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Study of Real Time Dry Bulb Temperature and Relative Humidity Monitoring Systems for Use in Underground Mines – Implementation Challenges

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Executive Summary

As the depth of mines increases, the temperature in the mine workings also increases due to the geothermal gradient. This offers a challenge to maintain adherence to regulations 364, 369 and 370 of the Coal Mining Safety and Health Regulation Act 2001 (Queensland) for underground workings.

The project "study of real time dry bulb temperature and relative humidity monitoring systems for use in underground mines – implementation challenges" was performed as follows:

1. Conducted a survey among mine ventilation engineers, consultants and academics to understand the current practices and equipment used to monitor temperature in underground coal mines.
2. Reviewed the various real time temperature monitoring devices available in the market which are suitable for use in underground coal mines in Queensland.
3. Purchased a suitable real time monitoring device for dry bulb temperature and relative humidity. Perform experiments in various simulated environments in the laboratory and compare the results with the results obtained using standard instruments.
4. Prepared the final report for presentation to ACARP.

A questionnaire was prepared and sent to a number of mine ventilation engineers, consultants and academics in order to gain an understanding of their experiences and current views on real time dry and relative humidity temperature monitoring practices. Eighteen persons provided a response to the questionnaire. The answers were compiled and analyzed. Similarly, a review of various real time temperature devices available for use in underground coal mines in Queensland was conducted.

At this point in time, we found that only one supplier has an IS approved real time temperature and humidity measuring device suitable for use in Queensland underground coal mines. Using this instrument, laboratory experiments were performed at various air velocities, various humidity ranges and dust concentration in order to gather data which could be compared to the dry bulb temperature and relative humidity readings obtained using an ISO 9001 standard calibrated instrument and a sling psychrometer. It was noted from the experimental results that when compared to the calibrated instrument (Dewlogger) readings, the IS approved (Trolex) instrument displayed a variation in the dry bulb temperature of -6% to +3% and up to 6% higher relative humidity readings. The Trolex dry bulb temperature reading variations are -4% to 2%, and Dewlogger reading variations are -2% to 2% when compared to the sling psychrometer readings for identical environmental conditions. The Trolex relative humidity reading variations are -2% to 2%, and Dewlogger reading variations are -3% to 1% when compared to the sling psychrometer readings for identical environmental conditions.

Use of IS approved real time temperature and relative humidity measurement instruments in underground coal mines would be beneficial due to improvements in work place health and safety, and other operational benefits.

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1 Introduction

Accurate measurement of dry bulb temperature and relative humidity at different critical locations of underground coal mines is a challenge to industry. A small change in dry bulb temperature and relative humidity can cause human fatigue, equipment failures and decreased production. Insufficient information and uncertainties associated with underground temperatures can cause difficulty in managing mine safety issues such as, weakening of roadways, change in strata properties, spontaneous combustion, fires and ventilation problems all of which can jeopardize mine safety and efficient production. All these issues necessitate the implementation of an Intrinsically Safe (IS) approved automated real time temperature monitoring system for underground coal mines, particularly for relative humidity measurements.

In Australian underground coal mines, the dry bulb and the wet bulb temperatures are measured using a psychrometer or whirling hygrometer. These temperatures are manually recorded in various locations of the mine workings at different time intervals.

The objectives of this project were to:

- Review the current state of the art for real time temperature instrumentation and monitoring practices applicable to underground coal mines.
- Identify challenges associated with the implementation of real time dry and wet bulb temperature monitoring systems, and determine the problems which are preventing or discouraging their use in underground coal mines.
- Compare and validate the real time temperature data with an existing temperature measurement system in the laboratory.
- Perform a review of data obtained from a real time temperature monitoring system in an underground coal mine.

There are a number of real time temperature monitoring devices on the market which require minimum human intervention when compared to the conventional whirling hygrometer measurement device. A real time temperature monitor can provide accurate dry bulb temperature and relative humidity measurements in various critical sections of mines, and this information can then be used to control and improve the mine working environment.

The researchers consulted with the relevant personnel from Australian underground coal mines in order to identify the pertinent issues associated with implementing a real time underground temperature monitoring system. They reviewed state of the art temperature monitoring systems currently available and identified a suitable type for use in underground coal mines. The advantages of an intrinsically safe real time temperature monitoring device were evaluated against the challenges associated with its implementation. The project also compared and contrasted the accuracy of the real time temperature monitoring system in comparison to the current non real time measurement devices and practices.

In Australia, the wet bulb temperature measurement is typically not monitored continuously. The use of a real time temperature monitoring system would provide reliable, representative and continuous records of the temperature of various mine workings. With this information, we can derive various psychometric properties, such as, relative humidity, dew point temperature, specific enthalpy, mixing ratio and specific volume on a real time basis. The benefits are as follows:

- Provide accurate dry and wet bulb temperatures at various mine workings and service stations to satisfy statutory and safety requirements and to maintain a safe and efficient underground working environment
- Helpful in preventing corrosion of devices and equipment present in underground mines
- Enable effective use of fan air flow quantity and cost of operation of air conditioning (if it is used in mine)
- Help to monitor environmental conditions which might support spontaneous combustion of the underground coal reserves and hence help to avoid the outbreak of fire

2 Background

Queensland Coal Mining Safety and Health Act (1999) under the sections on heat stress management (369 and 370) deal with managing risk from heat and methods of calculating the effective temperature. Section 370, refers to monitoring the atmosphere and provides guidelines for managing effective temperature at the coal face. To effectively achieve the safety compliance of underground workings it is necessary to have continuous monitoring of temperatures at all times. This can be fulfilled by implementing a real time temperature monitoring system.

This project focused on improving the production and safety in underground mines by accurately measuring real time temperature within critical areas of an underground mine. As per our knowledge, in Australia, there is not a mine that uses a real time relative humidity monitoring system in underground workings. The key questions are: (i) why the Australian underground coal mines are not using real time temperature monitoring systems (ii) what challenges mines would face in implementing real time temperature monitoring devices, and (iii) what needs to be done to facilitate their use in Australian underground coal mines.

With this background, the project reviewed the availability of state-of-the-art real time temperature monitoring systems which could be deployed in underground coal mines, and investigated how accurate temperature measurements could be obtained to assist in the control of heat and temperature related issues experienced at various critical locations within an underground coal mine.

3 Program schedule

The project was planned for 12 months as follows.

1. Conduct a survey among mine ventilation engineers, consultants and academics to understand the current practices and equipment used to monitor temperature in underground coal mines.
2. Review the various real time temperature monitoring devices available in the market which are suitable for use in underground coal mines in Queensland.
3. Purchase a suitable real time monitoring device for wet bulb temperature and relative humidity. Perform experiments in various simulated environments in the laboratory and compare the results with the results obtained using standard instruments.
4. Analyze mine site real time temperature measurement readings obtained using IS approved instruments.
5. Prepare the final report for presentation to ACARP.

4 State of the art

The aim of monitoring various parameters on a real time basis in underground workings is to provide a safe, efficient and productive working environment. Part 7 of Queensland's Coal Mining Safety and Health Regulation (2001) outlines the requirement for mines to have a gas monitoring system providing continuous monitoring of methane, carbon monoxide, carbon dioxide and oxygen at stated locations (http://www.amsj.com.au/news/modern-day-canary-coal-mine/). In mining engineering the importance of real time monitoring has been highlighted by various researchers (Belle 2014; Haustein et al, 2011; Brady, 2008; Shen et al 2006; Gillies et al, 2002). In contrast to real time monitoring research performed in other areas of underground coal mines, the research on real time dry bulb temperature and relative humidity monitoring has been neglected.

Real time temperature monitoring systems are very common in a range of manufacturing and processing industries, for example, powder handling, paper, drying, steel and pharmaceuticals. These devices are well developed, and used to scrutinize humidity and confirm the quality of processing operations in challenging but sensitive environments. The real time sensors can be either wired or wireless. A key benefit of real-time sensors is that they allow appropriate actions to be taken immediately or even automatically adjust a mode of operation, depending on the circumstances (Crowley et al, 2005).

In Australian underground coal mines, the dry bulb and the wet bulb temperatures are measured using a psychrometer or whirling hygrometer. These temperatures are manually recorded at various locations of the mine workings and at different time intervals. A small fluctuation on dry and wet bulb temperatures may add to human fatigue, mine hazards, equipment failures and decreased production. This necessitates the implementation of an Intrinsically Safe (IS) approved automated real time temperature monitoring system for underground coal mines, particularly for wet bulb temperature and relative humidity measurements.

4.1 Questionnaire Analysis

A questionnaire was prepared and sent to a number of mine ventilation engineers, consultants and academics in order to understand their recent experiences and current views on real time dry and wet bulb temperature monitoring practices. The questionnaire contained the following questions.

1. At what locations do you measure temperature and humidity in the underground coal mines?
2. What is the current method of measuring temperature and humidity in the underground coal mines?
3. What instrument/s do you currently use to measure temperature and humidity in the underground coal mines?
4. Currently, how frequent do you measure temperature and humidity in the underground coal mines?
5. How do you interpret and use the measured temperature and humidity data in the underground coal mines?
6. What are the practical and technical problems you are encountering at the moment in measuring temperature and humidity in the underground coal mines?
7. What are the instrumental problems you are encountering at the moment in measuring temperature and humidity in the underground coal mines?
8. Ideally, what type of instrument and output do you want for the measurement of temperature and humidity in the underground coal mines?
9. Are you aware of any real time temperature and humidity measurement device/system which can be used in the underground coal mines?
10. Are you aware of any real time temperature and humidity measurement device/system which are used in metalliferous mines?

11. If there is an availability of real time temperature and humidity monitoring device/system to be used in the underground coal mines, would you prefer using it rather than continuing with the current method?
12. If there is an availability of real time temperature and humidity monitoring system to be used in the underground coal mines, what sort of problems do you expect in using real time measurement device/system?
13. What are the restrictions do you think or expect in using real time temperature monitoring system in the underground coal mines?
14. Have you come across any mines in Queensland using a real time temperature monitoring system?
    - Why is it not being used in your mine at the moment?
    - Is it because of difficulty in maintaining the system?
    - Any other reason?
15. What are the challenges and advantages you can envision in implementing and using a real time temperature and humidity measurement system in an underground coal mine?
16. Any comment/suggestion on this topic?

Eighteen persons provided their responses to the questionnaire. The answers are compiled and analyzed as follows.

1. At what locations do you measure temperature and humidity in the underground coal mines?

In general, temperature and humidity measurement are conducted **as a part of the monthly statutory survey** conducted by deputies, **typically on a shift basis** but often when and where problems occur. Measurements are conducted at all specified ventilation measurement stations as per the mining regulations and where deemed necessary by ventilation officers. Detailed measurements are required to develop a heat model for underground coal mines. The measurements are also required to monitor for heat from spontaneous combustion and in accordance with the heat management plans. Mostly, hotter regions of underground old workings are measured for temperature and humidity.

Respondents mentioned that the **areas where men are working** are critical locations to measure temperature and relative humidity in underground coal mines. Temperature and humidity measurements are required at all monthly survey points, statutory locations and all ventilation stations. **Locations such as, entries to exhaust shafts, intake and exhaust ducts, all district regulators, longwall face areas (maingate, middle and tailgate), development face and return, tailgate outbye, intakes, last open cut through, driveheads and key areas in belt roads, upcast shafts, bottom of the cooling shaft, shaft collar, main returns to fans, panel entries and returns, and ventilation split regulators are critical locations to obtain temperature and humidity data**. The **explosive risk zone (ERZ) (at boundary and face) and surface weather station are also important locations to measure temperature and humidity in the mines**. In order to monitor heat from spontaneous combustion, measurements are also performed at regular intervals at the rear-leg of longwall chocks, longwall goaf stream and goaf seal traps.

The temperature measurements are critical in hotter and gassy mines of Queensland (for example, Bowen Basin) compared to the New South Wales mines, except for the very deep mines of the south coast (for example, Appin, Westcliff).

2. What is the current method of measuring temperature and humidity in the underground coal mines?

Dry bulb temperature, wet bulb temperature and relative humidity are **currently interpreted from manual readings using various hand held devices and a psychrometer chart**. Some mines use **conventional thermal expansion thermometers and mine approved infra-red spot temperature meters** to measure the dry bulb temperature. Several mines use a system involving thermographic cameras and spot measurements. One of the mines uses real time monitoring of dry bulb temperature using redline software logging system. One of the mines uses remote measurement of dry bulb temperature at main fan exhaust air. In other mines monthly ventilation surveys are conducted where temperature and relative humidity are measured.

3. What instrument/s do you currently use to measure temperature and humidity in the underground coal mines?

The following instruments are commonly used in the underground coal mines to measure temperature and humidity.

- Psychrometer chart
- Conventional thermal expansion thermometer
- Surface weather station
- Whirling hygrometer (dry and wet bulb)
- Brannan Sling psychrometer (dry and wet bulb)
- Infra-red spot temperature meters
- Thermographic cameras
- Digital temperature props
- Realtime monitoring (dry bulb) by Redline Software logging system
- Kestrel Instrument
- Bacharach Sling psychrometer (wet and dry bulb)
- Real time and/or remote monitoring of dry bulb temperature
- Fixed thermocouples mounted in surface mine fan ducts for measuring dry bulb temperature

4. Currently, how frequent do you measure temperature and humidity in the underground coal mines?

In working areas the measurements are obtained during **every shift**, and in ventilation stations, panel entries and return splits measurements are obtained **every month**. As per statutory ventilation reporting requirements, all mines perform measurement/surveys on a monthly basis. Similarly, shift measurements are performed in each panel by the deputy as per statutory inspections. Measurements are also performed as required to monitor potential spontaneous combustion, and in accordance with the heat management plan in order to determine the "effective temperature", where hot and humid conditions exist. These measurements can activate the **Trigger Action Response Plan (TARP)** when limits are likely to be or have been reached. In hot and humid conditions and when approaching TARP limits, measurements would be done several times during each shift. The temperature measurement information is managed under a principal hazard management plan which uses TARPs to trigger corrective action. Depending on the mine conditions, 4-6 hourly measurements are also performed. Some operations perform continuous monitoring of the temperature on the surface of the underground coal mine.

5. How do you interpret and use the measured temperature and humidity data in the underground coal mines?

The measured data are used to monitor legislative limits and to gauge current working conditions. Hotter mines use the data to **substantiate heat modelling** and analysis but in colder mines the measurements are for information only. The data are used to determine the effective temperature from wet bulb, dry bulb and air flow measurements. The data are also used to monitor goaf stream and goaf oxidation levels in gassy mines. Apart from using the interpolated standard nomograms for monthly or incidental temperature, humidity recording, trending, comparison and historic purposes, the data are used as part of the TARP for temperature, heat mapping after vent surveys and carbon emissions reporting. The data is also used to report greenhouse gas emissions from the bottom of the upcast. Surface heat trends are used to forward project for other ambient conditions.

6. What are the practical and technical problems you are encountering at the moment in measuring temperature and humidity in the underground coal mines?

The readings are **prone to human error associated with the location identification, interpretation and noting the temperature from the thermometer**. The **limited data points and placement of the instrument** (close or far from the human body which may also record/add additional human introduced heat), **crude**

instruments, limited ways to measure wet bulb temperature, represent/record and time taken to prepare data in a statistical report are the technical limitations experienced by the ventilation officers/deputies.

Due to the lack of continuous monitoring, the readings can be inconsistent due to **human interpretation and how/where the readings are taken**. Some of the survey participants also mentioned that **due to an inability to remotely measure the temperature and the difficulty in accessing returns, goaf stream areas and some other measurement spots, not enough measurements can be conducted in the time available**.

A snapshot measurement may not be representative of the actual conditions because heat loads will vary, particularly in areas where machines are in operation.

The above mentioned problems arise from a lack of personal, and from the absence of portable, robust, cheap and intrinsically safe electronic temperature and humidity sensors suitable for use in underground coal mines. Due to these limitations and in accordance with the heat management plans, deputies sometimes have to withdraw workers to a place of safety until the effective temperatures are confirmed below TARP limits. This means that due to the use of non-real time devices the delay in determining the effective temperature using a manual psychrometer can impede coal production and increase the environmental risk to workers. Further, current fugitive emission (GHG) legislation requires mines to monitor for fugitive mine gases as well as for relative humidity.

7. What are the instrumental problems you are encountering at the moment in measuring temperature and humidity in the underground coal mines?

At the moment, the instruments are **manual and analogue** which require manual interpretation and calculation of results, hence in an underground environment the **workers with visual impairment sometimes struggle to read the fine gradations on a psychrometer** (for example, Brannan psychrometer). Most of the electronic instruments would provide a digital readout with higher accuracy and repeatability, but they are not intrinsically safe to use in underground coal mines.

Limited data points (measurement locations), **hard to read** (for example, the sling psychrometer), **not able to recalibrate** (for example, Kestrels), **low accuracy and different measurement techniques between personnel** are instrumental limitations the deputies and ventilation officers are encountering. The instruments are also very prone to damage, there is limited availability of coal mine approved wet/dry bulb and relative humidity sensors, limitations in using the same sensors at various spots (for example, RT sensors used in the intake cannot be used in ERZ1) as well as human error involving location identification and mis-reading the true temperature are some problems experienced when using the instruments.

8. Ideally, what type of instrument and output do you want for the measurement of temperature and humidity in the underground coal mines?

An instrument capable of **digitally displaying** results with one decimal point resolution of wet/dry bulb temperature and relative humidity, and which displays the results in desired units (for example, degree centigrade, percentage of relative humidity) would be an ideal instrument. For the portable unit, an integrated anemometer/psychrometer displaying dry/wet bulb temperature, relative humidity and effective temperature to an accuracy of one decimal point. An instrument which provides TARP multi-level alarms, is capable of logging and includes a trend display would be a preferred choice.

Similarly, for fixed plant (for example, mine surface and underground fans) a relatively inexpensive instrument capable of providing accurate, precise, digital display in desired units, hazardous zone approved, not subject to output level drift, nor fouling from airstream contaminates would be an ideal instrument.

In general, more robust instruments taking real time measurements (reporting to control centre) for wet bulb, dry bulb and humidity and with telemetric monitoring, Group I approved, 4-20mA and accurate sensors with limited drift seem to be the ideal instrument. The instrument should be capable of measuring in real time at shafts and entry to the pit, conveyor belts, panel returns and at the base of shafts. The instrument

should be Intrinsically Safe (IS) equipment with digital display, capable of continuously recording and storing data, and able to provide trend data and feature an analysis tool, similar to a real time gas monitoring system. One of the respondents would like to have a single device capable for measuring temperatures and air velocities.

9. Are you aware of any real time temperature and humidity measurement device/system which can be used in the underground coal mines?

The respondents provided a **mixed response** to this question. One of the ventilation officers of Queensland mines is aware of the availability of a real time temperature and relative humidity measurement system and has ordered one. Similarly, a hand held device for dry bulb temperature and relative humidity is available but not approved for general underground use and can only be used in a controlled environment. Trolex brand seems to be a common name in underground coal mines, however, until recently it was not approved to be used in Queensland underground coal mines. Likewise, Kestrel brand is also known to mining personnel, however it is not IS approved to take underground for real time measurement. The respondents seem to be aware of other devices but their status with regard to approval for use in underground coal mines has not been researched in detail by the respondents.

10. Are you aware of any real time temperature and humidity measurement device/system which are used in metalliferous mines?

A **mixed response of *yes and no*** was noted from the participants. Even if they are available in the metalliferous mines, generally due to the restrictions in hazard zones in underground coal mines they are not applicable. The loading and drift from airborne contaminant would still preclude some applications in underground coal mines. VAISALA brand seems to be a known product in metalliferous mines for temperature and humidity measurement.

11. If there is an availability of real time temperature and humidity monitoring device/system to be used in the underground coal mines, would you prefer using it rather than continuing with the current method?

Depending on the mine location and heat issues, the respondents showed a **mixed response**. **Most of the mines in NSW are doubtful about using the real time temperature monitoring devices due to their minimal issues with heat in underground coal mines.** It would be hard to justify the change in measurement system, where heat is not a real issue in mines, especially in current economic climate if it involves an additional investment. However in QLD underground coal mines, due to the higher heat issues, the mines will consider using the instrument, particularly at the longwall face, main intakes and upcast fans. One of the mines in QLD is in the process of purchasing and trying the device. Mine personnel would be instructed to use it in addition to the existing system. The real time monitoring system can also be used when preparing monthly vent surveys. There is a scope for a robust, reliable, real time portable and fixed psychometric instrument which can be used in hazardous zones.

If the available devices are practically and technically robust, reliable, real time, portable and IS approved to use in hazardous zones, then that would be useful in the underground coal mines. An instrument with these characteristics will also help to conduct more detailed monitoring of the heat status assessment and improve the determination of heat loads in hot and gassy mines.

12. If there is an availability of real time temperature and humidity monitoring system to be used in the underground coal mines, what sort of problems do you expect in using real time measurement device/system?

The problems are expected to be related to **approvals for underground use, robustness, reliability, susceptibility to damage, accuracy, maintenance, integrity testing and calibration**. The availability of labour to run cables and cables damage, reliability in gassy and dusty environment, as well as integration into the

mine gas monitoring systems could be problems encountered when installing the instrument. Similar to real time gas sensors, loss of communications and false readings are other anticipated issues. In a portable personal system, robustness, maintainability and cost, and in a fixed system, drift (both electronic and from fouling), precision and accuracy could be possible problems.

Likewise, training in the use of the real time system, obtaining assistance from the electrical department to implement and connect to the existing electrical and communication networks, and dust and moisture ingress could be another set of problems the respondents mentioned.

13. What are the restrictions do you think or expect in using real time temperature monitoring system in the underground coal mines?

The restrictions the respondents are expecting while using real time temperature monitoring system are:

- The existing approvals regime (particularly QLD and NSW mine's approval) for use in ERZ1 locations
- Practicality and cost
- High maintenance and calibration
- Labour to run cables and cable damage
- Compatibility with existing systems
- Access within shaft collar
- Dust and moisture ingress
- Identification of mobile head sources/variation in environment
- Calibration process.

14. Have you come across any mines in Queensland using a real time temperature monitoring system?

The respondents unanimously responded that **no mine in Queensland** is using a real time temperature monitoring system. However, the real time system is available to measure other parameters (for example, air velocity) but for only use in "as approved" and non-hazardous zone applications.

Why is it not being used in your mine at the moment?

The main reason is the **unavailability of an IS approved real time temperature monitoring system**. The respondents have also mentioned that budget, **difficultly in maintaining the device**, labour resources and problems with electrical approvals would be other issues for not using real time temperature monitoring systems.

However, one of the mines in Queensland indicated that an instrument has been recently ordered. In NSW mines, due to the fact that heat is not a major issue, the mines are not in real need of it.

Is it because of the difficulty in maintaining the system?

Due to the unavailability of the IS approved real time temperature monitoring system, **the respondents are not aware of any maintenance required**.

Any other reason?

Generally temperature is not a primary issue when **compared to ventilation and gas management, hence the IS approved temperature monitoring systems for use in underground coal mines does not attract significant attention**. In addition, the overall cost of purchasing and maintaining a system is another reason for not implementing an IS approved temperature monitoring system.

15. What are the challenges and advantages you can envision when implementing and using a real time temperature and humidity measurement system in an underground coal mine?

The **challenges are approval, robustness, maintenance, electronic/fouling drift (particularly for fixed system), calibration, labour resources and cost.** In addition, choosing appropriate locations, control of data, implications of incorrect readings and possible cross contamination due to dust and moisture would be additional challenges when implementing the system. Installation into the mine ventilation network could also be an issue.

Selection of appropriate locations, and changing sensor positions in main drives during outbye activities or during diesel intensive outbye work, is another challenge.

The advantages with **portable systems** would be **instantaneous electronic detection and display** (ideally, integration of air flow and temperature display/alarming of effective temperature) for heat management and TARP levels.

Similarly, the advantages for **fixed systems** would be **accurate and precise long-term data for mine environmental monitoring, mine planning, assessment of fugitive emission, planning for personal heat load management, optimisation and control of mine air conditioning systems, and spontaneous combustion monitoring and control**. Presentation of data, trending and collation, and ease of interpretation would be an added advantage. The use of IS approved real time temperature monitoring system would justify flow and calculation of bulk air cooling (eg, SCD/chilled water), heating and fire detection. Apart from managing heat issues in real time, the system would also provide a better understanding of heat loads, underground temperatures and assist in the design of cooling plant.

16. Any comment/suggestion on this topic?

One underground coal mine is in the process of installing an IS approved real time temperature monitoring system, and would like to include us in the review. A couple of respondents believe that in comparison to the benefits of installing real time air velocity monitors for pressure and flow the installation of real time monitoring of temperature and humidity would not be embraced by mines.

One respondent believes that intrinsically safe, optic fibre, Raman scatter based sensing system capable of distributed temperature sensing, and capable of sensing wet bulb temperature would be invaluable in heat management and air conditioning within many Bowen Basin underground coal mines. Such a system deployed at regular intervals across active longwall goafs and gateroad goaf margins would be a "*God-send"* for management/monitoring of spontaneous combustion.

One of the companies, namely Trolex, has obtained an IS approval for temperature sensors for underground coal mines in Queensland.

4.2 Instrument Status Analysis

At the time of writing this report and to the best of our knowledge, none of the mines in Australia has been using real time temperature monitoring systems for wet bulb temperature or relative humidity monitoring. The table below shows a brief survey on availability, applicability and current certification status of wet bulb real time temperature/humidity monitoring instruments, in different applications, and designated by various approval standards. The table is generated by contacting the major distributors within Australia. Recent industrial trends in developing and obtaining certified IS approval for the real time devices which can be used underground shows the importance of such instruments to the coal industry. At the moment only Trolex/Austdac has obtained Queensland approval for the temperatures/humidity modules for one of their devices to be used in Queensland underground coal mines.

Table 1 Status of instrument

Supplier	**Device**	**Series/Range**	**Approval**
Trolex/Austdac	TX6273.AC TX 6356.06.01	Sentro	Obtained approval – see Appendix
ThermoFisher Scientific			Not IS approved
Industrial Scientific/AirMet	3M (Heat Stress Monitor)	QuestTemp	Intrinsic Safety UL/CSA standards for Class I groups C & D; Class II groups E, F & G; Class III temperature code T3C
Industrial Scientific/AirMet		TWL1S	Not IS approved
Temperature Control	Vaisala HMT361	HMT360	Division 1 and 2 (USA, Canada), Categories 1G / Zone 0 and 1D / Zone 20 with protection cover (EU) Ex ia IIC T4 Ga
Vaisala	Vaisala HMT361	HMT360	Division 1 and 2 (USA, Canada), Categories 1G / Zone 0 and 1D / Zone 20 with protection cover (EU) Ex ia IIC T4 Ga
Michell Instruments	Easidew IS (Dew Point Transmitter)		IECEx,CSA,FM,ATEX
Michell Instruments	Condumax II (Hydrocarbon Dew Point Analyser)		IECEx,CSA,FM,ATEX, CCSA, GOST
Michell Instruments	Nothing with coal mine approval		
Kenelec Scientific			Not IS approved for QLD mines
SICK Maihak			Not IS approved for QLD mines
AMPControl			Not IS approved for QLD mines

5 Experiment

The Trolex TX 6356.06.01 temperature sensor and TX6273 humidity sensor both of which are distributed through Austdac Australia were the only IS approved sensors available at the time of the project. Both instruments were purchased with the aim of comparing their relative humidity and temperature readings with those obtained using ISO 9001 standard calibrated relative humidity and temperature sensors, namely the Dewlogger (also known as thermo-hygrometer and humidity gauge). Similarly, a thermo-anemometer was selected to measure various air flow velocities. Both the instruments were supplied from PCWI Instrumentation Australia. A Beurer LB44 humidifier was used to produce various levels of humidity in the experimental room. The Trolex temperature probe was a type PT100. Figure 1 shows the various instruments used in the experiments. Data sheets of all the instruments are provided in the appendix of this report. A medium sized electric fan was used to generate various air flow velocities.

Why PCWI DewLogger Thermo-hygrometer?

PCWI has an ISO 9001 quality management system with laboratories operating under ISO/IEC 17025. As described on the PCWI website (PCWI, 2015) "Calibration Certificates issued by PCWI are traceable to NMIA (National Measurement Institute of Australia) which is Australia's peak measurement organization responsible for maintaining units and standards of measurement According to NATA endorsed reports. PCWI's Reference equipment that has been externally calibrated by NATA accredited Laboratories."

Before the project measurements began the PCWI Dewlogger was thoroughly checked at PCWI laboratories, where the unit showed 33.7%RH and 83.6%RH at the reference relative humidity of 33.86% and 85%, respectively. These records confirm information supplied by the distributor at the time of purchase. The PCWI laboratory, regularly tests and re-calibrates under controlled conditions a wide range of instruments supplied by this distributor.

The images shown in Figure 1 can be identified as those used in this project.

Trolex TX 6356 Sentro Humidity Sensor with humidity probe (supplied by Austdac Australia)

Trolex TX 6273 Sentro Temperature Sensor (supplied by Austdac Australia)

Trolex PT100 Temperature Sensor Probe (supplied by Austdac Australia)

Dewlogger Thermo-Hygrometer (supplied by PCWI Instrumentation)

Anemometer (Air Flow Meter, supplied by PCWI Instrumentation)

Beurer LB 44 Humidifier

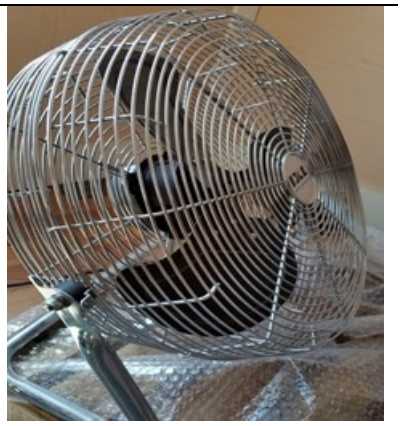
Fan (IXL appliances)	
Trolex TX9042 Modbus Programmable Sensor Controller (supplied by Austdac, Australia)	
RS485 and to USB controller	

Figure 1 Instruments used in experiments.

The experimental room was 2.8m long by 1.8m wide by 2.3m high. The instrument setup is shown in Figure 2. Experiments were conducted at various relative humidity, temperature, airflow velocity and dust concentration in order to investigate the effect of environmental parameters on real time measurement of temperature and relative humidity. The instruments were also remotely monitored and the data readings were recorded on a PC. Data transfer was facilitated using an RS485 to USB converter and a Modbus enabled programmable sensor controller (TX9042) supplied by Trolex for the duration of the project. Figure 3 shows the experimental setup at the Simtar's dusty environment laboratory.

Figure 2 Experimental setup (a) instruments, (b) with humidifier and (c) with fan.

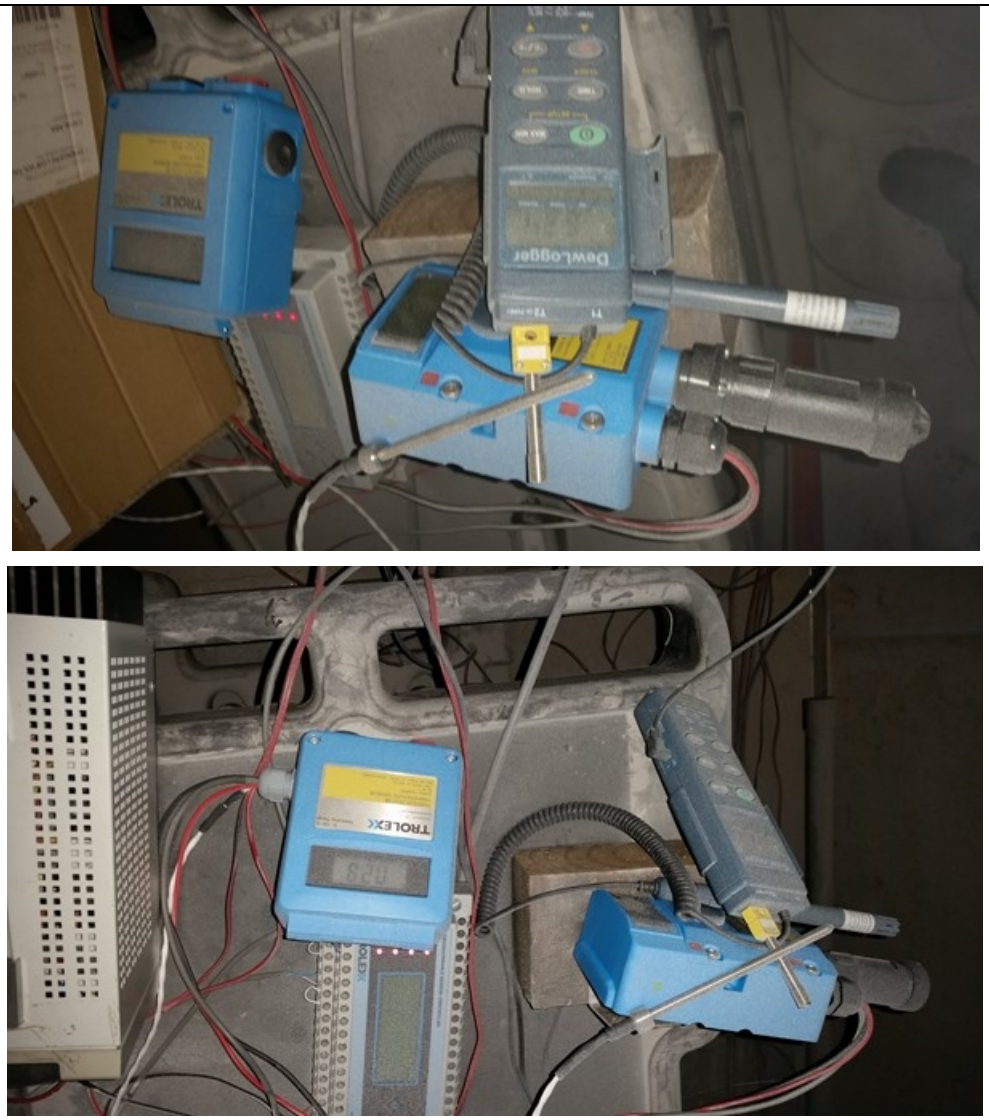


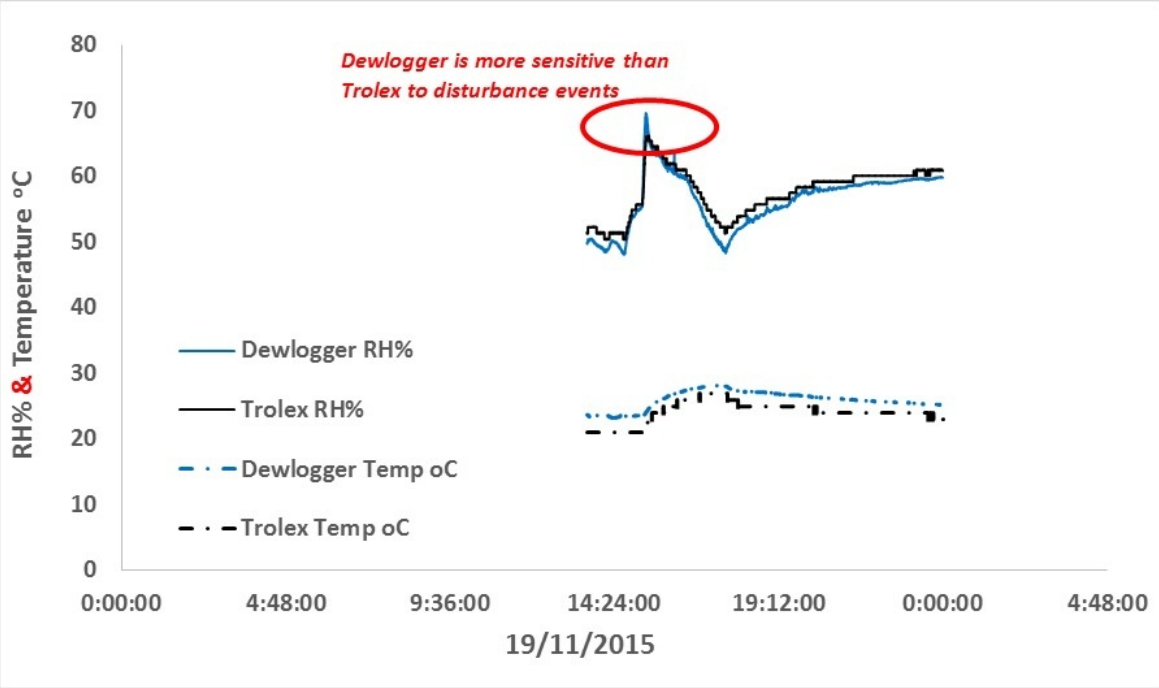
Figure 3 Experimental setup in dusty environment at Simtar's lab.

Numerous experiments were conducted in a wide variety of simulated environments. In all of the environmental combinations, the relative humidity and the temperature readings were observed on the monitoring instruments and the results were noted. The experiments were conducted on various days and readings were taken at a minimum interval of two minutes.

6 Experimental result analysis

Readings were recorded over two days of monitoring using the IS approved Trolex temperature and humidity monitors and a non-IS standard calibrated, Dewlogger instrument. The data is plotted in Figure 4 and the resulting observations are itemised below:

- Trolex and Dewlogger readings are similar when measuring temperature and relative humidity.
- Dewlogger is more sensitive than the Trolex, hence with the introduction of a disturbance the Dewlogger responded faster to an incremental change in relative humidity as shown by the segment circled in red.
- Trolex readings usually display slightly higher relative humidity and slightly lower dry bulb temperature readings when compared to the Dewlogger.



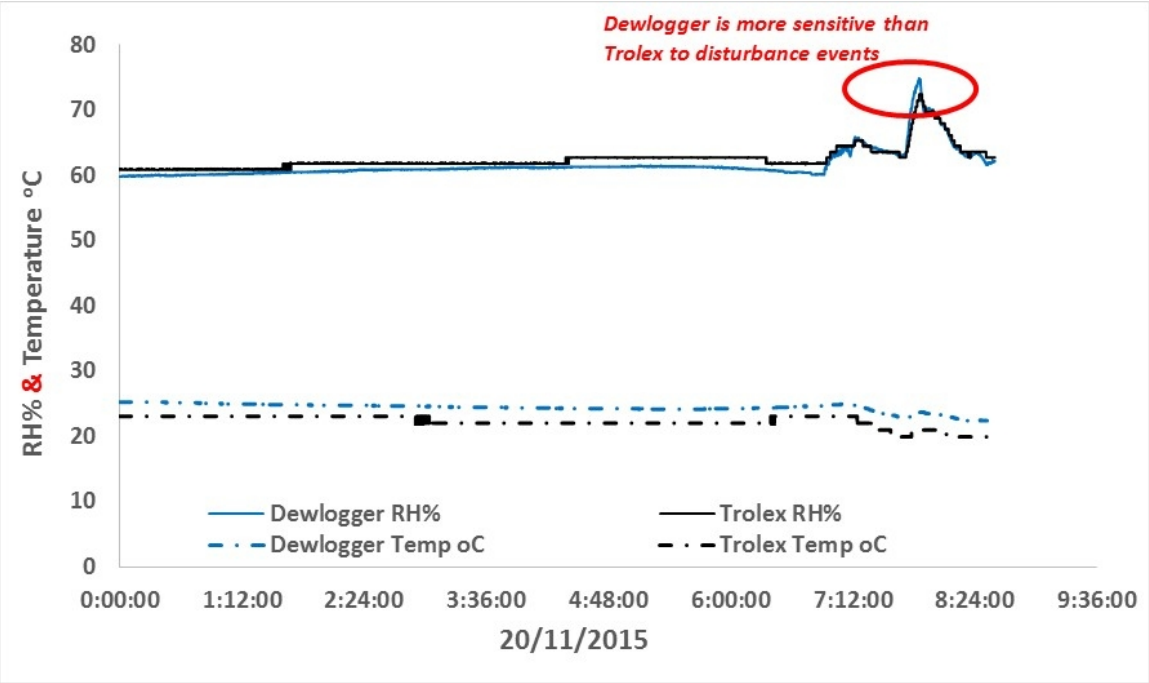
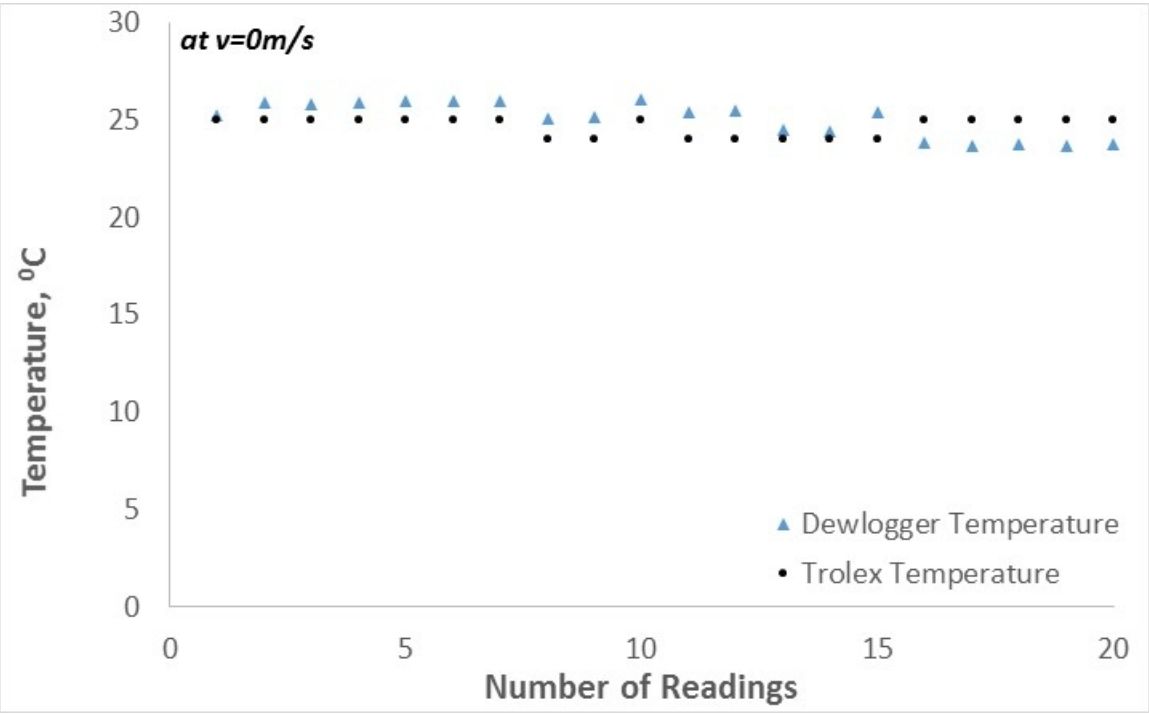


Figure 4 Continuous comparison of reference (Dewlogger) and IS approved (Trolex) instruments in two different days.

Figure 5 shows a comparison of temperature and relative humidity readings observed for the two instruments at an air velocity of approximately 0m/s with a dust concentration of 0 gm/m^3. The traces in Figure 5 show the comparison of temperature and relative humidity taken over a number of time intervals. The data suggest that:

- Trolex shows a higher relative humidity (up to 6% higher) when compared to the Dewlogger readings.
- Trolex dry bulb temperature readings are up to 6% lower than the Dewlogger readings.
- Trolex has the sensing range only up to 90% relative humidity, hence any readings above 90% may be discounted.



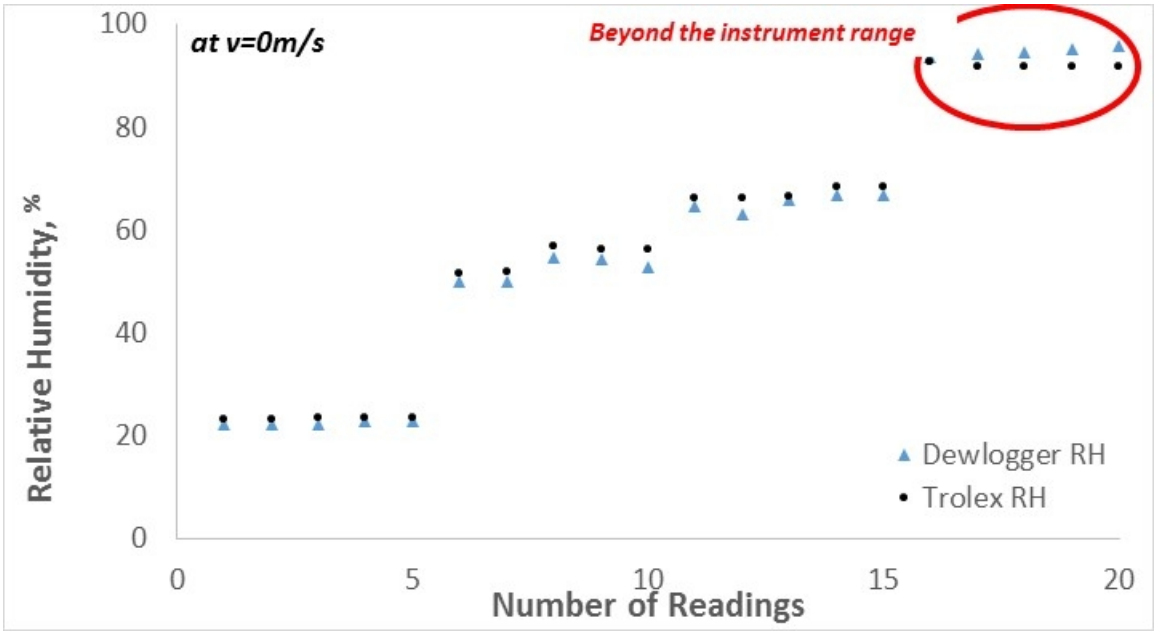


Figure 5 Top graph - comparison of temperature, and bottom graph – comparison of relative humidity (air flow velocity approximately 0m/s and dust concentration 0gm/m^3).

Similarly, Figure 6 shows a comparison of temperature and relative humidity readings for the two instruments at air flow velocity of 3.5 m/s with dust concentration of 0 gm/m^3. Similar to Figure 5, these graphs also show that:

- Trolex relative humidity readings are up to 6% higher than the Dewlogger readings.
- Trolex dry bulb temperature readings are between -5% to 3% range when compared to the Dewlogger readings.
- Trolex has a sensing range only up to 90% relative humidity, hence any readings above 90% may be discounted.

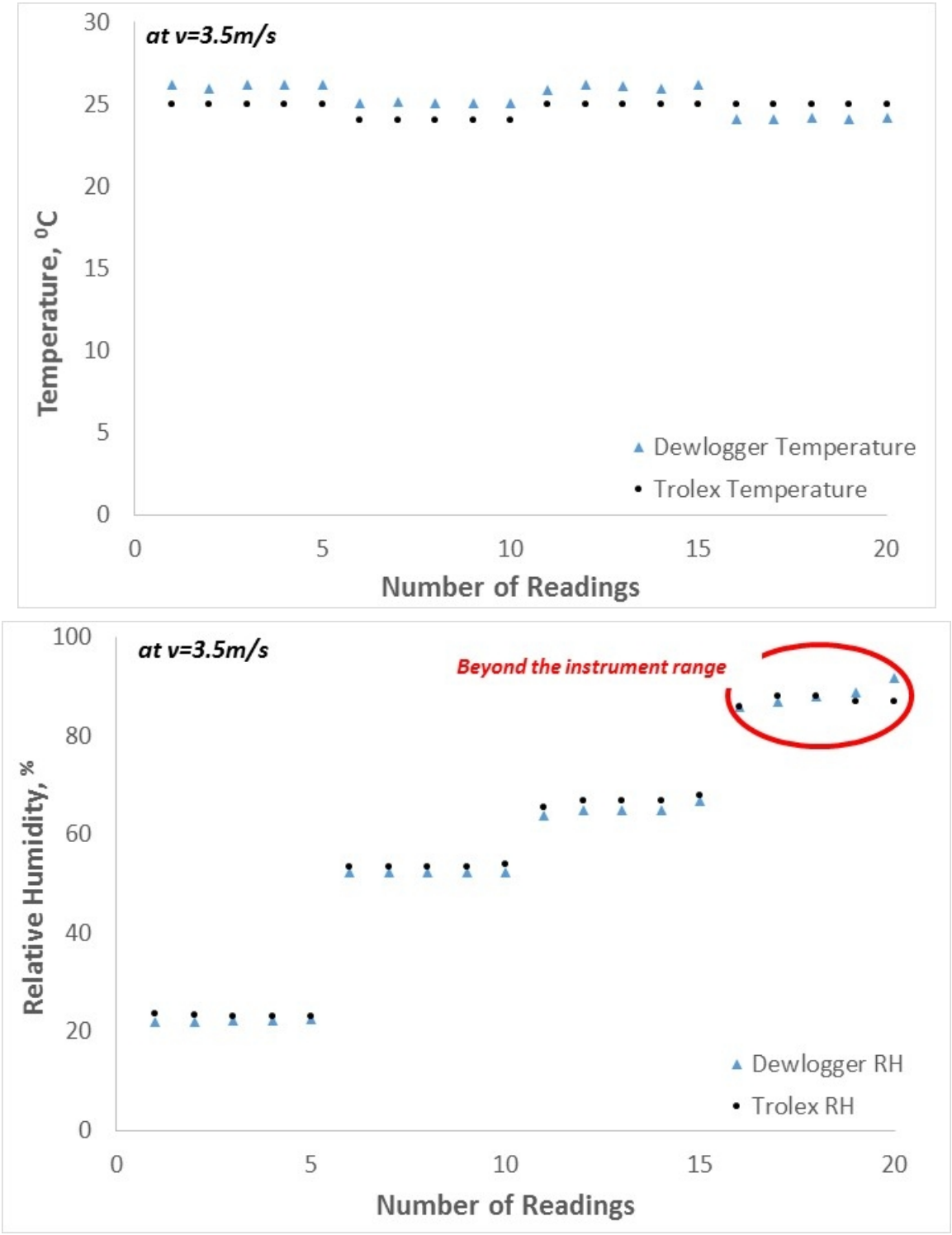
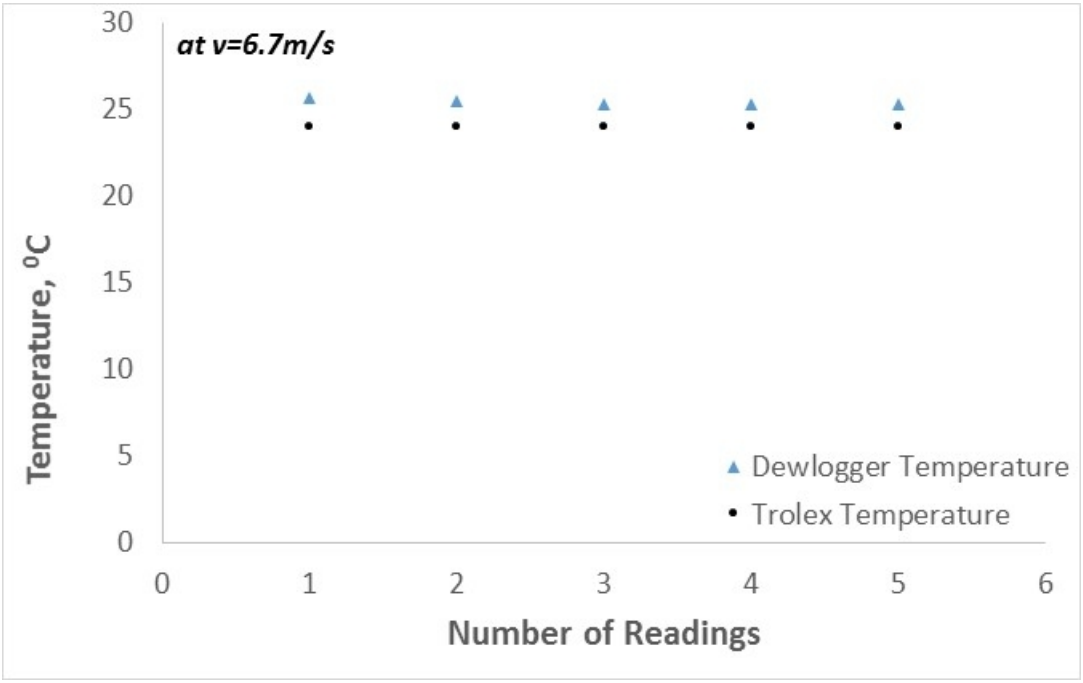


Figure 6 Top graph - comparison of temperature, and bottom graph – comparison of relative humidity (air flow velocity approximately 3.5m/s and dust concentration 0gm/m^3).

Figure 7 shows a comparison of temperature and relative humidity readings observed between the instruments at an air flow velocity of 6.7m/s with dust concentration of 0 gm/m^3. The graphs show that:

- Trolex relative humidity readings are up to 4% higher than the Dewlogger readings.
- Trolex dry bulb temperature readings are up to 5% lower when compared to the Dewlogger readings.



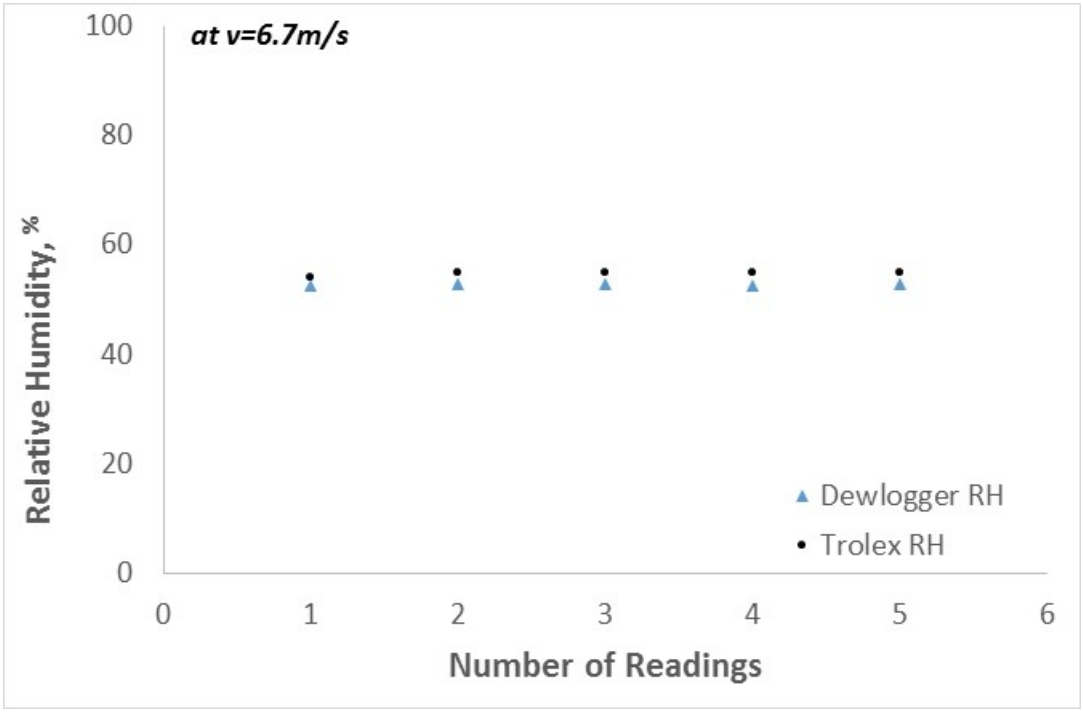


Figure 7 Top graph - comparison of temperature, and bottom graph – comparison of relative humidity (air flow velocity approximately 6.7m/s and dust concentration 0gm/m^3).

Figure 8 shows a comparison of temperature and relative humidity readings observed between the instruments at air flow velocity of approximately 7.2m/s with dust concentration of 0 gm/m^3. These graphs show that:

- Trolex relative humidity readings are up to 5% higher when compared to the Dewlogger readings.
- Trolex dry bulb temperature readings are up to 5% lower than the Dewlogger readings.

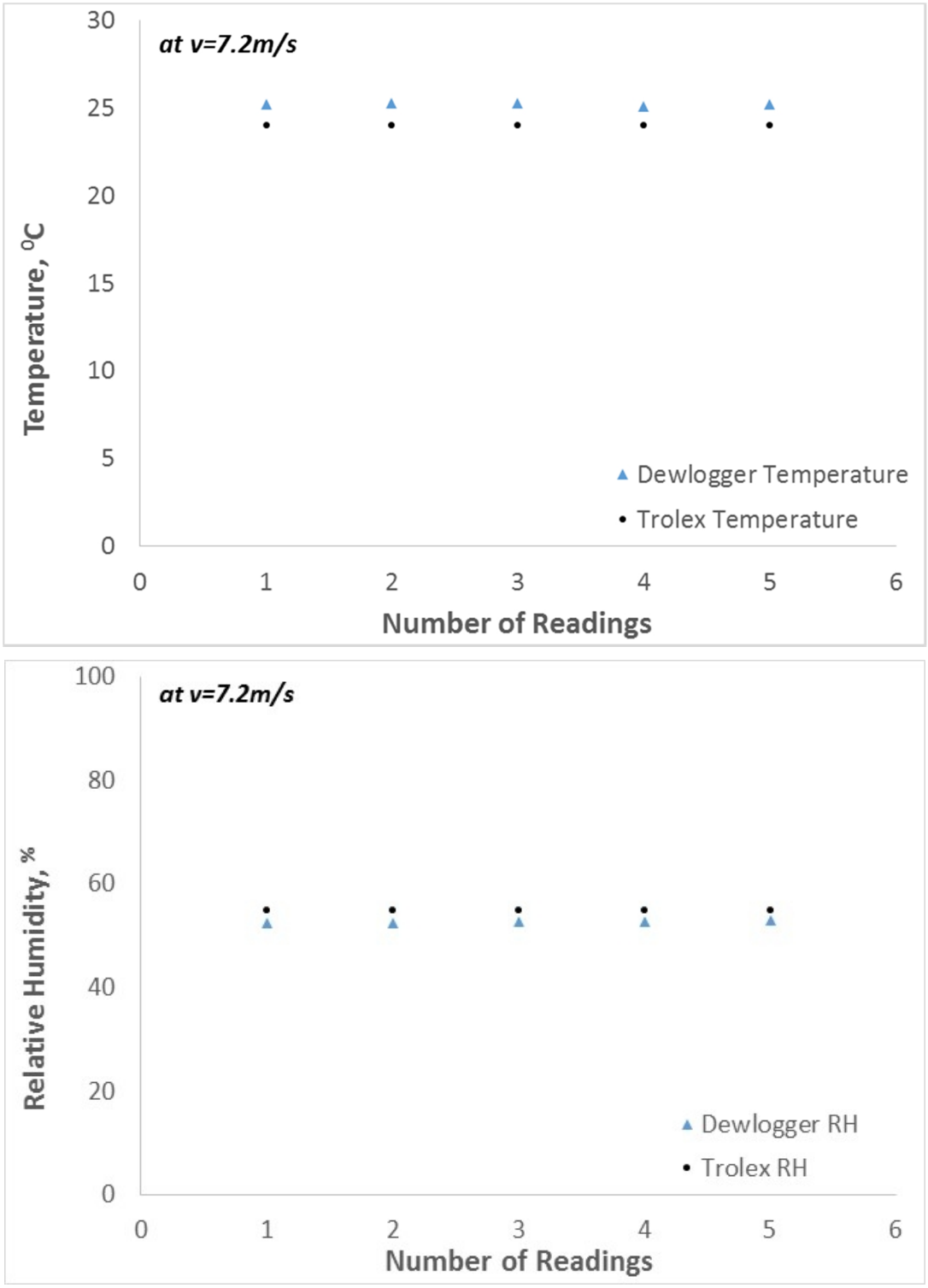


Figure 8 Top graph - comparison of temperature, and bottom graph – comparison of relative humidity (air flow velocity approximately 7.2m/s and dust concentration 0gm/m^3).

Figure 9 shows a comparison of temperature and relative humidity readings observed between the instruments at air flow velocity of approximately 8.3m/s with dust concentration of 0 gm/m^3. These graphs show that:

- Trolex relative humidity readings are up to 3% higher when compared to the Dewlogger readings.
- Trolex dry bulb temperature readings are up to 3% lower than the Dewlogger readings.

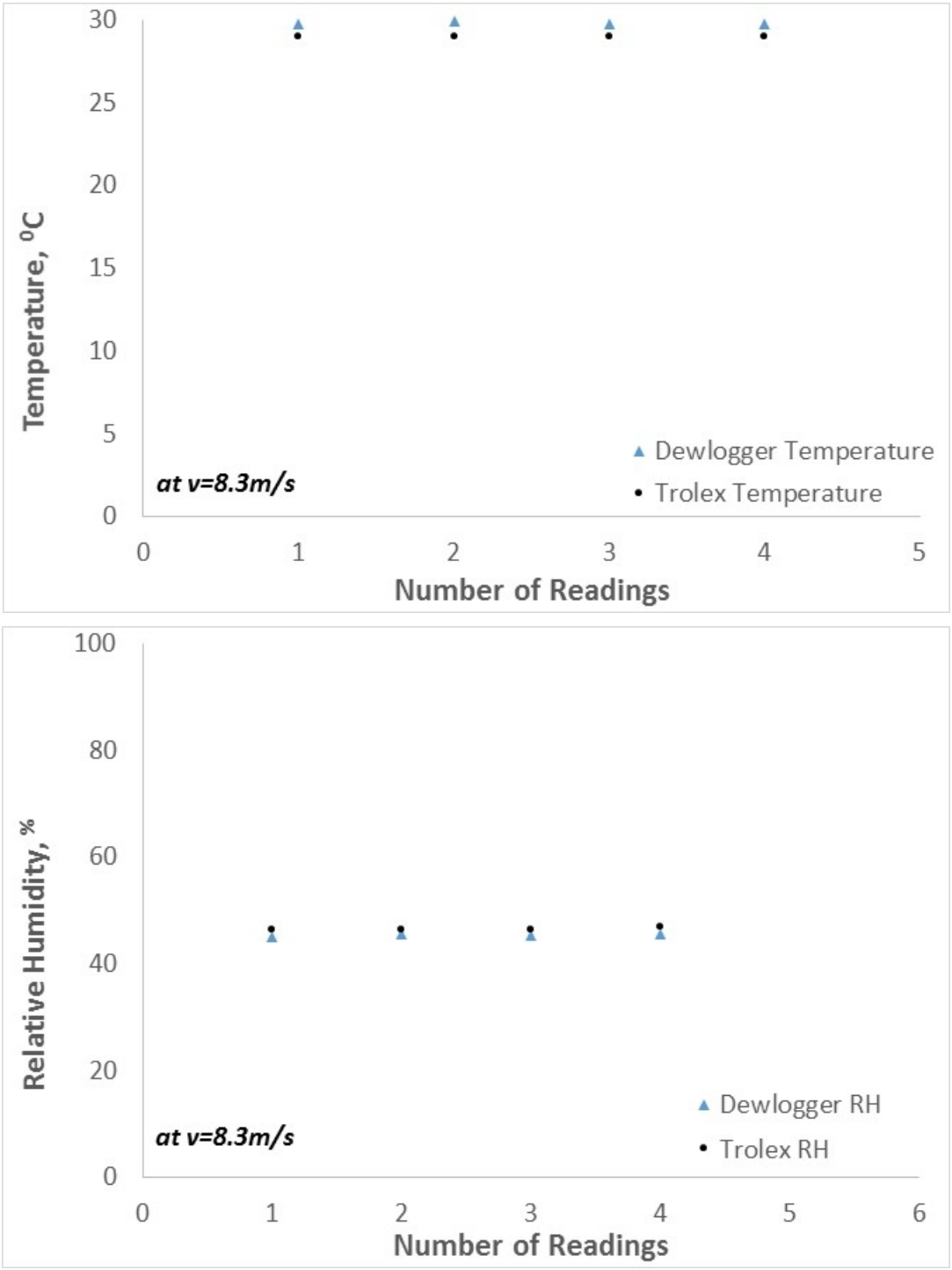


Figure 9 Top graph - comparison of temperature, and bottom graph – comparison of relative humidity (air flow velocity approximately 8.3m/s and dust concentration 0gm/m^3).

Figure 10 shows a comparison of temperature and relative humidity readings observed between the instrument at dusty concentration of approximately 25 gm/m^3. The dust chamber was not equipped with a dust concentration measuring instrument, but it was estimated from the quantity of dust spread in the chamber of known size, to be approximately 25gm/m^3 of dust concentration. These graphs show that the dry bulb temperature and relative humidity readings observed for each instrument are very close to each other.

- Trolex dry bulb temperature readings are in close agreement with the Dewlogger dry bulb readings. Trolex dry bulb temperature readings are up to 3% lower than the Dewlogger readings.
- Trolex relative humidity readings are up to 2% higher when compared to the Dewlogger readings.

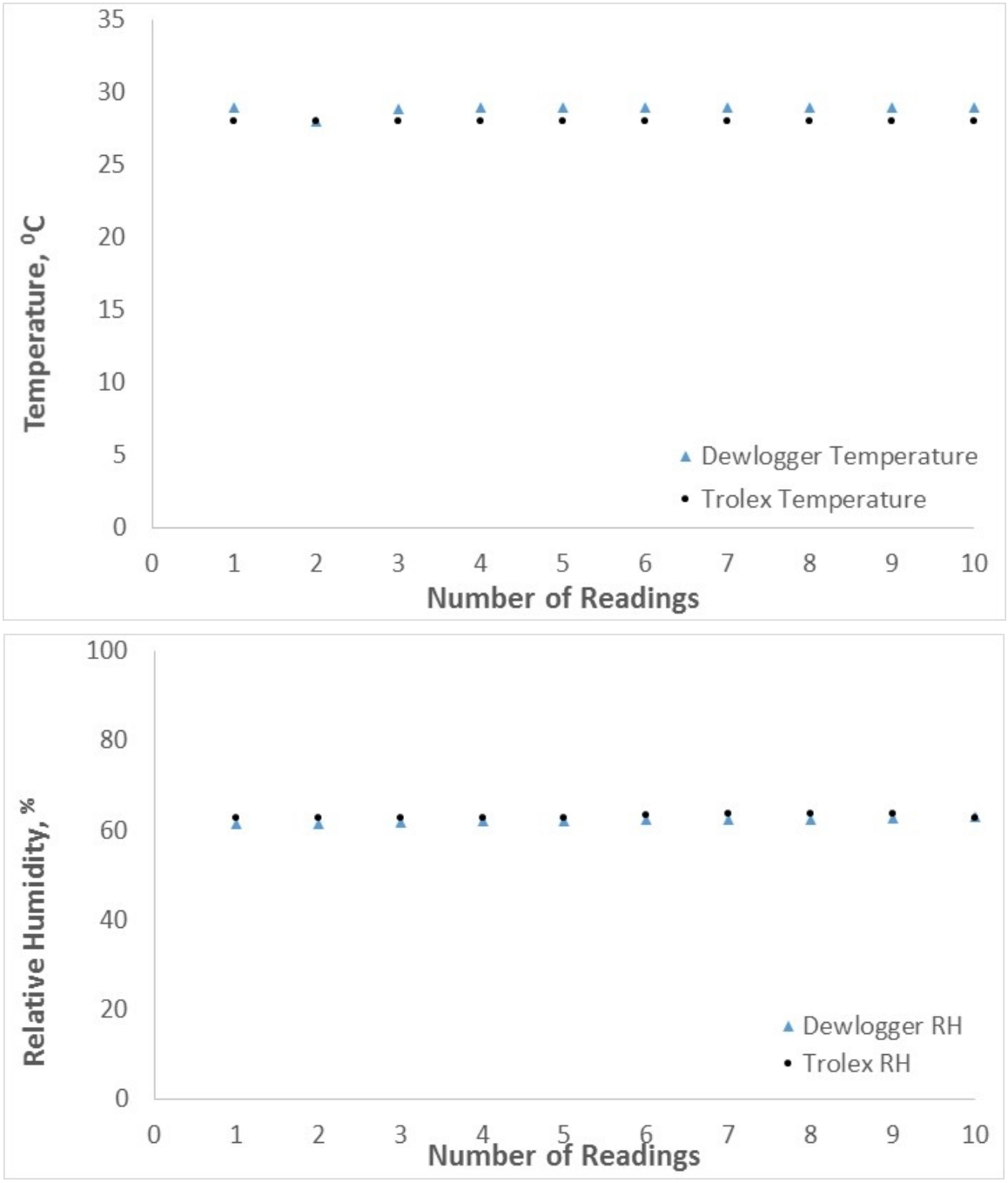


Figure 10 Top graph - comparison of temperature, and bottom graph – comparison of relative humidity with dust concentration of 25gm/m^3.

Comparison with Sling Psychrometer

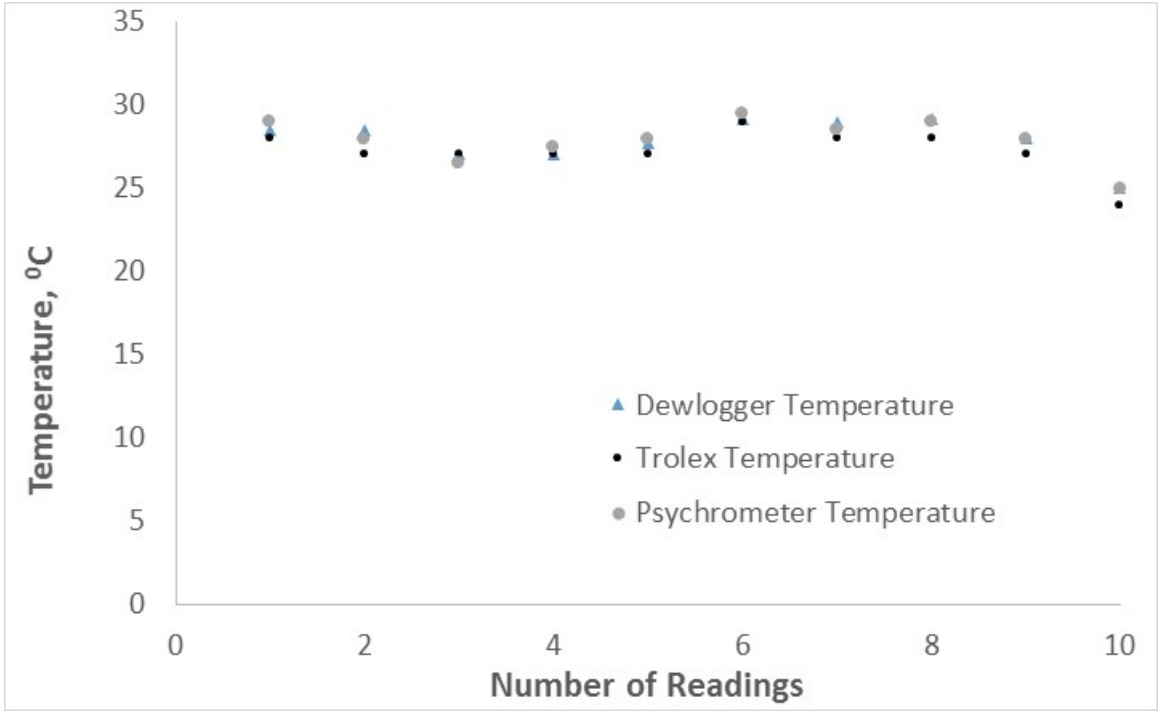
In order to gain confidence in the readings obtained from the Trolex instruments, the Trolex temperature and relative humidity readings were compared with readings obtained using a Bacharach sling psychrometer, shown in Figure 11. Figure 12 shows a comparison of the temperature and relative humidity readings obtained by the three instruments (the sling psychromter, the Trolex IS instrument and the non-IS instrument) at an air velocity of approximately 0m/s with a dust concentration of approximately 0 gm/m^3. The readings were taken in a single day (from 10am to 3pm on 8th of January 2016) at various time intervals in an external uncontrolled environment. The graphs of Figure 12 indicate that:

- The Trolex dry bulb temperature reading variations are -4% to 2%, and Dewlogger reading variations are -2% to 2% when compared to the sling psychrometer readings for identical environmental conditions.
- The Trolex relative humidity reading variations are -2% to 2%, and Dewlogger reading variations are -3% to 1% when compared to the sling psychrometer readings for identical environmental conditions.

Following points are to be considered while interpreting the results from the instruments:

- The readings obtained from the Trolex and Dewlogger were digitally displayed whereas the dry and wet bulb readings from the sling psychrometer were manually noted, and may be subject to parallax error. In addition the calculation of relative humidity from the dry and wet bulb readings obtained from the sling psychrometer was also prone to have parallax effect. The maximum effort was given to minimize such parallax effects while readings were taken and interpreted on the sling psychrometer.
- Similarly, low scale resolution and limited gradations may effect the interpretation of the readings obtained from the sling psychrometer.
- The sling psychrometer was held at arm's length while taking readings whereas the Trolex and Dewlogger were held at a greater distance, hence the former may be slightly influenced by the presence of a human body.
- From manufacturer's specifications the sensing accuracy of the Trolex relative humidity is +/- 5% whereas the accuracy of the Dewlogger relative humidity is +/-2.5%. The accuracy of sling psychrometer relative humidity is +/-5%. Similarly, the accuracy of Trolex temperature is 1% and the accuracy of the Dewlogger temperature is +/-0.7^{o}C.

Figure 11 Bacharach Sling Psychrometer



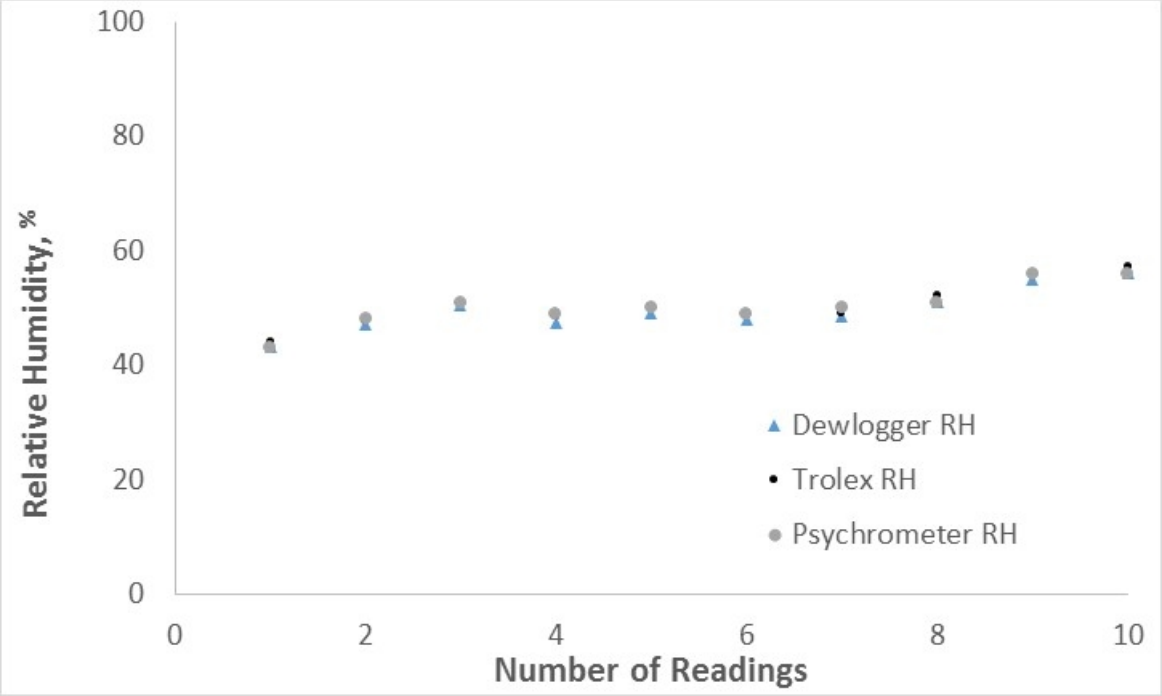


Figure 12 Comparison of Relative Humidity readings obtained from psychrometer and Trolex. The Dewlogger readings are also shown in the figure.

7 Overall Comparison and Limitation

The comparison of readings obtained from the experiments under the simulated conditions between Trolex and Dewlogger suggest that the IS relative humidity instrument (Trolex) consistently shows a slightly higher relative humidity readings up to 6% and IS temperature instrument (Trolex) shows a variation in temperature readings within -6% to +3% in comparison to the Dewlogger. Further, when compared to the relative humidity readings obtained using the sling psychrometer intervals in an external uncontrolled environment, the readings obtained from Trolex are within +/-2% and readings obtained from Dewlogger are within -3%. The Trolex dry bulb temperature reading variations are -4% to 2%, and Dewlogger reading variations are +/-2% when compared to the sling psychrometer dry bulb readings for identical environmental conditions.

The conclusions are based on a limited number of samples obtained in a known environment, where the temperature and relative humidity data obtained with the Trolex IS instrument were compared and contrasted with that obtained using a calibrated Dewlogger and a sling psychrometer.

A larger number of sample readings taken under more environmental scenarios and with a representative number of IS instruments, Dewlogger and sling psychrometer would provide a better degree of confidence in using the tested IS instruments.

As per the Trolex relative humidity sensor specifications, the instrument has a sensing range of 10 to 90% RH with sensing accuracy of +/-5%. This working range does not cover the whole spectrum of the relative humidity encountered in the underground coal mines. In some places in underground coal mines, the relative humidity measures up to 100%. The high humidity areas are the areas where the mine operators are most concerned.

8 Issues Noted during Study Period

During the study period, following issues were noted and considered while using the instruments.

Validation: The relative humidity readings obtained from four different relative humidity measuring instruments (Trolex, Dewlogger, In-house instrument and a sling psychrometer) were compared and it was noted that none of the readings matched exactly. However some readings varied by one decimal point only and in general they are in close agreement. Hence, achieving a decimal point comparison between two different instruments could be a challenging task. Relatively, for the dry bulb temperature measurements, the instruments are in very close agreement compared to the relative humidity readings.

Response time: In an abruptly changing environment, when two relative humidity instruments are continuously compared against each other, depending on the instruments' response time, the relative humidity readings could be different, as shown in Figure 4.

Drift/Divergence: In general, it can be expected that with the age of the sensing element, the measured readings may drift/diverge from the reference readings. However, in the tested environment, it was noted that the Trolex readings drifted fairly quickly and hence the original device was replaced with a second Trolex instrument. Even this new instrument diverged on the upper side within a few months. This could be a coincidence or it could be a characteristic of the Trolex device.

Calibration: As experienced during the experiments, the drift observed in the relative humidity readings obtained with the Trolex device was frequent and regular calibration of the instrument was needed. However this observation is of a single instrument and if the frequency of drifting is merely restricted to this particular instrument then, more frequent calibrations may not be needed and the recommended calibration interval would suffice.

Faulty Dewlogger: In the beginning, the relative humidity readings obtained from the Dewlogger did not match the other RH humidity measurement instruments tested during the study. Hence, the Dewlogger was sent for testing at the PCWI laboratory and it was found that the instrument was faulty and replaced under warranty.

Maintenance: The sling psychrometer requires little maintenance and each of the electronic instruments has its own maintenance requirements. Compared to the sling psychrometer, the Trolex device needs regular maintenance and calibration checks to maintain the functionality of the instrument.

Trolex Device: It has been experienced that if errors occur in the configuration file in the sensing module of the Trolex, an extra calibration device and some expertise is needed to reconfigure the instrument to its original status.

Site Trial: The mine measurement data had to be taken at various locations of the underground coal mine from the currently working mine, hence were constrained by practicalities, operational and logistics of data gathering activities.

9 Conclusion and Recommendation

The work up to the date has found that:

- In Queensland there is no mine which uses a real time temperature monitoring system for wet bulb and humidity measurements. One of the mines is in process of installing a real time relative humidity measurement device.
- The majority of the respondents from Queensland mines indicated that if a real time instrument for measuring dry bulb, wet bulb and humidity was available they would be interested to install such a device at their mine sites.
- At the moment, only one supplier (Austdac/Trolex) has an IS approved real time temperature and humidity measuring device approved for use in Queensland underground coal mines.
- Laboratory experiments performed during this project showed that the Trolex instrument exhibits a variation of dry bulb temperature by as much as -6% and up to +3% and always shows higher relative humidity readings by as much as +6% when compared to the standard calibrated non-IS instrument readings.
- Within the limitations of the current study, the tested IS Trolex relative humidity and temperature monitoring instruments could be considered. However, this conclusion is based on a limited sample size, limited number of instruments and the measurements were taken in a limited number of controlled environmental scenarios of temperature and relative humidity. A larger number of readings taken under more environmental scenarios and with a representative number of IS instruments would provide a better measure of confidence.
- It can be inferred from the work that presently, there is a definite need for the development of a reliable real time humidity measurement system suitable for use in Australian underground coal mines.

Based on the current study, the following work can be recommended.

- Use of IS approved real time temperature and relative humidity measurement instruments in underground coal mines would be beneficial due to improvements in work place health and safety, and other operational benefits.
- To obtain humidity measurements underground coal mines are currently using a manual psychrometer, however the survey trend shows that the mines are interested in using an IS approved real time digital relative humidity instrument. Also, the comparison between various instruments shows that it is a challenging task when using digital instruments to obtain measurements which match to the decimal point. To achieve this, it would be necessary to consider a single type of instrument which could standardize the measurement process.
- The underground coal mines operate in the relative humidity range spanning up to 100%. The only IS approved instrument, Trolex, at the moment measures up to 90% relative humidity (as per manufacture's specification). It is recommended to investigate the possible development of a new IS approved instrument which can measure up to 100% relative humidity.

10 Reference

ADS Gillies, HW Wu, TI Mayes and A Halim, The challenge of measuring airflow through Mine Regulators to Allow Real Time Ventilation Monitoring, Proceedings, Queensland Mining Industry Health and Safety Conference, Townsville, 145-150 August 2002.

B. Belle, Underground Mine Ventilation Air Methane (VAM) Monitoring – an Australian Journey towards Achieving Accuracy, 14th Coal Operators' Conference, University of Wollongong, The Australasian Institute of Mining and Metallurgy & Mine Managers Association of Australia, 2014, 230-242.

B. Shen, H. Guo, A. King, and M. Wood, An Integrated Real-Time Roof Monitoring System for Underground Coal Mines, in Aziz, N (ed), Coal 2006: Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2006, 64-76.

Coal Mining Safety and Health Act 1999. Queensland Coal Mining Safety and Health Regulation 2001.

D. Brady, The Role of Gas Monitoring in the Prevention and Treatment of Mine Fires in Aziz, N (ed), Coal 2008: Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2008, 202-208.

K. Crowley, J. Frisby, S. Murphy, M. Roantree and D. Diamond, Web-based real-time temperature monitoring of shellfish catches using a wireless sensor network, Sensors and Actuators A 122 (2005) 222–230

K. Haustein, E. Widzyk-Capehart, P. Wang, D. Kirkwood and R. Prout, The Nexsys Real-time Risk Management and Decision Support System: Redefining the Future of Mine Safety, 11th Underground Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2011, 205-213.

PCWI. 2015. http://www.pcwi.com.au/products/certification-compliance (12/11/2015)

11 Appendix

The data sheets have been referred from Trolex, PCWI and Sling Psychrometer catalogues provided to the authors.

11.1Trolex Datasheet

TX6356
Data Sheet

Sentro Humidity Sensor

Safety monitoring of humidity, in heavy-duty applications

Environments: Mining • Storage Areas • Process Plants • Utilities • Oil & Gas

Features

- High accuracy humidity sensor with calibrated input sensing modules
- Choice of output signals:

  - 0.4 to 2 V analogue
  - 4 to 20 mA analogue
  - 5 to 15 Hz analogue
  - Dual relay contacts
    normally open OR normally closed
  - RS485 addressable Modbus datacomms

- Large backlit LCD screen provides clear sensor information and diagnostic data
- Two programmable setpoints for inbuilt visual alarms
- Easy access terminal chamber with large, vibration secure, terminals for connecting heavy plant cables
- Sensing range: 10 to 90% RH non-condensing
- Sensing accuracy: +/- 5%

IECEx

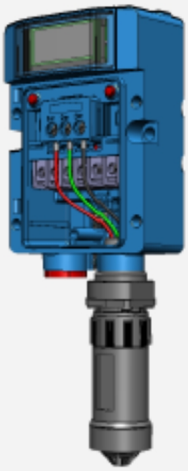
Benefits

- High strength, dual wall moulded housing for maximum impact protection
- Housing is dust and waterproof to IP65 - humidity sensor head is protected to IP54
- EMC conformity - pending
- Certified for use in hazardous areas

TX6356
Data Sheet

Humidity Sensing

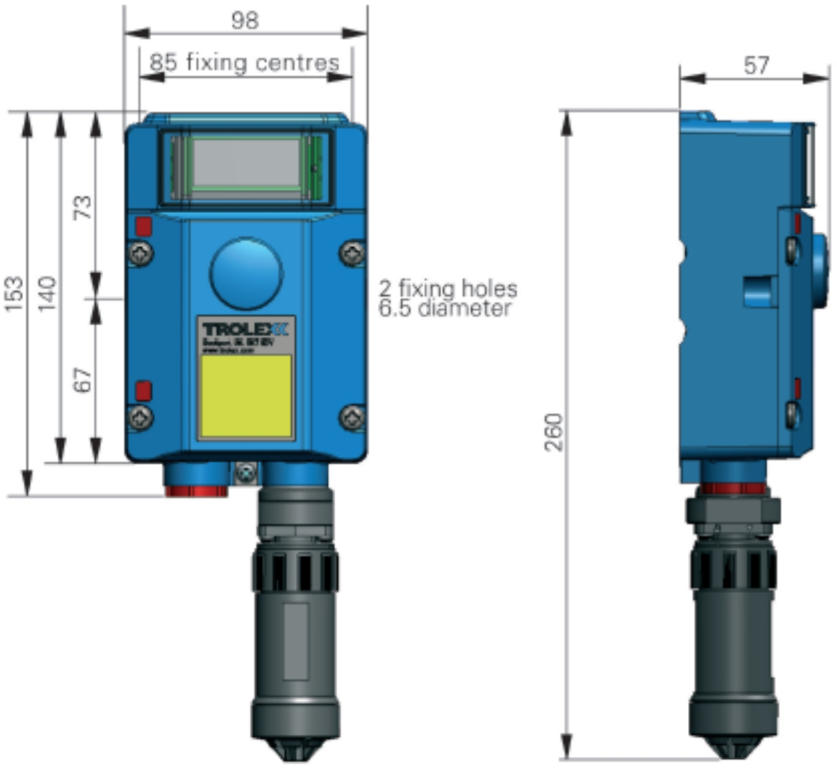
Heavy-duty, robust fixed point humidity sensor for safety monitoring of humidity in heavy-duty applications. Suitable for use in mining, storage areas, process plants, utilities and oil & gas. High accuracy humidity sensor with a choice of output signals, 0.4 to 2 V analogue, 4 to 20 mA analogue, 5 to 15 Hz analogue, dual relay contacts or RS485 addressable Modbus datacomms.



Large backlit LCD screen provides clear sensor information and diagnostic data. Two programmable setpoints for General and High alarm. Default values are entered during manufacture and these can be changed to preferred values. Inbuilt visual alarms are configured to operate when General and High alarms are activated. Easy access terminal chamber with large, vibration secure, terminals for connecting heavy plant cables.

Sensing range from 10 to 90% RH non-condensing with a sensing accuracy of +/- 5%. The sensing module stores all the necessary data about its type identification, sensing range and specific calibration. This data is automatically recognised by the Sentro when the sensing module is loaded into the module bay.

Dimensions



All dimensions in mm

Trolex Limited www.trolex.com

TROLEX

TX6356
Data Sheet

Technical Data

	Underground Mining	General Purpose
Supply voltage:	12 V dc	24 V dc
Supply voltage range:	7.5 to 14.4 V dc	7.5 to 28 V dc
Current consumption:	TBA mA	TBA mA
Current consumption with backlight:	TBA mA	TBA mA
Output signal data:	0.4 to 2 V analogue output 4 to 20 mA analogue output 5 to 15 Hz output Dual relay contacts (normally open OR normally closed) RS485 datacomms output	4 to 20 mA analogue output Dual relay contacts (normally open OR normally closed) RS485 datacomms output
Display:	128 x 64 dot LCD screen with backlit illumination	
Visual alarm indicators:	Inbuilt visual alarm LEDs for General and High alarms. Programmable alarm set-points and options selectable from the setup menus	
Type of sensor:	Humidity sensor built into ruggedised housing. Sensor data is output to Sentro rModule. Sentro rModule stores service life and sensing element condition	
Operating Temperature Range:	-20 to +40°C	
Sensing Range:	10 to 90% RH, non-condensing	
Sensing Accuracy:	+/- 5%	
Storage Temperature Limits:	-20 to +60°C	
Housing Materials:	Reinforced polymer EMC protected and proof against surface electrostatic charge	
Protection Classification:	Housing dust and waterproof to IP65 Sensor head - protected to IP54	
Weight:	750 g	
Mounting:	Two 6.5 mm diameter fixing holes (Unistrut 6946 compatible)	

TX6356
Data Sheet

Underground Mining • Intrinsically Safe • Ex ia M1 • TX6356

Coal Mining • Water Utilities • Telecommunications

Output Signal Options

TX6356	3/4 wire. Remote powered - 0.4 to 2 V analogue output
Supply voltage:	10 to 14 V
Min. line load:	10 Kohm - TBC
Supply current @ 12 V:	20 mA - TBC

TX6356	3/4 wire. Remote powered - 4 to 20 mA analogue output
Supply voltage:	10 to 14 V
Max. line load:	220 ohm maximum @ 12 V dc - TBC
Supply current @ 12 V:	48 mA - TBC

TX6356	3/4 wire. Remote powered - 5 to 15 Hz output
Supply voltage:	10 to 14 V
Max. line load:	Opto isolated to 2 mA maximum - TBC
Supply current @ 12 V:	20 mA - TBC

TX6356	3/4 wire. Remote powered - Dual relay contacts
Supply voltage:	10 to 14 V
Supply current @ 12 V:	60 mA - TBC

TX6356	3/4 wire. Remote powered - RS485 datacomms output
Supply voltage:	10 to 14 V
Line:	Modbus protocol
Supply current @ 12 V:	25 mA - TBC

TX6356
Data Sheet

General Purpose • Non-hazardous Areas • TX6356

Storage Areas • Process Plants • Water & Power Utilities • Car Parks

Output Signal Options

TX6356	3/4 wire. Remote powered - 4 to 20 mA analogue output
Supply voltage:	18 to 28 V
Max. line load:	500 ohm at 24 V - TBC
Supply current:	40 mA - TBC

TX6356	3/4 wire. Remote powered - Dual relay contacts
Supply voltage:	20 to 28 V
Supply current:	35 mA - TBC

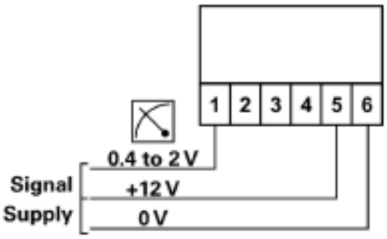
TX6356	3/4 wire. Remote powered - RS485 datacomms output
Supply voltage:	14 to 28 V
Line:	Modbus protocol
Supply current:	40 mA - TBC

Trolex Limited www.trolex.com

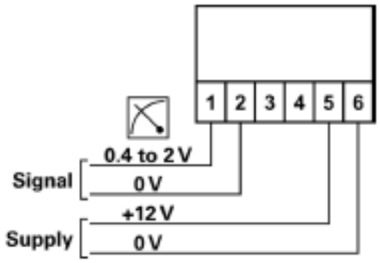
TROLEX

Connections

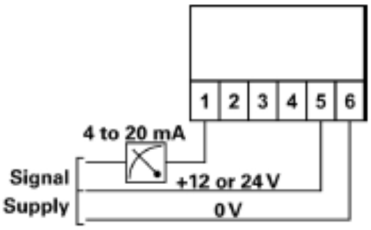
0.4 to 2 V • 3 Wire



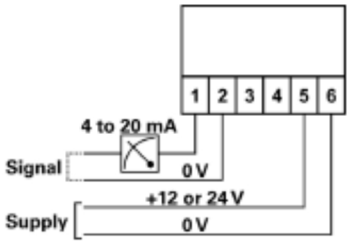
0.4 to 2 V • 4 Wire



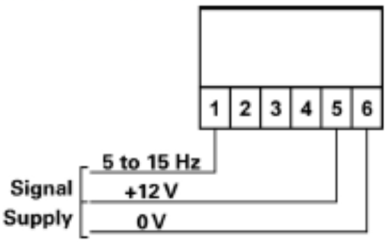
4 to 20 mA • 3 Wire



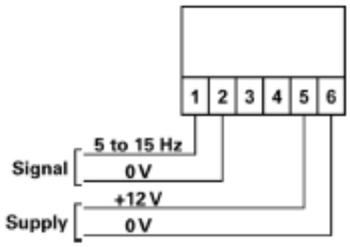
4 to 20 mA • 4 Wire



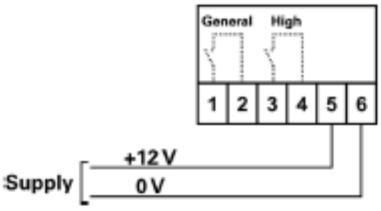
5 to 15 Hz • 3 Wire



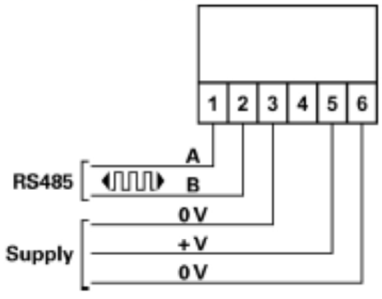
5 to 15 Hz • 4 Wire



Dual Relay Contacts



RS485 Modbus



TX6356
Data Sheet

Order Reference

TX6356.06.01	Sentro Humidity Sensor - Underground Mining - 4 to 20 mA output - 3/4 wire
TX6356.06.02	Sentro Humidity Sensor - Underground Mining - 0.4 to 2 V output - 3/4 wire
TX6356.06.03	Sentro Humidity Sensor - Underground Mining - 5 to 15 Hz output
TX6356.06.04	Sentro Humidity Sensor - Underground Mining - RS485 output
TX6356.06.05	Sentro Humidity Sensor - Underground Mining - Dual relay contact - normally closed
TX6356.06.06	Sentro Humidity Sensor - Underground Mining - Dual relay contact - normally open
TX6356.00.01	Sentro Humidity Sensor - General Purpose - 4 to 20 mA output - 3/4 wire
TX6356.00.04	Sentro Humidity Sensor - General Purpose - RS485 output
TX6356.00.05	Sentro Humidity Sensor - General Purpose - Dual relay contact - normally closed
TX6356.00.06	Sentro Humidity Sensor - General Purpose - Dual relay contact - normally open

Please contact the Trolex Sales Team for further information and advice:

+44 (0)161 483 1435
sales@trolex.com

Certification

Australia

Ex certified for use in underground mines: TX6356.06.xx

Ex Certificate Number: IECEx ITA 14.0006X
Ex ia I Ma (-20°C ≤ Ta ≤ + 40°C)

For applicable Conditions of Safe Use, refer to the Sentro Humidity User Manual TX6356-UM-EN

Copyright and Trademarks

Document history: Issue 01 19 December 2014 First publication of this document - fourth draft

TROLEX

TX6273 TX6274

TEMPERATURE SENSOR/ TRANSMITTER

ATEX
M 1
GROUP I & II
INTRINSICALLY
SAFE

high accuracy temperature sensor with integral signal transmitter

TUNNELS
•
MINING
•
TRENCHES
•
VESSELS
•
CONTAINERS
•
PROCESS PLANTS
•
STORAGE AREAS
•
CONFINED AREAS

ISSUE F 06/14

fast response

for temperature protection in pipes, vessels, bearings, power packs, gearboxes, drive heads, hydraulic circuits, brake shoes, and ambient air temperature.

reliable

Long signal transmission distance with automatic stability control.

choice

- 4...20mA • 0.4...2V • 5...15Hz analogue output signal.
- Optional LCD temperature readout.
- Use with integral or remote sensors.
- Semiconductor sensor or PT100 sensing element compatibility.

1/3

ATEX
M 1
GROUP I & II
INTRINSICALLY
SAFE

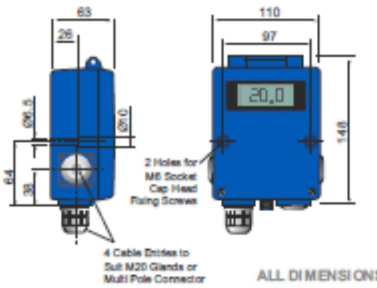
...simple
safety
monitoring

technical data...

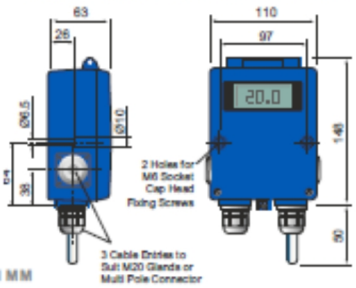
	SENSOR INPUT TYPES	
	Semi-conductor	PT100 (TX6273 only)
Temperature Measuring Range:	0...100°C	0...200°C
Overall Accuracy:	±2%	1% (dependent on class of probe)
Repeatability:	±1%	1%
Ambient Temperature Limits:	–10...70°C	
Housing Material:	Stainless steel filled Polyamide 6	
Indicator:	Green 'Power on' LED (on versions without LCD)	
Protection Classification:	Dust and waterproof to IP65	
Electrical Connections:	4mm barrier terminals	
Nett Weight:	500g	
Information Display:	3½ digit LCD calibrated in °C	

Dimensions

TX6273
REMOTE TEMPERATURE SENSING PROBES



TX6274
INTEGRAL AIR TEMPERATURE SENSING PROBE

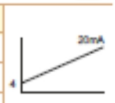


ALL DIMENSIONS IN MM

electrical data...

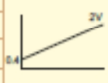
GENERAL PURPOSE AND
Ex GROUP II APPLICATIONS (24V dc)
TX6273 • TX6274

Output:	4...20mA
Max Load	600 ohms at 24V dc
Supply	10...30V dc
Current	Loop powered



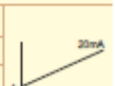
Ex GROUP I APPLICATIONS (12V dc)
TX6273 • TX6274

Output:	0.4...2V
Min Load	10k ohms
Supply	9...16.5V dc
Current	<10mA



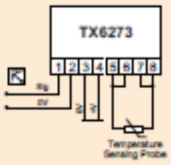
TX6273 • TX6274

Output:	5...15Hz
Max Load	200 ohms at 12V dc
Supply	9...16.5V dc
Current	Loop powered

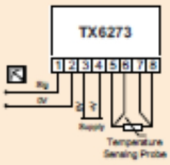


connections...

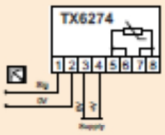
Two wire probe connection.



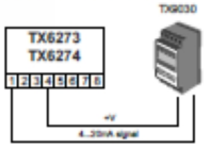
Four wire probe connection for line compensation.



Integral air temperature sensing probe.



The output signal from terminals 1 and 4 is a conventional 4...20mA two wire current regulated signal loop. Sensor/transmitter using PT100 or semiconductor sensing probes have very low power consumption so the same loop can be used to also power the sensor. No separate power supply is needed.



ISSUE F 06/14

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ATEX
M 1
GROUP I & II
INTRINSICALLY
SAFE

order reference...

TX6273 **TEMPERATURE SENSOR/ TRANSMITTER**

Remote Sensing Temperature Probe

Please specify:

CERTIFICATION

Intrinsically Safe Group I	(01)
Intrinsically Safe Group II	(02)
General Purpose	(03)

OUTPUT SIGNAL

0.4...2V (Group I only)	(11)
4...20mA	(12)
5...15Hz output available to special order (Group I only)	

SENSOR TYPE

KTY21-6 Semiconductor	(21)
PT100 Resistive	(23)

DISPLAY

With Display	(45)
Without Display	(46)

SENSING PROBES

Please order separately from Technical Datasheet TX2070.

TX6274 **TEMPERATURE SENSOR/ TRANSMITTER**

Integral Air Temperature Sensing Probe

Please specify:

CERTIFICATION

Intrinsically Safe Group I	(01)
Intrinsically Safe Group II	(02)
General Purpose	(03)

OUTPUT SIGNAL

0.4...2V (Group I only)	(11)
4...20mA	(12)
5...15Hz output available to special order (Group I only)	

DISPLAY

With Display	(45)
Without Display	(46)

certification & approval...

Ex	**Group I TX6273 TEMPERATURE SENSOR/TRANSMITTER:**	GROUP I EEx ia I
	Group II TX6274 TEMPERATURE SENSOR/TRANSMITTER:	GROUP II EEx ia IIC T4
CE	Designed to comply with the requirements of the EC directive:	• ATEX directive 94/9/EEC • EMC directive 89/336/EEC

TROLEX LIMITED
NEWBY ROAD, HAZEL GROVE, STOCKPORT,
CHESHIRE SK7 5DY, UK
+44 (0)161 483 1435
sales@trolex.com
www.trolex.com

ISSUE F 06/14

Australian/New Zealand
Certification Scheme for
EXPLOSION-PROTECTED ELECTRICAL EQUIPMENT
ANZEx Scheme

Certificate of Conformity

Certificate No.: **ANZEx 12.3004X**	Issue No.: **0**	Date of Issue: **2012-02-14**

Applicant: Trolex Limited
Newby Road, Hazel Grove
Stockport, Cheshire, SK7 5DY
UK

Electrical Apparatus: TX6273 and TX6274 Temperature Sensor/Transmitter

Type of Protection: Intrinsic Safety 'ia'

Marking Code: ANZEx 12.3004X
Ex ia I / Ex ia IIC T4
Ta = -20 ºC to +60 ºC

Manufacturer: Trolex Limited
Newby Road, Hazel Grove
Stockport, Cheshire, SK7 5DY
UK

Manufacturing Location(s): Trolex Limited
Newby Road, Hazel Grove
Stockport, Cheshire, SK7 5DY
UK

The EPEE certification database located at ***http://www.anzex.com.au*** *shows the validity of this Certificate.*

This certificate and schedule shall not be reproduced except in full

Certificate issued by:

TestSafe Australia
919 Londonderry Road, Londonderry NSW 2753
Australia
Phone: +61 2 4724 4900 Fax: +61 2 4724 4999
http://www.testsafe.com.au

www.jas-anz.com.au/register

Australian/New Zealand
Certification Scheme for
EXPLOSION-PROTECTED ELECTRICAL EQUIPMENT
ANZEx Scheme

Certificate of Conformity

Certificate No.: **ANZEx 12.3004X**	Issue No.: **0**	Date of Issue: **2012-02-14**

*This certificate is granted subject to the conditions as set out in Standards Australia/Standards New Zealand Miscellaneous Publication **MP87.1:2008**.*

STANDARDS:

The electrical apparatus and any acceptable variations to it specified in the schedule of this certificate and the identified documents, was found to comply with the following standards:

AS/NZS 60079-0:2005	Electrical apparatus for explosive gas atmospheres - Part 0: General requirements
AS/NZS 60079-11:2006	Explosive atmospheres - Part 11: Equipment protection by Intrinsic safety "i"
AS 60529:2004	Degree of protection provided by enclosures (IP code)

*This Certificate **does not** indicate compliance with electrical safety and performance requirements other than those expressly included in the Standard(s) listed above.*

ASSESSMENT & TEST REPORTS:

The equipment listed has successfully met the assessment and test requirements as recorded in:

Test Report No. and Issuing Body:	33377 ; TestSafe
Quality Assessment Report No. and Issuing Body:	GB/SIR/QAR07.0017/02 ; Sira
File Reference:	2011/021893

Signed for and on behalf of issuing body

2012-02-14

Date of Issue

Quality & Certification Manager

Position

Australian/New Zealand

Certification Scheme for

EXPLOSION-PROTECTED ELECTRICAL EQUIPMENT

ANZEx Scheme

Certificate of Conformity

Certificate No.: **ANZEx 12.3004X**	Issue No.: **0**	Date of Issue: **2012-02-14**

Schedule

EQUIPMENT:

The TX6273 and TX6274 Temperature Sensor/Transmitter are temperature sensors. They take a signal from an integral resistance temperature sensor, condition the signal and output it, in analogue form, to external monitoring equipment. The two models differ in the location of the sensing element.

There are five builds of the Sensor/Transmitter:

Group I	0.4-2V
Group I	5-15Hz
Group I	4-20mA, 3/4 wires
Group I	4-20mA, 2 wires
Group IIC	4-20mA, 2 wires

CONDITIONS OF CERTIFICATION:

1. It is a condition of safe use that the following entity parameters for the terminals shall be taken into account during installation:

	Group I 4-20mA, 3/4-wire		**Group I 0.4-2V**		**Group I 5-15Hz**	
	T1-T2 (signal)	**T3-T4 (supply)**	**T1-T2 (signal)**	**T3-T4 (supply)**	**T1-T2 (signal)**	**T3-T4 (supply)**
Ui	16.5V	16.5V	16.5V	16.5V	16.5V	16.5V
Ii	150mA	-	150mA	-	-	-
Pi	0.62W	-	0.62W	-	2.5W	-
Ci	1.2nF	0	1.2nF	0	0	0
Li/Ri	<20uH/Ω	<20uH/Ω	<20uH/Ω	<20uH/Ω	<20uH/Ω	<20uH/Ω
Uo	16.5V	-	-	-	-	-
Io	281mA	-	-	-	-	-
Po	1.158W	-	-	-	-	-
Co	857nF	-	-	-	-	-
Lo	2955uH	-	-	-	-	-

Certificate of Conformity

Certificate No.: **ANZEx 12.3004X**	Issue No.: **0**	Date of Issue: **2012-02-14**

	Group I 4-20mA, 2-wire		Group II 4-20mA, 2-wire	
	T1-T4	**T2-T3**	**T1-T4**	**T2-T3**
Ui	16.5V	1.5V	28V	1.5V
Ii	-	100mA	120mA	100mA
Pi	-	25mW	0.84W	25mW
R_{source}	-	-	234Ω	-
Ci	0	0	38nF	0
Li	-	-	9uH	9uH
Li/Ri	<20uH/Ω	<20uH/Ω	-	-
Uo	N/A	16.5V	N/A	28V
Io	N/A	17mA	N/A	28mA
Co	N/A	5nF	N/A	5nF
Lo	N/A	5uH	N/A	5uH

2. It is a condition of safe use that since potential electrostatic charging may develop on surface of the apparatus, the apparatus shall only be cleaned with a damp cloth.

Australian/New Zealand

Certification Scheme for

EXPLOSION-PROTECTED ELECTRICAL EQUIPMENT

ANZEx Scheme

Certificate of Conformity

Certificate No.: **ANZEx 12.3004X** Issue No.: **0** Date of Issue: **2012-02-14**

DOCUMENTS:

Document Number	Sheets	Document Title	Rev.	Date (yyyy-mm-dd)
P5460.24	1	PCB Artwork (5-15Hz)	A	1997-07-07
P5460.109	1	Circuit Diagram 5-15Hz Module P.C.B.	A	1998-05-18
P5485.02	1	General Arrangement	E	2010-11-04
P5485.03	1	Certified Block Diagram	A	2002-09-25
P5485.04 Sheet 1 of 2	1	Output PCB Certified Circuit Diagram (Gp I only)	C	2002-09-20
P5485.04 Sheet 2 of 2	1	Certified Parts List Group I 0.4 to 2V, 4 to 20mA and 5 to 15Hz	C	2002-09-20
P5486.06	4	Output PCB (track layout based on P5485.04)	A	1999-09-01
P5487.01	1	Certified Circuit Diagram Output PCB	B	2002-09-20
P5487.03	5	Output PCB (track layout based on P5487.01)	A	1999-09-21
P5487.04	4	Display PCB (track layout)	A	1999-09-01
P5487.07	1	Certified Circuit Diagram Display PCB	B	1999-12-14
P5485.27	1	Certification Labels	C	2012-02-06

IECEx Certificate of Conformity

INTERNATIONAL ELECTROTECHNICAL COMMISSION
IEC Certification Scheme for Explosive Atmospheres

for rules and details of the IECEx Scheme visit www.iecex.com

Certificate No.:	IECEx ITA 14.0006X	Issue No: 1	Certificate history:
			Issue No. 1 (2014-12-18)
Status:	**Current**	Page 1 of 4	Issue No. 0 (2014-06-05)
Date of Issue:	**2014-12-18**		
Applicant:	**Trolex Limited** 10 Newby Road, Hazel Grove Stockport Cheshire SK7 5DY **United Kingdom**		
Electrical Apparatus:	**Sentro 1 Sensor/Transmitter TX6351.01i, TX6352.01i & Sentro Trip Amp/Transmitter TX9081.01i**		
Optional accessory:			
Type of Protection:	**Intrinsically Safe**		
Marking:	Ex ia I Ma		

Approved for issue on behalf of the IECEx Certification Body: Jim Birch

Position: Certification Authority

Signature:
(for printed version)

Date: 2014-12-18

1. This certificate and schedule may only be reproduced in full.
2. This certificate is not transferable and remains the property of the issuing body.
3. The Status and authenticity of this certificate may be verified by visiting the Official IECEx Website.

Certificate issued by:

TUV Rheinland Australia Pty. Ltd
1/30 Kennington Drive
Tomago NSW 2322
Australia

TÜVRheinland

IECEx Certificate of Conformity

Certificate No:	IECEx ITA 14.0006X	Issue No: 1
Date of Issue:	**2014-12-18**	Page 2 of 4
Manufacturer:	**Trolex Limited** 10 Newby Road, Hazel Grove Stockport Cheshire SK7 5DY **United Kingdom**	
Additional Manufacturing location(s):		

This certificate is issued as verification that a sample(s), representative of production, was assessed and tested and found to comply with the IEC Standard list below and that the manufacturer's quality system, relating to the Ex products covered by this certificate, was assessed and found to comply with the IECEx Quality system requirements. This certificate is granted subject to the conditions as set out in IECEx Scheme Rules, IECEx 02 and Operational Documents as amended.

STANDARDS:

The electrical apparatus and any acceptable variations to it specified in the schedule of this certificate and the identified documents, was found to comply with the following standards:

IEC 60079-0 : 2011 Edition:6.0	Explosive atmospheres - Part 0: General requirements
IEC 60079-11 : 2011 Edition:6.0	Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"

*This Certificate **does not** indicate compliance with electrical safety and performance requirements other than those expressly included in the Standards listed above.*

TEST & ASSESSMENT REPORTS:

A sample(s) of the equipment listed has successfully met the examination and test requirements as recorded in

Test Report:

AU/ITA/ExTR13.0029/00
AU/ITA/ExTR14.0011/00
AU/ITA/ExTR14.0041/00
GB/SIR/ExTR10.0035/01
GB/SIR/ExTR12.0032/01
GB/SIR/ExTR13.0003/00
GB/SIR/ExTR14.0116/00

Quality Assessment Report:

GB/SIR/QAR07.0017/04

IECEx Certificate of Conformity

Certificate No:	IECEx ITA 14.0006X	Issue No: 1
Date of Issue:	**2014-12-18**	Page 3 of 4

Schedule

EQUIPMENT:

Equipment and systems covered by this certificate are as follows:

The Sentro 1 Sensor (or Trip Amp)/Transmitter monitors an input from a fully integrated eModule (or rModule). It provides a reading on an LCD display and an output signal based on the monitored input signal. The TX6351/TX6352 are fitted with an approved eModule to directly monitor toxic gas concentration, flammable gas concentration, ambient air temperature, or atmospheric pressure and humidity. The TX9081 is fitted with an approved rModule to monitor the input from an external sensor such as a sensor to measure airflow, pressure, vibration, etc.

- **TX6351** - 4 wire sensor/transmitter (2x power, 2x signal)
  - Output options: 4-20mA, 0.4-2V, RS485, Relay, 5-15Hz
  - Module options: any TX6350 eModule or TX9160 Climate eModule
- **TX6352** - 2 wire sensor/transmitter (loop powered)
  - Output options: 4-20mA
  - Module options: TX6350 Toxic gas eModule.
- **TX9081** - 4 wire Trip Amp/transmitter (2x power, 2x signal)
  - Output options: 4-20mA, 0.4-2V, RS485, Relay, 5-15Hz
  - Modules options: TX9160 rModule

Refer to the annexe for additional information.

CONDITIONS OF CERTIFICATION: YES as shown below:

Refer to the annexe for additional information.

IECEx Certificate of Conformity

Certificate No:	IECEx ITA 14.0006X	Issue No: 1
Date of Issue:	**2014-12-18**	Page 4 of 4

DETAILS OF CERTIFICATE CHANGES (for issues 1 and above):

Addition of the TX6356 Humidity Sensor/Transmitter

Refer to the annexe for additional information.

Annex:

IECEx ITA 14.0006X-01 (Certificate Annex).pdf

IECEx Certificate of Conformity

Annexe

Annexe for Certificate No.:	IECEx ITA 14.0006X	Issue No.:	1

Additional Information:

The unit comprises a Display PCB, Control PCB and an Output PCB, assembled on a plastic carcass, which in turn is encased in an outer polycarbonate ABS enclosure with antistatic properties with a polycarbonate window for the LCD display. The enclosure provides a degree of ingress protection to at least IP54. External circuit connections are made through the two gland entries at the bottom of the housing.

The Sentro has the option of the following output PCB's that give rise to the following products:

Model	Output PCB
TX6351.01i.11 and TX9081.01i.11	0.4-2 V Option Comms/Analogue Output
TX6351.01i.12 and TX9081.01i.12	4-20 mA 4 Wire Option Comms/ Analogue Output
TX6351.01i.15 and TX9081.01i.15	RS485 Option Comms/ Analogue Output
TX6351.01i.14 and TX9081.01i.14	Dual Relay Option Relay PCB
TX6351.01i.13 and TX9081.01i.13	5-15 Hz Option Relay PCB
TX6352.01i.12	4-20 mA 2 Wire (Loop Powered)

As part of this certification, the above modules can be used with any of the following sensors:

- TX6350 eModule – Flammable, assessed in IECEx ITA 13.0023X
- TX6350 eModule – Infrared, assessed in IECEx ITA 13.0023X
- TX6350 eModule – Toxic, assessed in IECEx ITA 13.0023X
- TX9160 eModule – Climate, assessed in IECEx ITA 13.0023X
- TX9160 rModule – 4..20mA, assessed in IECEx ITA 13.0023X
- TX9160 rModule – 0.4..2V, assessed in IECEx ITA 13.0023X
- TX9160 rModule – PT100, assessed in IECEx ITA 13.0023X
- TX9160 rModule – Namur, assessed in IECEx ITA 13.0023X

IECEx Certificate of Conformity Annexe			
Annexe for Certificate No.:	**IECEx ITA 14.0006X**	**Issue No.:**	**1**

The products covered by this certificate incorporate devices covered by reports reviewed by TUV Rheinland Australia Pty. Ltd. Any modifications of the devices shall require re-certification.

Existing Report Name	Existing Report	Device Name
Sentro 8 Sensor Station	AU/ITA/ExTR13.0029/00	TX9165.01.i
Sentro Sensor/Transmitter	GB/SIR/ExTR10.0035/01	TX635x.01i.xx
Sentro Sensor/Transmitter	GB/SIR/ExTR12.0032/01	TX635x.01i.xx and TX9081.01.xx
Variation to certificates Sira 09ATEX2352X and IECEx SIR 09.0147X	GB/SIR/ExTR13.0003/00	
(Variation to certificates Sira 09ATEX2352X and IECEx SIR 09.0147X)	GB/SIR/ExTR14.0116/00	

IECEx Certificate of Conformity

Annexe

Annexe for Certificate No.:	IECEx ITA 14.0006X	Issue No.:	1

Conditions of safe use pertaining to Issue 0 of this Certificate.

1. The following safety parameters are applicable to the Sentro 1 Sensors/Transmitters:

Model	Terminals	Input Parameters					Output Parameters				
		Ui	Ii	Ci	Li	Pi	Uo	Io	Po	Co	Lo *5
TX6351.01i.11 and TX9081.01i.11	5 wrt 6	14.4V	*1	*2	*3	-	-	-	-	-	-
	1 wrt (2 or 3)	-	-	-	-	-	14.4V	40mA	135mW	*4	292mH
TX6351.01i.12 and TX9081.01i.12	5 wrt 6	14.4V	*1	*2	*3	-	-	-	-	-	-
	1 wrt (2 or 3)	-	-	-	-	-	14.4V	477mA	1.72W	*4	2.1mH
TX6351.01i.15 and TX9081.01i.15	5 wrt 6	14.4V	*1	*2	*3	-	-	-	-	-	-
	1 wrt 2 2 wrt 3	6.88V	*1	0	0	-	5.88V	66mA	97mW	*4	26mH
TX6351.01i.14 and TX9081.01i.14	5 wrt 6	14.4V	*1	*2	*3	-	-	-	-	-	-
	1 wrt 2	30V	*1	0	0	-	0	0	0	0	0
	3 wrt 4	30V	*1	0	0	-	0	0	0	0	0
TX6351.01i.13 and TX9081.01i.13	5 wrt 6	14.4V	*1	*2	*3	-	-	-	-	-	-
	1 wrt 2	16.5V	-	0	0	2.5W	0	0	0	0	0
TX6352.01i.12	1 wrt 2	14.4V	*1	*2	*3	-	-	-	-	0	0

*1 – Ii : Not critical.

*2 – Ci : Ci = 0, unless a rModule is connected to the Sentro 1, then Ci=0.38uF plus the Ci of the external sensors connected to the rModule.

*3 – Li : Total Li of all external sensors and equipment connected to the rModule.

*4 – Co : 1uF, unless the conditions stated in 60079-11 2011, Clause 10.1.5.2 part b can be satisfied.

*5 – Lo : Is calculated using the formula ½Lo(Io*1.5)²=525uJ.

2. Where an external sensor is used with either a type TX9160.01i.301 (4-20mA), TX9160.01i.303 (0.4-2V), TX9160.01i.321 (4-20mA Differential) or TX9160.01i.323 (0.4-2V Differential) rModule and it is powered from a separate intrinsically safe power supply, the following conditions shall be met:

    1. No connection shall be made to rModule terminal 1m (power).
    2. The 0V of the external sensor power supply shall be connected to the 0V input of the equipment.
    3. The Ui presented by an externally powered sensor to the rModule shall not exceed 14.4V.

IECEx Certificate of Conformity

Annexe

Annexe for Certificate No.:	IECEx ITA 14.0006X	Issue No.:	1

Drawings pertaining to Issue 0 of this Certificate.

Manufacturer's Documents

Title:	Drawing No.:	Sheets	Rev. Level:	Date:
General Arrangement	P5536-100	1	D	2014-01-27
Relay Certification Details	P5536-103	1	A	2008-05-02
Relay Encapsulation Details	P5536-104	5	A	2010-01-18
Circuit Diagram Master Analogue/Comms Output PCB (Alternative Build)	P5536.276	5	A	2014-04-11
PCB, Analogue/Comms Output (Alternative Build)	P5536.277	1	A	2014-04-11
Circuit Diagram Control PCB (Group I Build)	P5536.202	2	E	2014-03-20
PCB, Control	P5559.203	1	B	2009-10-14
Circuit Diagram Display PCB (Group I Build)	P5536.204	2	B	2009-10-07
PCB, Display	P5536.205	1	C	2012-05-01
PCB, Connector	P5559.212	1	B	2009-10-14
Circuit Diagram Master 5-15Hz/Relay Output PCB (Alternative Build)	P5536.278	4	A	2014-04-10
PCB, 5-15Hz/ Relay Output (Alternative Build)	P5536.279	1	A	2014-04-11
Sentro Block Diagram Group I Versions	P5536.224	1	C	2011-10-19
Circuit Diagram 4-20mA Loop Powered Output PCB (Group I Build)	P5536.225	2	D	2014-01-24
PCB, Loop Powered 4-20mA / 2-Wire	P5559.226	1	C	2011-05-10
Label Details Group I (AUS)	P5536.251	1	A	2014-02-27

IECEx Certificate of Conformity

Annexe

Annexe for Certificate No.:	IECEx ITA 14.0006X	Issue No.:	1

Variations permitted by Issue 1 of this certificate:

The purpose of this issue is to add another sensor module to the existing range of sensors that may be fitted to the Sentro 1 Transmitter Stations.

When a Humidity Sensor Module is mounted to a Sentro 1 base unit, the combination is given the name TX6356 Humidity Sensor/Transmitter.

The Humidity Sensor Module comprises of two components; the Humidity rModule and the Humidity Sensor Head. These are joined with an interconnecting adapter cable.

The Humidity rModule plugs into the main module receptacle housing inside the Sentro 1 Base Unit, whereas the Humidity Sensor Head is external to the Sentro 1 Base station and mounted in a M20 gland entry of the Sentro 1 Base Unit.

A signal from a digital humidity sensor mounted on the sensor board is conditioned and an analogue signal is then transmitted to other monitoring equipment.

The Sentro has the option of the following output PCB's that give rise to the following products:

Model	Output PCB
TX6356.06.01	4-20 mA 4 Wire Option Comms/ Analogue Output
TX6356.06.02	0.4-2 V Option Comms/Analogue Output
TX6356.06.03	5-15 Hz Option Relay PCB
TX6356.06.04	RS485 Option Comms/ Analogue Output
TX6356.06.05	Dual Relay Normally closed
TX6356.06.06	Dual Relay Normally open

IECEx Certificate of Conformity

Annexe

Annexe for Certificate No.:	IECEx ITA 14.0006X	Issue No.:	1

Conditions of safe use pertaining to Issue 1 of this Certificate.

The following safety parameters are applicable to the Sentro 1 TX6356 Humidity Sensor/Transmitter:

Model	Field Screw Terminals	Input Parameters					Output Parameters				
		Ui	Ii	Ci	Li	Pi	Uo	Io	Po	Co	Lo *2
TX6356.06.01	5 wrt 6	14.4V	*1	0	0	-	-	-	-	-	-
(4..20mA)	1 wrt (2 or 3)	-	-	-	-	-	14.4V	477mA	1.72W	*3	2.1mH
TX6356.06.02	5 wrt 6	14.4V	*1	0	0	-	-	-	-	-	-
(0.4..2V)	1 wrt (2 or 3)	-	-	-	-	-	14.4V	40mA	135mW	*3	292mH
TX6356.06.03	5 wrt 6	14.4V	*1	0	0	-	-	-	-	-	-
(5-15Hz)	1 wrt 2	16.5V	-	0	0	2.5W	0	0	0	0	0
TX6356.06.04	5 wrt 6	14.4V	*1	0	0	-	-	-	-	-	-
(RS485)	1 wrt 2 2 wrt 3	6.88V	*1	0	0	-	5.88V	66mA	97mW	*3	26mH
TX6356.06.05	5 wrt 6	14.4V	*1	0	0	-	-	-	-	-	-
(Dual Relay Normally closed)	1 wrt 2	30V	*1	0	0	-	0	0	0	0	0
	3 wrt 4	30V	*1	0	0	-	0	0	0	0	0
TX6356.06.06	5 wrt 6	14.4V	*1	0	0	-	-	-	-	-	-
(Dual Relay Normally open)	1 wrt 2	30V	*1	0	0	-	0	0	0	0	0
	3 wrt 4	30V	*1	0	0	-	0	0	0	0	0

*1 – Ii : Not critical.

*2 – Lo : Is calculated using the formula ½Lo(Io*1.5)²=525uJ.

*3 – Co : 1uF, unless the conditions stated in 60079-11 2011, Clause 10.1.5.2 part b can be satisfied.

IECEx Certificate of Conformity

Annexe

Annexe for Certificate No.:	IECEx ITA 14.0006X	Issue No.:	1

Drawings pertaining to Issue 1 of this Certificate.

Manufacturer's Documents

Title:	Drawing No.:	Sheets	Rev. Level:	Date:
PCB, Connector Board	P5553.21	1	B	2010-06-14
Circuit Diagram Signal Conditioning CPU Board (Group I)	P5553.29	2	C	2014-12-16
PCB, Signal Conditioning CPU Board	P5553.30	1	B	2010-02-10
Circuit Diagram 0.4-2V Humidity Input Module Base PCB (Group I)	P5553.174	2	A	2014-04-24
PCB, Humidity I/P Module Baseboard	P5553.175	1	A	2014-04-24
0.4-2V Humidity Input rModule Block Diagram	P5553.176	1	A	2014-04-24
General Arrangement	P5553-177	1	B	2014-12-02
Certified Circuit Diagram Humidity Sensor Module	P5597.01	2	B	2014-02-06
rModule Interconnections Humidity Sensor Head	P5597.02	1	A	2014-07-30
PCB, Humidity Sensor Module	P5597.03	1	B	2014-04-09
Certification Markings	P5597.20	1	A	2014-12-03

11.2Dewlogger Datasheet

Climatic Condition

PCWI International are leaders in the manufacture, certification and distribution of specialist measuring instruments relevant to the metals construction and coating industries.

PCWI
PRECISION INSTRUMENTATION

DewMaster

Features

Simultaneously displays three channels: relative humidity and temperature of the air, and surface temperature
Dewpoint and DT (difference between dewpoint and surface temperature) calculated and displayed.
Also functions as a temperature gauge with K-type probe
Auto power off (selectable)
Hold and Max/Min functions
ºC/ºF switchable.

Additional DewLogger features

Measures and records air temperature, surface temperature, relative humidity, and dewpoint for transfer to PC for evaluation and printing.
Clock/Time function
Memory for 16,300 readings

Specifications

Range		
Temperature		
	Air/RH Probe	-20ºC to +60ºC
	K-type input	-200ºC to +1370ºC
Relative Humidity		
	Air/RH Probe	0 to 100%RH
Accuracy		
	Air/RH Probe	±0.7ºC; ±2.5%RH
	K-type input	-200 to +200ºC ±0.3%rdg+1ºC
		+200 to +400ºC ±0.5%rdg+1ºC
		+400 to +1370ºC ±0.3%rdg+1ºC
Resolution		
	Air/RH Probe	-20 to +60ºC 0.1ºC
		0 to 100%RH 0.1%
	K-type input	-200 to +200ºC 0.1ºC
		+200 to +1370ºC 1ºC

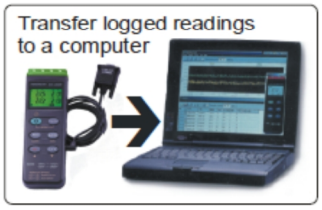
Dimensions	184 x 64 x 30mm
Weight	320g (approx)
Power	9V (100hrs logging)
	(optional power supply available)

DewLogger model	
Recording interval	1 sec to 1hr 40mins
	(1 to 99mins 99 secs)
Memory	16,300 readings

Complete with
Surface Probe
Operating Instructions

DewLogger also includes
RS232 Interface Cable & Software
USB Cable & Software
Datalogger Software

Also available
K-type temperature probes with lead lengths to your requirements
Stainless Steel (all types)
PTFE / Fibreglass cable with clamp or magnet
Magnetic Surface Probe



PCWI International Pty Ltd
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Ph: (02) 4954 3900 • Fax (02) 4954 3999
email: sales@pcwi.com.au • http://www.pcwi.com.au

PCWI International Pty Ltd ABN 73 078 380 186

PRO-FORMA T A X INVOICE

Page No: 1
Date: 28/08/2015

CR No: **PF49582**

Invoice To:
CSIRO QLD Centre For
Advanced Tecnhologies
1 Technology Court
PULLENVALE QLD 4069

Phone: 07 3327 4199
Fax:

Cust Order No: **None**
Cust Code: CSIPUL

Deliver To:

Att: Manoj
Ph: 07 3327 4199

Payment Terms: Net Cash
Special Conditions: Warranty

Workshop Status:

Due by: **28/08/2015**

Date/Time In:
By:

Date/Time Out:
By:

Item	Description	Bin No	Qty	Price	Disc	GST	Total
0633	Assess PCWI Dewlogger/Int Surf Pbe SN: 140702549 Replaced under warranty with new.		1	0.0000		0.00	0.00
0736	PCWI DewLogger/Int Surf Probe SN: 140702526 Unit has been thoroughly checked in our lab. At Ref 33.86%rh units reads 33.7%rh At Ref 85.00%rh units reads 83.6%rh	G21	1	0.0000		0.00	0.00
FRETNT	Freight via TNT		1	0.0000		0.00	0.00

TOTAL: $ 0.00

Prepared by: . . . . . .
Checked by: . . . . . .

Special Instructions: TNT

File: F18 Revision No.2 09.05.13

Sybiz Form: proforma Invoice2.frx

11.3Sling Psychrometer Datasheet

Sling Psychrometer
Relative Humidity

The uniquely compact Bacharach Sling Psychrometer accurately determines percent relative humidity without the necessity of consulting complex tables. There is no need to wet the wick each time a reading is taken; the Sling Psychrometer contains a slide rule calculator which correlates wet and dry bulb thermometer indications for direct reading of relative humidity. When not in use, the thermometer case telescopes into the handle for protection.

Features

- Designed for portability (7.5" long x 1" diameter)
- Slide rule construction quickly converts temperature to relative humidity
- Built-in water reservoir holds sufficient water for several hours of testing
- Thin bulb design gives fast thermal response
- Thermometers constructed of shock-resistant glass; stems have deep-etched numerals and 1° scale divisions for easy reading
- Accurate to within ±5% R.H.

Applications

- Measurement of comfort conditions in air conditioned environments, hospital operating rooms, storage areas and laboratories
- Tests in industrial atmospheres where high or low humidity may be critical in manufacturing processes
- School athletics – to determine safe conditions for practice

ORDERING INFORMATION

PART NO.	DESCRIPTION
0012-7012	+25°F + 120°F Red Spirit Filled
0012-7043	-5° to +50°C Red Spirit Filled
0012-0266	Thermometer	+25°F + 120°F Red Spirit Filled
0012-0327	Thermometer	-5° to +50°C Red Spirit Filled
0012-0011	Wick Replacement Kit - containg 4 wicks
0006-5456	Cap

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w www.csiro.au

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Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.

FOR FURTHER INFORMATION

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