



Advanced Lighting Technologies

Final Technical Report



Centers for Disease Control and Prevention National Institute for Occupational Safety and Health

Office of Mine Safety and Health Research
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Broad Agency Announcement

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Proposed Title: Method for Improving Ventilation and Gas and Temperature Monitoring with an Advanced Fiber Optic-Based Mine Wide Monitoring System

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Project Abstract:

The system consists of an advanced mine-wide distributed monitoring system utilizing a low power, intrinsically safe, fiber-optic backbone for improving ventilation and gas monitoring in underground mines. The major elements of the system are as follows:

- A fiber-optic-based methane detection system based on a commercially available product offering from OptoSci Ltd., a spin-off company from the University of Strathclyde in Glasgow, Scotland, focused on the development of innovative photonics technologies arising from internal and academic research. The system is currently in use in landfills and tunnels to monitor methane and natural gas. The system utilizes a low power (10mW) diode laser in conjunction with a distributed fiber network and a series of ruggedized sensor modules. It is largely unaffected by common mine conditions which can cause erroneous readings with many other sensor types including high humidity, anaerobic conditions, and the presence of other non-target gases. The system is tolerant of dust contamination, and fully functioning at signal losses of up to 90%. It can be configured as a distributed network with hundreds of sensing points at distances of up to 20 km from a central control unit. Methane levels from 0.5 to 100% can be accurately measured. Standard communication grade fiber cable is utilized. The system can be deployed in mined-out areas of the mine without risk of creating an ignition source, even in the event of a rock-fall compromising the mechanical enclosure.*
- A fiber-optic based temperature-sensing and monitoring system based on a commercially available product offering from AP Sensing. AP Sensing is a spin-off company from Agilent Technologies with a focus on developing fiber-based remote sensing systems. A low power (17mw) diode laser is utilized to generate an incident light pulse introduced into a single-mode fiber. The backscatter reflected pulse is analyzed. The ratio of the Stokes/anti-Stokes pulse characterizes the temperature rise in the cable, while an OTDR signal provides position data along the monitoring cable. The system utilizes a single leg of communications grade fiber per channel. The sensing range is up to 12 km per channel. The temperature anywhere along the fiber can be monitored within a resolution of approximately 0.5m in location and 1 degree C in magnitude. Various alarm schemes can be configured to look for over-temperature; and rapid temperature rise, as well as breaks in the sensing fiber. A number of interesting applications exist for this technology including belt-line monitoring, cable monitoring, and fire detection.*

1.0 Background:

The proposed system will utilize a mine wide fiber optic backbone to monitor the conditions within the mine, specifically methane levels and temperature. In the event of an excursion from normal operating conditions, a series of progressive alarm signals will be generated. These signals will be communicated to existing supervisory control systems.

The two major components of the system (methane detection, distributed temperature sensing) will each have its own dedicated fiber network within the backbone. The two networks will be bundled together and routed through the mine and/or long wall system in common wireways.

The fiber backbone utilizes commercially available MSHA approved data communication cables. These cables are jacketed with a material appropriate to severe mine environment. The system consists of two(2) sub-systems described below:

1.1 A fiber-optic-based distributed methane detection system based on a commercially available product offering from OptoSci Ltd., a spin-off company from the University of Strathclyde in Glasgow, Scotland, focused on the development of innovative photonics technologies arising from internal and academic research. The system is currently in use in landfills and tunnels to monitor methane and natural gas. The system utilizes a low power (10mW) diode laser in conjunction with a distributed fiber network and a series of ruggedized sensor modules. It is largely unaffected by common mine conditions which can cause erroneous readings with many other sensor types including high humidity, anaerobic conditions, and the presence of other non-target gases. The system is tolerant of dust contamination, and fully functioning at signal losses of up to 90%. It can be configured as a distributed network with hundreds of sensing points at distances of up to 20 km from a central control unit. Methane levels from 0.5 to 100% can be accurately measured. Standard communication grade fiber cable is utilized (MSHA approved). Unlike conventional methane detection systems currently employed, our proposed system does not require calibration at the remote sensor. Various alarm schemes can be configured to look for rising methane levels, over-limit conditions, and breaks in the sensing fiber. Key attributes of the system include:

- Real-time methane gas monitoring is enabled at hundreds of points over long distance (up to 20km) fiber-optic networks.
- System is totally electrically passive outside the central controller, which will be housed in an appropriate MSHA approved XP enclosure, or in a central control room outside the permissive zone, offering complete intrinsic safety and compatibility with all current safety standards.
- Rugged sensor modules, as shown in Fig. 1, consist of a perforated stainless steel sensor tube, junction box, and drip shield. They have rapid response and are unaffected by anaerobic conditions, catalytic poisoning, other non-target gases, water sprays as in a longwall, and excessive humidity.
- Gas sensing technique is self-referencing, which provides inherent calibration stability and ensures that the full system only requires a single, one-off calibration at the central controller.
- Automatic system self-checking function at central controller gives advance warning of any potential controller, network or sensor problems facilitating a predictive maintenance protocol.
- The system offers high gas sensitivity, wide measurement range (0.05% to 100% CH₄), exceptional gas selectivity and no gas cross-sensitivity.
- Plug-in modular format offers flexibility, easing component replacement and system expansion.
- Sensors have many years of proven, continuous, stable operation in hostile environments, require no scheduled maintenance and allow constant condition monitoring at the central controller.

- Sensors (see Fig. 1) can tolerate up to 90% signal loss, providing good immunity to high dust conditions.
- Since the system requires no calibration, does not require battery power, and is inherently intrinsically safe, it provides a viable method of sensing methane in mined-out areas.

1.2 A fiber-optic-based temperature-sensing and monitoring system based on a commercially available product offering from AP Sensing. AP Sensing is a spin-off company from Agilent Technologies with a focus on developing fiber-based remote sensing systems. A low power (17mw) diode laser is utilized to generate an incident light pulse introduced into a single mode fiber. The backscatter reflected pulse is analyzed. The ratio of the Stokes/anti-Stokes pulse characterizes the temperature rise in the cable, while an OTDR signal provides position data along the monitoring cable. The system utilizes a single leg of communications grade fiber per channel. The sensing range is up to 12 km per channel. The temperature anywhere along the fiber can be monitored within a resolution of approximately 0.5m in location and 1 degree C in magnitude. As with the methane system, standard communications grade MSHA-approved fiber will be used. Various alarm schemes can be configured to look for over-temperature, and rapid temperature rise, as well as breaks in the sensing fiber.

The DTS system, much like the methane-detection system, is a mature technology, with numerous installations in harsh environments such as “down-hole” oil/gas well temperature logging, tunnel distributed networks, cable tray applications, and pipeline monitoring. The system employs the Raman effect coupled with OTDR technology to determine the temperature rise as well as the location along the fiber where the temperature increase is evident.

- System is totally electrically passive outside the central controller, which will be housed in an appropriate MSHA-approved XP enclosure, offering complete intrinsic safety and compatibility with all current safety standards.
- The system uses a standard low-power semi-conductor telecommunications laser with less than 17mW of optical power.
- Optics are in a fully-sealed module, filled with inert gas. This as well as all components exclusive of the actual fiber cable will be housed in a XP enclosure.

2.0 Objective:

A proof-of-concept system consisting of the sub-systems described will be built and validated in a simulated lab environment, with special attention to environmental conditions specific to the mine environment. Once lab trials are completed, a field trial will be conducted in an actual working mine. The expectation is that a fully functional system will result from this effort, ready for mine installations.

3.0 Statement of Work

3.1 Title of Project:

Method for Improving Ventilation and Gas and Temperature Monitoring with an Advanced-Fiber-Optic-based Mine-Wide Monitoring System

3.2 Problem Statement or Focus Area:

RSL Fiber Systems is proposing an advanced mine-wide distributed monitoring system utilizing a low-power, intrinsically safe fiber-optic backbone for improving ventilation and gas and temperature monitoring in underground mines.

3.2.1 Background and Need

The Mine Improvement and New Emergency Response Act of 2006 established the Office of Mine Safety and Health Research. A stated purpose of this Office is to enhance the development of new technology and technological applications to expedite their commercial availability and implementation in mining environments. To address this goal, this Statement of Work (SOW) defines tasking to be performed for the Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH), Office of Mine Safety and Health Research (OMSHR) for research and development of a Mine Safety and Health Administration (MSHA) approved system that will provide indication of potential or actual explosion or fire conditions in underground coal mines. The primary focus of this SOW is to define the specific tasks necessary to create and deploy a prototype system within the contractual period of performance.

3.2.2 Project Objective

The objective of this project is to develop and test a prototype system based on laser energy distributed through a fiber-optic network that is capable of continuously monitoring and recording the atmospheric concentration of methane and the ambient temperature within section(s) of underground coal mines.

3.2.3 Scope of Work

The contractor will design, assemble and test in an operating underground coal mine, an prototype fiber-optic-based distributed sensor system that can reliably produce an alert signal when, at any sensor location, methane concentrations equal 1%; and reliably produce an alarm signal when, at any sensor location, methane concentrations equal 1.5%. The prototype system will also be capable of detecting ambient temperature and rate of temperature increase, and will provide alert and alarm signals when values exceed limits established via control software. The system will be designed and built in a manner that meets MSHA approval requirements.

3.2.4 Technical Requirements

3.2.4.1 The expected outcome of this contract is the design for an MSHA approved fully functioning prototype distributed fiber-optic-based methane and temperature monitoring system for underground coal mines that is designed and built in a manner that meets MSHA approval requirements.

The delivered system design shall include specifications for necessary hardware components, instructions for assembly/installation of hardware components, control and recording software, and hardware and software operations manual(s). The system software will be capable of exporting recorded data in a common file format such as but not limited to .txt or .csv.

3.2.4.1.1 Within thirty (30) days of award, the contractor will attend a project kick-off meeting at the OMSHR Pittsburgh, PA, facility.

3.2.4.1.2 Within thirty (30) days of award, the contractor will schedule and attend a preliminary consultation meeting at the MSHA Approval and Certification Center (A&CC) facility in Triadelphia, WV. The purpose of this meeting will be to describe the project to MSHA and identify requirements applicable to obtaining MSHA approval for the monitoring system. Additionally, the contractor will discuss with MSHA the timeline for obtaining an experimental permit for the purposes of the field trial. Following this meeting, the contractor will provide to OMSHR a summary report including a timeline describing their plan to achieve MSHA approval for the field trial as part of the Preliminary Design Report.

3.2.4.1.3 Within thirty (30) days of contract award, the contractor will initiate contact with coal mine operating companies to identify a mine to be used as the test site for the field trial. In the event that the meetings with MSHA do not result in a timeline for an experimental permit which can reasonably be supported under this contract, then the contractor will submit an alternate plan for the proof of concept as part of the Preliminary Design Report.

3.2.4.1.4 The contractor will provide to OMSHR monthly written progress reports summarizing work to date, and any significant deviations from schedule or budget and plans to recover from deviations. Project schedule and budget will be updated in the monthly report.

The contractor, with due regard for MSHA approval requirements, will procure and assemble a monitoring system in accord with its design knowledge and experience, and perform testing on the assembled system or its subassemblies as deemed necessary. Methane sensors will be tested in IOS fully-permitted flammable/toxic gas-test facilities provided by the Contractor. (Due to business conditions at IOS, they were unable to complete the Lab testing, the responsibility for this effort was assumed by CART – Center for Applied Research and Technology, Bluefield, WV) DTS sensors will be tested in computer-controlled environmental chambers. Annunciator cables will be tested for proper operation in the intended environment. Testing will be fully documented and included in the Critical Design Review report.

3.2.4.1.5 Prior to installation of the system at a test mine, the contractor will assure all of its employees and any partner or subcontractor employees have completed necessary training for entry into surface or underground mine areas. This includes training required by MSHA, and any mine or task-specific training required by the test mine. The contractor's employees,

partner employees and subcontractor employees will at all times be aware of and abide by applicable occupational safety and health requirements.

3.2.4.1.6 The contractor will prepare a test protocol and submit to OMSHR for approval. Upon receipt of authorization from MSHA, and agreement from the test mine management, the contractor will install the test system in an operating coal mine in accordance with the approved test protocol. The system will be installed in: 1) a belt entry, 2) a return airway, and 3) inby the last open crosscut of the active section(s). The contractor may install the system in other areas of the test mine with advance approval from OMSHR. The contractor will make provision for periodically extending the monitoring system as the face advances.

3.2.4.1.7 The contractor will document the mine areas in which the system was installed, the initial and if different, the interim and final distribution of sensors used during the testing.

3.2.4.1.8 The system will remain in place for a duration determined by the contractor as agreed to by the test mine management so that necessary performance testing and refinement can be completed.

3.2.4.1.9 Following completion of underground testing, the system will be removed unless the test mine management and MSHA explicitly permit abandoning it in place.

3.2.4.1.10 The contractor will analyze collected performance data and optimize the system hardware, control logic, and operating software.

3.2.4.1.11 The contractor will deliver a detailed design document for the optimized system to OMSHR. The design document will include detailed instructions for the installation, calibration, operation, maintenance, repair, and replacement of the system and its subsystems. The design document will also include a detailed document describing the function of the system software including creation of alert and alarm thresholds, interpretation of system outputs including any error codes or messages, and means to upgrade or patch the software. (see Appendices H – L)

3.2.5 *Special Considerations*

Coordination with other parties:

Contractor shall be responsible for all coordination and scheduling with other government agencies, mine-operating or controlling companies, contractors, suppliers, or commercial entities as necessary in conjunction with performance of any requirements in this SOW. The Government assumes no responsibility or represents any authority to intercede or coordinate interparty activities necessary for the successful completion of the technical requirements.

3.2.6 *Government Furnished Property*

The Government may provide access to Government-owned test facilities for the performance of testing associated with the technical requirements of this SOW on a non-interference basis. The contractor is responsible for identifying any

need for the use of Government facilities and coordinating with the appropriate technical representatives to ensure timely scheduling.

3.2.7 Place of Performance

The Contractor shall perform all work under this contract at the contractor’s facility, facilities of contractor’s partner organizations, facilities of subcontractor, and cooperating operating underground coal mines.

3.2.8 Period of performance is 18 months (extended to 24)

3.2.9 Deliverables

The following deliverables shall be delivered to the Government as a part of contract performance.

The Method for Improving Ventilation & Gas Monitoring with an Advanced-Fiber-Optic Based Mine Wide Monitoring System contract will consist of the following deliverables:

| Deliverable | Due Date |
|--|---|
| Monthly Reports | Fifteen (15) days after end of month. |
| Preliminary Design Report & MSHA Approval Compliance Plan | Thirty (30) days following the MSHA consultation meeting. |
| Critical Design Review Report | With the monthly report incorporating the design review activity. |
| Draft Underground Test Protocol | Forty-five days prior to installation of the system in the test mine. OMSHR will have 30 days to review and comment, the contractor will have 30 days to incorporate comments and submit final for approval. |
| Field Data Analysis with As-tested System Configuration | Sixty (60) days following completion of the underground testing. |
| Final Design Review Report | With the monthly report incorporating the design review activity. |
| Final Report with Detailed System Design, Technical, Operating and Software Manuals; Draft Commercialization Plan | A draft will be submitted sixty (90) days following conclusion of the field trial. OMSHR will have 30 days to review and comment, the contractor will have 30 days to incorporate comments and submit final for OMSHR approval. |

At the conclusion of the project the contractor will provide a working sensing system to NIOSH complete with three (3) sensors. The contractor assumes responsibility for all costs associated with removal of the systems from the test mine. NIOSH assumes no liability for the in-mine test system.

4.0 Project Schedule and Milestones

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|--|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|
| 1) Kick Off | | | | | | | | | | | | | | | | | | |
| 2) Define Optimal System Configuration | | | | | | | | | | | | | | | | | | |
| 3) Preliminary Design Review - milestone | | | | | | | | | | | | | | | | | | |
| 4) Fabricate and Assemble complete system | | | | | | | | | | | | | | | | | | |
| 5) Methane sensors will be tested in IOS fully permitted flammable/toxic gas test facilities. DTS sensors will be tested in computer controlled environmental chambers. Annunciator cables will be tested for proper operation in intended environment | | | | | | | | | | | | | | | | | | |
| 6) Testing will be fully documented and validated - milestone | | | | | | | | | | | | | | | | | | |
| 7) Critical Design Review - milestone | | | | | | | | | | | | | | | | | | |
| 8) The entire system will be installed in a coal mine, and left in place after preliminary check-out. A test protocol involving controlled heating of cables, and placement of methane sensors in regions where buildup occurs will be implemented. | | | | | | | | | | | | | | | | | | |
| Field trial ends | | | | | | | | | | | | | | | | | | |
| The system will be left in place or removed | | | | | | | | | | | | | | | | | | |
| 9) Field trial data analysis complete - milestone | | | | | | | | | | | | | | | | | | |
| 10) Results from the field trial, including complete temperature and methane records will be examined. Most important will be portions of the data where known heating and/or methane exposure have taken place. | | | | | | | | | | | | | | | | | | |
| 11) Final Design Review - milestone | | | | | | | | | | | | | | | | | | |
| 12) Data collected during the field trial, including methane values, and temperature profiles will be analyzed and verified where possible with other sensing system data | | | | | | | | | | | | | | | | | | |
| 13) Final Project report prepared - milestone | | | | | | | | | | | | | | | | | | |
| 14) A comprehensive commercialization plan will be presented and submitted | | | | | | | | | | | | | | | | | | |
| 15) MSHA Project Presentation - milestone | | | | | | | | | | | | | | | | | | |
| 16) Report Submission | | | | | | | | | | | | | | | | | | |

5.0 System Overview

5.1 Methane Detection System

Field Test Unit – OptoSci Model SR-CCU Serial No. 032013RSL

Lab Test Unit – OptoSci Model Optsniff Serial No. 3000001

The fiber-optic-based distributed-methane detection system is based on a product offering developed at OptoSci Ltd., a spin-off company from the University of Strathclyde in Glasgow, Scotland, focused on the development of innovative photonics technologies emanating from internal and academic research. The system is currently in use in landfills and tunnels to monitor methane and natural gas. The system utilizes a low power (10mW) diode laser in conjunction with a distributed-fiber network and a series of ruggedized sensor modules. It is largely unaffected by common environmental conditions which can cause erroneous readings with many other sensor types including high humidity, anaerobic conditions, and the presence of other non-target gases. The system is tolerant of dust contamination, and fully functioning at signal losses of up to 90%. It can be configured as a distributed network with hundreds of sensing points at distances of up to 20 km from a central control unit. Methane levels from 0.5 to 100% can be accurately measured. Standard communication-grade fiber cable is utilized. Unlike conventional methane-detection systems currently employed, the system described does not require calibration at the remote sensor. Various alarm schemes can be configured to look for rising methane levels, over-limit conditions, as well as breaks in the sensing fiber. Key attributes of the system include:

- Real-time methane gas monitoring is enabled at hundreds of points over long distance (up to 20km) fiber optic networks.
- System is totally electrically passive outside the central controller, which will be housed in an appropriate enclosure, or in a central control room outside the hazardous gas zone, offering complete intrinsic safety and compatibility with all current safety standards.
- Rugged sensor modules, as shown in Fig. 1, consist of a perforated stainless steel sensor tube, junction box, and drip shield. They have rapid response and are unaffected by anaerobic conditions, catalytic poisoning, other non-target gases, water sprays and excessive humidity.
- Gas sensing technique is self-referencing, which provides inherent calibration stability and ensures that the full system only requires a single, one-off calibration at the central controller.
- Automatic system self-checking function at central controller gives advance warning of any potential controller, network, or sensor problems facilitating a predictive maintenance protocol.
- The system offers high gas sensitivity, wide measurement range (0.02% to 100% CH₄), exceptional gas selectivity and no gas cross-sensitivity.

- Plug-in modular format offers flexibility, easing component replacement and system expansion.
- Sensors have many years of proven, continuous, stable operation in hostile environments, require no scheduled maintenance and allow constant condition monitoring at the central controller.
- Sensors (see Fig. 1) can tolerate up to 90% signal loss, providing good immunity to high dust conditions.

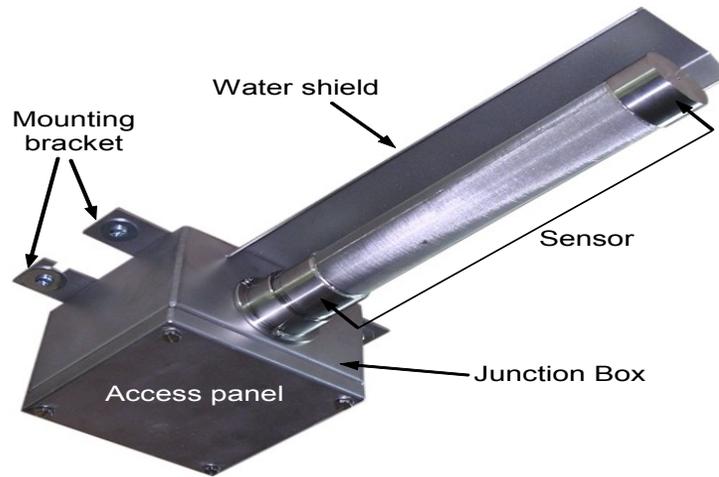


Fig. 1a – Remote Optical Methane Detector

- Methane in air cavity between lenses will absorb laser light in proportion to gas concentration.

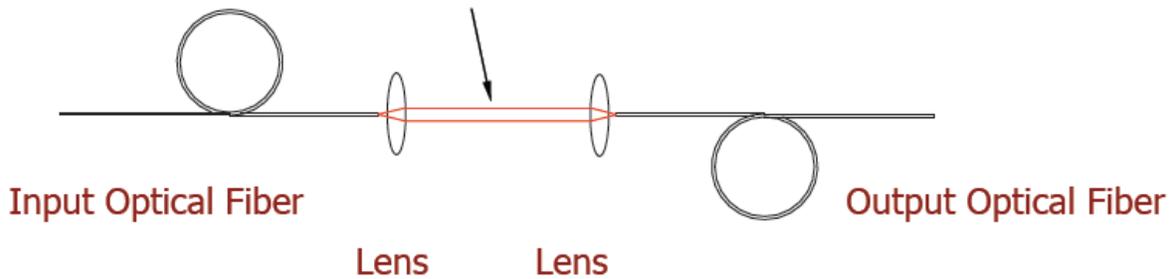


Fig. 1b – Remote Optical Methane Detector

5.1.1 Comparison to competitive sensor technologies

5.1.1.1 Pellistor/Catalytic Sensors

- Dust can block the sinter stopping sensor operation, reducing response time or affecting the accuracy of the reading.
- Water sprays have a similar effect to dust.
- Calibration interval is usually required at three (3) months minimum.
- Pellistors are only accurate up to the LEL (5% CH₄Vol) concentration. Higher than this and the readings are not reliable. Spontaneous large releases of gas would saturate the sensor and give no indication of failure.
- Cannot operate in atmosphere with less than 10% oxygen. This can be problematic in areas where these conditions are likely (e.g. methane layers close to ceiling).
- Safety concerns – Although the systems are certified safe for hazardous environments, the presence of electrical power at the active sensor is a concern for operators.

5.1.1.2 Mid IR Sensors

- Mist / water vapour can generate false readings or prevent the sensor from detecting gas at all.
- Dust deposits on the window / mirror causes sensor failure
- This system uses a power supply at each sensor head (usually for heating the optics to minimise condensation) and although products are rated intrinsically safe, this is still a concern for operators who would prefer a passive system.
- Experience shows that low concentrations (<2% LEL) return noisy signals, therefore this type of sensor is of limited use for low gas concentrations.
- Although twelve (12) monthly calibration is the stated interval, experience shows that this is required more regularly (offshore, calibration is required approximately at six (6) monthly intervals).

5.1.1.3 Benefits of Remote Fiber based sensing

- Application is perfect for a large multipoint optical-sensor network and cost benefits would be gained using this type of system.
- One off calibration at the central control unit would decrease cost of ownership as no regular calibration would be required.
- Does not require oxygen in atmosphere to detect target gas.
- Sensing cells are passive with no electrical power supply, ensuring safety and immunity to EMI.

- The ability to measure up to 100% CH₄ Volume and the accuracy at low concentrations is a considerable advantage over alternative solutions and would help to detect even small gas releases.
- Central control unit (CCU) with all sensor data is located remote from the active sensing area.
- No false readings due to dust & water vapour.
- Dust: Sensor design has been configured to have to reduce the possibility of dust coating the optics. However, any maintenance schedule required can be extended because each sensor can tolerate up to 90% signal loss and the system will automatically highlight any need for sensor maintenance or cleaning at the CCU.

5.1.2 Sensing Technology

Tunable Diode Laser Spectroscopy (TDLS)

- Tune narrow linewidth laser through the target gas absorption line with reference and signal readings taken on each scan. As laser is tuned through the gas absorption line the light is absorbed in proportion to the gas concentration. Particular advantages of TDLS are:
 - Self-referencing, eliminating zero point drift and need for re-calibration.
 - Not affected by input optical power variations.
 - Exhibits no cross-sensitivity to other gases.

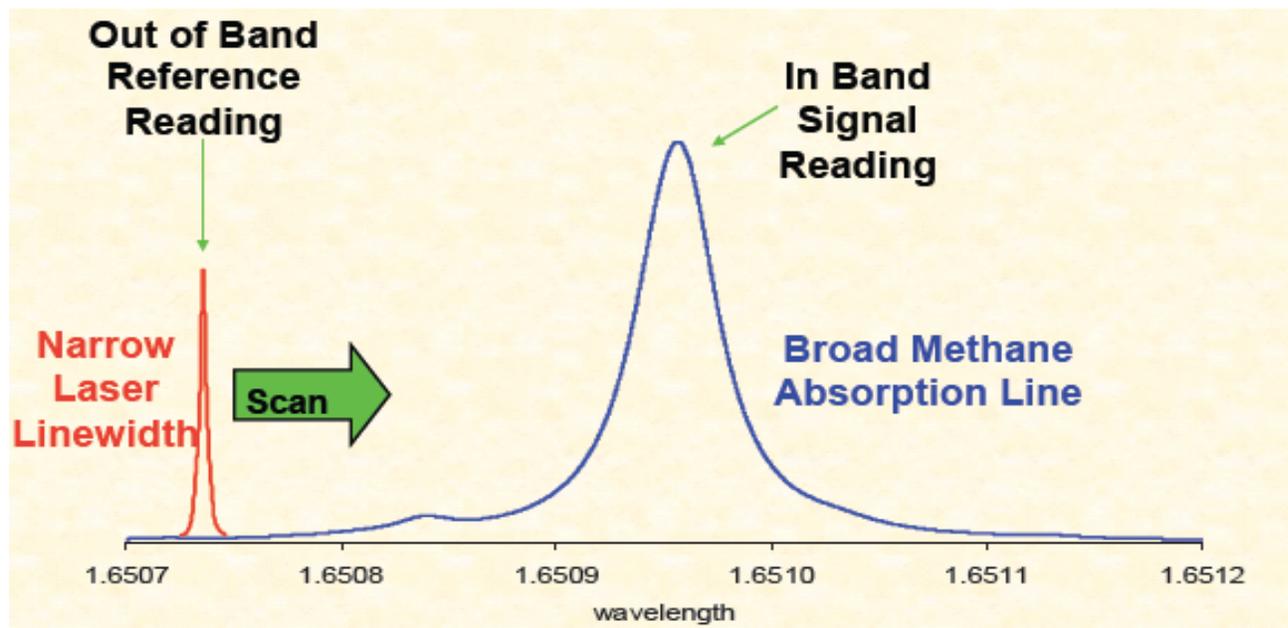


Fig. 2 – Scan Protocol

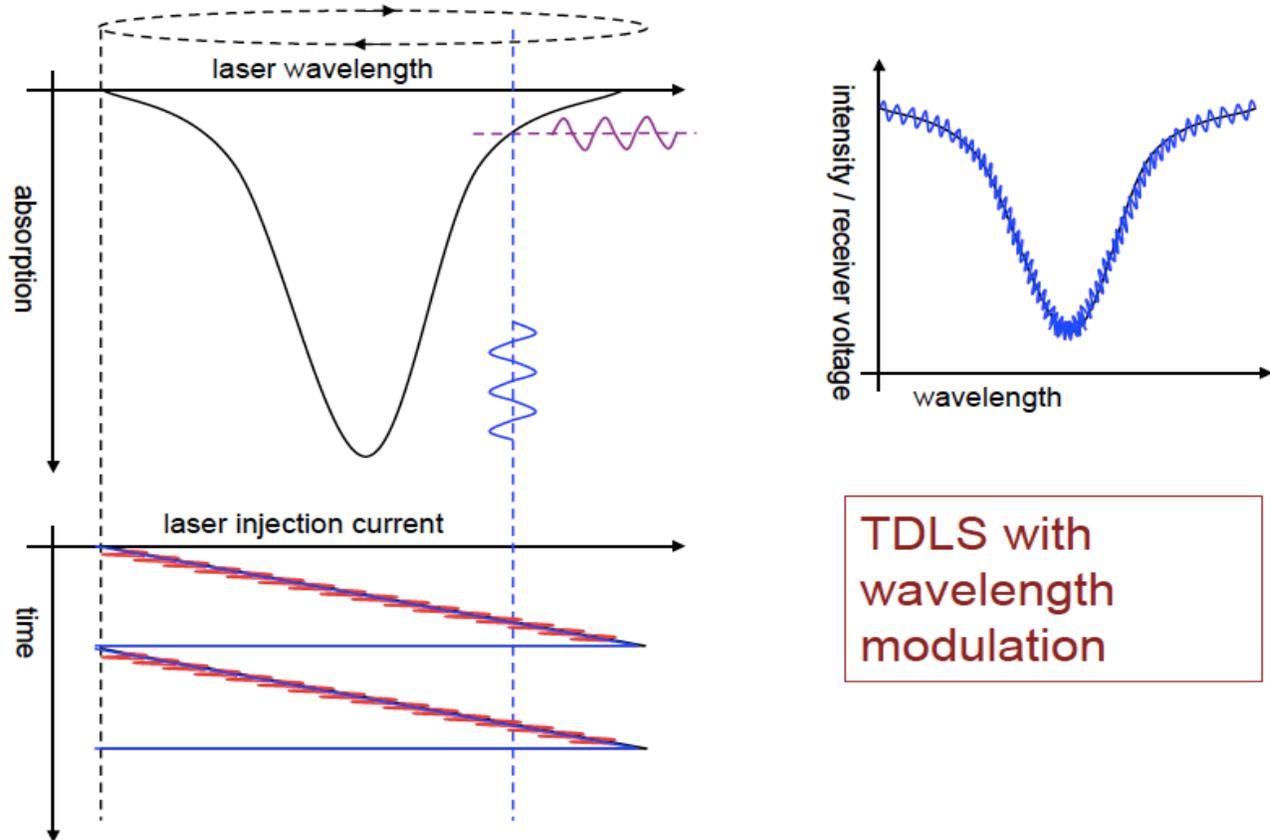


Fig. 3 – Principle of operations

Two methods of TDLS are used dependant on the relative concentration of methane present. For concentrations of $> 1\%$ a direct detection method is used. With concentrations less than 1% a wavelength modulation technique is used. The two methods are described below.

With TDLS and direct detection a gas absorption line somewhere in the near-IR, e.g. a methane absorption line at 1651nm . We begin by tuning the DFB laser to the proximity of the line using a combination of temperature and fine current control. We then apply a time-varying ramp signal (anywhere between 2 and 20Hz usually) to the laser's injection current to repeatedly sweep the laser's center frequency across the absorption feature. As we sweep through the line the transmission signal at the receiver is recorded. The signal is normalized to any power fluctuations and referenced to a point in the scan that is non-absorbing (a technique known as zero-point referencing) to produce the *absorption line transmission function*. The amplitude of this signal is then directly proportional to the gas concentration. By repeatedly sweeping the

entire absorption feature and taking a zero-point reference the system is inherently self-calibrating.

In instances of weak absorption, e.g. methane concentrations $<1\%$, the directly recovered signals lack the necessary sensitivity due to offset errors and system noise. To overcome this we employ TDLS with wavelength modulation...

In addition to the ramp sweep on the laser's injection current, we employ a relatively high frequency (10 to 100kHz) sine wave simultaneously. Interaction of this sine wave with the gas absorption line results in an amplitude modulation signal at the same frequency.

If resolution and sensitivity were no limit we would see the absorption line transmission signal, as with direct detection, with a residual amplitude modulation signal (brought about by the modulation of the injection current introducing a sinusoidal intensity modulation at the same frequency). Lock in detection at the receiver then recovers the first and second harmonics of the desired wavelength modulation induced amplitude modulation signal. These first and second harmonic signals are then proportional to the absorption line transmission function and it is therefore possible, through careful signal processing, to extract the gas concentration.

The CCU is capable of switching automatically between both TDLS measurement systems when required and performs individual measurements for each receiver signal to provide accurate concentration measurements across the range at each individual sensor location.

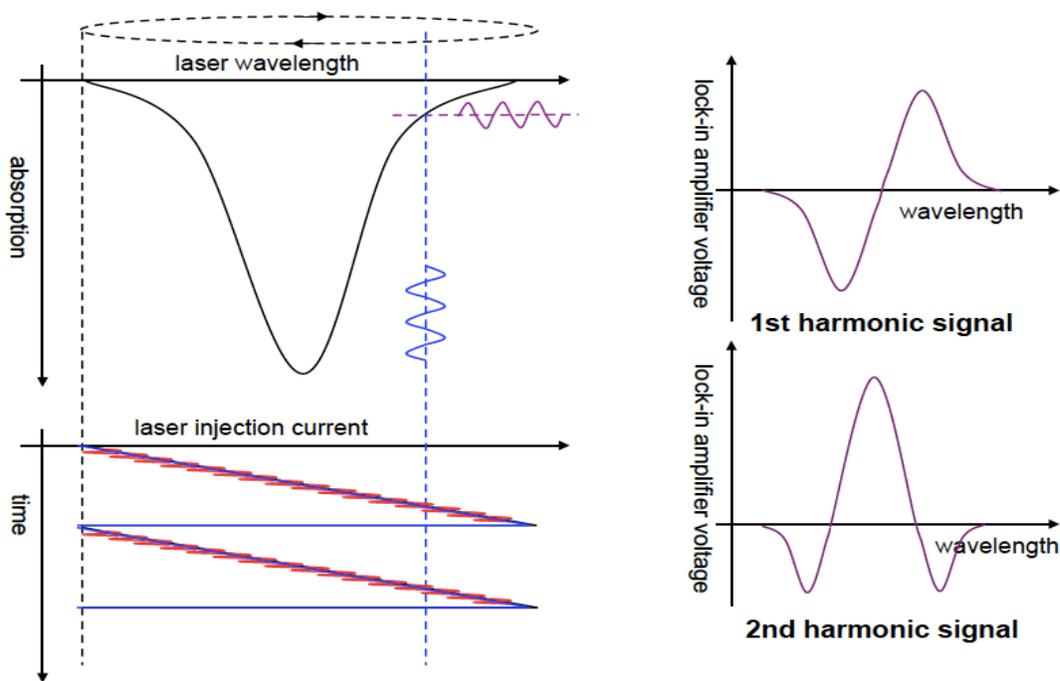


Fig. 4 – Wavelength modulation

Multipoint System Overview

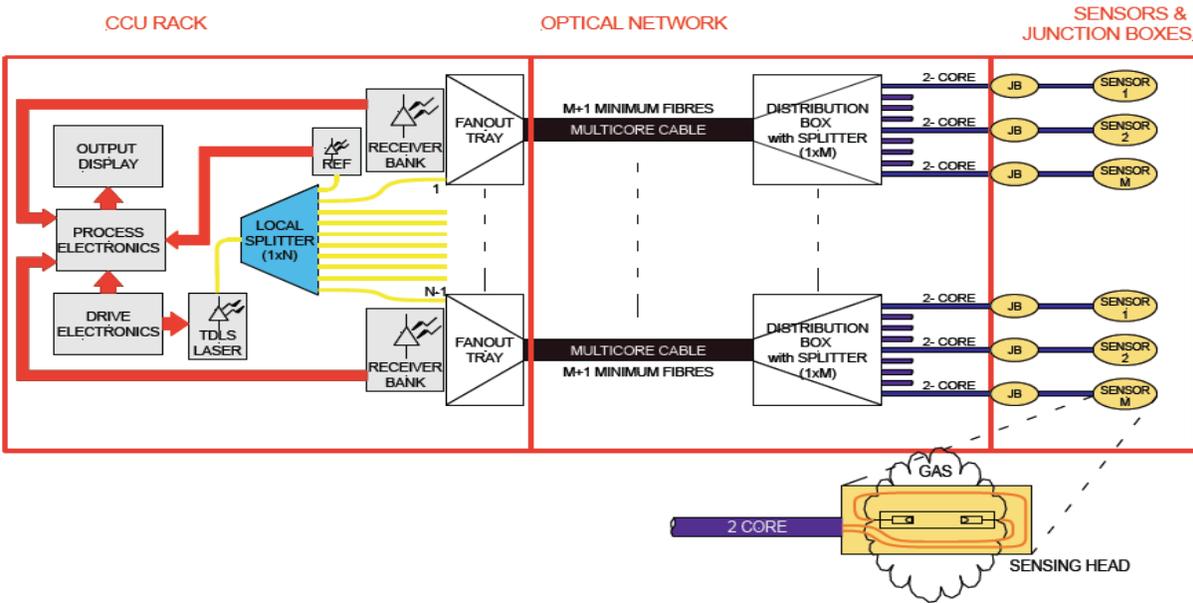


Fig. 5 – Overall system overview

Multipoint Gas Sensing

Central Control Unit (CCU)

Contains TDLS laser, detectors, all drive, processing & monitoring electronics, for **up to 200+ points** from a **single, central location**

All optical fibre network

Distributes and collects **low power optical signal** to & from network of sensors. Non electrical & up to **20km distance per point**

Passive sensor heads

Contains all optical sensor with no electronics, so **intrinsically safe** with **no spark or EMI risk**

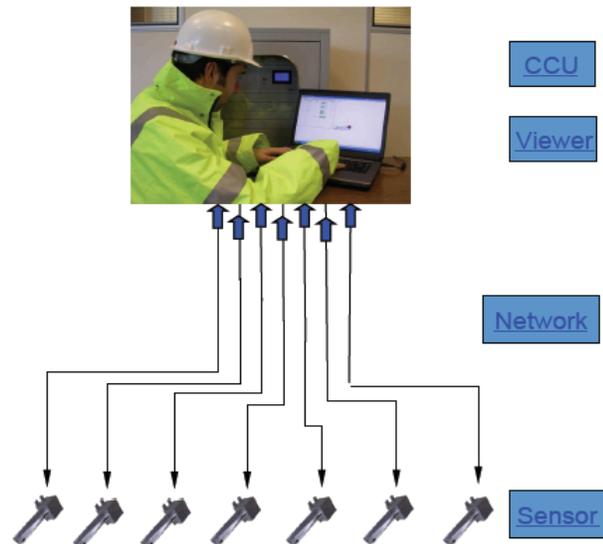


Fig. 6 – Overall system description

5.2 Distributed Temperature Sensing System

Lab and Field Trials – AP Sensing Linear Heat Type N4387A Options 008
200 050 060, Serial No. DE47501192

The fiber-optic-based temperature sensing and monitoring system is based on a commercially available product offering from AP Sensing. AP Sensing is a spin-off company from Agilent Technologies with a focus on developing fiber-based remote sensing systems. The system utilizes an intrinsically safe low-power fiber-optic backbone for monitoring temperature in coal mines, handling, conveyor, preparation, and processing facilities. The system can be utilized in many critical applications including early fire detection and equipment temperature monitoring. The system can sense temperature changes of as little as one degree C pinpointing the temperature change location on the fiber-sensing network to within less than one half meter. The major elements of the system are as follows:

- **Laser Light Generator**
 - A low power (17mw) diode laser is utilized to generate an incident light pulse introduced into a small, easy-to-install singlemode optical fiber
 - The backscatter reflected pulse is then analyzed
 - The Stokes/anti-Stokes pulse ratio characterizes the temperature rise in the cable, while an OTDR (Optical Time-Domain Reflectometer) signal provides position data along the monitoring cable
 - The system utilizes a single leg of communications grade fiber per channel
 - The sensing range is up to 12 km per channel
 - The temperature anywhere along the fiber can be monitored within a resolution of approximately 0.5m in location and 1 degree C in magnitude
 - Various alarm schemes can be configured to look for over-temperature, and rapid temperature rise, as well as breaks in the sensing fiber
 - The system will enable early detection of equipment problems such as bearing over-heating, lubrication issues, and worn conveyor guides and supports

- **System Monitor**
 - A supervisory Programmable Logic Controller (PLC) based control system to monitor, process and act upon the temperature data collected
 - The system has the capability to run control algorithms to characterize data, perform signature analysis, and correlate installed fiber locations to specific equipment locations

5.2.1 System Description:

A typical dual-channel system can provide for up to 24 km of sensing capability, consisting of two 12 km cable runs with capability to detect a temperature rise of as little as 1 degree C, specifying the area of the temperature rise to within 0.5 m.

Both of these primary sensor sub-systems can be placed in any area of the mine (including the permissible zone), as well as in a processing plant, handling prep area, or conveyor system. The system is also well suited to very remote mined-out areas with limited access, as there is no required planned maintenance schedule as with battery-operated devices.

The supervisory control system is capable of interpreting the incoming data from the sensor network, matching the data with the installed location in the mine or equipment and triggering the appropriate output (alarm annunciator, message to the mine network or central monitoring system).

The fiber-optic-alarm annunciator system is a series of non-electrical side-emitting optical fibers and discrete non-electrical luminaires with the ability to display various light colors and patterns to signal caution, warning, machine malfunction (over-temp) and evacuation alarms. In addition, the system can be used to safely illuminate escape routes in the event of an evacuation. This in conjunction with the HMI touch screen will allow actionable information to be provided to mine and equipment operators.

The basic functions of the system are shown in Fig. 7:

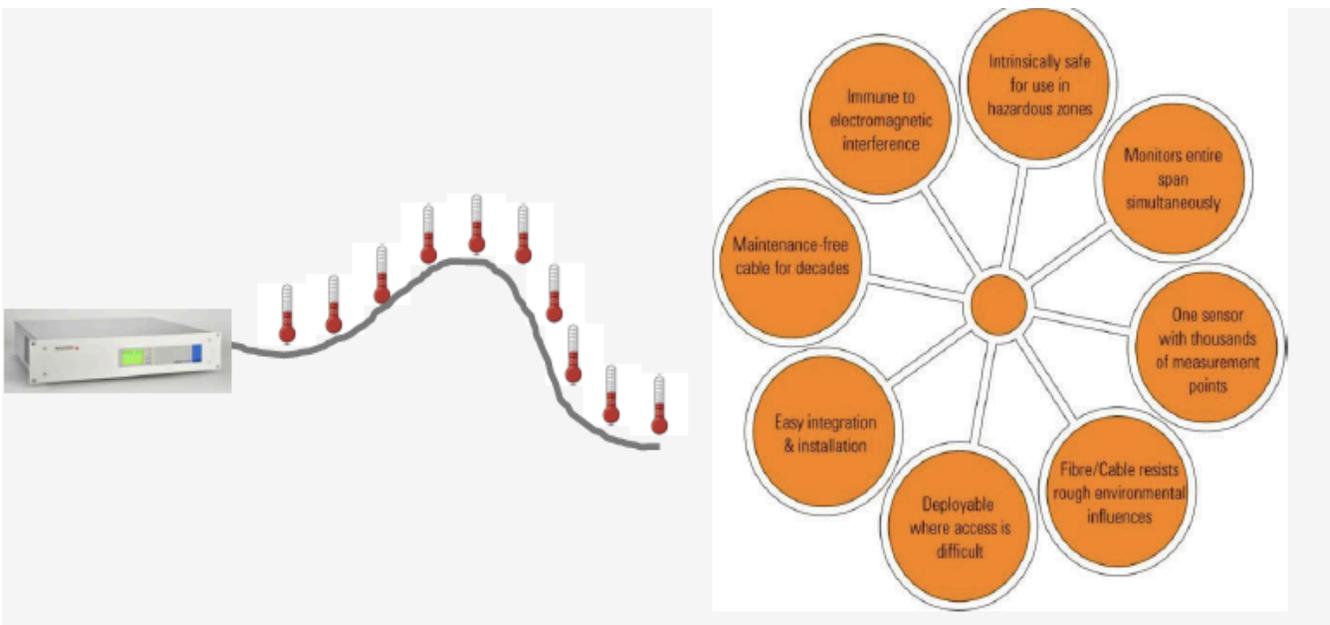


Fig. 7 – RSL DTS system architecture

5.2.2 Sensing Technology

Operation: a low power laser pulse propagating through the optical fiber sends a scattered light pulse back to the transmitting end where it is analyzed. A portion of the scattered pulse return signal has a higher wavelength than the incident pulse; this signal is known as the Raman Stokes signal. A corresponding portion has a lower wavelength than the incident; this is known as the Raman anti-Stokes signal. The ratio of these two return signals corresponds to a temperature change in the optical fiber. The position of the temperature reading is determined by measuring the arrival timing of the returning light pulse, utilizing standard OTDR methods.

The DTS system is a mature technology, with installations in harsh environments such as “down-hole” oil/gas well temperature logging, tunnel distributed networks, cable tray applications, and pipeline monitoring. The system employs Raman Effect coupled with established OTDR technology to determine the temperature rise and its location along the fiber where the temperature increase occurs.

- The system is totally electrically passive outside the central controller housed in a MSHA-approved XP enclosure, offering complete intrinsic safety and compatibility with all current safety standards
- The system uses a standard low power semi-conductor telecommunications laser with less than 17mW of optical power

6.0 Test Protocol

See Appendix A

7.0 Test Results

See Appendices B - G

8.0 Commercialization Plan

There are significant commercial opportunities for both the methane and temperature sensing products. There are stand-alone applications as described in this report, as well as synergistic applications such as leak detection from Natural Gas piping in which the two products complement each other, providing an extra level of detection when combined.

With respect to the methane product the applications in coal mines for a mine-wide distributed system provides a product which will increase safety significantly as well as reduce manpower requirements by dramatically reducing the need for a miner or Fire Boss to travel the mine taking manual gas concentration readings on the regular basis.

In addition the ability to sense in the mined-out sealed areas of the mine represents a significant opportunity to generate data, which will be extremely useful in anticipating the ventilation demands of the mine.

There is significant interest at MSHA concerning a mandate, which would require expanded monitoring of methane not only in active areas of the mine, but also in mined-out sealed areas as well. The product, which is discussed in this paper, would satisfy this need.

The temperature product has applications on conveyors as well as other pieces of equipment within the mine. An application, which was not the subject of this paper but brings significant opportunity, is utilizing the product as a means of fire detection, especially in conveyor tunnels. It is anticipated the performance would exceed the current CO sensors with lowered cost and maintenance.

Outside coal mining significant opportunities exist for both products in a variety of Oil and Gas applications.

RSL is pursuing all of the opportunities described above with partners in the specific market segments.

9.0 Conclusion

Multi-point fiber-optic-based remote methane (CH₄) detection and distributed temperature systems were researched, acquired, assembled, field-tested, and laboratory-tested by RSL Fiber Systems researchers. The systems successfully detected CH₄ methane and corresponding temperatures by utilizing a low-power (10mW) diode laser in conjunction with a distributed fiber network and a series of ruggedized sensor modules or MSHA-approved fiber-optic cable. The systems were largely unaffected by common mine conditions which can cause erroneous readings with many other sensor types including high humidity, anaerobic conditions, and the presence of other non-target gases. The system was tolerant of dust contamination, and fully-functioning at signal losses of up to 90%.

The fiber-optic cable used to direct the laser light sources to and from the remote control room was intrinsically safe, and therefore, eliminated any sparking hazard found in the power supplies of electrically-based remote detectors and sensor systems. Three methane sensors were placed in an underground coal mine for several months and

were able to accurately measure CH₄ concentrations as low as 0.5% as far away as 10,000 feet.

The results of this research are encouraging. However, these systems require more work to develop an advanced fiber-optic based Mine-wide-Monitoring (MWM) system that will greatly improve safety and health in mining by improving atmospheric monitoring in underground coal mines through achievement of the objectives stated earlier. This impact will be realized by reducing mining related fatalities, injuries, and disease by helping reduce the number of methane explosions that trigger subsequent catastrophic coal dust explosions.

Unlike conventional methane detection systems currently employed, our system did not require calibration at the remote sensor. Alarm schemes were configured to look for rising methane levels, over-limit conditions, as well as breaks in the sensing fiber. While no native over-limit conditions were detected, the system was periodically checked for correlation to calibration gases without error during the field test period.

The existing sensor modules will need to be further ruggedized for continual utilization in an underground coal mine. The perforated stainless steel sensor tube, junction box, and drip shield were retrofitted with an expanded metal cage for field tests. While the sensors were designed for rapid response and were not affected by anaerobic conditions, catalytic poisoning, and other non-target gases, water sprays and excessive impact and vibration would cause problems for existing fasteners and sheet metal gauges.

A low-power (17mW) diode laser was utilized to generate an incident light pulse introduced into a multi mode fiber. The temperature anywhere along the fiber can be monitored within a resolution of approximately 0.5m in location and 1 degree C in magnitude. As with the methane system, standard communications grade MSHA approved fiber was used. Various alarm schemes were configured to look for over-temperature, and rapid temperature rise, as well as breaks in the sensing fiber. Another challenge for more permanent installation will be the inherent conflict observed between access to useful temperature information versus exposure to fiber cable damage in and around underground coal mining structures and equipment.



A supervisory PC-based control system to combine the monitoring processes, display, and store the data collected was utilized in the mine operations control room. The system worked well with the exception of maintaining connection of remote web-based access from time to time during the field test period. More work will be needed to develop the capability to run control algorithms to signal bleeder ventilation systems and future VOD systems based on remote sensor data, historical data patterns and measured barometric pressures.

Impact:

Supporting information using appropriate surveillance data to quantify the anticipated impact in reducing mining related injuries and disease includes MSHA's Report of Investigation, Underground Coal Mine Explosion, April 5, 2010, Upper Big Branch Mine-South, Performance Coal Company, Montcoal, Raleigh County, West Virginia, ID No. 46-08436, was made available to the public on December 6, 2011.

At approximately 3:02 p.m. on April 5, 2010, a massive coal dust explosion occurred at UBB, resulting in the deaths of 29 miners and injuries to two miners who survived. This tragic event resulted in more fatalities than any other U.S. coal mine disaster in nearly four decades.

After the explosion, MSHA promptly began a comprehensive investigation into its cause. A team of MSHA managers, inspectors, specialists, and technical experts were assigned to conduct the investigation. The investigation included extensive inspection and testing of physical evidence, a review of pertinent documents, and interviews of persons having relevant information.

The MSHA Accident Investigation team determined that methane had accumulated at the tailgate of the long-wall. When the shearer cut out at the tailgate, worn shearer bits and missing water sprays created an ignition source for methane on the long-wall. Evidence indicated that the flame from the initial methane ignition then ignited a larger accumulation of methane in the tailgate area, triggering a localized explosion. Coal dust, including float coal dust, propagated the explosion throughout the northern area of the Mine. The McAteer team said the methane came from the mined-out "gob" area behind the long-wall machine, while MSHA concluded it came from a gas reservoir located along geological faults that were the likely source of methane in previous incidents at the mine in 1997, 2003 and 2004.

MSHA investigators believe small amounts of methane migrated from the mine floor and onto the longwall cutting tool, or shearer, from the long-wall's roof supports, or shields.

In a Review of MSHA's Actions at the Upper Big Branch Mine-South Performance Coal Company Montcoal, Raleigh County, West Virginia:

Include checks for compliance with 30 CFR 75.400 and 75.403 in the listing of inspection activities that can be conducted during section 103(i) spot inspections at mines selected for such inspections due to excessive methane liberation, methane hazards, or ignitions; define when inspectors are to collect total methane liberation (TL) air samples, consistent with the guidance in the Coal Mine Safety and Health Supervisor's Handbook, and Additionally, both district SOPs prohibit standalone Methane and Dust Control Plans and require them to be incorporated into a single mine ventilation plan, subject to a single review date.

Appendix C – Recommendations for Regulatory Changes:

30 CFR 75.325(c)(1) – The Assistant Secretary should consider rulemaking to state that the quantity of air shall be at least 75,000 cubic feet per minute reaching the working face of each long-wall. Progressive increases in the minimum quantity should be established according to the mine methane liberation rate or established schedule for spot inspections at 103(i) mines, such as 15, 10, and 5 day spots inspections. Respirable dust compliance is another factor to be consideration for increasing the intake air quantity. A quantity greater than 75,000 cubic feet per minute may be required to be specified in the approved ventilation plan. The following should be removed as part of the revised regulation: “unless the operator demonstrates that a lesser air quantity will maintain continual compliance with applicable methane and respirable dust standards.”

30 CFR 75.342(a)(2) – The Assistant Secretary should consider rulemaking to require additional methane sensors to be installed along the long-wall face and tied into an Atmosphere Monitoring System (AMS) for the mine. These sensors should be placed along the face at various distances and heights to aid in the detection of methane during normal mining and in the event of a methane inundation. These additional sensor locations should be approved by the District Manager in the mine ventilation plan.

30 CFR 75.342(a)(4)(ii) –The Assistant Secretary should consider rulemaking to require methane monitors be calibrated every seven days. In addition, calibration records shall be signed by a qualified electrician and countersigned by the Mine Foreman or equivalent official.

30 CFR 75.351 & 75.1103 – Combine the CO monitoring standards, automatic fire warning device standards (30 CFR 75.1103), and AMS (30 CFR 75.351) standards into a single standard.

30 CFR 75.351 – The Assistant Secretary should consider rulemaking to require an AMS to provide real-time monitoring of methane, carbon monoxide levels, airflow direction, and record quality and quantity of air at specific points in the mine, such as where air reversals are likely to impact the overall ventilation system, out-by loading points, where air courses split, and at certain intervals along the belt.

30 CFR 75.1714-7 (a) – The Assistant Secretary should consider rulemaking to require methane detectors to be in the on position whenever a person with the detector is underground.

The specific aims for follow-on work related to this research project include: **(1)** increasing the distance, range, and data collection scope of methane monitoring and temperature sensing beyond current Atmospheric Monitoring System (AMS) technology limitations, **(2)** keying Ventilation-On-Demand (VOD) potential for unlocking improved efficiency and allowing for the most efficient monitoring and dilution of contaminants with known adverse health effects; **(3)** improving real-time measurement of gas concentrations that lead to better rock dust application and tracking; **(4)** sensing and comprehensively characterizing the gob in real-time; **(5)** allowing for better engineering at the explosive fringe; **(6)** demonstrating the management of real-time continuous sensing data and addressing how that sensing data is best utilized; and **(7)** encouraging stakeholders to adopt the subsequently improved AMS technologies for safer methods in underground coal mining that lead to improved engineering methods at the explosive fringe and changes to related mining regulations over the long term.

10.0 Acknowledgements

We would like to thank Fenner Dunlop for allowing access to their R&D facility in Tazewell County, Virginia. Their help and assistance was invaluable in completing the temperature sensing aspect of the project.

The assistance of the personnel at the Pinnacle Mine was invaluable in the completion of the project.

The Center for Applied Research and Technology (CART), took on a significant task in completing the Lab Testing in the last phases of the project. Their willingness to take this on allowed the project to proceed to completion.

Appendix A - NIOSH Lab & Field Test Protocol

Method for Improving Ventilation and Gas and Temperature Monitoring with an Advanced Fiber Optic-based Mine-wide Monitoring System

1. Identification and Significance of the Test Protocol

1.1. Purpose

The test protocol sets the requirements for methane and temperature monitoring systems and components for their incorporation in or with permissible equipment that is used in underground coal mines.

1.2. Testing Methods

A methane and temperature monitoring system shall be tested by RSL Fiber Systems, LLC (RSL) to determine its functional performance, and its explosion-proof and other safety characteristics. Since the design, arrangement, and component combinations have been set, RSL will undertake tests, and place limitations on equipment, or components or subassemblies thereof, primarily to determine and assure the safety of such equipment with regard to explosion and fire hazards.

1.3. Responses to MSHA Title 30 CFR Part 22&27 Construction Requirements

1.3.1 Quality of material, workmanship, and design.

(a) RSL will test only equipment that, in its opinion, is constructed of suitable materials, is of good workmanship, is based on sound engineering principles, and is safe for its intended use.

(b) Unless otherwise noted, the requirements stated in this part shall apply to explosion-proof enclosures and intrinsically safe circuits.

(c) All components, subassemblies, and assemblies are designed and constructed in a manner that will not create an explosion or fire hazard.

(d) All assemblies or enclosures--explosion-proof or intrinsically safe--have been designed so that the temperatures of the external surfaces, during continuous operation, do not exceed 150° C. (302° F.) at any point.

(e) Lenses, globes, and sensors have been protected against damage by guards or by location.

1.3.2 Methane Monitoring System

(a) The methane-monitoring system is designed so that any machine or equipment, which is controlled by the system, cannot be operated unless the electrical components of the methane-monitoring system are functioning normally.

(b) The methane-monitoring system is rugged in construction so that its operation will not be affected by vibration or physical shock, such as normally encountered in mining operations.

(c) No insulating materials that give off flammable or explosive gases when decomposed have been used within enclosures where they might be subjected to destructive electrical action.

(d) The enclosure is equipped with a lock, seal, or acceptable equivalent if such protection necessary for safety.

(e) Components or subassemblies of the methane-monitoring system are constructed as a package unit or otherwise readily replaceable or removable without creating an ignition hazard.

(f) The completed system is "fail safe" in regard to safety requirements.

1.3.3 Methane Detector Components

(a) The methane detector components shall be suitably constructed for incorporation in or with permissible and approved equipment that is operated in underground mines and gassy tunnels.

(b) The methane detector shall include:

(1) A method of continuous sampling of the atmosphere in which it functions.

(2) A method for actuating a warning device which shall function automatically at a methane content of the mine atmosphere between 1.0 to 1.5 volume percent (%). The warning device shall also function automatically at all higher concentrations of methane in the mine atmosphere.

(3) A method for actuating a power-shutoff component, which shall function automatically when the methane content of the mine atmosphere is 2.0 volume percent (%) and at all higher concentrations of methane.

(4) A suitable filter on the sampling intake to prevent dust and moisture from entering and interfering with normal operation or the methane detector design is such that it precludes the need of a filter.

(c) The methane detector may provide means for sampling at more than one point; provided, the methane detector shall separately detect the methane in the atmosphere at each sampling point with sufficient frequency.

1.3.4 Automatic Warning Device

(a) The automatic warning device is suitably constructed for incorporation in or with permissible and approved equipment that is operated in underground coal mines and gassy tunnels.

(b) The automatic warning device includes an alarm signal (audible or colored light), which is made to function automatically at a methane content of the mine atmosphere between 1.0 to 1.5 volume percent (%) and at all higher concentrations of methane.

(c) It has been *recommended* that the automatic warning device be supplemented by a meter calibrated in volume percent (%) of methane.

1.3.5 Power Shutoff Requirement

(a) A power-shutoff component has been suitably constructed for incorporation in or with permissible and approved equipment that is operated in underground coal mines and gassy tunnels.

(b) The power-shutoff component includes:

(1) A means has been made to function automatically to de-energize the machine or equipment when actuated by the methane detector at a methane concentration of 2.0 volume percent (%) and at all higher concentrations in the mine atmosphere.

(b)(1)(i) For an electric-powered machine or equipment energized by means of a trailing cable, the power-shutoff component shall, when actuated by the methane detector, cause a control circuit to shut down the machine or equipment on which it is installed; or it shall cause a control circuit to de-energize both the machine or equipment and the trailing cable. It is not necessary that power be controlled both at the machine and at the outby end of the trailing cable.

(b)(1)(ii) For a battery-powered machine or equipment, the methane-monitor power-shutoff component shall, when actuated by the methane detector, cause a control circuit to de-energize the machine or equipment as near as possible to the battery terminals.

(b)(1)(iii) For a diesel-powered machine or equipment, the power-shutoff component, when actuated by the methane detector, shall shut down the prime mover and de-energize all electrical components of the machine or equipment. Batteries are to be disconnected as near as possible to the battery terminals.

(2) An arrangement for testing the power-shutoff characteristic to determine whether the power-shutoff component is functioning properly.

2. Laboratory and Field Test Requirements

2.1. Tests to determine reliability and durability of the system.

(a) Laboratory tests for reliability and durability. Five hundred successful consecutive tests for gas detection, temperature sensing, alarm action, and power shutoff in *natural gas*-air mixtures shall be conducted to demonstrate acceptable performance as to reliability and durability of a methane-monitoring system. The tests shall be conducted so that normal replacements and adjustments shall not constitute a failure. Investigation has shown that, for practical purposes, *natural gas* (containing a high percentage of methane) is a satisfactory substitute for *pure methane* in these tests. The methane detector component shall be placed in a test gallery into which natural gas shall be made to enter at various rates with sufficient turbulence for proper mixing with the air in the gallery. To comply with the requirements of this test, the detector shall provide an impulse to actuate an alarm at a predetermined percentage of gas and also provide an impulse to actuate a power shutoff at a second predetermined percentage of gas. (See other tests listed below). Optionally, these tests will be conducted with dust or moisture added to the atmosphere within the gallery.

(b) Field tests. RSL shall conduct tests, similar to those stated in paragraph (a) of this section, in underground workings to verify reliability and durability of a methane-monitoring and temperature sensing systems installed in connection with a piece of mining equipment.

2.2. Tests to determine explosion-proof construction.

Not Applicable

Rationale: By project definition, no assembly, subassembly, or component of the passive methane or temperature monitoring system requires explosion-proof construction. Therefore, no tests are applicable to determine the performance of explosion-proof construction.

2.3. Test for intrinsic safety.

Not Applicable

Rationale: By project definition, no assembly, subassembly, or component of the passive methane or temperature monitoring system requires intrinsically safe

construction. Therefore, no tests are applicable to determine the intrinsic safety in construction.

2.4. Tests to determine life of critical components and subassemblies.

Optional: Replaceable components may be subjected to appropriate optional life tests by RSL.

2.5. Test for adequacy of electrical insulation and clearances.

Not Applicable:

Rationale: By project definition, no assembly, subassembly, or component of the passive methane or temperature monitoring system requires electrical conductors. Therefore, no tests are applicable to determine the performance of electrical insulation and clearances between electrical conductors to determine adequacy for the intended service.

2.6. Tests to determine adequacy of safety devices for bulbs.

Not Applicable

Rationale: By project definition, no assembly, subassembly, or component of the passive methane or temperature monitoring system requires incandescent bulbs. Therefore, no tests are applicable to determine the performance of the glass envelope of bulbs with the filament incandescent at normal operating voltage. There are no bulbs to be broken in flammable methane-air or natural gas-air mixtures in a gallery to determine that the safety device will prevent ignition of the flammable mixtures.

2.7. Tests to determine adequacy of windows and lenses.

Not Applicable

Rational: By project definition, no assembly, subassembly, or component of the passive methane or temperature monitoring system requires exposed windows or lenses. Therefore, no impact tests are applicable to determine the adequacy of a window or lens under the weight of a 4-pound cylinder with a one-inch diameter hemispherical striking surface dropped (free fall) to strike the window or lens in its mounting or the equivalent thereof at or near the center.

Optional: RSL may perform other impact testing of components, where at least three out of four samples shall withstand the impact according to the following table:

| Overall diameter (inches) | Height of Fall (inches) |
|----------------------------------|--------------------------------|
| Less than 4 | 6 |
| 4 to 5 | 9 |
| 5 to 6 | 15 |
| Greater than 6 | 24 |

2.8. Tests to determine resistance to vibration.

(a) Laboratory tests for reliability and durability. Components, subassemblies, or assemblies that are to be mounted on permissible and approved equipment shall be subjected to two separate vibration tests, each of one-hour duration. The first test shall be conducted at a frequency of 30 cycles per second with a total movement per cycle of 1/16-inch. The second test shall be conducted at a frequency of 15 cycles per second with a total movement per cycle of 1/8-inch. Components, subassemblies, and assemblies shall be secured to the vibration testing equipment in their normal operating positions (with shock mounts, if regularly provided with shock mounts). Each component, subassembly and assembly shall function normally during and after each vibration test.

Note: The vibrating equipment is designed to impart a circular motion in a plane inclined 45° to the vertical or horizontal.

(b) Field tests. RSL will conduct tests to determine resistance to vibration in underground workings to verify the reliability and durability of a methane and temperature monitoring system or component(s) thereof where installed in connection with a piece of mining equipment.

2.9. Test to determine resistance to dust.

Components, subassemblies, or assemblies, the normal functioning of which might be affected by dust, such as coal or rock dust, shall be tested in an atmosphere containing an average concentration (50 million minus 40 micron particles per cubic foot) of such dust(s) for a continuous period of 4 hours. The component, subassembly, or assembly shall function normally after being subjected to this test.

Note: Dust measurements shall be made by impinge sampling and light-field counting technique.

2.10. Tests to determine resistance to moisture.

Components, subassemblies, or assemblies, the normal functioning of which might be affected by moisture, shall be tested in atmospheres of high relative humidity (80 percent or more at 65°-75°F.) for continuous operating and idle periods of 4 hours each. The component or subassembly or assembly shall function normally after being subjected to those tests.

3. Work Plan for Applicable Tests

3.1. Approach

RSL will conduct laboratory and field tests in four of the ten categories described above in 2.1, 2.8, 2.9 and 2.10 and Field Installation tests.

- 1. Tests to determine reliability and durability of the system.**
- 2. Tests to determine resistance to vibration.**
- 3. Test to determine resistance to dust.**
- 4. Tests to determine resistance to moisture.**
- 5. Field Installation**

3.2. What is planned

3.2.1 Tests to determine reliability and durability of the system.

3.2.1.1 Test Equipment

3.2.1.1.1 Test gallery of sufficient volume to house the methane detector.

3.2.1.1.2 Test gases consisting of methane and air.

3.2.1.1.3 Gas mixing/measuring equipment (if not using pre-mixed test gas) with the capability to give mixtures of 1.5 and 2.1 (± 0.1) percent by volume.[Modular Dyna-Blenders Models 8250].

3.2.1.1.4 Thermometer. Minimum resolution: 0.1°C; minimum accuracy: $\pm 1^\circ\text{C}$. [Fluke Model 2170A Digital Thermometer]

3.2.1.1.5 Equipment to monitor the status of the power shut-off components.

3.2.1.1.6 Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least 0.05 % volume methane-in-air [Horiba Model VIA-510].

3.2.1.2 Test Samples

One complete methane monitoring system and one complete temperature monitoring system. The samples shall be of a quality consistent with that of the final manufactured product.

3.2.1.3 Procedures

3.2.1.3.1 Conduct the test in an ambient temperature of $25 \pm 10^\circ$ C. Record the ambient temperature on the test sheet.

3.2.1.3.2 Assemble and calibrate the methane and temperature monitoring systems per the manufacturer's recommendations. Analyze the calibration gas with the gas analyzer. Record the reading.

3.2.1.3.3 Place the methane detector component of the assembled methane monitoring system, along with temperature sensing cable in the test gallery with only air present. The detector should be placed in the gallery so as to minimize the effects of test gas velocity on the sensing head.

3.2.1.3.4 Record display readings, power shut-off component status, warning indicator status, and alarm indicator status on the test sheet.

3.2.1.3.5 Introduce a gas mixture of 1.5 percent methane-in-air into the test gallery.

3.2.1.3.6 Record the display readings when the warning indication activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.

3.2.1.3.7 Increase the concentration of the gas mixture in the test gallery to 2.1 percent methane in air.

3.2.1.3.8 Record the display readings when the alarm indicator and the power shut-off component activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.

3.2.1.3.9 Reduce the concentration of the gas mixture in the test gallery to 0.0 percent methane in air.

3.2.1.3.10 Repeat steps 7.5 through 7.9 fifty times, unless the monitoring system features two sensor heads. In that case, repeat steps 7.5 through 7.9 twenty-five times on each sensor head.

3.2.1.3.11 Remove the methane detector component of the assembled methane monitoring system from the test gallery.

3.2.1.3.12 Apply a gas mixture of 1.5 percent methane-in-air to the sensor head using the manufacturer's calibration adapter. The flow rate of the test gas should be the same as the recommended calibration gas flow rate.

3.2.1.3.13 Record the display reading when the warning indication activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.

3.2.1.3.14 Apply a gas mixture of 2.1 percent methane-in-air to the sensor head using the manufacturer's calibration adapter. The flow rate of the test gas should be the same as the recommended calibration gas flow rate.

3.2.1.3.15 Record the display reading when the alarm indicator and the power shut-off component activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.

3.2.1.3.16 Reduce the concentration of the gas mixture to 0.0 percent methane in air.

3.2.1.3.17 If the methane monitoring system features a single methane detection head, repeat Sections 3.2.1.3.12 through 3.2.1.3.16 four hundred fifty times. If it features two detection heads, repeat Sections 7.12 through 7.16 two hundred twenty-five times on each head.

3.2.1.4 Test Data

3.2.1.4.1 Test number

3.2.1.4.2 Warning indicator status and display reading

3.2.1.4.3 Alarm indicator status and display reading

3.2.1.4.4 Power shut-off component status

3.2.1.4.5 Test equipment with calibration due dates

3.2.1.4.6 Description of methane monitoring and temperature monitoring systems including manufacturer, model, or type number and serial number of unit tested.

3.2.1.4.7 Description of method used to monitor status of power shut-off component.

3.2.1.4.8 Test gas concentration. Minimum resolution: 0.1%; minimum accuracy: $\pm 0.1\%$.

3.2.1.4.9 Ambient temperature. Minimum resolution: 0.1°C ; minimum accuracy: $\pm 1^{\circ}\text{C}$.

3.2.1.4.10 Reference to the manufacturer's calibration procedure (document number, section, revision date, etc.).

3.2.1.4.11 The analyzed reading of the calibration gas.

3.2.1.5 Pass/Fail Criteria

3.2.1.5.1 The methane monitor system shall provide a control signal to actuate a warning indicator device when 1.5 percent methane-in-air is applied to the methane detector.

3.2.1.5.2 The methane monitor system shall provide a control signal to actuate a warning indicator device and the power shutoff component when 2.1 percent methane-in-air is applied to the methane sensor.

3.2.1.5.3 Temperature readings from temperature system will be recorded along with standard temperature recording device

3.2.1.5.4 Normal replacements and adjustments shall not constitute a failure. Normal replacements and adjustments are considered to be replacement of components (sensor head, etc.).

3.2.2 Tests to determine resistance to vibration.

3.2.2.1 Test Equipment

3.2.2.1.1 Adapter for applying gas to detector head (manufacturer's calibration cup).

3.2.2.1.2 Test gas consisting of methane and air.

3.2.2.1.3 Gas mixing/measuring equipment (if not using pre-mixed test gas) with the capability to give mixtures of 1.5 and 2.1 ± 0.1 percent by volume [Modular Dyna-Blenders Models 8250].

3.2.2.1.4 A vibration table that is designed to impart a circular motion in a plane inclined 45° to the vertical or horizontal, at frequencies of 15 and 30 Hz, and with amplitudes of 1/16 in. and 1/8 in. [MRAD Model F2424(200)E- 45 Degree].

3.2.2.1.5 Equipment to monitor the status of the power shut-off component.

3.2.2.1.6 Equipment (e.g., accelerometer/amplifier) with sufficient range and resolution to monitor the frequency and amplitude of the vibration table within ± 2 Hz and ± 0.02 in. (± 0.5 mm) [MRAD DIGI-VIB Model 437 ADF- 2].

3.2.2.1.7 Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least ± 0.05 % volume methane-in-air [Horiba Model VIA-510].

3.2.2.2 Test Samples

3.2.2.2.1 One representative sample of a complete methane-monitoring system and a complete temperature monitoring system

3.2.2.3 Procedures

3.2.2.3.1 The tests shall be conducted in an ambient temperature of $25 \pm 10^\circ$ Celsius.

3.2.2.3.2 Assemble and calibrate the methane monitoring and temperature monitoring systems per the manufacturer's recommendations. Analyze the calibration gas with the gas analyzer. Record the reading.

3.2.2.3.3 Secure the components (power supply, readout/control unit, sensor assembly) to be tested to the vibration testing equipment in their normal operating positions (with shock mounts, if specified with shock mounts).

3.2.2.3.4 Apply a gas mixture of 1.5 percent methane-in-air to the methane detector. Note display reading and alarm indicator status on the test sheet.

3.2.2.3.5 Apply a gas mixture of 2.1 percent methane-in-air to the methane detector. Note display reading, alarm indicator status, and power shutoff component status on the test sheet.

3.2.2.3.6 Operate the vibration table at a frequency of 30 ± 2 cycles per second with a total movement per cycle of 0.0625 ± 0.03 in. (1.6 ± 0.8 mm) for one hour. Monitor the amplitude and frequency of the table and the status of the power shutoff component. Note vibration table frequency and amplitude on the test sheet.

3.2.2.3.7 Every fifteen minutes (\pm five minutes), apply a gas mixture of 2.1 percent methane-in-air to the methane detector. Note alarm indicator status and power shutoff component status on the test sheet.

3.2.2.3.8 Operate the vibration table at a frequency of 15 ± 2 cycles per second with a total movement per cycle of 0.125 ± 0.03 in. (3.2 ± 0.8 mm) for one hour. Monitor the amplitude and frequency of the table and the status of the power shutoff component. Note the vibration table frequency and amplitude on the test sheet.

3.2.2.3.9 Every fifteen minutes (\pm five minutes), apply a known gas mixture of 2.1 percent methane or natural gas-in-air to the methane detector. Note alarm indicator status and power shutoff component status on the test sheet.

3.2.2.4 Test Data

3.2.2.4.1 Vibration table frequency at the beginning and end of testing at both frequencies.

3.2.2.4.2 Vibration table amplitude at the beginning and end of testing at both frequencies.

3.2.2.4.3 Power shutoff component status before, during, and after testing at both frequencies.

3.2.2.4.4 Display reading and Alarm indicator status before, during, and after testing at both frequencies.

3.2.2.4.5 Test equipment with calibration due dates.

3.2.2.4.6 Description of methane-monitoring system including manufacturer and model or type number.

3.2.2.4.7 Test gas concentration before, during, and after testing at both frequencies.

3.2.2.4.8 Ambient temperature.

3.2.2.4.9 Details (written or photographic) of the method used to secure the component(s) of the methane monitoring system to the vibration table.

3.2.2.4.10 Reference to the manufacturer's calibration procedure (document number, section, revision date, etc.).

3.2.2.4.11 The analyzed reading of the calibration gas.

3.2.2.5 Pass/Fail Criteria

Each component, subassembly, and assembly shall:

3.2.2.5.1 Actuate a warning device when 1.5 percent methane-in-air is applied to the methane detector; (designated over-temp for temperature system)

3.2.2.5.2 Actuate a warning device and power shutoff component when 2.1 percent methane-in-air is applied to the methane detector;(designated over-temp for temperature system)

3.2.2.5.3 Not actuate these devices in fresh air before, during, and after each vibration test.

3.2.3 Test to determine resistance to dust.

3.2.3.1 Test Equipment

3.2.3.1.1 A rock drilling device

3.2.3.1.2 A dust-collector unit, combination unit, or dust-collecting system

3.2.3.1.3 Drill steels (drill bits)

3.2.3.1.4 A midjet impinger apparatus

3.2.3.2.5 Equipment under Test (Methane and Temperature Sensing systems)

3.2.3.2 **Test Samples** (See section 3.2.3.3.3 below)

3.2.3.3 Procedure

3.2.3.3.1 Test site

3.2.3.3.1.1 Tests shall be conducted at an appropriate Field location TBD

3.2.3.3.2 Test space

3.2.3.3.2.1 Drilling tests shall be conducted in a test space formed by two curtains suspended across a mine opening in such a manner that the volume of the test space shall be approximately 2,000 cubic feet.

3.2.3.3.2.2 No mechanical ventilation shall be provided in the test space during a drilling test, except such air movement as may be induced by operation of drilling or dust-collecting equipment.

3.2.3.3.2.3 All parts of a unit or system shall be within the test space during a drilling test.

3.2.3.3.3 Determination of dust concentration

3.2.3.3.3.1 Concentrations of airborne dust in the test space shall be determined by sampling with a midjet impinger apparatus, and a light-field microscopic technique shall be employed in determining concentrations of dust in terms of millions of particles (5 microns or less in diameter) per cubic foot of air sampled.

3.2.3.3.3.2 Before a drilling test is started the surfaces of the test space shall be wetted; the test space shall be cleared of air-borne dust insofar as practicable by mechanical ventilation or other means; and an atmospheric sample, designated as a control sample, shall be collected during a 5-minute period to determine residual airborne dust in the test space.

3.2.3.3.3.3 A sample of airborne dust, designated as a test sample, shall be collected in the proximity of the Equipment under Test.

3.2.3.3.3.4 Drilling test

3.2.3.3.3.4.1 A drilling test shall consist of drilling a set of 10 test holes, without undue delay, under specified operating conditions. When the test involves the control of dust from more than one drill, all the drills shall be used in the intended manner to complete the set of test holes.

3.2.3.3.3.4.2 Holes shall be drilled to a depth of 4 feet plus or minus 2 inches and shall be spaced so as not to interfere with adjacent holes. Each hole may be plugged after completion.

3.2.3.3.3.4.3 Receptacles and filters for collecting drill cuttings shall be emptied and cleaned before each drilling test is started.

3.2.3.3.3.4.4 Holes designated as "vertical" shall be drilled to incline not more than 10 degrees to the vertical. Holes designated as "angle" shall be drilled to incline not less than 30 and not more than 45 degrees to the vertical. Holes designated as "horizontal" shall be drilled to incline not more than 15 degrees to the horizontal.

3.2.3.3.3.5 Methods of drilling; dust-collector unit.

3.2.3.3.3.5.1 General. All drilling shall be done with conventional, commercial drilling equipment -- pneumatic-percussion, hydraulic-rotary, and/or electric-rotary types--in accordance with the applicant's specifications.

3.2.3.3.3.5.2 Pneumatic-percussion drilling. A stoper-type drill with a piston diameter of 2 1/2 to 3 inches shall be used for roof drilling, A hand-held, sinker-type drill with a piston diameter of 2 1/2 to 3 inches shall be used for down drilling and also for horizontal drilling, except that the drill shall be supported mechanically. Compressed air for operating the drill shall be supplied at a gage pressure of 85-95 pounds per square inch. Drill bits shall be detachable, cross type with hard inserts, and shall be sharp when starting to drill each set of 10 holes. In roof drilling, 1 1/4- and 1 1/2-inch diameter drill bits shall be used; in horizontal and down drilling, 1 3/4-inch diameter bits shall be used. The drill steel shall be 7/8-inch hexagonal and of hollow type to permit the introduction of compressed air through the drill steel when necessary to clean a hole during drilling.

3.2.3.3.3.5.3 Rotary drilling. A hydraulic-rotary drill with a rated drilling speed of 18 feet per minute free lift, capable of rotating drill steel at 900 revolutions per minute with 100 foot-pounds torque, and having a feed force of 7,000 pounds, shall be used for roof drilling. An electric-rotary drill, supported by a post mounting, with a rated drilling speed of 30 inches per minute and powered by a 2.25 horsepower motor, shall be used for horizontal drilling. For roof drilling, the bits shall be hard-tipped, 1 3/8 and 1 1/2 inches outside diameter, and 1 1/4-inch auger-type drill steel shall be used. For horizontal drilling, the bits shall be hard-tipped, 2 inches outside diameter, and 1 3/4-inch auger-type drill steel shall be used. Drill bits shall be sharp when starting to drill each set of 10 holes.

3.2.3.3.3.6 Method of drilling; combination unit or dust-collecting system

3.2.3.3.3.6.1 Drilling shall be conducted in accordance with RSL-Vandalia's specifications and operating instructions.

3.2.3.3.3.7 Test procedure

3.2.3.3.3.7.1 Roof drilling: Drilling shall be done in friable strata tends to produce large scale-like cuttings.

3.2.3.3.3.7.2 Horizontal drilling: Drilling shall be done in strata comparable in hardness to that of coal-mine draw slate. Holes shall be started near the roof of the test space under conditions simulating the drilling of draw slate in coal mining.

3.2.3.3.3.7.3 Down drilling: Drilling shall be done in typical mine floor strata with a pneumatic percussion-type drill. Five holes shall be drilled vertically and five holes shall be drilled at an angle.

3.2.3.3.3.7.4 Drilling in "on site" strata may be acceptable in lieu of strata requirements of this section.

3.2.3.4 Test Data (See section 3.2.3.5 below)

3.2.3.5 Pass/Fail Criteria

3.2.3.5.1 Allowable limits of dust concentration

3.2.3.5.2 Validation of Equipment under Test for Methane and Temperature sensing equipment. Portable calibrated gas will be used to validate methane equipment in-situ. Temperature measurements will be compared with independent calibrated portable temperature probe.

3.2.4 Tests to determine resistance to moisture.

3.2.4.1 Test Equipment

3.2.4.1.1 Test gases consisting of methane and air.

3.2.4.1.2 Gas mixing/measuring equipment (if not using pre-mixed test gas) with the capability to give mixtures of 1.5 and 2.1 (± 0.1) percent by volume.[Modular Dyna-Blenders Models 8250].

3.2.4.1.3 An environmental test chamber able to provide and measure 80 percent or more relative humidity at 65° - 75° F and sufficiently large to enclose the appropriate components, assemblies, and subassemblies of the methane and temperature monitoring systems. [Tenney Environmental Chamber]

3.2.4.1.4 Equipment to monitor the status of the power shut-off component.

3.2.4.1.5 Manufacturers calibration cap (designed for use with the monitor), tubing, and flow meter set to the manufacturers specified calibration flow rate for introduction of the test gas mixtures to the sensor.

3.2.4.1.6 Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least ± 0.05 % volume methane-in-air [Horiba Model VIA-510].

3.2.4.2 Test Samples

One representative sample of a complete methane-monitoring system and a complete temperature monitoring system

3.2.4.3 Procedures

3.2.4.3.1 Adjust the chamber controls such that the temperature inside the chamber is maintained between 65° - 75° F and the relative humidity is at least 80%.

3.2.4.3.2 Assemble and calibrate the methane and temperature monitoring systems per the manufacturer's recommendations. Analyze the calibration gas with the gas analyzer. Record the reading.

3.2.4.3.3 Place the appropriate components, subassemblies, and assemblies in the environmental chamber in their normal operating positions, as described in the manufacturer's installation instructions.

3.2.4.3.4 Energize the methane and temperature monitoring systems for four (4) hours, then de-energize it and allow it to remain in the chamber for four (4) additional hours.

3.2.4.3.5 Reenergize the methane and temperature monitoring systems then apply a known gas mixture of 1.5 percent methane in air to the methane detector. Record the display reading and the status of each alarm and warning light and the power shut-off component. Record the time required for the display reading to increase from its quiescent reading to its ultimate reading.

3.2.4.3.6 Increase the gas mixture to 2.1 percent methane in air to the methane detector. Record the display reading and the status of each alarm and warning light and the power shut-off component. Record the time required for the display reading to increase from the value recorded in Section 3.2.4.3.5 to its ultimate reading.

3.2.4.3.7 Decrease the gas mixture to 0.0 percent methane in air to the methane detector. Record the display reading and the status of each alarm and warning light and the power shut-off component. Record the time required for the display reading to decrease from the value recorded in Section 3.2.4.3.6 to its ultimate reading.

3.2.4.4 Test Data

3.2.4.4.1 Temperature inside the environmental chamber throughout the course of the test.

3.2.4.4.2 Relative humidity inside the environmental chamber throughout the course of the test.

3.2.4.4.3 Power shut-off component status during Sections 3.2.4.3.5 through 3.2.4.3.7.

3.2.4.4.4 Alarm indicator status during Sections 3.2.4.3.5 through 3.2.4.3.7.

3.2.4.4.5 Response times recorded during Sections 3.2.4.3.5 through 3.2.4.3.7.

3.2.4.4.6 Test equipment with calibration due dates.

3.2.4.4.7 Description of methane and temperature monitoring systems including position and orientation of the sensor during the test, manufacturer and model or type number.

3.2.4.4.8 Test gas concentration. Minimum precision: 0.1%; minimum accuracy: $\pm 0.1\%$.

3.2.4.4.9 Reference to the manufacturer's calibration procedure and installation instructions (document number, section, revision date, etc.).

3.2.4.4.10 The analyzed reading of the calibration gas.

3.2.4.5 Pass/Fail Criteria

Each component, subassembly, and assembly shall:

3.2.4.5.1 Actuate a warning device when 1.5 percent methane-in-air is applied to the methane detector;

3.2.4.5.2 Actuate a warning device and power shutoff component when 2.1 percent methane-in-air is applied to the methane detector;

3.2.4.5.3 Not actuate these devices in fresh air before and after the moisture test.

3.2.5 Field Test

3.2.5.1 Test Equipment

3.2.5.1.1 Sensors will be installed in the following locations:

- A bleeder split
- A ventilation split ventilating a sealed area
- A bleeder evaluation point, or perhaps a fan housing (TBD) which

would reflect the methane content for the entire mines. The latter could be used to calculate total methane production for the mining operation.

- Idler bearings on conveyor run (temperature sensing cable)

3.2.5.1.2 The suggested areas are required to be monitored on a weekly basis by a fire boss, providing a comparison data point

3.2.5.1.3 The Alpha Natural Resources' (Brooks Run Mining Subsidiary) Cucumber Mine in McDowell County, WV has been identified as the primary candidate for locating the field test.

3.2.5.2 Test Samples

Data will be collected on a continuous basis for installed sensors

3.2.5.3 Procedures

3.2.5.3.1 Sensors will be installed in indicated areas, with appropriate mounting methods

3.2.5.3.2 Control Units will be placed in Mine control room

3.2.5.3.3 MSHA approved fiber cable will be installed, connecting sensors and central control unit in mine control room. Similarly temperature-sensing cable will be installed on conveyor run, monitoring bearing temperatures of idlers

3.2.5.3.4 Data with embedded time markers will be collected for each installed temperature and methane sensing system

3.2.5.3.5 Correlations will be made with weekly methane readings by Fire Boss and temperature readings collected with portable IR temperature probe

3.2.5.4 Test Data

3.2.5.4.1 Methane values recorded on a continuous basis at each location

3.2.5.4.2 Temperature values recorded on a continuous basis at each installed location

3.2.5.4.3 Ambient Temperature, Barometric pressure, and mine operating conditions will be collected and correlated with methane and temperature data

3.2.5.4.4 Methane levels recorded during Fire Boss inspections

3.2.5.4.5 Temperature levels recorded by RSL weekly inspection on conveyor fiber installations

3.2.5.4.6 Test equipment with calibration due dates.

Pass/Fail Criteria

3.2.5.5.1 Correlations with system and measured data to be within accepted data windows (using 30 CFR 22.7 as guideline)

Appendix B – Vibration Test

(Vibration Section from Appendix A – Test Protocol)

2.8 Tests to determine resistance to vibration.

(a) Laboratory tests for reliability and durability. Components, subassemblies, or assemblies that are to be mounted on permissible and approved equipment shall be subjected to two separate vibration tests, each of one-hour duration. The first test shall be conducted at a frequency of 30 cycles per second with a total movement per cycle of 1/16-inch. The second test shall be conducted at a frequency of 15 cycles per second with a total movement per cycle of 1/8-inch. Components, subassemblies, and assemblies shall be secured to the vibration testing equipment in their normal operating positions (with shock mounts, if regularly provided with shock mounts). Each component, subassembly and assembly shall function normally during and after each vibration test.

Note: The vibrating equipment is designed to impart a circular motion in a plane inclined 45° to the vertical or horizontal.

(b) Field tests. RSL will conduct tests to determine resistance to vibration in underground workings to verify the reliability and durability of a methane and temperature monitoring system or component(s) thereof where installed in connection with a piece of mining equipment

3.0 Work Plan for Applicable Tests

3.2.2 Tests to determine resistance to vibration.

3.2.2.1 Test Equipment

3.2.2.1.1 *Adapter for applying gas to detector head (manufacturer's calibration cup).*

See Figure 1, in-line gas cell is shown in foreground on vibration table. A gas cell without the in-line enclosure is shown in the background.

Gas Cell – showing Fiber connection and GRIN Lens assembly (45 degree orientation)



Figure 1 – In-Line gas cell on vibration Table

3.2.2.1.2 *Test gas consisting of methane and air.*

See Figure 2 and 3



Figure 2 – Calibration Gas (2.5%)

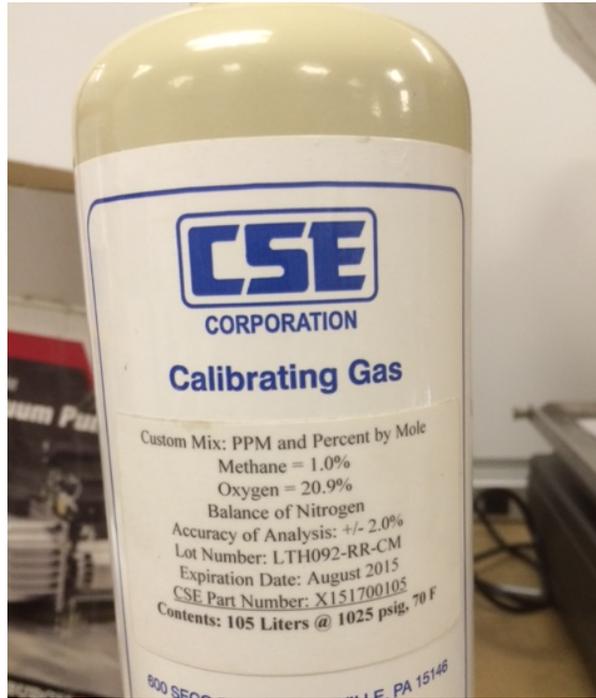


Figure 3 – Calibration Gas (1.0%)

3.2.2.1.3 *Gas mixing/measuring equipment (if not using pre-mixed test gas) with the capability to give mixtures of 1.5 and 2.1 ±0.1 percent by volume [Modular Dyna-Blenders Models 8250].*

N/A

3.2.2.1.4 *A vibration table that is designed to impart a circular motion in a plane inclined 45° to the vertical or horizontal, at frequencies of 15 and 30 Hz, and with amplitudes of 1/16 in. and 1/8 in. [MRAD Model F2424(200)E- 45 Degree].*

The MRAD vibration table is no longer in production. We were unsuccessful in finding a used model for purchase. We chose a similar table (Lab-Line model 4626) with a rotary motion and fixture the gas cell at the specified 45 degree angle (as shown in Figure 1). The amplitude is fixed at 3/4" on the Lab-Line table. The table is shown in Figures 4 and 5.



Figure 4 – Lab-Line vibration Table



Figure 5 – Lab-Line vibration Table

3.2.2.1.5 *Equipment to monitor the status of the power shut-off component.*

The PC-based controller has user configurable alarms which can be set to trigger an external output

3.2.2.1.6 *Equipment (e.g., accelerometer/amplifier) with sufficient range and resolution to monitor the frequency and amplitude of the vibration table within ± 2 Hz and ± 0.02 in. (± 0.5 mm) [MRAD DIGI-VIB Model 437 ADF- 2].*

The Lab-Line vibration table has a fixed amplitude of $\frac{3}{4}$ " (fixed mechanical eccentric). We chose frequencies of 170 RPM and 340 RPM with an intent to best represent frequencies and amplitude of MRAD equipment.

3.2.2.1.7 *Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least ± 0.05 % volume methane-in-air [Horiba Model VIA-510].*

N/A with Calibration Gas

3.2.2.2 Test Samples

3.2.2.2.1 One representative sample of a complete methane-monitoring system and a complete temperature monitoring system

Test Set-up shown in Figure 6. (Test was extended to temperature system, as the fiber for the methane system was included as equipment-under-test and it is the same construction as the temperature fiber)

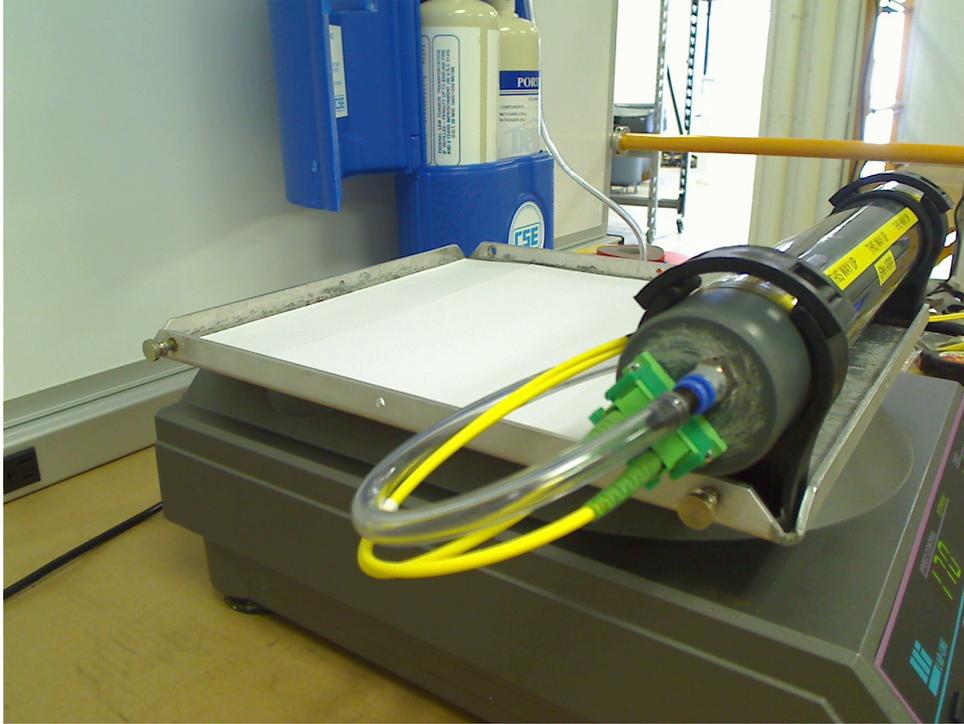


Figure 6 – Methane/temperature test set-up

3.2.2.3 Procedures

3.2.2.3.1 *The tests shall be conducted in an ambient temperature of $25 \pm 10^\circ$ Celsius.*

See Figure 7



Figure 7 – Lab Temperature during test

3.2.2.3.2 *Assemble and calibrate the methane monitoring and temperature monitoring systems per the manufacturer's recommendations. Analyze the calibration gas with the gas analyzer. Record the reading.*

3.2.2.3.3 *Secure the components (power supply, readout/control unit, sensor assembly) to be tested to the vibration testing equipment in their normal operating positions (with shock mounts, if specified with shock mounts).*

See Figure 6, 8, and 9



Figure 8 – Test Set-up (Front View)



Figure 9 – Test Set-up (Figure 9)

3.2.2.3.4 Apply a gas mixture of 1.5 percent methane-in-air to the methane detector. Note display reading and alarm indicator status on the test sheet.

Calibration Gas of 1.0% mixture was used. Alarms were set to correspond.

3.2.2.3.5 Apply a gas mixture of 2.1 percent methane-in-air to the methane detector. Note display reading, alarm indicator status, and power shutoff component status on the test sheet.

3.2.2.3.6 Operate the vibration table at a frequency of 30 ± 2 cycles per second with a total movement per cycle of 0.0625 ± 0.03 in. (1.6 ± 0.8 mm) for one hour. Monitor the amplitude and frequency of the table and the status of the power shutoff component. Note vibration table frequency and amplitude on the test sheet.

3.2.2.3.7 Every fifteen minutes (\pm five minutes), apply a gas mixture of 2.1 percent methane-in-air to the methane detector. Note alarm indicator status and power shutoff component status on the test sheet.

3.2.2.3.8 Operate the vibration table at a frequency of 15 ± 2 cycles per second with a total movement per cycle of 0.125 ± 0.03 in. (3.2 ± 0.8 mm) for one hour. Monitor the amplitude and frequency of the table and the status of the power shutoff component. Note the vibration table frequency and amplitude on the test sheet.

3.2.2.3.9 Every fifteen minutes (\pm five minutes), apply a known gas mixture of 2.1 percent methane or natural gas-in-air to the methane detector. Note alarm indicator status and power shutoff component status on the test sheet.

3.2.2.4 Test Data

| | |
|--|---------------|
| RSL Fiber Systems LLC | |
| Vibration Test | Date: 4/24/14 |
| Equipment: Lab-Line 4626 Vibration Table Serial Number 1197-0258 | |
| Run By: J. Browning | |

| Test 1: | | | | | | |
|----------------------|---------------------|-----------|--------------|----------------|-----------|--|
| 340 cycles/minute | | | | | | |
| 3/4" amplitude | | | | | | |
| 2.5% calibration gas | | | | | | |
| 1.0% calibration gas | | | | | | |
| Time | Calibration gas (%) | Methane % | Alarm Status | Power Shut-off | pass/fail | |
| 11:00 AM | 1.0 | 0.88 | On | Active | pass | |
| 11:05AM | 2.5 | 2.43 | On | Active | pass | |
| 11:20 AM | 2.5 | 2.54 | On | Active | pass | |
| 11:35 AM | 2.5 | 2.5 | On | Active | pass | |
| 11:50 AM | 2.5 | 2.52 | On | Active | pass | |
| 12:05 AM | 2.5 | 2.5 | On | Active | pass | |

Test 2:
 170 cycles/minute
 3/4" amplitude
 2.5% calibration gas
 1.0% calibration gas

| Time | Calibration gas (%) | Methane % | Alarm Status | Power Shut-off | pass/fail |
|---------|---------------------|-----------|--------------|----------------|-----------|
| 1:00 PM | 1.0 | 0.88 | On | Active | pass |
| 1:05 PM | 2.5 | 2.5 | On | Active | pass |
| 1:20 PM | 2.5 | 2.47 | On | Active | pass |
| 1:35 PM | 2.5 | 2.48 | On | Active | pass |
| 1:50 PM | 2.5 | 2.5 | On | Active | pass |
| 2:05 PM | 2.5 | 2.52 | On | Active | pass |

Figure 10 – Test Data Summary

Alarm display at 1% level

The screenshot shows the OptoSci OptoSniff Data Viewer interface. At the top, it displays 'Select FUR to view: 3140004' and 'COM Port: COM4'. The main data table is as follows:

| Sensor | Measured CH4 | Alarm | RSSI | Status |
|--------|--------------|-------|-------------|-----------|
| S1 | 8805ppm | AL 1 | | Valid |
| S2 | ---- | ---- | | NO SIGNAL |
| S3 | ---- | ---- | | NO SIGNAL |
| | | | Laser Power | Valid |

An arrow points from the 'Alarm display at 1% level' text to the yellow alarm icon for sensor S1. The 'Events' window on the right shows a list of warnings and errors, including 'Warning: Alarm Level 1 exceeded on sensor 1' and 'Error: No signal on sensor 3'.



Figure 11 – Initial Methane Reading (1% cal. gas)

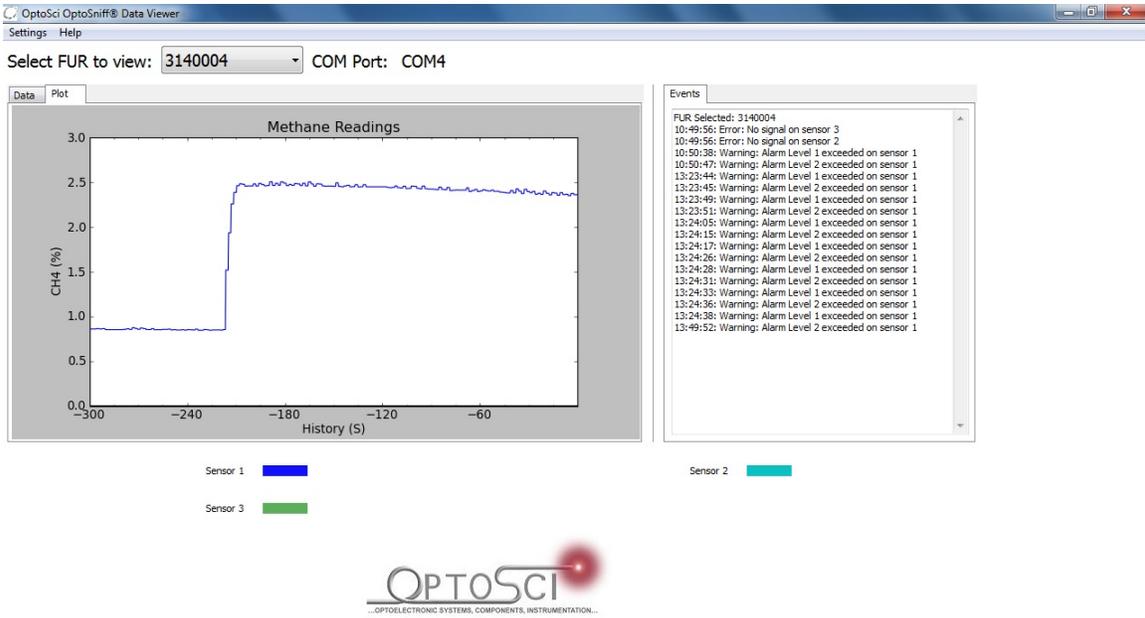


Figure 12 – Transition from 1% to 2.5% methane calibration gas

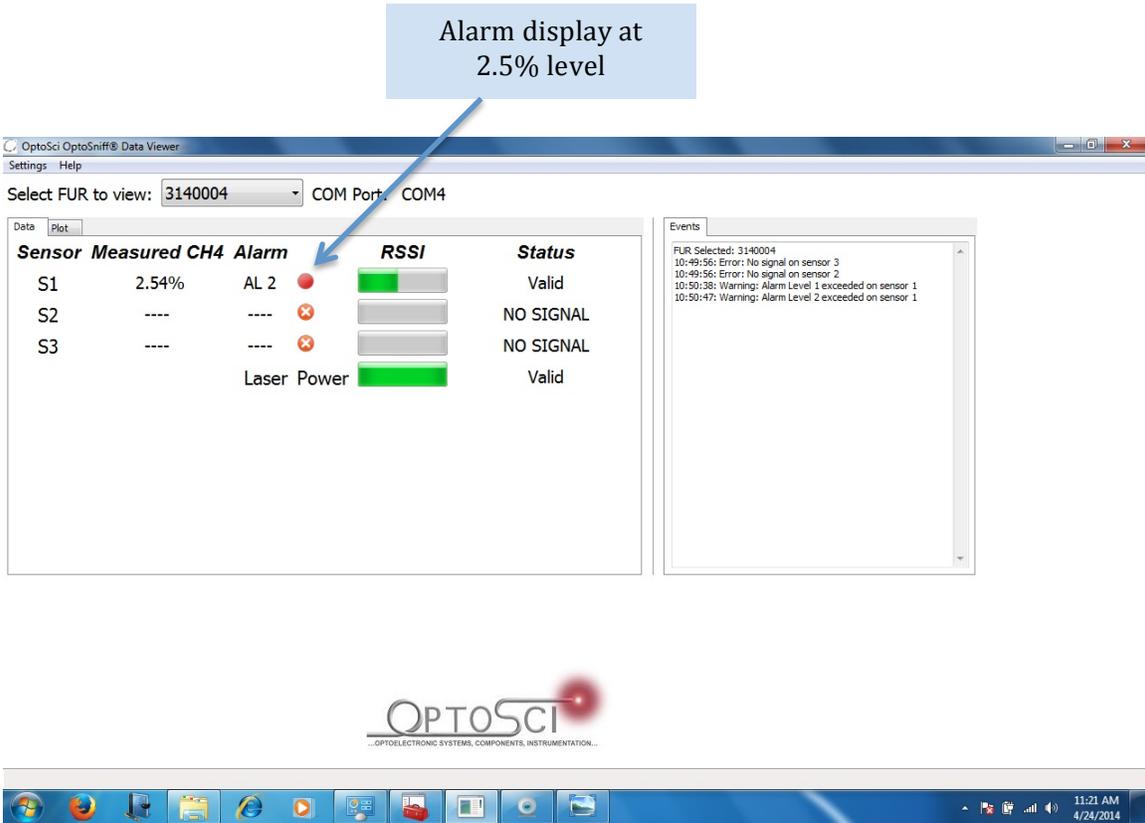


Figure 12 – Methane Reading (Typ.) (2.5% cal. gas)

Appendix C – Moisture Resistance

(Moisture Resistance Section from Appendix A – Test Protocol)

2.10 Tests to determine resistance to moisture.

Components, subassemblies, or assemblies, the normal functioning of which might be affected by moisture, shall be tested in atmospheres of high relative humidity (80 percent or more at 65°-75°F.) for continuous operating and idle periods of 4 hours each. The component or subassembly or assembly shall function normally after being subjected to those tests. A portion of this test was combined with the Reliability and Durability section, by maintaining the appropriate levels of humidity as required.

3.0 Work Plan for Applicable Tests

3.2.4 Tests to determine resistance to moisture.

3.2.4.1 Test Equipment

3.2.4.1.1 *Test gases consisting of methane and air.*

See Figures 1 and 2



Figure 1 – Calibration Gas (2.5%)

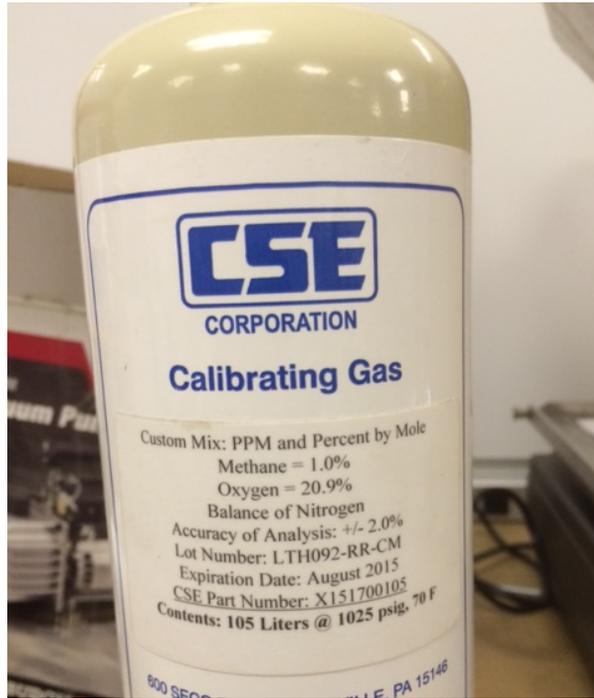


Figure 2- Calibration Gas (1%)

3.2.4.1.2 *Gas mixing/measuring equipment (if not using pre-mixed test gas) with the capability to give mixtures of 1.5 and 2.1 (± 0.1) percent by volume. [Modular Dyna-Blenders Models 8250].*

N/A

3.2.4.1.3 *An environmental test chamber able to provide and measure 80 percent or more relative humidity at 65° - 75° F and sufficiently large to enclose the appropriate components, assemblies, and subassemblies of the methane and temperature monitoring systems. [Tenney Environmental Chamber]*

See Figure 3

3.2.4.1.4 *Equipment to monitor the status of the power shut-off component.*

The PC-based controller has user configurable alarms which can be set to trigger an external output

3.2.4.1.5 *Manufacturers calibration cap (designed for use with the monitor), tubing, and flow meter set to the manufacturers specified calibration flow rate for introduction of the test gas mixtures to the sensor.*

See Figure 3

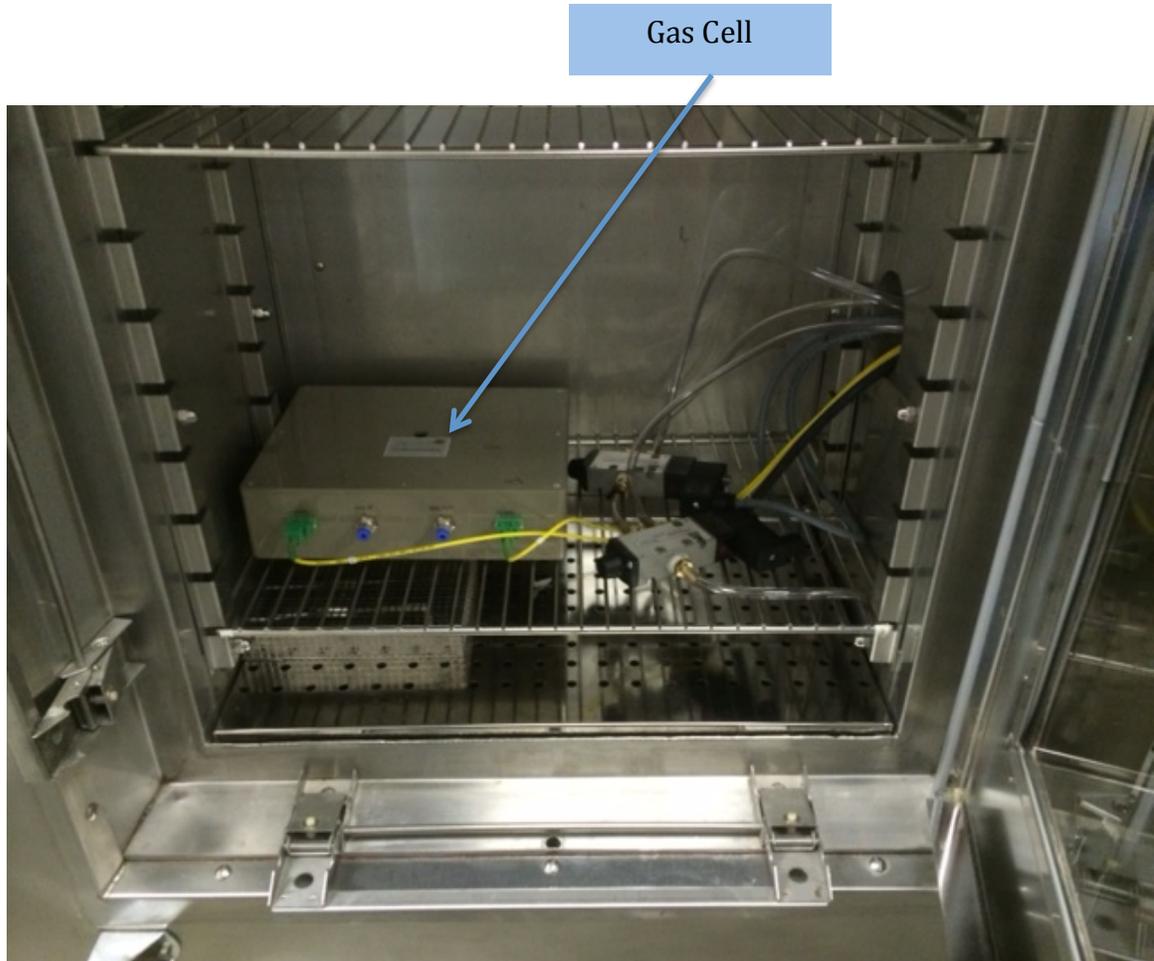


Figure 3 – Test Set-up for Humidity. The test is automated with a PLC controller. Methane Calibration gas is introduced to the gas cell, followed by conditioned air from the chamber (at recorded humidity and temperature). The gas cell has the same GRIN lens configuration as in other tests, The data from this run was also used with Reliability and Durability Test (Appendix E)



Figure 4 – 3 point methane detection unit



Figure 5 – Humidity/Temperature Chamber



Figure 6 – Humidity/Temperature Chamber

3.2.4.1.6 *Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least ± 0.05 % volume methane-in-air [Horiba Model VIA-510].*

3.2.4.2 Test Samples

One representative sample of a complete methane-monitoring system and a complete temperature monitoring system

3.2.4.3 Procedures

3.2.4.3.1 *Adjust the chamber controls such that the temperature inside the chamber is maintained between 65°- 75° F and the relative humidity is at least 80%.*

3.2.4.3.2 *Assemble and calibrate the methane and temperature monitoring systems per the manufacturer's recommendations. Analyze the calibration gas with the gas analyzer. Record the reading.*

3.2.4.3.3 *Place the appropriate components, subassemblies, and assemblies in the environmental chamber in their normal operating positions, as described in the manufacturer's installation instructions.*

3.2.4.3.4 *Energize the methane and temperature monitoring systems for four (4) hours, then de-energize it and allow it to remain in the chamber for four (4) additional hours.*

3.2.4.3.5 *Reenergize the methane and temperature monitoring systems then apply a known gas mixture of 1.5 percent methane in air to the methane detector. Record the display reading and the status of each alarm and warning light and the power shut-off component. Record the time required for the display reading to increase from its quiescent reading to its ultimate reading.*

3.2.4.3.6 *Increase the gas mixture to 2.1 percent methane in air to the methane detector. Record the display reading and the status of each alarm and warning light and the power shut-off component. Record the time required for the display reading to increase from the value recorded in Section 3.2.4.3.5 to its ultimate reading.*

3.2.4.3.7 *Decrease the gas mixture to 0.0 percent methane in air to the methane detector. Record the display reading and the status of each alarm and warning light and the power shut-off component. Record the time required for the display reading to decrease from the value recorded in Section 3.2.4.3.6 to its ultimate reading.*

3.2.4.4 Test Data

3.2.4.4.1 *Temperature inside the environmental chamber throughout the course of the test.*

See Test Results table and Figure 9

3.2.4.4.2 *Relative humidity inside the environmental chamber throughout the course of the test.*

See Test Results table and Figure 10

3.2.4.4.3 *Power shut-off component status during Sections 3.2.4.3.5 through 3.2.4.3.7.*

See Test Results table

3.2.4.4.4 *Alarm indicator status during Sections 3.2.4.3.5 through 3.2.4.3.7.*

See Test Results table

3.2.4.4.5 *Response times recorded during Sections 3.2.4.3.5 through 3.2.4.3.7.*

See Test Results table

3.2.4.4.6 *Test equipment with calibration due dates.*

Humidity/Temperature Chamber - Blue M Electric Model No. AC 7502
TDA-4-A, Serial AC-697 Calibration Due Date 4/1/2015

3.2.4.4.7 *Description of methane and temperature monitoring systems including position and orientation of the sensor during the test, manufacturer and model or type number.*

Included in System Description

3.2.4.4.8 *Test gas concentration. Minimum precision: 0.1%; minimum accuracy: $\pm 0.1\%$.*

3.2.4.4.9 *Reference to the manufacturer's calibration procedure and installation instructions (document number, section, revision date, etc.).*

N/A

3.2.4.4.10 *The analyzed reading of the calibration gas.*

See Test Results table

3.2.4.5 Pass/Fail Criteria

Each component, subassembly, and assembly shall:

3.2.4.5.1 *Actuate a warning device when 1.5 percent methane-in-air is applied to the methane detector;*

See Test Results table

3.2.4.5.2 *Actuate a warning device and power shutoff component when 2.1 percent methane-in-air is applied to the methane detector;*

See Test Results table

3.2.4.5.3 *Not actuate these devices in fresh air before and after the moisture test.*

See Test Results table

Test Results Table (representative data from 450 repetitions)

| Time Stamp | (a) | (b) | (c) | (d) | (e) | Alarm Status |
|-----------------------|------------|------------|------------|------------|------------|-----------------------|
| 05/24/14 16:25:39.652 | 1 | 72.9 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:40.665 | 1 | 72.9 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:41.677 | 1 | 72.9 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:42.698 | 1 | 73 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:43.627 | 1 | 72.9 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:44.647 | 1 | 72.9 | 91.67 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:45.657 | 1 | 73 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:46.671 | 1 | 73 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:47.688 | 1 | 72.9 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:48.619 | 1 | 72.9 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:49.634 | 1 | 73 | 92.12 | 2.5 | 1.531 | Warning Methane > 1% |
| 05/24/14 16:25:50.647 | 1 | 73 | 92.12 | 2.5 | 1.531 | Warning Methane > 1% |
| 05/24/14 16:25:51.661 | 1 | 72.9 | 91.68 | 2.5 | 1.531 | Warning Methane > 1% |
| 05/24/14 16:25:52.675 | 1 | 73 | 91.68 | 2.5 | 2.637 | Danger Methane > 1.9% |
| 05/24/14 16:25:53.689 | 1 | 72.9 | 91.68 | 2.5 | 2.637 | Danger Methane > 1.9% |
| 05/24/14 16:25:54.625 | 1 | 73 | 92.12 | 2.5 | 2.583 | Danger Methane > 1.9% |
| 05/24/14 16:25:55.640 | 1 | 73 | 92.12 | 2.5 | 2.583 | Danger Methane > 1.9% |
| 05/24/14 16:25:56.654 | 1 | 73 | 92.12 | 2.5 | 2.564 | Danger Methane > 1.9% |
| 05/24/14 16:25:57.668 | 1 | 73 | 92.12 | 2.5 | 2.564 | Danger Methane > 1.9% |
| 05/24/14 16:25:58.682 | 1 | 73 | 92.12 | 2.5 | 2.564 | Danger Methane > 1.9% |

- (a) – Test Number (1-450) – cycle run 450 times (4 ½ hours)
- (b) - Temperature (degrees F)
- (c) - Relative Humidity
- (d) - Measured Methane %

Notes:

- 1) As shown in 1.5% to 2.5% transition (timestamp 16:25:49.634 to 16:25:52:675) the response time of system was consistently less than 3 seconds (including gas diffusion time)
- 2) Warning/Danger alarm response instantaneous
- 3) Sample Data (Data Points 1-20), Graphs below show Date Set 1-51, complete data set provided if desired

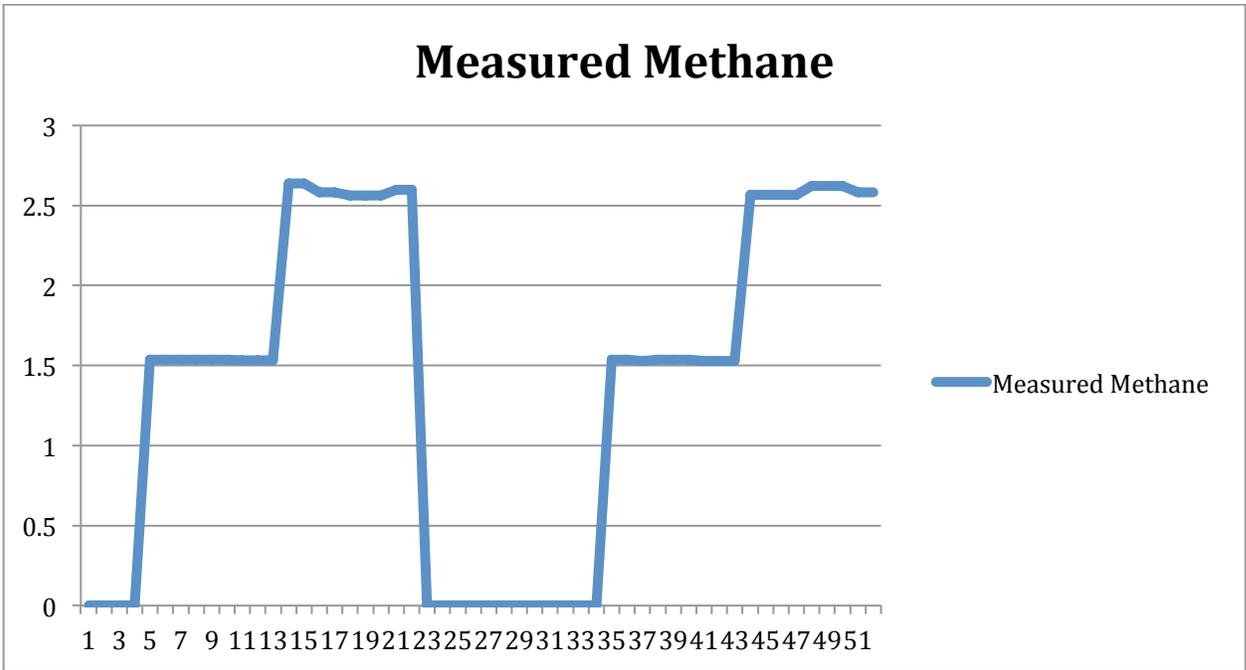


Figure 7 – Measured Methane (Data Set 1-51)

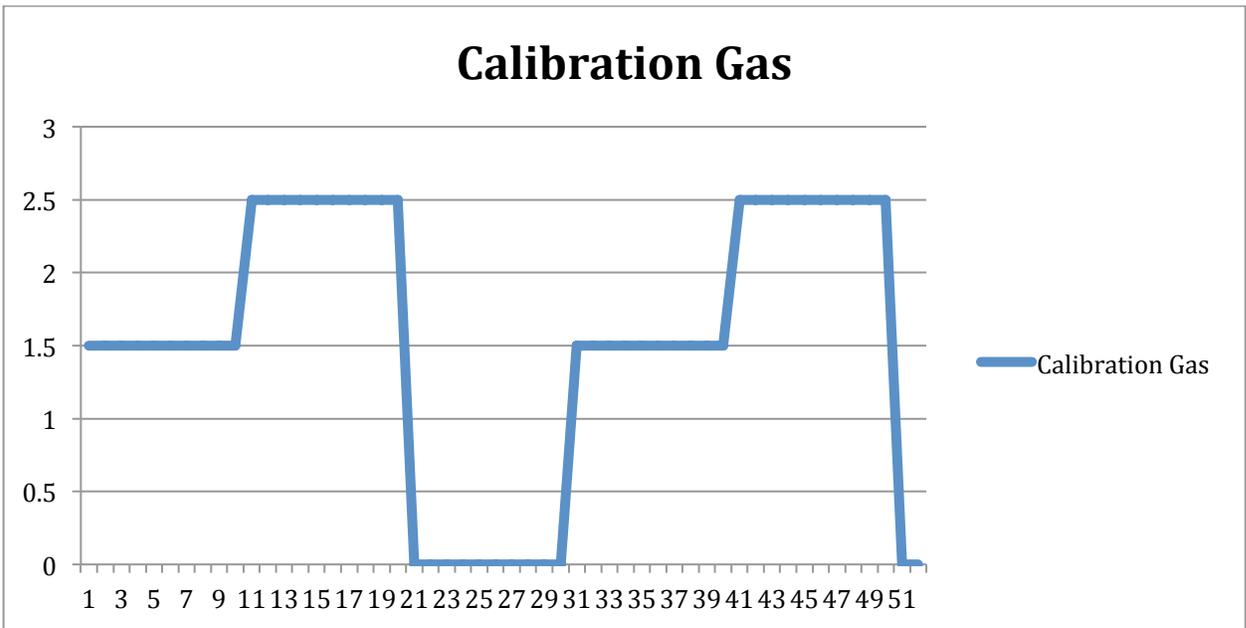


Figure 8 – Calibration Gas (Data Set 1-51)

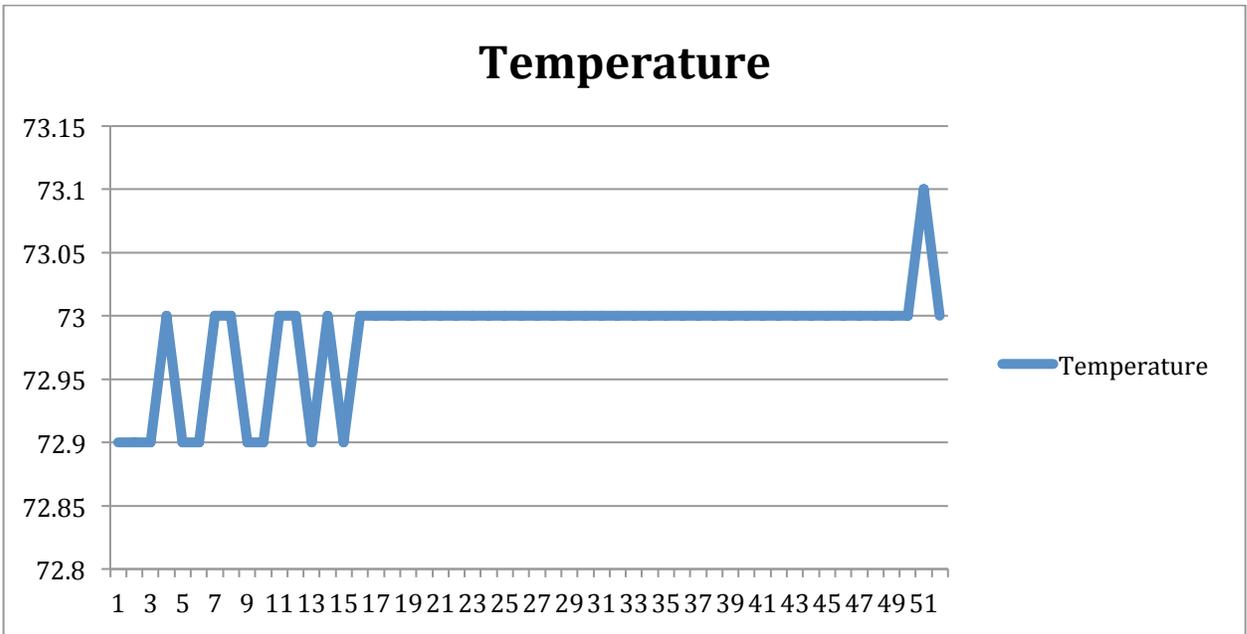


Figure 9 – Temperature (Data Set 1-51)

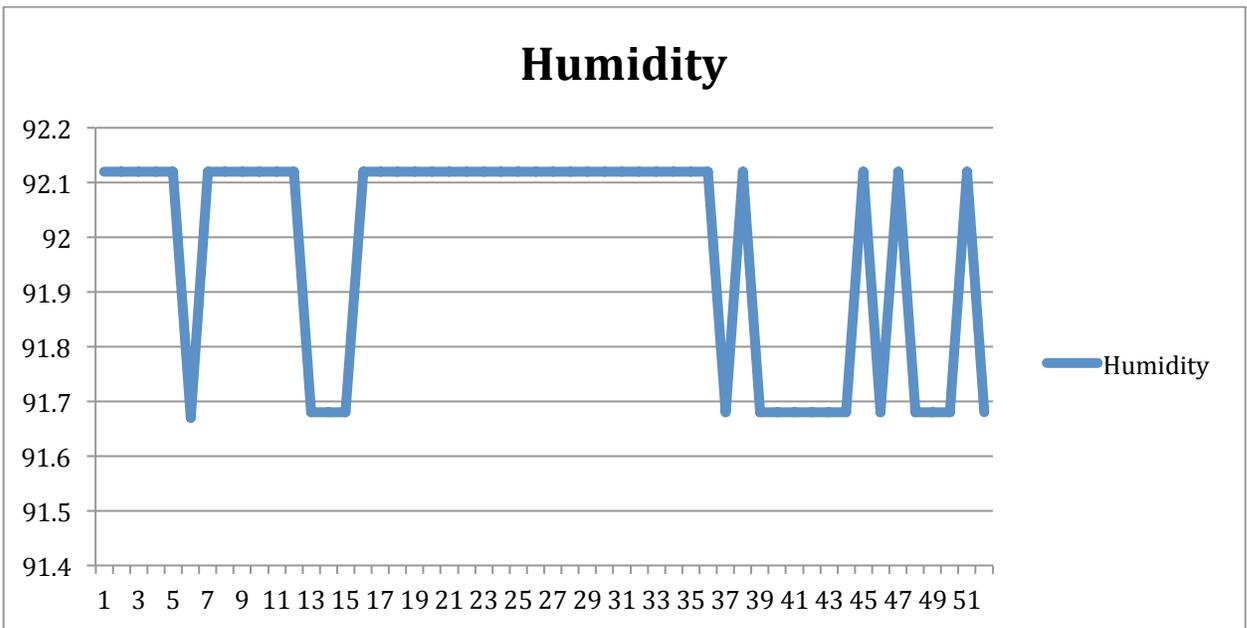


Figure 10 – Humidity (Data Set 1-51)

Appendix D – Test of Distributed Temperature System – Field and Lab Trials

Equipment under Test : AP Sensing Linear Heat Type N4387A Options 008
200 050 060, Serial No. DE47501192

Background:

The original Test Protocol called for Lab testing as well as Field Testing of the DTS (Distributed Temperature system). The DTS was installed in the Pinnacle mine on a conveyor belt, configured to measure temperature profiles of the various roller segments as the conveyor operated through the various states (idle, running w/light load, running w/heavy load, deteriorating roller/bearing, etc.). Due to production requirements at the mine the section feeding the conveyor was shut down. We anticipated a return to operation, but this did not materialize. Due to manpower constraints at the mine it became impractical to re-position the system on an active section.

As a recovery plan, we were able to utilize the facilities of Fenner Dunlop in Tazwell County, Virginia. Fenner Dunlop is the largest supplier of belting material in the world. They operate a state-of-the-art Research and Development facility in their Virginia facility, which includes a fully operational conveyor system as would be utilized in an active mine (see Figure 1 and 2). They were extremely gracious in allowing us to utilize this facility.

Test Protocol:

Lab Testing

With the DTS the fiber cable is actually the sensor element. As such it is the only component that is exposed to the rigors of the mine environment. The fiber cable used with the DTS is the same construction (fiber material, cladding, and jacket), and was tested in each of the four lab protocols:

| | |
|-------------------|--|
| Appendix B | Tests to determine resistance to vibration |
| Appendix C | Tests to determine resistance to moisture |
| Appendix E | Tests to determine reliability and durability of the system |
| Appendix F | Test to determine resistance to dust |

In each case the fiber exhibited no damage as determined by a visual inspection of the jacket and a measure of the fiber attenuation (before and after laser power levels).



Figure 1 – Conveyor at Fenner Dunlop facility



Figure 2 – Conveyor

The accuracy of the instrument was verified with a digital thermometer (Figure 3) on several occasions with excellent correlation. This was not a focus of the testing, as the absolute measurement value is not of great concern.



Figure 3 – Digital Thermometer

As will be shown in subsequent charts (Field Trial) the primary use of the instrument is to establish a “signature” of the temperature profile for a given set of operating conditions. Deviation for this signature is indicative of a potential problem.

Field Trials

In the Field Trials the fiber was run in close proximity to various components within the conveyor. The drive motor, gearbox, and idlers were of especial interest. The DTS unit was housed in a Stainless Steel electrical enclosure as shown in Figure 4.

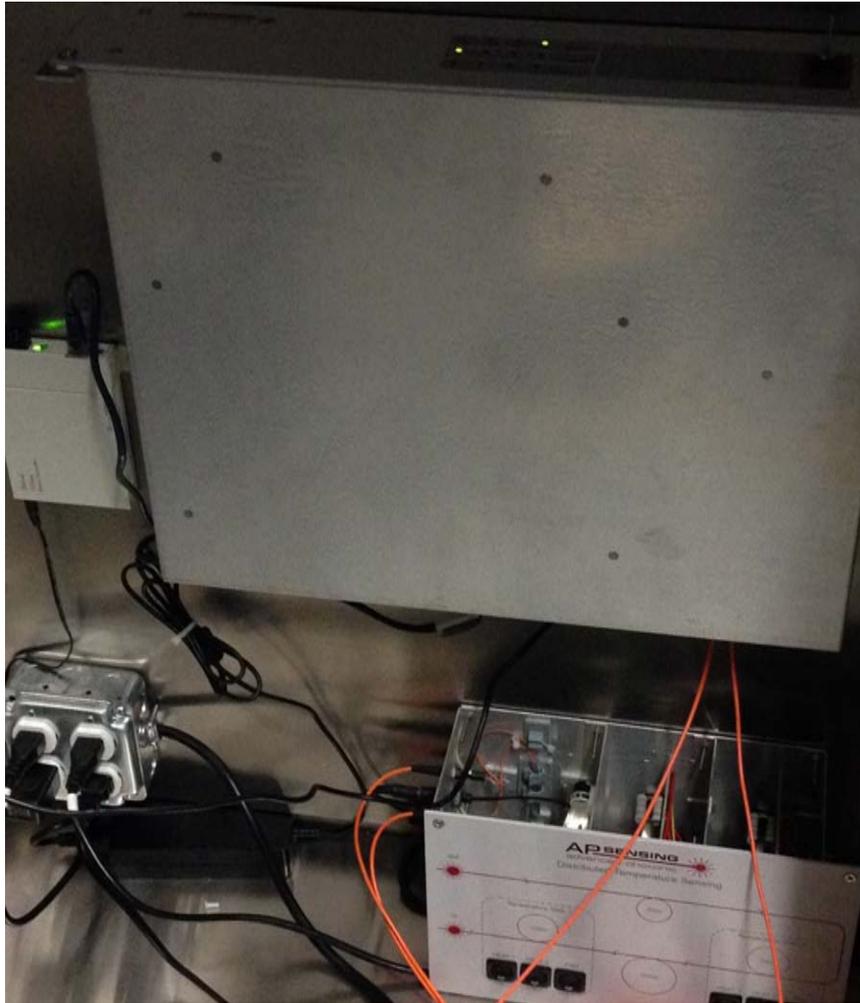


Figure 4 – DTS in Enclosure



**Figure 5 – Panoramic View of convey or
with key components labeled**

As shown in Figure 5 the fiber was run in close proximity to the drive motor, gearbox, end bearing, and 10 rollers. Images of the various components along with fiber placement and proximity are shown in Figures 6 – 9.

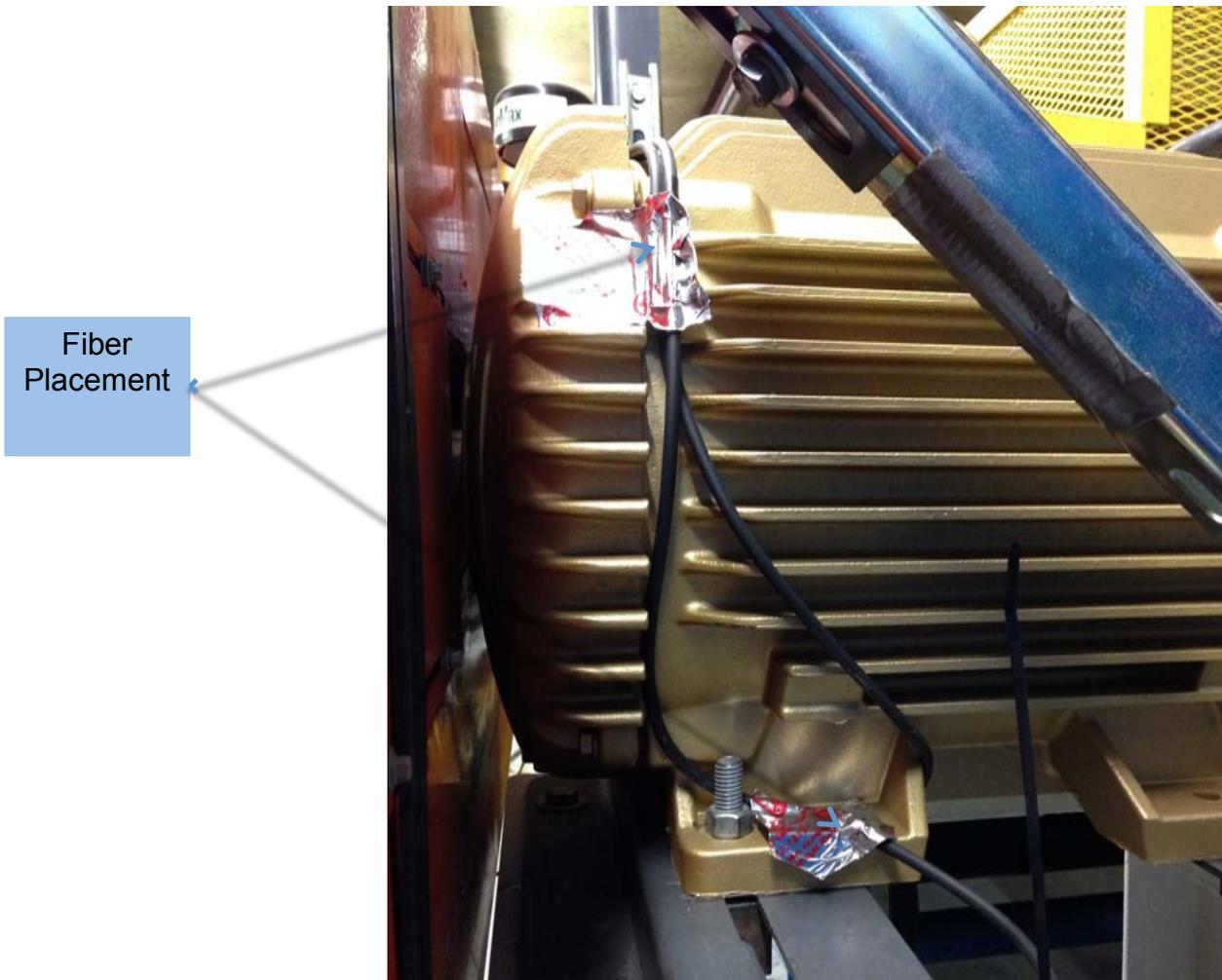


Figure 6 – Drive Motor

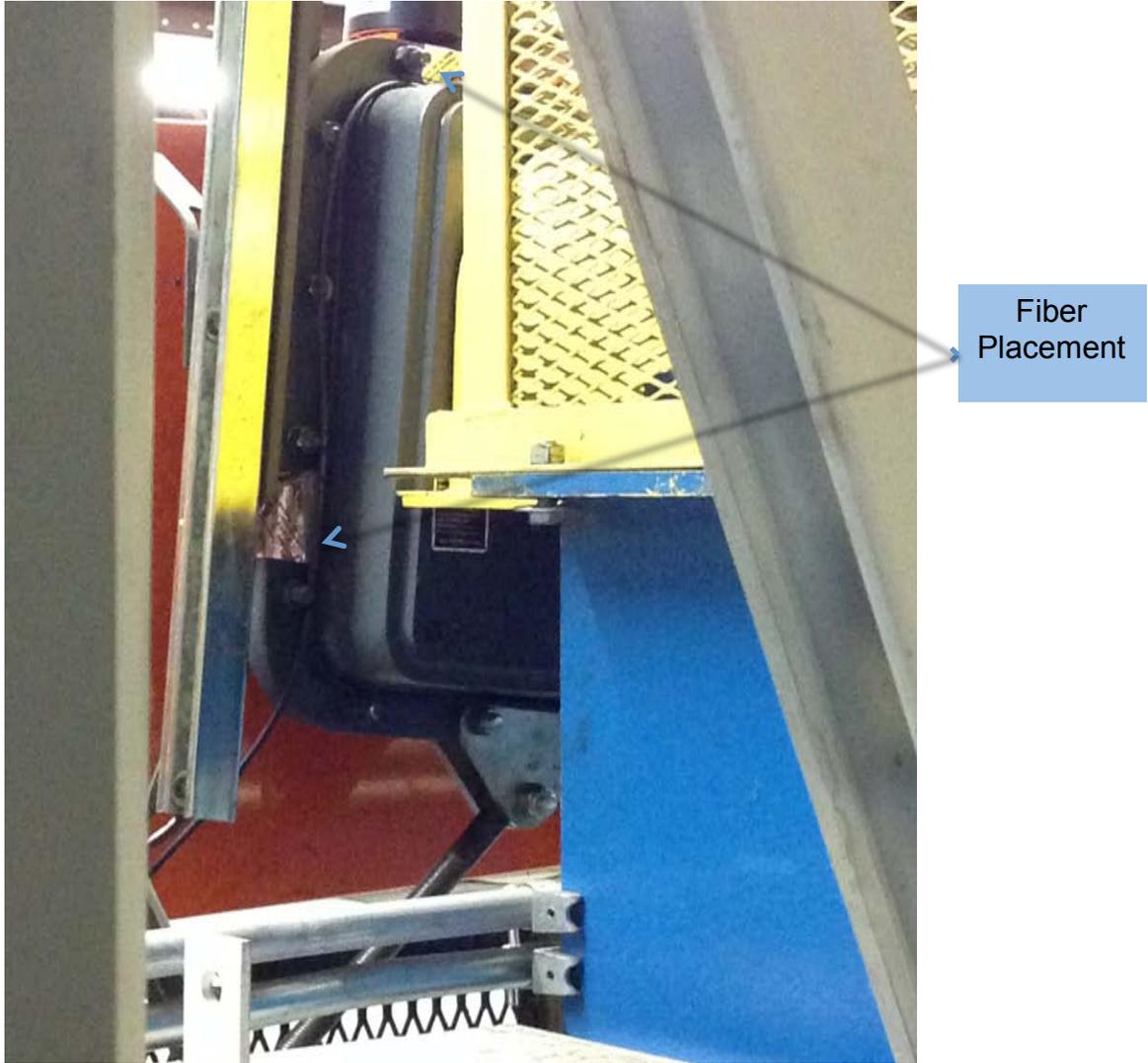


Figure 7 – Gearbox



Figure 8 – Roller 10



Fiber Placement

Figure 9 – Roller 10 w/end bearing

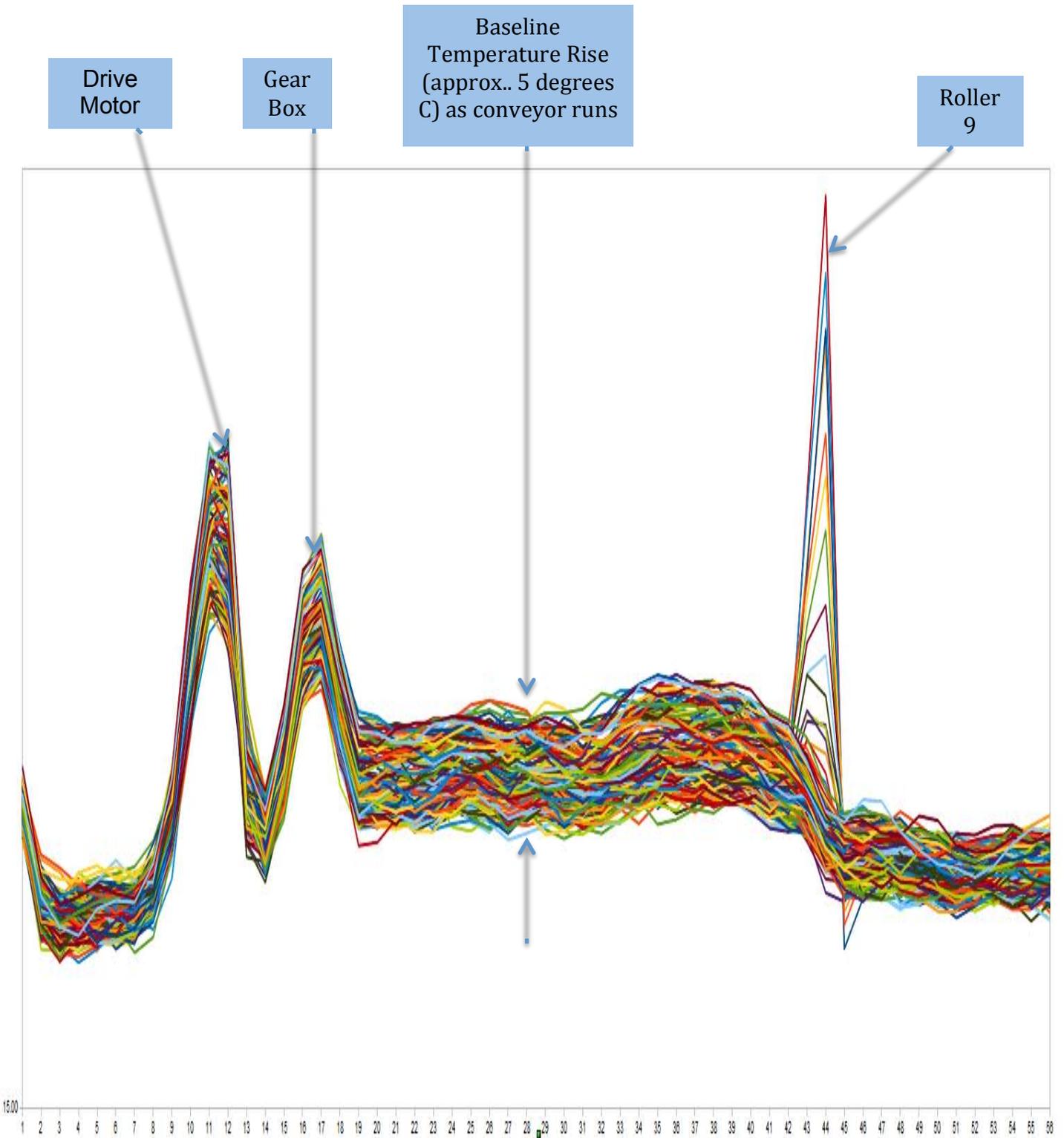


Figure 10 - Repeated scans showing signature rise over time as conveyor runs (rise in roller 9 was created with heat gun as shown in Figure 11)



Figure 11 – Heat gun simulating overheating roller

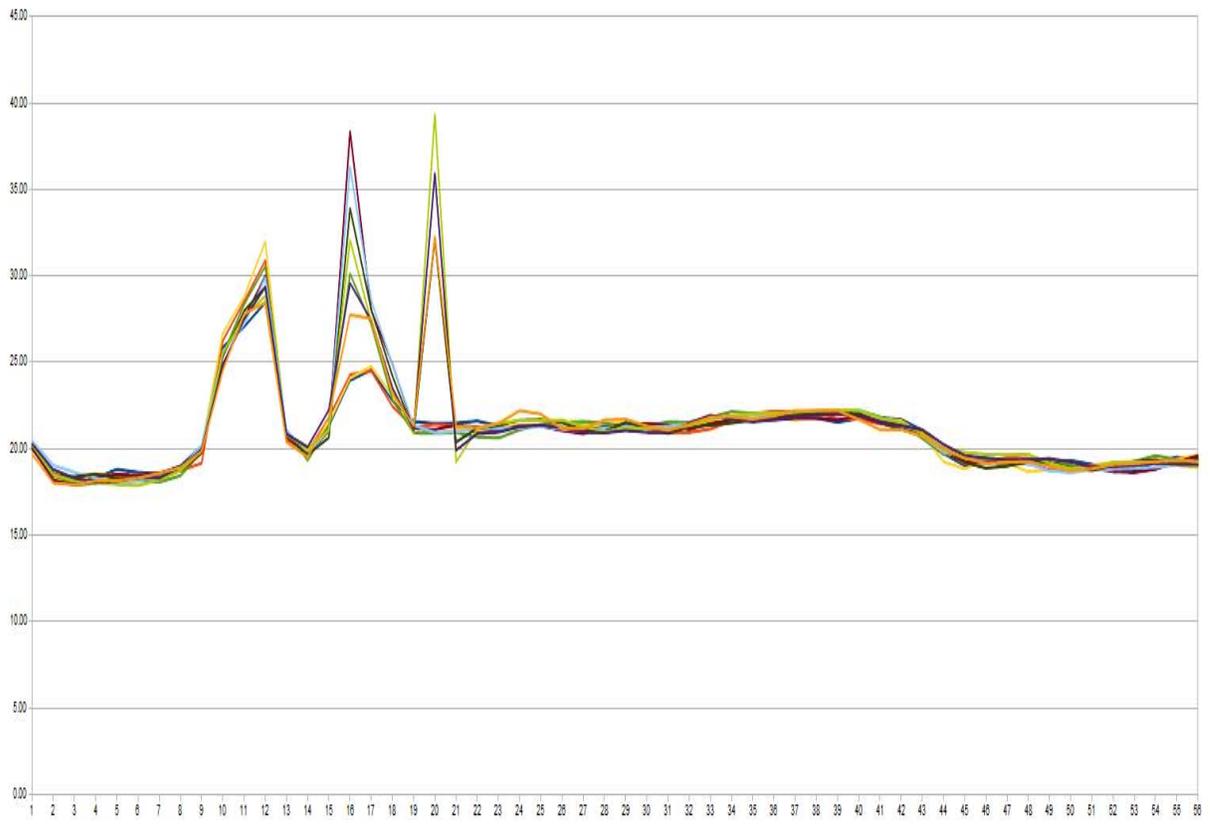


Figure 12 – Temperature Rise simulating overheating gearbox and Roller #1 using heat gun

Overall the DTS proved to be quite useful for detecting temperature rise in equipment. The methods of securing and positioning the fiber in actual use will need to be more robust as with a mechanical clamp. The fiber itself would be protected as much as possible from inadvertent damage.

Appendix E – Tests to determine reliability and durability of the system

(Reliability and Durability Section from Appendix A – Test Protocol)

2.1 Tests to determine reliability and durability of the system.

(a) Laboratory tests for reliability and durability. Five hundred successful consecutive tests for gas detection, temperature sensing, alarm action, and power shutoff in *natural gas*-air mixtures shall be conducted to demonstrate acceptable performance as to reliability and durability of a methane-monitoring system. The tests shall be conducted so that normal replacements and adjustments shall not constitute a failure. Investigation has shown that, for practical purposes, *natural gas* (containing a high percentage of methane) is a satisfactory substitute for *pure methane* in these tests. The methane detector component shall be placed in a test gallery into which natural gas shall be made to enter at various rates with sufficient turbulence for proper mixing with the air in the gallery. To comply with the requirements of this test, the detector shall provide an impulse to actuate an alarm at a predetermined percentage of gas and also provide an impulse to actuate a power shutoff at a second predetermined percentage of gas. (See other tests listed below). Optionally, these tests will be conducted with dust or moisture added to the atmosphere within the gallery. A portion of this test was also used to satisfy the moisture resistance section (appropriate humidity levels were maintained as required)

3.2.1 Tests to determine reliability and durability of the system.

3.2.1.1 Test Equipment

3.2.1.1.1 *Test gallery of sufficient volume to house the methane detector.*

See Figure 1

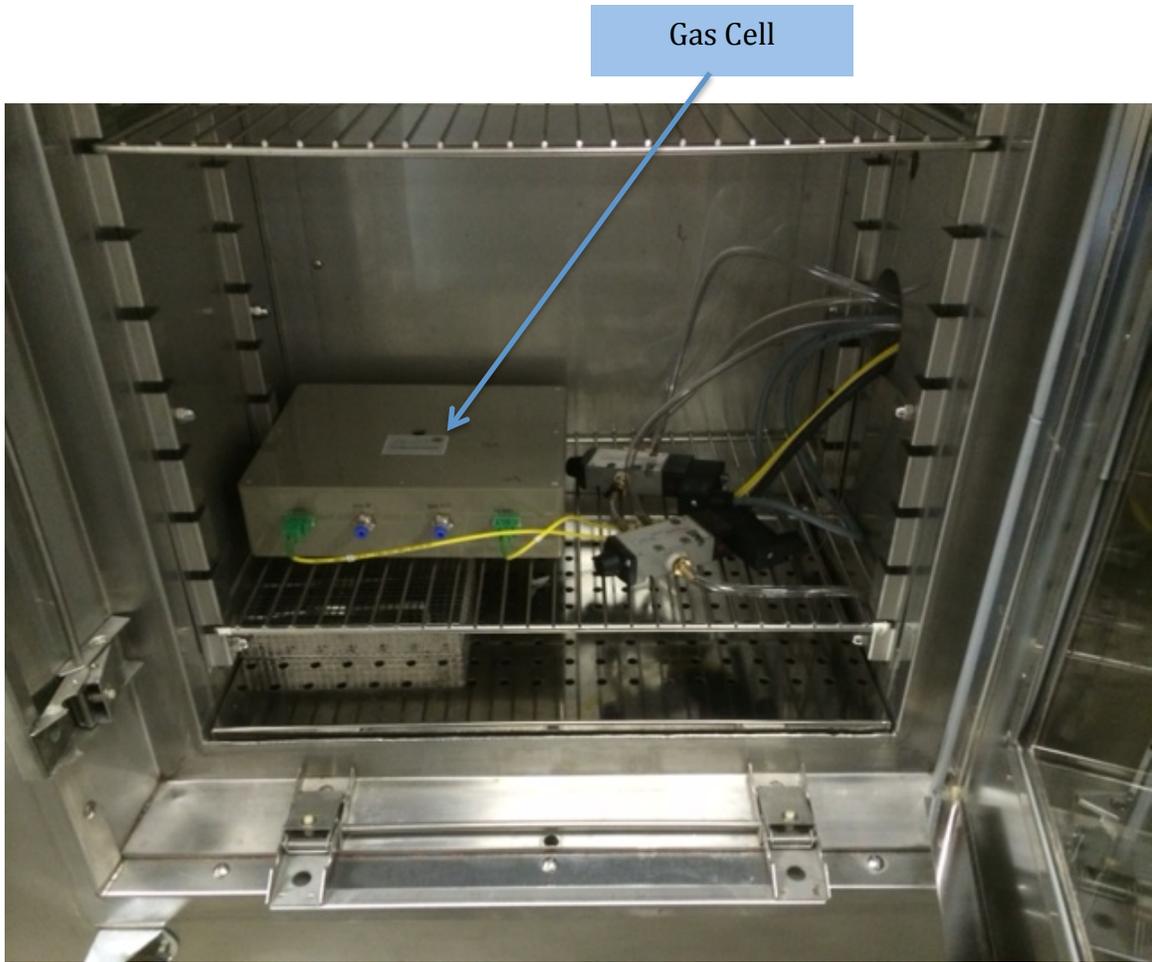


Figure 1 – Test Set-up for Reliability and Durability test. The test is automated with a PLC controller. Methane Calibration gas is introduced to the gas cell, followed by conditioned air from the chamber (at recorded humidity and temperature). The gas cell has the same GRIN lens configuration as in other tests, The data from this run was also used with the Moisture resistance test (Appendix C)

3.2.1.1.2 *Test gases consisting of methane and air.*

See Figure 2 and 3



Figure 2 – Calibration Gas (2.5%)

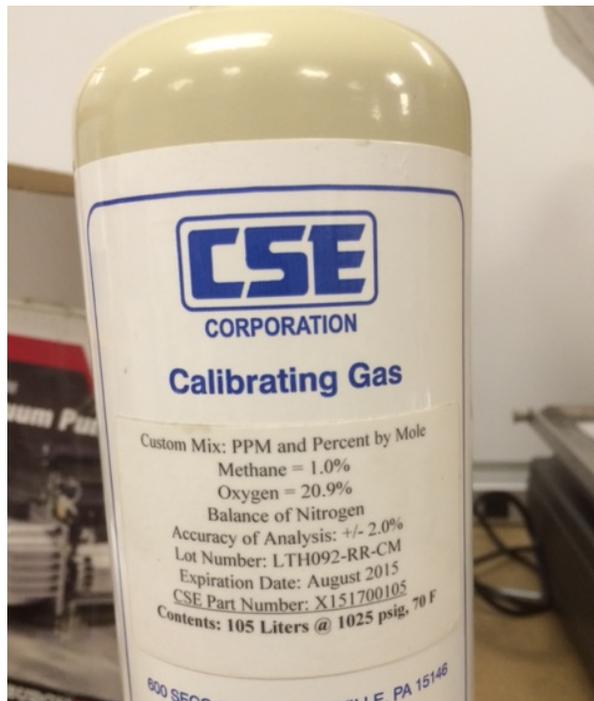


Figure 3- Calibration Gas (1%)

3.2.1.1.3 *Gas mixing/measuring equipment (if not using pre-mixed test gas) with the capability to give mixtures of 1.5 and 2.1 (± 0.1) percent by volume.[Modular Dyna-Blenders Models 8250].*

N/A

3.2.1.1.4 *Thermometer. Minimum resolution: 0.1°C; minimum accuracy: $\pm 1^\circ\text{C}$. [Fluke Model 2170A Digital Thermometer]*

Temperature monitored with Environmental chamber controls:
Humidity/Temperature Environmental Chamber - Blue M Electric Model
No. AC 7502 TDA-4-A, Serial AC-697 Calibration Due Date 4/1/2015

3.2.1.1.5 *Equipment to monitor the status of the power shut-off components.*

The PC-based controller has user configurable alarms which can be set to trigger an external output

3.2.1.1.6 *Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least 0.05 % volume methane-in-air [Horiba Model VIA-510].*

N/A

3.2.1.2 Test Samples

One complete methane monitoring system and one complete temperature monitoring system. The samples shall be of a quality consistent with that of the final manufactured product.

See Figure 4



Figure 4 – 3 point methane detection unit

3.2.1.3 Procedures

3.2.1.3.1 *Conduct the test in an ambient temperature of $25 \pm 10^\circ \text{C}$. Record the ambient temperature on the test sheet.*

Temperature recorded in Test Results Table and Figure

3.2.1.3.2 *Assemble and calibrate the methane and temperature monitoring systems per the manufacturer's recommendations. Analyze the calibration gas with the gas analyzer. Record the reading.*

N/A

3.2.1.3.3 *Place the methane detector component of the assembled methane monitoring system, along with temperature sensing cable in the test gallery with only air present. The detector should be placed in the gallery so as to minimize the effects of test gas velocity on the sensing head.*

Reference Figure 1

3.2.1.3.4 *Record display readings, power shut-off component status, warning indicator status, and alarm indicator status on the test sheet.*

3.2.1.3.5 *Introduce a gas mixture of 1.5 percent methane-in-air into the test gallery.*

3.2.1.3.6 *Record the display readings when the warning indication activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.*

3.2.1.3.7 *Increase the concentration of the gas mixture in the test gallery to 2.1 percent methane in air.*

3.2.1.3.8 *Record the display readings when the alarm indicator and the power shut-off component activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.*

3.2.1.3.9 *Reduce the concentration of the gas mixture in the test gallery to 0.0 percent methane in air.*

3.2.1.3.10 *Repeat steps 3.5 through 3.9 fifty times, unless the monitoring system features two sensor heads. In that case, repeat steps 7.5 through 7.9 twenty-five times on each sensor head.*

3.2.1.3.11 *Remove the methane detector component of the assembled methane monitoring system from the test gallery.*

3.2.1.3.12 *Apply a gas mixture of 1.5 percent methane-in-air to the sensor head using the manufacturer's calibration adapter. The flow rate of the test gas should be the same as the recommended calibration gas flow rate.*

3.2.1.3.13 *Record the display reading when the warning indication activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.*

3.2.1.3.14 *Apply a gas mixture of 2.1 percent methane-in-air to the sensor head using the manufacturer's calibration adapter. The flow rate of the test gas should be the same as the recommended calibration gas flow rate.*

3.2.1.3.15 *Record the display reading when the alarm indicator and the power shut-off component activates. Once the display reaches its final reading, record the display reading, power shut-off component status, and alarm indicator status on the test sheet.*

3.2.1.3.16 *Reduce the concentration of the gas mixture to 0.0 percent methane in air.*

3.2.1.3.17 *If the methane monitoring system features a single methane detection head, repeat Sections 3.2.1.3.12 through 3.2.1.3.16 four hundred fifty times. If it features two detection heads, repeat Sections 7.12 through 7.16 two hundred twenty-five times on each head.*

3.2.1.4 Test Data

3.2.1.4.1 Test number

See Tables 1 and 2 corresponding to Tests 1 and 2

3.2.1.4.2 Warning indicator status and display reading

See tables 1 and 2

3.2.1.4.3 Alarm indicator status and display reading

See tables 1 and 2

3.2.1.4.4 Power shut-off component status

See tables 1 and 2

3.2.1.4.5 Test equipment with calibration due dates

Humidity/Temperature Environmental Chamber - Blue M Electric Model No. AC 7502 TDA-4-A, Serial AC-697 Calibration Due Date 4/1/2015

3.2.1.4.6 Description of methane monitoring and temperature monitoring systems including manufacturer, model, or type number and serial number of unit tested.

See System Description

3.2.1.4.7 Description of method used to monitor status of power shut-off component.

The PC-based controller has user configurable alarms which can be set to trigger an external output (Appendix J and K)

3.2.1.4.8 Test gas concentration. Minimum resolution: 0.1%; minimum accuracy: $\pm 0.1\%$.

3.2.1.4.9 Ambient temperature. Minimum resolution: 0.1° C; minimum accuracy: ± 1° C.

See tables 1 and 2

3.2.1.4.10 Reference to the manufacturer's calibration procedure (document number, section, revision date, etc.).

N/A

3.2.1.4.11 The analyzed reading of the calibration gas.

3.2.1.5 Pass/Fail Criteria

3.2.1.5.1 The methane monitor system shall provide a control signal to actuate a warning indicator device when 1.5 percent methane-in-air is applied to the methane detector.

See tables 1 and 2

3.2.1.5.2 The methane monitor system shall provide a control signal to actuate a warning indicator device and the power shutoff component when 2.1 percent methane-in-air is applied to the methane sensor.

See tables 1 and 2

3.2.1.5.3 Temperature readings from temperature system will be recorded along with standard temperature recording device

See tables 1 and 2

3.2.1.5.4 Normal replacements and adjustments shall not constitute a failure. Normal replacements and adjustments are considered to be replacement of components (sensor head, etc.).

No replacements needed

Table 1 – Test 1 (reference Procedure 3.2.1.3.5 through 3.2.1.3.9) Trials 0 and 1 shown, 50 trials completed

| <u>Date and Time</u> | <u>Test #</u> | <u>Temp Deg F</u> | <u>Humidity</u> | <u>Gas Selected</u> | <u>Methane Level</u> |
|-----------------------|---------------|-------------------|-----------------|---------------------|----------------------|
| 05/14/14 11:39:07.322 | 0 | 74.7 | 84.77 | Air | 0 |
| 05/14/14 11:39:08.336 | 0 | 74.7 | 84.77 | Air | 0 |
| 05/14/14 11:39:09.350 | 0 | 74.7 | 84.77 | Air | 0 |
| 05/14/14 11:39:10.284 | 0 | 74.7 | 84.77 | Air | 0 |
| 05/14/14 11:39:11.299 | 0 | 74.7 | 84.77 | Air | 0 |
| 05/14/14 11:39:12.315 | 0 | 74.7 | 84.77 | Air | 0 |
| 05/14/14 11:39:13.326 | 0 | 74.7 | 84.77 | Methane 1.5% | 0 |
| 05/14/14 11:39:14.344 | 0 | 74.7 | 84.77 | Methane 1.5% | 0 |
| 05/14/14 11:39:15.276 | 0 | 74.7 | 84.77 | Methane 1.5% | 0 |
| 05/14/14 11:39:16.290 | 0 | 74.6 | 85.19 | Methane 1.5% | 1.668 |
| 05/14/14 11:39:17.304 | 0 | 74.6 | 85.19 | Methane 1.5% | 1.668 |
| 05/14/14 11:39:18.317 | 0 | 74.7 | 84.77 | Methane 1.5% | 1.668 |
| 05/14/14 11:39:19.331 | 0 | 74.7 | 84.77 | Methane 1.5% | 1.668 |
| 05/14/14 11:39:20.345 | 0 | 74.6 | 85.19 | Methane 1.5% | 1.665 |
| 05/14/14 11:39:21.282 | 0 | 74.6 | 85.19 | Methane 1.5% | 1.665 |
| 05/14/14 11:39:22.295 | 0 | 74.6 | 85.19 | Methane 1.5% | 1.665 |
| 05/14/14 11:39:23.319 | 0 | 74.6 | 85.19 | Methane 2.5% | 1.665 |
| 05/14/14 11:39:24.325 | 0 | 74.6 | 85.19 | Methane 2.5% | 1.665 |
| 05/14/14 11:39:25.338 | 0 | 74.6 | 85.19 | Methane 2.5% | 1.614 |
| 05/14/14 11:39:26.277 | 0 | 74.6 | 85.19 | Methane 2.5% | 1.614 |
| 05/14/14 11:39:27.289 | 0 | 74.6 | 85.19 | Methane 2.5% | 2.579 |
| 05/14/14 11:39:28.303 | 0 | 74.6 | 85.19 | Methane 2.5% | 2.606 |
| 05/14/14 11:39:29.320 | 0 | 74.6 | 85.19 | Methane 2.5% | 2.606 |
| 05/14/14 11:39:30.337 | 0 | 74.6 | 85.19 | Methane 2.5% | 2.606 |
| 05/14/14 11:39:31.349 | 0 | 74.6 | 85.19 | Methane 2.5% | 2.606 |
| 05/14/14 11:39:32.280 | 0 | 74.6 | 85.19 | Methane 2.5% | 2.633 |
| 05/14/14 11:39:33.300 | 1 | 74.6 | 85.19 | Air | 2.633 |
| 05/14/14 11:39:34.310 | 1 | 74.6 | 85.19 | Air | 2.609 |
| 05/14/14 11:39:35.326 | 1 | 74.6 | 85.19 | Air | 2.609 |
| 05/14/14 11:39:36.336 | 1 | 74.6 | 85.19 | Air | 2.609 |
| 05/14/14 11:39:37.354 | 1 | 74.6 | 85.19 | Air | 0 |
| 05/14/14 11:39:38.287 | 1 | 74.6 | 85.19 | Air | 0 |
| 05/14/14 11:39:39.306 | 1 | 74.6 | 85.19 | Air | 0 |
| 05/14/14 11:39:40.313 | 1 | 74.6 | 85.19 | Air | 0 |
| 05/14/14 11:39:41.329 | 1 | 74.6 | 85.19 | Air | 0 |
| 05/14/14 11:39:42.344 | 1 | 74.6 | 85.19 | Air | 0 |
| 05/14/14 11:39:43.279 | 1 | 74.6 | 85.19 | Methane 1.5% | 0 |
| 05/14/14 11:39:44.292 | 1 | 74.6 | 85.19 | Methane 1.5% | 0 |
| 05/14/14 11:39:45.306 | 1 | 74.6 | 85.19 | Methane 1.5% | 0 |
| 05/14/14 11:39:46.320 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.757 |
| 05/14/14 11:39:47.334 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.757 |
| 05/14/14 11:39:48.349 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.757 |
| 05/14/14 11:39:49.284 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.702 |
| 05/14/14 11:39:50.298 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.702 |
| 05/14/14 11:39:51.312 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.743 |
| 05/14/14 11:39:52.326 | 1 | 74.6 | 85.19 | Methane 1.5% | 1.743 |
| 05/14/14 11:39:53.341 | 1 | 74.6 | 85.19 | Methane 2.5% | 1.743 |
| 05/14/14 11:39:54.276 | 1 | 74.6 | 85.19 | Methane 2.5% | 1.743 |
| 05/14/14 11:39:55.290 | 1 | 74.6 | 85.19 | Methane 2.5% | 1.653 |
| 05/14/14 11:39:56.304 | 1 | 74.6 | 85.19 | Methane 2.5% | 1.653 |
| 05/14/14 11:39:57.317 | 1 | 74.6 | 85.19 | Methane 2.5% | 2.581 |
| 05/14/14 11:39:58.332 | 1 | 74.6 | 85.19 | Methane 2.5% | 2.583 |

Table 2 – Test 2 (reference Procedure 3.2.1.3.12 through 3.2.1.3.16) Trials 1 shown, 450 trials completed

| Time Stamp | (a) | (b) | (c) | (d) | (e) | Alarm Status |
|-----------------------|-----|------|-------|-----|-------|-----------------------|
| 05/24/14 16:25:39.652 | 1 | 72.9 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:40.665 | 1 | 72.9 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:41.677 | 1 | 72.9 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:42.698 | 1 | 73 | 92.12 | 1.5 | 0 | No Methane |
| 05/24/14 16:25:43.627 | 1 | 72.9 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:44.647 | 1 | 72.9 | 91.67 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:45.657 | 1 | 73 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:46.671 | 1 | 73 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:47.688 | 1 | 72.9 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:48.619 | 1 | 72.9 | 92.12 | 1.5 | 1.536 | Warning Methane > 1% |
| 05/24/14 16:25:49.634 | 1 | 73 | 92.12 | 2.5 | 1.531 | Warning Methane > 1% |
| 05/24/14 16:25:50.647 | 1 | 73 | 92.12 | 2.5 | 1.531 | Warning Methane > 1% |
| 05/24/14 16:25:51.661 | 1 | 72.9 | 91.68 | 2.5 | 1.531 | Warning Methane > 1% |
| 05/24/14 16:25:52.675 | 1 | 73 | 91.68 | 2.5 | 2.637 | Danger Methane > 1.9% |
| 05/24/14 16:25:53.689 | 1 | 72.9 | 91.68 | 2.5 | 2.637 | Danger Methane > 1.9% |
| 05/24/14 16:25:54.625 | 1 | 73 | 92.12 | 2.5 | 2.583 | Danger Methane > 1.9% |
| 05/24/14 16:25:55.640 | 1 | 73 | 92.12 | 2.5 | 2.583 | Danger Methane > 1.9% |
| 05/24/14 16:25:56.654 | 1 | 73 | 92.12 | 2.5 | 2.564 | Danger Methane > 1.9% |
| 05/24/14 16:25:57.668 | 1 | 73 | 92.12 | 2.5 | 2.564 | Danger Methane > 1.9% |
| 05/24/14 16:25:58.682 | 1 | 73 | 92.12 | 2.5 | 2.564 | Danger Methane > 1.9% |

- (a) – Test Number (1-450) – cycle run 450 times (4 ½ hours)
- (b) - Temperature (degrees F)
- (c) - Relative Humidity
- (d) - Measured Methane %

Notes:

- 1) As shown in 1.5% to 2.5% transition (timestamp 16:25:49.634 to 16:25:52:675) the response time of system was consistently less than 3 seconds (including gas diffusion time)
- 2) Warning/Danger alarm response instantaneous
- 3) Sample Data (Data Points 1-20), Graphs below show Date Set 1-51, complete data set provided if desired

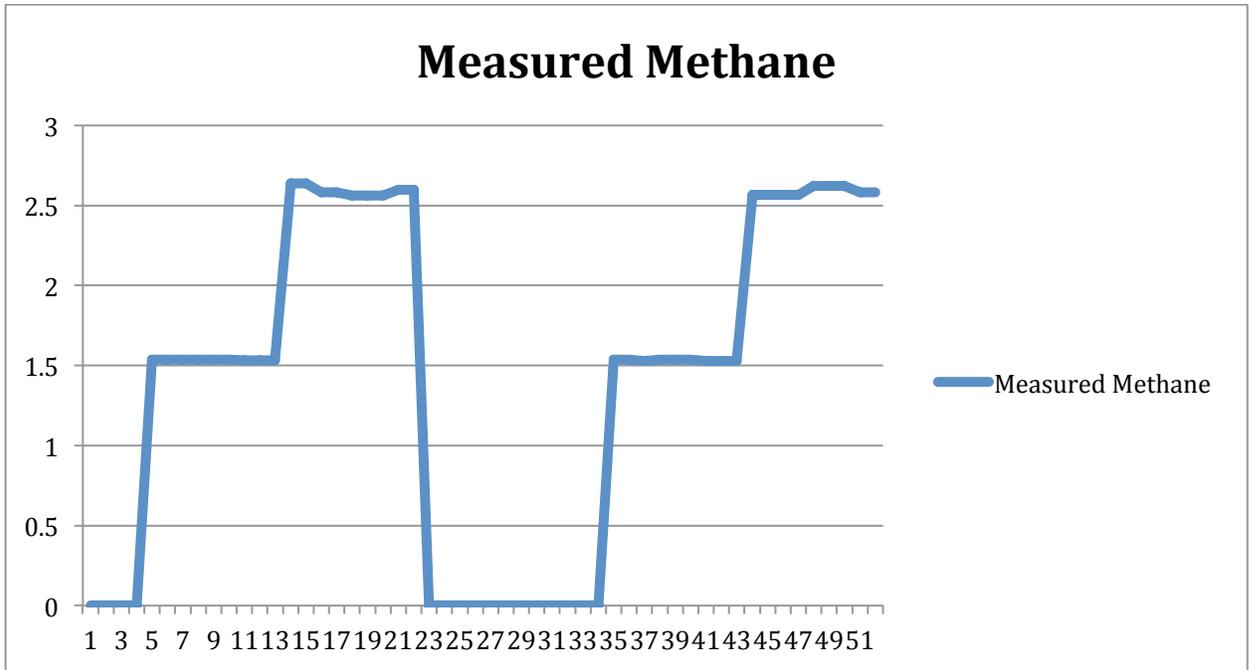


Figure 5 – Measured Methane (Data Set 1-51)

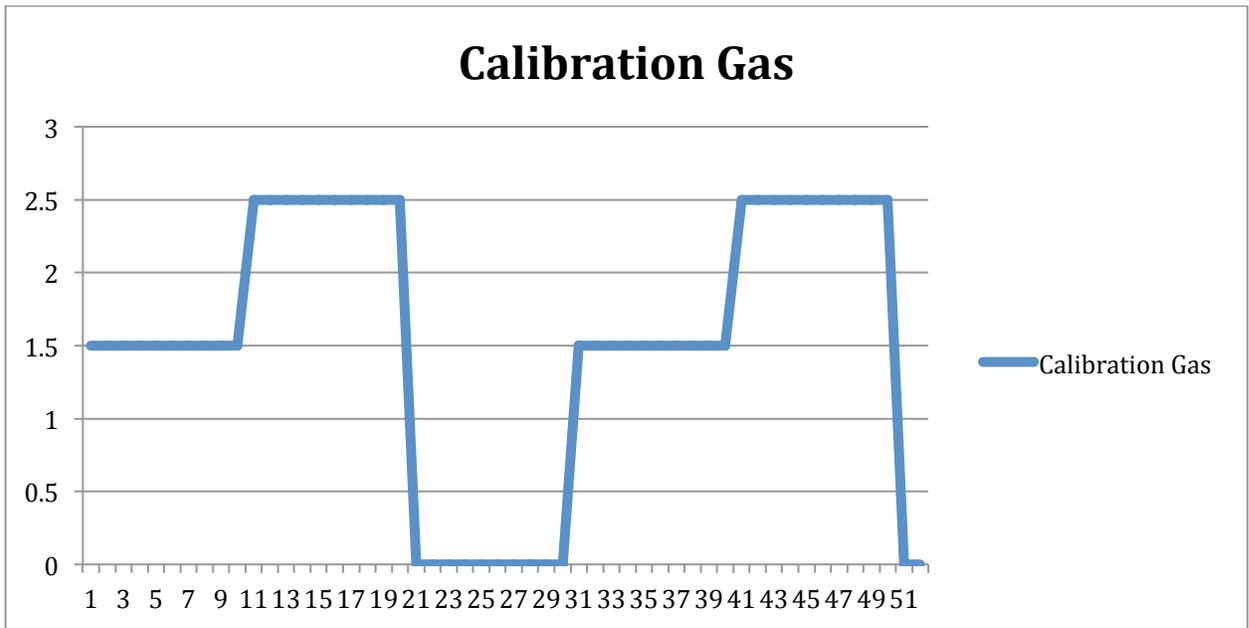


Figure 6 – Calibration Gas (Data Set 1-51)

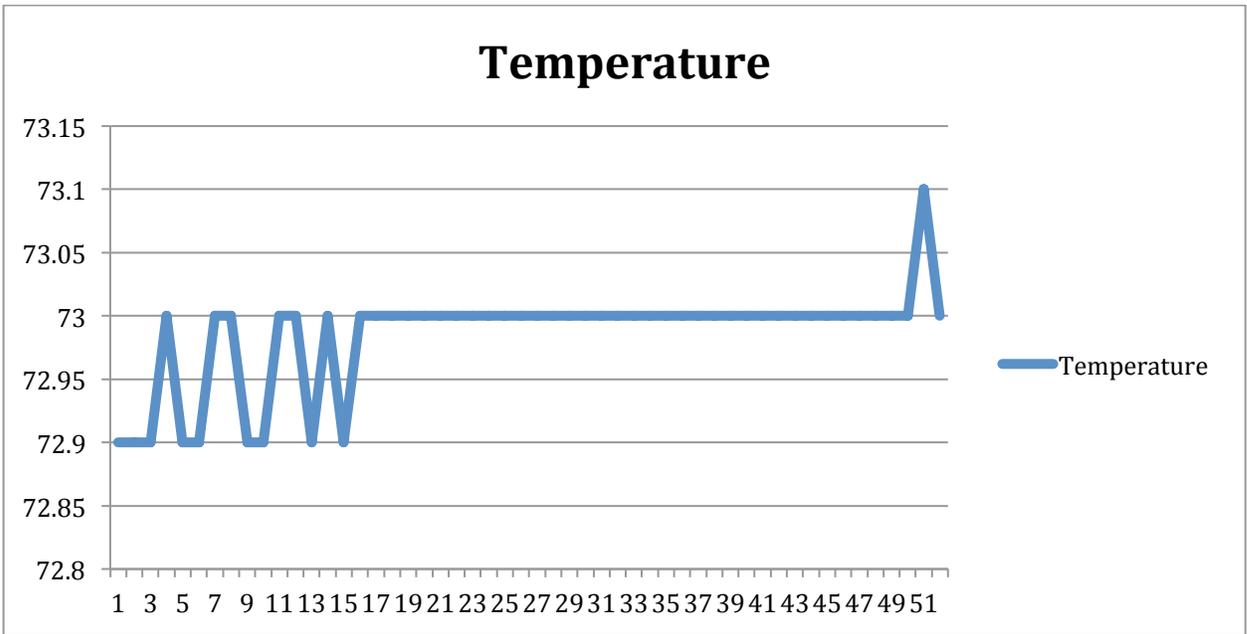


Figure 7 – Temperature (Data Set 1-51)

Appendix F – Tests to determine dust resistance of the system

(Dust Resistance Section from Appendix A – Test Protocol)

2.9 Test to determine resistance to dust.

Components, subassemblies, or assemblies, the normal functioning of which might be affected by dust, such as coal or rock dust, shall be tested in an atmosphere containing an average concentration (50 million minus 40 micron particles per cubic foot) of such dust(s) for a continuous period of 4 hours. The component, subassembly, or assembly shall function normally after being subjected to this test.

Note: Dust measurements shall be made by impinge sampling and light-field counting technique

Background:

The original test protocol submitted utilized a method based on rock drilling to create a dust-laden environment. Upon further evaluation, as well as looking at the characteristics and potential failure points with the system under test an alternate method was developed. The intent was to develop a repeatable method, which would exploit possible failure modes in the lab setting. Essentially we completed two series of tests; 1) utilize tape to progressively block the sensor screen to determine what effective level of blockage could be tolerated and still successfully read methane levels. 2a) We utilized mine rock dust to cover the sensor screen, then testing methane measurement capabilities. 2b) Determine the ability of the actual sensing element to withstand dust, we removed the screen from the sensor, then placed the bare sensor element in the chamber, at which point we blew the dust at the element as would be expected in a coal mine. We utilized a commercial dust cabinet (see Figure 1 and 2) to conduct the dust tests. Ability to read methane as well as power level values were recorded for each test.

Test Procedure (Test 1)

1. Sensor Screen is blocked with tape to stated percentage as measured by area
2. Baseline level of methane is measured
3. Sensor is inserted into calibration tube
4. Methane (2.5%) is flowed through tube at 0.5 SCFH (standard cubic feet per hour)
5. Methane Reading is taken at 5 minutes (or as specified)



Figure 1 – Dust Chamber



Figure 2 – Dust Chamber (note camera on inspection window)

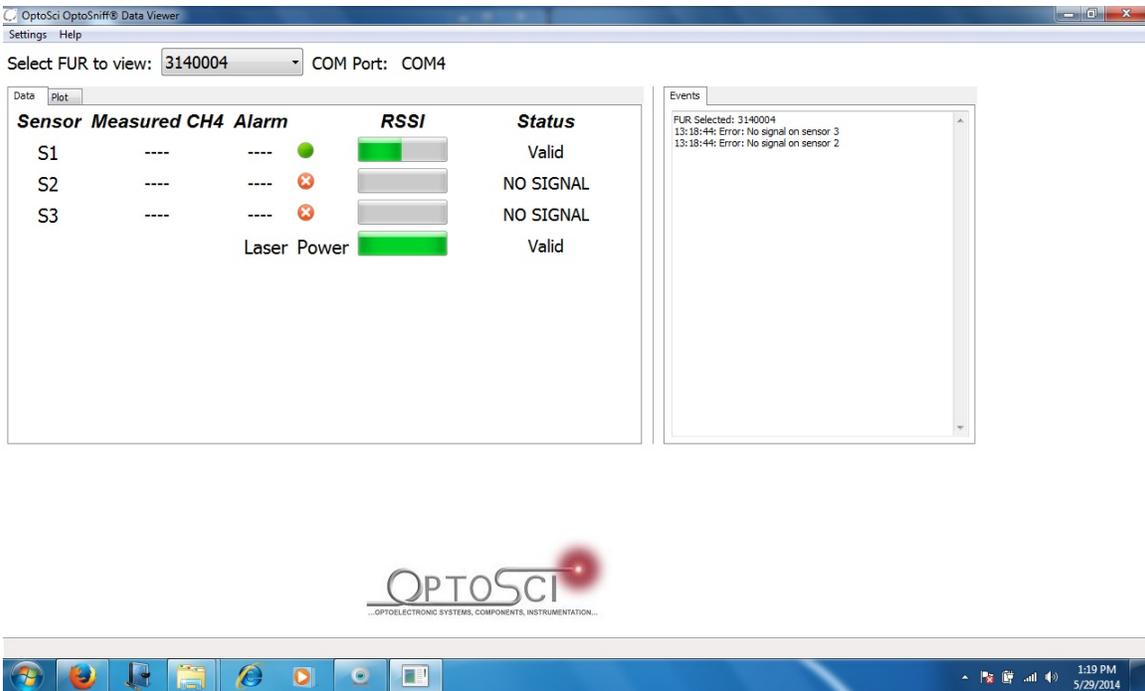


Figure 3 – “Before Test” data viewer indicating zero methane

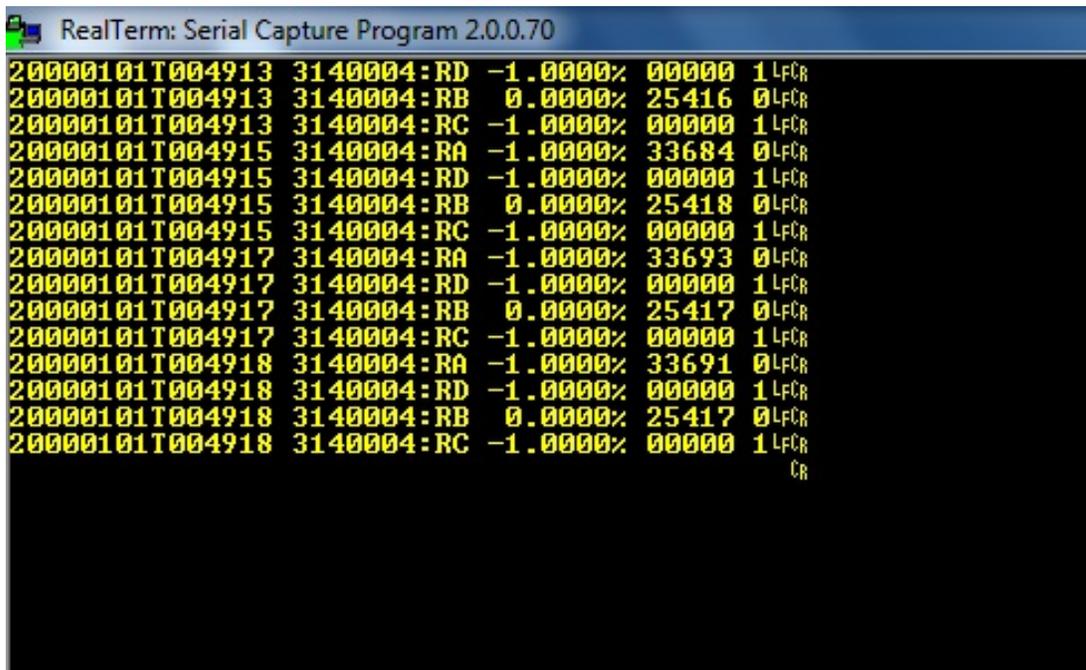


Figure 3 – “Before Test” data viewer indicating Laser power level

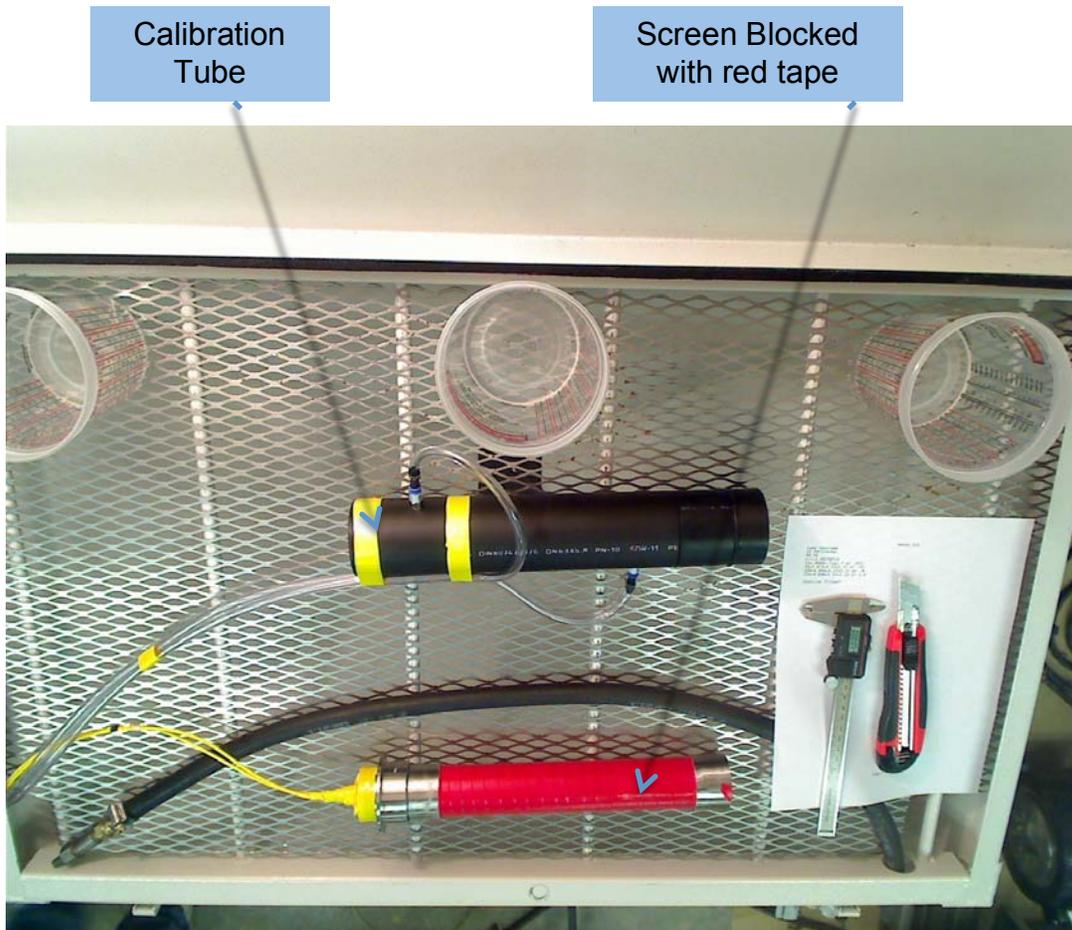


Figure 4 – 100% Blockage of Sensor screen

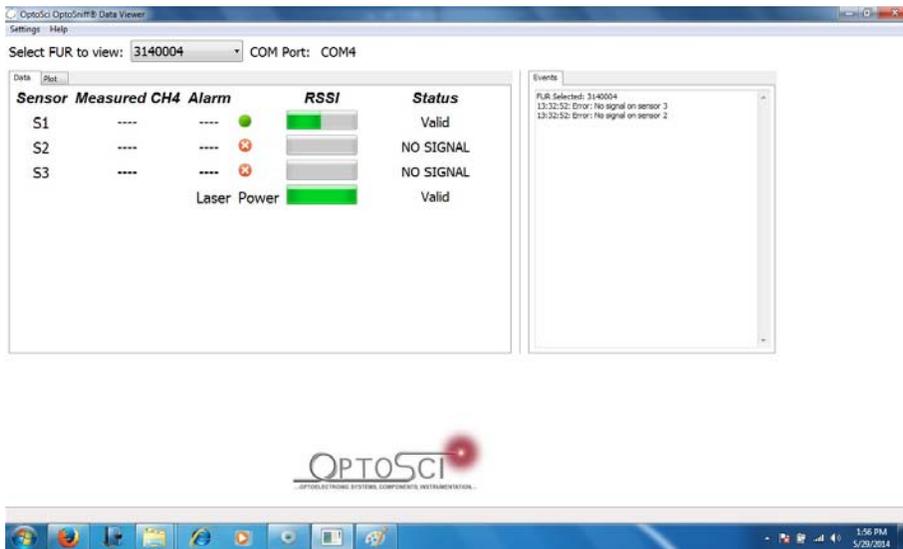


Figure 5 – 100% Blockage - Before Gas is released (zero methane level recorded)

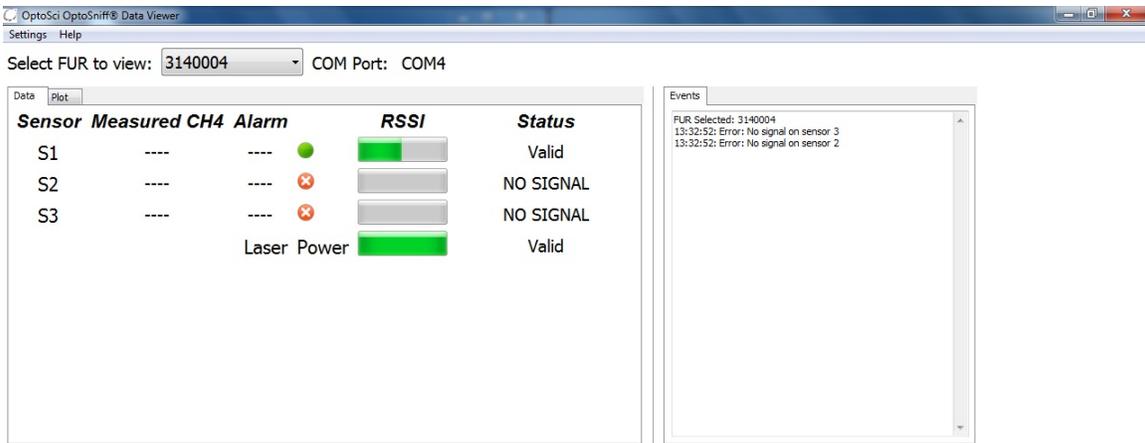


Figure 6 – 100% Blockage – After 5 minutes of exposure to 2.5% methane Gas (zero methane level recorded), as expected with 100% screen blockage



Figure 7 – 99% Blockage of Sensor screen

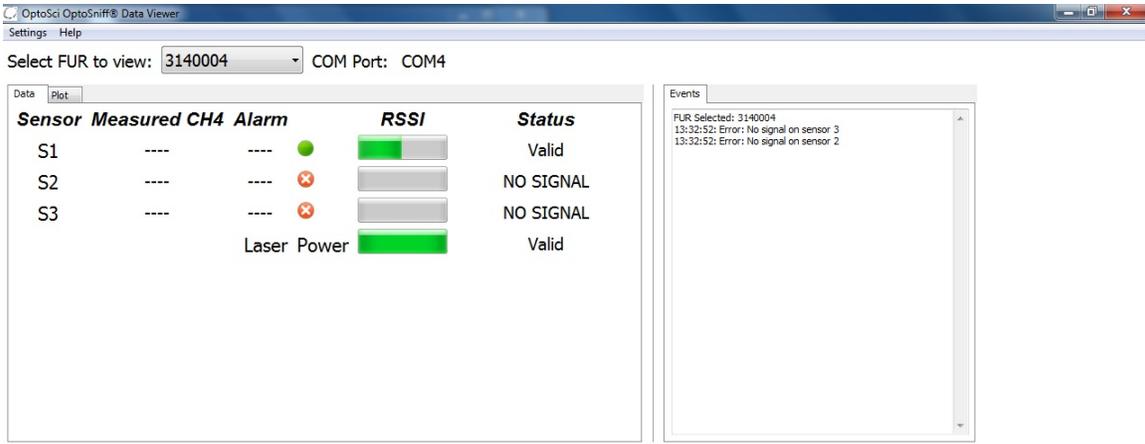


Figure 8 – 99% Blockage - Before Gas is released (zero methane level recorded)

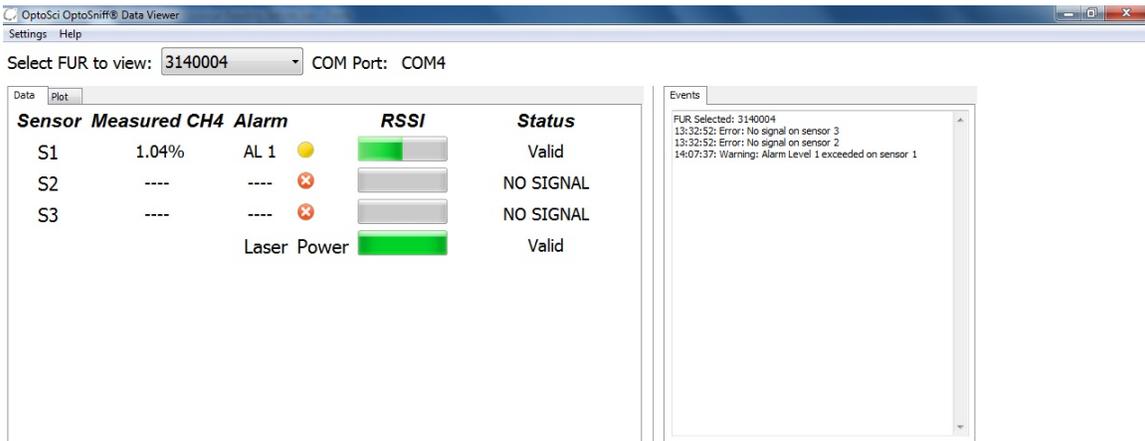


Figure 9 – 99% Blockage – After 5 minutes of exposure to 2.5% methane Gas (1.04% methane level recorded)



Figure 10 – 95% Blockage of Sensor screen

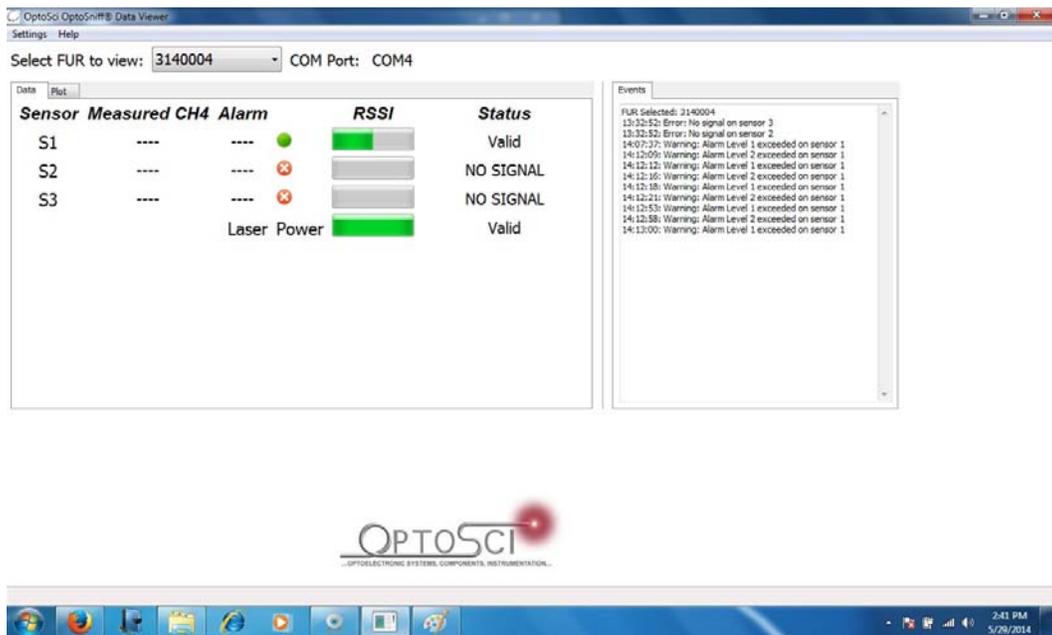


Figure 11 – 95% Blockage - Before Gas is released (zero methane level recorded)

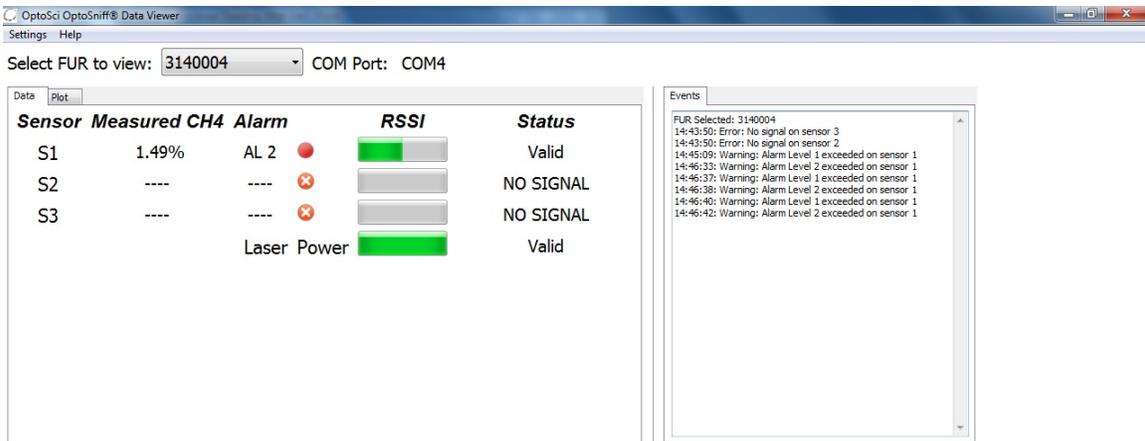


Figure 12 – 95% Blockage – After 5 minutes of exposure to 2.5% methane Gas (1.49% methane level recorded)

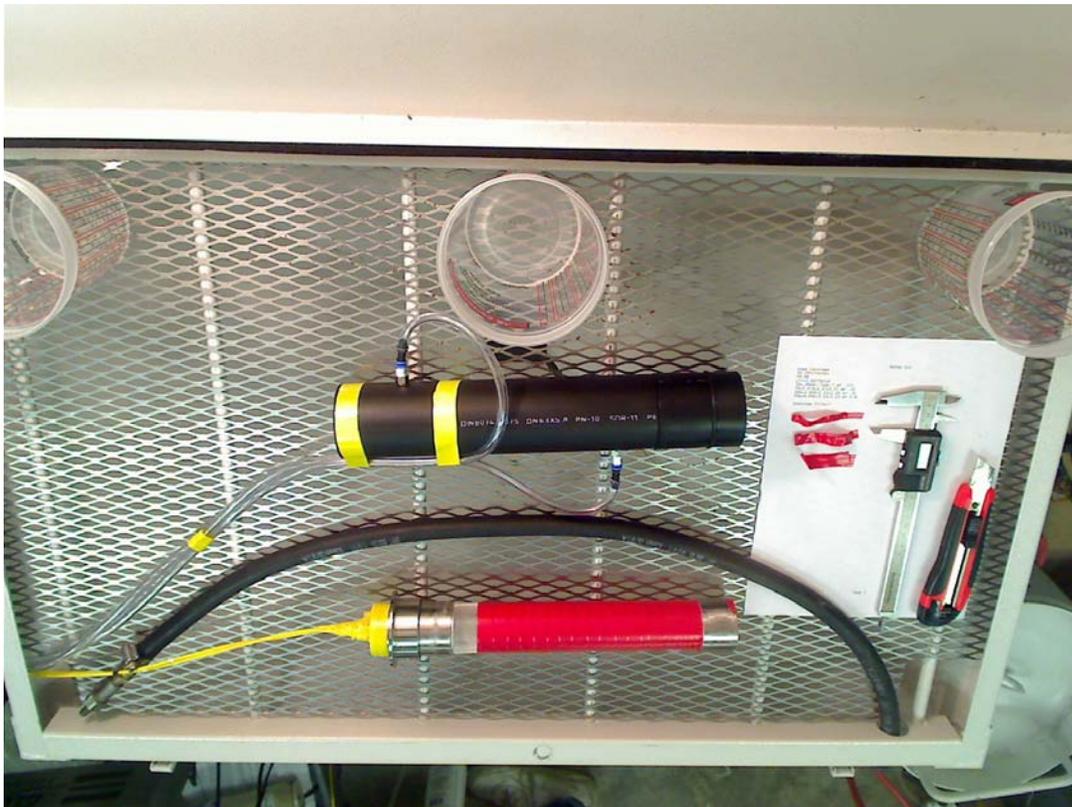


Figure 13 – 90% Blockage of Sensor screen

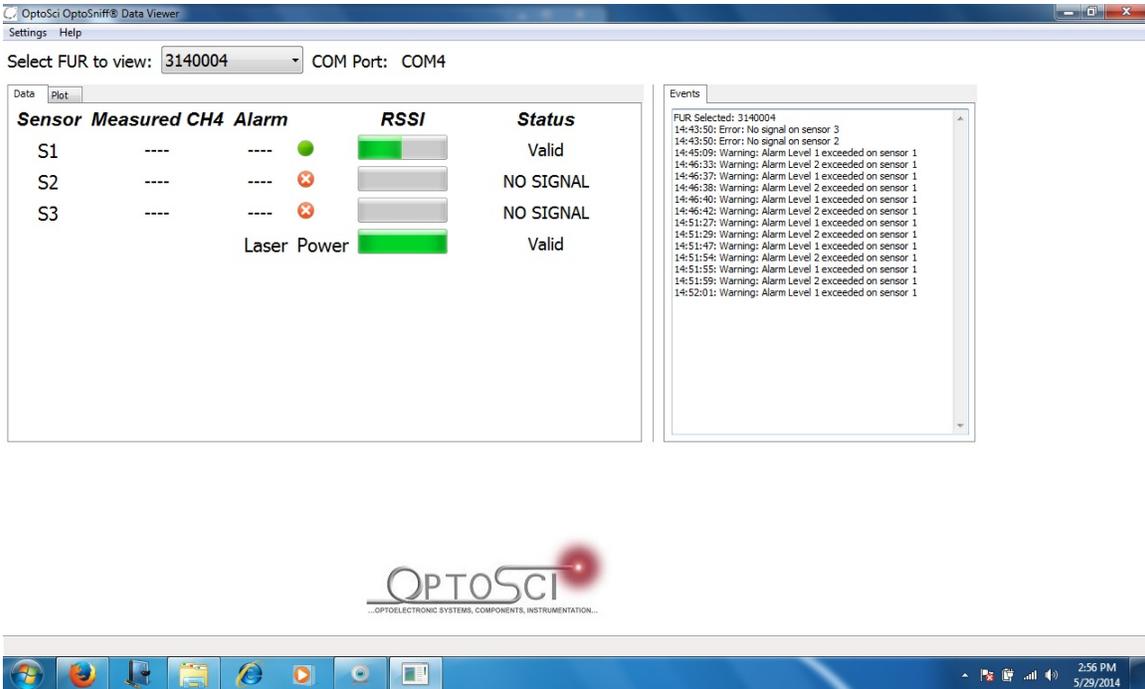


Figure 14 – 90% Blockage - Before Gas is released (zero methane level recorded)

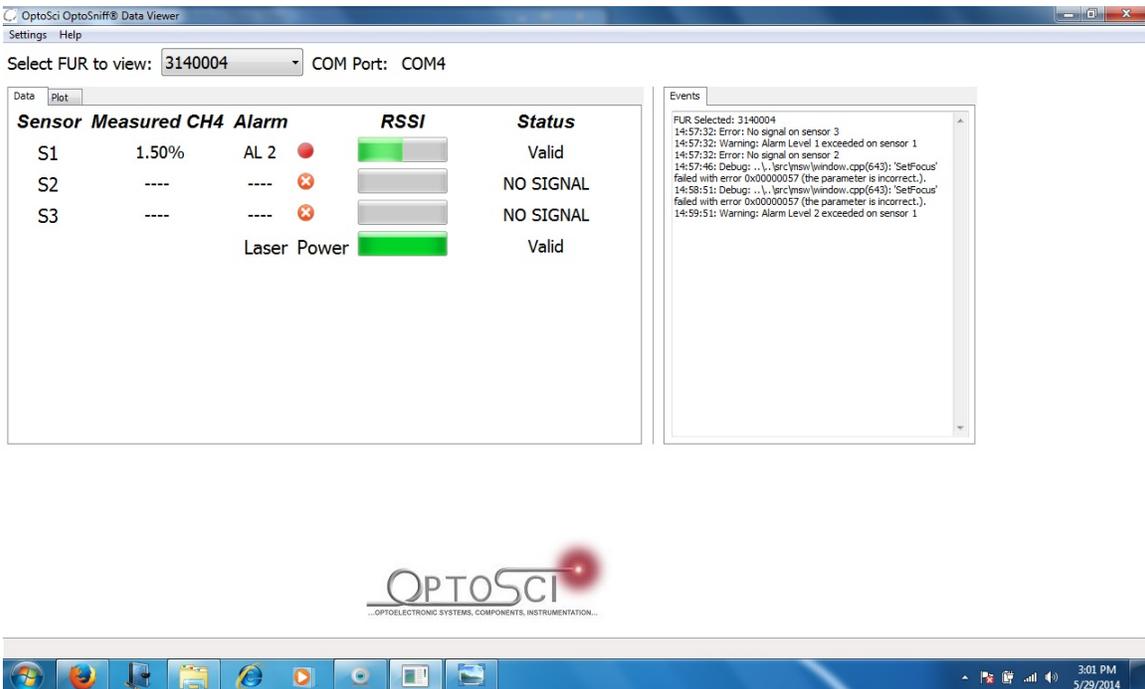


Figure 15 – 90% Blockage – After 5 minutes of exposure to 2.5% methane Gas (1.50% methane level recorded)

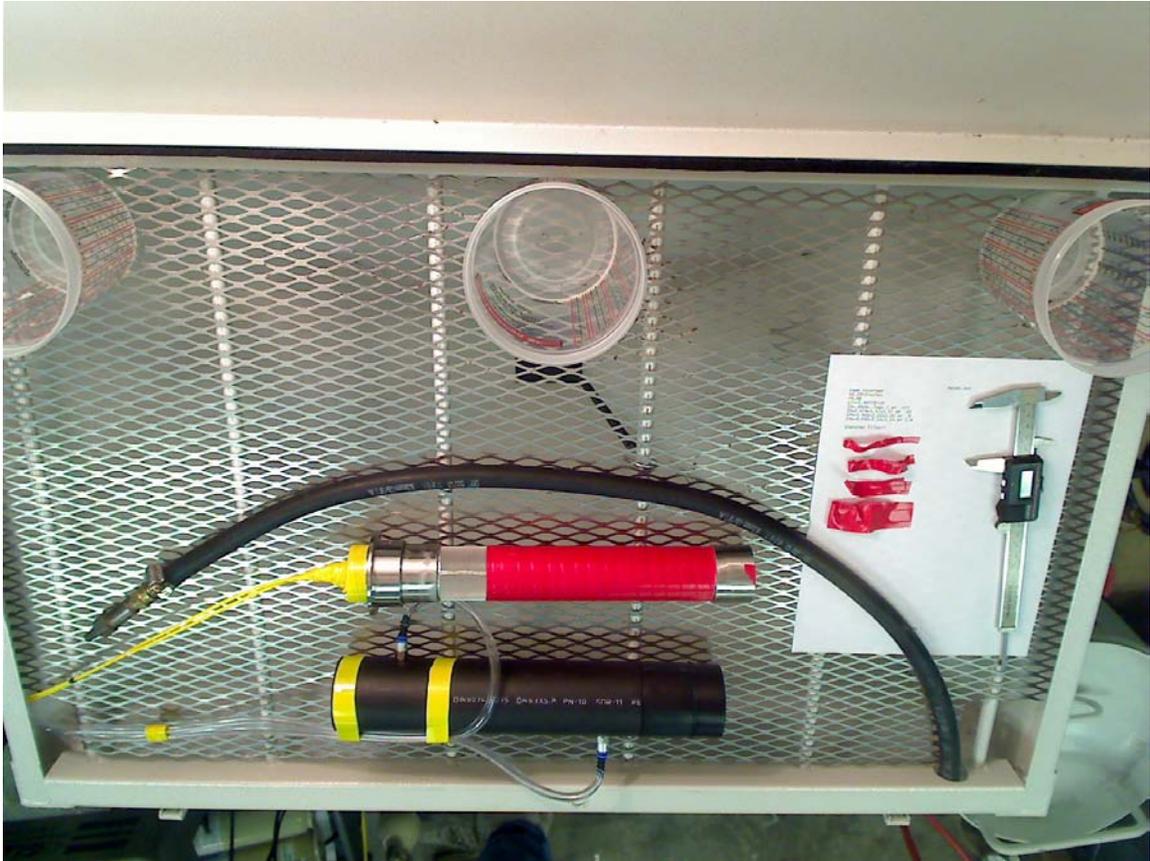


Figure 16 – 80% Blockage of Sensor screen

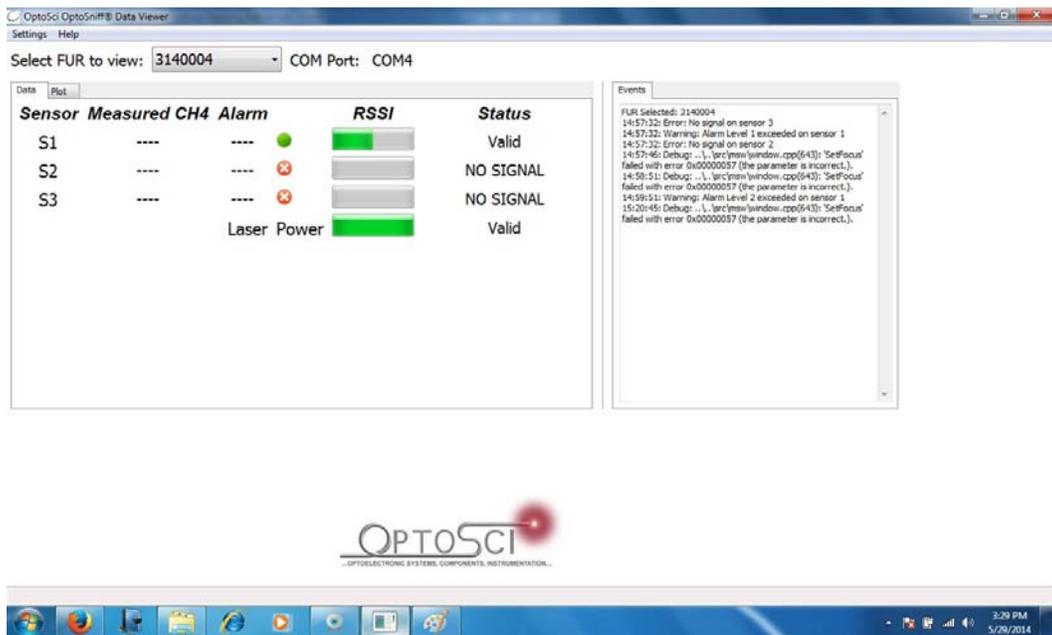


Figure 17 – 80% Blockage - Before Gas is released (zero methane level recorded)

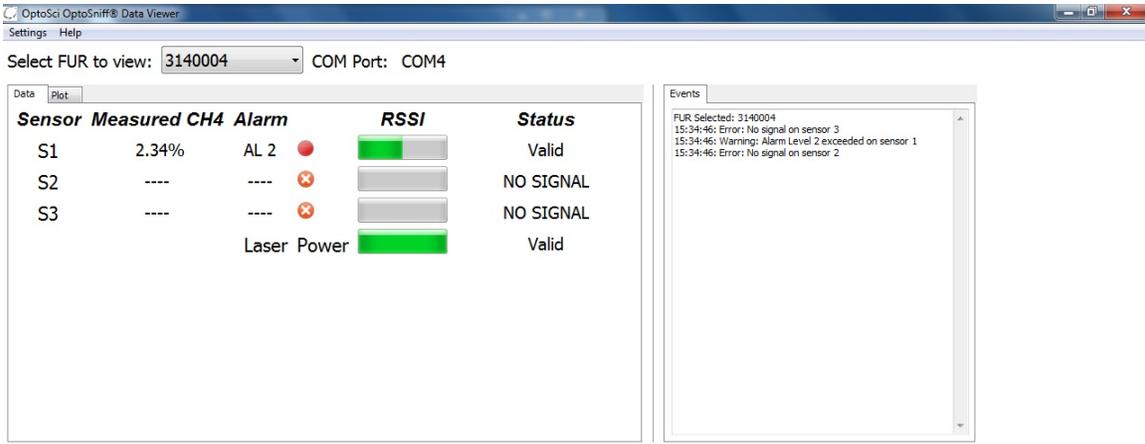


Figure 18 – 90% Blockage – After 5 minutes of exposure to 2.5% methane Gas (2.34% methane level recorded)

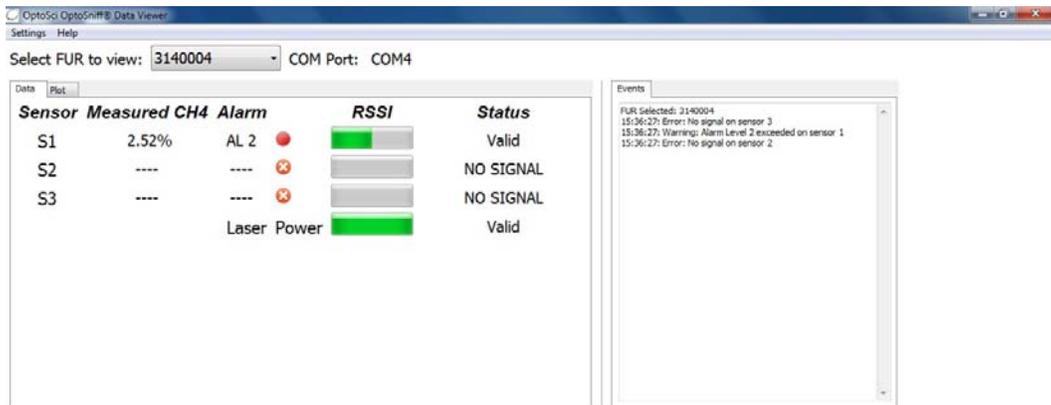


Figure 19 – 90% Blockage – After 7 minutes of exposure to 2.5% methane Gas (2.50% methane level recorded)

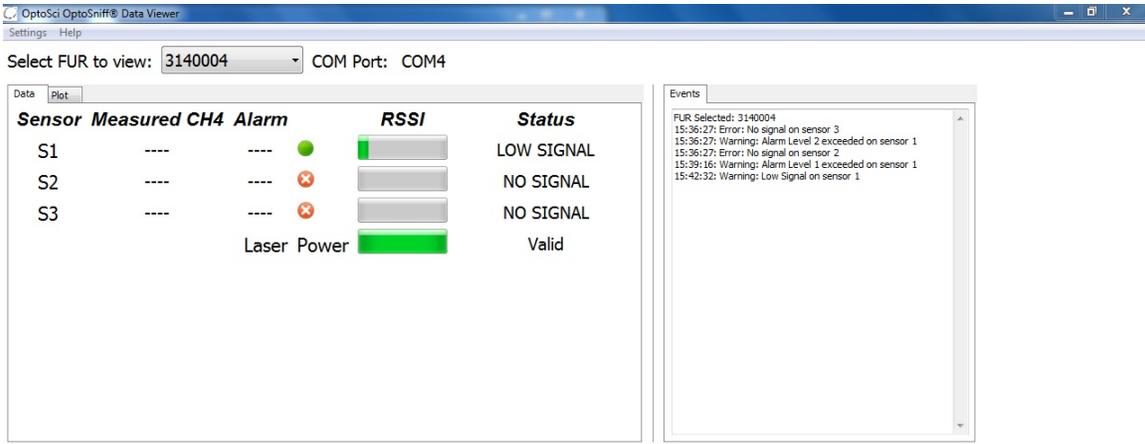


Figure 20 – 0% Blockage - Before Gas is released (zero methane level recorded)

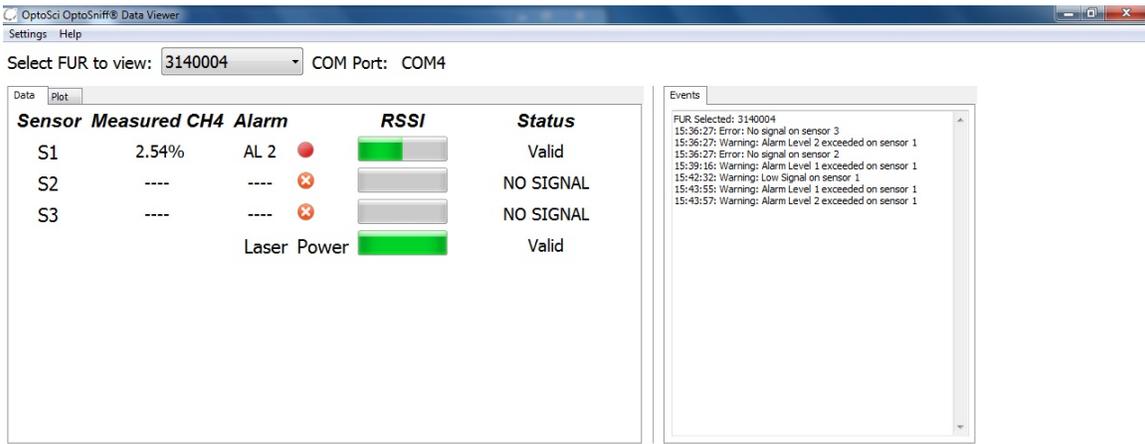


Figure 21 – 0% Blockage – After 2 minutes of exposure to 2.5% methane Gas (2.54% methane level recorded)

Test Procedure (Test 2a)

1. Sensor Screen is coated with mine rock dust by pouring dust directly onto screen
2. Baseline level of methane is measured
3. Sensor is inserted into calibration tube
4. Methane (2.5%) is flowed through tube at 0.5 SCFH (standard cubic feet per hour)
5. Methane Reading is taken at 5 minutes (or as specified)



Figure 22 – Test Set-up prior to subjecting screen to rock dust



Figure 23 – Rock Dust being poured onto screen. Screen/sensor was rotated 45 degrees between applications to ensure complete coverage



Figure 24 – Rock Dust being poured onto screen. (additional view)



Figure 25 – Rock Dust coated onto screen.



Figure 26 – Rock Dust coated screen being inserted into calibration tube



Figure 27 – Rock Dust coated screen ready for testing

RealTerm: Serial Capture Program 2.0.0.70

| | | | | |
|-----------------|------------|----------|-------|--------|
| 20000101T035117 | 3140004:RD | -1.0000% | 00000 | 1 LFCR |
| 20000101T035117 | 3140004:RB | 2.5276% | 25638 | 0 LFCR |
| 20000101T035117 | 3140004:RC | -1.0000% | 00000 | 1 LFCR |
| 20000101T035119 | 3140004:RA | -1.0000% | 33679 | 0 LFCR |
| 20000101T035119 | 3140004:RD | -1.0000% | 00000 | 1 LFCR |
| 20000101T035119 | 3140004:RB | 2.5477% | 25636 | 0 LFCR |
| 20000101T035119 | 3140004:RC | -1.0000% | 00000 | 1 LFCR |
| 20000101T035120 | 3140004:RA | -1.0000% | 33674 | 0 LFCR |
| 20000101T035120 | 3140004:RD | -1.0000% | 00000 | 1 LFCR |
| 20000101T035120 | 3140004:RB | 2.5233% | 25638 | 0 LFCR |
| 20000101T035120 | 3140004:RC | -1.0000% | 00000 | 1 LFCR |
| 20000101T035122 | 3140004:RA | -1.0000% | 33677 | 0 LFCR |
| 20000101T035122 | 3140004:RD | -1.0000% | 00000 | 1 LFCR |
| 20000101T035122 | 3140004:RB | 2.5673% | 25631 | 0 LFCR |
| 20000101T035122 | 3140004:RC | -1.0000% | 00000 | 1 LFCR |

CR

Figure 28 – Methane value of 2.5673% (cal gas of 2.5%), power levels essentially unchanged from Figure 3 (pre-test) (25417 to 25631)

Test Procedure (Test 2b)

1. Sensor Screen is removed, bare sensor element is set with long axis horizontal, short axis vertical (see Figure 30)
2. Sensor is dusted with rock dust
3. Sensor is inserted into calibration tube
4. Methane (2.5%) is flowed through tube at 0.5 SCFH (standard cubic feet per hour)
5. Methane Reading is taken at 5 minutes (or as specified)



Figure 29 – Test 2b Set-up, bare sensor element set with calibration tube



Figure 30 – Bare sensor orientation (behind support plate)



Figure 31 – Start of blowing dust cycle



Figure 32 – Rock Dust fills chamber



Figure 33 – Dust settling



Figure 34 – Sensor frame tapped to remove excess clumping of dust

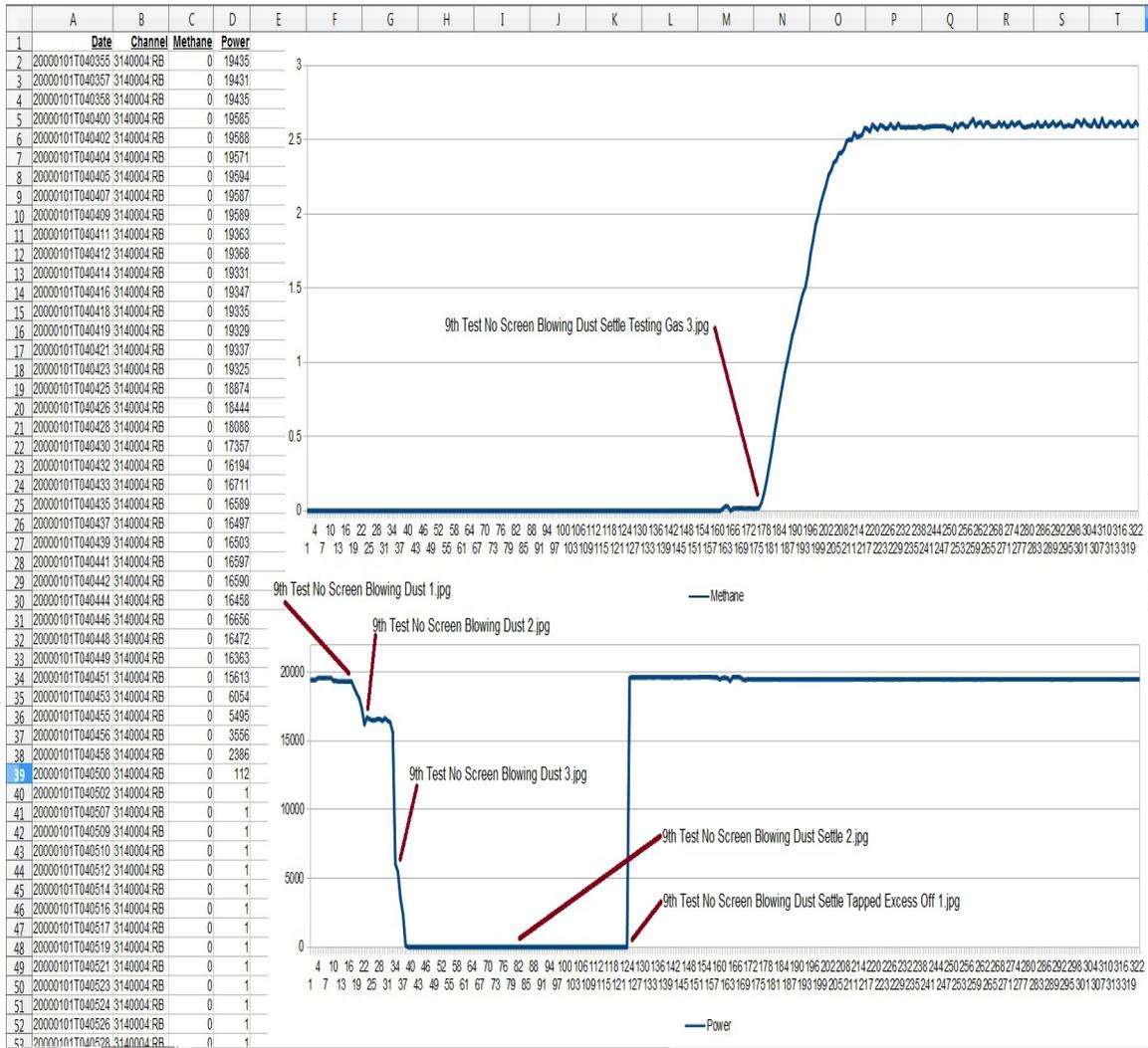


Figure 35 – Test Results for Test 2b – showing complete recovery of sensor element after settling/tapping to remove clumped dust from element

Appendix G – Field Installation

(Field Test Section from Appendix A – Test Protocol)

3.2.5 Field Test

3.2.5.1 Test Equipment

3.2.5.1.1 *Sensors will be installed in the following locations:*

- *A bleeder split*
- *A ventilation split ventilating a sealed area*
- *A bleeder evaluation point, or perhaps a fan housing (TBD) which would reflect the methane content for the entire mines. The latter could be used to calculate total methane production for the mining operation.*
- *Idler bearings on conveyor run (temperature sensing cable)*

The installed locations can be seen in Figure 1

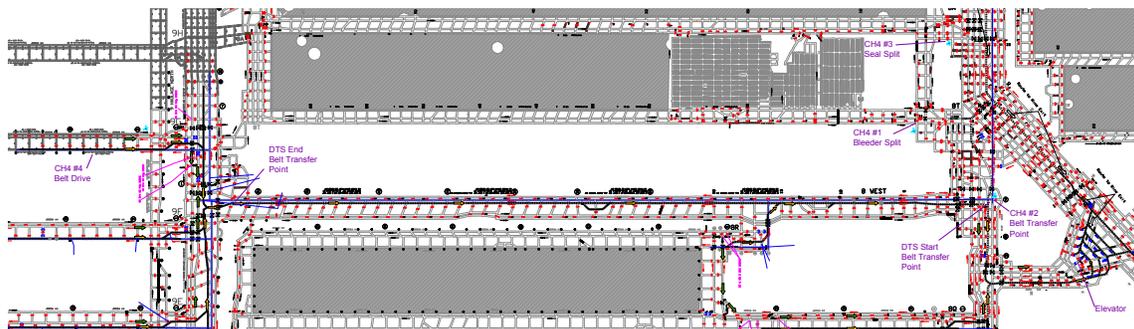


Figure 1 – Sensor Locations

3.2.5.1.2 *The suggested areas are required to be monitored on a weekly basis by a fire boss, providing a comparison data point.*

We were unable to secure Fire Boss data from the mine for comparison purposes. We continued to receive data from the installed gas cells throughout the trial. The system calibration was verified at the surface providing strong support for the validity of the data recorded.

3.2.5.1.3 *The Alpha Natural Resources' (Brooks Run Mining Subsidiary) Cucumber Mine in McDowell County, WV has been identified as the primary candidate for locating the field test.*

Due to manpower limitations, Alpha was unable to assist with the project. We approached Pinnacle Mine in Wyoming, WV a subsidiary of Cliffs Natural Resources and they agreed to support the test

3.2.5.2 Test Samples

Data will be collected on a continuous basis for installed sensors

Data was collected on the methane system on an essentially continuous basis (occasional network glitches caused link from mine to Princeton, WV facility to go down). Well over 2 million records recorded. As indicated in Appendix D the temperature system was installed on a conveyor run, which subsequently become inactive due to mine production requirements. We were unable to re-position the system, due to manpower constraints. As an alternative we were able to utilize the Fenner Dunlop R&D facility in Tazewell County, VA.. This is further elaborated in Appendix D.

3.2.5.3 Procedures

3.2.5.3.1 *Sensors will be installed in indicated areas, with appropriate mounting methods*

Completed, we were unable to secure photographs underground due to Mine regulations

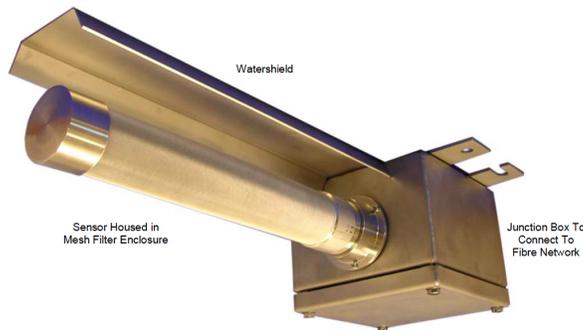


Figure 2 – Gas Cell

3.2.5.3.2 *Control Units will be placed in Mine control room*

Completed, See Figure 3 and 4

3.2.5.3.3 *MSHA approved fiber cable will be installed, connecting sensors and central control unit in mine control room. Similarly temperature-sensing cable will be installed on conveyor run, monitoring bearing temperatures of idlers*

Completed

3.2.5.3.4 *Data with embedded time markers will be collected for each installed temperature and methane sensing system*

Completed

3.2.5.3.5 *Correlations will be made with weekly methane readings by Fire Boss and temperature readings collected with portable IR temperature probe*

We consistently recorded ppm levels (typically hundreds of ppm) at all locations. Sensors were moved several times between identified areas on mine map, we were never able to record levels of methane above the “hundreds of ppm” levels, nor identify any significant trends. The data would tend to suggest we were seeing background levels, which would rise and fall randomly.

3.2.5.4 Test Data

3.2.5.4.1 *Methane values recorded on a continuous basis at each location*

Completed, see Figure 5 - 6 for representative data. The timestamp reads YYYYMMDDTHHmmSS (Y-year, M – month, DD – date, T – delimiter, H – hours (24 hr), mm – minutes, SS – seconds). The power level decline from Figure 5 to Figure 6 (11/12/2013 to 4/28/2014) was determined to be degradation in the existing fiber backbone used to get from the control room to the closest patch panel. Interestingly, the sensors are still working at these levels. In future installations, we would require a dedicated fiber backbone from the control room through dedicated patch panels to the sensor.

Figures 7,8 and 9 depict the mobile app, which reads the data (in this case streaming) from the mine. The three images are taken consecutively over several seconds. The display can also be made to read running numerical values as with the PC display. This data was taken on 5/29/24.

| Timestamp | Sensor ID | Methane % | Laser Power Level |
|-----------------|-----------|-----------|-------------------|
| 20131112T154427 | 3140024:C | 0.0367% | 5279 |
| 20131112T154429 | 3140024:A | 0.0000% | 48336 |
| 20131112T154429 | 3140024:B | 0.0000% | 4260 |
| 20131112T154429 | 3140024:C | 0.0426% | 5277 |
| 20131112T154431 | 3140024:A | 0.0000% | 48336 |
| 20131112T154431 | 3140024:B | 0.0318% | 4259 |
| 20131112T154431 | 3140024:C | 0.0357% | 5280 |
| 20131112T154433 | 3140024:A | 0.0000% | 48335 |
| 20131112T154433 | 3140024:B | 0.0321% | 4260 |
| 20131112T154433 | 3140024:C | 0.0427% | 5279 |
| 20131112T154434 | 3140024:A | 0.0000% | 48336 |
| 20131112T154434 | 3140024:B | 0.0305% | 4258 |
| 20131112T154434 | 3140024:C | 0.0402% | 5280 |
| 20131112T154436 | 3140024:A | 0.0000% | 48335 |
| 20131112T154436 | 3140024:B | 0.0000% | 4257 |
| 20131112T154436 | 3140024:C | 0.0000% | 5280 |
| 20131112T154438 | 3140024:A | 0.0000% | 48336 |
| 20131112T154438 | 3140024:B | 0.0000% | 4259 |
| 20131112T154438 | 3140024:C | 0.0426% | 5281 |
| 20131112T154440 | 3140024:A | 0.0000% | 48336 |
| 20131112T154440 | 3140024:B | 0.0337% | 4257 |
| 20131112T154440 | 3140024:C | 0.0000% | 5281 |
| 20131112T154441 | 3140024:A | 0.0000% | 48336 |
| 20131112T154441 | 3140024:B | 0.0304% | 4258 |
| 20131112T154441 | 3140024:C | 0.0401% | 5280 |
| 20131112T154443 | 3140024:A | 0.0000% | 48336 |
| 20131112T154443 | 3140024:B | 0.0318% | 4259 |
| 20131112T154443 | 3140024:C | 0.0438% | 5280 |
| 20131112T154445 | 3140024:A | 0.0000% | 48336 |
| 20131112T154445 | 3140024:B | 0.0308% | 4259 |
| 20131112T154445 | 3140024:C | 0.0458% | 5281 |
| 20131112T154447 | 3140024:A | 0.0000% | 48336 |
| 20131112T154447 | 3140024:B | 0.0000% | 4258 |
| 20131112T154447 | 3140024:C | 0.0478% | 5278 |
| 20131112T154448 | 3140024:A | 0.0000% | 48335 |
| 20131112T154448 | 3140024:B | 0.0317% | 4258 |
| 20131112T154448 | 3140024:C | 0.0000% | 5280 |
| 20131112T154450 | 3140024:A | 0.0000% | 48336 |
| 20131112T154450 | 3140024:B | 0.0000% | 4254 |
| 20131112T154450 | 3140024:C | 0.0000% | 5280 |
| 20131112T154452 | 3140024:A | 0.0000% | 48336 |
| 20131112T154452 | 3140024:B | 0.0337% | 4255 |
| 20131112T154452 | 3140024:C | 0.0505% | 5280 |

Figure 5 – Random Snapshot of Methane Data

| Timestamp | Sensor ID | Methane % | Laser Power Level |
|-----------------|-----------|-----------|-------------------|
| 20140428T164221 | 3140024:B | 0.0300% | 2904 |
| 20140428T164221 | 3140024:C | 0.0000% | 6361 |
| 20140428T164222 | 3140024:A | 0.0000% | 665 |
| 20140428T164222 | 3140024:B | 0.0000% | 2902 |
| 20140428T164222 | 3140024:C | 0.0000% | 6354 |
| 20140428T164224 | 3140024:A | 0.0000% | 665 |
| 20140428T164224 | 3140024:B | 0.0000% | 2901 |
| 20140428T164224 | 3140024:C | 0.0000% | 6352 |
| 20140428T164226 | 3140024:A | 0.0000% | 665 |
| 20140428T164226 | 3140024:B | 0.0000% | 2901 |
| 20140428T164226 | 3140024:C | 0.0000% | 6354 |
| 20140428T164228 | 3140024:A | 0.0000% | 665 |
| 20140428T164228 | 3140024:B | 0.0000% | 2902 |
| 20140428T164228 | 3140024:C | 0.0000% | 6358 |
| 20140428T164229 | 3140024:A | 0.0000% | 665 |
| 20140428T164229 | 3140024:B | 0.0000% | 2900 |
| 20140428T164229 | 3140024:C | 0.0000% | 6353 |
| 20140428T164231 | 3140024:A | 0.0000% | 665 |
| 20140428T164231 | 3140024:B | 0.0000% | 2898 |
| 20140428T164231 | 3140024:C | 0.0000% | 6348 |
| 20140428T164233 | 3140024:A | 0.0000% | 665 |
| 20140428T164233 | 3140024:B | 0.0000% | 2903 |
| 20140428T164233 | 3140024:C | 0.0000% | 6357 |
| 20140428T164235 | 3140024:A | 0.0000% | 665 |
| 20140428T164235 | 3140024:B | 0.0303% | 2900 |
| 20140428T164235 | 3140024:C | 0.0470% | 6346 |
| 20140428T164237 | 3140024:A | 0.0000% | 665 |
| 20140428T164237 | 3140024:B | 0.0000% | 2896 |
| 20140428T164237 | 3140024:C | 0.0000% | 6349 |
| 20140428T164238 | 3140024:A | 0.0000% | 665 |
| 20140428T164238 | 3140024:B | 0.0000% | 2900 |
| 20140428T164238 | 3140024:C | 0.0000% | 6357 |
| 20140428T164240 | 3140024:A | 0.0000% | 665 |
| 20140428T164240 | 3140024:B | 0.0000% | 2900 |
| 20140428T164240 | 3140024:C | 0.0000% | 6358 |
| 20140428T164242 | 3140024:A | 0.0000% | 665 |
| 20140428T164242 | 3140024:B | 0.0000% | 2899 |
| 20140428T164242 | 3140024:C | 0.0000% | 6348 |
| 20140428T164244 | 3140024:A | 0.0000% | 665 |
| 20140428T164244 | 3140024:B | 0.0000% | 2900 |
| 20140428T164244 | 3140024:C | 0.0000% | 6354 |
| 20140428T164245 | 3140024:A | 0.0000% | 665 |
| 20140428T164245 | 3140024:B | 0.0000% | 2900 |
| 20140428T164245 | 3140024:C | 0.0000% | 6353 |
| 20140428T164247 | 3140024:A | 0.0000% | 665 |
| 20140428T164247 | 3140024:B | 0.0000% | 2902 |
| 20140428T164247 | 3140024:C | 0.0000% | 6360 |
| 20140428T164249 | 3140024:A | 0.0000% | 665 |
| 20140428T164249 | 3140024:B | 0.0000% | 2902 |
| 20140428T164249 | 3140024:C | 0.0000% | 6357 |

Figure 6 – Random Snapshot of Methane Data

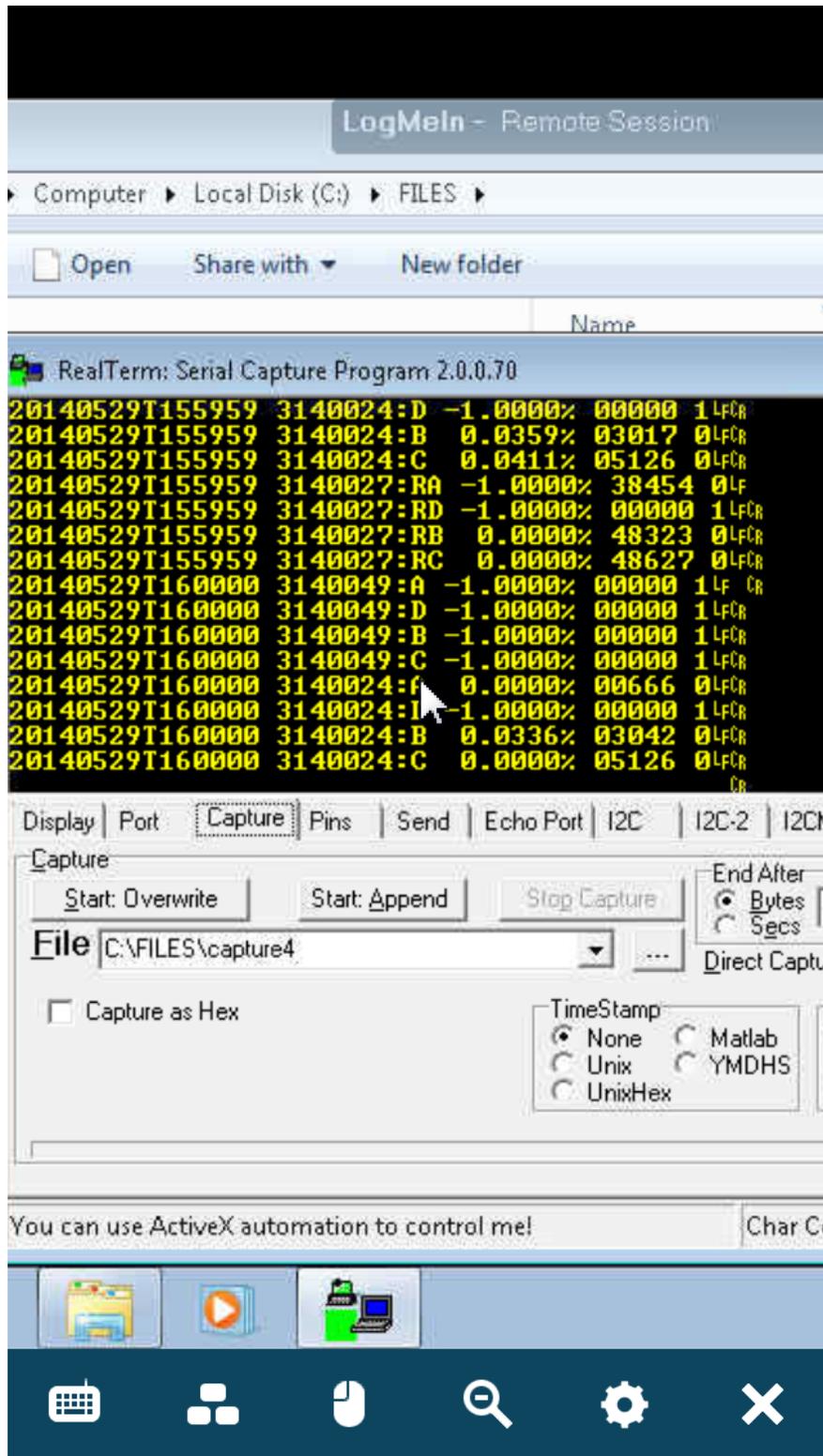


Figure 7 – Mobile App reading actual mine data (Figure 7,8,9 are consecutive screenshots)

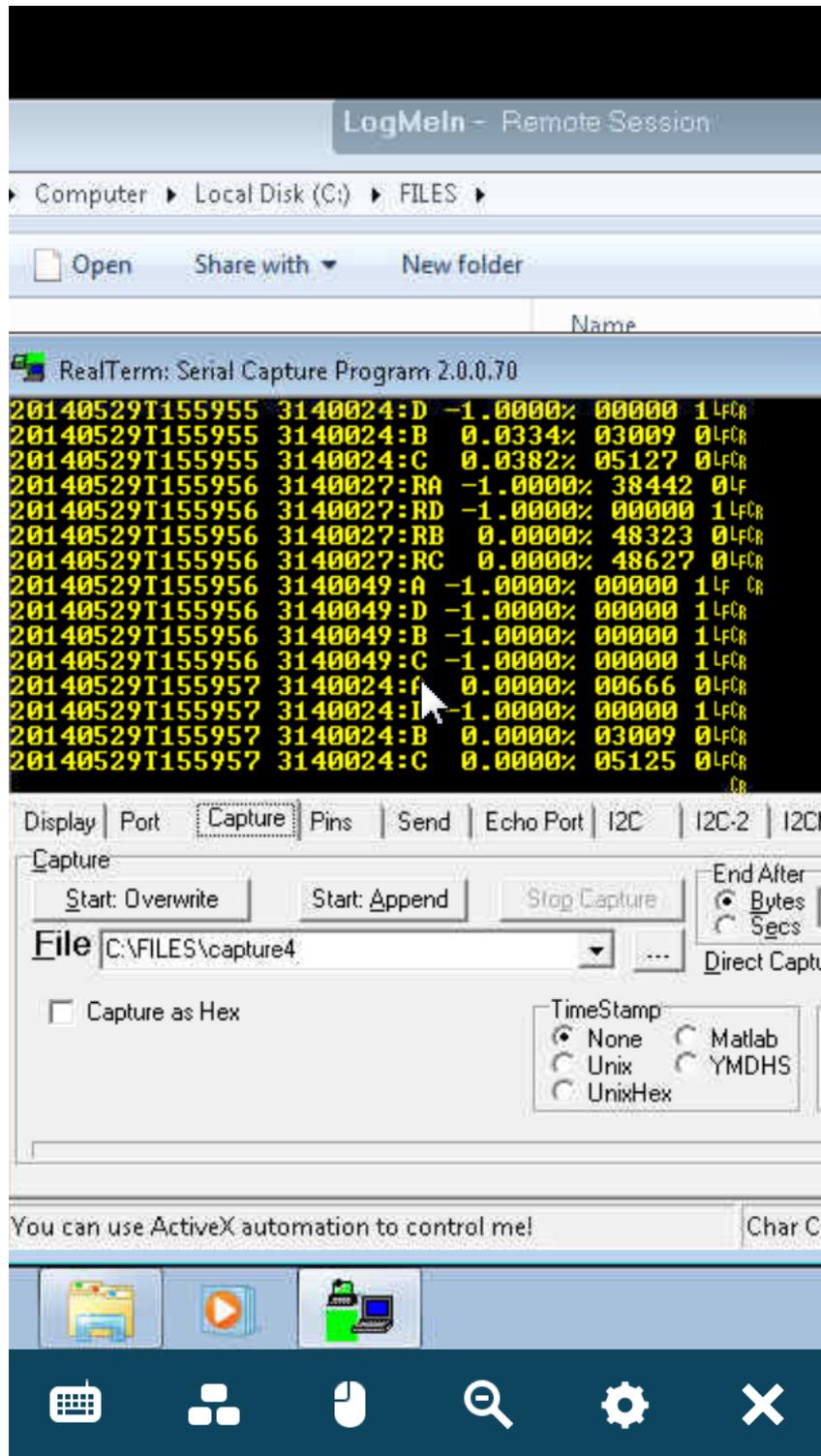


Figure 8 – Mobile App reading actual mine data (Figure 7,8,9 are consecutive screenshots)

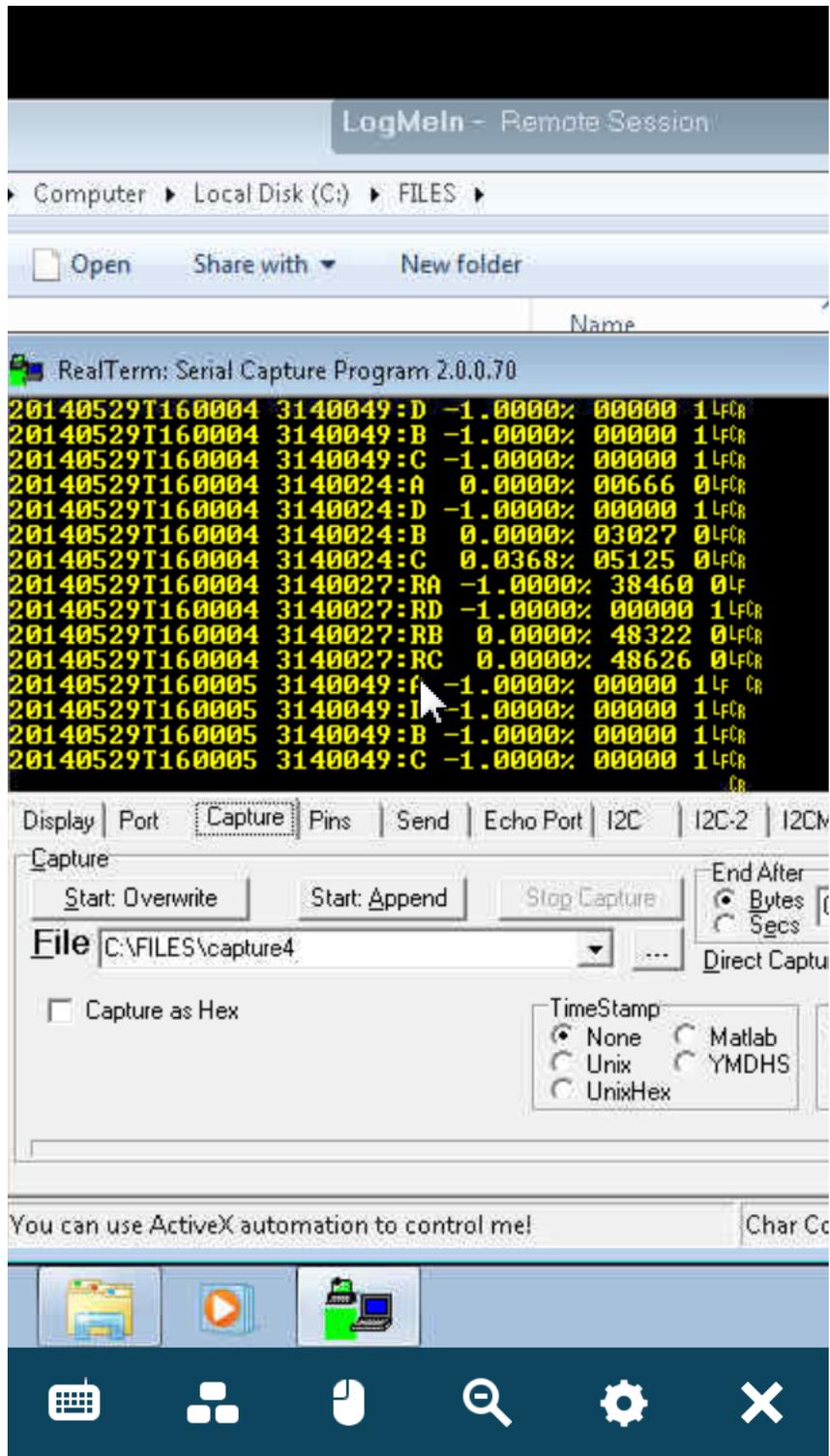


Figure 9 – Mobile App reading actual mine data (Figure 7,8,9 are consecutive screenshots)

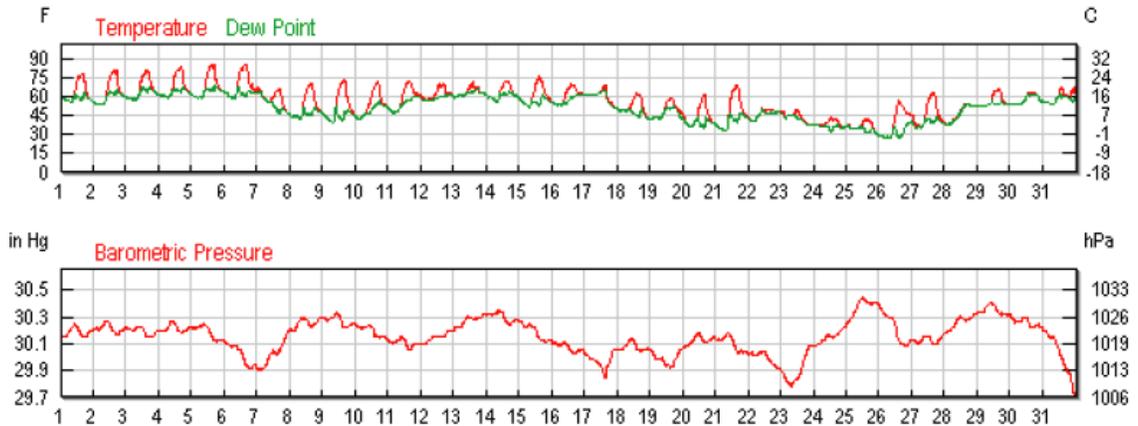
3.2.5.4.2 *Temperature values recorded on a continuous basis at each installed location*

Data recorded underground was discarded, as it was essentially ambient without the conveyor running. Moving to the Fenner Dunlop facility provided useful data

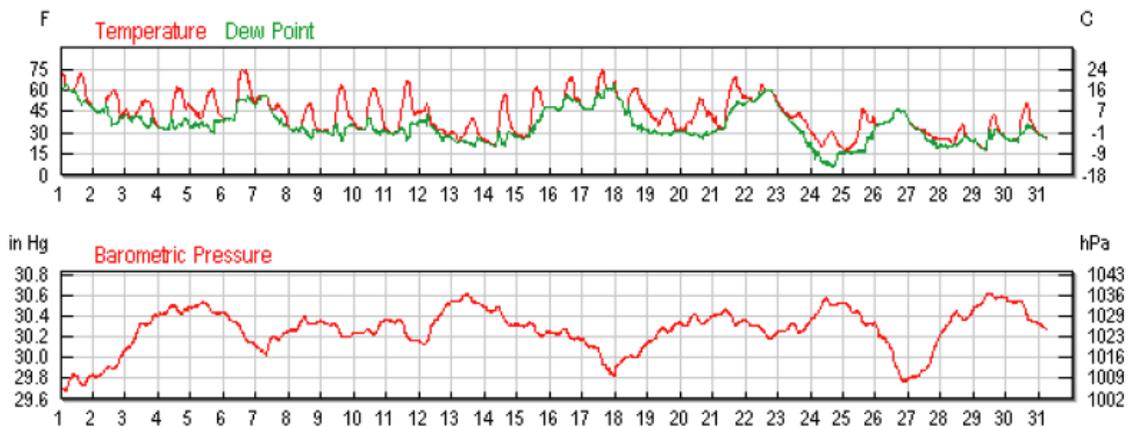
3.2.5.4.3 *Ambient Temperature, Barometric pressure, and mine operating conditions will be collected and correlated with methane and temperature data*

Data was collected, but no correlations were recognized, as methane levels appeared to be random fluctuations in background levels (See Figure 10)

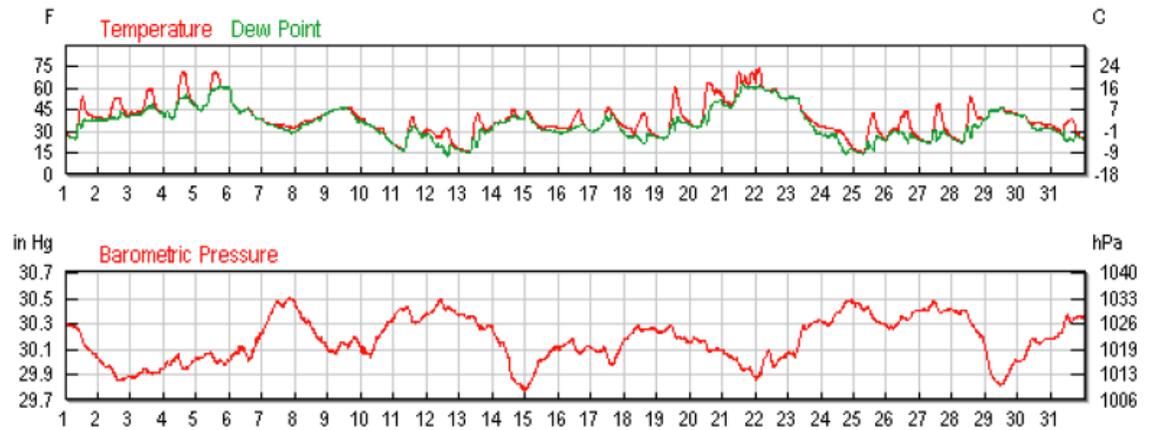
October 2013



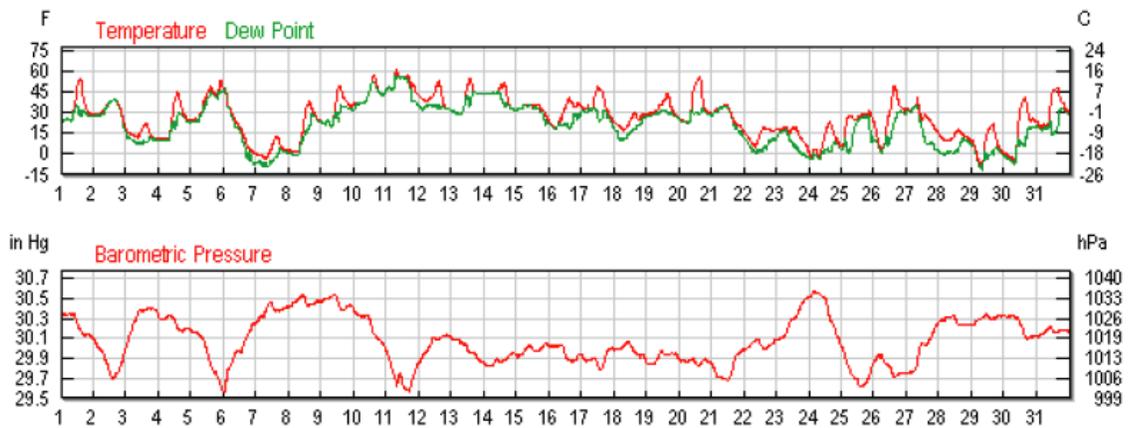
November 2013



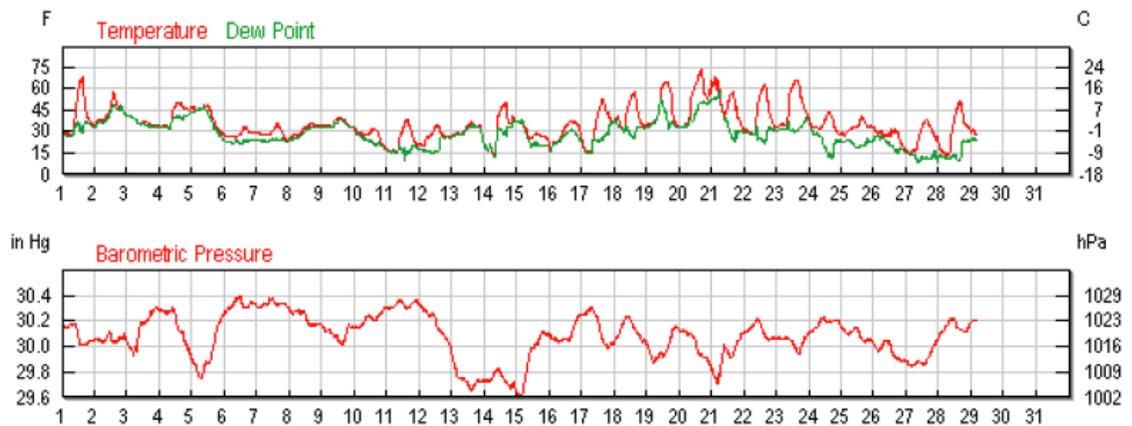
December 2013



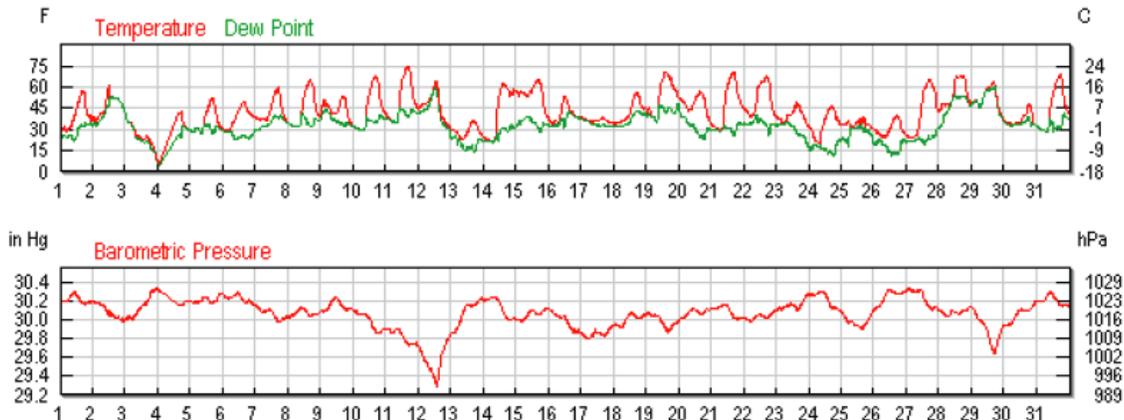
January 2014



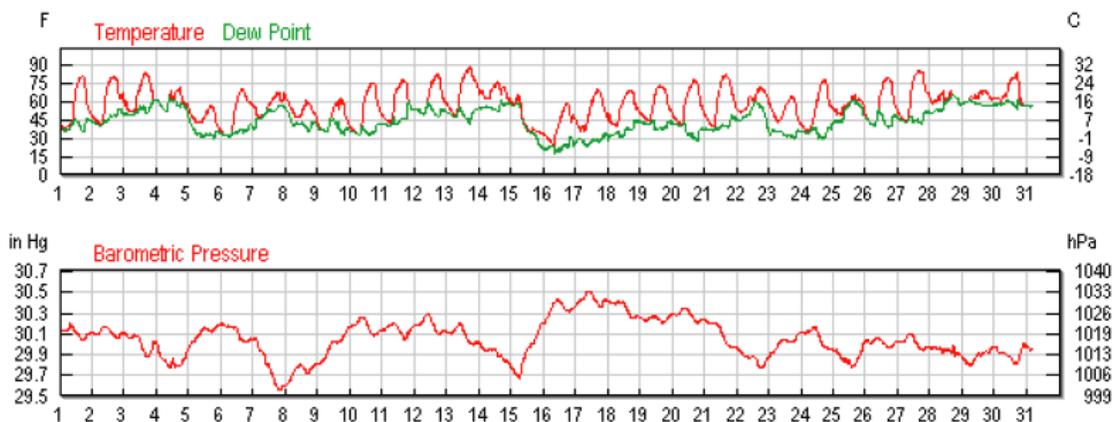
February 2014



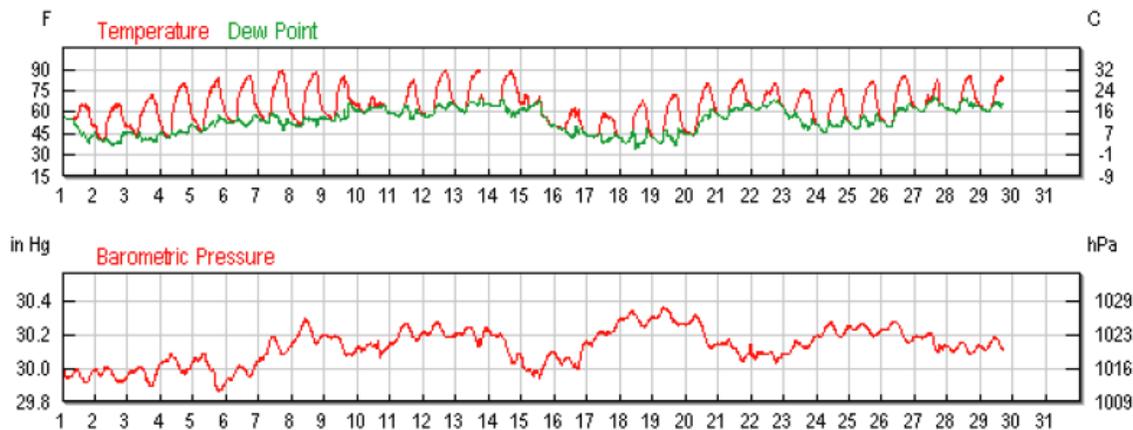
March 2014



April 2014



May 2014



3.2.5.4.4 Methane levels recorded during Fire Boss inspections

See 3.2.5.1.2

3.2.5.4.5 Temperature levels recorded by RSL weekly inspection on conveyor fiber installations

See 3.2.5.4.2

3.2.5.4.6 Test equipment with calibration due dates.

Commercial calibration gas was used, representative C of C shown in Figure 4.



CERTIFICATE OF ANALYSIS

| | |
|---|--|
| Date: May 14, 2014 Order Number: 18488 Lot Number: FAO-135A-1.5-2 | Customer: Instrument Depot, Inc. Use Before: 05/14/2018 |
|---|--|

| Component | Specification (+/- 10%) | Analytical Result (+/- 2%) |
|-----------|-------------------------|----------------------------|
| Methane | 1.5% vol. (30% LEL) | 1.485% vol. |
| Air | Balance | Balance |

| | |
|--|---|
| Cylinder Size: 3.6 Cu. Ft. Contents: 103 Lbar | Valve: 5/8" -18UNF Pressure: 1000 psig |
|--|---|

The calibration gas prepared by Gasco is considered a certified standard. It is prepared by gravimetric, or partial pressure techniques. The calibration standard provided is certified against Gasco's G.M.I.S. (Gas Manufacturer's Intermediate Standard) which is either prepared by weights traceable to the National Institute of Standards and Technology (NIST) or by using NIST Standard Reference Materials where available.

Analyst


Figure 4 – Calibration gas C of C (representative – all are on file)

Pass/Fail Criteria

3.2.5.5.1 *Correlations with system and measured data to be within accepted data windows (using 30 CFR 22.7 as guideline)*

Lab and Field Testing support adherence to 30 CFR 22.7



AP Sensing

N4386B Linear *Pro* Series

Technical Training



Agenda

- Welcome Introduction
- Module #1 AP Sensing Company Overview
- Module #2 Instrument Overview
- Module #3 Solution Options (e.g. Pipeline Monitoring)
- Module #4 System Overview & Measurement Basics
- Module #5 Installation Planning
- Module #6 Software Installation
 Software installation on attendees PCs
 Install DTS instrument / connect sensor cable
 Connect DTS to PC
- Module #7 Take DTS in service
 Define measurement and start
- Module #8 Review and Acceptance
 Verification / checklist / documentation /
 store data

- Module #9 Troubleshooting / Maintenance

- Module #10 DTS Interface Options
 SCPI Commands
 Internal Modbus TCP Interface

- Module #11 Internal Modbus TCP (LAN) Interface

- Module #12 Modbus RS232/ RS485 RTU/ ASCII
 & External Relay Controller

Module #1

N4386B Linear *Pro* Series

AP Sensing Company Overview

AP Sensing's History

- Hewlett-Packard (HP) began as a test and measurement company in 1939
- November of 1999, the measurement business from HP was spun off creating the largest Test & Measurement company in the world – Agilent Technologies
- November of 2007, Agilent's fiber sensing business began a new business model creating AP Sensing as dedicated and focused DTS company
- AP Sensing is co-located with Agilent Technologies in Boeblingen, Germany



Distributed Temperature Sensing

Power Cable Monitoring

Measurement and Calculation of Conductor Temperatures in HV and EHV Power Cables to Increase Safe Operation with Enhanced Capacity.



Linear Heat / Fire Detection

Cutting Edge Linear Heat Detection to Protect Traffic Tunnels , Cable Trays and Special Hazard Applications.



Oil&Gas/Geophysical/Hydrology

Optimization of Oil & Gas Exploration and Production through Smart Temperature Monitoring of Oil & Gas Wells.

Hydrology and Geophysical applications to understand water flow and other geophysical effects.



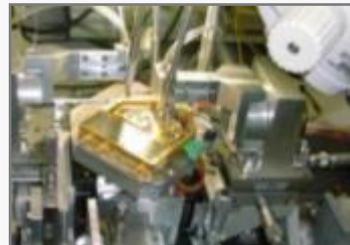
Pipeline / Process / Industrial

Extreme Wide Range of Application Fit to Improve Safe and Efficient Control of Pipelines, Dykes , Dams.





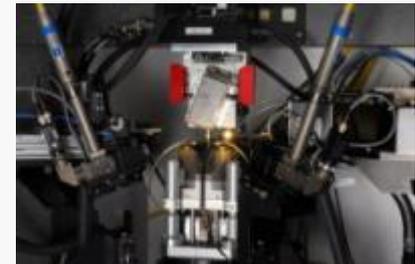
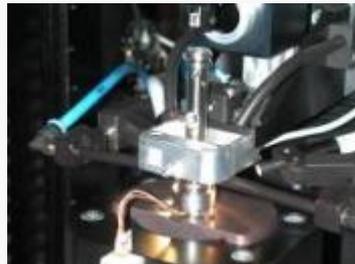
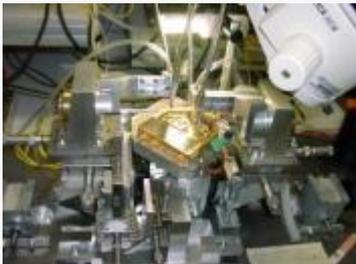
- Agilent Technologies is the world's premier Test & Measurement company and a technology leader in communications, electronics, life sciences and chemical analysis. With 19,000 employees and customers in 110 countries, their revenue exceeded \$ 5.4B in 2010.
- Agilent's Photonic Test Division (in Boblingen, Germany) is the market leader in Optical Component Test, two of their core Intellectual Properties are Optical Time Domain Reflectometry and Precision Optical Assembly.
- Agilent combined its OTDR competency with its unique laser packaging to innovate the most reliable and integrated DTS instrument on the market.



Precision Optical Assembly

Automated Alignment & Laser Welding

- Pick and place of optical components
- Micro optical alignment
- Pigtailed of optical components
- Packaging and integration of laser components



Agilent Tunable Laser Source

Highly Integrated Technology

Highly integrated tunable laser module containing optical, optoelectronic, & electrical components



Cost effective and reliable through propriety, highly automated and integrated production technology.

The Key Component Provides:

- measurement accuracy
- stability vs. the environment
- ultimate reliability & robustness
- cost effectiveness



Complex Wavemeter
Opto & Optoelectronic Assembly

Agilent / AP Sensing - DTS Design



**Agilent's optoelectronic block
– the heart of the AP Sensing DTS**



AP Sensing DTS card cage



19" Rack Mount Enclosure



Outdoor Pole Mount Enclosure



Portable Case

Distributed Temperature Sensing (DTS)

Primary markets

Power



Fire



Oil & Gas



Fiber optic sensor cable for temperature sensing

Linear Pro Series DTS Instrument



Module #2

N4386B Linear *Pro* Series

Instrument Overview

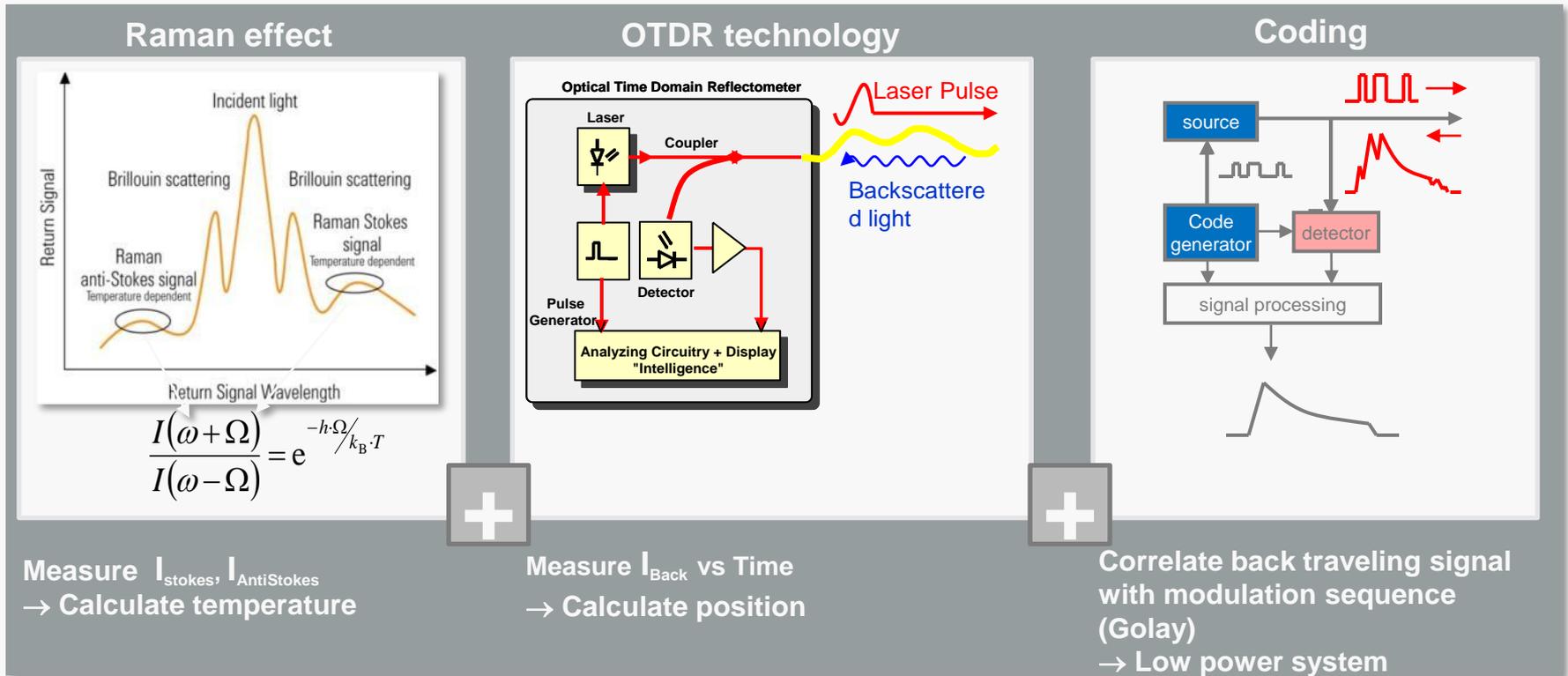
Innovations

| DTS Architecture | Benefits |
|---|---|
| <ul style="list-style-type: none"> Proprietary code correlation technique | <ul style="list-style-type: none"> Driving high temp. resolution by meeting 1M Laser Class requirements |
| <ul style="list-style-type: none"> Highly integrated optical building block, hermetically sealed and filled with inert gas | <ul style="list-style-type: none"> Enabling extended operating conditions, preventing condensation of optical components |
| <ul style="list-style-type: none"> Single receiver design | <ul style="list-style-type: none"> Long-term measurement stability, eliminating tracking issues |
| <ul style="list-style-type: none"> Temperature reference design & temperature stabilized opto-electronics | <ul style="list-style-type: none"> Insensitive to changing operating condition and high measurement repeatability |
| <ul style="list-style-type: none"> Outdoor series | <ul style="list-style-type: none"> Withstands rain, dust, heat, shock, vibration |
| <ul style="list-style-type: none"> Low power consumption | <ul style="list-style-type: none"> Allows solar panel powering |
| <ul style="list-style-type: none"> Incorporated switch, trace memory, inside alarm analysis | <ul style="list-style-type: none"> Reduces cost per channel, enables cost effective network solutions |

Enabling fast, reliable and cost-effective sensing through highly integrated optical measurement systems.



Raman Effect Measurement Concept



AP Sensing's DTS system, using low power laser

Low Power Laser Advantages

- Standard semi conductor laser is used in Telecom. Other DTS systems are typically based on YAG lasers or solid state lasers.
- Long life time, about 60 years in combination with our DTS operating mode.
- System falls in laser class 1M, minimizing user hazards. In contrast YAG laser have mostly 3B. Regulation issues with 3B operation is a key issue.

Note:

In most countries: 3B-lasers needs a laser safety specialist for operation (see IEC 60825-1 (2001) for a complete description of the laser classes)

DTS – Linear Pro Series

DTS Front



The heart of the DTS



DTS Back



Card Cage DTS



Access to Fiber



Linear Power Series

Performance Characteristic

- Spatial resolution: down to 0,5 meter
- Measurement temp. range: - 250 to 750°C
- Operating temperature:
 - 10°C to 60°C
 - 25°C to +60°C (Extreme Outdoor Alternative 1)
 - 40°C to +40°C (Extreme Outdoor Alternative 2)
- Supply voltage: 10 to 30 V DC
- Power: 15 W typ. (28 W max.)
- Number of sensor channels: 1, 2, 4, 8, 12
- Relay board: 20 out- / 4 inputs
- Zones & Alarm: Free definable 256 Zones, 5+2 Alarm criteria
- Autonomous acquisition system
- Interfaces: USB / Ethernet; SD Card (B-Series); Modbus optionally
- Housing: Indoor 19" / outdoor IP66 (~ NEMA 4)
- Laser Class 1M (eye safe)



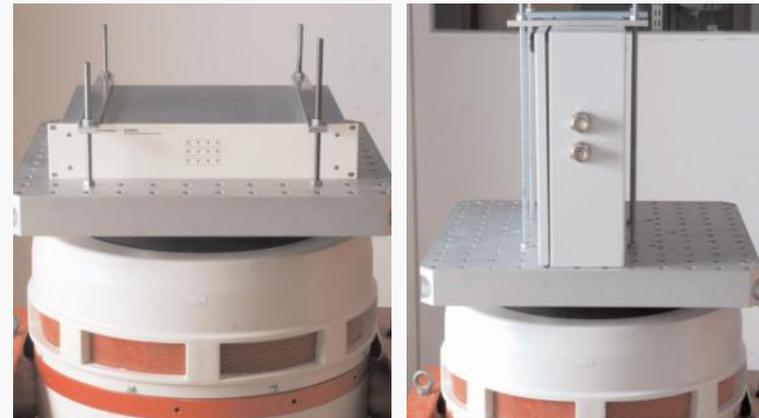
DTS Instrument Robustness 1/2

Certifications & Tests

IEC 60068-2-6/-64, IEC 60068-2-27 & ISO 13628-6

| | |
|--|--|
| <i>Vibration</i> | |
| - operating functional | IEC 60068-2-6/-64 5 to 500 Hz, 0.0001-0.0002 g ² Hz, 10 min. p. axis |
| - operating swept sine (resonance search), 5 min. Per 4 highest Resonance frequencies | 5 to 500 to 5 Hz, 0.75g (0-peak) |
| - random survival 10 min per axis | 5 to 500 Hz, 0.0052-0.02 g ² Hz |
| - package swept sine | 5 to 500 to 5 Hz, 0.5g (0-peak) |
| - package random | 5 to 200 Hz, 0.01 g ² Hz, 30 min. p. axis |
| <i>Shock</i> | |
| - half-sine on all 6 sides | IEC 60068-2-27 240g, 3ms |
| - trapez on all 6 sides | 30g, 25 ms drop height 81 cm (N4386A) drop height 93 cm (N4385A) |
| - package drop test on 6 sides, 8 corners | drop height 76 cm |

| | |
|-------------------------|---|
| <i>Subsea Vibration</i> | |
| - thermal stress | ISO 13628-6 -10 and 60°C / 48 hrs / 10 cycles |
| - shock | half sine 10 g / 11ms / all 6 sides |
| - vibration | swept sine 5 g / 5 to 150 Hz random 2 to 2000 Hz / 6 g _{RMS} / 10 min |



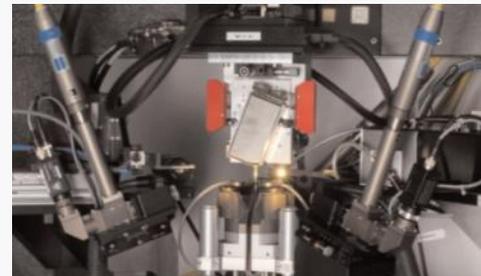
Shock & Vibration Testing

➔ AP Sensing's instruments are the most robust DTS instruments on the market

watch the video: <http://www.apsensing.com/applications/>

DTS Instrument Robustness 2/2

- **MTBF Value = 33 year or 289080 hours**
- **Laser Class 1M**
(IEC 60825-1:2001 / EN 60825-1:1994 +A11:1996+A2:2001)
- **Low power semiconductor laser and single receiver design**
Enables inherently safe operation with maximum life time, widest operating temperature range and lowest power consumption long lasting measurement stability by eliminating drift effects.
- **Optics are protected in a sealed block filled with inert gas**
The components in the heart of the instrument are surrounded by inert gas in a hermetically sealed block, protecting against condensation, dust or moisture – insuring long term operation, independent of ambient changes.
- **vxWorks real-time operating system**
used for many critical applications stable and resistant to viruses



DTS Instrument EMV Compliance

EMV Test & Certifications



| | | |
|---|---|--|
| EMC requirements for Electrical equipment for measurement, control and laboratory use | IEC 61326:2002 / EN 61326:1997 +A1:1998+A2:2001+A3:2003 | |
| <i>EMISSIONS</i> | | |
| - Conducted Emissions | CISPR 11:1997+A1:1999 / EN 55011:1998+A1:1999 | Group 1 Class A |
| - Radiated Emissions | CISPR 11:1997+A1:1999 / EN 55011:1998+A1:1999 | Group 1 Class A |
| - Harmonic Current Emission | IEC 61000-3-2:2000 / EN 61000-3-2:2000 | |
| - Voltage Fluctuations and Flicker | IEC 61000-3-3:1994+A1:2001 / EN 61000-3-3:1995+A1:2001 | |
| <i>IMMUNITY</i> | | |
| - Electrostatic Discharge Immunity | IEC 61000-4-2:1995+A1:1998+A2:2000 / EN 61000-4-2:1995+A1:1998+A2:2001 | +/-4kV, Contact Discharge, Coupling Plate +/-8kV, Air Discharge |
| - Radiated Field Immunity | IEC 61000-4-3:2002+A1:2002 / EN 61000-4-3:2002+A1:2002 | 10V/m, Modulation 80% AM 80MHz to 2000MHz |
| - Fast Transients Immunity | IEC 61000-4-4:1995+A1:2000+A2:2001 / EN 61000-4-4:1995+A1:2001+A2:2001 | +/-2kV, Power Line +/-1kV, Signal Lines |
| - Surge Immunity | IEC 61000-4-5:1995+A1:2000 / EN 61000-4-5:1995+A1:2001 | +/-2kV, Common Mode, Signal Lines +/-1kV, Differential Mode |
| - Conducted Immunity | IEC 61000-4-6:1996+A1:2000 / EN 61000-4-6:1996+A1:2001 | 3Vrms, Modulation 80% AM 150kHz to 80MHz |
| - Power Frequency Magnetic Field Immunity | IEC 61000-4-8:1993+A1:2000 / EN 61000-4-8:1993+A1:2001 | 30A/m |
| - Voltage Dips, Short Interruptions and Voltage Variations Immunity | IEC 61000-4-11:1994+A1:2000 / EN 61000-4-11:1994+A1:2001 | 100% / 20ms 100% / 10ms 0° and 100% / 10ms 180° |

➔ AP Sensing's instruments have passed a comprehensive set of EMV tests.

Module #3

N4386B Linear *Pro* Series

Solution Options

e.g. Pipeline Monitoring

Standard Solution



Form Factor
portable
Outdoor IP66
19" rack mount
+
Software
PC Application SW
DTS Configurator
Single DTS Management
+
Data Storage
Flat Files
(Export to Excel)

Advanced Solution



Form Factor
outdoor
19" rack mount
Integrated System Rack
+
Software
PC Application SW
DTS Monitor
Asset Visualization
Multiple DTS Management
+
Data Storage
SQL Database

DTS Configurator

Standard Software Supplied with Every Instrument

- Windows XP™ / Windows 7™ based software
- All commissioning and configuration functionalities
- Single DTS Management
- Flat file data storage in a simple ASCII format
- Auto Save function for all traces
- Graphical temperature profile
- Graphical loss profile (OTDR Mode)
- Zone table with
 - Minimum temperature
 - Maximum temperature
 - Average temperature
 - Gradient change of temperature
 - Max / Min Temperature compared to zone average
- Alarm table

DTS Configurator

Standard Software Supplied with Every Instrument

The screenshot displays the AP Sensing DTS Configurator software interface. It features two main panels for data visualization and a table for zone configuration.

Temperature Trace (Left Panel): Shows a temperature profile for 'M2-Circuit_I_2L44_4.7km_temp'. The y-axis ranges from 20.99°C to 24.67°C. Markers indicate temperatures at 0.00m (23.42°C), 1182.00m (23.22°C), and a differential of -0.20K at 1182.00m.

Loss Trace (Right Panel): Shows a loss profile for 'M2-Circuit_II_2L20_3.6km_temp'. The y-axis ranges from 21.05dB to 24.65dB. Markers indicate loss at 0.00m (23.03°C), 907.00m (23.35°C), and a differential of 0.32K at 907.00m.

Loss Trace (Bottom Left Panel): Shows a loss profile for 'M2-Circuit_I_2L44_4.7km_temp'. The y-axis ranges from -5.91dB to 0.82dB. Markers indicate loss at 0.00m (-0.44dB), 1182.00m (-1.56dB), and a differential of -1.12dB at 1182.00m.

Loss Trace (Bottom Right Panel): Shows a loss profile for 'M2-Circuit_II_2L20_3.6km_temp'. The y-axis ranges from -4.68dB to 5.4dB. Markers indicate loss at 1000.00m (-1.40dB), 3000.00m (-3.15dB), and a differential of -1.75dB at 2000.00m.

Zone Table (Bottom Left): A table listing zones for 'M2-Circuit_I_2L44_4.7km_temp'.

| No | Name | Start[m] | Stop[m] | Avg[°C] | Max[°C] | Min[°C] | MaxD+[K] | G1[K/s] | G2[K/s] |
|----|------------------------|----------|---------|---------|---------|---------|----------|----------|-----------|
| 1 | Ambinet Temperature | 20,00 | 30,00 | 23,87 | 23,92 | 23,82 | 0,05 | 0,1 | 0,1 |
| 2 | 2L44-Section 1 | 40,00 | 850,00 | 23,64 | 23,98 | 23,30 | 0,33 | 0,2 | 0,2 |
| 3 | 2L44-Jointing Area 1/2 | 850,00 | 860,00 | 23,36 | 23,39 | 23,32 | 0,03 | 0,0 | 0,0 |
| 4 | 2L44-Section 2 | 860,00 | 1700,00 | 23,12 | 23,61 | 22,71 | 0,49 | 0,2 | 0,2 |
| 5 | 2L44-Section 3 | 1700,00 | 2360,00 | 22,66 | 22,96 | 22,38 | 0,31 | 0,17/300 | 0,23/600 |
| 6 | 2L44-Jointing Area 3/4 | 2360,00 | 2510,00 | 22,53 | 22,77 | 22,39 | 0,23 | 0,20/300 | -0,21/600 |
| 7 | 2L44-Section 4 | 2500,00 | 3400,00 | 22,29 | 22,66 | 21,86 | 0,37 | 0,34/300 | -0,32/600 |
| 8 | 2L44-Jointing Area 4/5 | 3400,00 | 3410,00 | 21,93 | 21,97 | 21,87 | 0,04 | 0,00/300 | -0,06/600 |
| 9 | 2L44-Section 5 | 3410,00 | 4700,00 | 22,07 | 22,65 | 21,68 | 0,58 | 0,51/300 | -0,42/600 |

Zone Table (Bottom Right): A table listing zones for 'M2-Circuit_II_2L20_3.6km_temp'.

| No | Name | Start[m] | Stop[m] | Avg[°C] | Max[°C] | Min[°C] | MaxD+[K] | G1[K/s] | G2[K/s] |
|----|------------------------|----------|---------|---------|---------|---------|----------|----------|-----------|
| 1 | Ambinet Temperature | 20,00 | 30,00 | 23,83 | 23,84 | 23,79 | 0,01 | 0,01/300 | 0,10/600 |
| 2 | 2L20-Section 1 | 40,00 | 800,00 | 23,66 | 23,98 | 23,35 | 0,32 | 0,27/300 | -0,12/600 |
| 3 | 2L20-Jointing Area 1/2 | 800,00 | 810,00 | 23,46 | 23,50 | 23,42 | 0,04 | 0,15/300 | 0,06/600 |
| 4 | 2L20-Section 2 | 810,00 | 1700,00 | 23,13 | 23,58 | 22,77 | 0,45 | 0,24/300 | -0,18/600 |
| 5 | 2L20-Section 3 | 1700,00 | 2500,00 | 22,63 | 22,97 | 22,36 | 0,34 | 0,30/300 | -0,17/600 |
| 6 | 2L20-Jointing Area 3/4 | 2500,00 | 2510,00 | 22,48 | 22,53 | 22,42 | 0,05 | 0,25/300 | -0,04/600 |
| 7 | 2L20-Section 4 | 2500,00 | 3600,00 | 22,19 | 22,65 | 21,73 | 0,46 | 0,42/300 | -0,32/600 |

Relay, Fiber Break Connection Status (Bottom Center): Shows 'No Fiber Breaks.' and a 'Reset Alarms' button.

Instrument Information (Bottom Left): N4386A DE47500101 TCP/IP0::192.168.2.160::inst0::INSTR Sequence Measurement 24/Infinity

Active Outputs (Bottom Left): A grid of buttons numbered 1 to 20.

Footer: [M1-Circuit_I_2L44_4.7km_temp.tra (Trace count=2, Save Mode=Temperature, 2010/04/13 10:41:34)]

DTS Data Warehouse (DDW)

- High Performance Multimode DTS Engine
- Up to 12 km Measurement Range
- Up to 12 Measurement Channels
- Powerful Data Management & Analysis
- Customizable Data Transmission (WYNIWYG)
- Highly Flexible Communication
- Multi DTS / Multi Client Capabilities
- Flexible Setup and Scaling



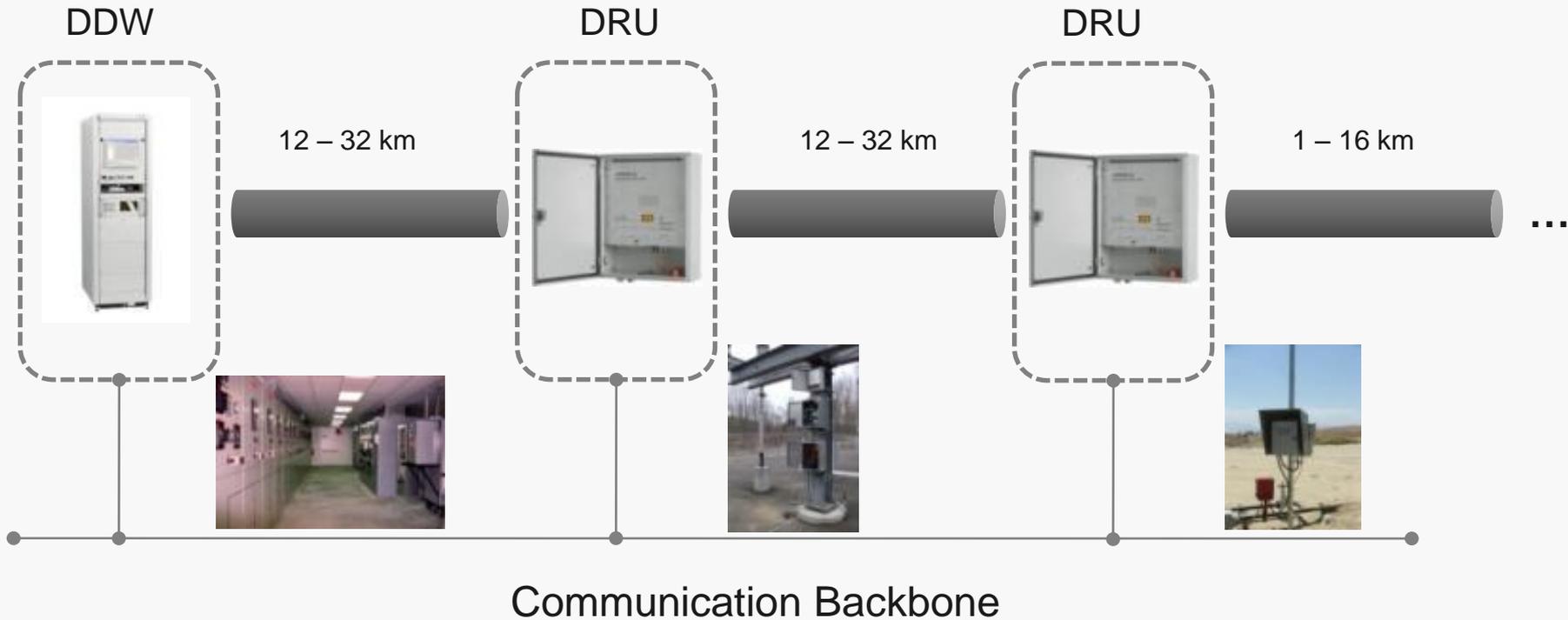
DTS Remote Unit (DRU)

- High Performance Multimode DTS Engine
- Up to 12 km Measurement Range
- Up to 12 Measurement Channels
- Very Low Power Consumption – 17 Watt typical
- Operating Temperature Range -40 to +60 °C
- IP66 Rated Enclosure
- Communication via LAN or Wireless
- Embedded VxWorks Real Time Operating System



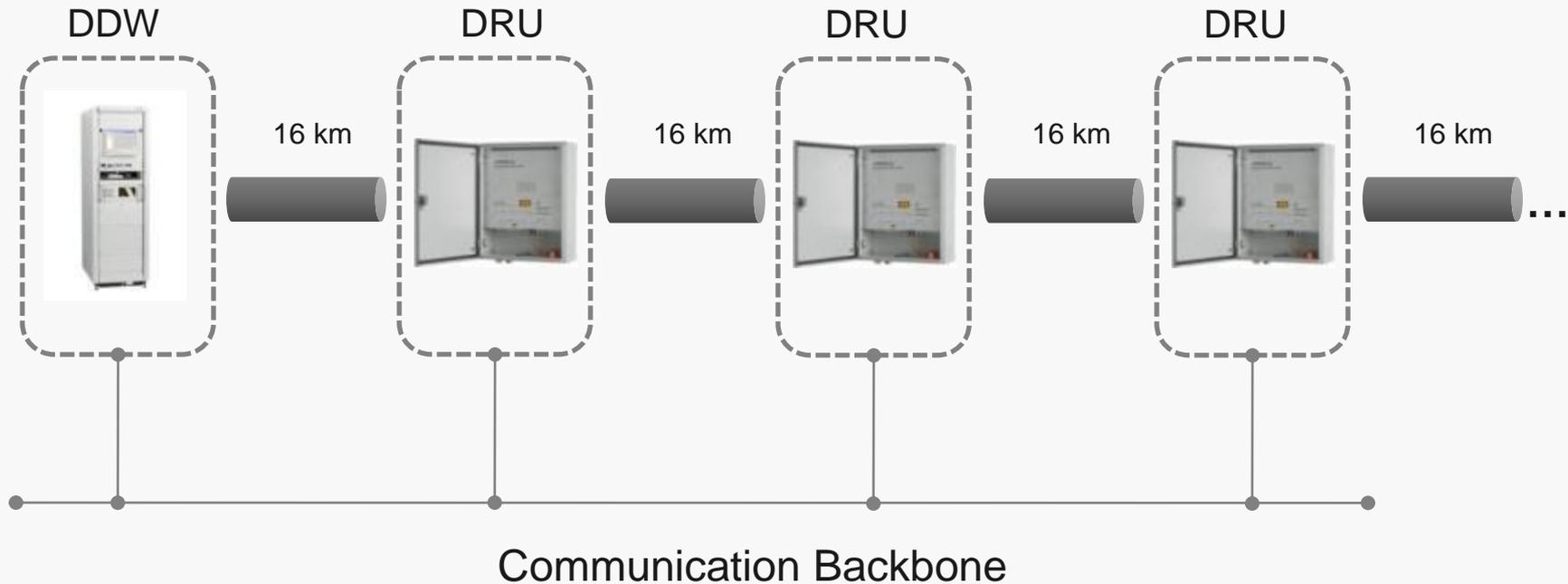
Flexible Scaling

Able to accomodate any distance and optical budget



Flexible Scaling

... Customizable for each application



DTS Monitor

Features

- Graphical User Interface
- Central SQL Database
- Multi User Management
- Multi DTS Management
 - Consolidate measurement and alarm data from one or more DTS instruments in one management application
- Distributed Temperature Monitoring
 - Real time view of temperature graph with lines for defined alarm level
- Asset Visualization
 - Visualization of infrastructure as color coded lines (color depending on temperature)
- Alarm Management
 - Alarm list with time stamps
 - Alarm summary
 - Quick status view (green – yellow – red)
 - Fiber break alarm indication
- Administrative Functions
 - User management
 - Database backup/restore
 - Print functions

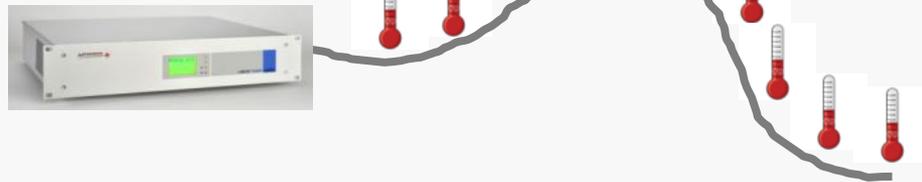
Module #4

N4386B Linear *Pro* Series

System Overview & Measurement Basics

Fiber Optic Linear Power Detection

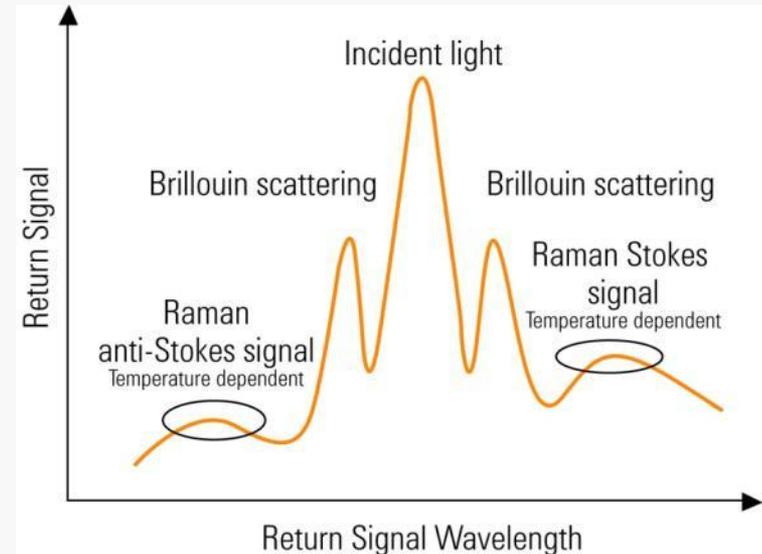
Fiber optic linear heat detectors also called DTS – Distributed Temperature Sensing – measure a temperature profile along an optical fiber over several kilometers. The technology offers many advantages over conventional methods:



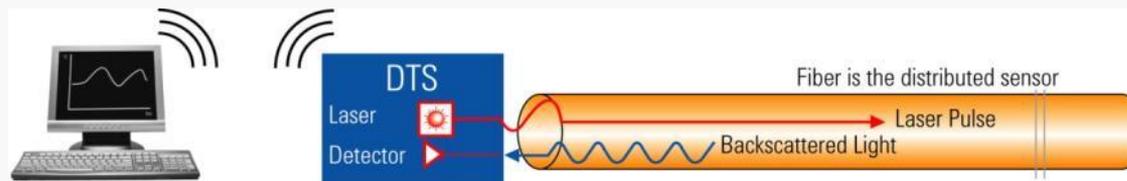
Measurement Principle

DTS utilizes the Raman effect to measure temperature. An optical laser pulse propagating through the fiber gets scattered light back to the transmitting end, where it is analyzed. The intensity of the Raman scattering is a measure for the temperature along the fiber.

Similar to a radar echo.

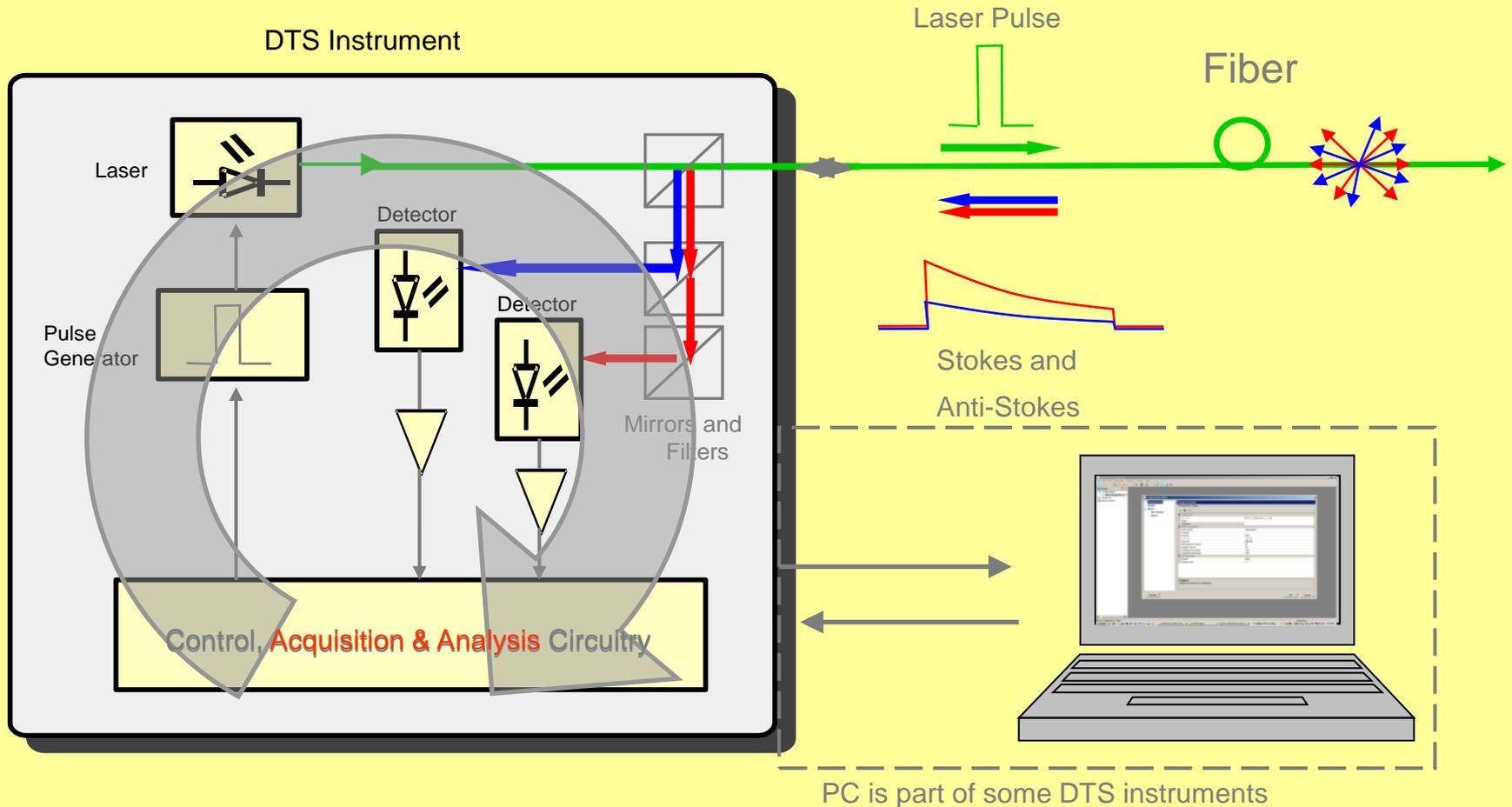


The position of the temperature reading is determined by measuring the arrival timing of the returning light pulse similar to a radar echo.



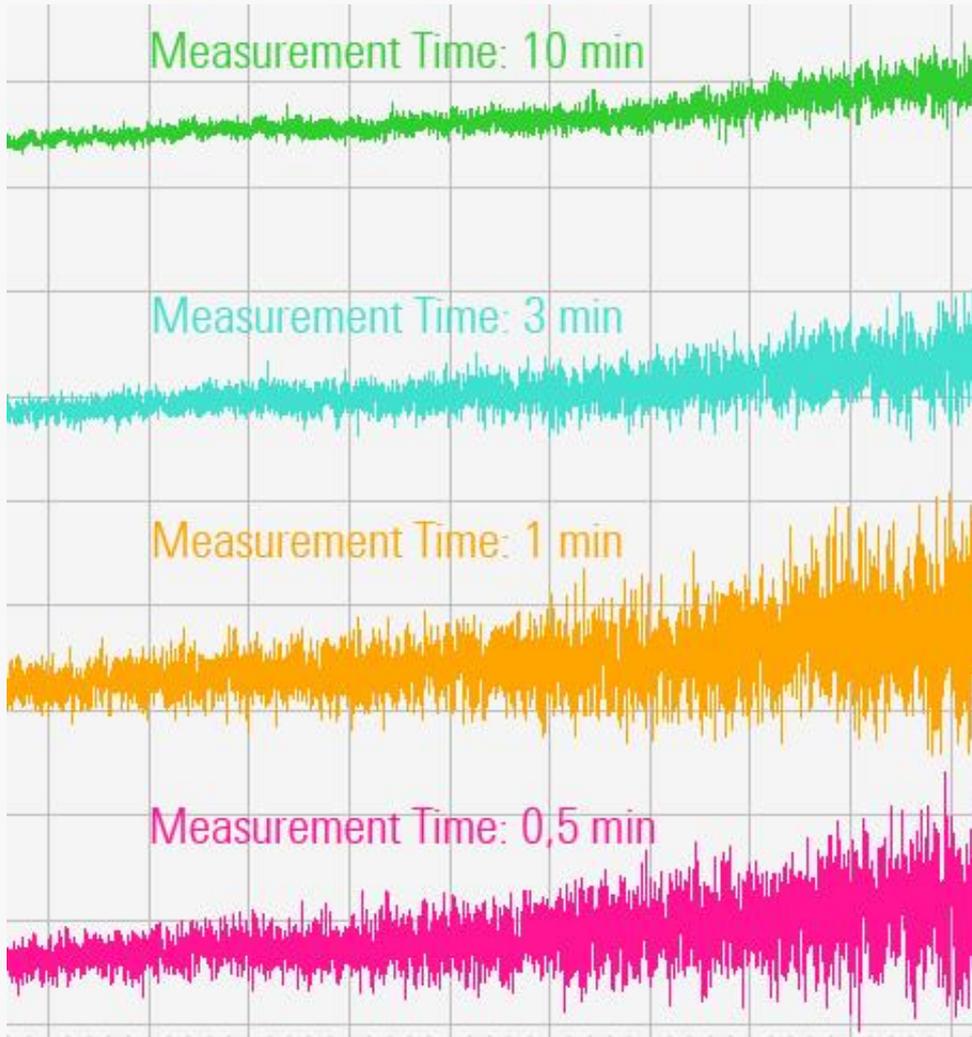
Measurement Technology

Repeat until measurement time is done



Note: AP Sensing DTS incorporates a single detector design

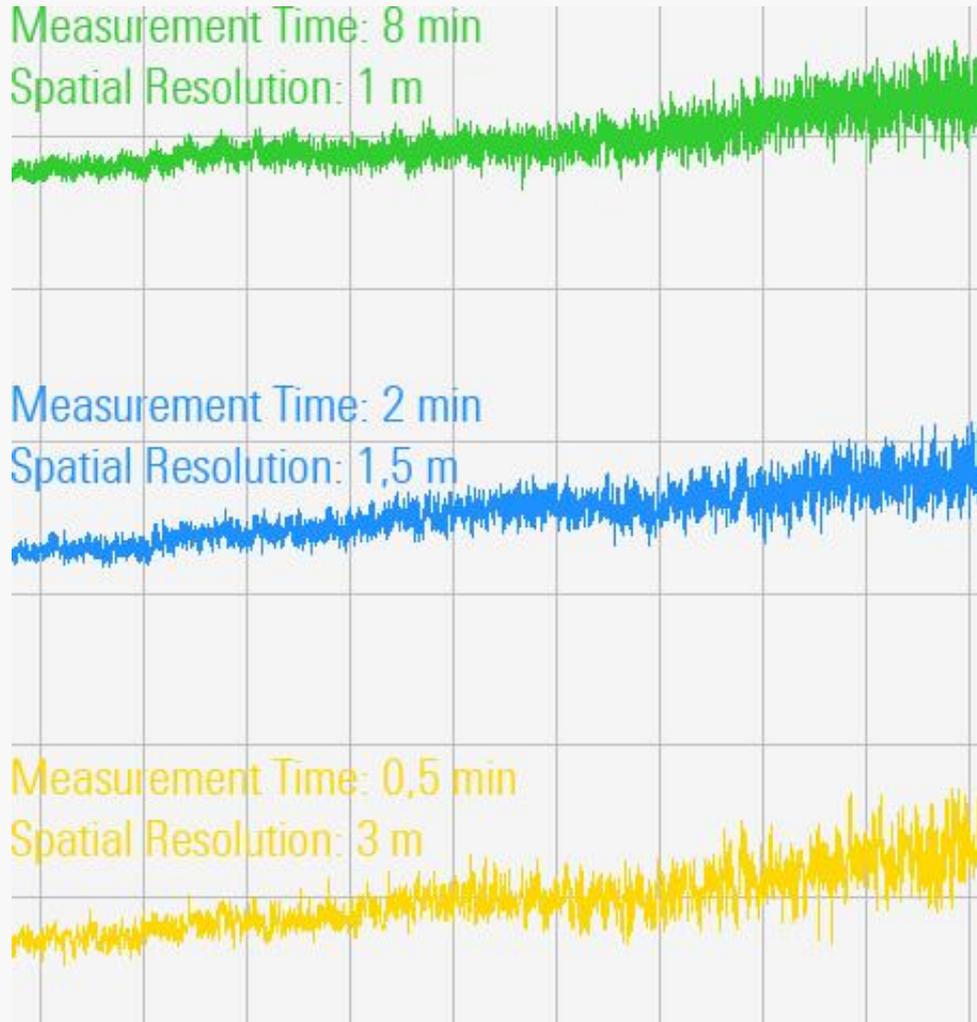
Measurement Basics – Temperature Resolution



Longer
Measurement Time

Better Temperature
Resolution

Measurement Basics – Spatial Resolution



Trade Off
Spatial Resolution for
Temperature Resolution

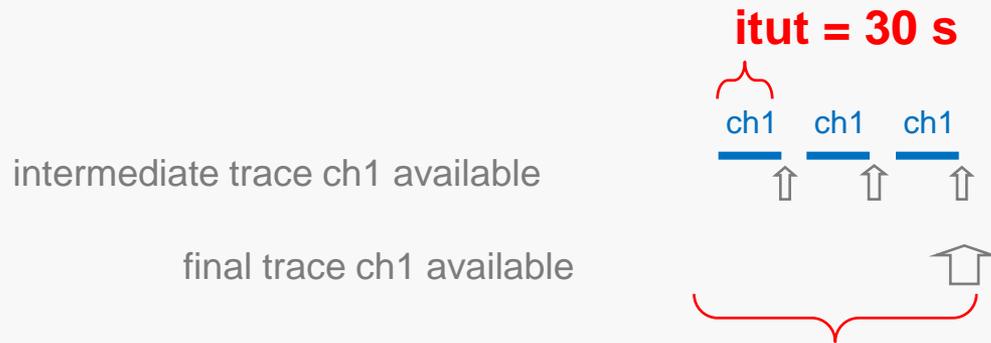
DTS Configurator

Measurement Setup Terms

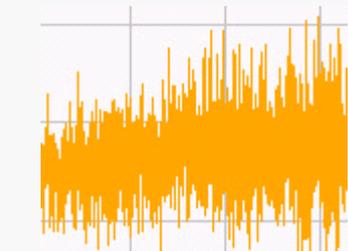
Update Time vs. Measurement Time

Example:

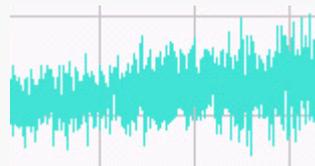
measurement time (mtime) = 3 x intermediate update time (itut)
 measurement time = 90 s and update time = 30 s



Measurement Time = 90 s



intermediate trace 1



intermediate trace 2



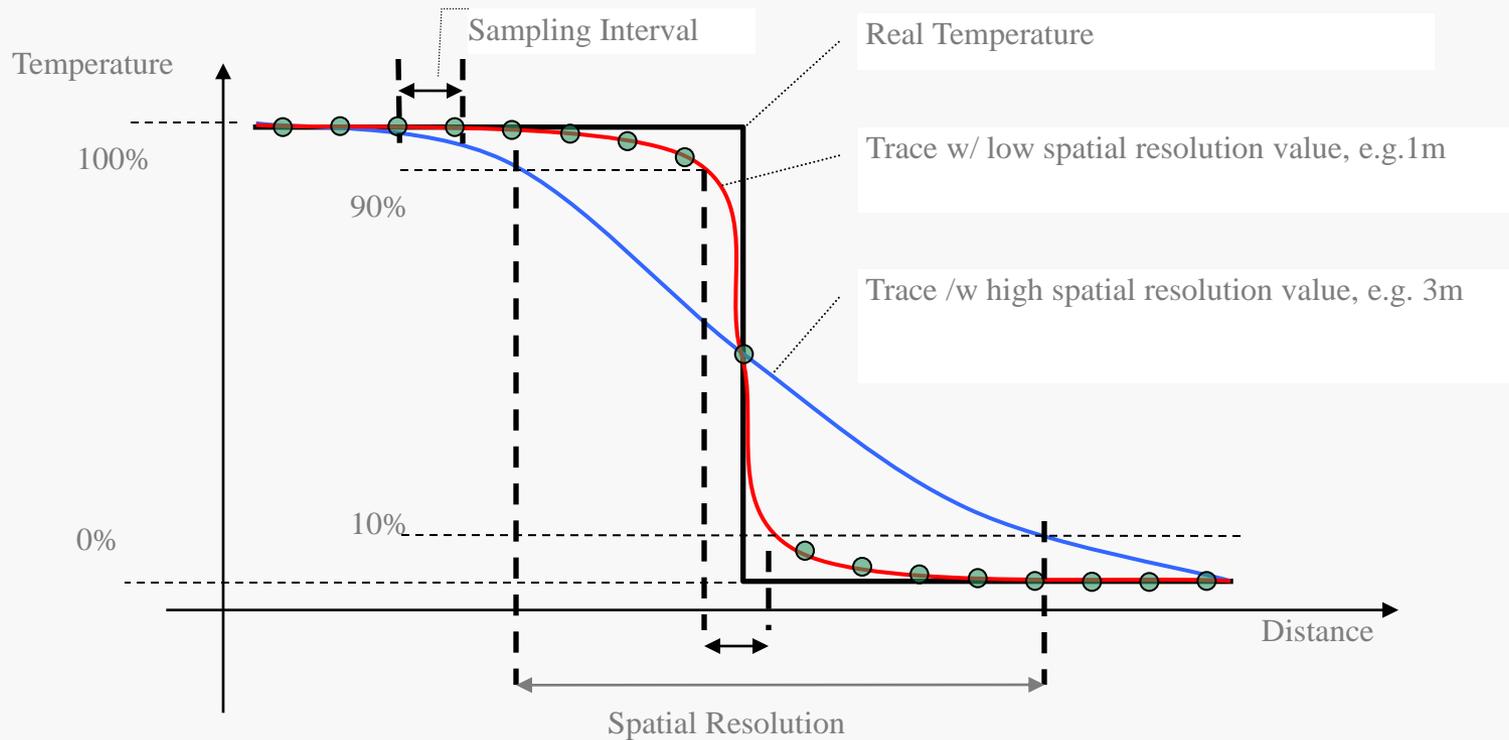
intermediate trace 3



standard trace 1

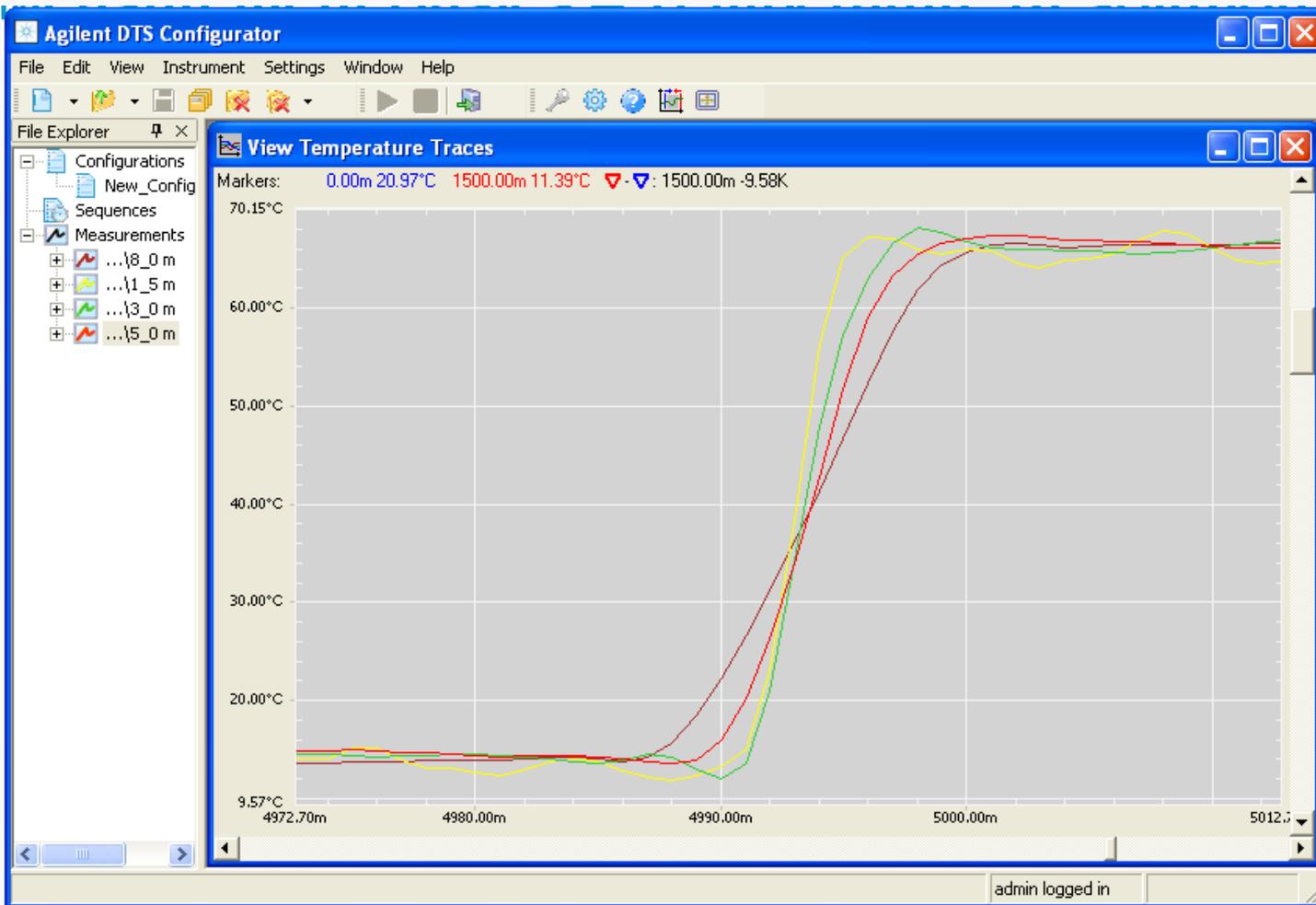
Measurement Basics – Spatial Resolution

Sampling Interval vs. Spatial Resolution



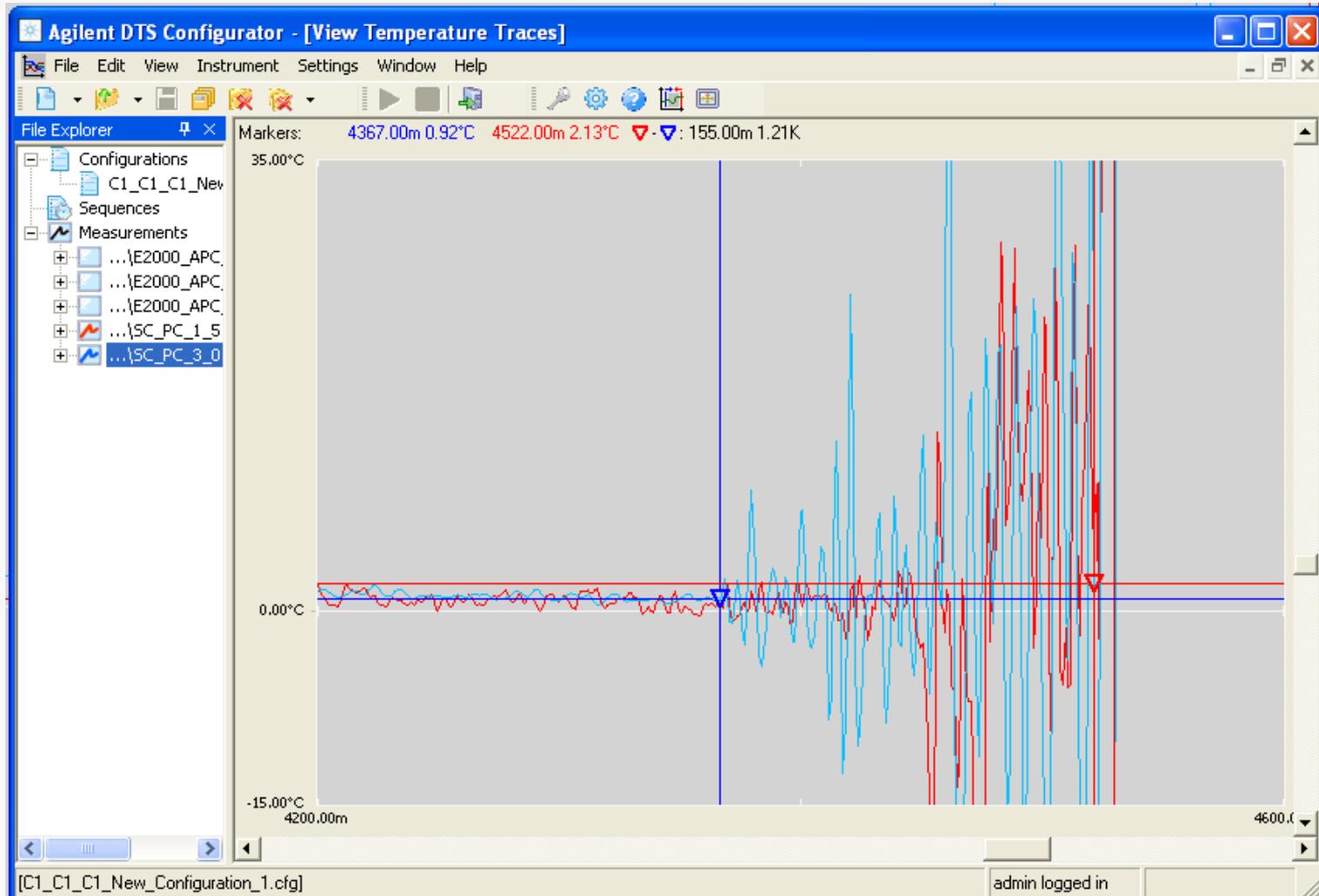
Measurement Basics

Spatial Resolution



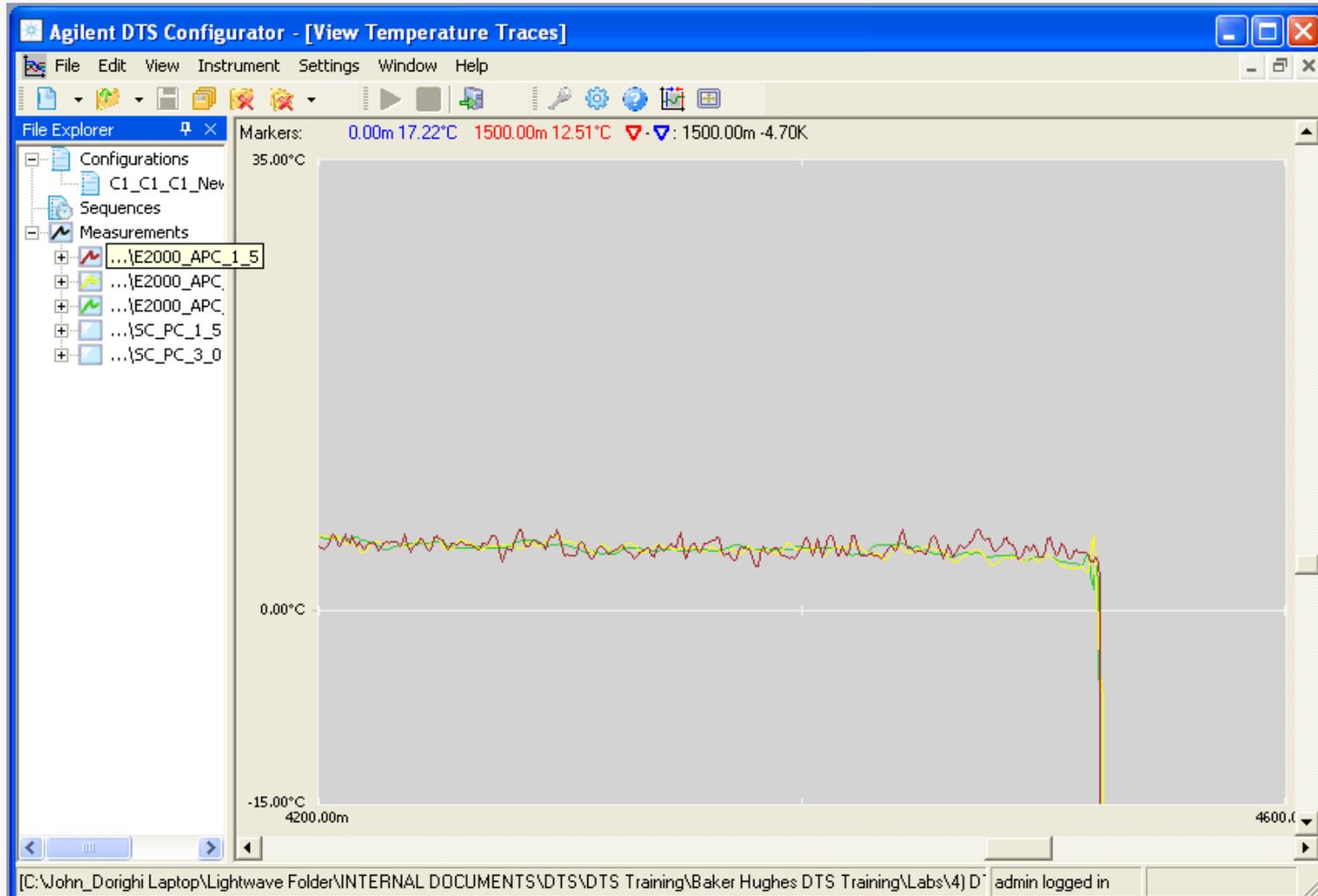
Fiber-End Performance

With rectangular cleave or straight (90 degree) connector



Fiber-End Performance

With properly cleaved (8 degree) angled termination

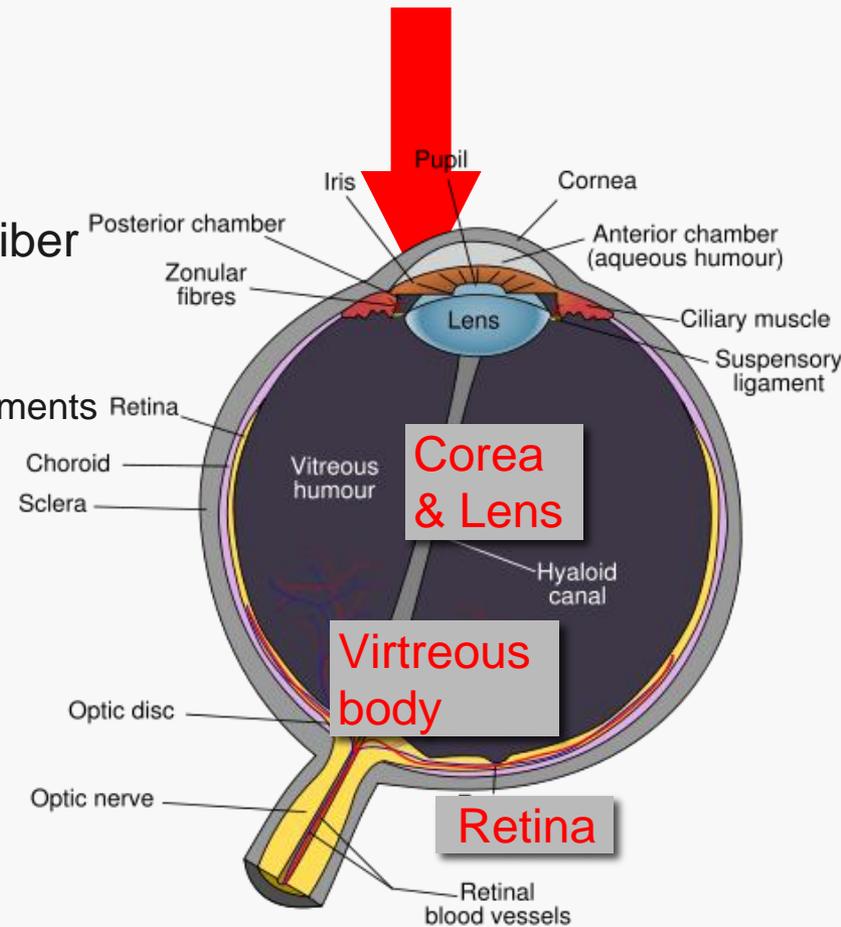


DTS System Operation

Advice

- Make it a habit to never look at the end of a fiber
 - Highest power density along the parallel axis!
 - Class 1M not considered dangerous
 - No special precaution required with AP Sensing instruments

- Keep connectors clean
 - 50 % of instrument repairs are due to bad connectors!
 - Use cleaning tape or
 - Cleaning paper & propanol & compressed air



Module #5

N4386B Linear *Pro* Series

Installation Planning

General Recommendations

- Apart from technical factors and geometric dimensions, the fire load and air flows through natural convection and ventilation shall be taken into account in the project design of the fire alarm systems.
- Good knowledge of the site as well as consultation with the customer about his requirements is beneficial for efficient project design. In addition, precise plans and information about climactic and ventilation conditions are advantageous.
- Please ensure that you obtain suitable information in order to fulfill the detection objective, e.g. the expectations of the customer and the requirements of regulations and specifications.
- Plan Accessible Test & Reference Areas for calibration, commissioning and system revision.

Sensor Cable

Laying sensor cable

- Sensor cable should be laid in one piece as far as possible

Cable length

- Maximum cable length is 12000 m
- Minimum of 20 m sensor cable at the end of the measurement section is required
- Allow for 5 m cable inside the controller cabinet
- One splice means a requirement of at least 2x3 m of additional length
- Test areas, if any, must be taken into consideration

Test areas

- Test areas allow to test the detection system periodically without entering the monitored space.

Recommendation: one test area at the end of the sensor cable (but before the 20 m extra length at the cable end) e.g. located inside a control room.

Control Unit / Zone

Control Unit

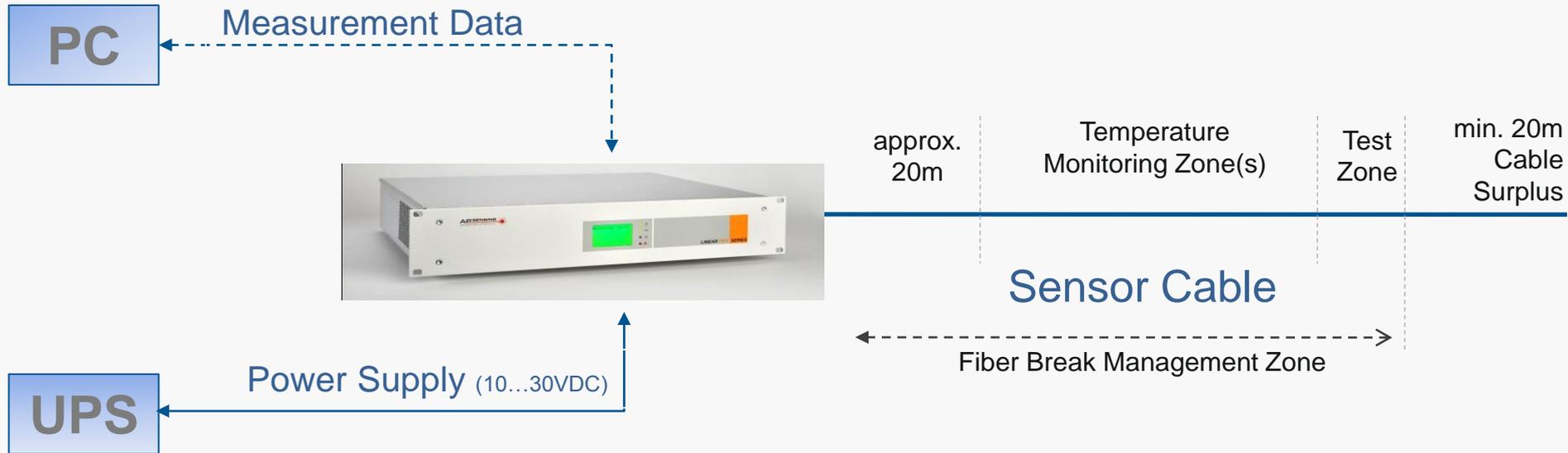
- Install in a suitable 19" control cabinet or an AP Sensing outdoor housing
- Indoor operating environment should be free from dust, dirt and dry
- Temperature inside the cabinet should not be below -10°C or exceed 60°C during operation (Standard Indoor Housing)
- Operating Temperature of Outdoor Extreme Housing: -25 to 60°C or -40 to 40°C
- Outdoor Housing have the Protection Class IP 66 (NEMA 4)

Zones

- Sensor cables are labeled with meter marks
- Zones, with their corresponding mark points, should be recorded in a zone table
- The data is used to configure the zones in the Control Unit. Zones may overlap.

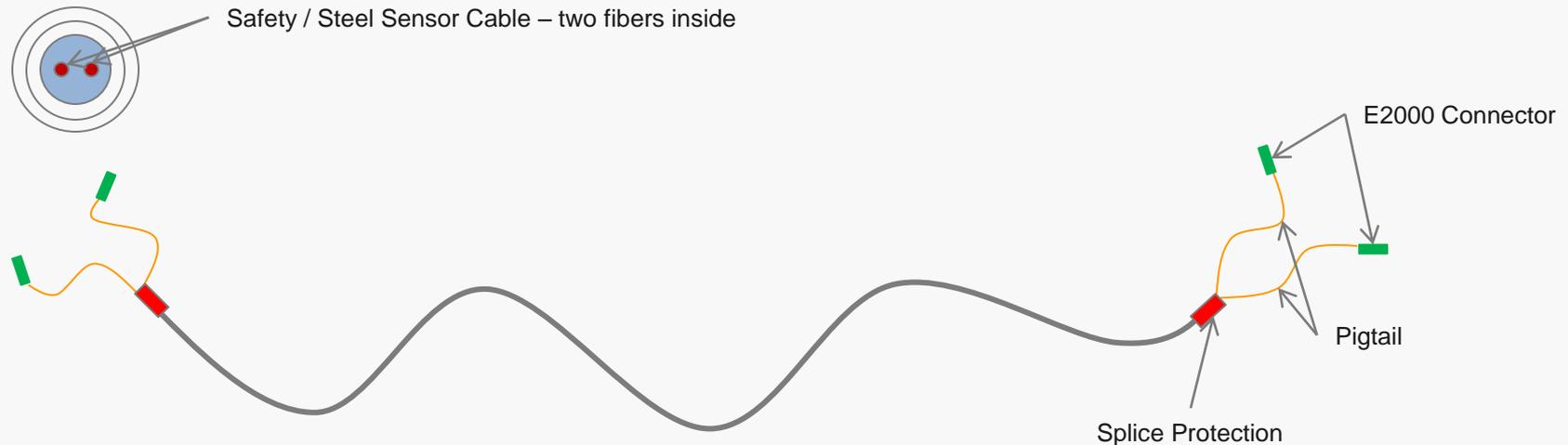
Note: Alarms are ONLY processed within the defined zones!

Simple Setup



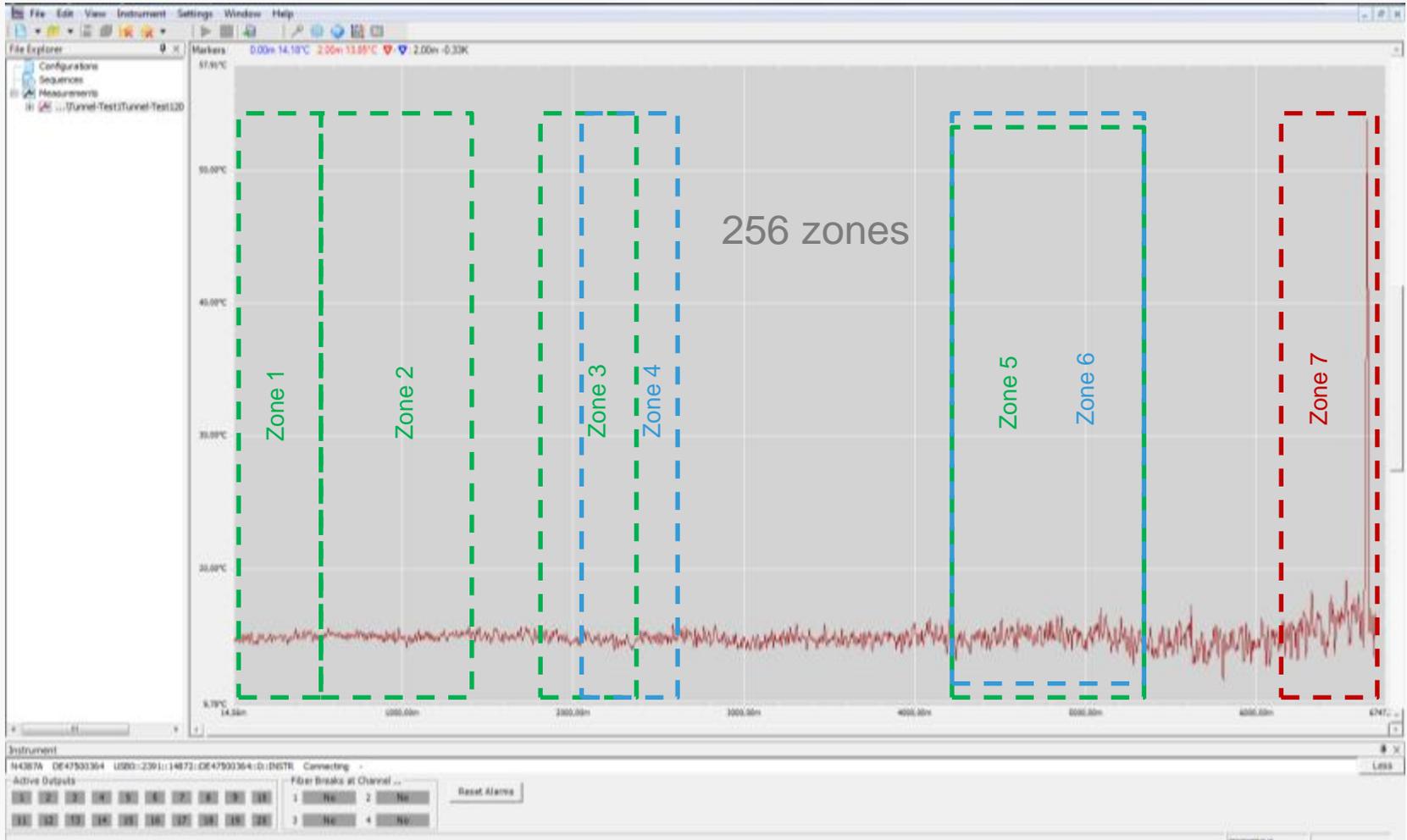
PC = Personal Computer with DTS Configurator
 UPS = Uninterruptable Power Supply or Battery Package
 DTS = Distributed Temperature Sensing instrument

Preassembled Sensor Cable



A **preassembled** sensor cable already comes with pigtails and connectors. Each fiber end (4) of the sensor cable are connected with a **pigtail** and **E2000 connector**. This avoids additional splice works on site and saves time and costs. To enable safe handling during installation the pigtails and connectors are **protected** with plastic tubes. This option is very suitable for short sensor cable length and all installation where the sensor cable will be installed in one run.

DTS – Zone Concept



Module #6

N4386B Linear *Pro* Series

Software Installation

Installation Management PC

1. PC Requirements:
 - Pentium III, 700 MHz CPU, 256 MB RAM, 15 MB free disk space, Ethernet or USB, CD-ROM
 - Windows XP or Windows 7
 - 96 dpi font size
2. To configure the system, 2 software packages are required on the management PC:
 - Agilent Connection Expert
 - DTS Configuration
3. Following additional packages need to be installed - if not already part of PCs installation (also available on installation CD):
 - Acrobat Adobe Reader (to view Manuals)
 - .NET 1.1 C++ Redistributable (DTS Configurator)
 - .NET 2.0 C++ Redistributable (Agilent Connection Expert)

Instrument Set Up and First Measurement

Install Management PC

1. Install Agilent IO Libraries Suite on PC
2. Install AP Sensing DTS Configurator on PC

Connect the Instrument

1. Clean and connect sensor cable to the instrument
2. Power up instrument with 10 to 30V UPS
3. Connect instrument via USB with PC

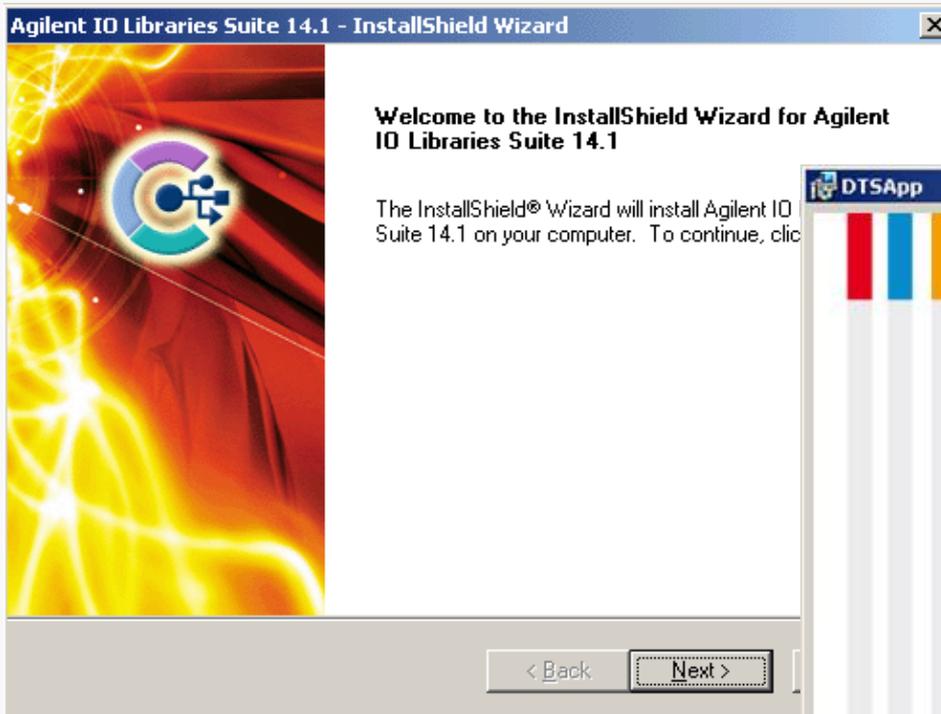
Connect and start 1st Measurement

1. Run Agilent Connection Expert (part of IO Library) and connect instrument via USB or LAN
2. Open DTS Configurator
3. Open a new configuration and simply start the first measurement using default settings

DTS Connectivity

Software Installation and Setup

Lab: Install the Management PC

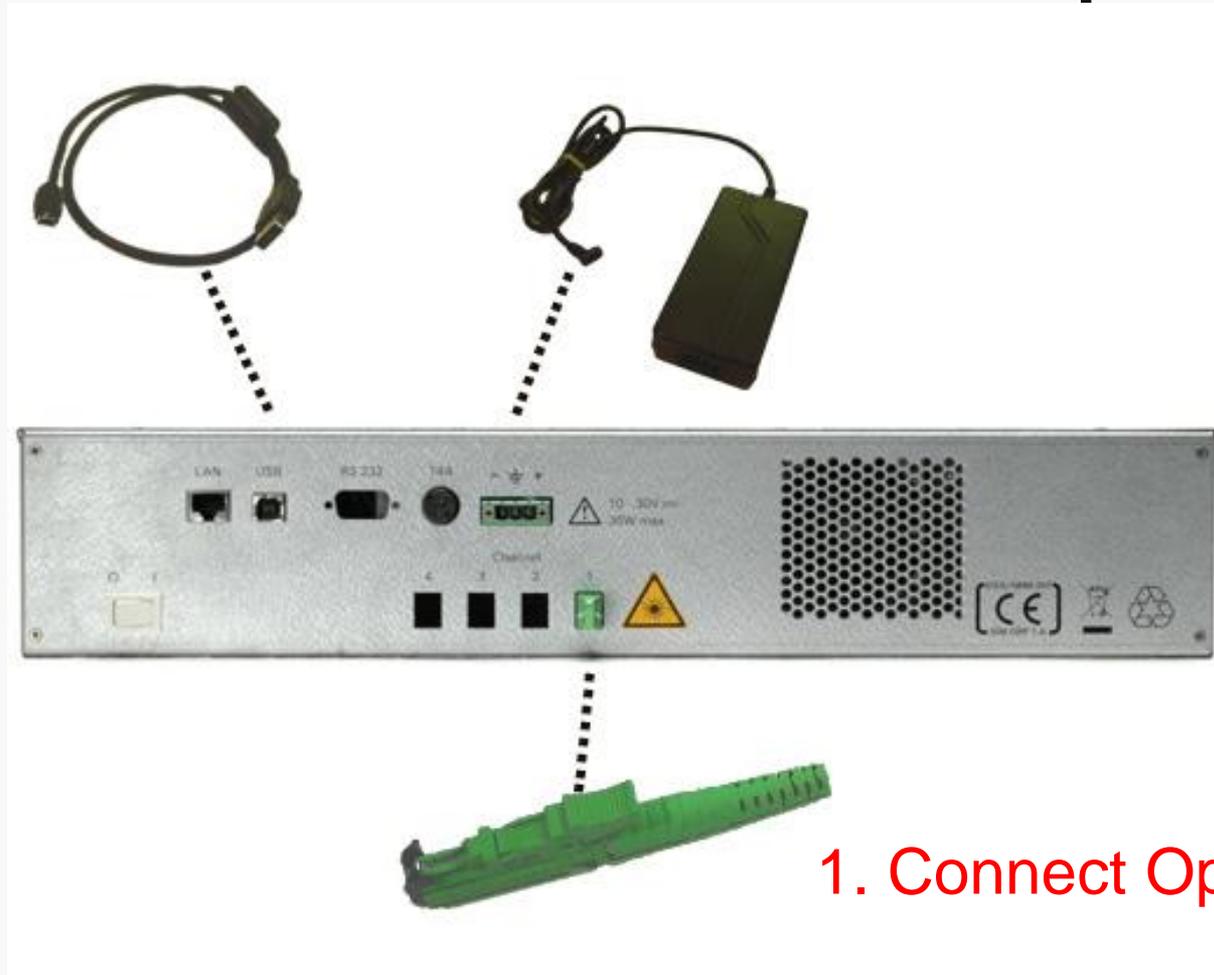


Install *Agilent IO Libraries*

Install *DTS Configurator*



DTS Operation - Installation and Setup



1. Connect Optical Fiber

How to clean an optical connector ?

- It is recommended to clean the optical E2000 connector of the sensor cable before connecting the cable to the system
- What you need:
 - One “Kimtech Science Precisions Wipe”
 - 1-Propanol
 - An E2000 Service Adapter
 - A can with compressed air
- The connector on the DTS is factory cleaned and sealed with a sensor cap. If not removed before connecting to the sensor fiber, no cleaning is required.

Lab: Clean E2000 Plug

DTS Operation - Installation and Setup

3. Connect USB Cable

2. Connect Power Supply

Lab: Connect DTS to PC with USB Cable



1. Connect Optical Fiber

Module #7

N4386B Linear *Pro* Series

Take the DTS in service

1st Measurement

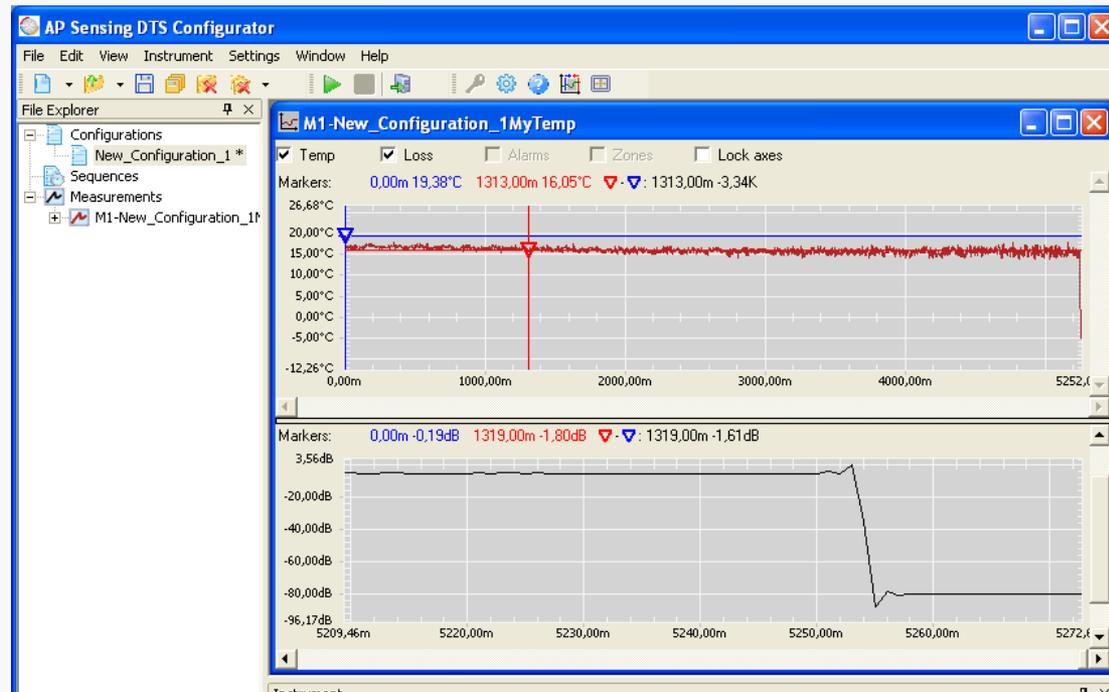
Lab: 1st Measurement

In most cases^[1] it is possible to start an initial measurement with the default settings.

From the results you can:

- See the length of the installed fiber
- Initial un-calibrated temperature reading

[1] The sensor cable length might have to be modified according to ordered measurement range.

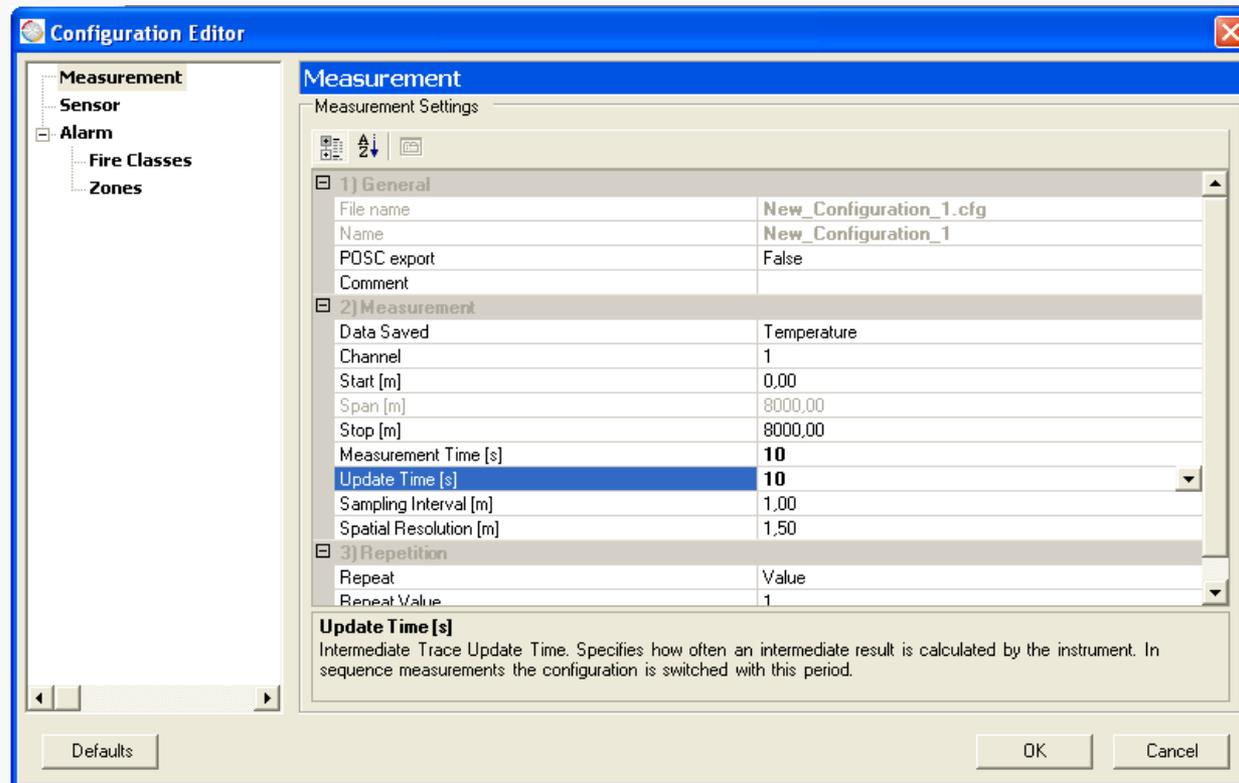


Configuration & Calibration

Lab: Configure your example

The **Configuration Editor** is used to

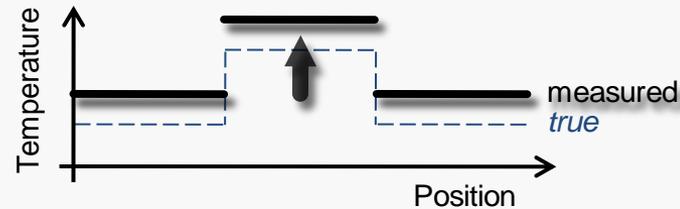
- configure the measurement,
 - calibrate the sensor (if necessary)
- and*
- define alarms



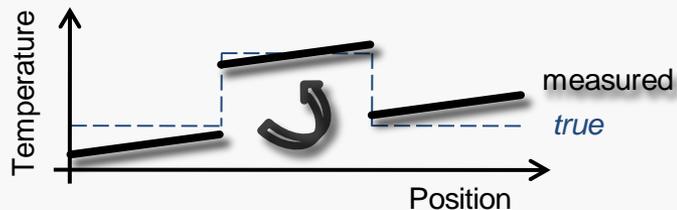
DTS Sensor Calibration

- Each fiber has its own characteristics
- AP Sensing DTS allows combination of different fibers, "Sections"
- 3 Parameters can be calibrated to improve the measurement

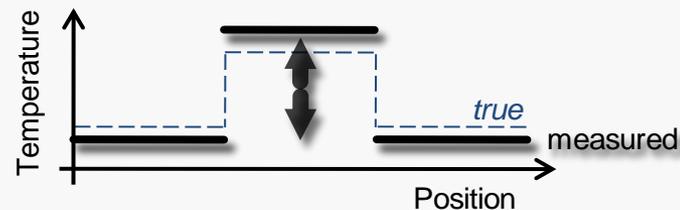
1. Offset (= constant shift)



2. Attenuation ratio (= tilt.) Not required for dual-ended configuration



3. Gain (= stretch) (often not required)



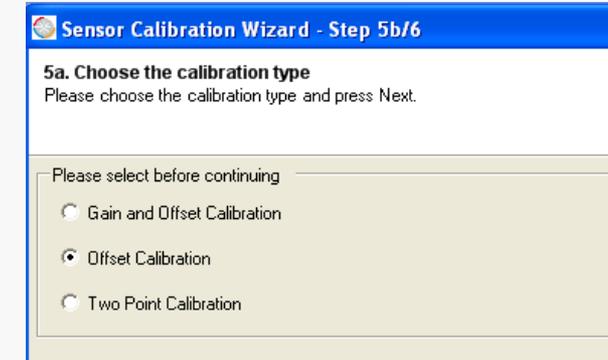
DTS Sensor Calibration

The Sensor Calibration Wizard is designed to guide to the necessary calibration steps:

Two regions of the fiber are at a different temperature.

- The temperature difference must be in the same magnitude as the working range
- Temperature deltas < 25°C lead typically to non sufficient results
- It is possible to use two trace files at different temperatures (sequential Gain/Offset calibration)

Gain and Offset Calibration



- Offset is calibrated
- Gain is calibrated
- Attenuation Ratio is calibrated (optional)

Large portion of the sensor fiber is at a constant temperature

Offset Calibration

- Offset is calibrated
- Attenuation Ratio is calibrated (optional)
- Gain = 1

It is possible to measure the temperature in 2 regions of the fiber

Two Point Calibration

- Offset is calibrated
- Attenuation Ratio is calibrated
- Gain = 1

Dual Ended Configurations

Multi Channel Configurations

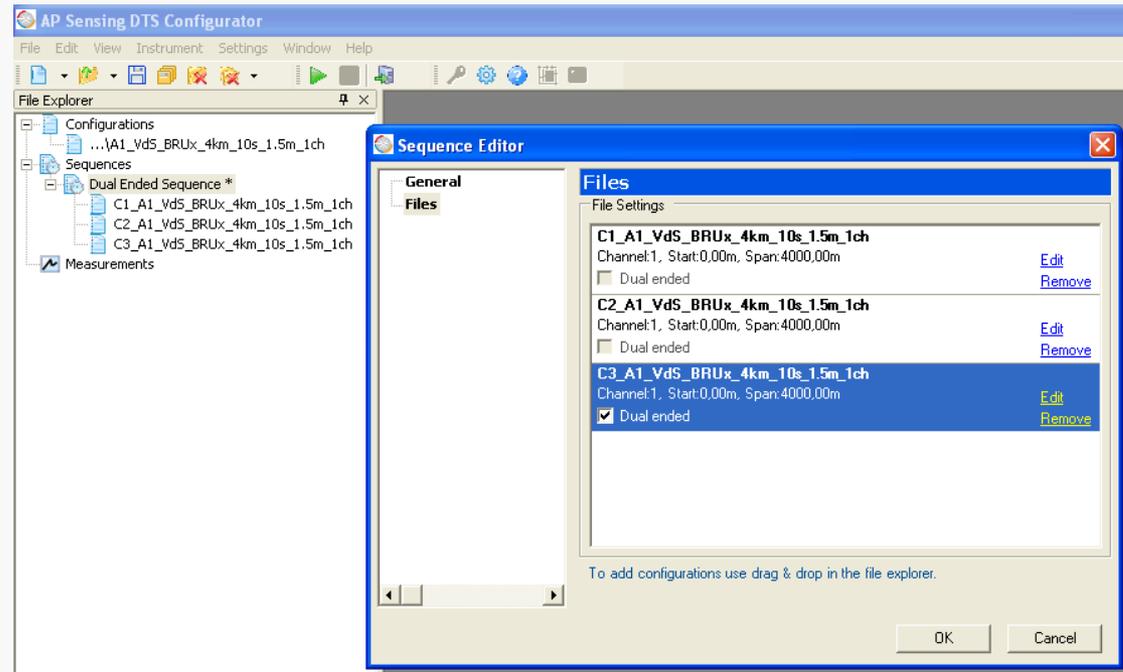
- Dual Ended / Multi Channel configurations are handled as “Sequences”
- Within a sequence the individual configurations will be measured in a sequential mode
- Dual configurations can be only channel 1 & 2 or channel 3 & 4
- Example

Sequence

Channel 1

Channel 2

Channel 3-4 Dual Ended

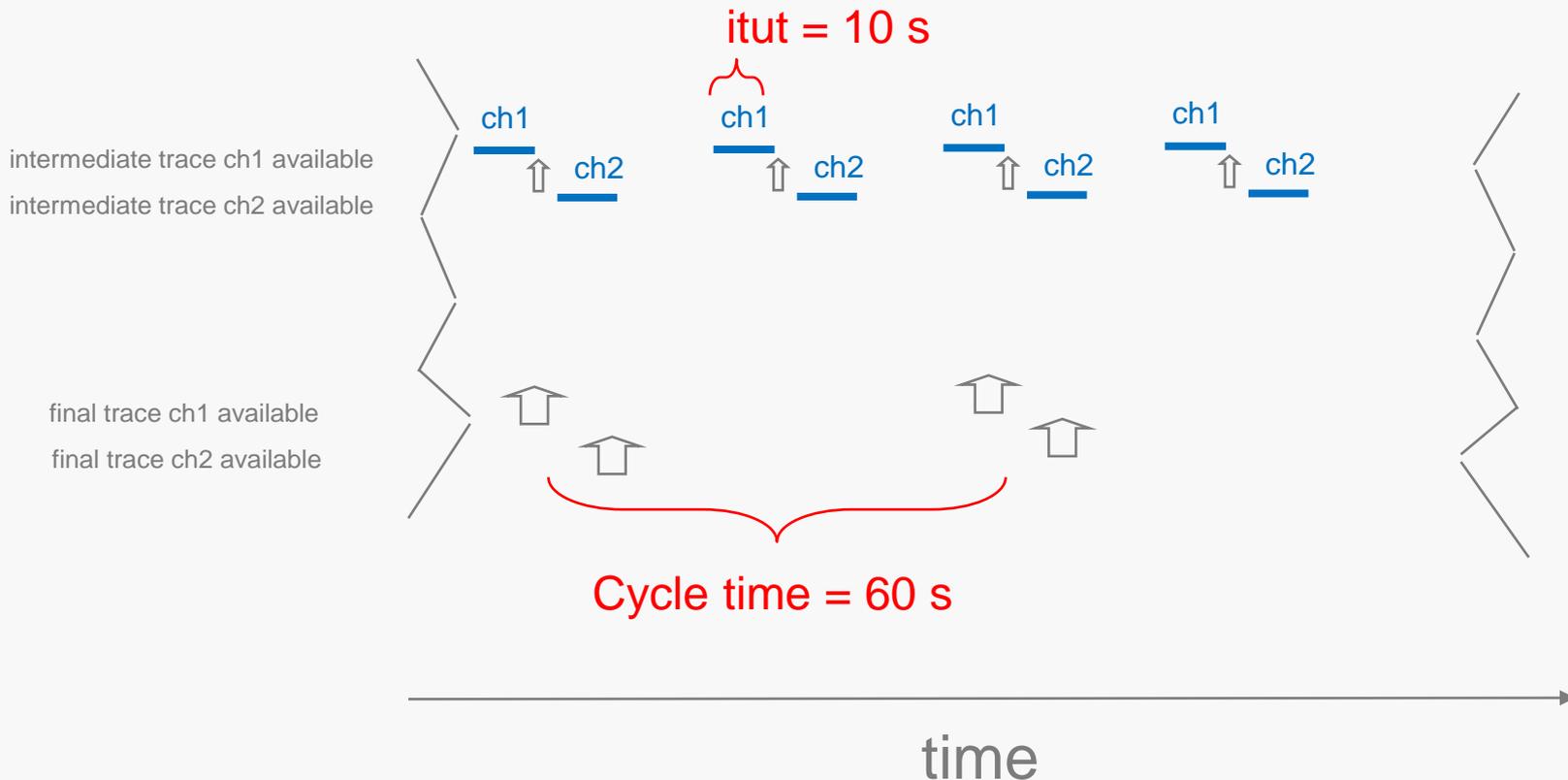


Lab: Configure a Sequence

Sequences

Example: 2 optical port used, single ended

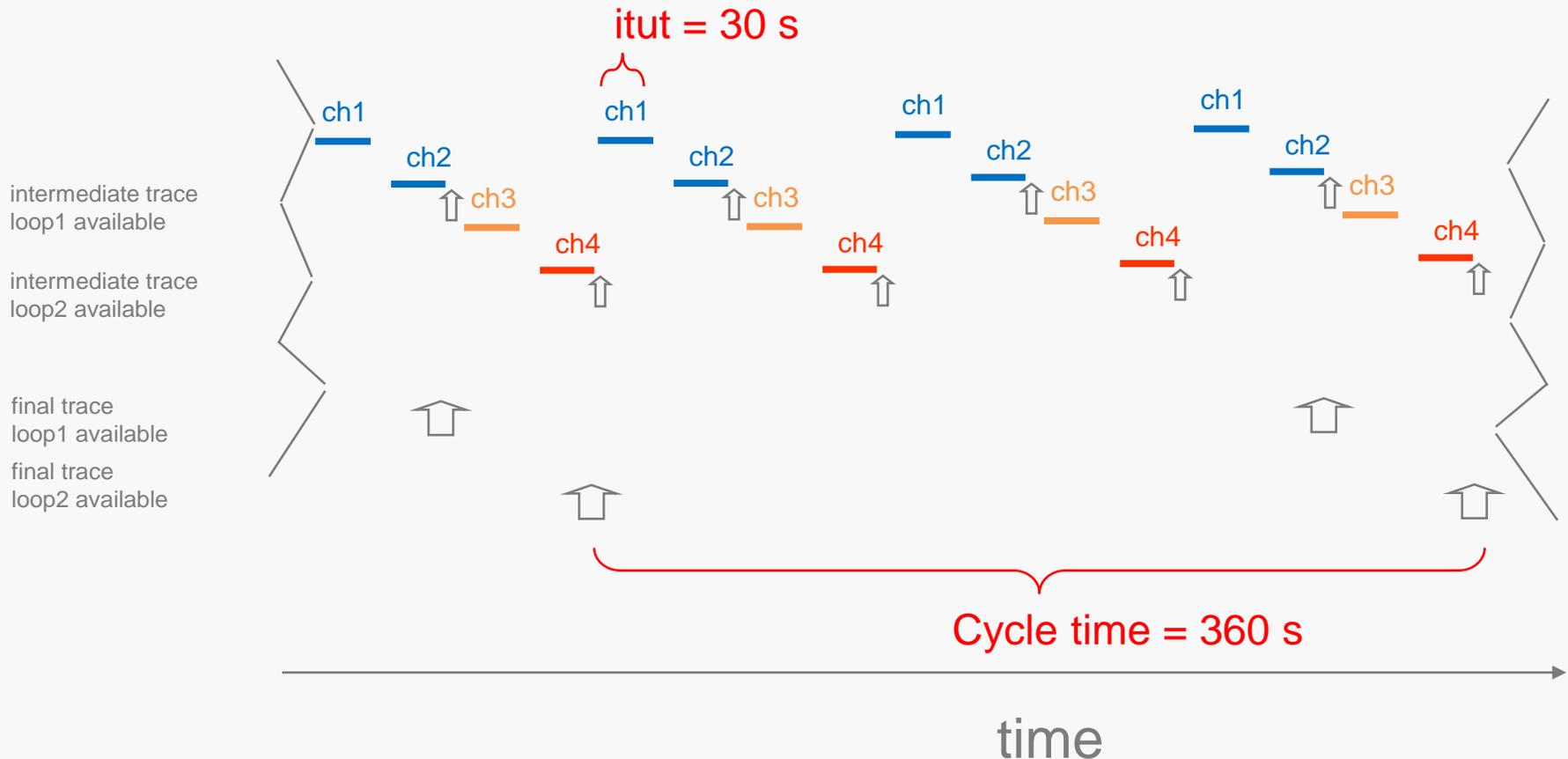
measurement time (mtime) = 3 x intermediate update time (itut)
 measurement time = 30 s and update time = 10 s



Sequences

Example: 4 optical ports used, doubled ended

measurement time (mtime) = 3 x intermediate update time (itut)
 measurement time = 90 s and update time = 30 s



Module #8

N4386B Linear *Pro* Series

Review and Acceptance

Documentation

Following steps are suggested to document and archive a completed installation:

1. Review the installation with site acceptance protocol
2. Archive configuration files:
 - MyConfig.**cfg** File for Single Configuration
 - MySequence.**seq** for Sequences
3. Record and Archive IP addresses and password.
4. Archive a loss trace file for reference.
 - MyLossTrace.**tra**
5. (Do at least one alarm trigger by heating up 2m of test zone at the end of the sensor cable.)
6. (Check the wiring of all relays.)
(they can be switched under Instrument Setting / Electrical In-Out in the DTS Configurator)
7. Check Sensor cable for physical damage.

Lab: Examination and
Performance Test

Lab: Save Configuration
and Trace

Module #9

N4386B Linear *Pro* Series

Troubleshooting & Maintenance

Troubleshooting

- **Check the sensor cable**
 - Use the Loss measurement capability of the DTS
 - Check for fiber breaks (correct fiber length)
 - The cable loss should be about 1 dB per km
 - Check your connectors. The connector loss should be typically < 0.4 dB
 - Check your splices. A splice loss should be typically < 0.1 dB
- **Check the data connection**
 - Use the *Agilent Connection Expert* to search for all connected instruments
 - Send the `*IDN?` command to check the connection.
- **Check the DTS instrument**
 - Check the LED status on the front panel
 - Check the instrument's internal log file using DTS Configurator
 - Is there a valid configuration and is it selected?
 - Is the fiber length span shorter or equal to the sum of the calibrated segments?

Service and Maintenance

AP Sensing's **Linear Pro Series** instruments, due to their unique single receiver design and permanent self check (with its built-in reference coil) are virtually maintenance free. Follow legal requirements for maintenance intervals, otherwise do the following checks once a year:

1. Review the loss trace and make sure that the total loss has not increased since the last instrument functional verification (or the initial instrument commissioning).
2. Archive configuration
3. (Do at least one alarm trigger by heating up a range of cable)
4. Check sensor cable for physical damage - no other sensor cable maintenance needed
5. Take temperatures at known locations, compare with measurement results
6. Use the option Instrument → Read Log File to download the log file. Verify that no error, out of specification, or other unusual event (e.g. fiber breaks) or warnings are recorded in the log file.

Module #10

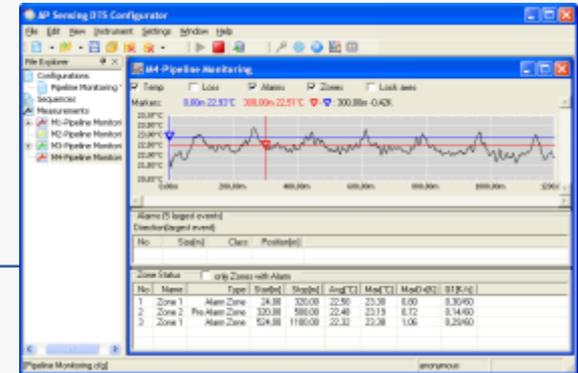
N4386B Linear *Pro* Series

Interface Options

Interfacing Solutions

3rd party applications or Driver (e.g. Labview™)

DTS Configurator
(Windows XP or 7™ application / supplied with instrument)



10-Base-T LAN
(SCPI Protocol or Modbus)

Optional:
DTS Interface Box

Modbus TCP (LAN)



Modbus RTU or ASCII
(RS232 or RS485)



Linear Pro Series

Standard:
USB (SCPI Protocol)

Optional:
4 reset inputs
19+1 internal relay contacts
(flexible assignment)



Controller + N x 8 Relays (up to 256)

Optional:
External Relay Controller
plus 8...256 additional relays

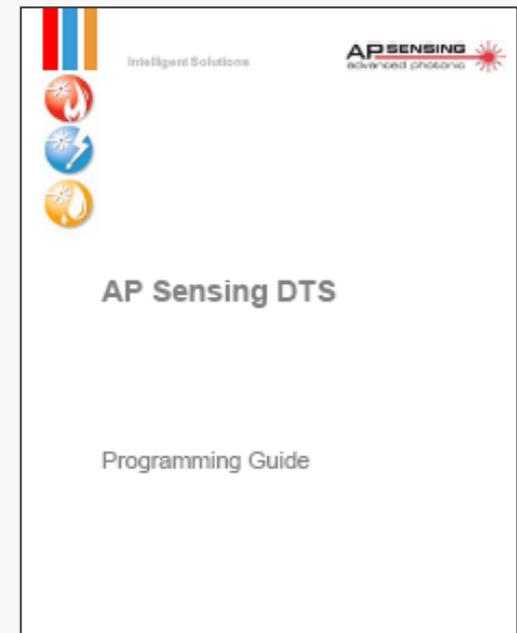
SCPI Protocol

- Fully documented protocol to control all functions of the DTS and read measurement results
- All instruments of the Linear Power Series support SCPI over LAN and USB.
- The **Standard Commands for Programmable Instrumentation (SCPI)** Consortium is an organization whose members share a common commitment to develop a common interface language between computers and test instruments. The SCPI Standard is built on the foundation of IEEE-488.2, Standard Codes and Formats. It requires conformance to IEEE-488.2, but is pure software standard. SCPI syntax is ASCII text, and therefore can be attached to any computer test language, such as BASIC, C, or C++. It can also be used with Test Application Environments such as LabWindows/CVI, LabVIEW, or AGILENT VEE. SCPI is hardware-independent. SCPI strings can be sent over any instrument interface. It works equally well over GPIB, RS-232, VXIbus or LAN networks.

(from www.ivifoundation.org / accessed 23.10.2009)

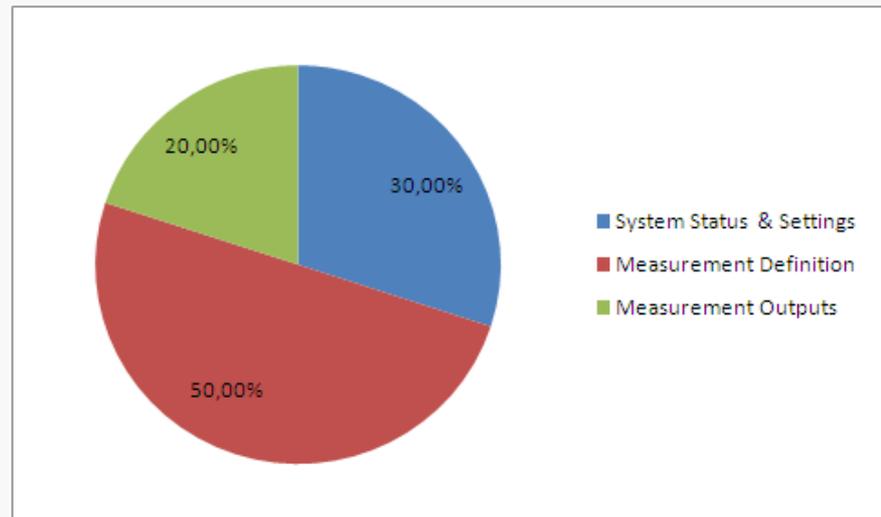
SCPI Protocol – Programming Guide

- All commands are described in the Programming Guide
- System & Status Settings
 - e.g. SYST:ERR?
- Measurement Definition
 - e.g. CONFIGure:MEASurement:SETup:SPAN
- Measurement Out
 - e.g. READout:TRACe:INDex?



SCPI Protocol – Programming Guide

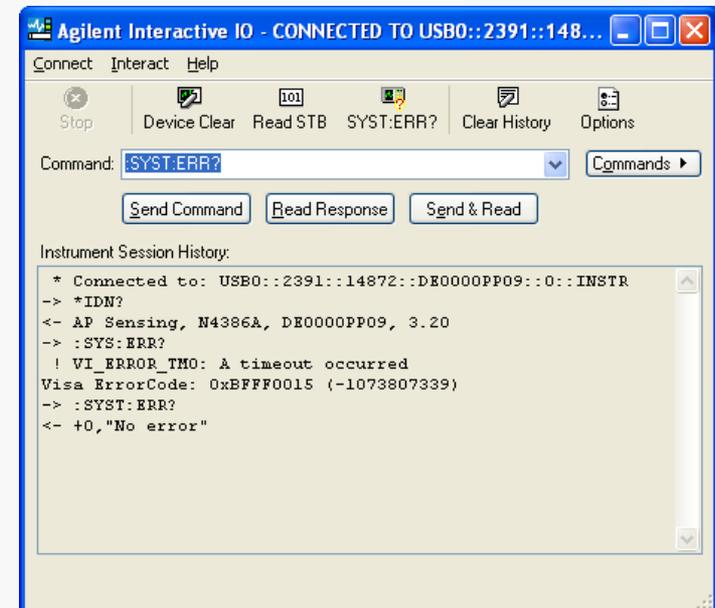
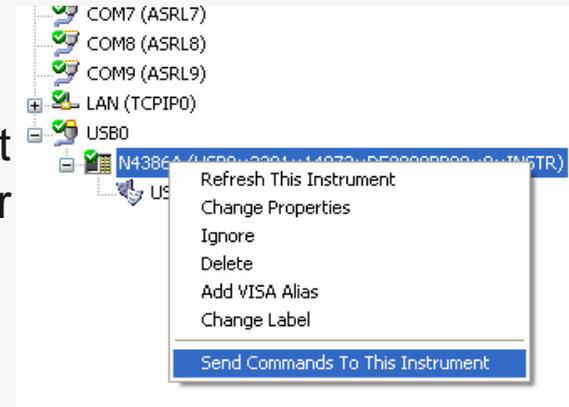
- As the majority of commands is dedicated to the configuration of a measurement, following approach is often realized:
 1. *Define measurement and system settings as (time, IP Address) with DTS Configurator*
 2. *Retrieve Measurements results and system status via SCPI commands*



SCPI Protocol – Command Test

- All commands can easily be tested in the Agilent connection Expert to get a feeling regarding their behavior:
 - Open Agilent Connection Expert and select the Instrument
 - Use the context menu “Send commands to the instrument”

- In the “Interactive IO” it is possible to send commands and view the results.



SCPI Protocol – Status Subsystem

- As many commands do not have an acknowledgement, you have to frequently check the error queue to catch faults and system issues:

- e.g.

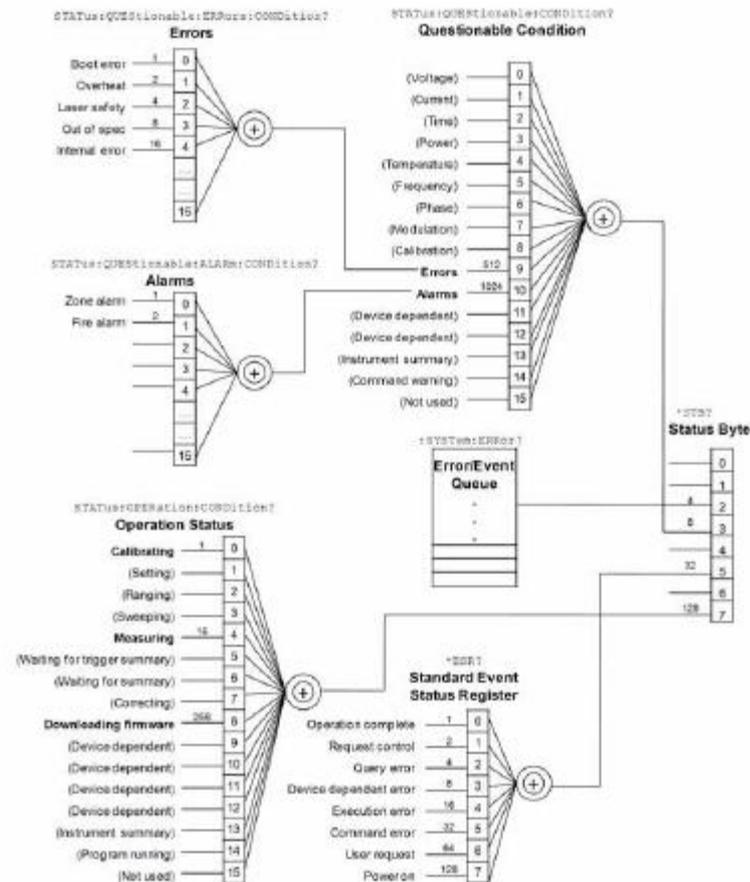
:STATus:OPERation[:EVENT]?

:SYST:ERR?

*STB?

Status Reporting – the :STATus Subsystem

The Status subsystem allows you to return and set details from the Status Model.



Modbus (Slave) Interface

Modbus is a serial communications protocol published by Modicon in 1979 for use with its programmable logic controllers (PLCs).

It has become a de facto standard communications protocol in industry, and is now the most commonly available means of connecting industrial electronic devices.

The main reasons for the extensive use of Modbus over other communications protocols are:

- It is openly published and royalty-free
- Relatively easy industrial network to deploy
- It moves raw bits or words without placing many restrictions on vendors.

Modbus allows for communication between many devices connected to the same network, for example a system that measures temperature and humidity and communicates the results to a computer. Modbus is often used to connect a supervisory computer with a remote terminal unit (RTU) in supervisory control and data acquisition (SCADA) systems

[\[Wikipedia , accessed September 10th, 2010\]](#)

Modbus (Slave) Interface - Principle

Master/Slave Architecture

- Modbus is a Master/Slave Architecture. Typically only the Master is sending out request messages and the Modbus Slave answers to this requests.

→ **AP Sensing Modbus options are read only & slave implementation.**

Coils vs. Registers

- RegisterCoils = Boolean Information 0 / 1

→ for Alarms / Fiber Breaks
- RegisterHoldings = 16 Bit Info = -32715.... +32715 signed numbers

→ for Temperatures

Modbus (Slave) Interface - Variants

There are popular Modbus variants

- Modbus RTU (serial RS232/RS485)
- Modbus ASCII (serial RS232/RS485)
- Modbus TCP (LAN)

AP Sensing's Linear Power Series supports all 3 of them:

N4385B-060 – Internal Modbus TCP Slave

A1100A - DTS Interface Box - **External** Modbus TCP/RTU/ASCII Slave

Modbus is a Master/Slave Architecture. Typically only the Master is sending out request messages and the Modbus Slave answers to this requests. **AP Sensing Modbus options are read only slave implementation.**

Module #11

N4386B Linear *Pro* Series

Internal

Modbus TCP (LAN) Interface

Internal Modbus Interface

Modbus TCP

1. The internal Modbus interface is a Modbus TCP (LAN) interface
2. The following information can be exported over the Modbus interface:
 - Maximum temperature per zone
 - Minimum temperature per zone
 - Average temperature per zone
 - Alarms per zone
 - Fiber Breaks per zone
 - Running trace index
 - Last measurement Time Stamp
 - Complete temperature traces
3. The internal interface is compatible with the external Modbus RTU/ASCII (serial) interface over the DTS Interface Box

Internal Modbus Interface

Modbus TCP

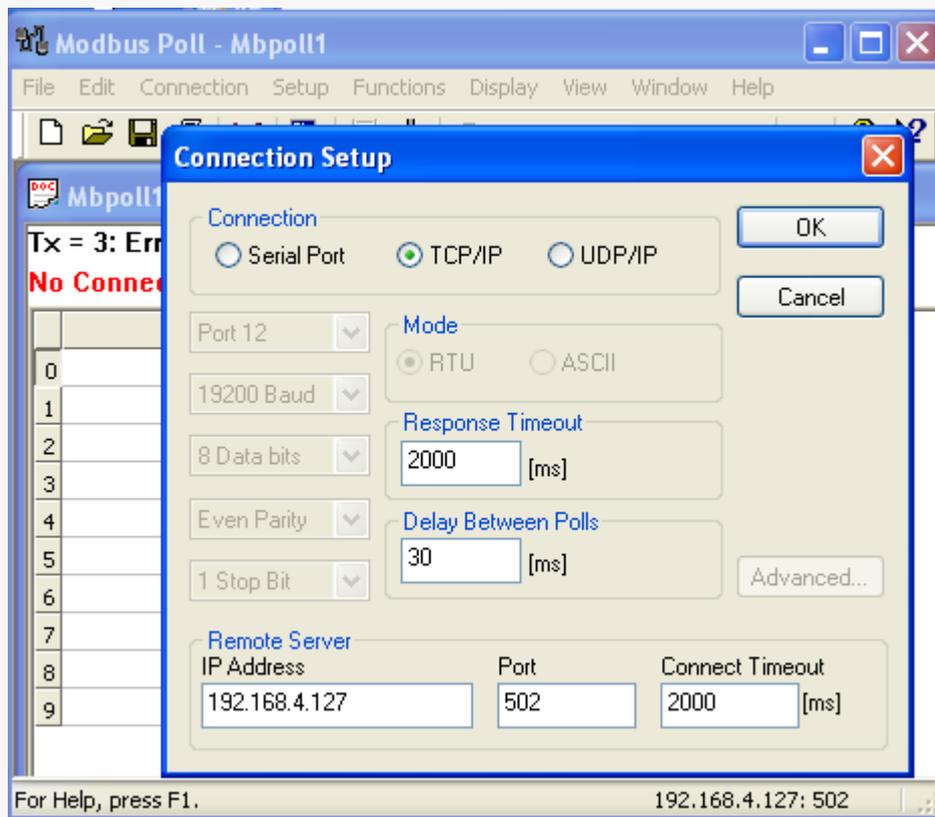
4. The internal Modbus interface is configured with 2 definition files:
 - **RegisterCoil.csv** Configuration of Modbus Registers Coils
 - **RegisterHolding.csv** Configuration of Modbus Registers Holdings

→ The files need to be downloaded with DTS Configurator to the instrument

5. Default configuration files, which serve most DTS applications, are supplied by AP Sensing with every DTS instrument.

Testing the Modbus Export Functionality

- With a Program like “Modbus Poll” the Register Holdings and Register Coils can easily be read



Modbus Test Alternatives

- Modbus Poll
(www.modbustools.com / approx. 129 \$)

Lab: Read temperature values over Modbus

Module #12
N4386B Linear *Pro* Series

Modbus
RS232 / RS485 RTU / ASCII &
External Relay Controller

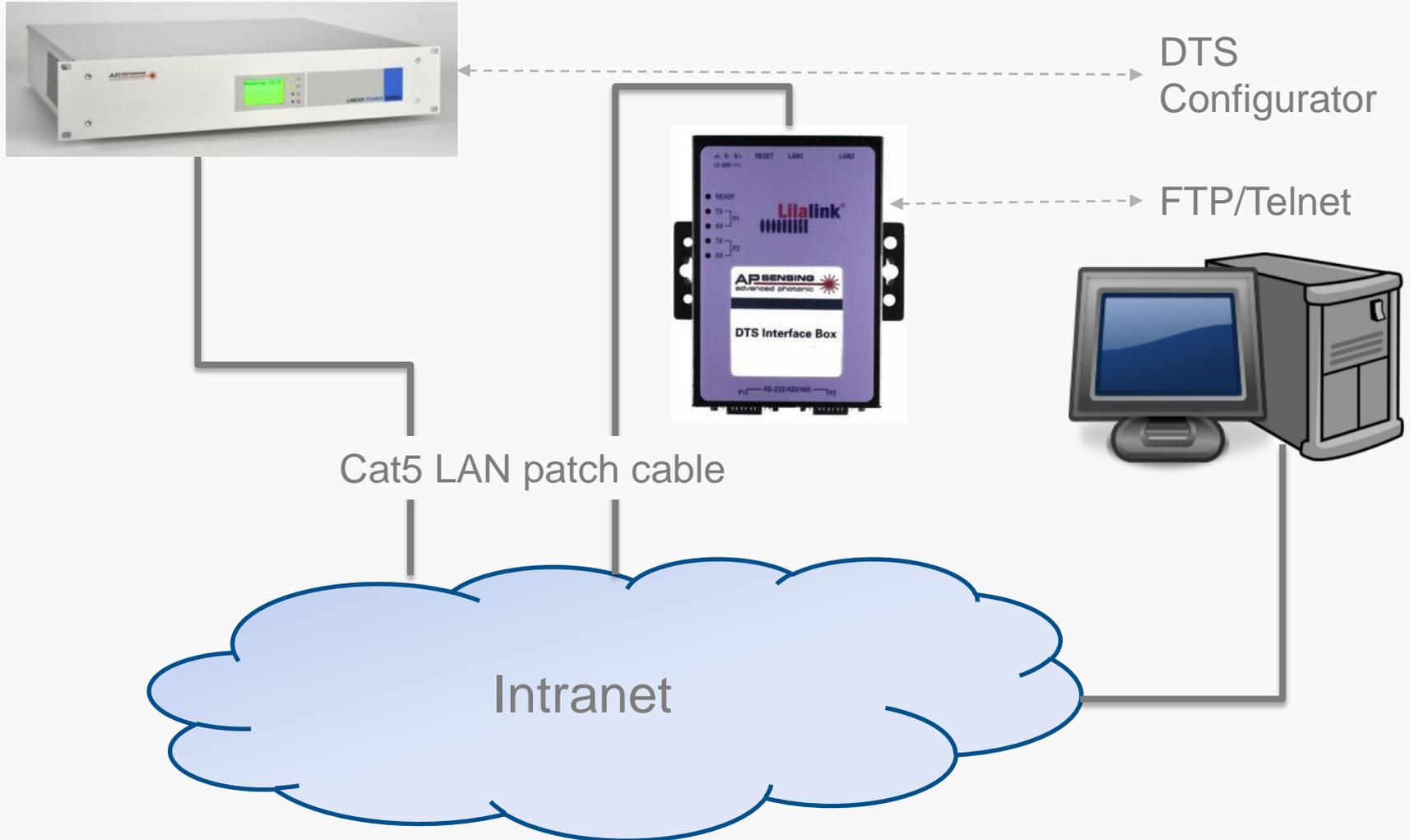
DTS Interface Box Overview

The DTS Interface Box is a powerful and flexible IO extension of AP Sensing DTS systems, providing:

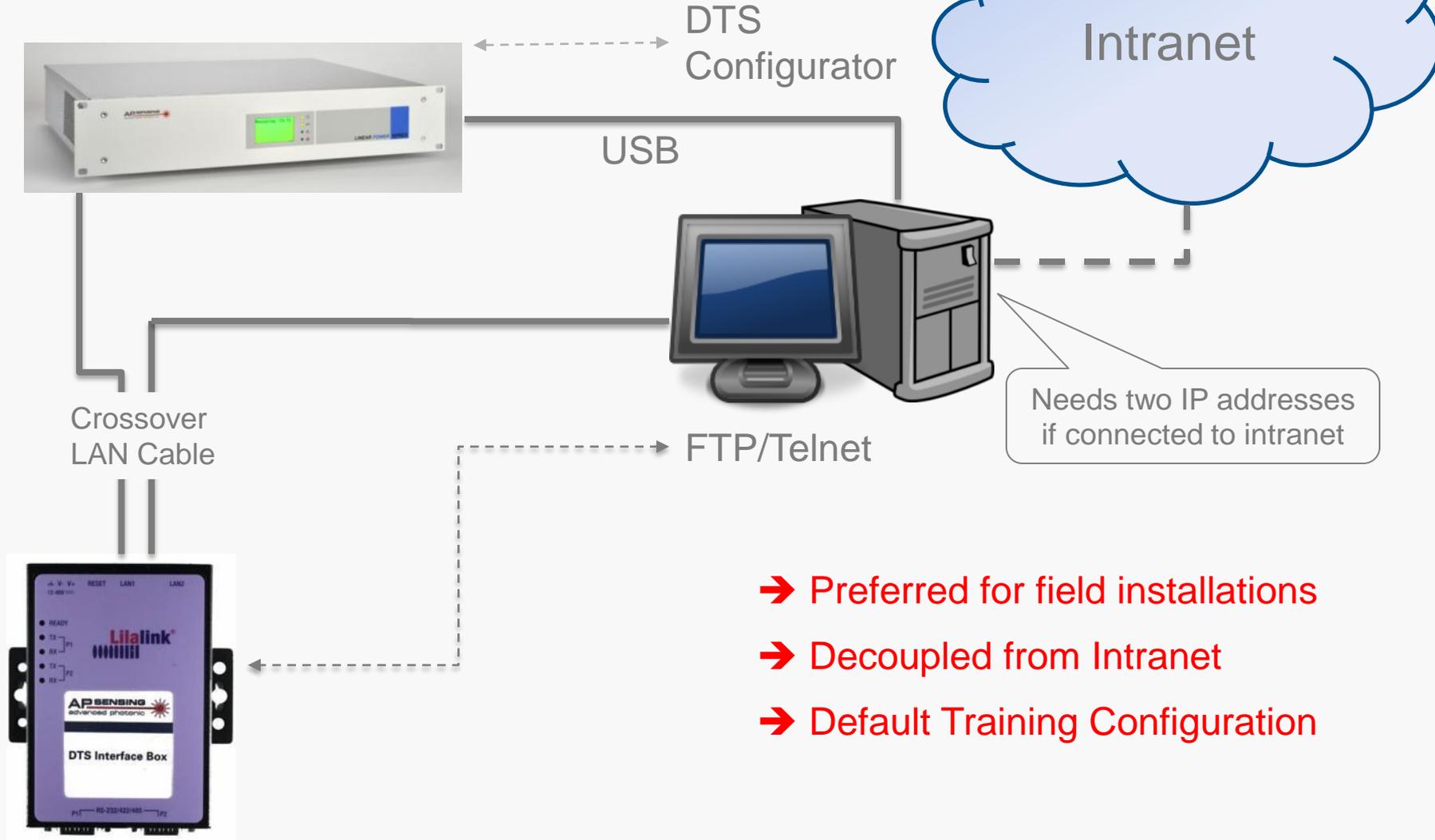
- Up to 256 additional relay contacts
- A Modbus slave interface (TCP/IP or RS232/485) to SCADA Applications
 - *Modbus TCP (LAN)*
 - *Modbus RTU (RS232/485)*
 - *Modbus ASCII (RS232/485)*



Configuration #1 (LAN)

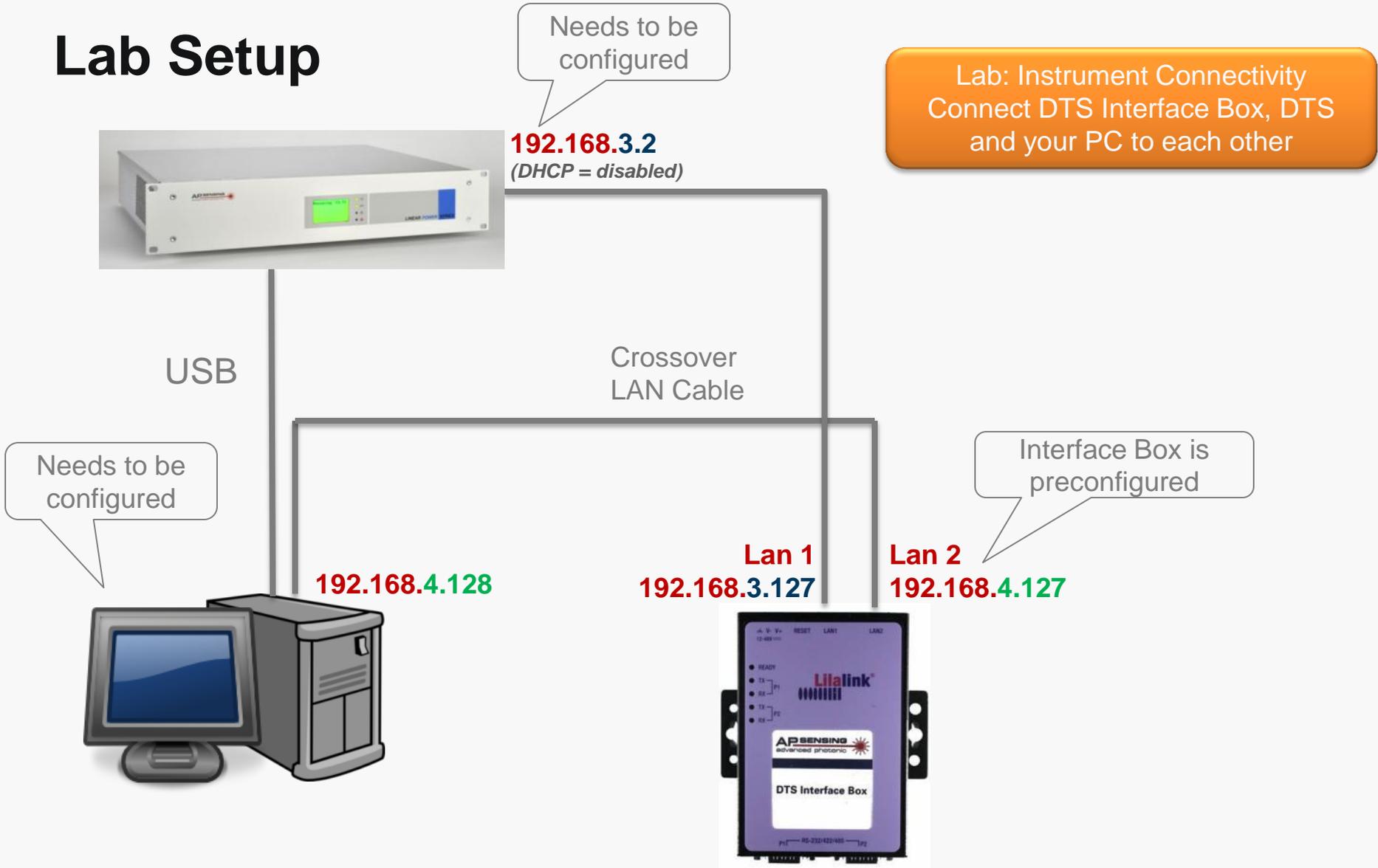


Configuration #2 (Crossover)



- ➔ Preferred for field installations
- ➔ Decoupled from Intranet
- ➔ Default Training Configuration

Lab Setup



DTS Interface Box

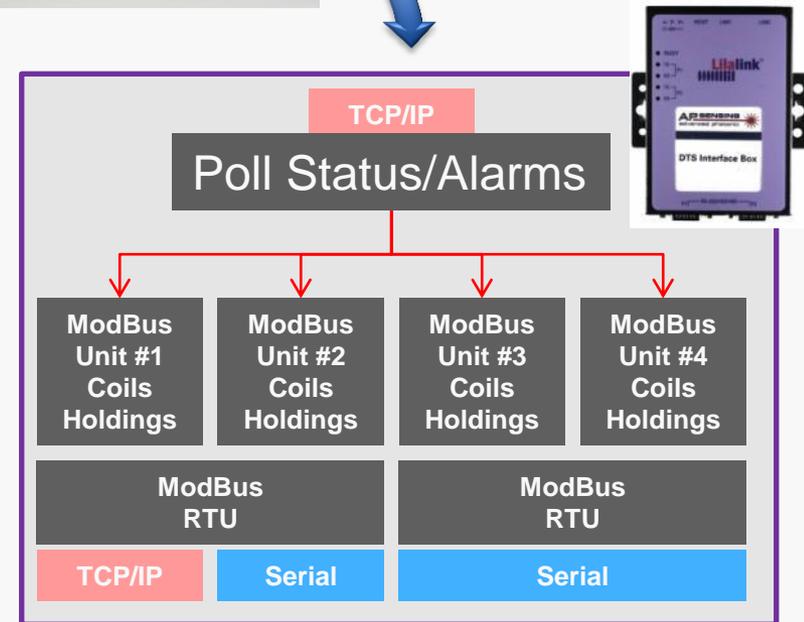
Operating Principle



1. The Interface Box is constantly polling the alarm and status information from the DTS system.
2. The received information is saved in Modbus compatible registers:
 - “Register Coils” True/False registers
 - “Register Holdings” Integer Values

Each Interface Box has 4 virtual Modbus Units implemented.

3. Optionally, received alarms can be communicated to an external alarm controller to trigger external relay contacts.



DTS Interface Box - Deliverables

DTS Interface Box
A1100A



plus 1 x X-LAN cable

DTS Relay Controller
A100A



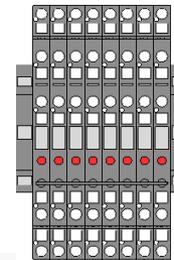
FieldBusController



8x Digital IO



EndModule
Required to terminate
the digital bus.



8x Relay

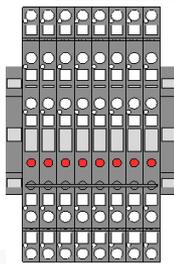


230 VAC / 24VDC 5A

DTS Extension
Set A1201A



8x Digital IO



Power Supply
A1202A



Relay Extension Set

- Comes with
 - 8x Digital Outputs
 - 8x Relays
 - Bridge 8x
 - Jumper

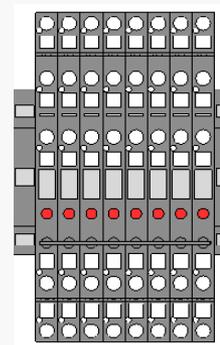


8x Digital IO



Jumper

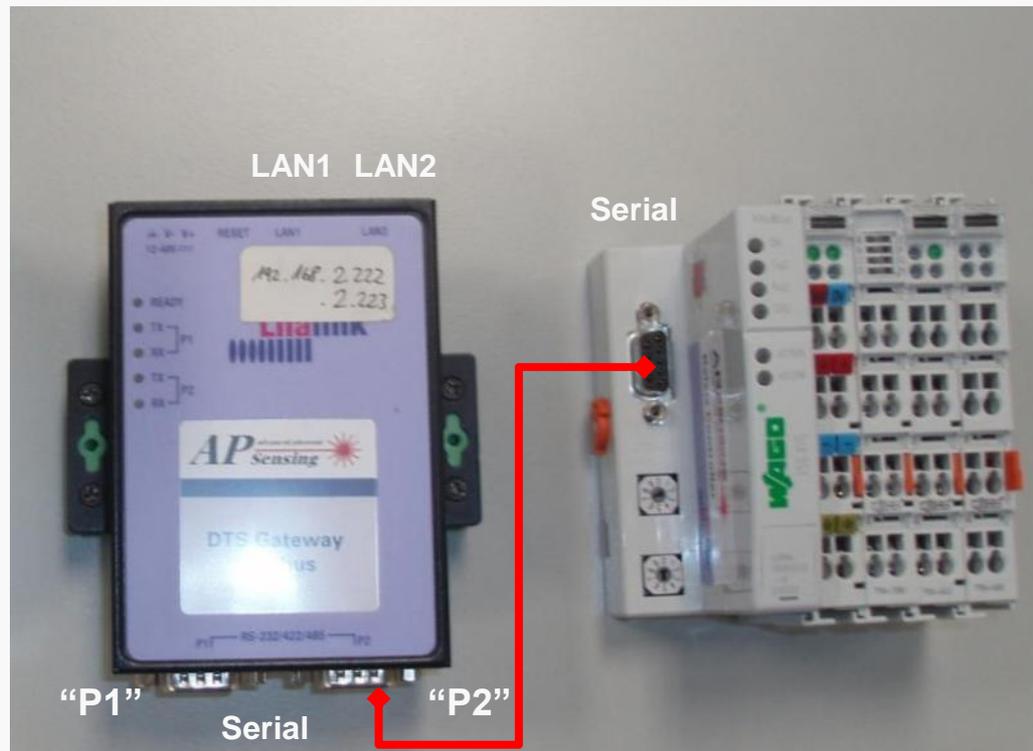
Bridge 8x



8x Relay

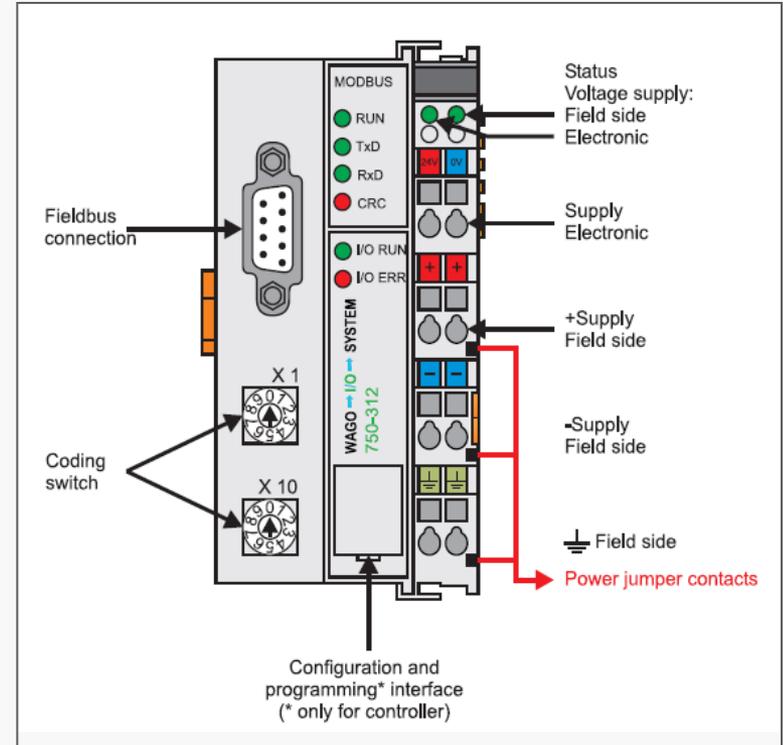
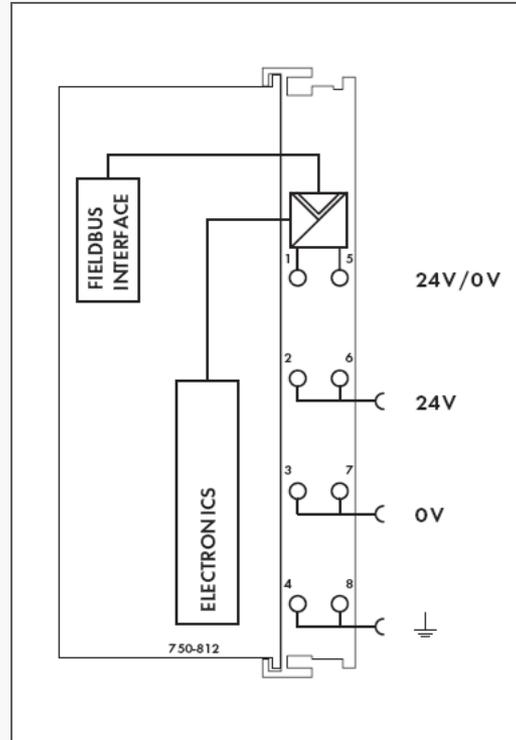
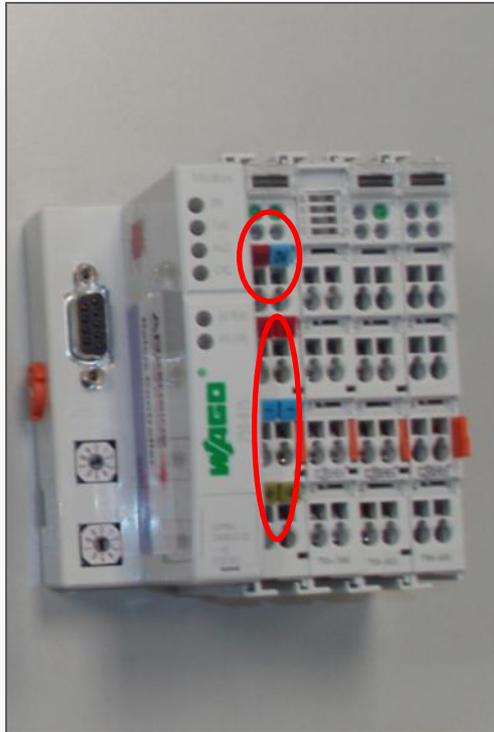
Serial Connection

Connect Interface Box to external additional relays



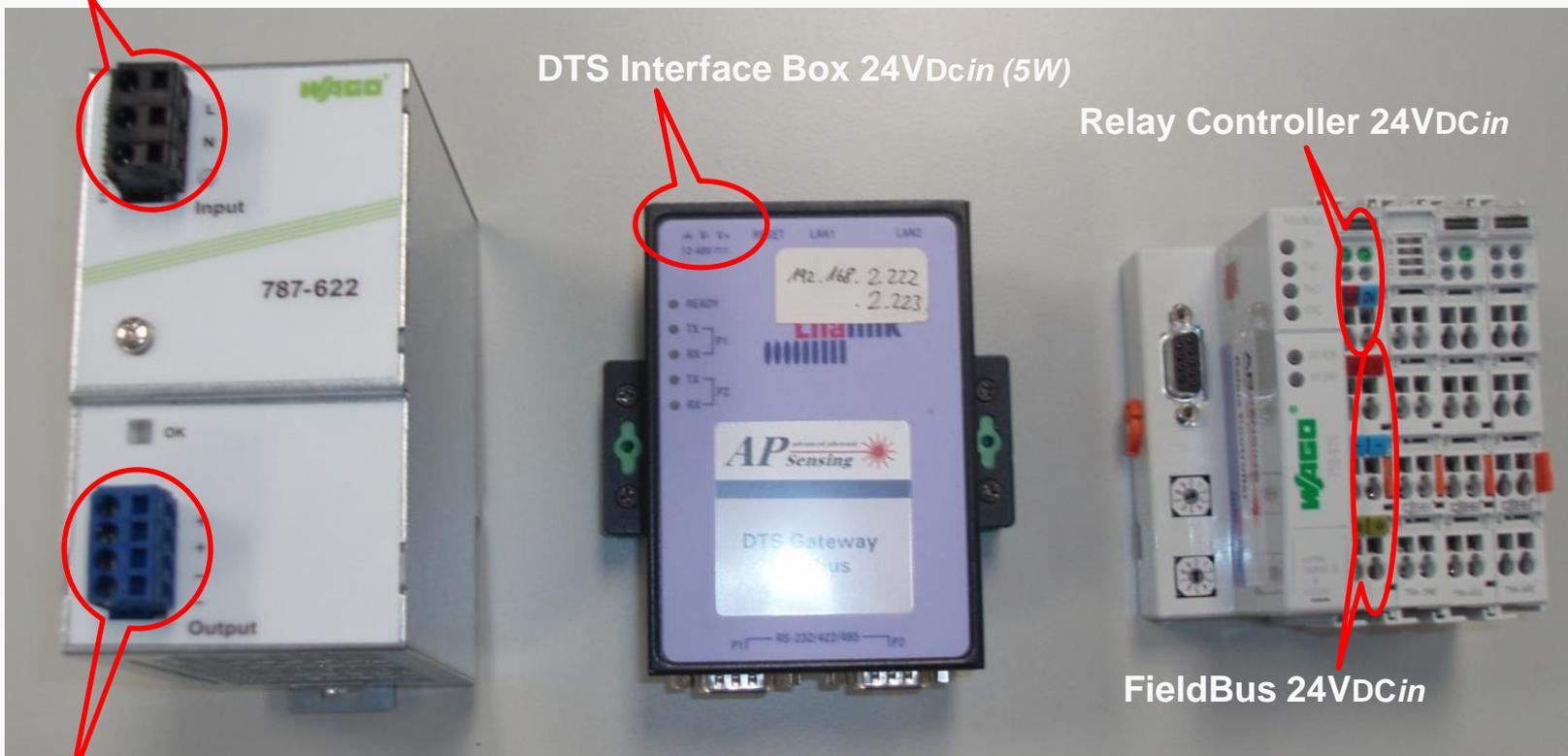
- *Serial Connection Cable - supplied with EXTERNAL (ADDITIONAL) RELAYS Set*

External (additional) Relays / FieldBus Controller



Power Connections

230VAC Power Connection (typ 1.2A & 230VAC)



24VDC Outputs



- *Make all connections in accordance with local requirements & regulations and add circuit breakers / fuses as required.*
- *Power cabling not supplied.*

DTS Interface Box / Relay Controller Parameters

1. Power Requirements:

- DTS Interface Box Power 12-48VDC / 340mA @ 12V; 90mA @ 48V
- DTS Relay Controller Power 24VDC / 340mA @ 24V
plus 25 mA per Digital IO Card
plus 25 mA per Relay
- DTS Interface Box Power 12-48VDC / 340mA @ 12V; 90mA @ 48V

1. DTS Interface Box and external Relay Controller are not Part of the VdS Certification:

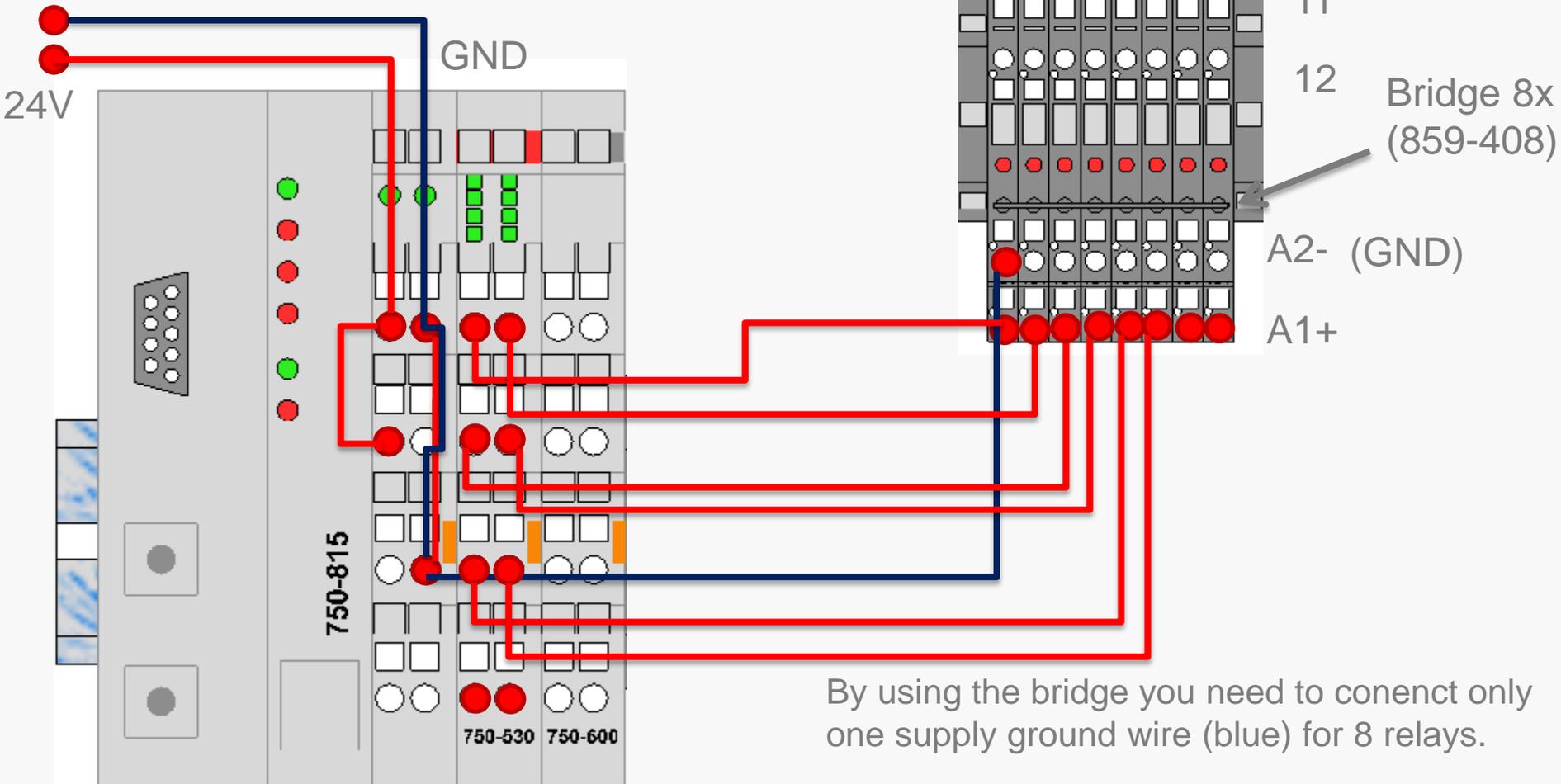
- ➔ Always use at least one internal master - relay per zone on the DTS unit for direct connection to fire alarm panel.



2. Temp. Range 0 ... 55 ° C / 5% to 95% r.h. (non-condensing)

Cabling

Supply 24 V DC (Digital Bus + FieldBus)



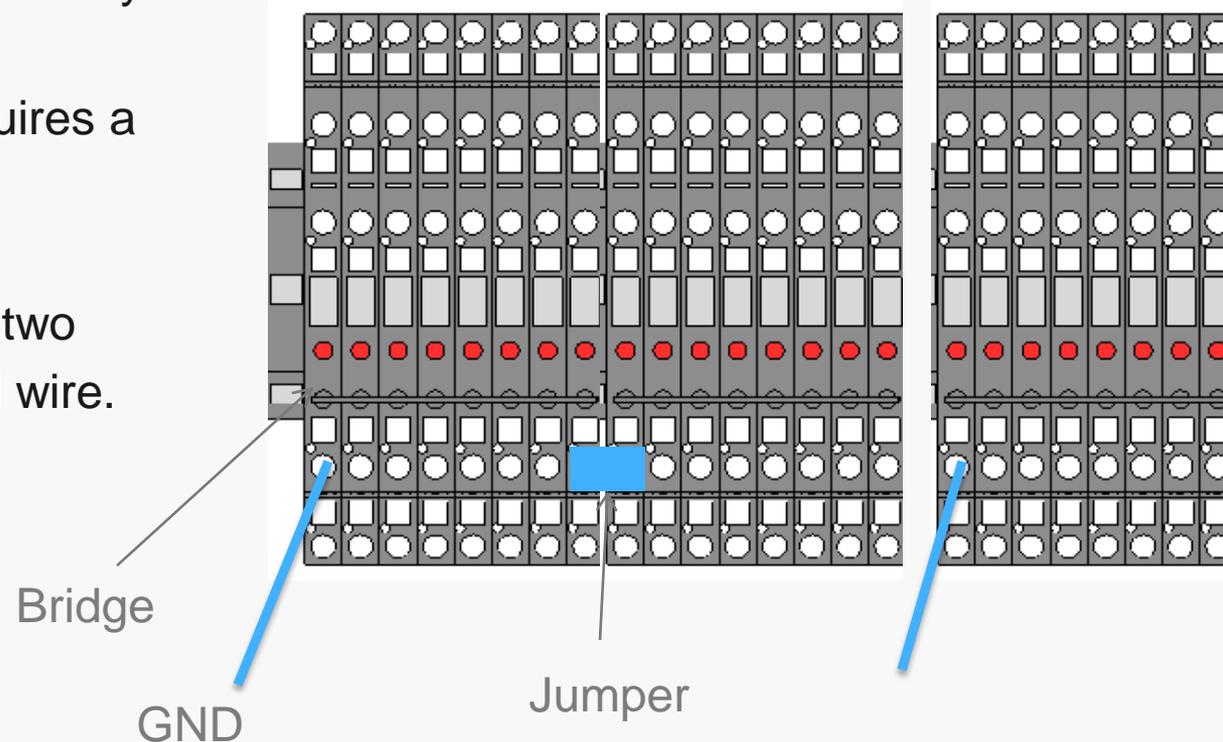
By using the bridge you need to connect only one supply ground wire (blue) for 8 relays.

Using the Bridge 8x and Jumper

Use the Bridge to connect 8 Relays

Each Block of 8 Relays requires a ground wire.

Use the Jumper to connect two blocks and save the ground wire.



Default Modbus Interface Setup

LAN Setting of the DTS needs to be configured
Instrument → Settings → Communication

X-LAN Cable



192.168.4.128

LAN Setting of Modbus Master on the PC (SCADA – System) needs to be configured

Lan 1
192.168.3.127



Lan 2
192.168.4.127

LAN Setting on the Interface Box is preconfigured

192.168.3.2
(DHCP = disabled)



DTS Interface Box Configuration

1. DTS Interface Box is configured with 1 x setup and 3 x configuration files, which are read upon startup of the unit.
 - **dtsgw.ini** Setup File
 - **RegisterCoil.csv** Configuration of Modbus Coils
 - **RegisterHolding.csv** Configuration of Modbus Holdings
 - **IOBox.csv** Configuration for external Alarm Controller
2. Files can be edited with a standard text editor and are copied with FTP onto the unit.
3. Changes are active after reboot
 - Log onto the Interface Box via Telnet session and enter “reboot” or
 - Unplug and plug the power adapter of the Interface Box.

DTS Interface Box Configuration

Read/Write of Configuration Files

1. Open an FTP connection to the DTS Interface Box:
 - The user is always: root
 - The password is always: 3579
2. Copy the Files to your PC / Save a backup copy
3. Change configuration as needed
4. Copy files back to the Interface Box
5. Restart the Interface

Lab: Install "T-Setup"

Lab: Read and Write Configuration Files

FTP Alternatives

- FileZilla
- FTP Utility of the DOS Command Shell
- TotalCommander (approx.. 30€)

“T-Setup”



192.168.3.2
(DHCP = disabled)



LAN 1
192.168.3.127

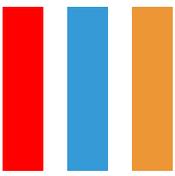


To remote
control room



Thank you!





Intelligent Solutions

AP SENSING
advanced photonic 



AP Sensing DTS

Programming Guide

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1 Introduction to Programming

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This chapter introduces some background information that may help you when programming distributed temperature systems. You can find general information about SCPI commands here, and lists and descriptions of some useful IEEE standard common commands.

Command Messages

A command message is a message from the controller to the distributed temperature system. The following are a few points about command messages:

- The commands are case-independent.
- The parts in upper-case characters in the command descriptions must be given. The parts in lower-case characters can also be given, but they are optional. It is possible to mix mandatory and optional parts of the commands.
- The parts in brackets [] in the command description can be given, but they are optional.
- {?:?} denote “subopcodes”:
These are used as indices.
The {?:?} has to be replaced with the number indicating the subopcode.
The default value is 1.
- In the syntax descriptions the characters between angled brackets (<...>) show the kind of data that you require. You do not type these brackets in the actual command. “<wsp>” stands for a white space character.
- A command message is ended by a line feed character <LF> or carriage return and line feed characters <CR><LF>.
- Leading colons can be omitted.
- Several commands can be sent in a single message.
The leading colon can only be omitted from the first command of several sent in a single message.
Each command must be separated from the next one by a semicolon “;”.
Commands starting with a * cannot be sent together, and must be sent individually.
- Some commands are only permitted in certain instrument states. For example, it is not allowed to change settings while a measurement is running.

Units

Where units are given with a command, usually only the base units are specified. The full sets of units are given in the table below.

Table 1 Units used with commands

| Unit | Default | Allowed Mnemonics |
|---------|---------|-------------------|
| meters | M | M, KM |
| seconds | S | S |

The default unit of length is usually m.

Temperatures are in degrees Celsius, temperature differences in Kelvin.

Units are not case sensitive.

Differences between A- and B-versions

This guide list the programming commands for both the A- and B-versions, and for the Multi Sensor Board option (Option -052).

A note is made in the description of commands that are not applicable to all versions and options.

Please also note the following differences:

- The possible values for measurement spatial resolution are different for the A- and B-versions.
`:CONFigure:MEASurement:SETup:SRESolution:VALues?`
returns a list with the valid values.
- You must set a measurement update time
`(:CONFigure:MEASurement:SETup:UPDatetime)` for B-version instruments.
- Commands related to the relay boards for the A-version use one bitmap value, for the B-version these use two bitmap values.

Trace array

The distributed temperature system can load up to 150 traces (A version) or 120 traces (B version) into a ring buffer that is cleared at the start of each measurement and when the instrument is switched off. These traces form a trace array. One of the entries in this array is always the current entry. Most operations work on this entry.

Data

With the commands you give parameters to the distributed temperature system and receive response values from the distributed temperature system. Unless explicitly noticed these data are given in ASCII format (in fact, only the trace data are given in binary format). The following types of data are used:

- **Boolean** data may only have the values 0 or off, or 1 or on. In replies, 0 or 1 are returned.
- **Float** variables may be given in decimal or exponential writing (0.123 or 123E-3).
Float numbers are always 32bits.
- A **string** is contained between a " at the start and at the end or a ' at the start and at the end. When the distributed temperature system returns a string, it is always included in "" and terminated by <END>.
- When a **register** value is given or returned (for example *ESE), the decimal values for the single bits are added. For example, a value of nine means that bit 0 and bit 3 are set.
- Larger blocks of data are given as a **list** of comma separated values.
- **Binary byte arrays** have the format: $\#n_1l_1\dots l_n d_1\dots d_l$
where # marks the start of the block,
 n is the number of digits in the number l , and
 l is the number of bytes of data in d .

For example *#212Hello World!* consists of #, for the start of the block, 2, to indicate that the next 2 digits are the length of the data block, 12 to indicate that 12 bytes of data follow, and finally the 12 bytes of data: *Hello World!*

- Binary data is transmitted as big-endian. This means you must swap the bytes for Intel platforms.
- Hexadecimal numbers can be given with a leading "#h...", for example "#hff"

Message exchange

The distributed temperature system exchanges messages using an input and an output queue. Error messages are kept in a separate error queue.

The input queue

The input queue is a FIFO queue (first-in first-out). Incoming bytes are stored in the input queue as follows:

- Receiving a byte:
 - Clears the output queue.
- No modification is made inside strings or binary byte arrays.

Outside strings and binary byte arrays, the following modifications are made:

- Lower-case characters are converted to upper-case.
- Two or more blanks are truncated to one.
- The parser is started if the LF character is received or if the input queue is full.

Clearing the input queue

Switching the power off causes commands that are in the input queue, but have not been executed to be lost.

The output queue

The output queue contains responses to query messages. The distributed temperature system transmits any data from the output queue immediately.

The error queue

The error queue is 20 errors long. It is a FIFO queue (first-in first-out). That is, the first error read is the first error to have occurred.

If more than 19 errors are put into the queue, the message **-350, "Queue overflow"** is placed as the last message in the queue.

The queue continues to work, but now with only the first 19 positions. No further errors are appended until older errors are read (at which time the older errors are removed from the queue).

Error messages

When the SCPI parser generates an error messages, it marks the place where the problem occurred with "<Err>". If the error message is generated by the firmware, "<Err>" is placed at the end.

Example 1: If you were to send, `:syst:time 12,-1,0` this will cause an error as the parser expects unsigned integer values

Sending `:syst:err?` will return the reply

```
-222,"Data out of range;syst:time 12,-1<Err>,0 "
```

Example 2: If you were to send, `:syst:time 12,65,0`, this will cause an error because the firmware doesn't accept 65 as a valid value for 'minutes'

Sending `:syst:err?` will return the reply

```
-222,"Data out of range;syst:time 12,65,0
<NL+END><Err>"
```

The table below shows some typical errors:

(column origin: S = SCPI Parser, F = Firmware, SF = both)

| Error Message | Note/Explanation | Origin |
|---|--|--------|
| 103, "Invalid separator" | e.g. ';' instead of ':' | S |
| 108, "Parameter not allowed" | Too many parameters. | S |
| 109, "Missing parameter" | Too few parameters | S |
| 113, "Undefined header" | Unknown command received. | S |
| 113, "Command not supported" | The commands is valid but not supported in the current firmware or current instrument configuration. | F |
| 114, "Header suffix out of range" | An invalid subopcode was used. | SF |
| 220, "Parameter not allowed for single measurement" | Sequence intermediate trace query, in single measurement | F |
| 222, "Data out of Range" | | SF |
| 222, "Data out of range (ParmTooSmall) " | | F |
| 222, "Data out of range (ParmTooLarge) " | | F |
| 223, "Too much data" | | SF |
| 224, "Illegal parameter value" | | SF |
| 240, "No data available yet" | | F |

| Error Message | Note/Explanation | Origin |
|--|--|--------|
| 290, "Invalid setting" | The selected setting is invalid (e.g. if a non-existing setting is recalled or an invalid index is used) | F |
| 291, "Inconsistent setting" | | F |
| 292. "Validation failed" | For example, if a measurement was started with inconsistent parameter settings | F |
| 310, "System Error" | | SF |
| 310, "System error (CaldataAccessError) " | | F |
| 310, "System error (SettingAccessError) " | | F |
| 310, "System error (EepromAccessError) " | | F |
| 310, "System error (RtcAccessError) " | RTC = real time clock | F |
| 311, "Hardware not available / option not installed" | | F |
| 321, "Out of memory" | | SF |
| 601, "Not allowed while (re)starting network" | | F |
| 602, "Network startup failed" | | F |
| 610, "Not allowed before bootup finished" | Hardware not fully initialized | F |
| 611, "Not allowed because of bootup error" | Hardware not fully initialized | F |
| 612, "Not allowed while measurement is running" | | F |
| 613, "Not allowed during firmware download" | | F |
| 614, "Not allowed during selfcal" | | F |
| 615, "Not allowed while trace buffer not empty" | | F |

Depending on the error number, the following bit is set in the Standard Event Status Register:

| Error Number | Error Class | Bit |
|---------------------|--------------------|------------|
| -100..-199 | Command | 5 |
| -200..-299 | Execution | 4 |
| -300..-399 | Device Specific | 3 |
| 1..32767 | Device Specific | 3 |
| -400..-499 | Query | 2 |
| -500..-599 | Power On | 7 |
| -600..-699 | User Request | 6 |
| -700..-799 | Request Control | 1 |
| -800..-899 | Operation Complete | 0 |

Common Commands

This section describes the implemented common commands.

Common command summary

Table 2 Common Command Summary

| Command | Parameter | Function |
|---------|-----------|--------------------------------------|
| *CLS | | Clear Status command |
| *ESE | | Standard Event Status Enable command |
| *ESE? | | Standard Event Status Enable query |
| *ESR? | | Standard Event Status Register query |
| *IDN? | | Identification query |
| *STB? | | Read Status Byte query |

NOTE

These commands are described in more detail in “IEEE-Common Commands” on page 34.

Common status information

There are four registers for the status information. Two of these are status-registers and two are enable-registers. These registers conform to the IEEE Standard 488.2-1987.

You can find further descriptions of these registers under *ESE, *ESR?, and *STB?.

The questionable and operation status command trees are described in “Status Reporting – the :STATus Subsystem” on page 38.

NOTE

Unused bits in any of the registers return 0 when you read them.

Status command summary

Table 3 Status Command Summary

| | |
|-------|---------------------------------------|
| *STB? | returns status byte, value 0 ... +255 |
|-------|---------------------------------------|

Table 3 Status Command Summary (Continued)

| | |
|-------|---|
| *ESE | sets the standard event status enable register, parameter 0 ... +255 |
| *ESR? | returns the standard event status register, value 0 ... +255 |
| *CLS | clears the status byte and the event status register, and removes any entries from the error queue. |

Other commands

Table 4 Other Commands

| | |
|-------|------------------------------|
| *IDN? | is an identification string. |
|-------|------------------------------|

2 Specific Commands

This chapter gives information about the AP Sensing distributed temperature system remote commands. It lists all the remote commands relating to the distributed temperature system, with a single-line description.

Each of these summaries contains a page reference for more detailed information about the particular command later in this manual.

Command Tree and Format

The commands are ordered in a command tree. Every command belongs to a node in this tree.

The root nodes are also called the subsystems. A subsystem contains all commands belonging to a specific topic. In a subsystem there may be further subtrees and subnodes.

All the nodes have to be given with a command. For example in the command `:CONFigure:MEASurement:SENSor:STARtpos`

- `CONFigure` is the subsystem containing all commands for configuring the distributed temperature system,
- `MEASurement` is the subsystem for configuring the measurement,
- `SENSor` is the subsystem for setting all the sensor parameters.
- `STARtpos` is the command for setting the start position.

NOTE

If a command and a query are both available, the command ends `/?`.

So, `:SYSTem:LOCation/?` means `:SYSTem:LOCation` and `:SYSTem:LOCation?` are both available.

The following table gives an overview of the command tree. You see the nodes, the subnodes, and the included commands.

| Command | Description | Page |
|---|---|----------|
| <code>:ALARm:RESet</code> | Reset the alarm. | page 123 |
| <code>:CONFigure:BBEHaviour:AREStart/?</code> | Select whether the measurement restarts automatically after power on. | page 64 |
| <code>:CONFigure:ERRor:RELay/?</code> | Set/get the relay used by an error. | page 83 |

| Command | Description | Page |
|-------------------------------|--|---------|
| :CONFigure:MEASurement | | |
| :ALARm | | |
| :CCYcles/? | Set/get the number of measurement cycles to confirm an alarm condition. | page 83 |
| :ENABle/? | Set/get whether the alarm handling is enabled. | page 84 |
| :KTRaces/? | Set/get the number of traces to be preserved in the event of an alarm condition. | page 82 |
| :NOGradients? | Get the number of gradients in each alarm zone. | page 85 |
| :NOZones? | Get the number of alarm zones. | page 85 |
| :RINPut/? | Set/get the reset inputs. | page 84 |
| :ZONE{?:?} | | |
| [:ALARm]:RELay/? | Set/get a bitmap of the relays associated with an alarm in a specific alarm zone. | page 93 |
| :CONDition:ENABle/? | Enable/disable the conditions which cause an alarm. | page 87 |
| :FBReak:RELay/? | Set/get a bitmap of the relays associated with a fiber break in a specific alarm zone. | page 94 |
| :GRADient{?:?} | | |
| :TCHange/? | Set/get the temperature change for a specific gradient setting in the alarm zone. | page 90 |
| :TIME/? | Set/get the time for a specific gradient setting in the alarm zone. | page 91 |
| :LIMit | | |
| :DEViation | | |
| :LOWer/? | Set/get the lower deviation limit. | page 89 |
| :UPPer/? | Set/get the upper deviation limit. | page 90 |
| :TEMPerature | | |
| :LOWer/? | Set/get the lower temperature limit. | page 87 |
| :UPPer/? | Set/get the upper temperature limit. | page 88 |
| :NAME/? | Set/get the name for the alarm zone. | page 92 |
| :SPAN/? | Set/get the length of the alarm zone. | page 86 |
| :STARt/? | Set/get the start of the alarm zone. | page 85 |
| :TYPE/? | Set/get the type of the alarm zone. | page 92 |

| Command | Description | Page |
|---|---|----------|
| :CONFigure:MEASurement:AUXiliary | | |
| :CURRent:SENSor{?:?} | | |
| :ENABle/? | Enable, disable or check external current sensor tracking | page 107 |
| :GAIN/? | Set/get the user gain that is added to the external current sensor results. | page 109 |
| :OFFSet/? | Set/get the user offset that is added to the external current sensor results. | page 108 |
| :UNIT/? | Set/get the user unit for the external current sensor results. | page 109 |
| :DIGital | | |
| :ENABle/? | Enable, disable or check external digital input lines tracking | page 101 |
| :VOLTage:SENSor{?:?} | | |
| :ENABle/? | Enable, disable/check external voltage sensor | page 105 |
| :GAIN/? | Set/get the user gain that is added to the external voltage sensor results. | page 106 |
| :OFFSet/? | Set/get the user offset that is added to the external voltage sensor results. | page 105 |
| :UNIT/? | Set/get the user unit for the external voltage sensor results. | page 107 |
| :CONFigure:MEASurement | | |
| :FIRedef{?:?} | | |
| :RELay/? | Set/get the bitmap of the relays used if a temperature event of this size occurs. | page 96 |
| :SIZE/? | Set/get the size for a temperature event class. | page 95 |
| :NOFiredefs? | Get the number of temperature event definitions. | page 95 |
| :CONFigure:MEASurement:REFerence:TEMPerature | | |
| :CALSensors/? | Set/get which external temperature sensors are to be used for calibration. | page 102 |
| :SENSor{?:?} | | |
| :ENABle/? | Enable, disable or check external temperature sensor tracking | page 103 |
| :STARtdist/? | Set/get the start distance, that is the distance from the start position | page 103 |
| :SPAN/? | Set/get the external temperature sensor span. | page 104 |

| Command | Description | Page |
|-------------------------------|--|----------|
| :CONFigure:MEASurement | | |
| :SENSor | | |
| :NOSEctions? | Get the number of fiber sections. | page 67 |
| :SECTion{?:?} | | |
| :ARATio/? | Set/get the attenuation ratio. | page 68 |
| :LENGth/? | Set/get the length of the section. | page 67 |
| :RINDex/? | Set/get the refractive index. | page 68 |
| :SFACtor/? | Set/get the length scaling factor. | page 69 |
| :TGCorrecction/? | Set/get the temperature gain correction. | page 72 |
| :TOCorrection/? | Set/get the temperature offset correction. | page 71 |
| :STARtpos/? | Set/get the start position, i.e. distance '0'. | page 65 |
| :TOFFset/? | Set/get the temperature offset. | page 66 |
| :CONFigure:MEASurement | | |
| :SETTing | | |
| :ACTual? | Get the number of currently used setting. | page 97 |
| :CANCel | Discard all changes. | page 98 |
| :ERASe | Erase a stored setting. | page 101 |
| :NUMBer? | Get the number of setting memory locations. | page 97 |
| :PRESet | Reset the setting. | page 98 |
| :PROTect/? | Set/get whether settings are protected. | page 98 |
| :RECall | Recall a setting from memory. | page 100 |
| :SAVE | Save a setting in memory. | page 100 |
| :VALidate/? | Check if the setting being edited is valid. | page 99 |
| :VALidate:SEQuence/? | Check if all the settings in a sequence are valid. | page 99 |

| Command | Description | Page |
|---------------------------------|---|----------|
| :CONFigure:MEASurement | | |
| :SETup | | |
| :CHANnel/? | Set/get the measurement channel (for systems with an optical switch). | page 73 |
| :HIBernate:ENABLE/? | Set/get whether hibernation is enabled. | page 81 |
| :ITUTime/? | Set/get the intermediate trace update time. | page 79 |
| :ITUTime:VALues? | Get the valid intermediate trace update times. | page 79 |
| :MTIME/? | Set/get the measurement time. | page 78 |
| :NAME/? | Set/get the name for the setting. | page 73 |
| :POReturn/? | Set/get the point at which the fiber turns back. | page 69 |
| :REMark/? | Set/get the comment for the setting. | page 74 |
| :REPeatmode/? | Set/get the repeat mode. | page 80 |
| :SINTerval/? | Set/get the sample interval between the temperature measurements. | page 76 |
| :SPAN/? | Set/get the measurement span. | page 75 |
| :SRESolution/? | Set/get the spatial resolution for the measurement. | page 74 |
| :SRESolution:VALues? | Get the valid values for the measurement resolution. | page 74 |
| :STARtdist/? | Set/get the start distance, that is, the distance from which to get measurement results. | page 74 |
| :STORedata/? | Set/get which data should be stored in the trace history. | page 82 |
| :UPDatetime/? | Note: B VERSION ONLY! Set the measurement update time. | page 80 |
| :CONFigure:SEquence | | |
| :REPeatmode/? | Set/get if the sequence of settings should only be measured once or repeatedly. | page 112 |
| :SEquence/? | Set/get the setting sequence | page 111 |
| :SLENgth? | Get the maximum sequence size. | page 111 |
| :VALidate/? | Validate the sequence | page 112 |
| :INPut:STATe? | Get the state of the input lines. | page 117 |
| :MEASurement | | |
| :SEquence[:STATe]/? | Start or stop a sequence measurement or check if a sequence measurement is running. | |
| :SINGLE[:STATe]/? | Start or stop a single measurement or check if a single measurement is running. | page 114 |
| :OUTPut:RELays[:STATe]/? | Configure the output relays. (The number of relays can be queried using :SYSTem:HARDware:NOReLay?). | page 116 |

| Command | Description | Page |
|----------------------------------|---|----------|
| :READout:ALARm | | |
| :DATA? | Get the alarm information for all zones of a trace. | page 124 |
| :DATA:ACCumulated? | Get the alarm information for all zones of all traces since the last alarm reset. | page 124 |
| :DETECTED? | Get whether an alarm was detected. | page 123 |
| :DETECTED:ACCumulated? | Get whether any alarms were detected. | page 123 |
| :RELays[:STATE]? | Read the state of the output relays. (Same as :OUTPut:RELays[:STATE].) | page 125 |
| :TINdex? | Get the index of the last trace with a completed alarm calculation. | page 124 |
| :READout:AUXiliary | | |
| :CURRent:SENSor{?:?}?? | Get the external current sensor value. | page 141 |
| :DIGital? | Get the external digital input value. | page 142 |
| :VOLTage:SENSor{?:?}?? | Get the external voltage sensor value. | page 142 |
| :READout:FBReak | | |
| :DETECTED? | Get whether a break in the fiber has been detected. | page 125 |
| :POSition? | Get the fiber break position. | page 125 |
| :READout:FIRE | | |
| :DATA? | Get the temperature event data for the current trace. | page 127 |
| :DETECTED? | Get whether a temperature event has been detected. | page 126 |
| :DIRection? | Get the direction in which the temperature event is moving. | page 126 |
| :POSition? | Get the position of the temperature event. | page 126 |
| :SIZE[:ABSolut]? | Get the size of the temperature event. | page 127 |
| :SIZE:INdex? | Get the size classification of the temperature event. | page 127 |
| :READout:ITRace:AUXiliary | | |
| :DIGital? | Get the external digital input value. | page 139 |
| :VOLTage:SENSor{?:?}?? | Get the external voltage sensor value. | page 140 |
| :CURRent:SENSor{?:?}?? | Get the external current sensor value. | page 140 |

| Command | Description | Page |
|--|---|----------|
| :READout:ITRace | | |
| :DATA? | Get the current intermediate trace. | page 137 |
| :INDEX? | Get the number of the current iteration, (to see whether there is new data). | page 136 |
| :INFO? | Get whether a trace is from a dual ended measurement, or whether the fiber has a break. | page 137 |
| :POINTS? | Get the number of points in a trace. | page 136 |
| :READout:ITRace:REFERENCE:TEMPerature | | |
| :CALibration:OFFSet? | Get the external temperature calibration offset correction. | page 138 |
| :CALibration:SENSors? | Get which external temperature sensors are to be used for calibration. | page 138 |
| :CALibration:SLOPe? | Get the external temperature calibration slope correction. | page 138 |
| :SENSOR{?:?:}TEMPerature? | Get the external temperature reference temperature | page 139 |
| :READout:ITRace | | |
| :SINDEX? | Get the index of the setting used to measure the intermediate trace. | page 136 |
| :READout:LOGFile? | Get the log file. | page 128 |
| :READout:MEASurement:ZONE{?:?} | | |
| :DEViation | | |
| :LOWer? | Get the current minimum deviation from zone average. | page 121 |
| :UPPer? | Get the current maximum deviation from zone average. | page 121 |
| :GRADient{?:?:}TCHange? | Get the current temperature change. | page 122 |
| :TEMPerature | | |
| :AVERage? | Get the current average temperature. | page 120 |
| :LOWer? | Get the current minimum temperature. | page 121 |
| :UPPer? | Get the current maximum temperature. | page 121 |
| :READout:REFERENCE:TEMPerature | | |
| :SENSOR{?:?:}TEMPerature? | Get the current external temperature sensor temperature | page 141 |
| :READout:TEMPerature? | Get the temperature values | page 140 |
| :READout:TRACe:AUXiliary | | |
| :CURRent:SENSOR{?:?:}? | Get the external current sensor value. | page 135 |
| :DIGital? | Get the external digital input value. | page 134 |
| :VOLTage:SENSOR{?:?:}? | Get the external voltage sensor value. | page 135 |

| Command | Description | Page |
|---|---|----------|
| :READout:TRACe | | |
| :BSIZe? | Get the size of the trace ring buffer. | page 130 |
| :CLEAr | Clear the trace ring buffer. | page 130 |
| :DATA? | Get a specific trace. | page 132 |
| :EMPTy? | Get whether the trace ring buffer is empty. | page 130 |
| :INDex? | Get the index of the last trace. | page 130 |
| :INFO? | Get whether a trace is from a dual ended measurement, or whether the fiber has a break. | page 132 |
| :POINts? | Get the number of points in a trace. | page 131 |
| :READout:TRACe:REFerence:TEMPerature | | |
| :CALibration:OFFSet? | Get the external temperature calibration offset correction. | page 133 |
| :CALibration:SENSors? | Get which external temperature sensors are to be used for calibration. | page 133 |
| :CALibration:SLOPe? | Get the external temperature calibration slope correction. | page 134 |
| :SENSor{?:?}:TEMPerature? | Get the external reference sensor temperature | page 134 |
| :READout:TRACe | | |
| :SINDex? | Get the index of the setting used to measure a trace. | page 131 |
| :SINTerval? | Get the sampling interval of a trace. | page 132 |
| :STARtdist? | Get the start distance of a trace. | page 131 |
| :STORedata | Get the type of a trace. | page 132 |
| :TIME? | Get the time stamp of a trace. | page 131 |
| :STATus:OPERation | | |
| :CONDition? | Read the contents of the operation condition register. | page 40 |
| :ENABle/? | Set/get the operation enable mask. | page 40 |
| [:EVENT]? | Read the contents of the operation event register. | page 39 |
| :NTRansition/? | Set/get the operation negative transition mask. | page 41 |
| :PTRansition/? | Set/get the operation positive transition mask. | page 41 |
| :STATus:PRESet | Presets all the event registers | page 39 |

| Command | Description | Page |
|------------------------------------|--|---------|
| :STATus:QUESTionable:ALARms | | |
| :CONDition | Read the contents of the questionable alarms condition register. | page 45 |
| :ENABle/? | Set/get the questionable alarms enable mask. | page 45 |
| [:EVENT]? | Read the contents of the questionable alarms event register. | page 44 |
| :NTRansition/? | Set/get the questionable alarms negative transition mask. | page 46 |
| :PTRansition/? | Set/get the questionable alarms positive transition mask. | page 46 |
| :STATus:QUESTionable | | |
| :CONDition? | Read the contents of the questionable condition register. Set/get the questionable enable mask. | page 42 |
| :ENABle/? | | page 42 |
| :STATus:QUESTionable:ERRors | | |
| :CONDition? | Read the contents of the questionable errors condition register. | page 47 |
| :ENABle/? | Set/get the questionable errors enable mask. | page 47 |
| [:EVENT]? | Read the contents of the questionable errors event register. | page 47 |
| :NTRansition/? | Set/get the questionable errors negative transition mask. | page 48 |
| :PTRansition/? | Set/get the questionable errors positive transition mask. | page 49 |
| :STATus:QUESTionable | | |
| [:EVENT]? | Read the contents of the questionable event register. | page 42 |
| :NTRansition/? | Set/get the questionable negative transition mask. | page 43 |
| :PTRansition/? | Set/get the questionable positive transition mask. | page 44 |
| :SYSTem:BSTate? | Get the boot state of the instrument | page 50 |

| Command | Description | Page |
|-------------------------------------|---|---------|
| :SYSTem:COMMunicate:ETHernet | | |
| :CANCel | Cancel all changes to network parameters not yet in use. | page 60 |
| :DGATeway/? | Set/get the default gateway. | page 59 |
| :DGATeway:CURRent? | Get the currently used default gateway. | page 56 |
| :DOMainname/? | Set/get the domain name. | page 57 |
| :DOMainname:CURRent? | Get the currently used domain name. | page 56 |
| :DHCP:ENABLE/? | Enable/Disable DHCP. | page 55 |
| :HOSTname/? | Set/get the host name. | page 57 |
| :HOSTname:CURRent? | Get the currently used host name. | page 56 |
| :IPADdress/? | Set/get the IP address. | page 58 |
| :IPADdress:CURRent? | Get the currently used IP address. | page 55 |
| :MACaddress? | Get the MAC address of the network adapter. | page 54 |
| :REStart | Restart the network interface (using the new values). | page 60 |
| :SAVE | Save the network interface values. | page 60 |
| :SMASK/? | Set/get the network (subnet) mask. | page 58 |
| :SMASK:CURRent? | Set/get the network (subnet) mask. | page 55 |
| :SYSTem | | |
| :DATE/? | Set/get the date. | page 50 |
| :ERRor? | Get (and delete!) the last error from error queue. | page 51 |
| :SYSTem:HARDware:AUXiliary | | |
| :DIGital:NOINputs? | Get the number of digital external sensor inputs. | page 62 |
| :VOLTage:NOINputs? | Get the number of analog external voltage sensor inputs. | page 62 |
| ::CURRent:NOINputs? | Get the number of analog external current sensor inputs. | page 62 |
| :SYSTem:HARDware | | |
| :DUALended? | Check whether the instrument supports dual ended measurements | page 61 |
| :NOINputs? | Get the number of available inputs. | page 61 |
| :NORelays? | Get the number of available relays. | page 60 |
| :SYSTem:HARDware:REFerence | | |
| :TEMPerature:NOINputs? | Get the number of external temperature sensor inputs. | page 61 |

| Command | Description | Page |
|------------------------|---|---------|
| :SYSTem | | |
| :HELP:HEADers? | Return the whole SCPI command tree. | page 51 |
| :LOCation/? | Set/get a location string (to identify the instrument). | page 53 |
| :SYSTem:LOGic | | |
| :INPutactive/? | Set/get the input logic. | page 63 |
| :OUTPutactive/? | Set/get the output logic. | page 63 |
| :SYSTem | | |
| :Options? | Get the installed option numbers from the instrument. | page 52 |
| :PRESet | Reset the instrument | page 52 |
| :REBoot? | Reboot the instrument | page 50 |
| :REMark/? | Set/get a comment used to recognise the instrument | page 53 |
| :TIME/? | Set/get the time used by the instrument | page 51 |
| :VERSion? | Get the SCPI version used by the instrument | page 52 |

3 Instrument Setup and Status

This chapter gives descriptions of commands that you can use when setting up your Distributed Temperature System. The commands are split into the following separate subsystems:

- IEEE Specific commands: which were introduced in “Introduction to Programming” .
- :STATus: commands which relate to the status model.
- :SYSTem: commands which control the LAN interface and system specific data.
- :CONFigure: commands which configure the measurement parameters.
- :MEASurement: commands which control the measurement.
- :OUTPut: commands which control how the output relays react.
- :INPut: commands which control how to interpret signals on the input lines.

Further commands are described in “Operations on Results” .

IEEE-Common Commands

“Common Commands” on page 19 gave a brief introduction to the IEEE-common commands which can be used with distributed temperature systems. This section gives fuller descriptions of each of these commands.

Table 5 *CLS

| | |
|--------------------|---|
| syntax | *CLS |
| description | <p>Clears all the event registers summarized in the Status Byte register.</p> <p>Except for the output queue, all queues summarized in the Status Byte register are emptied. The error queue is emptied. The Standard Event Status Enable registries are not affected by this command.</p> <p>After the *CLS command the instrument is left in the idle state. The command does not alter the instrument setting.</p> |
| parameters | none |
| response | none |
| example | *CLS |

Table 6 *ESE

| | |
|--------------------|---|
| syntax | *ESE<wsp><integer> |
| description | <p>The standard Event Status Enable command sets bits in the Standard Event Status Enable register.</p> <p>The Standard Event Status register monitors SCPI errors and synchronization conditions. The parameter is interpreted as a binary number, representing the bit values of the register.</p> <p>The Standard Event Status Enable Register contains a mask value that determines which bits in the Standard Event Status Register are summarized in the Event Status Bit (ESB).</p> <ul style="list-style-type: none"> • A “1” in the Standard Event Status Enable Register means a “1” in the corresponding bit in the Standard Event Status Register will set the ESB. • A “0” in the enable register disables means a “1” in the corresponding bit of the Standard Event Status Register will not affect the ESB. <p>The register is set to 32767 (all bits set to “1”) at power-on. The *RST and *CLS commands do not affect the register.</p> |

Table 6 *ESE (Continued)

| | | | |
|-------------------|--------------------------|------------------------|----------------------|
| parameters | An integer from 0 to 255 | | |
| | Bit | Mnemonic | Decimal Value |
| | 7 (MSB) | Power On | 128 |
| | 6 | User Request | 64 |
| | 5 | Command Error | 32 |
| | 4 | Execution Error | 16 |
| | 3 | Device Dependent Error | 8 |
| | 2 | Query Error | 4 |
| | 1 | Request Control | 2 |
| | 0 (LSB) | Operation Complete | 1 |
| response | none | | |
| example | *ESE 21 | | |

Table 7 *ESE?

| | |
|--------------------|--|
| syntax | *ESE? |
| description | The *ESE? query returns the current contents of the Standard Event Status Enable Register. |
| parameters | none |
| response | The bit value for the register (a short): |
| example | *ESE? → +21<END> |

Table 8 *ESR?

| | |
|--------------------|---|
| syntax | *ESR? |
| description | The standard Event Status Register query *ESR? returns the contents of the Standard Event Status register. The register is cleared after being read. The response value is an integer, to be interpreted as a binary number, representing the bit values of the register. |
| parameters | none |

Table 8 *ESR? (Continued)

| | | | |
|-----------------|---|------------------------|----------------------|
| response | The bit value for the register (a short): | | |
| | Bit | Mnemonic | Decimal Value |
| | 7 (MSB) | Power On | 128 |
| | 6 | User Request | 64 |
| | 5 | Command Error | 32 |
| | 4 | Execution Error | 16 |
| | 3 | Device Dependent Error | 8 |
| | 2 | Query Error | 4 |
| | 1 | Request Control | 2 |
| | 0 (LSB) | Operation Complete | 1 |
| example | *ESR? → +21<END> | | |

Table 9 *IDN?

| | |
|--------------------|--|
| syntax | *IDN? |
| description | The IDeNtification query *IDN? gets the instrument identification over the interface. |
| parameters | none |
| response | The identification terminated by <END>: AP Sensing, N4386B, DExxxxxxx, y.yy where xxxxxxx is the serial number, and y.yy is the software revision. |
| example | *IDN? → AP Sensing N4386B, DE0123456789, 4.3<END> |

Table 10 *STB?

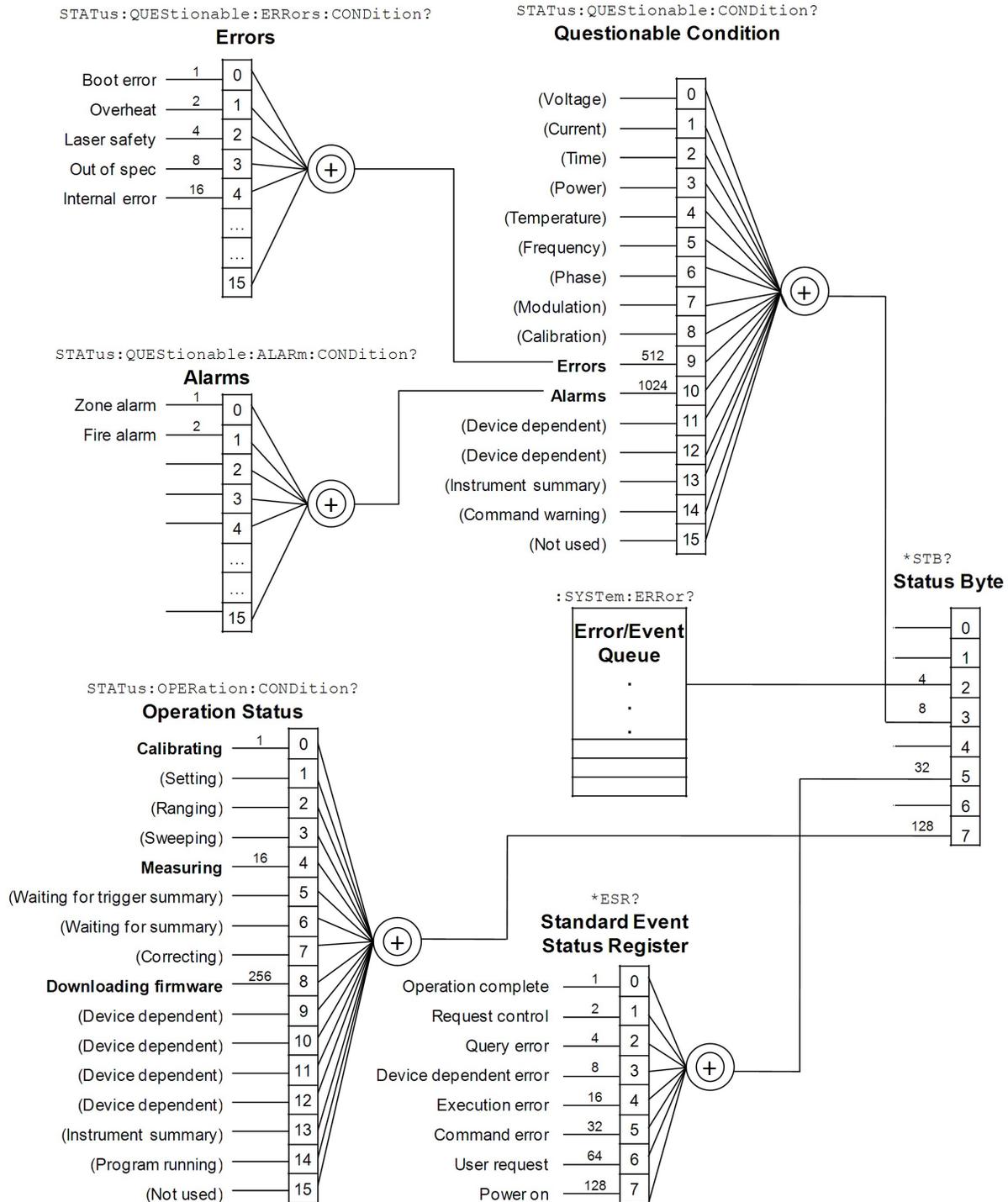
| | |
|--------------------|--|
| syntax | *STB? |
| description | The S T atus B yte query *STB? returns the contents of the Status Byte register. The Status Byte register summarizes the states of the other register sets. It is also responsible for generating service requests. The Master Summary Status (MSS) bit is true when any enabled bit of the STB register is set (excluding Bit 6). The Status Byte register including, the master summary bit, MSS, is not directly altered because of an *STB? query. Performing a serial poll on the instrument also reads the Status Byte register. The most convenient way to clear the Status Byte register is to send a *CLS command. |
| parameters | none |

Table 10 *STB?

| | | | |
|-----------------|---|-----------------------|----------------------|
| response | The bit value for the register (a short value): | | |
| | Bit | Mnemonic | Decimal Value |
| | 7 (MSB) | Operation Status | 128 |
| | 6 | Master Summary Status | 64 |
| | 5 | Event Status Bit | 32 |
| | 4 | Not used | 16 |
| | 3 | Questionable Status | 8 |
| | 2 | Error queue | 4 |
| | 1 | Not used | 2 |
| | 0 | Not used | 1 |
| example | *STB? → +21<END> | | |

Status Reporting – the :STATus Subsystem

The Status subsystem allows you to return and set details from the Status Model.



- Condition registers show the current state.
- Event registers keep their values until read. That is, reading them clears the contents.
- Bits in the registers can report a single state/event or a summary.
- The status byte can be read with `*STB?`
- Bit 2 in the Status Byte is set if the Error Queue is not empty.
- The Power On bit (bit 7 in the SESR) can only be read in VXI-11 and USB connection, because other connections are created dynamically and their SESR doesn't exist at boot time.
- The power on bit is not set before bootup is finished.
- A “fire” alarm means at least one of the alarm conditions is met in at least one zone. Though this is referred to as a *fire* alarm for historical reasons, it can also mean that it is too cold!
- A zone alarm means something else has happened in at least one zone. At this stage of development, this can only be a fiber break.

Table 11 :STATus:PRESet

| | |
|--------------------|--|
| syntax | :STATus:PRESet |
| description | Clears all the event registers summarized in the Status Byte register. Except for the output queue, all queues summarized in the Status Byte register are emptied. The error queue is emptied. Neither the Standard Event Status Enable register, nor the Service Request Enable register are affected by this command. The instrument is left in the idle state. The command does not alter the instrument setting. Please note: this command may take a few seconds to complete. |
| parameters | none |
| response | none |
| example | :stat:pres |

Table 12 :STATus:OPERation[:EVENT]?

| | |
|--------------------|--------------------------------------|
| syntax | :STATus:OPERation[:EVENT]? |
| description | Queries the operation event register |

Table 12 :STATus:OPERation[:EVENT]? (Continued)

| | |
|-------------------|--|
| parameters | none |
| response | The bit value for the operation event register as a short value (0 ... +32767) |
| example | :stat:oper? → +0<END> |

Table 13 :STATus:OPERation:CONDition?

| | |
|--------------------|--|
| syntax | :STATus:OPERation:CONDition? |
| description | Queries the operation condition register |
| parameters | none |
| response | The bit value for the operation condition register as a short value (0 ... +32767) |
| example | :stat:oper:cond? → +16<END> |

Table 14 :STATus:OPERation:ENABLE

| | |
|--------------------|---|
| syntax | :STATus:OPERation:ENABLE |
| description | Sets the operation enable mask for the event register |
| parameters | The bit value for the operation enable mask as a short value (0 ... +32767). The mask allows true conditions to be reported in the summary bit. If a bit is 1 in the enable mask, and its associated event bit transitions to true, a positive transition will occur in the summary bit. |
| response | none |
| example | :stat:oper:enab 273 |

Table 15 :STATus:OPERation:ENABLE?

| | |
|--------------------|---|
| syntax | :STATus:OPERation:ENABLE? |
| description | Returns the operation enable mask for the event register |
| parameters | none |
| response | The bit value for the operation enable mask as a short value (0 ... +32767) |
| example | :stat:oper:enab? → +273<END> |

Table 16 :STATUS:OPERation:NTRansition

| | |
|--------------------|--|
| syntax | :STATUS:OPERation:NTRansition |
| description | Sets the operation negative transition mask for the event register |
| parameters | The bit value for the operation negative transition mask as a short value (0 ... +32767) Setting a bit in the negative transition mask causes a 1 to 0 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:oper:ntr 256 |

Table 17 :STATUS:OPERation:NTRansition?

| | |
|--------------------|--|
| syntax | :STATUS:OPERation:NTRansition? |
| description | Returns the operation negative transition mask for the event register |
| parameters | none |
| response | The bit value for the operation negative transition mask as a short value (0 ... +32767) |
| example | :stat:oper:ntr? → +256<END> |

Table 18 :STATUS:OPERation:PTRansition

| | |
|--------------------|--|
| syntax | :STATUS:OPERation:PTRansition |
| description | Sets the operation positive transition mask for the event register |
| parameters | The bit value for the operation positive transition mask as a short value (0 ... +32767) Setting a bit in the positive transition mask causes a 0 to 1 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:oper:ptr 17 |

Table 19 :STATus:OPERation:PTRansition?

| | |
|--------------------|--|
| syntax | :STATus:OPERation:PTRansition? |
| description | Returns the operation positive transition mask for the event register |
| parameters | none |
| response | The bit value for the operation positive transition mask as a short value (0 ... +32767) |
| example | :stat:oper:ptr? → +17<END> |

Table 20 :STATus:QUEStionable[:EVENT]?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable[:EVENT]? |
| description | Queries the questionable event register |
| parameters | none |
| response | The bit value for the questionable event register as a short value (0 ... +32767) |
| example | :stat:ques? → +0<END> |

Table 21 :STATus:QUEStionable:CONDition?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:CONDition? |
| description | Queries the questionable condition register |
| parameters | none |
| response | The bit value for the questionable condition register as a short value (0 ... +32767) |
| example | :stat:ques:cond? → +0<END> |

Table 22 :STATus:QUEStionable:ENABLE

| | |
|--------------------|--|
| syntax | :STATus:QUEStionable:ENABLE |
| description | Sets the questionable enable mask for the event register |

Table 22 :STATus:QUESTionable:ENABle (Continued)

| | |
|-------------------|--|
| parameters | The bit value for the questionable enable mask as a short value (0 ... +32767). The mask allows true conditions to be reported in the summary bit. If a bit is 1 in the enable mask, and its associated event bit transitions to true, a positive transition will occur in the summary bit. |
| response | none |
| example | :stat:ques:enab 1536 |

Table 23 :STATus:QUESTionable:ENABle?

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ENABle? |
| description | Returns the questionable enable mask for the event register |
| parameters | none |
| response | The bit value for the questionable enable mask as a short value (0 ... +32767) |
| example | :stat:ques:enab? → +1536<END> |

Table 24 :STATus:QUESTionable:NTRansition

| | |
|--------------------|---|
| syntax | :STATus:QUESTionable:NTRansition |
| description | Sets the questionable negative transition mask for the event register |
| parameters | The bit value for the questionable negative transition mask as a short value (0 ... +32767) Setting a bit in the negative transition mask causes a 1 to 0 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:ques:ntr 0 |

Table 25 :STATus:QUESTionable:NTRansition?

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:NTRansition? |
| description | Returns the questionable negative transition mask for the event register |

Table 25 :STATus:QUEStionable:NTRansition? (Continued)

| | |
|-------------------|---|
| parameters | none |
| response | The bit value for the questionable negative transition mask as a short value (0 ... +32767) |
| example | :stat:ques:ntr? → +0<END> |

Table 26 :STATus:QUEStionable:PTRansition

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:PTRansition |
| description | Sets the questionable positive transition mask for the event register |
| parameters | The bit value for the questionable positive transition mask as a short value (0 ... +32767) Setting a bit in the positive transition mask causes a 0 to 1 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:ques:ptr 1536 |

Table 27 :STATus:QUEStionable:PTRansition?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:PTRansition? |
| description | Returns the questionable positive transition mask for the event register |
| parameters | none |
| response | The bit value for the questionable positive transition mask as a short value (0 ... +32767) |
| example | :stat:ques:ptr? → +1536<END> |

Table 28 :STATus:QUEStionable:ALARms[:EVENT]?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:ALARms[:EVENT]? |
| description | Queries the questionable alarms event register |
| parameters | none |
| response | The bit value for the questionable alarms event register as a short value (0 .. +32767) |
| example | :stat:ques:alar? → +0<END> |

Table 29 :STATus:QUESTionable:ALARms:CONDition?

| | |
|--------------------|---|
| syntax | :STATus:QUESTionable:ALARms:CONDition? |
| description | Queries the questionable alarms condition register |
| parameters | none |
| response | The bit value for the questionable alarms condition register as a short value (0 .. +32767) |
| example | :stat:ques:alar:cond? → +0<END> |

Table 30 :STATus:QUESTionable:ALARms:ENABLE

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ALARms:ENABLE |
| description | Sets the questionable alarms enable mask for the event register |
| parameters | The bit value for the questionable alarms enable mask as a short value (0 .. +32767). The mask allows true conditions to be reported in the summary bit. If a bit is 1 in the enable mask, and its associated event bit transitions to true, a positive transition will occur in the summary bit. |
| response | none |
| example | :stat:ques:alar:enab 3 |

Table 31 :STATus:QUESTionable:ALARms:ENABLE?

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ALARms:ENABLE? |
| description | Returns the questionable alarms enable mask for the event register |
| parameters | none |
| response | The bit value for the questionable alarms enable mask as a short value (0 .. +32767) |
| example | :stat:ques:alar:enab? → +3<END> |

Table 32 :STATus:QUEStionable:ALARms:NTRansition

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:ALARms:NTRansition |
| description | Sets the questionable alarms negative transition mask for the event register |
| parameters | The bit value for the questionable alarms negative transition mask as a short value (0 .. +32767) Setting a bit in the negative transition mask causes a 1 to 0 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:ques:alar:ntr 3 |

Table 33 :STATus:QUEStionable:ALARms:NTRansition?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:ALARms:NTRansition? |
| description | Returns the questionable alarms negative transition mask for the event register |
| parameters | none |
| response | The bit value for the questionable alarms negative transition mask as a short value (0 .. +32767) |
| example | :stat:ques:alar:ntr? → +3<END> |

Table 34 :STATus:QUEStionable:ALARms:PTRansition

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:ALARms:PTRansition |
| description | Sets the questionable alarms positive transition mask for the event register |
| parameters | The bit value for the questionable alarms positive transition mask as a short value (0 .. +32767) Setting a bit in the positive transition mask causes a 0 to 1 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:ques:alar:ptr 3 |

Table 35 :STATus:QUESTionable:ALARms:PTRansition?

| | |
|--------------------|---|
| syntax | :STATus:QUESTionable:ALARms:PTRansition? |
| description | Returns the questionable alarms positive transition mask for the event register |
| parameters | none |
| response | The bit value for the questionable alarms positive transition mask as a short value (0 .. +32767) |
| example | :stat:ques:alar:ptr? → +3<END> |

Table 36 :STATus:QUESTionable:ERRors[:EVENT]?

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ERRors[:EVENT]? |
| description | Queries the questionable errors event register |
| parameters | none |
| response | The bit value for the questionable errors event register as a short value (0 ... +32767) |
| example | :stat:ques:err? → +0<END> |

Table 37 :STATus:QUESTionable:ERRors:CONDition?

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ERRors:CONDition? |
| description | Queries the questionable errors condition register |
| parameters | none |
| response | The bit value for the questionable errors condition register as a short value (0 ... +32767) |
| example | :stat:ques:err:cond? → +0<END> |

Table 38 :STATus:QUESTionable:ERRors:ENABLE

| | |
|--------------------|---|
| syntax | :STATus:QUESTionable:ERRors:ENABLE |
| description | Sets the questionable errors enable mask for the event register |

Table 38 :STATus:QUEStionable:ERRors:ENABle (Continued)

| | |
|-------------------|---|
| parameters | The bit value for the questionable errors enable mask as a short value (0 ... +32767). The mask allows true conditions to be reported in the summary bit. If a bit is 1 in the enable mask, and its associated event bit transitions to true, a positive transition will occur in the summary bit. |
| response | none |
| example | :stat:ques:err:enab 31 |

Table 39 :STATus:QUEStionable:ERRors:ENABle?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:ERRors:ENABle? |
| description | Returns the questionable errors enable mask for the event register |
| parameters | none |
| response | The bit value for the questionable errors enable mask as a short value (0 ... +32767) |
| example | :stat:ques:err:enab? → +31<END> |

Table 40 :STATus:QUEStionable:ERRors:NTRansition

| | |
|--------------------|--|
| syntax | :STATus:QUEStionable:ERRors:NTRansition |
| description | Sets the questionable errors negative transition mask for the event register |
| parameters | The bit value for the questionable errors negative transition mask as a short value (0 ... +32767) Setting a bit in the negative transition mask causes a 1 to 0 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:ques:err:ntr 0 |

Table 41 :STATus:QUEStionable:ERRors:NTRansition?

| | |
|--------------------|---|
| syntax | :STATus:QUEStionable:ERRors:NTRansition? |
| description | Returns the questionable errors negative transition mask for the event register |

Table 41 :STATus:QUESTionable:ERRors:NTRansition? (Continued)

| | |
|-------------------|--|
| parameters | none |
| response | The bit value for the questionable errors negative transition mask as a short value (0 ... +32767) |
| example | :stat:ques:err:ntr? → +0<END> |

Table 42 :STATus:QUESTionable:ERRors:PTRansition

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ERRors:PTRansition |
| description | Sets the questionable errors positive transition mask for the event register |
| parameters | The bit value for the questionable errors positive transition mask as a short value (0 ... +32767) Setting a bit in the positive transition mask causes a 0 to 1 transition in the corresponding bit of the condition register to cause a 1 to be written to the corresponding bit of the event register. |
| response | none |
| example | :stat:ques:err:ptr 31 |

Table 43 :STATus:QUESTionable:ERRors:PTRansition?

| | |
|--------------------|--|
| syntax | :STATus:QUESTionable:ERRors:PTRansition? |
| description | Returns the questionable errors positive transition mask for the event register |
| parameters | none |
| response | The bit value for the questionable errors positive transition mask as a short value (0 ... +32767) |
| example | :stat:ques:err:ptr? → +31<END> |

Interface/Instrument Behavior Settings – the :SYSTEM Subsystem

The `SYSTEM` subsystem lets you control the instrument's interface and internal data (like date, time, and so on).

General system commands

Table 44 :SYSTEM:REBoot

| | |
|--------------------|-------------------|
| syntax | :SYSTEM:REBoot |
| description | Reboot the system |
| parameters | none |
| response | none |
| example | :syst:reb |

Table 45 :SYSTEM:BSTate?

| | |
|--------------------|--|
| syntax | :SYSTEM:BSTate |
| description | Check the boot state of the instrument |
| parameters | none |
| response | ONGOING FINISHED ERROR |
| example | :syst:bst? → FINISHED<END> |

Table 46 :SYSTEM:DATE

| | |
|--------------------|------------------------------------|
| syntax | :SYSTEM:DATE |
| description | Set the date |
| parameters | int (year), int (month), int (day) |
| response | none |
| example | :syst:date 2006, 4, 16 |

Table 47 :SYSTEM:DATE?

| | |
|--------------------|---------------|
| syntax | :SYSTEM:DATE? |
| description | Get the date |

Table 47 :SYSTem:DATE?

| | |
|-------------------|------------------------------------|
| parameters | none |
| response | int (year), int (month), int (day) |
| example | :syst:date? → +2006, +4, +16<END> |

Table 48 :SYSTem:TIME

| | |
|--------------------|---|
| syntax | :SYSTem:TIME |
| description | Set the time |
| parameters | int (hour), int (minute), optional int (second) |
| response | none |
| example | :syst:time 17, 50, 27 |

Table 49 :SYSTem:TIME?

| | |
|--------------------|--|
| syntax | :SYSTem:TIME? |
| description | Get the time |
| parameters | none |
| response | int (hour), int (minute), int (second) |
| example | :syst:time? → +17, +50, +27<END> |

Table 50 :SYSTem:ERRor?

| | |
|--------------------|--|
| syntax | :SYSTem:ERRor? |
| description | Get (and delete!) the last error from error queue. |
| parameters | none |
| response | int (error number), string (error message) If no error is left in the queue the response is '+0,"OK"' |
| example | :syst:err? → +0, "OK"<END> |

Table 51 :SYSTem:HELP:HEADers?

| | |
|--------------------|-----------------------------|
| syntax | :SYSTem:HELP:HEADers? |
| description | Return the whole SCPI tree. |

Table 51 :SYSTem:HELP:HEADers?

| | |
|-------------------|--|
| parameters | none |
| response | ASCII block. The exact SCPI tree depends on the instrument queried. |
| example | :syst:help:head? → #43416 :CONFigure:BBEHaviour:AREStart ... :SYSTem:TIME :SYSTem:VERSion?/qonly/ *CLS/nquery/ *ESE *ESR?/qonly/ *IDN?/qonly/ *STB?/qonly/<END> |

Table 52 :SYSTem:PRESet

| | |
|--------------------|--|
| syntax | :SYSTem:PRESet |
| description | Reset instrument: stop running measurement, erase all settings stored in FLASH, preset actual setting, preset EEPROM, clear trace history, resets the alarms. (DOES NOT change the ethernet parameters!) (DOES NOT change the status bytes (use *CLS)) |
| parameters | optional string (user name, maximum 79 characters) |
| response | none |
| example | :syst:pres |

Table 53 :SYSTem:VERSion?

| | |
|--------------------|---|
| syntax | :SYSTem:VERSion? |
| description | Return the SCPI version number in the DTS system |
| parameters | none |
| response | float in the format YYYY.V, where YYYY is the year and V is the approved revision number. |
| example | :syst:vers? → 1990.0<END> |

Table 54 :SYSTem:OPTions?

| | |
|--------------------|--------------------------------------|
| syntax | :SYSTem:OPTions? |
| description | Return the instrument option numbers |

Table 54 :SYSTem:OPTions?

| | |
|-------------------|----------------------------|
| parameters | none |
| response | integer list |
| example | :syst:opt? → +12, +24<END> |

Table 55 :SYSTem:LOCation

| | |
|--------------------|--|
| syntax | :SYSTem:LOCation |
| description | Set a location string, which may help identify the instrument. |
| parameters | string (maximum 79 characters) |
| response | none |
| example | :syst:loc "Tunnel East" |

Table 56 :SYSTem:LOCation?

| | |
|--------------------|---|
| syntax | :SYSTem:LOCation? |
| description | Get the location string assigned to an instrument. This may help identify the instrument. |
| parameters | none |
| response | string |
| example | :syst:loc? → "Tunnel East"<END> |

Table 57 :SYSTem:REMark

| | |
|--------------------|---|
| syntax | :SYSTem:REMark |
| description | Set a remark string for an instrument. This may help identify the instrument. |
| parameters | string (maximum 79 characters) |
| response | none |
| example | :syst:rem "Trial installation system" |

Table 58 :SYSTem:REMark?

| | |
|--------------------|--|
| syntax | :SYSTem:REMark? |
| description | Get the remark string from an instrument. This may help identify the instrument. |

Table 58 :SYSTem:REMark?

| | |
|-------------------|---|
| parameters | none |
| response | string |
| example | :syst:rem? → "Trial installation system"<END> |

:SYSTem:COMMunicate subtree

The DTS supports USB and LAN interfaces.

The :SYSTem:COMMunicate subtree is only necessary for setting up the LAN (ETHERnet subtree).

When first delivered, DHCP is enabled. If you do not want to use DHCP, or if it is not supported by your network, the network settings can be configured initially over USB. Although later changes can be made using the LAN interface, we recommend always changing ethernet parameters via USB connection, otherwise you may lose your connection.

The default host name is of the format

A-PPPPPP-SSSSSS

(for example, A-N4385A-123456)

where, *PPPPPP* is the product number (for example, N4385A), and *SSSSSS* is the last six digits of the serial number.

Some notes on DHCP/AutoIP/DNS

If DHCP is enabled but no DHCP server is found, the DTS system tries to use AutoIP as a fallback.

Depending on the available network capabilities the DTS system tries to tell the DNS server its host name or read the host name it has been assigned.

MAC address

The Media Access Control (MAC) number is a unique number associated with each DTS network adapter.

Table 59 :SYSTem:COMMunicate:ETHERnet:MACaddress?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHERnet:MACaddress? |
| description | Get the MAC address of the network adapter. |
| parameters | none |
| response | string (hex value without a prefix or separators). |
| example | :syst:comm:eth:mac? → "0007E014AE08"<END> |

Automatically set Ethernet parameters

If DHCP/AutoIP is enabled, the DTS system may use other parameters than specified explicitly, that is, it will use the parameters provided by the DHCP server. It tries to use its configured hostname (which may fail, depending on the network setup).

There will be an error if you try to query these parameters while the network is not connected, or before they have been set by the DHCP server.

Table 60 :SYSTem:COMMunicate:ETHernet:DHCP:ENABle

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:DHCP:ENABle |
| description | Enable or disable DHCP |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :syst:comm:eth:dhcp:enab on |

Table 61 :SYSTem:COMMunicate:ETHernet:DHCP:ENABle?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:DHCP:ENABle? |
| description | Check whether DHCP is enabled or disabled. |
| parameters | none |
| response | boolean (0 1) |
| example | :syst:comm:eth:dhcp:enab? → 1<END> |

Table 62 :SYSTem:COMMunicate:ETHernet:IPADdress:CURRent?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:IPADdress:CURRent? |
| description | Get the current IP address of the system |
| parameters | none |
| response | string |
| example | :syst:comm:eth:ipad:curr? → "192.132.13.2"<END> |

Table 63 :SYSTem:COMMunicate:ETHernet:SMASk:CURRent?

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:SMASk:CURRent? |
| description | Get the currently used subnet mask. |

Table 63 :SYSTem:COMMunicate:ETHernet:SMASk:CURRent?

| | |
|-------------------|---|
| parameters | none |
| response | string |
| example | :syst:comm:eth:smas:curr? → "255.255.255.0"<END> |

Table 64 :SYSTem:COMMunicate:ETHernet:HOSTname:CURRent?

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:HOSTname:CURRent? |
| description | Get the current host name. The default host name is A-P..P-S..S; where A is for AP Sensing, P..P is the Product Number, and S..S is as many of the last digits of the Serial Number to get a 15 character hostname. For example: A-N4386A-012345 |
| parameters | none |
| response | string |
| example | :syst:comm:eth:host:curr? → "A- N4386A-123456"<END> |

Table 65 :SYSTem:COMMunicate:ETHernet:DOMainname:CURRent?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:DOMainname:CURRent? |
| description | Get the currently used domain name |
| parameters | none |
| response | string |
| example | :syst:comm:eth:dom:curr? → ".companyame.com"<END> |

Table 66 :SYSTem:COMMunicate:ETHernet:DGATeway:CURRent?

| | |
|--------------------|--|
| syntax | SYSTem:COMMunicate:ETHernet:DGATeway:CURRent? |
| description | Get the currently used default gateway. |
| parameters | none |
| response | string (maximum 79 characters) |
| example | :syst:comm:eth:dgat:curr? → "192.168.101.11"<END> |

Explicitly set Ethernet parameters

You must reboot the instrument or send a `SYST:COMM:ETH:REStart` command before any alterations to the Ethernet parameters become effective.

If you query one of the alterable parameters, you always get the most recently set value, even if you have not yet activated it.

To undo any changes before they become active, send `SYST:COMM:ETH:CANceL`.

Table 67 :SYSTem:COMMunicate:ETHernet:HOSTname

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:HOSTname |
| description | Set the host name |
| parameters | string (maximum 79 characters, though not all characters can be used) |
| response | none |
| example | :syst:comm:eth:host "dts1" |

Table 68 :SYSTem:COMMunicate:ETHernet:HOSTname?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:HOSTname? |
| description | Get the host name |
| parameters | none |
| response | string |
| example | :syst:comm:eth:host? → "dts1"<END> |

Table 69 :SYSTem:COMMunicate:ETHernet:DOMainname

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:DOMainname |
| description | Set the domain name (used if DHCP is disabled) |
| parameters | string (maximum 79 characters, though not all characters can be used) |
| response | none |
| example | :syst:comm:eth:dom ".companyname.com" |

Table 70 :SYSTem:COMMunicate:ETHernet:DOMainname?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:DOMainname? |
| description | Get the domain name |
| parameters | none |
| response | string |
| example | :syst:comm:eth:dom? → ".companyname.com"<END> |

Table 71 :SYSTem:COMMunicate:ETHernet:IPADdress

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:IPADdress |
| description | Set the IP address of the system manually (used if DHCP is disabled). |
| parameters | string (maximum 79 characters, though only integers and the period, ".", can be used) |
| response | none |
| example | :syst:comm:eth:ipad "192.132.13.2" |

Table 72 :SYSTem:COMMunicate:ETHernet:IPADdress?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:IPADdress? |
| description | Get the manually set IP address of the system. |
| parameters | none |
| response | string |
| example | :syst:comm:eth:ipad? → "192.132.13.2"<END> |

Table 73 :SYSTem:COMMunicate:ETHernet:SMASk

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:SMASk |
| description | Set the subnet mask. |
| parameters | string (maximum 79 characters, though only integers and the period, ".", can be used) |
| response | none |
| example | :syst:comm:eth:smas "255.255.255.0" |

Table 74 :SYSTem:COMMunicate:ETHernet:SMASK?

| | |
|--------------------|--|
| syntax | :SYSTem:COMMunicate:ETHernet:SMASK? |
| description | Get the subnet mask. |
| parameters | none |
| response | string |
| example | :syst:comm:eth:smas? → "255.255.255.0"<END> |

Table 75 :SYSTem:COMMunicate:ETHernet:DGATeway

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:DGATeway |
| description | Set the default gateway. |
| parameters | string (maximum 79 characters, though only integers and the period, ".", can be used) |
| response | none |
| example | :syst:comm:eth:dgat "192.168.101.11" |

Table 76 :SYSTem:COMMunicate:ETHernet:DGATeway?

| | |
|--------------------|---|
| syntax | SYSTem:COMMunicate:ETHernet:DGATeway? |
| description | Get the default gateway. |
| parameters | string (maximum 79 characters, though not all characters can be used) |
| response | none |
| example | :syst:comm:eth:dgat? → "192.168.101.11"<END> |

Changing the Ethernet parameters

In most cases, instead of using :SYSTem:COMMunicate:ETHernet:REStart, it is better to save the new parameters (:SYSTem:COMMunicate:SAVE) and reboot the instrument (:SYSTem:REBoot).

Table 77 :SYSTem:COMMunicate:ETHernet:REStart

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:REStart |
| description | Restart the system's network interface with the new parameters. This command only works if the instrument has a working network connection at the time the command is issued. If you are connected by USB, use :SYSTem:COMMunicate:ETHernet:SAVE followed by :SYSTem:REBoot. |
| parameters | none |
| response | none |
| example | :syst:comm:eth:rest |

Table 78 :SYSTem:COMMunicate:ETHernet:SAVE

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:SAVE |
| description | Save the system's network interface parameters. |
| parameters | none |
| response | none |
| example | :syst:comm:eth:save |

Table 79 :SYSTem:COMMunicate:ETHernet:CANCEl

| | |
|--------------------|---|
| syntax | :SYSTem:COMMunicate:ETHernet:CANCEl |
| description | Undo all changes to the network parameters that have been made since the last save, reboot or ":syst:comm:eth:restart" command. |
| parameters | none |
| response | none |
| example | :syst:comm:eth:canc |

:SYSTem:HARDware subtree

Table 80 :SYSTem:HARDware:NORelays?

| | |
|--------------------|------------------------------------|
| syntax | :SYSTem:HARDware:NORelays? |
| description | Get the number of relays available |

Table 80 :SYSTem:HARDware:NORelays?

| | |
|-------------------|---------------------------|
| parameters | none |
| response | int (number of relays) |
| example | :syst:hard:nor? → 25<END> |

Table 81 :SYSTem:HARDware:NOINputs?

| | |
|--------------------|------------------------------------|
| syntax | :SYSTem:HARDware:NOINputs? |
| description | Get the number of inputs available |
| parameters | none |
| response | int (number of inputs) |
| example | :syst:hard:noin? → 25<END> |

Table 82 :SYSTem:HARDware:DUALended?

| | |
|--------------------|--|
| syntax | :SYSTem:HARDware:DUALended? |
| description | <p>Check whether the instrument supports dual ended measurements.</p> <p>In a dual ended measurement each end of the fiber is connected to a channel of the DTS. Because of the internal optical assembly, they must be defined starting with an odd numbered channel n. The dual channel measurement then automatically uses channel $n+1$ too.</p> <p>The DTS then performs measurements from both ends and combines the result.</p> <p>This has several advantages, including the DTS can automatically calculate the attenuation ratio, and the measurement still works after a fiber break.</p> |
| parameters | none |
| response | boolean |
| example | :syst:hard:dual? → 1<END> |

Table 83 :SYSTem:HARDware:REFerence:TEMPerature:NOINputs?

| | |
|--------------------|---|
| syntax | :SYSTem:HARDware:REFerence:TEMPerature:NOINputs? |
| description | <p>Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY!</p> <p>Get the number of external temperature sensor inputs.</p> |
| parameters | none |
| response | int (number of inputs) |
| example | syst:hard:ref:temp:noin? -> 4<END> |

Table 84 :SYSTem:HARDware:AUXiliary:DIGital:NOINputs?

| | |
|--------------------|--|
| syntax | :SYSTem:HARDware:AUXiliary:DIGital:NOINputs? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the number of digital external sensor inputs. |
| parameters | none |
| response | int (number of inputs) |
| example | <code>syst:hard:aux:dig:noin? -> 2<END></code> |

Table 85 :SYSTem:HARDware:AUXiliary:VOLTage:NOINputs?

| | |
|--------------------|---|
| syntax | :SYSTem:HARDware:AUXiliary:VOLTage:NOINputs? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the number of analog external voltage sensor inputs. |
| parameters | none |
| response | int (number of inputs) |
| example | <code>syst:hard:aux:volt:noin? -> 2<END></code> |

Table 86 :SYSTem:HARDware:AUXiliary:CURREnt:NOINputs?

| | |
|--------------------|---|
| syntax | :SYSTem:HARDware:AUXiliary:CURREnt:NOINputs? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the number of analog external current sensor inputs. |
| parameters | none |
| response | int (number of inputs) |
| example | <code>syst:hard:aux:curr:noin? -> 2<END></code> |

:SYSTem:LOGic subtree

The :SYST:LOGic subtree sets how the output relays and the inputs are to be handled or interpreted.

Table 87 :SYSTEM:LOGic:OUTPutactive

| | |
|--------------------|---|
| syntax | :SYSTEM:LOGic:OUTPutactive |
| description | Set how the output relays are to be handled. OPENactive means the relays are opened in the event of an alarm, but otherwise closed. CLOSEdactive means that the relays are closed in the event of an alarm, but otherwise open. |
| parameters | enum (OPENactive CLOSEdactive) |
| response | none |
| example | :syst:log:outp open |

Table 88 :SYSTEM:LOGic:OUTPutactive?

| | |
|--------------------|---|
| syntax | :SYSTEM:LOGic:OUTPutactive? |
| description | Gets how the output relays are being handled. |
| parameters | none |
| response | enum (OPEN CLOS) |
| example | :syst:log:outp? → OPEN<END> |

Table 89 :SYSTEM:LOGic:INPutactive

| | |
|--------------------|---|
| syntax | :SYSTEM:LOGic:INPutactive |
| description | Set how the inputs are to be interpreted. HIGHactive means the alarm is reset by a high at the input (a low does nothing). LOWactive means that the alarm is reset by a low at the input (a high does nothing). |
| parameters | enum (LOWactive HIGHactive) |
| response | none |
| example | :syst:log:inp low |

Table 90 :SYSTEM:LOGic:INPutactive?

| | |
|--------------------|--|
| syntax | :SYSTEM:LOGic:INPutactive? |
| description | Gets how the inputs are being interpreted. |
| parameters | none |
| response | enum (LOW HIGH) |
| example | :syst:log:inp? → LOW<END> |

Measurement Settings – the :CONFigure Subsystem

:CONFigure:BBEHaviour subtree

This subtree configures the boot behavior of the DTS.

Table 91 :CONFigure:BBEHaviour:AREStart

| | |
|--------------------|--|
| syntax | :CONFigure:BBEHaviour:AREStart |
| description | Sets whether the measurement automatically restarts after power on. The measurement is only restarted if a measurement was running when the instrument was switched off or if the last measurement was stopped because of an error. |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:bbeh:ares on |

Table 92 :CONFigure:BBEHaviour:AREStart?

| | |
|--------------------|---|
| syntax | :CONFigure:BBEHaviour:AREStart? |
| description | Gets whether the measurement automatically restarts after power on. |
| parameters | none |
| response | boolean (0 1) |
| example | :conf:bbeh:ares? → 1<END> |

:CONFigure:MEASurement:SENSor subtree

You need to describe both the complete sensor and just the part of the sensor that used for the measurement.

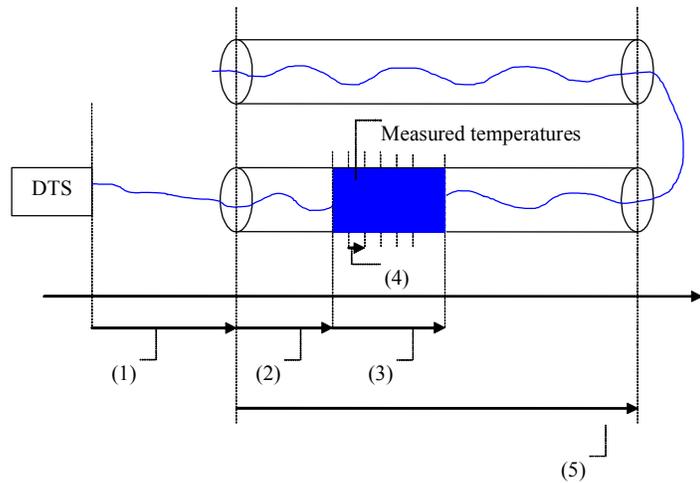
The complete sensor is described by the

:CONFigure:MEASurement:SENSor subtree

The part of the sensor used for measurements is described by the

:CONFigure:MEASurement:SETup subtree.

The relationship between some of the more significant parameters is shown in the figure below.



- (1) :CONFigure:MEASurement:SENsOr:STARtpos
- (2) :CONFigure:MEASurement:SETup:STARtdist
- (3) :CONFigure:MEASurement:SETup:SPAN
- (4) :CONFigure:MEASurement:SETup:SINTerval
- (5) :CONFigure:MEASurement:SETup:POReturn

Table 93 :CONFigure:MEASurement:SENsOr:STARtpos

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENsOr:STARtpos |
| description | Set the start position of the sensor relative to the connector, that is distance '0'. Alarm zones and Setup / start distances are relative to this point. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:sens:star 3 |

Table 94 :CONFigure:MEASurement:SENsOr:STARtpos?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENsOr:STARtpos? |
| description | Get the start position, that is the distance '0'. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |

Table 94 :CONFigure:MEASurement:SENSor:STARtpos?

| | |
|-------------------|--|
| parameters | optional int (setting index) MINimum MAXimum DEFault |
| response | float (in meters) |
| example | :conf:meas:sens:star? → 3.00000000E+002<END> |

Table 95 :CONFigure:MEASurement:SENSor:TOFFset

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:TOFFset |
| description | Set a temperature offset. This offset will be added to the measured temperature to give the final measurement. That is, this value should be the difference between the actual temperature and the measured temperature. In addition it is possible to set a temperature gain and offset correction for each section of the fiber. See “Section temperature gain and offset correction” on page 70. |
| parameters | float (in K) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:sens:toff -2.23 |

Table 96 :CONFigure:MEASurement:SENSor:TOFFset?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:TOFFset? |
| description | Get the temperature offset added to the measured temperature to give the final measurement. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in K) |
| example | :conf:meas:sens:toff? → - 2.23000000E+000<END> |

Sensor sections

The sensor can be made from a number of contiguous sections (that is, different fibers).

To ensure proper measurements the DTS needs to know the characteristics of each section, starting at the connector. Measuring cannot start if the last measurement point on the fiber has not been characterized. That is, the sum of the section lengths must be greater than the distance to the last measurement point.

NOTE

The number of supported sections depends on the instrument setup, and can be found out using

`:CONFigure:MEASurement:SENSor:NOSections?`

Table 97 `:CONFigure:MEASurement:SENSor:NOSections?`

| | |
|--------------------|---|
| syntax | <code>:CONFigure:MEASurement:SENSor:NOSections?</code> |
| description | Get the maximum number of fiber sections possible. This is used where the sensor is made of multiple sections of fiber with different physical characteristics. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | none |
| response | int |
| example | <code>:conf:meas:sens:nos? → +3<END></code> |

Table 98 `:CONFigure:MEASurement:SENSor:SECTion{?:?}:LENGth`

| | |
|--------------------|--|
| syntax | <code>:CONFigure:MEASurement:SENSor:SECTion{?:?}:LENGth</code> |
| description | Set the length of the section. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | <code>:conf:meas:sens:sect2:leng 13.3</code> |

Table 99 `:CONFigure:MEASurement:SENSor:SECTion{?:?}:LENGth?`

| | |
|--------------------|--|
| syntax | <code>:CONFigure:MEASurement:SENSor:SECTion{?:?}:LENGth?</code> |
| description | Get the length of the section. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |

Table 99 :CONFigure:MEASurement:SENSor:SECTion{?:?}:LENGth?

| | |
|-------------------|--|
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in meters) |
| example | :conf:meas:sens:sect2:leng? → 1.33000000E+001<END> |

Table 100 :CONFigure:MEASurement:SENSor:SECTion{?:?}:RINDex

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:RINDex |
| description | Set the refractive index at 1064nm. |
| parameters | float MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:sens:sect2:rind 1.0029 |

Table 101 :CONFigure:MEASurement:SENSor:SECTion{?:?}:RINDex?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:RINDex? |
| description | Get the refractive index. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float |
| example | :conf:meas:sens:sect2:rind? → +1.00290000E+000<END> |

Table 102 :CONFigure:MEASurement:SENSor:SECTion{?:?}:ARATio

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:ARATio |
| description | Set the attenuation ratio in dB/km. To calculate the attenuation ratio calculate the difference of the fiber attenuation expressed in dB/km at the anti-Stokes and at the Stokes wavelength. The length in km refers to the cable length (please see "Section scaling" for further information) For a typical sensing fiber this number is approximately 0.25 dB/km (that is, the attenuation for the anti-Stokes wavelength is larger than for the Stokes wavelength by 0.25 dB/km) |

Table 102 :CONFigure:MEASurement:SENSor:SECTion{?:?}:ARATio

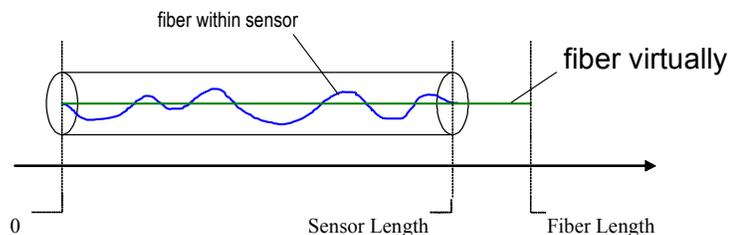
| | |
|-------------------|-------------------------------------|
| parameters | float MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:sens:sect2:arat 0.25 |

Table 103 :CONFigure:MEASurement:SENSor:SECTion{?:?}:ARATio?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:ARATio? |
| description | Get the attenuation ratio. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float |
| example | :conf:meas:sens:sect2:arat? → 2.50000000E-001<END> |

Section scaling

Because the fiber may be loose in the measurement sheath, the fiber length may not correspond directly with the sensor length (or cable length). The scaling factor corrects for this.



$$\text{Scaling Factor} = \frac{\text{Sensor Length (cable length)}}{\text{Fiber Length}}$$

Table 104 :CONFigure:MEASurement:SENSor:SECTion{?:?}:SFACtor

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:SFACtor |
| description | Set the scaling factor |

Table 104 :CONFigure:MEASurement:SENSor:SECTion{?:?}:SFACtor

| | |
|-------------------|-------------------------------------|
| parameters | float MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:sens:sect2:sfac 0.97 |

Table 105 :CONFigure:MEASurement:SENSor:SECTion{?:?}:SFACtor?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:SFACtor? |
| description | Get the scaling factor. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float |
| example | :conf:meas:sens:sect2:sfac? → 9.70000000E-001<END> |

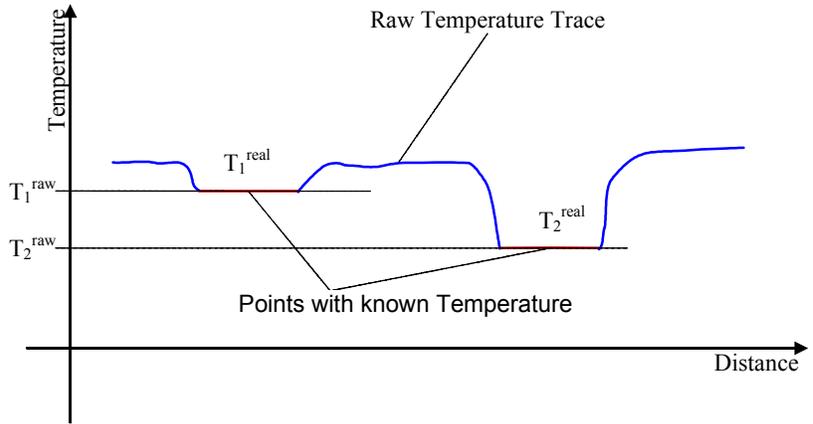
Section temperature gain and offset correction

In addition to the overall temperature offset for the sensor (set by :CONFigure:MEASurement:SENSor:TOFFset) each section can be corrected for temperature gain and offset.

To calibrate the temperature gain and offset you must have two points with known (real) temperatures on your sensor fiber and a measured temperature trace to get two corresponding uncalibrated (raw) temperature readings. Alternatively you can apply two different temperatures at the same point and again use the corresponding measurement readings. So it doesn't matter if you get your values at different times or points.

- The precondition is that the attenuation ratio must already be known and set (using :CONFigure:MEASurement:SENSor:ARATio).
- Temperatures are in °C

The figure shows the raw temperature trace where you can see the two points with known temperature.



From these known temperatures and the raw temperatures taken from the measured trace the gain and offset correction values can be calculated according to the formulas below:

Temperature Gain Correction:

$$T_{gain} = \frac{T_2^{real} - T_1^{real}}{T_2^{raw} - T_1^{raw}}$$

Temperature Offset Correction:

$$T_{offsetcorrection} = \frac{(T_1^{real} \cdot T_2^{raw}) - (T_1^{raw} \cdot T_2^{real})}{T_2^{raw} - T_1^{raw}}$$

Real Temperature:

$$T_{real} = T_{offset} + T_{raw} \cdot T_{gain}$$

Table 106 :CONFigure:MEASurement:SENSor:SECTion{?:?}:TOCorrecTion

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:TOCorrecTion |
| description | Set the temperature offset correction. |
| parameters | float (in K) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:sens:sect2:toc 0.02 |

Table 107 :CONFigure:MEASurement:SENSor:SECTion{?:?}:TOCorrection?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:TOCorrecti on? |
| description | Get the temperature offset correction. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in K) |
| example | : conf : meas : sens : sect2 : toc ? → 2 . 00000000E - 002 <END> |

Table 108 :CONFigure:MEASurement:SENSor:SECTion{?:?}:TGCORrection

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:TGCORrecti on |
| description | Set the temperature gain correction. |
| parameters | float MINimum DEFault MAXimum |
| response | none |
| example | : conf : meas : sens : sect2 : tgc 1 . 032 |

Table 109 :CONFigure:MEASurement:SENSor:SECTion{?:?}:TGCORrection?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SENSor:SECTion{?:?}:TGCORrecti on? |
| description | Get the temperature gain correction. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float |
| example | : conf : meas : sens : sect2 : tgc ? → 1 . 03200000E + 000 <END> |

:CONFigure:MEASurement:SETup subtree

This subtree defines which results are included in the trace.

Table 110 :CONFigure:MEASurement:SETup:CHANnel

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:CHANnel |
| description | Set the optical output to be used for the measurement (only for use with DTSs with an optical switch). You can check whether the DTS has an optical switch with :CONFigure:MEASurement:SETup:CHANnel?max". |
| parameters | int (channel number) |
| response | none |
| example | :conf:meas:set:chan 2 |

Table 111 :CONFigure:MEASurement:SETup:CHANnel?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:CHANnel? |
| description | Get the optical output to be used for the measurement (only for use with DTSs with an optical switch). It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | int (setting index) MINimum DEFault MAXimum |
| response | int (channel number) |
| example | :conf:meas:set:chan? 3 → +2<END> |

Table 112 :CONFigure:MEASurement:SETup:NAME

| | |
|--------------------|-----------------------------------|
| syntax | :CONFigure:MEASurement:SETup:NAME |
| description | Set the name for the setting. |
| parameters | string (maximum 79 characters) |
| response | none |
| example | :conf:meas:set:name "bore1" |

Table 113 :CONFigure:MEASurement:SETup:NAME?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:NAME? |
| description | Get the name for a current setting. If no setting index is specified, the query is for the setting in working memory (current setting). |

Table 113 :CONFigure:MEASurement:SETup:NAME?

| | |
|-------------------|-------------------------------------|
| parameters | optional int (setting index) |
| response | string |
| example | :conf:meas:set:name? → "bore1"<END> |

Table 114 :CONFigure:MEASurement:SETup:REMark

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:REMark |
| description | Set a comment for the setting. |
| parameters | string (maximum 79 characters) |
| response | none |
| example | :conf:meas:set:rem "trial measurement" |

Table 115 :CONFigure:MEASurement:SETup:REMark?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:REMark? |
| description | Get the comment for a setting. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | string |
| example | :conf:meas:set:rem? → "trial measurement"<END> |

Table 116 :CONFigure:MEASurement:SETup:STARtdist

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:STARtdist |
| description | Set the start distance, that is the distance from the start position (defined by CONF:MEAS:SENS:STARtpos), from which to collect measurement results. Setting a negative value can be used to show a part before the start position or even show the internal reference fiber before the connector. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:star 25.5 |

Table 117 :CONFigure:MEASurement:SETup:STARtdist?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:STARtdist? |
| description | Get the start distance from which measurement results are collected. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in meters) |
| example | :conf:meas:set:star? → 2.55000000E+001<END> |

Table 118 :CONFigure:MEASurement:SETup:SPAN

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:SPAN |
| description | Set the measurement span. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:span 600 |

Table 119 :CONFigure:MEASurement:SETup:SPAN?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:SPAN? |
| description | Get the measurement span. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in meters) |
| example | :conf:meas:set:span? → +6.00000000E+002<END> |

The sampling Interval is the distance between two temperature samples in the result trace.

The spatial resolution specifies the slope width of a measured step temperature profile ΔT (rising or falling). The slope width is defined as the spatial distance between the measured 10% and 90% levels of the slope, with 0% and 100% being the stationary temperature levels before or after the step.

Spatial resolution does not include noise effects..

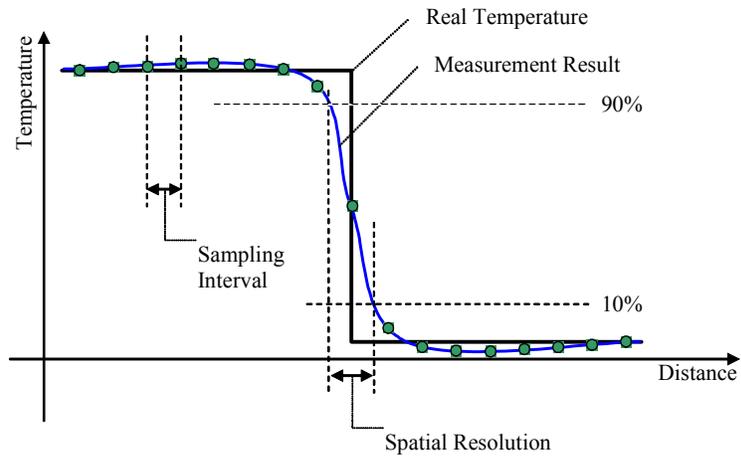


Table 120 :CONFigure:MEASurement:SETup:SINTerval

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:SINTerval |
| description | Set the sample interval between the temperature measurements. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:sint 1.1 |

Table 121 :CONFigure:MEASurement:SETup:SINTerval?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:SINTerval? |
| description | Get the sample interval between the temperature measurements. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in meters) |
| example | :conf:meas:set:sint? → 1.10000000E+000<END> |

Table 122 :CONFigure:MEASurement:SETup:SRESolution

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:SRESolution |
| description | Set the measurement spatial resolution. :CONFigure:MEASurement:SETup:SRESoluti on:VALues? returns a list with all valid values. |
| parameters | A float in the range 1.0 to 8.0. |
| response | none |
| example | :conf:meas:set:sres MIN |

Table 123 :CONFigure:MEASurement:SETup:SRESolution?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:SRESolution? |
| description | Get the measurement spatial resolution. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in meters) |
| example | :conf:meas:set:sres? → 1.00000000E+000<END> |

Table 124 :CONFigure:MEASurement:SETup:SRESolution:VALues?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:SRESolution:VALues? |
| description | Get the list of valid values for spatial resolution. |
| parameters | none |
| response | list of floats (in meters) |
| example | :conf:meas:set:sres:val? → 1.00000000E+000, 1.50000000E+000, 3.00000000E+000, 5.00000000E+000, 8.00000000E+000<END> |

Table 125 :CONFigure:MEASurement:SETup:POReturn

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:POReturn |
| description | Set the point of return, that is the point where the fiber turns back. This is relevant for working out the direction in which a temperature event is travelling. A value of 0 means this parameter is ignored. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:por 145.5 |

Table 126 :CONFigure:MEASurement:SETup:POReturn?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:POReturn? |
| description | Get the point of return, that is the point where the fiber turns back. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float (in meters) |
| example | :conf:meas:set:por? → 1.45500000E+002<END> |

Table 127 :CONFigure:MEASurement:SETup:MTIME

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:MTIME |
| description | Set the measurement time. The measurement time must be a multiple of the intermediate trace update time (see “:CONFigure:MEASurement:SETup:ITUTime” on page 79). |
| parameters | float (in seconds) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:mtim 30.0 |

Table 128 :CONFigure:MEASurement:SETup:MTIME?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:MTIME? |
| description | Get the measurement time. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in seconds). |
| example | :conf:meas:set:mtim? → 3.00000000E+001<END> |

Table 129 :CONFigure:MEASurement:SETup:ITUTime

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:ITUTime |
| description | Set the intermediate trace update time. The intermediate trace update time must be at least 30 seconds. <ul style="list-style-type: none"> • If you are using an SD card. • If you are using hibernation mode (which requires an SD card). :CONFigure:MEASurement:SETup:ITUTime:VALues? returns a list with all valid values. |
| parameters | float (in seconds) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:itut max |

Table 130 :CONFigure:MEASurement:SETup:ITUTime?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:ITUTime? |
| description | Get the intermediate trace update time. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in seconds) |
| example | :conf:meas:set:itut? → 3.00000000E+001<END> |

Table 131 :CONFigure:MEASurement:SETup:ITUTime:VALues?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:ITUTime:VALues? |
| description | Get the list of permitted values for the intermediate trace update time. |
| parameters | none |
| response | A list of floats (in seconds) |
| example | :conf:meas:set:itut:val? → +1.00000000E+001, 3.00000000E+001<END> |

Table 132 :CONFigure:MEASurement:SETup:UPDatetime

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:UPDatetime |
| description | Note: B VERSION ONLY! Set the measurement update time. |
| parameters | float (in seconds) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:set:upd 7200 |

Table 133 :CONFigure:MEASurement:SETup:UPDatetime?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:UPDatetime? |
| description | Note: B VERSION ONLY! Get the measurement update time. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | float (in seconds) |
| example | :conf:meas:set:upd? → 7.20000000E+003<END> |

Table 134 :CONFigure:MEASurement:SETup:REPeatmode

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:REPeatmode |
| description | Set the number of repeats or the repeat mode. For sequence measurements, the repeat mode must be set to 1. |

Table 134 :CONFigure:MEASurement:SETup:REPeatmode

| | |
|-------------------|---|
| parameters | int (to set a number of repeats) ONCE CONTInuous UBFull (where UBFull means until the trace buffer is full) |
| response | none |
| example | :conf:meas:set:rep FOR<END> |

Table 135 :CONFigure:MEASurement:SETup:REPeatmode?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:REPeatmode? |
| description | Get the number of repeats. It is also possible to query the minimum, default or maximum value. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum DEFault MAXimum |
| response | int (number of repeats). "1" is returned for a single repeat; "0" is returned for continuous repeat, and "-1" for repeat until buffer full. |
| example | :conf:meas:set:rep? → +30<END> |

Table 136 :CONFigure:MEASurement:SETup:HIberNate:ENABLE

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:HIberNate:ENABLE |
| description | Note: B VERSION ONLY! Set whether the hibernation is enabled. Please note, if you are using hibernation mode, you must use an SD card, and set the intermediate trace update time to at least 30 seconds . |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:meas:set:hib:enab on |

Table 137 :CONFigure:MEASurement:SETup:HIberNate:ENABLE?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:HIberNate:ENABLE? |
| description | Note: B VERSION ONLY! Get whether hibernation is enabled. |
| parameters | optional int (setting index) |
| response | boolean (0 1) |
| example | :conf:meas:set:hib:enab? → 1<END> |

Table 138 :CONFigure:MEASurement:SETup:STORedata

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETup:STORedata |
| description | Set which data should be stored in the trace history. Note: if LOSS data is stored, the alarm zones are not analyzed, and no alarms can be generated. |
| parameters | TEMPerature to store the temperature values LOSS to store the raw data |
| response | none |
| example | :conf:meas:set:stor temp |

Table 139 :CONFigure:MEASurement:SETup:STORedata?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETup:STORedata? |
| description | Get which data is stored in the trace history. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | TEMP LOSS |
| example | :conf:meas:set:stor? → TEMP<END> |

:CONFigure:MEASurement:ALARm subtree

Table 140 :CONFigure:MEASurement:ALARm:KTRaces

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:KTRaces |
| description | Set the number of traces to keep in the trace buffer if an alarm condition occurs. This includes (number -1) of the traces preceding the alarm condition, and the first trace where the alarm was detected. The measurement is stopped, even if repeat mode is set to FORever. If repeat mode was set to FORever, stopping the measurement is added as an entry in the log file. Confirmation measurement cycles are not counted. If the value is 0, the measurement is not stopped, and the alarm trace can be overwritten. |
| parameters | int 0 |
| response | none |
| example | :conf:meas:alar:ktr 4 |

Table 141 :CONFigure:MEASurement:ALARm:KTRaces?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:KTRaces? |
| description | Get the number of traces preserved in the trace buffer if an alarm condition is detected. |
| parameters | none |
| response | int |
| example | :conf:meas:alar:ktr? → 4<END> |

Table 142 :CONFigure:MEASurement:ALARm:CCYCles

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:CCYCles |
| description | Set the number of additional confirmation cycles for which the alarm condition must be met before it is communicated. Confirmation cycles do not include the initial measurement for which the alarm condition is detected, so the alarm condition has to be met for (number + 1) consecutive measurements. Note: in a measurement sequence, the whole sequence counts as one cycle. |
| parameters | int MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:alar:ccyc 4 |

Table 143 :CONFigure:MEASurement:ALARm:CCYCles?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:CCYCles? |
| description | Get the number of confirmation cycles. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | int |
| example | :conf:meas:alar:ccyc? → 4<END> |

Table 144 :CONFigure:MEASurement:ALARm:RINPut

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:RINPut |
| description | Set which of the inputs reset the alarm condition. Note: In a <i>sequence</i> , the last <i>configuration</i> defines which inputs are active for alarm resetting. Be sure to have <i>Alarm Handling</i> enabled in the last configuration to enable alarm resetting. |
| parameters | bitmap |
| response | none |
| example | :conf:meas:alar:rinp 3 |

Table 145 :CONFigure:MEASurement:ALARm:RINPut?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:RINPut? |
| description | Get the inputs that reset the alarm condition. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | bitmap |
| example | :conf:meas:alar:rinp? → 3<END> |

Table 146 :CONFigure:MEASurement:ALARm:ENABLE

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ENABLE |
| description | Set whether the alarm handling is enabled. |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:meas:alar:enab on |

Table 147 :CONFigure:MEASurement:ALARm:ENABLE?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ENABLE? |
| description | Get whether the alarm is enabled. If no setting index is specified, the query is for the setting in working memory (current setting). |

Table 147 :CONFigure:MEASurement:ALARm:ENABLE?

| | |
|-------------------|--------------------------------|
| parameters | optional int (setting index) |
| response | boolean (0 1) |
| example | :conf:meas:alar:enab? → 1<END> |

Table 148 :CONFigure:MEASurement:ALARm:NOZones?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:NOZones? |
| description | Get the number of alarm zones. This query can be used to check whether the DTS supports alarms. |
| parameters | none |
| response | int |
| example | :conf:meas:alar:noz? → 256<END> |

Table 149 :CONFigure:MEASurement:ALARm:NOGradients?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:NOGradients? |
| description | Get the number of gradients in each alarm zone. |
| parameters | none |
| response | int |
| example | :conf:meas:alar:nog? → 3<END> |

NOTE

Alarm zones can overlap.

NOTE

If LOSS data is stored, the alarm zones are not analyzed, and no alarms can be generated. See “:CONFigure:MEASurement:SETup:STORedata” on page 82.

Table 150 :CONFigure:MEASurement:ALARm:ZONE{?:?}:START

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:START |
| description | Set the start of the alarm zone. |

Table 150 :CONFigure:MEASurement:ALARm:ZONE{?:?}:START

| | |
|-------------------|---------------------------------------|
| parameters | float (in meters) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:star 230.5 |

Table 151 :CONFigure:MEASurement:ALARm:ZONE{?:?}:START?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:START? |
| description | Get the start of the alarm zone, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in meters) |
| example | :conf:meas:alar:zone3:star? → 2.30500000E+002<END> |

Table 152 :CONFigure:MEASurement:ALARm:ZONE{?:?}:SPAN

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:SPAN |
| description | Set the length of the alarm zone |
| parameters | float (in meters) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:span 125 |

Table 153 :CONFigure:MEASurement:ALARm:ZONE{?:?}:SPAN?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:SPAN? |
| description | Get the length of the alarm zone, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in meters) |
| example | :conf:meas:alar:zone3:span? → 1.25000000E+002<END> |

Table 154 :CONFigure:MEASurement:ALARm:ZONE{?:?}:CONDition:ENABle

| | | | |
|--------------------|---|--------------------------|----------------------|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:CONDition:ENABle | | |
| description | Enable/disable the conditions which cause an alarm. | | |
| parameters | bitmap | | |
| | Bit | Meaning | Decimal Value |
| | 7 (MSB) | Not used | 128 |
| | 6 | Gradient ₃ | 64 |
| | 5 | Gradient ₂ | 32 |
| | 4 | Gradient ₁ | 16 |
| | 3 | Deviation _{max} | 8 |
| | 2 | Deviation _{min} | 4 |
| | 1 | T _{max} | 2 |
| | 0 | T _{min} | 1 |
| response | none | | |
| example | :conf:meas:alar:zone3:cond:enab 11 | | |

Table 155 :CONFigure:MEASurement:ALARm:ZONE{?:?}:CONDition:ENABle?

| | | | |
|--------------------|---|--|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:CONDition:ENABle? | | |
| description | Checks which conditions are enabled or disabled to cause an alarm. If no setting index is specified, the query is for the setting in working memory (current setting). | | |
| parameters | optional int (setting index) | | |
| response | bitmap (see Table 154) | | |
| example | :conf:meas:alar:zone3:cond:enab? → 11<END> | | |

Table 156 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:LOWer

| | | | |
|--------------------|--|--|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:LOWer | | |
| description | Set the minimum temperature limit | | |

Table 156 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:LOWer

| | |
|-------------------|---|
| parameters | float (in °C) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:lim:temp:low - 3.5 |

Table 157 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:LOWer?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:LOWer? |
| description | Get the minimum temperature limit, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in °C) |
| example | :conf:meas:alar:zone3:lim:temp:low? → -3.50000000E-001<END> |

Table 158 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:UPPer

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:UPPer |
| description | Set the maximum temperature limit |
| parameters | float (in °C) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:lim:temp:upp 70 |

Table 159 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:UPPer?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:TEMPerature:UPPer? |
| description | Get maximum temperature limit, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in °C) |
| example | :conf:meas:alar:zone3:lim:temp:upp? → 7.00000000E+001<END> |

Table 160 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:DEViation:LOWer

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:DEViation:LOWer |
| description | Set the minimum value above which the local temperature can deviate from the average temperature for the zone. Note: this is a negative value |
| parameters | float (in K) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:lim:dev:low 0 |

Table 161 :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:DEViation:LOWer?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:LIMit:DEViation:LOWer? |
| description | Get minimum value above which the local temperature can deviate from the average temperature for the zone, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in K) |
| example | :conf:meas:alar:zone3:lim:dev:low? → 0.00000000E+000<END> |

Table 162 :CONFigure:MEASurement:ALARm:ZONE{?:?:LIMit:DEViation:UPPer

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?:LIMit:DEViation:UPPer |
| description | Set the maximum that the local temperature can deviate from the average temperature for the zone. |
| parameters | float (in K) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:lim:dev:upp 20.5 |

Table 163 :CONFigure:MEASurement:ALARm:ZONE{?:?:LIMit:DEViation:UPPer?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?:LIMit:DEViation:UPPer? |
| description | Get maximum value below which the local temperature can deviate from the average temperature for the zone, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in K) |
| example | :conf:meas:alar:zone3:lim:dev:upp? → 0.00000000E+000<END> |

Table 164 :CONFigure:MEASurement:ALARm:ZONE{?:?:GRADient{?:?:TCHange

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?:GRADient{?:?:TCHange |
| description | Set the temperature change allowed over the specified time, for the specified gradient in the alarm zone. |
| parameters | float (in K) MINimum MAXimum |
| response | none |
| example | :conf:meas:alar:zone3:grad1:tch 11.25 |

Table 165 :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TCHange?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TCHange? |
| description | Get the temperature change allowed over the specified time, for the specified gradient in the alarm zone, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in K) |
| example | :conf:meas:alar:zone3:grad1:tch? → 1.12500000E+001<END> |

Table 166 :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TIME

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TIME |
| description | Set the time for temperature change for a specific gradient in the alarm zone. For single measurements, this value must be a multiple of the measurement time (see “:CONFigure:MEASurement:SETup:MTIME” on page 78). For measurement sequences, this value must be a multiple of the measurement time multiplied by the number of measurements in the sequence (see “:CONFigure:MEASurement:SETup:MTIME” on page 78, and “:CONFigure:SEquence:SEquence” on page 111). |
| parameters | float (in seconds) MINimum MAXimum |
| response | none |
| example | :conf:meas:alarm:zone3:grad1:time 7200 |

Table 167 :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TIME?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TIME? |
| description | Get the time for temperature change for a specific gradient in the alarm zone, or the minimum or maximum value possible. If no setting index is specified, the query is for the setting in working memory (current setting). |

Table 167 :CONFigure:MEASurement:ALARm:ZONE{?:?}:GRADient{?:?}:TIMe?

| | |
|-------------------|--|
| parameters | optional int (setting index) MINimum MAXimum |
| response | float (in seconds) |
| example | :conf:meas:alarm:zone3:grad1:time? → 7.20000000E+003<END> |

Table 168 :CONFigure:MEASurement:ALARm:ZONE{?:?}:NAME

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:NAME |
| description | Set the name for the alarms zone. |
| parameters | string (40 characters) |
| response | none |
| example | :conf:meas:alarm:zone3:name "Tunnel Entrance" |

Table 169 :CONFigure:MEASurement:ALARm:ZONE{?:?}:NAME?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:NAME? |
| description | Get the name for the alarm zone. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | string |
| example | :conf:meas:alarm:zone3:ali? → "Tunnel Entrance"<END> |

Table 170 :CONFigure:MEASurement:ALARm:ZONE{?:?}:TYPE

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:TYPE |
| description | Set the type of the alarms zone. |
| parameters | string (20 characters) |
| response | none |
| example | :conf:meas:alarm:zone3:type "Ventilation Zone" |

Table 171 :CONFigure:MEASurement:ALARm:ZONE{?:?}:TYPE?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:TYPE? |
| description | Get the type of the alarm zone. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | string |
| example | :conf:meas:alarm:zone3:typ? → "Ventilation Zone"<END> |

Table 172 :CONFigure:MEASurement:ALARm:ZONE{?:?}[:ALARm]:RELay

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}[:ALARm]:RELay |
| description | Set the bitmap for the relays associated with the alarm in the specified zone. |
| parameters | For the A version: bitmap For the B version: bitmap, bitmap LSB is relay 1. The total number of relays is given by :SYSTem:HARDware:NOrelays. |
| response | none |
| example | For the A version: :conf:meas:alar:zone3:rel 4 For the B version: :conf:meas:alar:zone3:rel 4,0 For the both versions, this assigns the third relay to zone 3. |

Table 173 :CONFigure:MEASurement:ALARm:ZONE{?:?}[:ALARm]:RELay?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}[:ALARm]:RELay? |
| description | Get the bitmap of the relays associated with the alarm in the specified zone. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | For the A version: bitmap For the B version: bitmap, bitmap LSB is relay 1. |
| example | For the A version: :conf:meas:alar:zone3:rel? → 4<END> For the B version: :conf:meas:alar:zone3:rel? → 4,0<END> |

Table 174 :CONFigure:MEASurement:ALARm:ZONE{?:?}:FBReak:RELAy

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:FBReak:RELAy |
| description | Set the bitmap for which of the relays is associated with a fiber break in the specified zone. Note: Fiber breaks are only detected in alarm zones that are enabled and where there are alarm conditions. |
| parameters | For the A version: bitmap For the B version: bitmap, bitmap LSB is relay 1. |
| response | none |
| example | For the A version: :conf:meas:alar:zone3:fbr:rel 5 For the B version: :conf:meas:alar:zone3:fbr:rel 5,0 |

Table 175 :CONFigure:MEASurement:ALARm:ZONE{?:?}:FBReak:RELAy?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:ALARm:ZONE{?:?}:FBReak:RELAy? |
| description | Get the bitmap for the relays associated with a fiber break in the specified zone. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | For the A version: bitmap For the B version: bitmap, bitmap LSB is relay 1. |
| example | For the A version: :conf:meas:alar:zone3:fbr:rel? → 5<END> For the B version: :conf:meas:alar:zone3:fbr:rel? → 5,0<END> |

:CONFigure:MEASurement:FIRedefs subtree

Though these commands refer to “fire”, they can be used for any temperature event.

Table 176 :CONFigure:MEASurement:NOFiredefs?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:NOFiredefs? |
| description | Get the number of definitions of temperature events. |
| parameters | none |
| response | int |
| example | :conf:meas:nof? → 5<END> |

NOTE

Define the different sizes of temperature event in ascending order, with the smallest temperature event as size “1”.

Table 177 :CONFigure:MEASurement:FIRedef{?:?}SIZE

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:FIRedef{?:?}SIZE |
| description | Set the size for a temperature event definition. The factory default temperature event size classes are 5m, 10m, 50m, 100m, 500m. A fire belongs to a class n if $size_{n-1} < size_{fire} \leq size_n$. Fires belong to the last fire definition even if they are bigger than the corresponding size. |
| parameters | float (in meters) MINimum DEFault MAXimum |
| response | none |
| example | :conf:meas:fir1:size 25.0 |

Table 178 :CONFigure:MEASurement:FIRedef{?:?}SIZE?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:FIRedef{?:?}SIZE? |
| description | Get the size for a temperature event definition. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float (in meters) |
| example | :conf:meas:fir1:size? → 2.50000000E+001<END> |

Table 179 :CONFigure:MEASurement:FIRedef{?:?}:RELay

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:FIRedef{?:?}:RELay |
| description | Set a bitmap for which of the relays is used if a temperature event occurs according to this definition. |
| parameters | bitmap (LSB is relay 1) |
| response | none |
| example | :conf:meas:fir1:rel 12 |

Table 180 :CONFigure:MEASurement:FIRedef{?:?}:RELay?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:FIRedef{?:?}:RELay? |
| description | Get a bitmap of the relays used if a temperature event occurs according to this definition. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | bitmap (LSB is relay 1) |
| example | :conf:meas:fir1:rel? → 12<END> |

:CONFigure:MEASurement:SETTing subtree

The instrument can store a number of settings in FLASH memory in the DTS. The number of memory places can be queried with

`CONF:MEAS:SETT:NUMBER?`.

A 'measurement setting consists of all parameters which can be set with the `:CONF:MEAS:*` commands, except

`:CONF:MEAS:ALAR:KTRaces`. That is, including the

`:CONF:MEAS:SENS` and `:CONF:MEAS:SET`, `:CONF:MEAS:ALAR`,

`:CONF:MEAS:FIR` and `:CONF:MEAS:ERR` subtrees.

After each parameter change, you can use `:SYSTEM:ERROR?` to check if is OK. Some parameters depend on each other so you need to check the whole setting before you can use it. Do this with the

`:CONFigure:MEASurement:SETTing:VALidate` command or query.

This check also takes place when you use

`:CONFigure:MEASurement:SETTing:SAVE`,

`:CONFigure:MEASurement:SETTing:RECall`, or when a measurement is started.

For parameter dependencies and restrictions, please see “:CONFigure:MEASurement:SETup:MTIME” on page 78, “:CONFigure:MEASurement:SETup:ITUTime” on page 79, “:CONFigure:MEASurement:ALARm:ZONE{??:}:GRADient{??:}:TIME” on page 91, and “:CONFigure:MEASurement:SETTing:VALidate” on page 99).

For logging purposes most setting commands take an optional ‘user’ parameter.

Table 181 :CONFigure:MEASurement:SETTing:ACTual?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:ACTual? |
| description | Get the index of the setting currently being used. |
| parameters | none |
| response | int A value >0 is returned if the setting has been stored in FLASH memory (using :CONFigure:MEASurement:SETTing:SAVE), or has been recalled from FLASH memory (using :CONFigure:MEASurement:SETTing:RECall), and has not been changed since. 0 is returned if the FLASH setting has been deleted (using :CONFigure:MEASurement:SETTing:ERASe) since the last recall or store. 0 is also returned if the setting has not yet been stored, but has been validated, either explicitly (using :CONFigure:MEASurement:SETTing:VALidate), or by starting a measurement. -1 is returned if the setting was changed but has not been validated yet. |
| example | :conf:meas:sett:act? → +20<END> |

Table 182 :CONFigure:MEASurement:SETTing:NUMBer?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:NUMBer? |
| description | Get the number of settings. In addition to the settings spaces in FLASH memory, the working memory can hold a setting. |
| parameters | none |
| response | int |
| example | :conf:meas:sett:numb? → +20<END> |

Table 183 :CONFigure:MEASurement:SETTing:PRESet

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETTing:PRESet |
| description | Resets the setting values in the working memory |
| parameters | optional string (user name, maximum 79 characters) |
| response | none |
| example | :conf:meas:sett:pres |

Table 184 :CONFigure:MEASurement:SETTing:PROTect

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETTing:PROTect |
| description | Sets whether the settings are protected. Protecting the settings ensures that the settings with which the measurements in the instrument's trace buffer were made cannot be changed. The settings cannot be changed while the trace buffer is not empty. Use :READ:TRAC:EMPT? to find out if the buffer is empty. Use :READ:TRAC:CLE to clear the trace buffer. |
| parameters | boolean (0 1 off on), optional string (user name, maximum 79 characters) |
| response | none |
| example | :conf:meas:sett:prot on |

Table 185 :CONFigure:MEASurement:SETTing:PROTect?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETTing:PROTect? |
| description | Gets whether the settings are protected. The factory default is for settings to not be protected. |
| parameters | none |
| response | boolean (0 1) |
| example | :conf:meas:sett:prot? → 1<END> |

Table 186 :CONFigure:MEASurement:SETTing:CANCel

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETTing:CANCel |
| description | Discard all the changes to the setting since the last save or recall |

Table 186 :CONFigure:MEASurement:SETTing:CANcel

| | |
|-------------------|----------------------|
| parameters | none |
| response | none |
| example | :conf:meas:sett:canc |

Table 187 :CONFigure:MEASurement:SETTing:VALidate

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:VALidate |
| description | Check if a setting is valid. If no setting index is specified, the command is for the setting in working memory (current setting). |
| parameters | optional int (setting index), optional string (user name, maximum 79 characters) |
| response | The result can be found using :SYSTem:ERRor? (see “:SYSTem:ERRor?” on page 51). |
| example | :conf:meas:sett:val 1 |

Table 188 :CONFigure:MEASurement:SETTing:VALidate?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETTing:VALidate? |
| description | Check if a setting is valid. If no setting number is specified, the setting in working memory is validated. |
| parameters | optional int (setting index), optional string (user name, maximum 79 characters) |
| response | unquoted string (error message) If there is no error, the response is 'OK' If there is an error, then the response is 'ERROR: <description>' |
| example | :conf:meas:sett:val? 1 → OK<END> |

Table 189 :CONFigure:MEASurement:SETTing:VALidate:SEQuence

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:SETTing:VALidate:SEQuence |
| description | Check if all of the settings in the sequence are valid and the sequence is consistent. |
| parameters | string (user, maximum 80 characters) |
| response | The result can be found using :SYSTem:ERRor? (see “:SYSTem:ERRor?” on page 51). |
| example | conf:meas:sett:val:seq |

Table 190 :CONFigure:MEASurement:SETTing:VALidate:SEQUence?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:VALidate:SEQUence? |
| description | Check if all of the settings in the sequence are valid and the sequence is consistent. |
| parameters | string (user, maximum 80 characters) |
| response | unquoted string (error message) If the setting is valid, the response is 'OK' If there is an error, then the response is 'ERROR: <description>' |
| example | <code>conf:meas:sett:val:seq? → OK<END></code> |

Table 191 :CONFigure:MEASurement:SETTing:RECall

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:RECall |
| description | Recall a setting from FLASH memory. |
| parameters | int (setting index), optional string (user name, maximum 79 characters) |
| response | none |
| example | <code>:conf:meas:sett:rec 13</code> |

`:conf:meas:sett:save` only works if the contents of the settings are valid.

If you are unsure about the validity of the settings, you can use `:SYSTEM:ERROR?` to detect any problems during the save, and `:CONFigure:MEASurement:SETTing:VALidate?` to identify the source of any problems.

Table 192 :CONFigure:MEASurement:SETTing:SAVE

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:SAVE |
| description | Save the current setting to FLASH memory. |
| parameters | int (setting index), optional string (user name, maximum 79 characters) |
| response | none |
| example | <code>:conf:meas:sett:save 13</code> |

Table 193 :CONFigure:MEASurement:SETTing:ERASe

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:SETTing:ERASe |
| description | Erase a setting from memory. |
| parameters | int (setting index), optional string (user name, maximum 79 characters) |
| response | none |
| example | :conf:meas:sett:eras 13 |

:CONFigure:MEASurement:AUXiliary:DIGital subtree

Table 194 :CONFigure:MEASurement:AUXiliary:DIGital:ENABLE

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:DIGital:ENABLE |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Enable or disable external digital input lines tracking |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:meas:aux:dig:enab on |

Table 195 :CONFigure:MEASurement:AUXiliary:DIGital:ENABLE?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:DIGital:ENABLE? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Check whether external digital input lines tracking are enabled or disabled. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | boolean (0 1) |
| example | :conf:meas:aux:dig:enab? -> 1<END> |

:CONFigure:MEASurement:REFerence:TEMPerature subtree

Table 196 :CONFigure:::CONFigure:MEASurement:REFerence:TEMPerature:CALSenSors

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:CALSenSors |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set which external temperature sensors are to be used for calibration. 0 means no sensor is used for calibration. > 0 means the number of the sensor, which is used for calibration. |
| parameters | int (first sensor number, necessary for offset or slope calibration), int (second sensor number, necessary for slope calibration) |
| response | none |
| example | :conf:meas:ref:temp:cals 1,2 |

Table 197 :CONFigure:MEASurement:REFerence:TEMPerature:CALSenSors?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:CALSenSors? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get which external temperature sensors are to be used for calibration. 0 means no sensor is used for calibration. > 0 means the number of the sensor, which is used for calibration. |
| parameters | none |
| response | int (first sensor number, necessary for offset or slope calibration), int (second sensor number, necessary for slope calibration) |
| example | :conf:meas:ref:temp:cals? -> 1,2<END> |

CONFigure:MEASurement:REFerence:TEMPerature:SENSoR{?:?} subtree

{?:?} is the sensor number, so following scpi commands ENABLE, STARTdist and SPAN are referencing to this sensor.

Table 198 :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:ENABLE

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:ENABLE |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Enable or disable external temperature sensor tracking |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:meas:ref:temp:sens4:enab on |

Table 199 :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:ENABLE?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:ENABLE? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Check whether external temperature sensor tracking is enabled or disabled. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | boolean (0 1) |
| example | :conf:meas:ref:temp:sens4:enab? -> 1<END> |

Table 200 :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:STARTdist

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:STARTdist |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the start distance, that is the distance from the start position (defined by CONF:MEAS:SENS:STARtpos), from which to collect Temperature sensor results. |
| parameters | float (in meters) |
| response | none |
| example | :conf:meas:ref:temp:sens3:star 100.0 |

Table 201 :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:S
TARtdist?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:STARtdist? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the start distance. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float (in meters) |
| example | :conf:meas:ref:temp:sens3:star? -> +1.00000000E+002<END> |

Table 202 :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:S
PAN

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:SPAN |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the external temperature sensor span. |
| parameters | float (in meters) |
| response | none |
| example | :conf:meas:ref:temp:sens3:span 10.0: |

Table 203 :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:S
PAN?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:REFerence:TEMPerature:SENSor{?:?}:SPAN? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external temperature sensor span. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float (in meters) |
| example | :conf:meas:ref:temp:sens3:span? -> +1.00000000E+001<END> |

:CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?} subtree

{?:?} is the physical voltage sensor number, so following commands referencing to this sensor.

Table 204 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:ENABLE

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:ENABLE |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Enable or disable external voltage sensor |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:meas:aux:volt:sens2:enab on |

Table 205 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:ENABLE?

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:ENABLE? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Check whether external voltage sensor is enabled or disabled. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | boolean (0 1) |
| example | :conf:meas:aux:volt:sens2:enab? -> 1<END> |

Table 206 CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:OFFSet

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:OFFSet |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the user offset that is added to the external voltage sensor results. |
| parameters | float |
| response | none |
| example | :conf:meas:aux:volt:sens2:offs 10.0 |

Table 207 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:OFFSet?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:OFFSet? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the user offset. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float |
| example | :conf:meas:aux:volt:sens2:offs? -> +1.00000000E+001<END> |

Table 208 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:GAIN

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:GAIN |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the user gain that is added to the external voltage sensor results. |
| parameters | float |
| response | none |
| example | :conf:meas:aux:volt:sens2:gain 1.1 |

Table 209 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:GAIN?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:GAIN? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the user gain. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float |
| example | :conf:meas:aux:volt:sens2:gain? -> +1.10000000E+000<END> |

Table 210 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:UNIT

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:UNIT |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the user unit for the external voltage sensor results. |
| parameters | string (maximum 19 characters) |
| response | none |
| example | :conf:meas:aux:volt:sens2:unit "Watt" |

Table 211 :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:UNIT?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:VOLTage:SENSor{?:?}:UNIT? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the user unit. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | string |
| example | :conf:meas:aux:volt:sens2:unit? -> "Watt"<END> |

:CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?} subtree

{?:?} is the physical current sensor number, so following commands reference this sensor.

Table 212 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:ENABLE

| | |
|--------------------|---|
| syntax | ::CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:ENABLE |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Enable or disable external current sensor tracking |
| parameters | boolean (0 1 off on) |
| response | none |
| example | :conf:meas:aux:curr:sens2:enab on |

Table 213 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:ENABLE?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:ENABLE? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Check whether external current sensor tracking is enabled or disabled. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | boolean (0 1) |
| example | :conf:meas:aux:curr:sens2:enab? -> 1<END> |

Table 214 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:OFFSet

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:OFFSet |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the user offset that is added to the external current sensor results. |
| parameters | float |
| response | none |
| example | :conf:meas:aux:curr:sens2:offs 10.0 |

Table 215 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:OFFSet?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:OFFSet? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the user offset. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float |
| example | :conf:meas:aux:curr:sens2:offs? -> +1.00000000E+001<END> |

Table 216 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:GAIN

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:GAIN |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the user gain that is added to the external current sensor results. |
| parameters | float |
| response | none |
| example | :conf:meas:aux:curr:sens2:gain 1.1 |

Table 217 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:GAIN?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:GAIN? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the user gain. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | float |
| example | :conf:meas:aux:curr:sens2:gain? -> +1.10000000E+000<END> |

Table 218 :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:UNIT

| | |
|--------------------|---|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:UNIT |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Set the user unit for the external current sensor results. |
| parameters | string (maximum 19 characters) |
| response | none |
| example | :conf:meas:aux:curr:sens2:unit "Watt" |

Table 219 ? :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:UNIT?

| | |
|--------------------|--|
| syntax | :CONFigure:MEASurement:AUXiliary:CURRent:SENSor{?:?}:UNIT? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the user unit. If no setting index is specified, the query is for the setting in working memory (current setting). |
| parameters | optional int (setting index) |
| response | string |
| example | :conf:meas:aux:curr:sens2:unit? -> "Watt"<END> |

:CONFigure:ERRor subtree

Table 220 :CONFigure:ERRor:RELAy

| | |
|--------------------|--|
| syntax | :CONFigure:ERRor:RELAy |
| description | Set which relay is used if an error occurs. |
| parameters | int (relay number) (Note: Allowed numbers may be limited depending on FW version) |
| response | none |
| example | :conf:err:rel 1 |

:CONFigure:ERRor:RELAy?

| | |
|--------------------|--|
| syntax | :CONFigure:ERRor:RELAy? |
| description | Get the number of the relay used if an error occurs. |
| parameters | none |
| response | int (relay number) |
| example | :conf:err:rel? → 1<END> |

:CONFigure:SEQuence subtree

Table 221 :CONFigure:SEQuence:SLENgth?

| | |
|--------------------|---|
| syntax | :CONFigure:SEQuence:SLENgth? |
| description | Get the maximum length of the sequence of settings. |
| parameters | none |
| response | int |
| example | :conf:seq:slen? → 4<END> |

Table 222 :CONFigure:SEQuence:SEQuence

| | |
|--------------------|--|
| syntax | :CONFigure:SEQuence:SEQuence |
| description | <p>Set the settings to be used, and the order in which they are to be measured.</p> <p>This allows you to perform a variety of measurements for different purposes.</p> <ul style="list-style-type: none">• $1 \leq \text{number of settings} \leq \text{CONF:SEQ:SLEN?}$.• Measurement time, intermediate trace update time, sampling interval, spatial resolution must be the same for all settings used.• Each setting is only allowed once in a sequence. That is, duplicate settings are not supported. (You can workaroud this restriction by saving the same setting more than once.)• Repeat Mode must be 1 for each setting.• Dual ended measurements are defined by adding first the setting index and second the negative setting index. For example, CONF:SEQ:SEQ 1, -1, 2, 3 is a sequence with a dual ended measurement using setting 1, followed by single ended measurements with settings 2 and 3. See “:SYSTem:HARDware:DUALended?” on page 61 for determining whether your hardware supports dual ended measurements.• The list can be deleted by using the command with an empty list. |
| parameters | int list |
| response | none |
| example | :conf:seq:seq 1, 2, 3 |

Table 223 :CONFigure:SEquence:SEquence?

| | |
|--------------------|--|
| syntax | :CONFigure:SEquence:SEquence? |
| description | Get the sequence of settings to be measured. |
| parameters | none |
| response | int list An empty list is returned as the value "0" |
| example | :conf:seq:seq? → 1, 2, 3<END> |

Table 224 :CONFigure:SEquence:REPeatmode

| | |
|--------------------|--|
| syntax | :CONFigure:SEquence:REPeatmode |
| description | Set whether or not the sequence of measurements is to be measured just once or repeatedly. |
| parameters | int (number of repeats) or enum (ONCE FORever UBFfull, where UBFfull means until the buffer is full) |
| response | none |
| example | :conf:seq:rep ubf |

Table 225 :CONFigure:SEquence:REPeatmode?

| | |
|--------------------|--|
| syntax | :CONFigure:SEquence:REPeatmode? |
| description | Get whether or not the sequence of measurements is to be measured just once. |
| parameters | none |
| response | int (number of repeats) where "1" is returned for either a single repeat; "0" is returned for repeat forever, and "-1" for repeat until buffer full. |
| example | :conf:seq:rep? → 1<END> |

Table 226 :CONFigure:SEquence:VALidate

| | |
|--------------------|--|
| syntax | :CONFigure:SEquence:VALidate |
| description | Check if all of the settings in the sequence are valid and the sequence is consistent. |
| parameters | string (user, maximum 80 characters) |
| response | The result can be found using :SYSTem:ERRor? (see ":SYSTem:ERRor?" on page 51). |
| example | conf:seq:val |

Table 227 :CONFigure:SEquence:VALidate?

| | |
|--------------------|--|
| syntax | :CONFigure:SEquence:VALidate? |
| description | Check if all of the settings in the sequence are valid and the sequence is consistent. |
| parameters | string (user, maximum 80 characters) |
| response | unquoted string (error message) If the sequence is valid, the response is 'OK' If there is an error, then the response is 'ERROR: <description>' |
| example | conf:seq:val? → OK<END> |

Starting and Stopping Measurements – the :MEASurement Subsystem

`:meas:sing` only works if the contents of the settings are valid. If you are unsure about the validity of the settings, you can use `:SYSTEM:ERROR?` to detect any problems when you try to start, and `:CONFIGure:MEASurement:SETTing:VALidate?` to identify the source of any problems.

Table 228 :MEASurement:SINGle[:STATe]

| | |
|--------------------|--|
| syntax | :MEASurement:SINGle[:STATe] |
| description | Start or stop a single measurement |
| parameters | boolean (0 1 off on), optional string (user name, maximum 79 characters) |
| response | none |
| example | :meas:sing on |

Table 229 :MEASurement:SINGle[:STATe]?

| | |
|--------------------|---|
| syntax | :MEASurement:SINGle[:STATe]? |
| description | Check if a single measurement is running. |
| parameters | none |
| response | boolean (0 1) |
| example | :meas:sing? → 1<END> |

Table 230 :MEASurement:SEQuence[:STATe]

| | |
|--------------------|---|
| syntax | :MEASurement:SEQuence[:STATe] |
| description | Start or stop a sequential measurement |
| parameters | boolean (0 1 off on), optional string (user, maximum 79 characters) |
| response | none |
| example | meas:seq on |

Table 231 :MEASurement:SEQuence[:STATe]?

| | |
|--------------------|---|
| syntax | :MEASurement:SEQuence[:STATe]? |
| description | Check if a sequential measurement is running. |
| parameters | none |
| response | boolean (0 1) |
| example | :meas:seq? → 1<END> |

Output – the :OUTPut Subsystem

The outputs are relays used to notify external hardware of alarms, fiber breaks, or errors.

The relays are reset when a measurement with active alarm zones starts, or after receiving `:ALARm:RESet`.

Which relays are assigned to which function is determined by `:CONFigure:MEASurement:ALARm:ZONE{?:?}[:ALARm]:RELay`, `:CONFigure:MEASurement:ALARm:ZONE{?:?}:FBReak:RELay`, `:CONFigure:MEASurement:FIReDef{?:?}:RELay`, and `:CONFigure:ERRor:RELay`, and can be found using the corresponding queries.

`:SYSTem:LOGic:OUTPut` determines whether the relays are active open or closed.

Table 232 :OUTPut:RELays[:STATe]

| | |
|--------------------|--|
| syntax | <code>:OUTPut:RELays[:STATe]</code> |
| description | The relays can be configured with this command. Use <code>:SYSTem:HARDware:NOReLay?</code> to get the exact number of relays. |
| parameters | For the A version: bitmap For the B version: bitmap, bitmap LSB is relay 1. |
| response | none |
| example | For the A version: <code>:outp:rel 6</code> For the B version: <code>:outp:rel 6,0</code> |

Table 233 :OUTPut:RELays[:STATe]?

| | |
|--------------------|---|
| syntax | <code>:OUTPut:RELays[:STATe]?</code> |
| description | The status of the output relays can be determined with this query. The relays are reset by <code>:ALARm:RESet</code> , or when a measurement with at least one active alarm zone is started. |
| parameters | none |
| response | For the A version: bitmap For the B version: bitmap, bitmap LSB is relay 1. |
| example | For the A version: <code>:outp:rel? → 6<END></code> For the B version: <code>:outp:rel? → 6,0<END></code> |

Input – the :INPut Subsystem

The inputs are used to reset alarms.

Table 234 :INPut:STATe?

| | |
|--------------------|--|
| syntax | :INPut:STATe? |
| description | The status of the input lines can be determined with this query. Whether the input is active high or low is determined by the :SYSTem:LOGic:INPut command. |
| parameters | none |
| response | bitmap (the LSB corresponds to input line 1) |
| example | :inp:stat? → 6<END> |

4 Operations on Results

Checking Results – the :READout Subsystem

:READout:MEASurement subtree

This subtree lets you read measurement values.

For a measurement sequence, a mandatory sequence index refers to the position of the setting used in the sequence. The sequence index cannot be used for single measurements. That is, if the measurement sequence consists of the settings 13, 14, 15, 16, the sequence index 2 refers to the measurement made with setting 14; the sequence index 3 refers to the measurement made with setting 15.

If the measurement sequence contains a dual ended measurement, the sequence index for both settings refer to the dual ended measurement.

That is, if the measurement sequence consists of the settings 13, 14, -14, 15, the sequence index 2 or 3 both refer to the dual ended measurement made with setting 14.

NOTE

For reading values using the commands of Table 202 up to Table 207 if it is necessary to enable alarming (“Table 138”) and to enable the corresponding alarm condition in the zone (see “Table 146”)

Table 235 :READout:MEASurement:ZONE{?:?}:TEMPerature:UPPer?

| | |
|--------------------|---|
| syntax | :READout:MEASurement:ZONE{?:?}:TEMPerature:UPPer? |
| description | Get the maximum temperature recorded. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:meas:zone4:temp:upp? → 4.50650000E+0001<END> |

Table 236 :READout:MEASurement:ZONE{?:?}:TEMPerature:AVERage?

| | |
|--------------------|---|
| syntax | :READout:MEASurement:ZONE{?:?}:TEMPerature:AVERage? |
| description | Get the mean temperature recorded. |

Table 236 :READout:MEASurement:ZONE{?:?}:TEMPerature:AVERage?

| | |
|-------------------|---|
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:meas:zone4:temp:aver? → 2.00000000E+001<END> |

Table 237 :READout:MEASurement:ZONE{?:?}:TEMPerature:LOWer?

| | |
|--------------------|---|
| syntax | :READout:MEASurement:ZONE{?:?}:TEMPerature:LOWer? |
| description | Get the minimum temperature recorded. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:meas:zone4:temp:low? → - 5.06500000E+000<END> |

Table 238 :READout:MEASurement:ZONE{?:?}:DEViation:UPPer?

| | |
|--------------------|---|
| syntax | :READout:MEASurement:ZONE{?:?}:DEViation:UPPer? |
| description | Get the maximum deviation from the zone average |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:meas:zone4:dev:upp? → 5.60500000E+000<END> |

Table 239 :READout:MEASurement:ZONE{?:?}:DEViation:LOWer?

| | |
|--------------------|---|
| syntax | :READout:MEASurement:ZONE{?:?}:DEViation:LOWer? |
| description | Get the minimum deviation from the zone average |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:meas:zone4:dev:low? → 6.00000000E-002<END> |

Table 240 :READout:MEASurement:ZONE{?:?}:GRADient{?:?}:TCHange?

| | |
|--------------------|---|
| syntax | :READout:MEASurement:ZONE{?:?}:GRADient{?:?}:TCHange? |
| description | Get the current change in temperature in the gradient time |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:meas:zone4:grad2:tch? → 6.00000000E-002<END> |

Table 241 :READout:MEASurement: ZONEARRay:TEMPerature:UPPer?

| | |
|--------------------|--|
| syntax | :READout:MEASurement: ZONEARRay:TEMPerature:UPPer/qonly/ |
| description | Get the actual maximum temperature for all possible zones (from firmware 3.20) |
| parameters | optional int (sequence index) |
| response | binary byte array (floats) |
| example | :read:meas:zonearr:temp>upp? → #3123..<END> |

Table 242 :READout:MEASurement: ZONEARRay:TEMPerature:LOWer?

| | |
|--------------------|--|
| syntax | :READout:MEASurement: ZONEARRay:TEMPerature:LOWer/qonly/ |
| description | Get the actual minimum temperature for all possible zones (from firmware 3.20) |
| parameters | optional int (sequence index) |
| response | binary byte array (floats) |
| example | :read:meas:zonearr:temp>low? → #3123..<END> |

Table 243 :READout:MEASurement: ZONEARRay:TEMPerature:AVERage?

| | |
|--------------------|--|
| syntax | :READout:MEASurement: ZONEARRay:TEMPerature:AVERage/qonly |
| description | Get the actual average temperature for all possible zones (from firmware 3.20) |
| parameters | optional int (sequence index) |
| response | binary byte array (floats) |
| example | :read:meas:zonearr:temp>aver? → #3123..<END> |

:ALARm subtree

Table 244 :ALARm:RESet

| | |
|--------------------|--|
| syntax | :ALARm:RESet |
| description | Resets the alarm relays, turns off the alarm LED and resets the corresponding status bits. |
| parameters | optional string (user name, maximum 79 characters) |
| response | none |
| example | :alar:res |

:READout:ALARm subtree

Table 245 :READout:ALARm:DETEcted?

| | |
|--------------------|--|
| syntax | :READout:ALARm:DETEcted? |
| description | Ask the instrument if an alarm was detected |
| parameters | optional int (trace index) MINimum MAXimum |
| response | boolean (0 if there is no alarm, 1 if there is an alarm) |
| example | :read:alar:det? → 0<END> |

Table 246 :READout:ALARm:DETEcted:ACCumulated?

| | |
|--------------------|---|
| syntax | :READout:ALARm:DETEcted:ACCumulated? |
| description | Get alarm status information for all zones, since the last alarm reset. See “:READout:ALARm:DETEcted?” on page 123. |

Table 246 :READout:ALARm:DETEcted:ACCumulated?

| | |
|-------------------|------------------------------|
| parameters | none |
| response | boolean |
| example | :read:alar:det:acc? → 0<END> |

Table 247 :READout:ALARm:TINDEx?

| | |
|--------------------|---|
| syntax | :READout:ALARm:TINDEx? |
| description | Get the index of the last trace with a completed alarm calculation (the measurement data may be available earlier than the alarm data). |
| parameters | none |
| response | int |
| example | :read:alar:tind? → +64<END> |

Table 248 :READout:ALARm:DATA?

| | |
|--------------------|--|
| syntax | :READout:ALARm:DATA? |
| description | Get alarm information for all zones: each byte in the block returned by the instrument corresponds to a zone (first byte for the first zone, and so on). Each byte is a bitmask (see “:CONFigure:MEASurement:ALARm:ZONE{?}:CONDition:ENABLE” on page 87) |
| parameters | optional int (trace index) |
| response | binary byte array |
| example | :read:alar:data? → #3512...<END> |

Table 249 :READout:ALARm:DATA:ACCumulated?

| | |
|--------------------|--|
| syntax | :READout:ALARm:DATA:ACCumulated? |
| description | Get alarm information for all zones, since the last alarm reset. See “:READout:ALARm:DATA?” on page 124. |
| parameters | none |
| response | binary byte array |
| example | :read:alar:data:acc? → #3512...<END> |

Table 250 :READout:ALARm:RELays[:STATe]?

| | |
|--------------------|---|
| syntax | :READout:ALARm:RELays[:STATe]? |
| description | Get the relay state. By giving the specifying the trace index, you can read a relay state from the past. |
| parameters | optional int (trace index) |
| response | bitmap |
| example | :read:alar:rel? → 1025<END> |

:READout:FBReak subtree

Fiber breaks can only be detected in alarm zones that are enabled and that have active alarms.

If you want to detect a fiber break, without detecting alarms, define a zone for the whole sensor fiber, and enable a temperature minimum check with limit = -273.15 degree C.

Table 251 :READout:FBReak:DETEcted?

| | |
|--------------------|---|
| syntax | :READout:FBReak:DETEcted? |
| description | Check whether a break has been detected in the current measurement of the fiber. Fiber breaks can only be detected in active alarm zones, that is for which alarms are enabled, and for which at least one bit is set in the condition bitmap. |
| parameters | int (channel) |
| response | Boolean (0 if there no break has been detected, 1 if a break has been detected) |
| example | :read:fbr:det? → 1<END> |

Table 252 :READout:FBReak:POSition?

| | |
|--------------------|---|
| syntax | :READout:FBReak:POSition? |
| description | Get the position of a break in the current measurement of the fiber |
| parameters | int (channel) |
| response | float (in meters) |
| example | :read:fbr:pos? → 2.36188000E+003<END> |

:READout:FIRE subtree

Though these commands refer to “fire”, they can be used for any temperature event.

Table 253 :READout:FIRE:DETECTED?

| | |
|--------------------|---|
| syntax | :READout:FIRE:DETECTED? |
| description | Ask the instrument if there is a temperature event. |
| parameters | optional int (trace index) |
| response | boolean (0 if there is no temperature event, 1 if there is a temperature event) |
| example | :read:fire:det? → 1<END> |

Table 254 :READout:FIRE:DIRrection?

| | |
|--------------------|---|
| syntax | :READout:FIRE:DIRrection? |
| description | Get the direction in which the temperature event is moving. Please note: this query takes the turn back point of the fiber into consideration (as set using :CONFigure:MEASurement:SETup:POReturn). |
| parameters | optional int (trace index) |
| response | 1 if the temperature event is moving away from the DTS 0 if the temperature event is stationary -1 if the temperature event is moving toward the DTS |
| example | :read:fire:dir? → -1<END> |

Table 255 :READout:FIRE:POSition?

| | |
|--------------------|---|
| syntax | :READout:FIRE:POSition? |
| description | Get the position of the temperature event (centre). |
| parameters | optional int (trace index) |
| response | float (in meters) from the sensor start position |
| example | :read:fire:pos? → 1.02435000E+003<END> |

Table 256 :READout:FIRE:SIZE[:ABSolut]?

| | |
|--------------------|---|
| syntax | :READout:FIRE:SIZE[:ABSolut]? |
| description | Get the size of the temperature event. |
| parameters | optional int (trace index) |
| response | float with the length of the temperature event in meters; 0.0 means no fire / not confirmed |
| example | :read:fire:size? → 4.70000000E+001<END> |

Table 257 :READout:FIRE:SIZE:INDEX?

| | |
|--------------------|---|
| syntax | :READout:FIRE:SIZE:INDEX? |
| description | Get the specified size class of a temperature event. |
| parameters | optional int (trace index) |
| response | int indicating the size index of the temperature event (as defined by the CONFigure:MEASurement:FIRedef{?:?:}SIZE command); 0 means no fire |
| example | :read:fire:size:ind? → 3<END> |

Table 258 :READout:FIRE:DATA?

| | |
|--------------------|---|
| syntax | :READout:FIRE:DATA? |
| description | Get the temperature event data for all sample points of the current trace. Each byte corresponds to a sample point. The first byte corresponds to the sample point at the <i>start distance</i> (:CONF:MEAS:SETup:START); the second sample point corresponds to <i>start distance + sampling interval</i> (:CONF:MEAS:SETup:SINTERVAL); and so on. If a temperature event is detected at the sample point, the byte has the value 1. If no temperature event is detected at the sample point, the byte has the value 0. The number of bytes is determined by , :CONF:MEAS:SETup:SPAN / :CONF:MEAS:SETup:SINTERVAL. |

Table 258 :READout:FIRE:DATA?

| | |
|-------------------|--|
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) - for information on the sequence index, see “:READout:MEASurement subtree” on page 120. |
| response | binary byte array |
| example | :read:fire:data? → #41001...<END> First digit (4) says, how many digits follow; following (here) four digits (1001) determine block size; following is actual content. |

:READ:LOGFile subtree

Table 259 :READout:LOGFile?

| | |
|--------------------|--|
| syntax | :READout:LOGFile? |
| description | Get the log file. |
| parameters | none |
| response | ASCII bloc, with the format: yyyy:mm:dd HH:MM:SS <space><message><carriage return><newline> |
| example | :read:log? → 2006:07:17 11:03:21 #545027 ... 2006-11-28.09:46:16, SelfcalStarted 2006-11-28.09:46:39, SelfcalFinished 2006-11-28.09:46:39, BootFinished 2006-11-28.10:53:33, setting preset by <unknown> 2006-11-28.10:53:33, setting validated by <unknown> 2006-11-28.10:53:33, MeasurementStarted, single, by <unknown> 2006-11-28.10:53:33, FireAlarmOK, by Meas Start 2006-11-28.10:53:33, ZoneAlarmOK, by Meas Start 2006-11-28.10:54:00, MeasurementFinished, normal ... |

The log file contains up to (approximately) 64 kB of data. If the file gets bigger than this, the first half of the older messages are discarded (reducing the log file to around 32kB).

Message examples:

| Message | Note |
|--|---|
| BootFinished | boot finished |
| setting preset by <user name> | measurement setting has been preset |
| setting validated by <user name> | measurement setting has been validated |
| MeasurementStarted, single, by <user name> | single measurement started |
| MeasurementStarted, sequence, by <user name> | measurement sequence started |
| FireAlarmOK, by Meas Start | temperature event alarm reset at measurement start |
| ZoneAlarmOK, by Meas Start | zone alarm reset at measurement start |
| MeasurementFinished, normal | measurement finished |
| MeasurementFinished, Keep <number> Traces before first Alarm | measurement finished because the DTS was configured to keep the specified number of traces when an alarm is detected (see “:CONFigure:MEASurement:ALARm:KTRaces” on page 82). |
| MeasurementFinished, by <user name> | measurement stopped by user |
| FireAlarmDetected | temperature event alarm occurred |
| ZoneAlarmDetected | zone alarm occurred (for example, a fiber break) |

If <user name> is not specified or is empty, it is replaced by “<unknown>”.

That is, if <user name> is set to “David Smith”, then “setting preset by David Smith” is returned; If it is not set, then “setting preset by <unknown>” is returned.

:READout:TRACe subtree

The trace buffer is emptied when a measurement is started, or if the DTS is switched off.

Table 260 :READout:TRACe:EMPTy?

| | |
|--------------------|---|
| syntax | :READout:TRACe:EMPTy? |
| description | Checks whether the trace buffer is empty. |
| parameters | none |
| response | boolean (0 1) |
| example | :read:trac:empt? → 0<END> |

Table 261 :READout:TRACe:CLEAr

| | |
|--------------------|-------------------------|
| syntax | :READout:TRACe:CLEAr |
| description | Empty the trace buffer. |
| parameters | none |
| response | none |
| example | :read:trac:cle |

Table 262 :READout:TRACe:BSIZe?

| | |
|--------------------|--|
| syntax | :READout:TRACe:BSIZe? |
| description | Get the size of the trace buffer, that is the maximum number of traces that can be stored. |
| parameters | none |
| response | int |
| example | :read:trac:bsiz? → +150<END> |

Table 263 :READout:TRACe:INDex?

| | |
|--------------------|--|
| syntax | :READout:TRACe:INDex? |
| description | Get the index of the most recent trace. When performing a repeated measurement, this index is increased with every result trace stored in the trace ring buffer. You can always access the last trace and at most the <trace ring buffer size - 1> previous traces. For example, if the ring buffer size is 150 and the index of the last measured trace is 500, you can read traces 351 to 500 from the buffer. |
| parameters | none |
| response | int |
| example | :read:trac:ind? → +13<END> |

Table 264 :READout:TRACe:TIME?

| | |
|--------------------|---|
| syntax | :READout:TRACe:TIME? |
| description | Get the date and time a trace was measured |
| parameters | int (trace index) |
| response | int (year), int (month), int (day), int(hour), int (minute), int (second) |
| example | :read:trac:time? 3 → +2006, +5, +17, +22, +58, +23<END> |

Table 265 :READout:TRACe:SINDeX?

| | |
|--------------------|--|
| syntax | :READout:TRACe:SINDeX? |
| description | Get the index of the setting used to measure the trace |
| parameters | int (trace index) |
| response | int (setting index) |
| example | :read:trac:sind? 3 → +13<END> |

Table 266 :READout:TRACe:POINts?

| | |
|--------------------|-------------------------------------|
| syntax | :READout:TRACe:POINts? |
| description | Get the number of points in a trace |
| parameters | int (trace index) |
| response | int (number of points) |
| example | :read:trac:poin? 3 → +124<END> |

Table 267 :READout:TRACe:STARtdist?

| | |
|--------------------|--|
| syntax | :READout:TRACe:STARtdist? |
| description | Get the start distance used when measuring the trace |
| parameters | int (trace index) |
| response | float (in meters) |
| example | :read:trac:star? 3 → 2.55000000E+001<END> |

Table 268 :READout:TRACe:SINterval?

| | |
|--------------------|---|
| syntax | :READout:TRACe:SINterval? |
| description | Get the sampling interval with which a trace was measured |
| parameters | int (trace index) |
| response | float (in meters) |
| example | :read:trac:sint? 3 → 1.10000000E+000<END> |

Table 269 :READout:TRACe:STORedata?

| | |
|--------------------|---|
| syntax | :READout:TRACe:STORedata? |
| description | Get the type of a trace (see “:CONFigure:MEASurement:SETup:STORedata” on page 82) |
| parameters | int (trace index) |
| response | enum (data type) TEMPerature if the trace stores temperature values LOSS if the trace stores raw data |
| example | :read:trac:stor? 3 → TEMP<END> |

Table 270 :READout:TRACe:DATA?

| | |
|--------------------|-------------------------------------|
| syntax | :READout:TRACe:DATA? |
| description | Get a specific trace. |
| parameters | int (trace index) |
| response | binary float array |
| example | :read:trac:data? 3 → #49404...<END> |

Table 271 :READout:TRACe:INFO?

| | |
|--------------------|---|
| syntax | :READout:TRACe:INFO? |
| description | Check whether a trace is from a dual ended measurement, and the status of the measurement. |

Table 271 :READout:TRACe:INFO?

| | |
|-------------------|--|
| parameters | int (trace index) |
| response | boolean (0 1, whether the trace is from a dual ended measurement), boolean (0 1, whether there was a fiber break, that is whether the trace was build from one or both channels), boolean (0 1, reserved for future use, currently always returns '0') |
| example | :read:trac:info? 3 → 1,0,0<END> |

READout:TRACe:REFerence:TEMPerature:CALibration subtree

Table 272 :READout:TRACe:REFerence:TEMPerature:CALibration:SENSors?

| | |
|--------------------|---|
| syntax | :READout:TRACe:REFerence:TEMPerature:CALibration:SENSors? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get which external temperature sensors are to be used for calibration. 0 means no sensor is used for calibration. > 0 means the number of the sensor, which is used for calibration. |
| parameters | int (trace index) |
| response | int (first sensor number, necessary for offset or slope calibration), int (second sensor number, necessary for slope calibration) |
| example | :read:trac:ref:temp:cal:sens? 1 -> 1,2<END> |

Table 273 :READout:TRACe:REFerence:TEMPerature:CALibration:OFFSet?

| | |
|--------------------|--|
| syntax | :READout:TRACe:REFerence:TEMPerature:CALibration:OFFSet? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external temperature calibration offset correction. |
| parameters | int (trace index) |
| response | float (in K) |
| example | :read:trac:ref:temp:cal:offs? 1 -> +1.00000000E+001<END> |

Table 274 :READout:TRACe:REFerence:TEMPerature:CALibration:SLOPe?

| | |
|--------------------|---|
| syntax | :READout:TRACe:REFerence:TEMPerature:Calibration:SLOPe? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external temperature calibration slope correction. |
| parameters | int (trace index) |
| response | float (in K/km) |
| example | :read:trac:ref:temp:cal:slop? 1 -> +3.00000000E-003<END> |

READout:TRACe:REFerence:TEMPerature:SENSor{?:?} subtree

Table 275 :READout:TRACe:REFerence:TEMPerature:SENSor{?:?}:TEMPerature?

| | |
|--------------------|--|
| syntax | :READout:TRACe:REFerence:TEMPerature:SENSor{?:?}:TEMPerature? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external reference sensor temperature |
| parameters | int (trace index) |
| response | float (in C) |
| example | :read:trac:ref:temp:sens1:temp? 1 -> +1.00000000E+001<END> |

:READout:TRACe:AUXiliary subtree

Table 276 :READout:TRACe:AUXiliary:DIGital?

| | |
|--------------------|--|
| syntax | :READout:TRACe:AUXiliary:DIGital? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external digital input value. |
| parameters | int (trace index) |
| response | bitmap (the LSB corresponds to input line 1) |
| example | :read:trac:aux:dig? -> 3<END> |

Table 277 :READout:TRACe:AUXiliary:VOLTage:SENSor{?:?}?

| | |
|--------------------|---|
| syntax | :READout:TRACe:AUXiliary:VOLTage:SENSor{?:?}? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external voltage sensor value. |
| parameters | int (trace index) |
| response | float |
| example | :read:trac:aux:volt:sens1? -> +2.00000000E+001<END> |

Table 278 :READout:TRACe:AUXiliary:CURREnt:SENSor{?:?}?

| | |
|--------------------|---|
| syntax | :READout:TRACe:AUXiliary:CURREnt:SENSor{?:?}? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external current sensor value. |
| parameters | int (trace index) |
| response | float |
| example | :read:trac:aux:curr:sens2? -> +2.00000000E+001<END> |

:READout:ITRace subtree

You can access the intermediate results buffer, which is updated with each measurement iteration (determined with :CONFIgure:MEASurement:SETup:ITUTime).

For a measurement sequence, a mandatory sequence index refers to the position of the setting used in the sequence. The sequence index cannot be used for single measurements. That is, if the measurement sequence consists of the settings 13, 14, 15, 16, the sequence index 2 refers to the measurement made with setting 14; the sequence index 3 refers to the measurement made with setting 15.

If the measurement sequence contains a dual ended measurement, the sequence index for both settings refer to the dual ended measurement.

That is, if the measurement sequence consists of the settings 13, 14, -14, 15, the sequence index 2 or 3 both refer to the dual ended measurement made with setting 14.

Table 279 :READout:ITRace:INDex?

| | |
|--------------------|--|
| syntax | :READout:ITRace:INDex? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the iteration of the current measurement. This will indicate whether new measurements are available. For example, if the intermediate trace time is a third of the measurement time, the trace and intermediate trace indices are related as follows: Trace Index: 01 2 3 4 Intermediate trace index: 0 1 2 3 1 2 3 1 2 3 1 2 |
| parameter | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | int |
| example | :read:itr:ind? → +53<END> |

Table 280 :READout:ITRace:SINDex?

| | |
|--------------------|--|
| syntax | :READout:ITRace:SINDex? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the setting index of the intermediate trace |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | int |
| example | :read:itr:sind? → +13<END> |

Table 281 :READout:ITRace:POINts?

| | |
|--------------------|---|
| syntax | :READout:ITRace:POINts? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the number of points in a trace. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | int |
| example | :read:itr:poin? → +244<END> |

Table 282 :READout:ITRace:DATA?

| | |
|--------------------|---|
| syntax | :READout:ITRace:DATA? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the intermediate temperature, loss or ratio trace data The TEMPerature trace is in degrees Celsius, with the averaged data getting better with each iteration. This is the default trace. The LOSS trace is in dB, normalised to 0dB at the connector, not avaraged. The RATIo trace is of the Stokes to the Anti-Stokes power (in dB: $10 \log_{10} (P_{\text{Antistokes}}/P_{\text{Stokes}})$), with the averaged data getting better with each iteration. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) TEMPerature LOSS RATIo |
| response | binary float array |
| example | :read:itr:data? → #49404...<END> :read:itr:data? LOSS,1 → ...<END> |

Table 283 :READout:ITRACe:INFO?

| | |
|--------------------|--|
| syntax | :READout:ITRACe:INFO? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Check whether an intermediate trace is from a dual ended measurement, and the status of the measurement. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | boolean (0 1, whether the trace is from a dual ended measurement), boolean (0 1, whether there was a fiber break, that is whether the trace was build from one or both channels), boolean (0 1, reserved for future use, currently always returns '0') |
| example | :read:itr:info? 3 → 1,0,0<END> |

:READout:ITRace:REFerence:TEMPerature:CALibration subtree

Table 284 :READout:ITRace:REFerence:TEMPerature:CALibration:SENSors?

| | |
|--------------------|---|
| syntax | :READout:ITRace:REFerence:TEMPerature:CALibration:SENSors? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get which external temperature sensors are to be used for calibration. 0 means no sensor is used for calibration. > 0 means the number of the sensor, which is used for calibration. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | int (first sensor number, necessary for offset or slope calibration), int (second sensor number, necessary for slope calibration) |
| example | :read:itr:ref:temp:cal:sens? 1 -> 1,2<END> |

Table 285 :READout:ITRace:REFerence:TEMPerature:CALibration:OFFSet?

| | |
|--------------------|--|
| syntax | :READout:ITRace:REFerence:TEMPerature:CALibration:OFFSet? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external temperature calibration offset correction. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float (in K) |
| example | :read:itr:ref:temp:cal:offs? 1 -> +1.00000000E+001<END> |

Table 286 :READout:ITRace:REFerence:TEMPerature:CALibration:SLOPe?

| | |
|--------------------|---|
| syntax | :READout:ITRace:REFerence:TEMPerature:CALibration:SLOPe? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external temperature calibration slope correction. |

Table 286 :READout:ITRace:REFerence:TEMPerature:CALibration:SLOPe?

| | |
|-------------------|---|
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float (in K/km) |
| example | :read:itr:ref:temp:cal:slop? 1 -> +3.00000000E-003<END> |

READout:ITRace:REFerence:TEMPerature:SENSor{?:?} subtree

Table 287 READout:ITRace:REFerence:TEMPerature:SENSor{?:?}:TEMPerature?

| | |
|--------------------|---|
| syntax | READout:ITRace:REFerence:TEMPerature:SENSor{?:?}:TEMPerature? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external temperature reference temperature |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float (in C) |
| example | :read:itr:ref:temp:sens:temp? 1 -> +1.00000000E+001<END> |

:READout:ITRace:AUXiliary subtree

Table 288 :READout:ITRace:AUXiliary:DIGital?

| | |
|--------------------|--|
| syntax | :READout:ITRace:AUXiliary:DIGital? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external digital input value. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | bitmap (the LSB corresponds to input line 1) |
| example | :read:itr:aux:dig? -> 3<END> |

Table 289 :READout:ITRace:AUXiliary:VOLTage:SENSor{?:?}?

| | |
|--------------------|---|
| syntax | :READout:ITRace:AUXiliary:VOLTage:SENSor{?:?}? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external voltage sensor value. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:itr:aux:volt:sens1? -> +2.00000000E+001<END> |

Table 290 :READout:ITRace:AUXiliary:CURREnt:SENSor{?:?}?

| | |
|--------------------|---|
| syntax | :READout:ITRace:AUXiliary:CURREnt:SENSor{?:?}? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external current sensor value. |
| parameters | int (sequence index, mandatory for measurement sequences, not for use with single measurements) |
| response | float |
| example | :read:itr:aux:curr:sens2? -> +2.00000000E+001<END> |

:READout:TEMPerature subtree

Table 291 :READout:TEMPerature?

| | |
|--------------------|--|
| syntax | :READout:TEMPerature? |
| description | Get the temperature value for the selected source. |
| parameters | RFIBer for the reference fiber. |
| response | float |
| example | :read:temp? rfib -> 1.56738492E+001<END> |

:READout:REFerence:TEMPerature:SENSor{?:?} subtree

Table 292 :READout:REFerence:TEMPerature:SENSor{?:?}:TEMPerature?

| | |
|--------------------|---|
| syntax | :READout:REFerence:TEMPerature:SENSor{?:?}:TEMPerature? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the actual external temperature sensor temperature |
| parameters | none |
| response | float |
| example | :read:ref:temp:sens1:temp? -> +1.00000000E+001<END> |

:READout:AUXiliary subtree

Table 293 :READout: AUXiliary:VOLTage:SENSor{?:?}?

| | |
|--------------------|---|
| syntax | :READout:AUXiliary:VOLTage:SENSor{?:?}? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external voltage sensor value. |
| parameters | none |
| response | float |
| example | :read:aux:volt:sens1? -> +2.00000000E+001<END> |

Table 294 :READout:AUXiliary:CURRent:SENSor{?:?}?

| | |
|--------------------|---|
| syntax | :READout:AUXiliary:CURRent:SENSor{?:?}? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external current sensor value. |
| parameters | none |
| response | float |
| example | :read:aux:curr:sens2? -> +2.00000000E+001<END> |

Table 295 :READout:AUXiliary:DIGital?

| | |
|--------------------|--|
| syntax | :READout:AUXiliary:DIGital? |
| description | Note: B VERSION WITH OPTION -052 (MULTI SENSOR BOARD) ONLY! Get the external digital input value. |
| parameters | none |
| response | bitmap (the LSB corresponds to input line 1) |
| example | :read:aux:dig? -> 3<END> |

5 Programming Examples

| | |
|--|-----|
| How to Connect your Distributed Temperature System to a PC | 144 |
| How to Send Commands and Queries | 146 |

This section contains some example programs that you can use to run a Distributed Temperature System.

This programming examples do not cover the full command set for the instrument. They are intended only as an introduction to the method of programming the instrument.

We recommend that you send commands via a program, examples of which are contained in this chapter. However, for testing processes you can enter individual commands (for example, `*idn?`) using Telnet (port 5024) (see “How to Send Commands and Queries” on page 146).

How to Connect your Distributed Temperature System to a PC

You can connect your PC to the DTS using

- USB
- LAN (using VXI-11 (RPC))
Please note that VXI-11 connections are about 50% slower than socket or USB connections.
- LAN (using TCP sockets, port 5025)
- LAN (using Telnet, port 5024)
(In this case, you should end the telnet session with “Ctrl-D”)

The ports for socket and telnet connections cannot be modified.

- Only up to 2 VXI-11 connections are possible.
- Only up to a total of 5 TCP socket and telnet connections are possible.
- All LAN VXI-11 connections share their status information (Error queue, status registers).
- Socket and telnet connections are independent of each other.
- The Errors, Alarms, Operation Status registers are updated if a new socket or telnet connection is opened.
- If there is more than one connection, please be aware of the following:
 - When using a VISA layer you can lock a device, so another controller with the same connection type (VISA VXI-11 or VISA socket) cannot access this device. However the device can be accessed with a different connection.

For example: if a device is locked in a VISA socket connection it can still be accessed with VXI-11.

- A telnet connection can't be locked.
- When using VXI-11 connections, we recommend you lock the device. Otherwise one controller may get the reply for another controller's query.
- If the device is locked in a VISA socket connection, it can still be accessed with raw sockets (that is, by using sockets directly).
- When using sockets (VISA and raw) there are some extra points to take care of:
 - Always append a 'newline' to your command or query.
 - Don't use indefinite blocks.

- It is the programmers responsibility to make sure that he reads all the data transmitted.
- VISA Assistant is confused by 'newline' inside a reply, you have to click the button [viScanf] until the whole reply is read.

How to Send Commands and Queries

There are two types of SCPI entities: queries which end with a question mark (?), and commands which do not. Only queries expect a response.

Commands and queries are discussed below.

NOTE

For more information about SCPI, please consult Chapter 1, "Introduction to Programming"

The SCPI commands specific to Distributed Temperature Systems are listed in Chapter 2, "Specific Commands", and explained in subsequent chapters.

The programming examples given here can also be found on the DTS documentation CD.

Commands

Commands can be followed by a newline (\n). They must be followed by a newline if you are using a socket connection. For example, the reboot command `:SYSTEM:REBOOT` should be formatted as:

Using visa.dll, C:

```
int instr;
viOpen(..., &instr);
const char* cmd = ":SYSTEM:REBOOT\n";
int sent = 0;
viWrite(instr, cmd, strlen(cmd), &sent);
```

Using Test & Measurement Toolkit, C#:

```
DirectIO instr;
instr = new DirectIO(...);
const char* cmd = ":SYSTEM:REBOOT";
instr.WriteLine(cmd);
```

There is no response.

You can check that a command has been recognized correctly by sending the query **SYST:ERR?**, which returns the contents of the Distributed Temperature System's error queue.

Queries

A query produces a response from the instrument.

Using visa.dll, C:

```
int instr;
viOpen(..., &instr);
const char* query = "*idn\n";
int sent = 0;
viWrite(instr, query, strlen(query), &sent);
char reply[256];
int maxSize = 256;
int count = 0;
viRead(instr, reply, maxSize, &count);
```

Using Test & Measurement Toolkit, C#:

```
DirecIO instr;
instr = new DirectIO(...);
string query = "*idn";
instr.WriteLine(query);
string reply = instr.Read();
```

Further examples

*IDN? query

Here is another example in C, using visa.dll and the *IDN? query.

```
#include <visa.h>
#include <stdio.h>
void main ()
{
    ViSession defaultRM, instr;
    char idn [256] = {0};

    /* Open session */
    viOpenDefaultRM (&defaultRM);
    viOpen (defaultRM,
    "TCPIP1::192.168.1.10::inst0::INSTR", VI_NULL, VI_NULL, &instr);

    /* Send an *IDN? query to the device */
    viPrintf (instr, "*IDN?\n");
```

```

/* Read identification string */
viScanf (instr, "%t", &buf);

/* Print it */
printf ("Instrument identification string: %s\n", buf);

/* Close session */
viClose (instr);
viClose (defaultRM);
}

```

Using PERL

This example accesses an AP Sensing Distributed Temperature Sensing System using sockets.

```

use strict;
use Getopt::Std;
use Socket;

use FileHandle; # just for autoflush
autoflush STDOUT;

#-----
# some variables
#-----

my $dtsIpAddress = "";
my $dtsPort = 5025;
my $changeByteOrder = 1; # change byteorder by default
my $query;                # will be sent to the DTS
my $reply;                # will be read from the DTS

#-----
# process command line option(s)
#-----
my %opt;

getopts('a:o:h?', \%opt);

if (exists($opt{'a'}))
{
    $dtsIpAddress = $opt{'a'};
}

```

```

if (exists($opt{'o'}))
{
    $opt{'o'} =~ /^[01]$/
        or die "ERROR: -o requires argument 0 or 1.\n";

    $changeByteOrder = $opt{'o'} == 0 ? 0 : 1;
}

if (exists($opt{'?'}) or exists($opt{'h'}))
{
    print <<EOH # end of help
    Usage: "perl DTS.pl -a <IP address> [-o (0|1)] [-h]"

    Args:  -a <IP address>    specify, where the DTS can be found.
           -o (0|1)          change byteorder of trace data (1) or not (0).
           -h                display help.
EOH
    ;
    exit;
}

#-----
# simple sanity check
#-----
$dtsIpAddress =~ /^[1-9]\d*\.[1-9]\d*\.[1-9]\d*\.[1-9]\d*/
    or die "ERROR: a valid DTS IP address must be specified with '-a <addr>'\n";

#-----
# connect to the DTS system via socket
#-----
my $proto = getprotobyname('tcp');

my $iaddr = inet_aton($dtsIpAddress)
    or die "ERROR: couldn't convert IP address ($dtsIpAddress)\n";

my $paddr = sockaddr_in($dtsPort, $iaddr);

socket(SOCK, PF_INET, SOCK_STREAM, $proto)
    or die "ERROR: couldn't create socket.\n";

connect(SOCK, $paddr)

```

```

    or die "ERROR: couldn't connect.\n";

# now we can talk to the instrument via socket SOCK.

#-----
# send "*CLS" command (clear error queue)
#-----
send SOCK, "*CLS\n", 0;

#-----
# perform "*IDN?" query
#-----
print "\nCheck *IDN?\n";

send SOCK, "*idn?\n", 0;
print " " . <SOCK> . "\n"; # "<SOCK>" just reads the next line from the socket

#-----
# perform a measurement
#-----
print "Measurement\n";
#
# setup measurement parameters
#
print "Setup\n";
send SOCK, "CONF:MEAS:SETT:PRES\n", 0;           # preset setting
send SOCK, "CONF:MEAS:SET:STAR 0\n", 0;         # start distance
send SOCK, "CONF:MEAS:SET:SPAN 100\n", 0;      # measurement span
send SOCK, "CONF:MEAS:SET:SINT 1\n", 0;       # sampling interval
send SOCK, "CONF:MEAS:SET:MTIM MIN\n", 0;     # measurement time
send SOCK, "CONF:MEAS:SET:REP ONCE\n", 0;     # repeat mode
# ...

#
# check error queue with "SYST:ERR?"
#
my $numErrors = 0;
$query = "SYST:ERR?";
while(1)
{
    send SOCK, "$query\n", 0;

```

```

$reply = <SOCK>;
chop $reply;
if ($reply ne '+0,"No error"')
{
    print "Parameter Errors:\n" unless $numErrors++ > 0;
    print " $reply\n"; # indented
}
else
{
    last;
}
}
$numErrors == 0 or die "\n";

#
# check if parameters are OK
#
send SOCK, "CONF:MEAS:SETT:VAL?\n", 0;
$reply = <SOCK>;
chop $reply;
$reply eq "OK" or die "ERROR: setting not valid.\n($reply)\n";

#
# start measurement
#
print "Start\n";
send SOCK, "MEAS:SING:STAT ON\n", 0;

my $cnt = 0;
my @progressChars = ("|", "/", "-", "\\");
$query = "MEAS:SING:STAT?\n";
$reply = "1";
while($reply ne "0")
{
    send SOCK, "$query", 0;
    $reply = <SOCK>;
    chop $reply;

    # show progress
    print "$progressChars[$cnt++%4]\r";
    sleep 1;
}
print "Finished\n";

```

```

#
# get data
#
print "Get data\n";
send SOCK, "READ:TRAC:POIN? 1\n", 0; # read the number of points in trace 1
$reply = <SOCK>;
chop $reply;
my $points = $reply;
$points =~ s/^[+-]//;
print "Measurement Result ($points points):\n";

my $buf;
send SOCK, "READ:TRAC:DATA? 1\n", 0; # query trace 1 data
read SOCK, $buf, 1; # read first byte (should be '#')
$buf eq "#" or die "ERROR: block doesn't start with '#'.\n";

read SOCK, $buf, 1;
my $len = $buf; # number of digits denoting the block length
read SOCK, $buf, $len;
my $len = $buf; # block length
read SOCK, $buf, $len;

if ($changeByteOrder)
{
    #
    # different byte order but no way to convert floats in Perl
    # solution: read longs in network (i.e. big endian) byte order, this swaps
    # them to native (i.e. little endian) byte order, then pack them again and
    # unpack them as floats ;- )
    #
    my @longs = unpack "N*", $buf;
    $buf = pack "l*", @longs;
}

my @float;
@float = unpack "f*", $buf;

#
# print result
#
for (my $i = 0; $i < $points; $i++)
{
    printf "%05d: %f\n", $i, $float[$i];
}

```

```
}
```

```
#-----
```

```
# disconnect
```

```
#-----
```

```
close(SOCK);
```

```
#
```

```
print "\nbye.\n";
```


6 Further Information

This Appendix lists the documents where you can find more information about the DTS.

Related Documents

For information about the Distributed Temperature System, please consult the following documents:

- AP Sensing DTS User's Guide

DTS website

The DTS website (<http://www.apsensing.com>) contains a set of our documentation, training materials, and other information.

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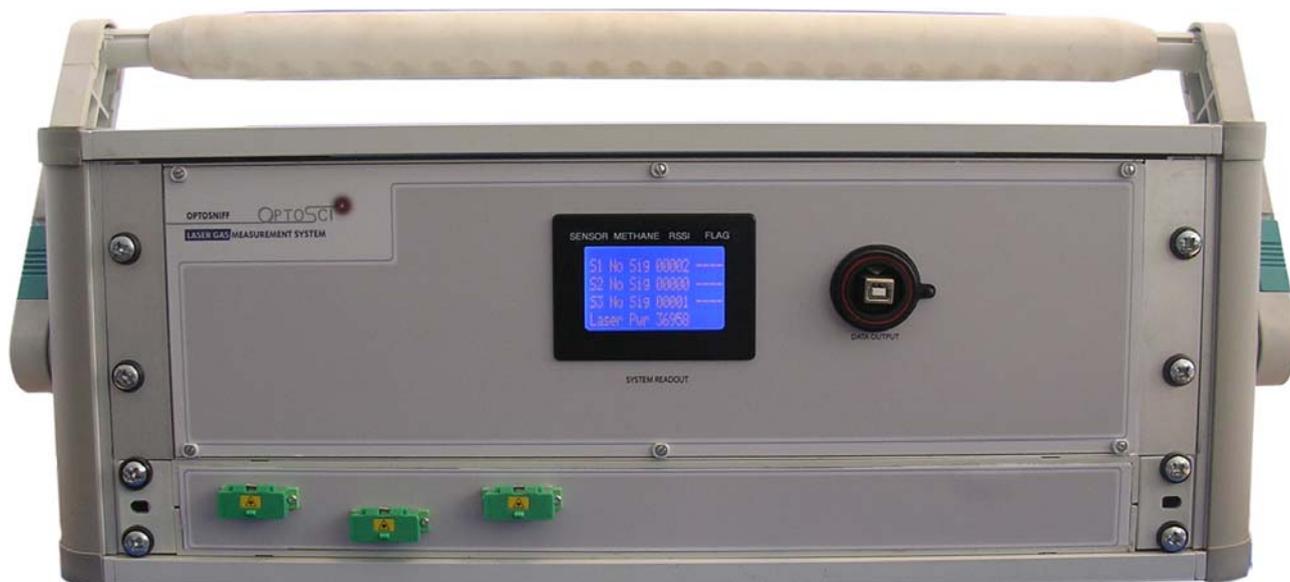
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**OPTOSNIFF[®] 3-POINT TDLS TEST
SYSTEM FOR METHANE MONITORING**

CONTENTS



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3-POINT OPTOSNIFF[®] TDLS TEST SYSTEM FOR METHANE

Introduction:

The OptoSniff[®] tuneable diode laser spectroscopy (TDLS) Test Kit is a portable gas measurement system based around the OptoSniff[®] Central Control Unit (CCU). The system is housed in a robust and portable enclosure and will simultaneously measure methane levels at three external sensors over the range 0.05% (500ppm) to 100% v/v.

The front panel LCD displays the latest sensor readings and system status, and the various sensors and accessories supplied enable a comprehensive demonstration of the system capabilities. The front panel also provides a USB Serial output of the sensor readings as they are calculated, enabling storage and a more detailed computer display and analysis of the gas levels detected via the Software Viewer & Display Interface.

System Contents:

Main contents of the 3-point OptoSniff[®] TDLS Test system:

1. Central Control Unit (CCU) with methane laser source, three optical signal output/input ports, integral front panel LCD display for gas readings, and a USB data output for connection to a PC.
2. A 4-point optical receiver module to monitor 3 sensors and 1 reference channel included in CCU.
3. Three stainless steel Optical Gas Sensors with SC/APC input connectors and one tunnel junction box.
4. A calibration sensor module designed for testing calibrated gas mixtures with SC/APC optical inputs and gas connector seals.
5. Cover tube with gas connector seals to slide over and temporarily seal stainless steel gas sensor and enable sensor testing with calibrated gas mixtures.
6. 8km singlemode fibre reel with SC/APC terminations along with various SC/APC unites and fibre patchcords to allow flexible combination of fibre reel and patchcords with the CCU and sensors.
7. 5dB, 10dB and 15dB plug in optical attenuators are included to simulate optical signal loss of 69% (5dB), 90% (10dB) and 97% (15dB) on individual sensor channels.
8. Data Viewer Software to monitor system output on a PC.

All of the items required to connect the system in a “plug & play” format and allow monitoring of up to 3 sensors on the CCU display are supplied (schematic shown in Figure 1).

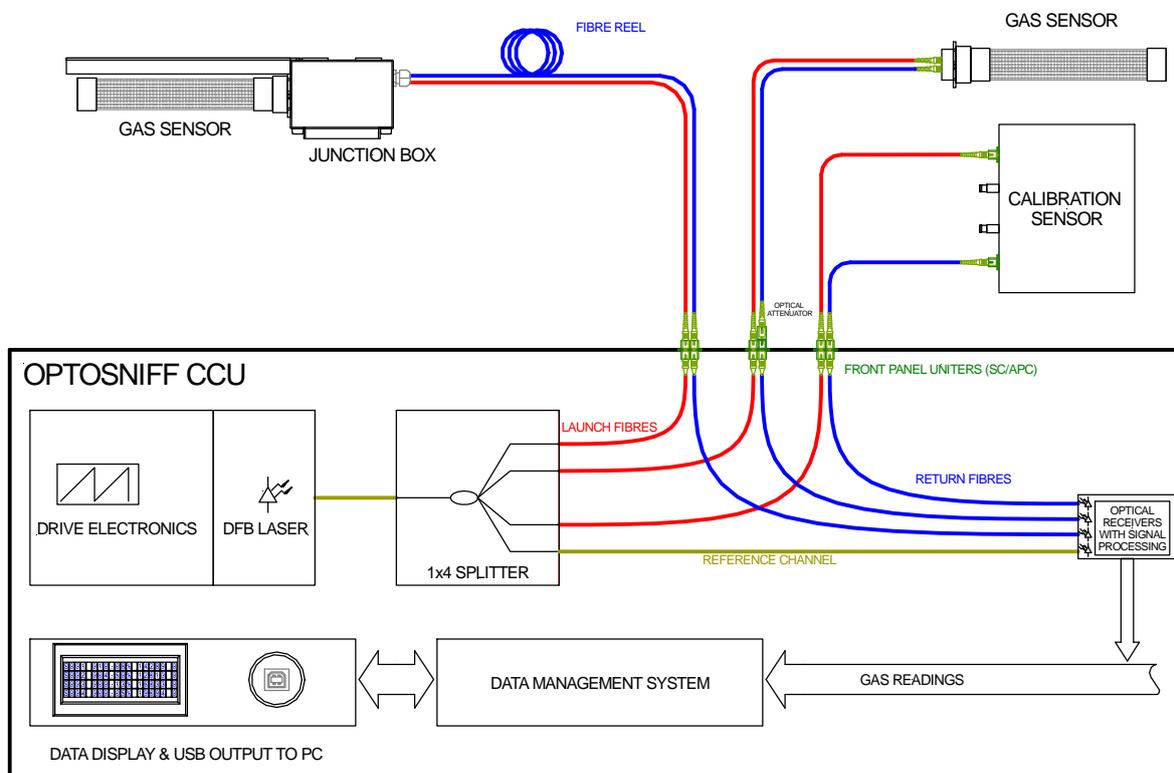


Figure 1: Schematic of 3-Point TDLS Test OptoSniff[®] System

Contents List:

| Description | Qty/Unit |
|--|----------|
| <i>HARDWARE</i> | |
| OptoSniff® 3-point Benchtop CCU Instrument for Methane | 1 |
| Stainless Steel Optical Gas Sensors (SC/APC) | 3 |
| Tunnel Junction Box to accept Optical Gas Sensor | 1 |
| Calibration gas test sensor module (SC/APC) | 1 |
| Cover tube to allow gas testing of cylindrical sensor | 1 |
| Evacuation bulb pump, clear tubing & gas connectors for calibration sensor | 1 set |
| 8km Test Fibre Reel with connectorised patchleads (SC/APC) | 1 |
| Patchcord – SC/APC, 3m Duplex Cabled | 3 |
| Patchcord – SC/APC, 3m Simplex Cabled | 6 |
| 5dB SC/APC plug-in attenuator | 2 |
| 10dB SC/APC plug-in attenuator | 2 |
| 15dB SC/APC plug-in attenuator | 2 |
| SC/APC Fibre Unifiers – Simplex | 3 |
| SC/APC Fibre Unifiers – Duplex | 3 |
| Data Viewer Software for Windows PC | 1 |
| USB Lead | 1 |
| Mains Power Lead | 1 |

Please note that calibration gases and gas control valves must be supplied by the user (OptoSci can provide guidance on these items if required).

Central Control Unit:

The front and back panels of the 3-point TDLS Test instrument are shown in Figures 2a & 2b.

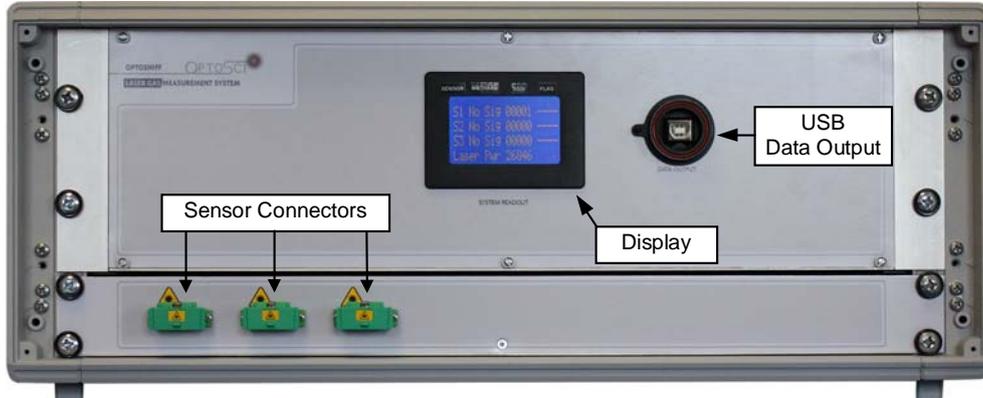


Figure 2a: Front panel view of 3-Point TDLS Test OptoSniff® System



Figure 2b: Rear panel view of 3-Point TDLS Test OptoSniff® System

The LCD screen of the 3-point OptoSniff® TDLS Test system (Figure 3) shows a table with the sensor number, detected methane level, the *received optical signal strength indicator* (RSSI) and an alert that a gas level has been detected above one of the set alarm levels.

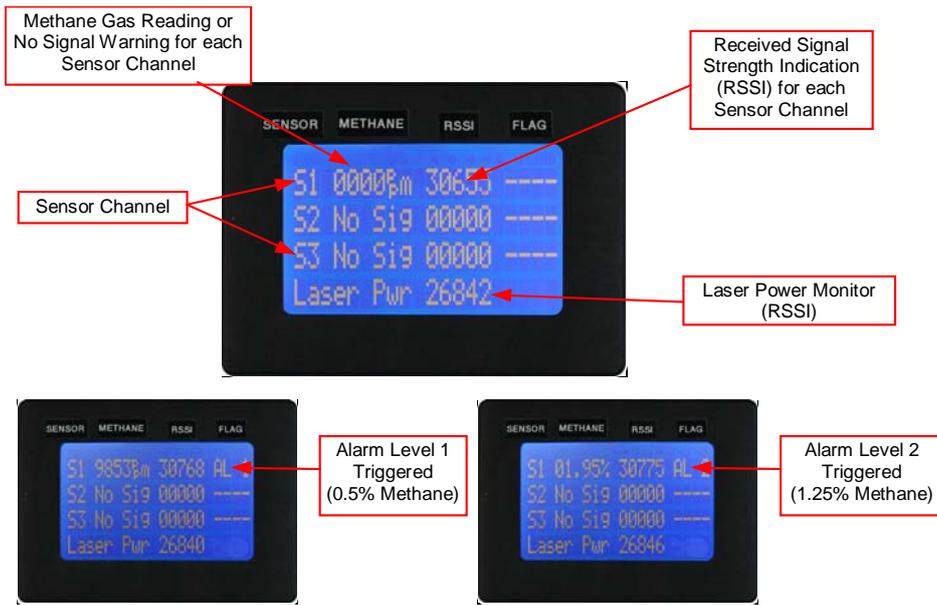


Figure 3: OptoSniff® CCU Display

Gas Sensors & Junction Box:

Figure 4a shows the stainless steel optical sensor.

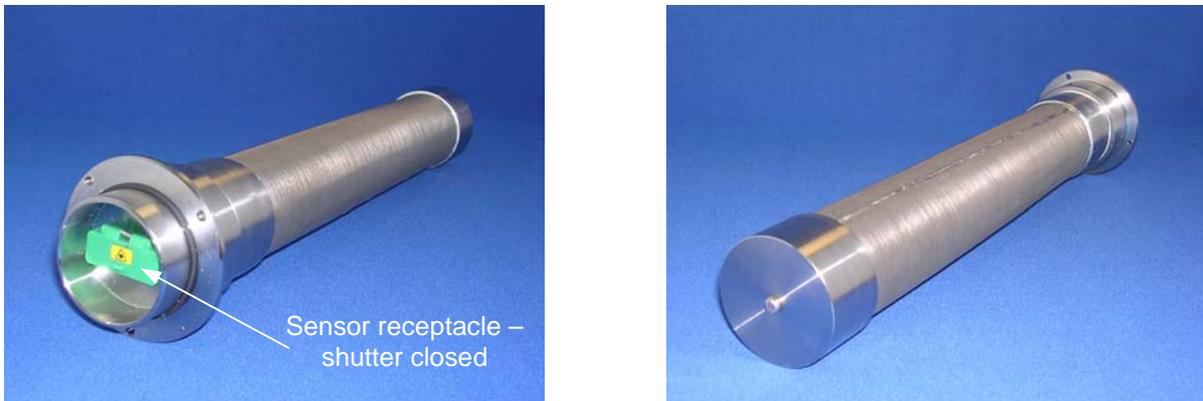


Figure 4a: Stainless steel optical sensor

Figure 4b shows the sensor mounted in the junction box.

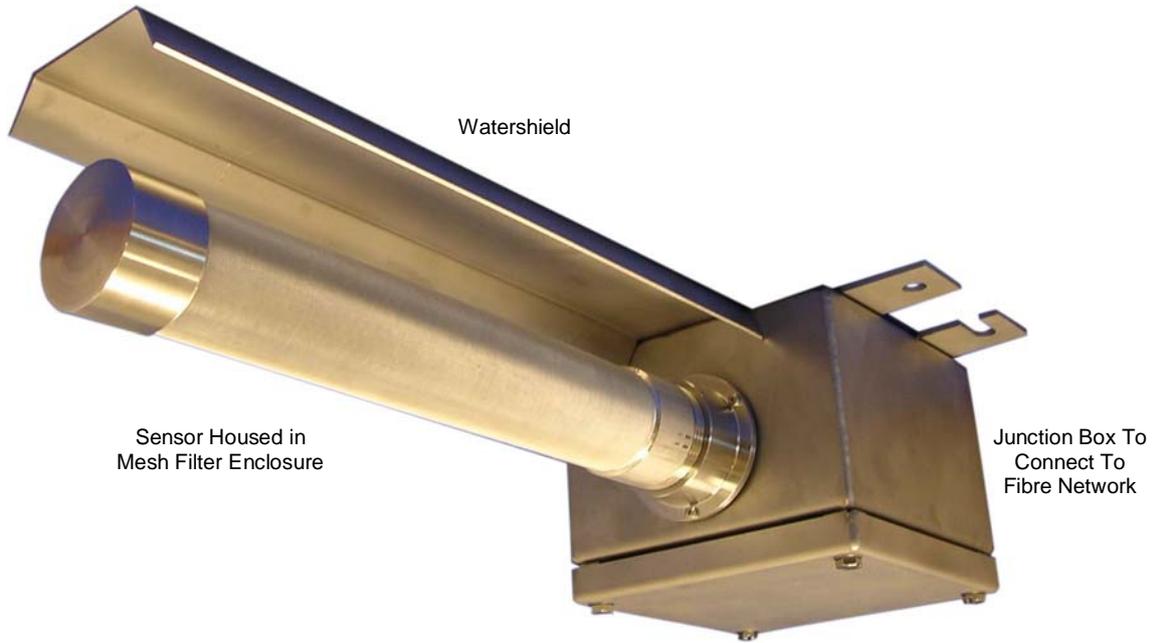


Figure 4b: Optical sensor mounted in junction box

Calibration Gas Sensor:

The calibration test sensor depicted in Figure 5a allows the gas detection accuracy of the system to be demonstrated and checked using a cylinder of calibrated test gas.



Figure 5a: Sensor module designed for testing calibrated gas mixtures

The cover tube (Figure 5b) slides over the stainless steel sensor to temporarily seal it and enable sensor testing with calibrated gas mixtures.



Figure 5b: Cover tube being used to test gas sensor.

Fibre Reels and Accessories:

Pictures of a plug-in optical attenuator, uniter, various patchcords and 8km fibre reel are shown in Figures 6a and 6b below. Note regarding the Optical Attenuator: 0.3dB of loss is roughly equivalent to the optical attenuation experienced over 1km of optical fibre using a laser at a wavelength around 1650nm. Hence a 5dB attenuator can be used to simulate the loss experienced over 15km of fibre.

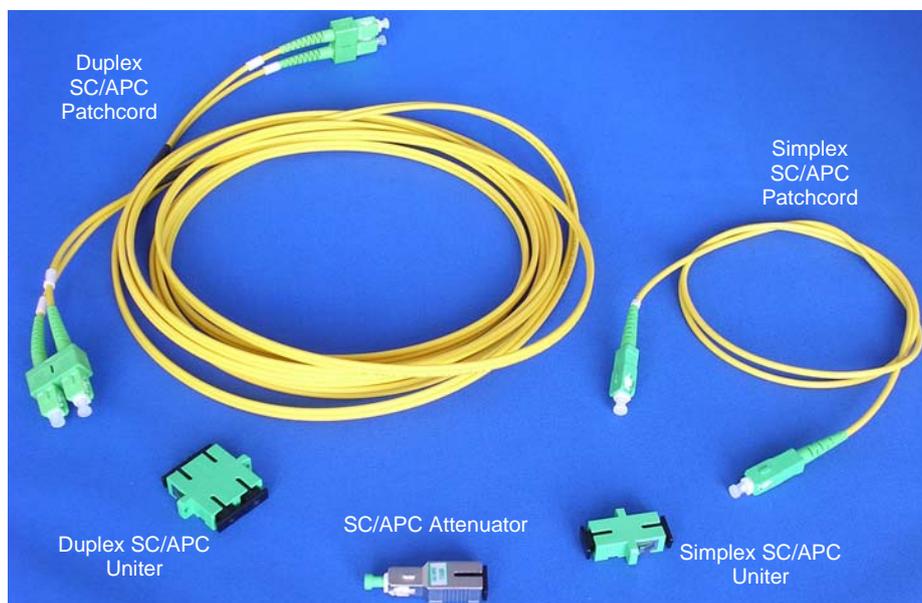


Figure 6a: SC/APC fibre components



Figure 6b: SC/APC connectorised singlemode fibre reel

Data Viewer Software:

The addition of a PC running the supplied Data Viewer Software will allow the full system data output to be viewed, alarm levels set, etc. on the PC screen (example viewer screen shown in Figure 7).

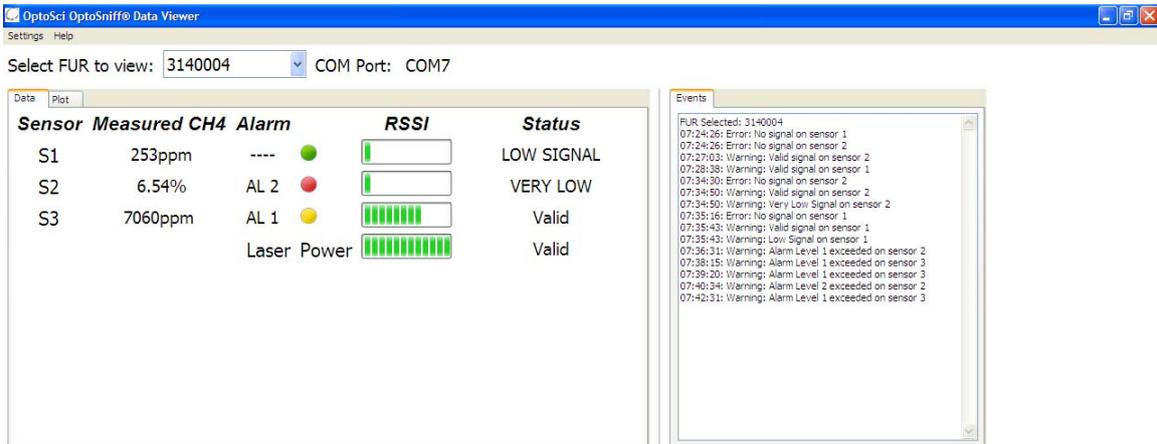


Figure 7: Example OptoSniff® Data Viewer Software

View of 3-Point OptoSniff® System under Test:

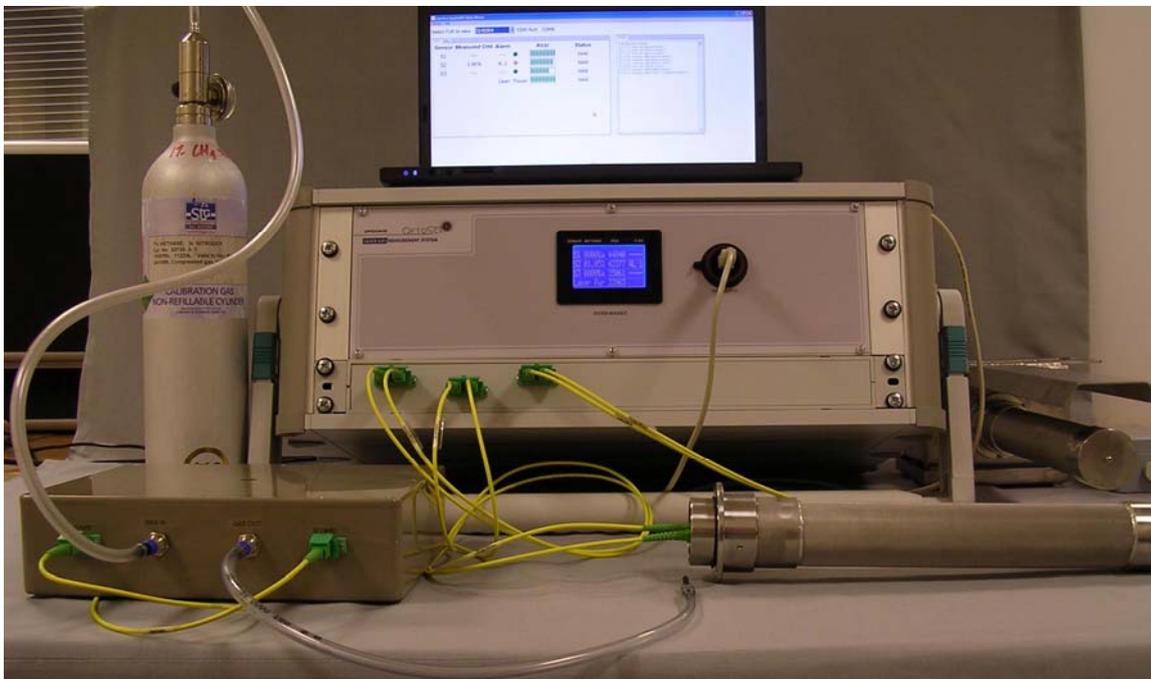


Figure 8: OptoSniff® 3-point TDLS System under test.

Technical Data: OptoSniff® 3-Point TDLS Test Unit

| PARAMETER | SPECIFICATION | NOTES |
|---------------------------------------|--|--|
| GENERAL | | |
| Detection Method | Tuneable Diode Laser Spectroscopy (TDLS) | Automatic range switching from direct detection to wavelength modulation spectroscopy detection |
| Gases Detected & Range | CH ₄ : 0.05% to 100% v/v | Using standard tunnel sensor |
| System Self-Checking | Continuous laser, sensor and optical network condition monitor | Full diagnostic data available at control unit; Automatic gain control ensures system still operates reliably with 90% signal drop from original launch power. |
| Calibration | Factory calibration of full system | TDLS detection technique is self-referencing, so calibration stable; Calibration can be confirmed with calibration sensor and test gas |
| PERFORMANCE | | |
| Sensor Response Time | T ₉₀ < 30 seconds | With unforced gas diffusion |
| System Update Time | < 5 seconds | Full system update from all sensors in < 5s (programmable) |
| Repeatable Accuracy | ±100ppm or ±2% of reading | Whichever is greater, Valid at STP |
| Number of Sensing Points | Up to 3 sensors | |
| Maximum Link Distance | Up to 20km from control unit to each sensor | Fibre reels can be interconnected to increase link length or plug-in attenuators can be used to simulate additional link loss at ~ 0.3dB/km |
| CENTRAL CONTROL UNIT | | |
| Operating Temperature | 0°C to +40°C | Control unit usually sited in standard office environment |
| Input / Output Signal | Optical / USB | ASCII datastream from USB output to link to PC data monitor & alarm system |
| Display | 35mm x 60mm LCD Display | Displays 3 sensor signals and laser reference signal |
| Receiver | One, 4-channel InGaAs photodiode receiver | Automatic Gain Control system covering four decades; Detection wavelength range 1000 to 1700nm |
| Dimensions & Weight | 560L x 420D x 210H (mm); 13kg | 19" rack system |
| Electrical Power Requirement | 115/230V AC, 50/60Hz | Electrical power only required at control unit |
| SENSOR | | |
| Operating Temperature | -15°C to +65°C | Many years stable operation demonstrated in harsh environments |
| Operating Humidity | 0 to 95%, non-condensing | Sensor shows full recovery after water evaporation |
| Input / Output Signal | Optical | Sensor uses standard optical connectors & telecommunications fibre |
| Insertion Loss | < 3dB signal loss @ 1650nm | |
| Dimensions & Weight | Sensor: 325L x 49 diam. (mm); 0.8kg Junction Box: 150L x 150W x 120H (mm); 2.8kg | Sensor can be used independently of junction box |
| OPTICAL SPLITTER & NETWORK | | |
| Architecture | 1x4 split from laser to 3 sensor outputs and internal reference channel, return signals routed to an individual photodiode in receiver | Uses standard optical telecommunications cable and components |
| Fibre Reel | Singlemode optical fibre reel, SC/APC connectors on fibre patchleads | Attenuation @ 1650nm ~ 0.3dB/km |
| APPROVALS | | |
| Laser Safety | Class 1M, IEC60825-1:2002 | Fully enclosed <10mW laser module, λ = 1645 – 1670nm; <5µW of optical power emitted to any sensor |
| Sensor Ingress protection | IP54 | Sensor fully recovers after flooding |
| EMC | EN61326-1:2006 | Designed to these standards |
| Explosive Atmosphere | Intrinsically safe all-optical sensor and fibre link | Sensor and fibre link compatible with ATEX requirements as no electrical power in gas sensing area |

USB-Serial Data Output

The Fast Update OptoSniff Demo Kit provides a serial data stream of the methane reading, RSSIs and error notices through a USB port on the front panel. The stream can be used by a computer to record the methane levels as they are calculated allowing a history to be retained and warning systems activated as levels increase. The device is presented as a virtual COM port, therefore applications can access the data using standard serial port libraries. The required settings are given in the table below.

| Serial Setting | Value |
|----------------|---------------|
| Baud Rate | Up to 57600 |
| Data bits | 8 |
| Parity | None |
| Stop bits | 1 |
| Flow control | None/Hardware |

The data stream is a one-way flow from the Demo Kit consisting of lines of ASCII text which describe time-stamped data for an individual sensor. The fields are space delimited and are terminated by a newline (CR+LF, ASCII 0x0E, 0x0A).

Each line contains the following fields in the order given:

- **Timestamp:** an ISO8601 basic format timestamp giving the time of the result to the nearest second. The format is a four digit year, two digit month, two digit day of month, the character "T", two digit hour, two digit minute and two digit second, e.g.

"20090120T113025" meaning 20th January 2009 at 11:30:25

- **Sensor ID:** Each FUR module has its own unique MAC address to identify it on the network and each receiver port on the module is identified by the letter A, B, C or D. In addition the Reference FUR module is identified by the prefix: R.
- **Methane Level:** The methane level as a floating-point percentage, including the % symbol, e.g. 0.045%.
- **RSSI:** The Received Signal Strength Indicator, an integer denoting the strength of the sensor signal, e.g. 19856. See the section of this manual "Viewing Results" for further information on this field.
- **Error Indicator:** An integer 0, 1 or 3 indicating any error status detected, e.g. "0":

| Error Code | Explanation |
|------------|--------------------------|
| 0 | Valid reading, No Errors |
| 1 | Loss of signal |
| 3 | Signal level too high |

An example of the OptoSniff data stream:

| Timestamp | Sensor ID | CH ₄ | RSSI | Error |
|-----------------|------------|-----------------|-------|-------|
| 20120828T040328 | 3140054:RA | -1.0000% | 20611 | 0 |
| 20120828T040328 | 3140054:RD | 0.0000% | 02373 | 0 |
| 20120828T040328 | 3140054:RB | 0.0000% | 02020 | 0 |
| 20120828T040328 | 3140054:RC | 0.0000% | 02315 | 0 |
| 20120828T040328 | 3140052:A | 0.9956% | 20611 | 0 |
| 20120828T040328 | 3140052:D | 0.0000% | 02373 | 0 |
| 20120828T040328 | 3140052:B | 0.0000% | 02020 | 0 |
| 20120828T040328 | 3140052:C | 0.0000% | 02315 | 0 |

The Timestamp column indicates that the date is: 28th August 2012 and the time is: 28 seconds and 3 minutes past 4am. The reference board Sensor ID has the serial number: 3140054, where RA marks the reference input port. The RSSI of the reference channel is: 20611. A second FUR board is connected and channel A has the RSSI level: 20611 and is reporting a gas level of: 9956ppm. All channels are valid in this instance and therefore the error indicator is 0.

Error Special Case

To ensure data lines notifying errors are of exactly the same format as normal data lines when they lack a valid methane reading, the methane concentration entry is set to an invalid place-holder value of '-1.00%'.

Reference Channel

These data lines use the same '-1.00%' place-holder value in the methane concentration field as error messages. These entries are of use for monitoring the condition of the laser source, as the RSSI is a direct measure of the laser signal.