically calibrated instruments were coupled in series with a gravimetric sampling pump. At a flow of 2.0 l/m all the readings obtained, simultaneously from the three flow meters, were within 5% of the minimum.

A set of readings was also taken from the flow meter with both inlet and outlet ends blocked off. The purpose was to establish the presence of electronic "noise".

Figure 1 Hot wire flow meter

The results are shown in Figure 2. The electronic noise is negligible in relation to the test flow rate and is therefore not considered further as it does not have a discernable effect on the results.

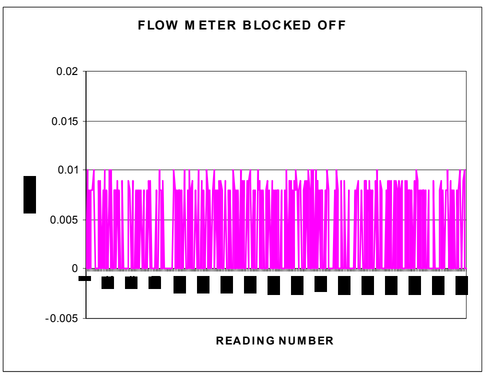

Figure 2 Readings from blocked off flow meter

2.2 Micro-Manometer

The electronic digital micro-manometer used for measuring pressure differences is shown in Figure 3. It was verified against a U-tube manometer. The pressure readings were recorded manually.

2.3 Flow Stabilizer in Laboratory

A simple improvised flow stabilizer was incorporated in the flow test train in the laboratory. The purpose of this was to demonstrate the presence of the pulsation in the flow and the reliability of the equipment. (See Figure 4.)
This flow stabilizer consisted of an empty five-liter vessel installed in the flow train immediately upstream of the pump. This flow stabilizer is obviously impractical for field personal or positional sampling. Figures 5 and 6 show the flow without and the flow with damping at 0.8 l/m, 1.2 l/m, 2.0 l/m and 2.5 l/m.

Figure 3 Micro-manometer

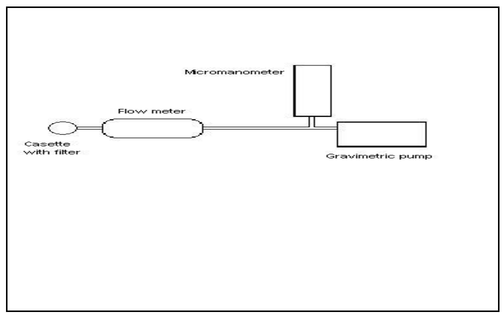

Figure 4 Pump flow test train

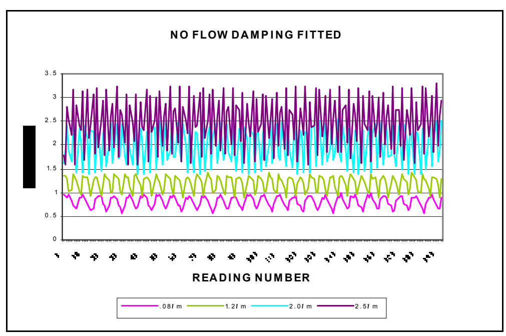

Figure 5 Flow without damping

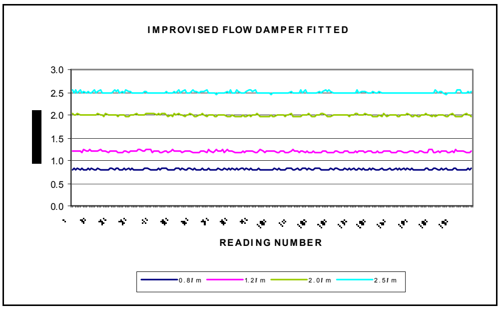

Figure 6 Flow with damping

3 Test Methodology

3.1 Gravimetric Sampling Pump Tests

A flow measurement train was set up as per Figure 4 in accordance with BS EN 1232:1997. It is important to note that BS EN 1232:1997 states that the flow is to be maintained within the 10% limit throughout the sampling period. There is, however, no specification for the measurement method with respect to measurement frequency or duration.

A filter was used to present the pumps with a resistance that resulted in pressure of 1.6 kpa at 2.0 l/m, which represents a typical sampling condition. Flow measurements were taken at a rate of 1000 per second. Several pumps from each of three different independent manufacturers were tested at the same flow rates in the same measurement train.

The pumps were calibrated at a flow of 2.0 l/m. The pumps were connected to the test train and left running to stabilize for at least five minutes. The flow rate readings were then taken and the pressure recorded simultaneously.

The flow meter used has a stabilization period of 4 ms. Readings were taken at 1 ms intervals. The result is a profile, which is “softened”. The negative and positive peaks have in fact been reduced. The line-graphs in the Figures 5 and 7 are therefore not representative of the actual extent of the pulsation and the reality is in fact even worse.

3.2 Cyclone Tests

The test train was set up to measure the air pressure loss through the cyclone at a specific flow rate. Air-flow of 3.5 l/m was drawn through the cyclones and the pressure loss recorded.

The air temperature and barometric pressure were also recorded for the purpose of calculating the air density.

The air inlet aperture size of all the cyclones was physically measured using a micrometer.

4 Results

4.1 Gravimetric Sampling Pump Test Results

Pumps from three different independent manufacturers were tested. The flow characteristics of pumps from the same manufacturer were basically the same. The flow characteristics of pumps from different manufacturers were different, mainly as a result of the difference in speed (revolutions per second) at which the pumps were running. The difference in pulsation in the flow of the pumps of different manufacturers was, however, small. The pumps were calibrated at 2.0 l/m. Figure 7 shows the flow measured. The average flow is indicated as well as the maximum deviation tolerated, i.e. 10% below and above the average as stipulated by BS EN 1232:1997. It can be seen that the flow is outside the limits for a substantial portion of the sampling time. In fact 77% of the readings exceeded the limit.

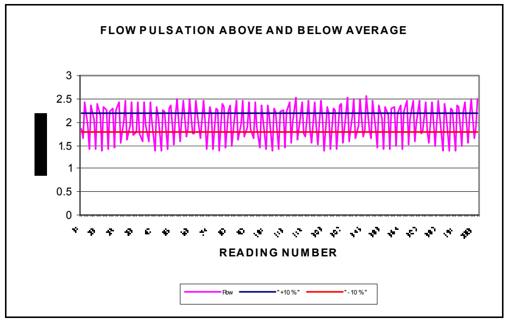

Figure 7. Flow pulsation at average of 2.0 l/m

Traditionally air-flow measurement by soap-bubble method provides an average measurement over the period taken by the bubble to travel the length of the tube. More rapid measurements revealed inconsistencies in flow, which had previously been masked.

4.2 Cyclone Test Results

The results of the determination of the pressure loss for each individual cyclone are shown in Figure 8.

The air-flow rate through the cyclones was kept the same during the tests. The difference in pressure loss therefore indicates a difference in construction dimensions resulting in a difference in air velocity as the air passes through the cyclone. The different velocities would result in different dust separation profiles. Higher air velocity would result in more and smaller particles being removed from the air.

5 Conclusion and Recommendation

It is concluded that the flow measurements indicate that all the pumps tested had pulsation in air-flow, which would adversely affect the accuracy of the samples taken with these pumps in conjunction with cyclones. The cyclones tested were different in construction to the extent that the accuracy of size separation of samples taken with these cyclones was questionable. The combination of the irregular sampling flow rates and the major differences found in the cyclones’ characteristics can only have

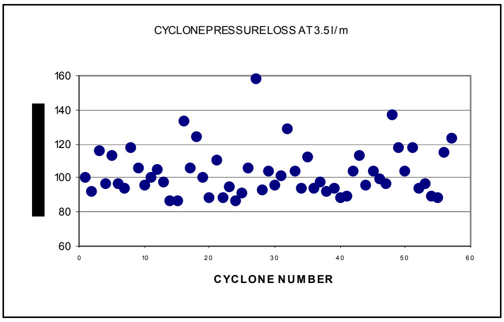

Figure 8 Pressure loss of individual cyclones at 3.5 l/m

Figure 9 graphically shows the difference of the air inlet aperture areas of the cyclones tested.

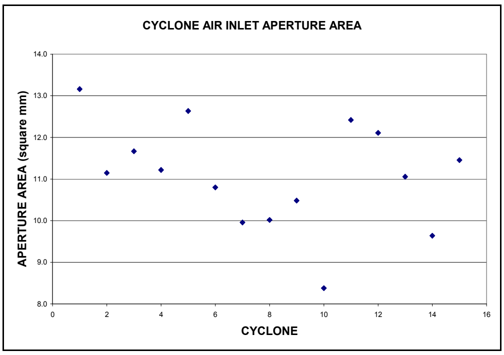

Figure 9 Cyclone air inlet aperture area

unpredictable effects on the results of the sampling.

It is recommended that BS EN 1232:1997 be revised to include an improved specification of air-flow profile and for appropriate air-flow measurement of pumps. Gravimetric sampling pumps should be re-engineered to minimize air-flow pulsation. Urgent attention should be directed at designing pulsation dampers suitable for field use until improved pumps are available.

A performance standard is to be compiled for each type of cyclone. Cyclones are to be tested individually and certificates issued to end users to assure quality.

The fight against the occurrence of silicosis cannot be won if the exposure to silica cannot be measured accurately and with confidence.

Reference

BRITISH STANDARD BS EN 1232:1997. Workplace atmospheres – Pumps for personal sampling of chemical agents – Requirements and test methods.