

A Plant Monitoring and Density Gauge Calibration Device

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ABSTRACT

This paper describes the development and ‘proof of concept’ testing of a device for monitoring of magnetite slurry density for calibration purposes. The device provides an on-line measurement of density and magnetite content and has dimensions of 90x70x45 cm with a mass of 14kg. The inlet hose attaches to an existing “quick connect” sampling port to allow medium to continually flow through the device. There are no breaks or connections in the length of the hose to prevent capture of magnetite and to simplify replacement of the hose if required. The medium continually flows through the device which measures the total density and magnetite content.

The density is calculated by measurement of the mass of the hose in which the medium is flowing. To achieve this measurement, a length of hose to attain a volume of 2.14 litres is coiled around an arm of a load cell. A fast acquisition of the load cell signal is averaged to provide a mass measurement of resolution less than 5 grams resulting in a resolution of ± 0.002 in relative density measurement.

The hose also passes through an induction coil to allow measurement of the magnetic susceptibility. The magnetite fraction is calculated using the mass and magnetic susceptibility measurement. A radiation density gauge, “densiMag” density gauge and physical sampling were used to test the accuracy of the device. The gauge is able to run continuously in the high vibration environment of the Coal Preparation Plant.

INTRODUCTION

There are three ways in which feed medium density is commonly measured on-line in dense medium plants:

- By a nuclear density gauge mounted on the feed pipe
- By a pair of pressure sensors mounted on a separate tester leg
- By magnetic susceptibility (Cavanough, Holtham & Powell, 2008).

The calibration of these gauges relies on taking a spot sample and then measuring the mass of the sample. This procedure requires manual handling of media and gives a limited number of calibration readings due to the labour required to acquire, transport and then measure the samples. The motivation for the development of the device described in this paper is to provide a large number of calibration readings and reduce the requirements for manual handling.

It was also decided to provide a measurement of the magnetite content in addition to relative density to provide an indication of other components in the slurry. Consequently the following four functions were required to be provided by the device:

- Measurement of total mass of the medium sample.
- Measurement of total volume of the medium sample.
- Establishment of medium flow through the device without blockages.
- On-line measurement of magnetite content.

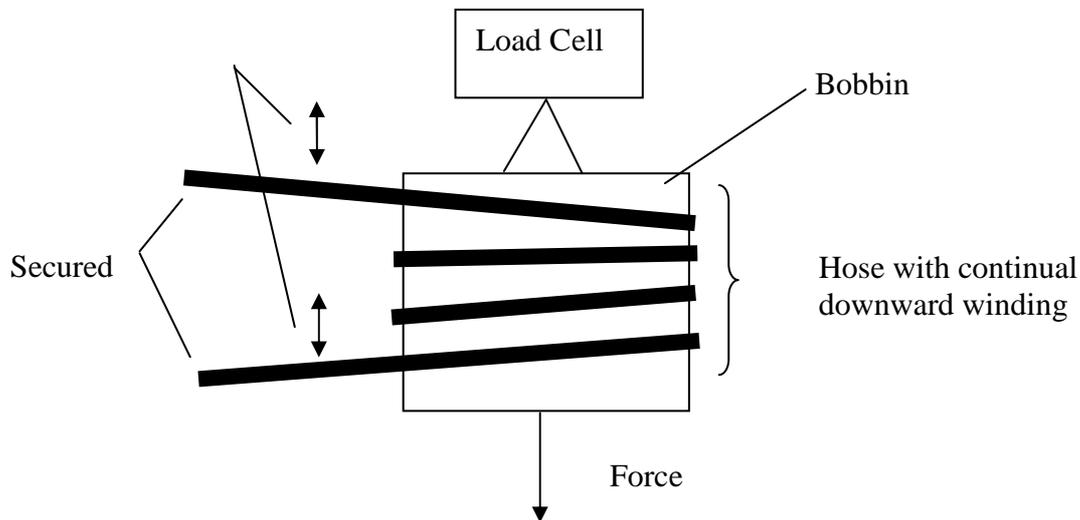
Each of these functions will be discussed in this paper in addition to the results of plant trials and the conclusions.

TOTAL MASS MEASUREMENT

It was decided to use a load cell to achieve mass measurement. Vibration was identified as a major problem with this measurement. A vibrating test bench was used to test the load cell performance in the laboratory. It was found that using high speed sampling of the highly variable signal provided a resolution of <2 g when a moving average was applied. It was concluded that the load cell would be able to give an accurate measurement in the coal preparation plant.

TOTAL VOLUME MEASUREMENT

The next task was to maintain a constant volume of slurry in the chamber suspended from the load cell. To achieve this a 'bobbin' was attached to the load cell and a 25 mm ID hose was wound around the bobbin. The hose was wound to provide a downward spiral to prevent build up of magnetite (refer to Figure 1). The hose was secured at either end of the bobbin. To eliminate errors in the mass measurement due to hose deformation (i.e. when the hose is twisted there is an inherent force that will oppose the twisting motion), the hose was positioned so that movement would be an uncoil type motion with very little resulting tangential force (refer to Figure 1). It should be noted that the actual movement caused by filling the hose with media was only tenths of millimetres.



**Figure 1. Schematic of the device showing path of hose.
Medium flow.**

ESTABLISHMENT OF FLOW

Establishing a continual flow of medium was identified as the most difficult task. The primary aim was to limit any 'back-pressure' to prevent blocking the sampling port. To achieve this a 25 mm diameter hose was used in a configuration to provide a continual downward flow of medium. The pipe diameter was chosen to both maintain flow velocity (to prevent solids dropping out) and allow adequate pipe diameter to prevent particles from bridging together to block the hose.

To measure the density a constant volume has to be maintained in the pipe. This is normally achieved in applications with fluids by elevating the drain pipe to maintain the level above the sample chamber. Unfortunately this would not work for heavy media as the resulting back-pressure would cause blockages. Due to experience the authors expected that the pipe should remain full without the need to elevate the pipe. The confirmation of this would be made during plant trials by observing any differences in readings with the outlet above and below the bobbin (an elevated pipe will ensure the bobbin pipe is full of medium).

ON-LINE MEASUREMMENT OF MAGNETITE CONTENT

Magnetic susceptibility provides an accurate measure of the magnetite content of a sample (Cavanough, Holtham & Powell 2006). For this application an induction coil device was used as the sensor. A 40 mm diameter coil that was 80 mm long was wound and used to encircle the 25 mm ID pipe. The resulting magnetic susceptibility reading was calibrated to provide a measure of the total mass of magnetite within the volume of the pipe.

CALIBRATION

Mass calibration was achieved by placing mass calibration standards on the spool and recording the resulting voltages from the load cell. A calibration equation was derived and implemented in the computer data logger. A 12 bit analogue to digital converter achieved a resolution of ± 1 mV. This equated to a mass resolution of ± 5 grams and relative density resolution of ± 0.002 .

Magnetite mass calibration was achieved by mixing five calibration samples of different magnetite masses and measuring their magnetic susceptibility. The calibration samples were made from mixing the magnetite samples with silica sand to achieve equal sample volumes. Using the relationship between the volume of the hose and the volume of the calibration samples, the total mass of magnetite that would be contained in the hose (with regard to each calibration sample) was calculated. These values in addition to the magnetic susceptibility readings were used to generate the calibration equation implemented in the logging computer.

PLANT TRIALS

Figure 2 shows the prototype gauge during the plant trial. The gauge was installed and run for over 60 minutes. Figures 3 and 4 show the slurry discharge and the sampling port connections respectively. The sample port is situated at the bottom of the U-tube. It is evident from the agreement of the result with that of the densiMag, radiation gauge and spot samples that there was no sample bias between the different measurement methods and devices.

A 100 g calibration mass was placed on the spool before the sampling port was turned on to confirm calibration.

The hose was configured to allow the continual downward flow of medium and the slurry ran through the test rig without blockages for approximately 30 minutes. The hose was then elevated and the flow continued for approximately 10 minutes before a blockage occurred. The hose was lowered to the original position and the blockage cleared. The flow continued uninterrupted for the rest of the trial. The purpose of elevating the hose was to determine if the hose was not completely full of medium when the hose was in the low position. This would have been detected by a change in the mass reading when the hose was elevated.

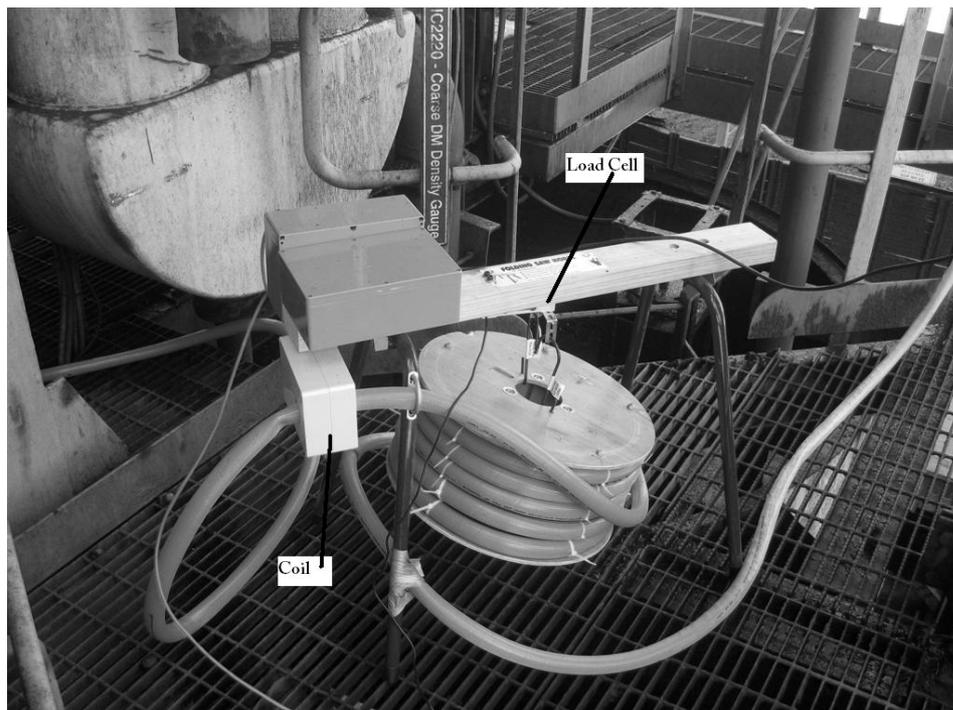


Figure 2. Device in plant trial

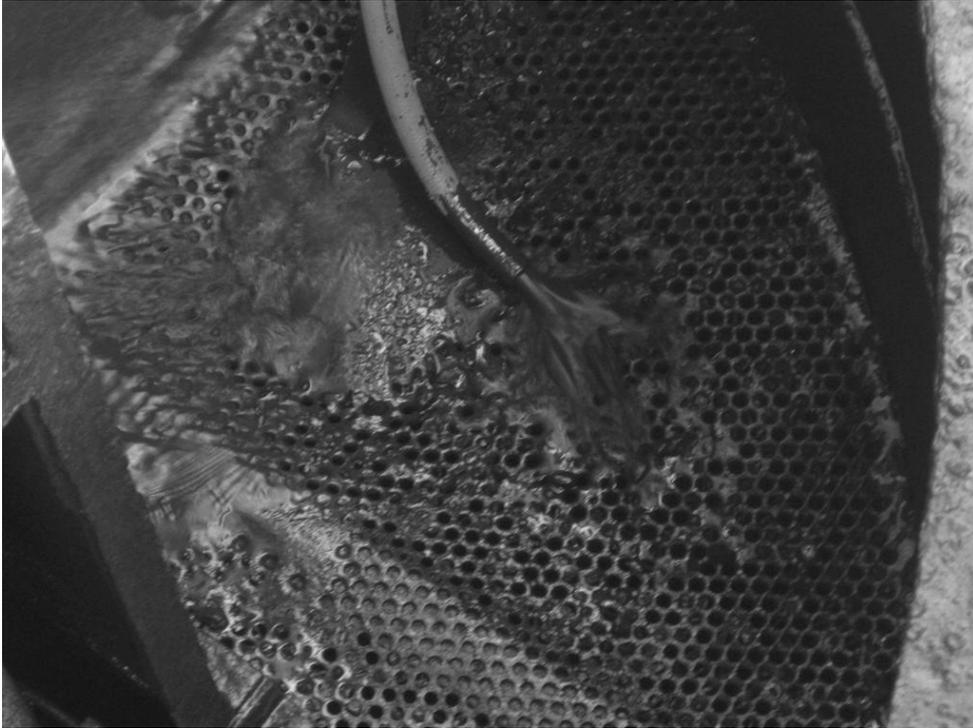


Figure 3. Slurry discharge



Figure 4. Connection to Sample Port



Figure 5. densiMAG magnetic density gauge and nuclear density gauge (at up and down side of a U tube).



Figure 6. densiMAG magnetic density gauge showing ceramic probe that is inserted into sample port.

RESULTS

Figure 7 shows the raw and averaged signal when the 100 g calibration mass was placed on the bobbin. Figure 8 and Figure 9 compare the relative density and magnetite mass measurements for the hose at the low and high

position. The low position provided a continual downward flow and the high position caused the fluid level to be above the coiled hose. The nuclear gauge, the densiMAG density gauge (refer to Figure 5 and Figure 6), spot samples and the calibration device all gave an average RD of approximately 1.48. It should be noted that the nuclear gauge had been recently installed and calibrated by taking physical samples. Previous to the trial the densiMag was calibrated to the radiation gauge reading. The densiMag is calibrated in the factory with a subsequent field calibration consisting of a minor offset adjustment. Offset adjustment is required to compensate for the signals that the pipe induces in the detection probe. Figure 10 shows a typical plot of the densiMag and radiation gauge measurements.

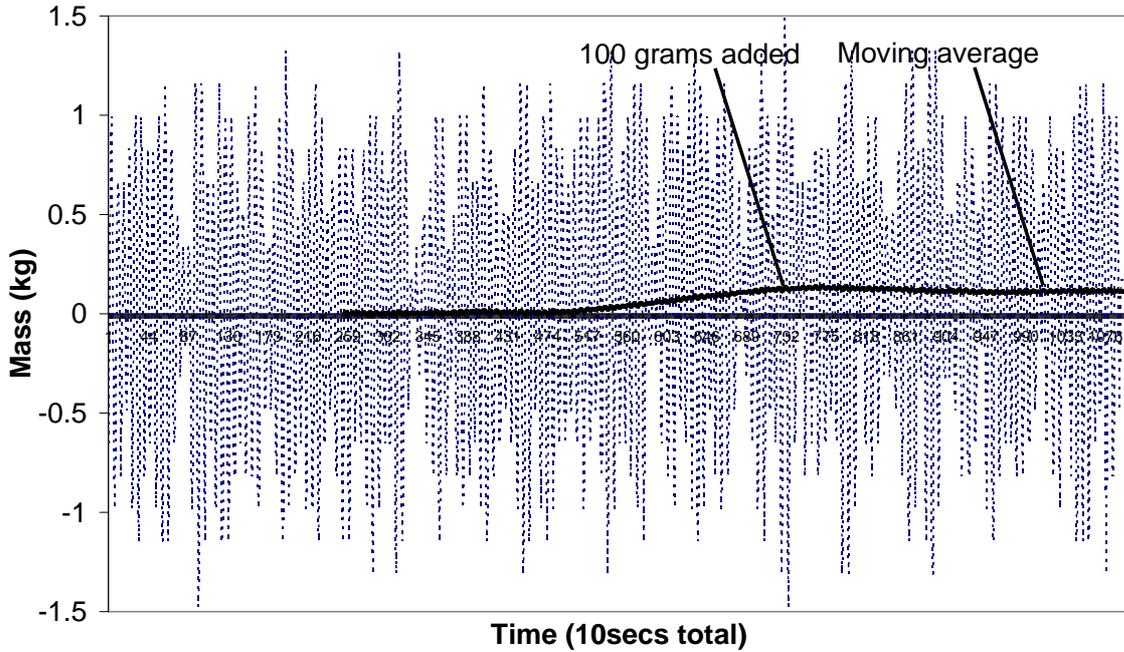


Figure 7. Raw signal and moving average showing results of placing 100 g calibration mass onto spool.

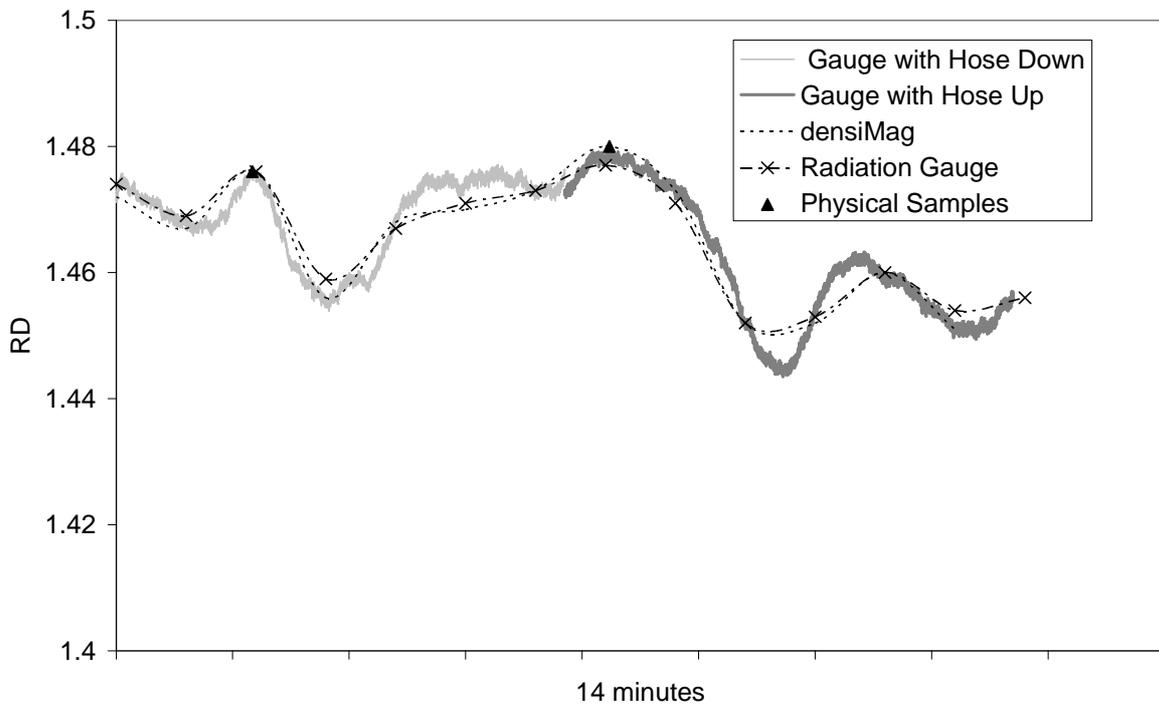


Figure 8. Comparison of RD measurement with drain hose up and down.

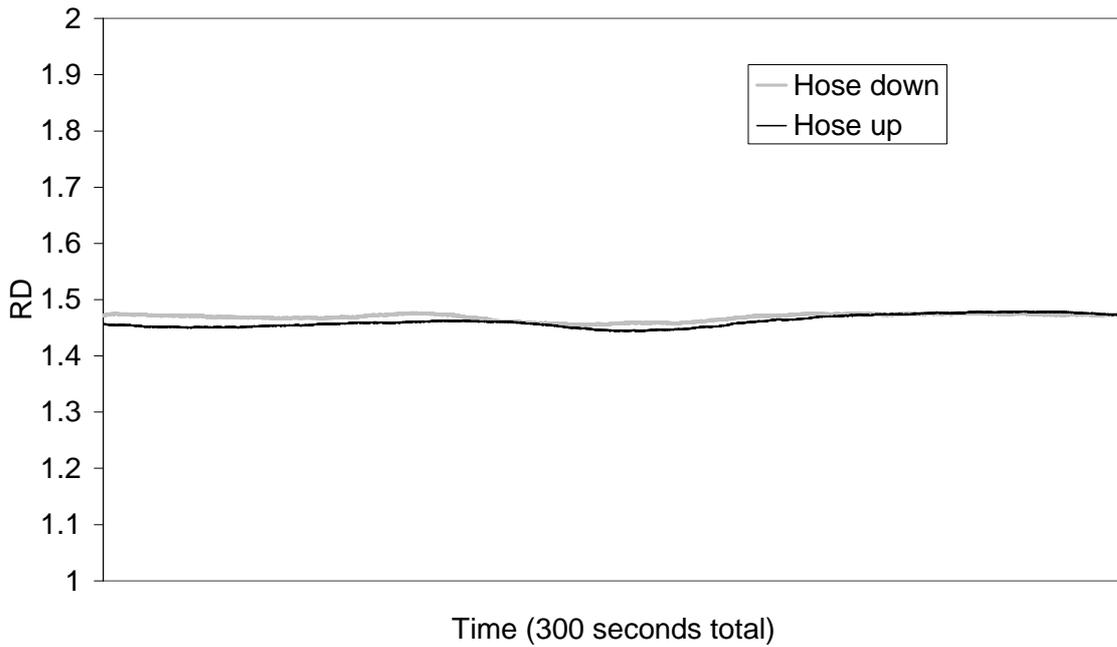


Figure 9. Comparison of magnetite mass measurement with drain hose up and down.

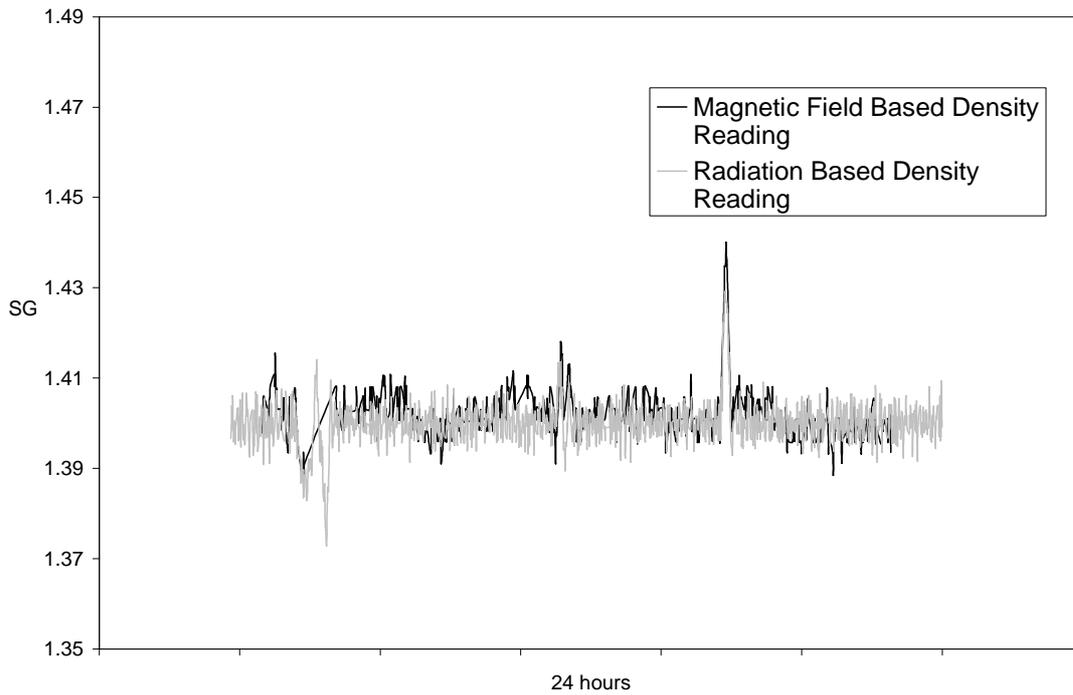


Figure10. Comparison radiation gauge and densiMag.

CONCLUSION

A load cell is able to provide an accurate measurement in the high vibration environment of the coal plant (refer to Figure 7). It has been demonstrated that a full volume measurement can be achieved without elevating the hose above the level of the weigh scale sample chamber (refer to Figure 8 and Figure 9). It has also been shown

that a relatively long term flow of medium through a sampling port can be achieved by ensuring minimum back pressure at the sample port.

The coal plant at which the trial was conducted had a newly installed and calibrated nuclear density gauge and a densiMAG magnetic susceptibility type density gauge installed (refer Figure 5 and Figure 6). The average RD from both these devices and manual tested spot samples all gave a relative density of 1.48. This was in agreement with the calibration device. The calibration device was calibrated in the laboratory and subsequently provided the correct reading in the plant; therefore, the successful operation of the gauge has been demonstrated with a resolution of 0.002RD.

FUTURE WORK

This paper has described a proof of concept test of the calibration device. The next stage of the development is to:

- Decrease the size of the device and provide housing.
- Install a 3 way valve with a connection to water. This will enable water flushing on completion of test work.
- Install a sparge type flush probe integral to the “quick connect coupling” that is inserted into the sample port. This will be plumbed to allow water flushing to clear a blocked sample port. (This is required as the sampling ports are sometimes blocked before the device is even connected.)

REFERENCES

Cavanough G.L. Holtham P.N. & Powell T.M. 2008 “Medium Density Measurement without the Need for a Gamma Ray Source”, Australian Coal Preparation Society 12th Conference, Darling Harbour, Sydney NSW

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