DRAFT REPORT

CONFIDENTIAL

Title	**:**	**Evaluation of Flow Sensors for Hatch Africa**
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Symbols

KW	kilo Watt
Mm	millimeter
M	meter
m/s	meters per second
%	percentage

1 Introduction

CSIR Miningtek's Kloppersbos test facility was tasked by Hatch Africa (Pty) Limited to compare the functionality of three different type of flow meters.

Two of the sensors work on the principle of vortex shedding and the third on temperature variations due to flow.

All the sensors are tested against a fixed set of criteria to enable for a quantitative assessment of the operational functionality of the sensors to be made.

2 Aim of the Evaluation

The aim of the evaluation is to qualitatively and quantitatively evaluate the sensors against a fixed set of criteria.

The instruments are to qualitatively assessed against the following criteria:

- Measuring range
- Display
- Mounting / Installation procedure
- Housing

The sensors also need to be evaluated with regard to their operational ability. To be able to compare the operational ability of the sensors directly, the sensors are tested under the same controlled conditions. The sensors are evaluated against the following criteria.

- Signal output
- Accuracy
- Repeatability
- Stability

- Response time

3 Qualitative Evaluation Procedure

The qualitative evaluation is based on visual inspection of the units and it's applicability to typical underground conditions. Factors such as perceived durability, mounting brackets, display methodology, sensor head protection etc. are typically used for this evaluation. The ease of use during the testing of the sensors i.e. calibration procedure, operational procedure etc. is also used as inputs for the evaluation.

The qualitative assessment of the sensors was made on the units, as they were received form the client.

The qualitative evaluation does not take into account the pricing of the units.

4 Quantitative Evaluation Procedure

To ensure that all sensors are tested against the same conditions a test was devised that would ensure that all sensors are exposed to similar flow conditions. A test set-up, as depicted in figure 4.1, was used.

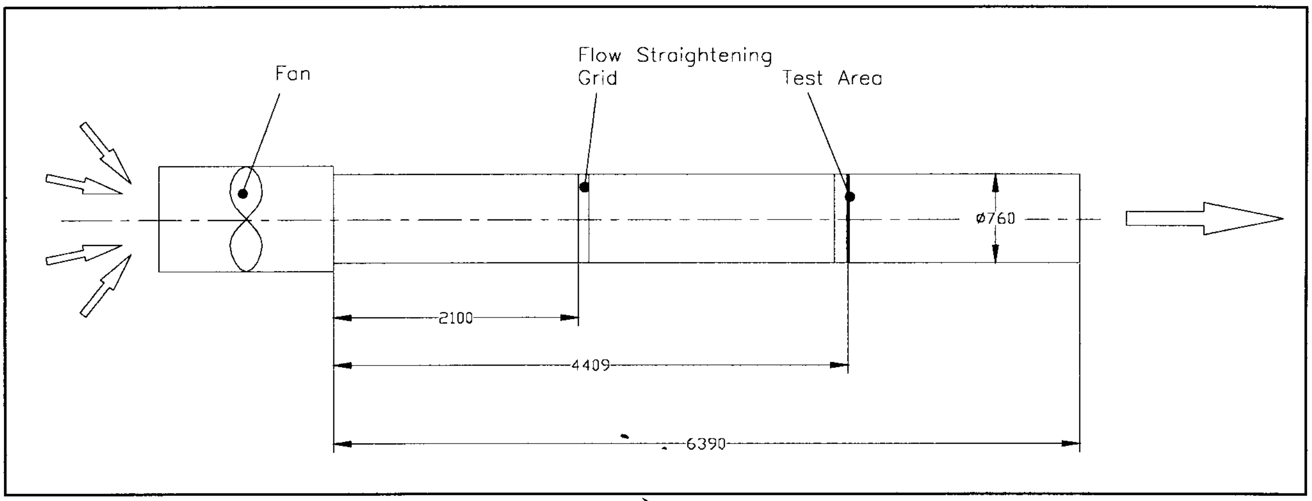

Figure 4.1 Flow sensor evaluation test set-up

The test set-up consists of a 6,39 m x 0,76 mm diameter steel duct. An 11KW axial fan is placed at the inlet side of the test section and sealed into the duct. A flow-straightening grid is placed at a distance of 2,10 m from the fan outlet. This grid assists in taking out sufficient amounts of non-axial flow components generated by the axial fan to allow for adequately stable airflow in the test area for sensor evaluations. The test section has a maximum velocity of 26 m/s. The lower test velocities in the test section are obtained by choking the fan inlet.

The test cross section is situated 4,40 m from the fan outlet. The test section has a Pitot tube in it to serve as a reference value during testing. A digital micro-manometer is used to generate a digital signal from the Pitot tube to store on the data acquisition system.

During a test two flow sensors are tested simultaneously. This is done to be able to compare sensor operation directly, even if changes in flow conditions may occur in the test section between tests due to atmospheric fluctuations.

The test procedure followed is as follows:

1. Locate the two sensors in the test section with the measuring part of the sensors 200 mm perpendicular form the test section wall. See figure 4.2. Ensure that the data acquisition system is operating and that the two instruments and the Pitot tube is responding.
2. Start the test and allow the unit to read zero levels for 60 seconds.
3. Start the fan and measure the flow rate of the test section at the location of each flow sensor using a calibrated vane anemometer.
4. Run the test for 120 seconds and switch off the fan. Use the Pitot tube data to determine the response time of the flow sensors.
5. Start the fan and run for another 120 seconds.
6. Switch off the fan for 60 seconds.
7. Switch on the fan and introduce dust to the amount off approximately 300g/min for 30 seconds.
8. Introduce water mist for 30 seconds.
9. Switch off the fan.

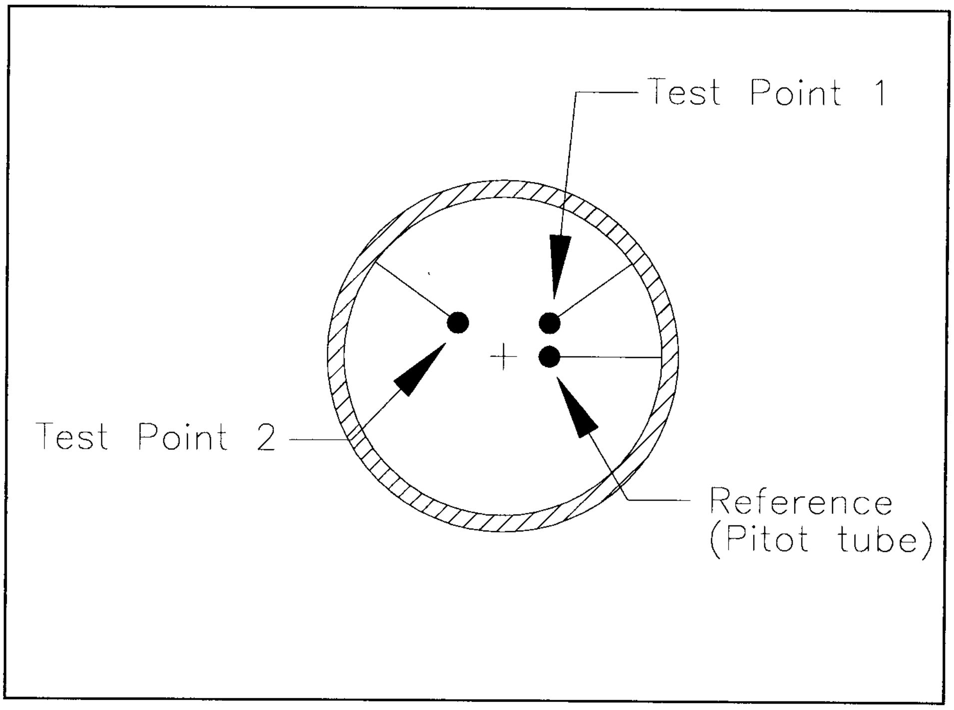

Figure 4.2 Sensor locations in the test section.

5 Data Analysis

5.1 Accuracy

All the units received are sealed and no calibration can be performed. The units were tested as received.

To determine the accuracy of the units it is exposed to a known velocity. The velocity in the test section is measured with a calibrated vane anemometer and a Pitot tube monitors instantaneous variations in velocity at the test cross section. The units are tested at velocities in the region of 3 m/s, 8 m/s, and 15 m/s. The difference between the recorded and actual velocity is expressed as a percentage of the actual velocity.

5.2 Repeatability

As repeated exposures to velocity fluctuations can have an influence on the accuracy of the instruments, each unit was exposed to three cycles of zero to test level velocities.

To determine the repeatability of an instrument it is exposed to zero and test velocities alternatively for one-minute intervals. This cycle is repeated three times. To determine the repeatability of an instrument the percentage drift in instrument reading per cycle at fixed time intervals is calculated, with the first cycle being the base cycle. This is done for both the test and zero velocity readings.

5.3 Stability

The stability of the output signal from the unit is investigated. The stability of the signal output is defined as the amount of noise on the signal output from the sensor unit. The stability is quantified as the variance of the arithmetic mean of the output signal at full scale.

5.4 Response Time

The response time of an instrument is defined as the time it takes the unit to reach full-scale (T_{100}) test value of the applied velocity. Similarly the response time to reach zero levels is defined as the time it takes the unit to reach zero after test velocity exposure. As the flow in the test section is not instantaneous, the reading form the Pitot tube is used to determine when the airflow in the test section is zero. This value is used to evaluate the decay time of the units.

6 Sensors Evaluated

Table 6.1: Flow Sensors Evaluated

No.	Supplier	Sensor Model	Operating Principle	Range (m/s)
1	Safdy Systems	Vortex Flow	Vortex shedding	0 –20
2	Sperotek	FM421 Air Velocity	Vortex shedding	0 – 10
3	Sharrock Senior Assoc.	Efector 300	Calorific variation	0 – 20

7 Qualitative Evaluation Feedback

7.1 Safdy Systems Vortex Flow Unit

The measuring head and associated electronics is housed in a sturdy rectangular metal enclosure of 300 x 150 x 100 mm. The enclosure can be easily mounted from the hanging wall or side walls. The enclosure is mounted parallel to the direction of flow. The length of the enclosure provides good protection against the effects of cross flow over the sensor head. The enclosure protects the measuring head and the vortex-shedding beam well from general impacts from material handling activities or falling material. The unit is suitable for underground installation as is.

The unit does not have any indicator lights or display window to indicate operational status or levels recorded.

7.2 Sperotek FM421 Directional Air Velocity Sensor

The measuring head is fitted at the end of a cylinder shaped housing (250 x ∅ 100 mm) containing the associated electronics. Specialized brackets might be required to install the unit to the side or hanging wall. A separate box is used for signal processing and power supply. The measuring head and vortex shedding beam is reasonably exposed to impacts form general material handling or falling, which can cause the unit to malfunction. The measuring head is also exposed to effects of cross flow. It is suggested that extra protective measures be taken when the unit is used in underground conditions.

The unit does not have any indicator lights or display window to indicate operational status or levels recorded.

7.3 Sharrock Senior Associates Efector 300

The temperature probes is situated at the end of a small cylindrical housing (120 x ∅ 25 mm). The unit appears to have been designed for ducts with a maximum diameter of 240 mm. The unit can be placed in a general body of airflow to measure flow rate. Special brackets would be required to mount the unit to the hanging or side wall of a tunnel. Some additional protection might be required to protect the unit from underground wear and tear.

8 Operational Test Data

8.1 Safdy Systems Vortex Flow Unit

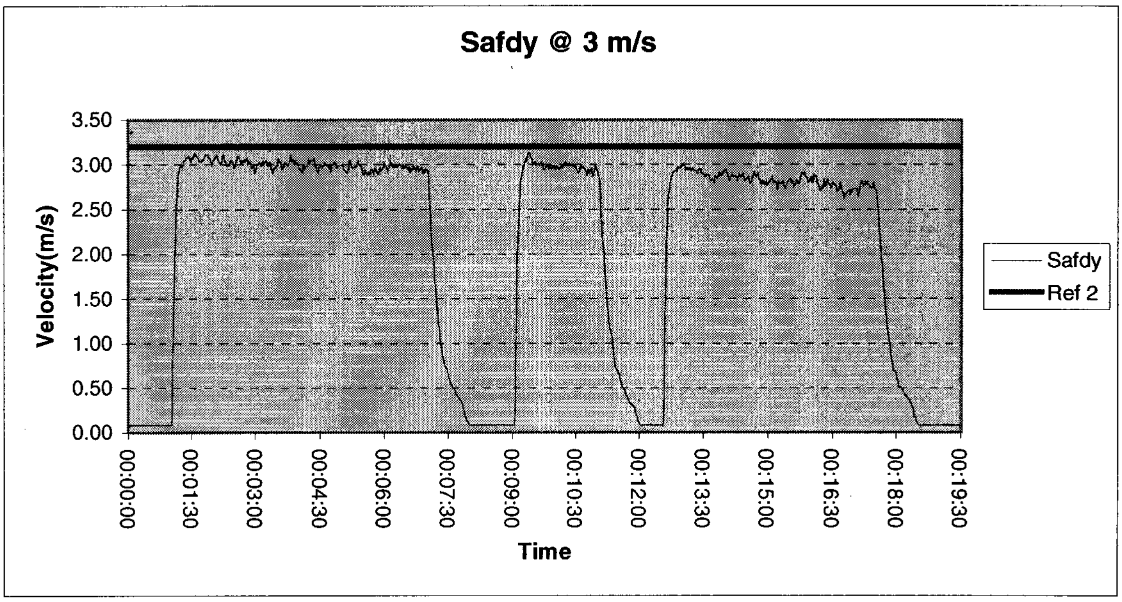

Figure 8.1a: Safdy System Vortex Flow Unit test at 3,0 m/s

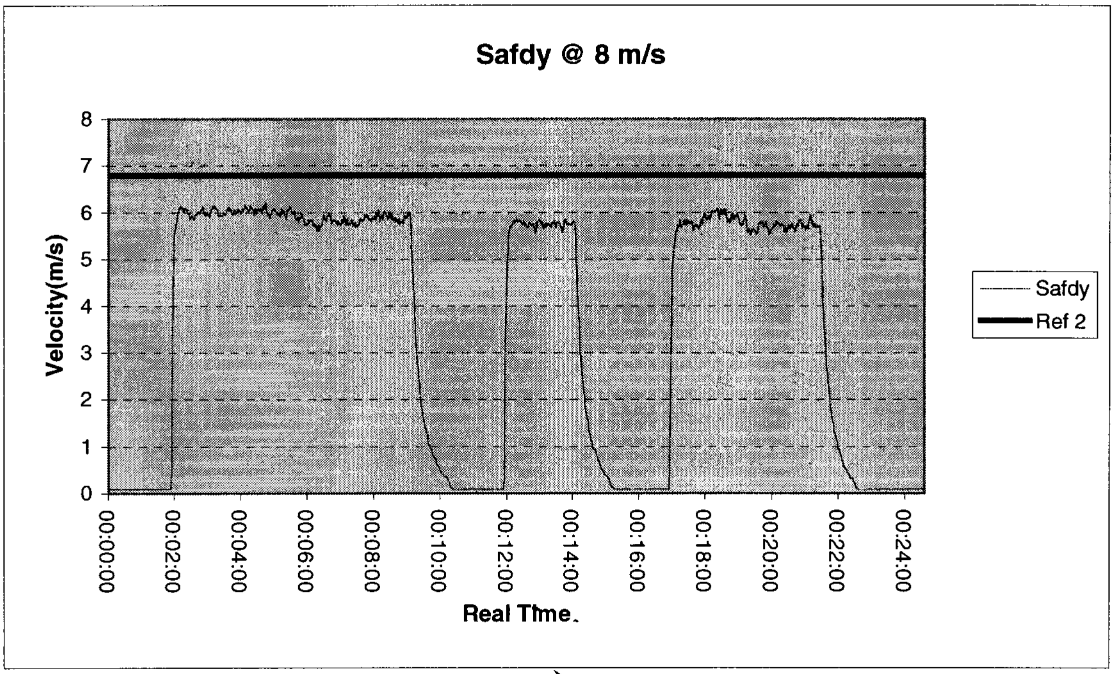

Figure 8.1b: Safdy Systems Vortex Flow Unit test at 8,0 m/s

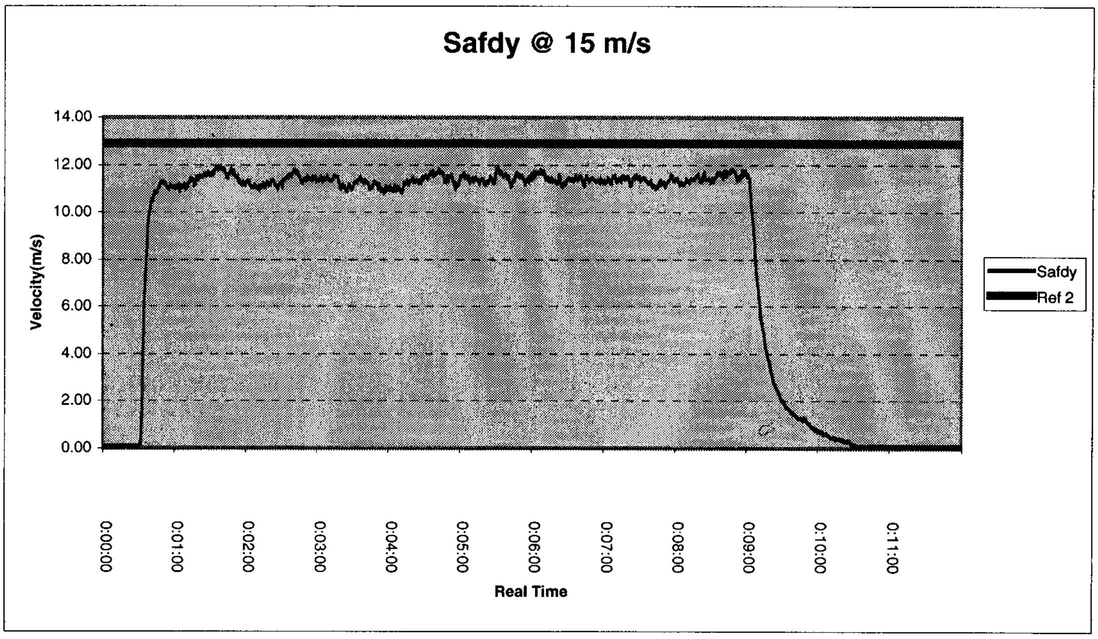

Figure 8.1c: Safdy Systems Vortex Flow Unit test at 15,0 m/s

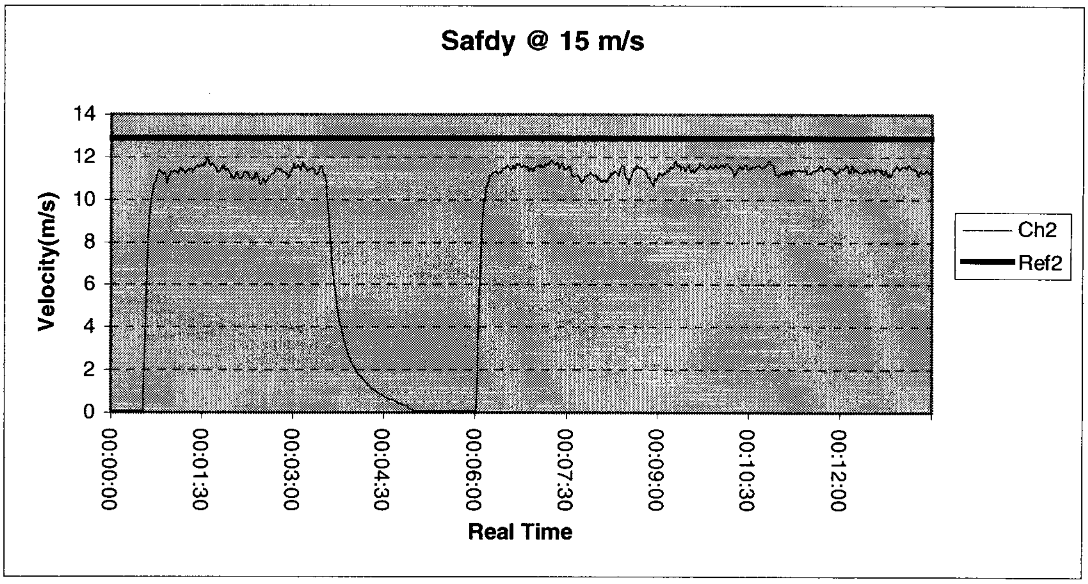

Figure 8.1d: Safdy Systems Vortex Flow Unit test at 15,0 m/s (continued).

Table 8.1a: Evaluation of Safdy Test Data

	3,5 m/s	6,8 m/s	12,9 m/s
Accuracy – full (%)	94	86	88
Accuracy – 0 (%)	2	2	0,7
Drift – Full-scale (%)	-1	-1	0
Drift – zero (%)	0	0	0
Signal average (m/s)	3,0	5,9	11,3
Signal variance	0	0	0
T_{100} Response time (s)	19 (7)*	17 (7)	17 (8)
Decay time (s)	60 (35)	72 (54)	68 (62)

- All calculations based on averages.
- * Values in brackets represent Pitot tube values.

8.2 Sperotek FM421 Directional Air Velocity Sensor

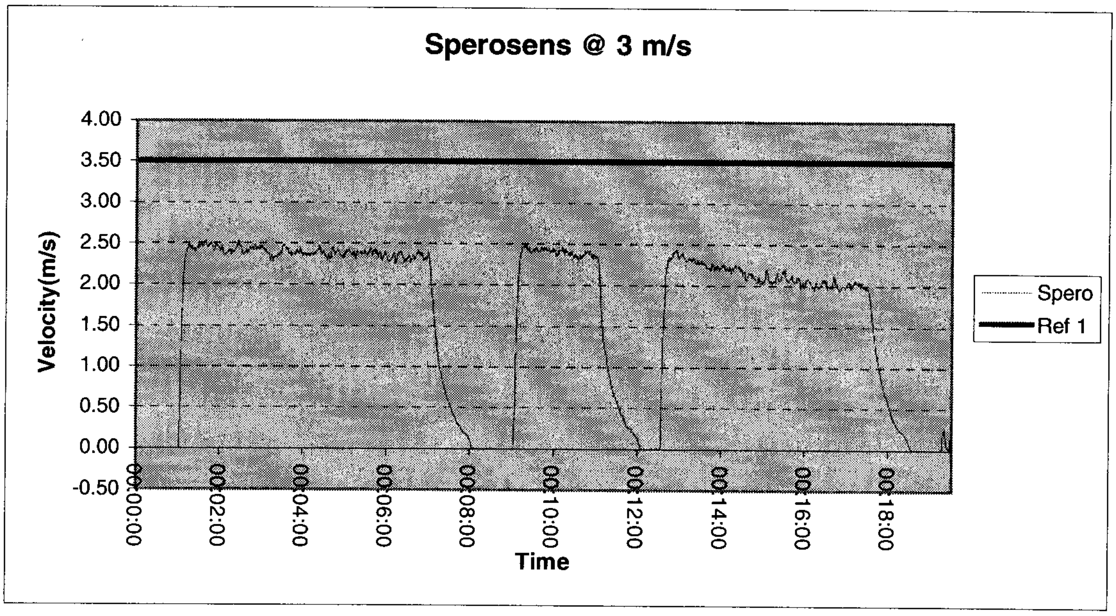

Figure 8.2a: Sperotek FM421 Flow Sensor test at 3,0 m/s.

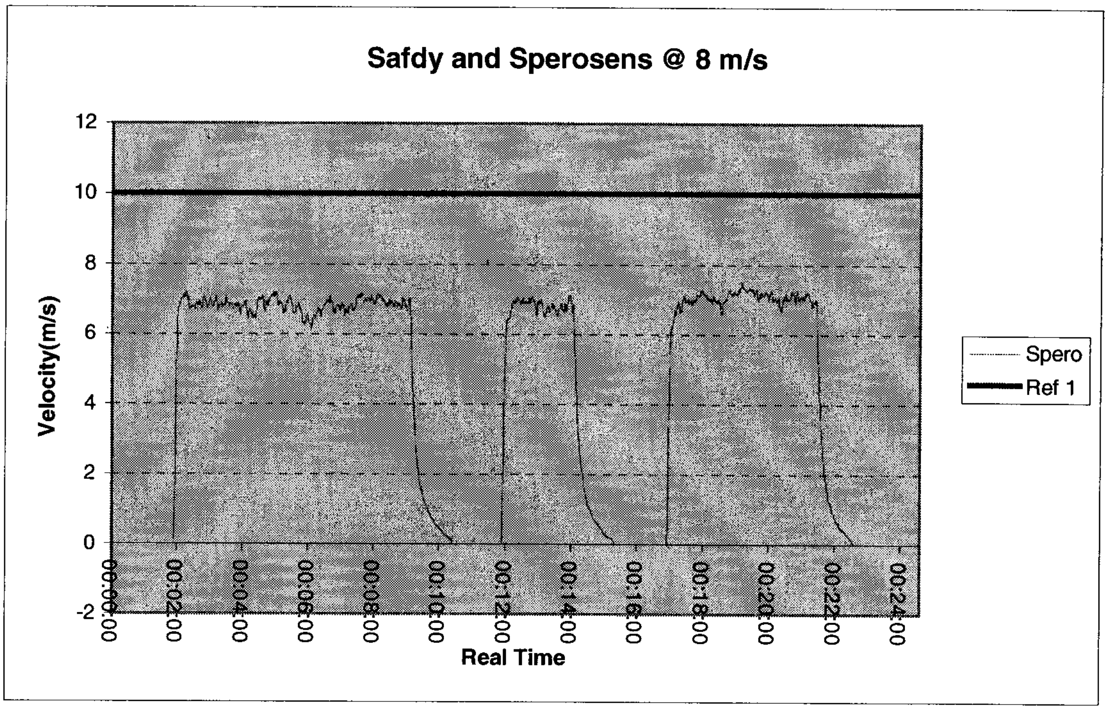

Figure 8.2b: Sperotek FM421 Flow Sensor test at 8,0 m/s.

Table 8.2a: Evaluation of Sperotek Test Data

	3,2 m/s	10,0 m/s	15,0 m/s
Accuracy – full (%)	76	69	N/A
Accuracy – 0 (%)	100	100	N/A
Drift – Full-scale (%)	0	0	N/A
Drift – zero (%)	± 1	0	N/A
Signal average (m/s)	2,4	6,9	N/A
Signal variance	0	0	N/A
T_{100} Response time (s)	18 (7)*	23 (7)	N/A
Decay time (s)	64 (35)	79 (54)	N/A

- All calculations based on averages.
- * Values in brackets represent Pitot tube values.

8.3 Efector 300 Flow Unit

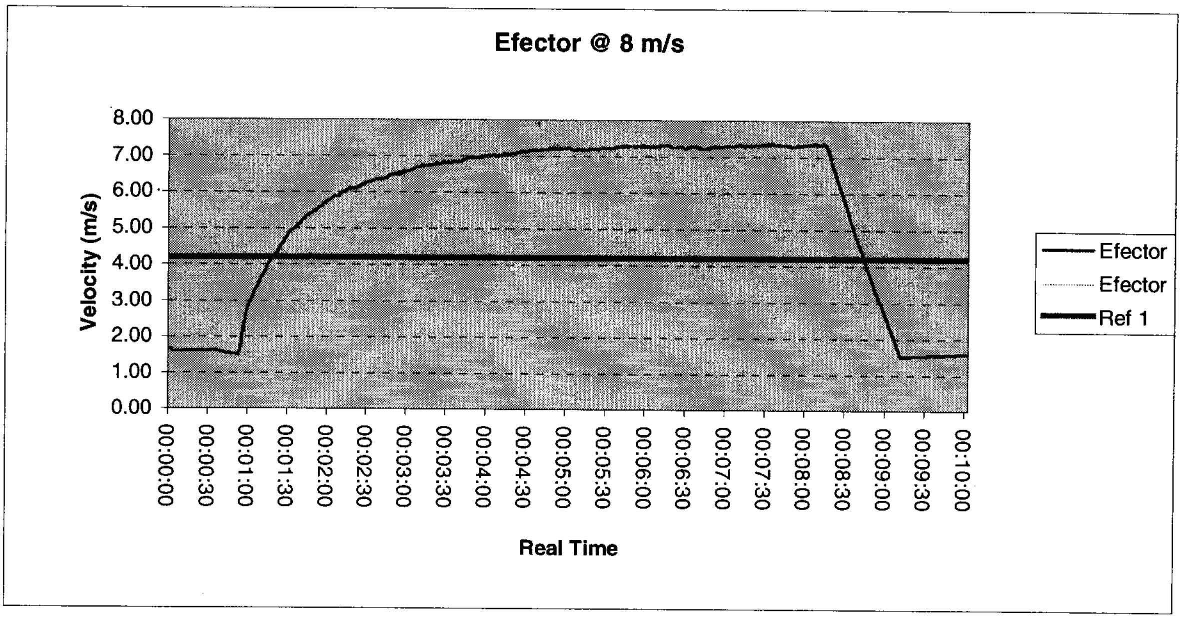

Figure 8.3a: Efector 300 test at 8,0 m/s in dry air.

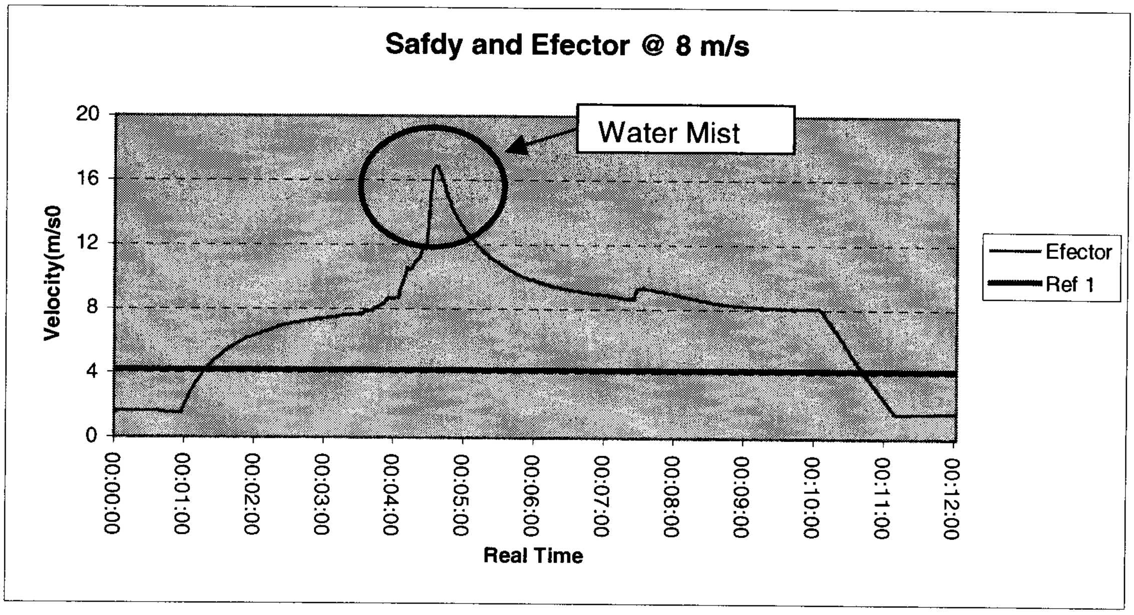

Figure 8.3b: Efector 300 test at 8,0 m/s with water mist.

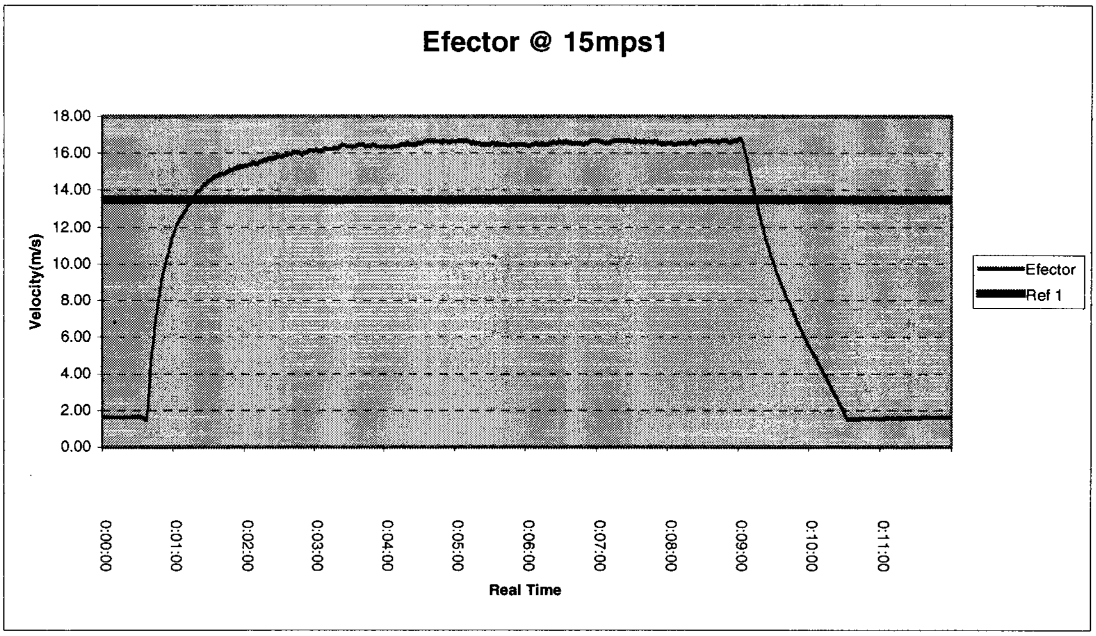

Figure 8.3c: Efector 300 test at 15,0 m/s in dry air.

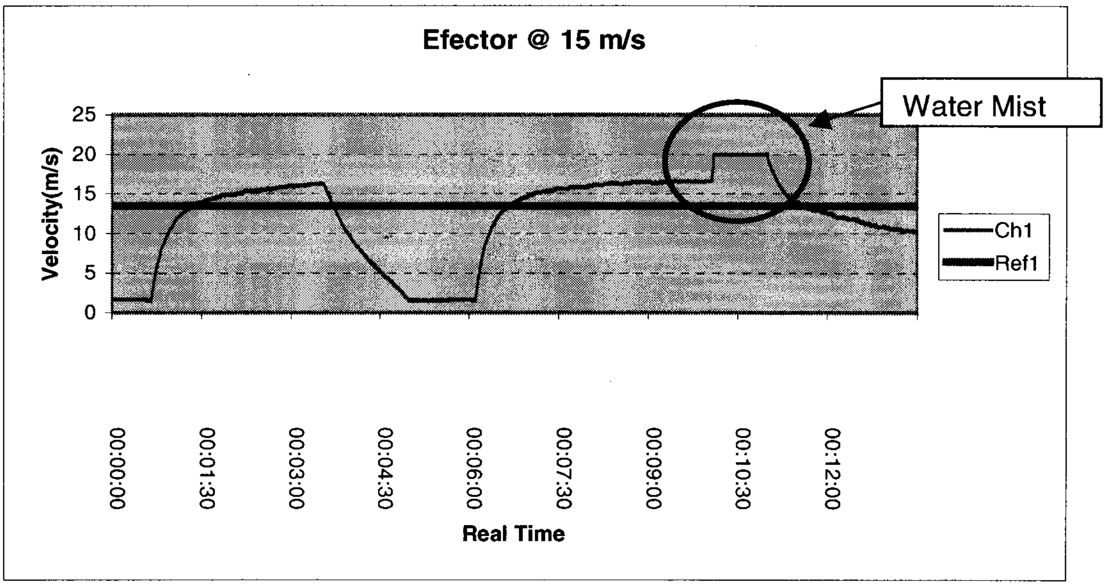

Figure 8.3d: Efector 300 test at 15,0 m/s in dry air (continued).

Table 8.3a: Efector 300 Test Data

	3,0 m/s	4,2 m/s	13,5 m/s
Accuracy – full (%)	N/A	175	124
Accuracy – 0 (%)	N/A	N/A	N/A
Drift – Full-scale (%)	N/A	N.C.	N.C.
Drift – zero (%)	N/A	N/A	N/A
Signal average (m/s)	N/A	7.3	16,7
Signal variance	N/A	0	0
T_{100} Response time (s)	N/A	392 (7)**	203 (8)
Decay time (s)	N/A	57 (54)	81 (62)

- All calculations based on averages.
- * N.C. – not calculated.
- ** Values in brackets represent Pitot tube values.

9 Conclusions

- For this evaluation the costs of the individual units are not considered.
- Of the units delivered, as is, the Safdy flow meter appears to be the most suitable for underground application from a durability and applicability point of view.
- All the units tested have adequate signal damping to allow for a stable signal output.
- None of the units tested have *in situ* calibration facilities. Of the units tested the Safdy unit had the most accurate output (approximately 89 %). The Sperotek unit had an accuracy of 79 % and the Efector unit had significant over reading.
- As can be expected from the operating principles of the units tested no drift was recorded for the units.
- Water mist and excessive dust loads did not influence the accuracy of the Safdy or Sperotek units i.e. vortex shedding instruments. For the Efector, calorific instrument, the addition of water mist caused the unit to over read significantly (Figure 8.3c & 8.3d). It appears that dust has no effect on the output of this unit.
- Both the Safdy and Sperotek units have acceptable response times, i.e. rise times of approximately 10 seconds and decay times of approximately 25 seconds. The Efector on the other hand has a rise time of up to 390 seconds with an associated decay time of 20 seconds.
- The zero reading of the Sperotek unit was accurate, with the Safdy unit showing a little offset (2 %) at the zero reading for the first test.

- Both the Safdy and Sperotek units have exactly the same measuring head and vortex shedding beam design.

10 Acknowledgements

CSIR Kloppersbos would like to thank Mr. Don Bryden for his valued inputs in the design, construction and operating of the test equipment.