GasFinder3-OP Operation Manual

Part No. NDC-200036

12846-146 Street NW, Edmonton, AB, CA T5L 2H7 P +1.780.488.5173 F +1.780.488.0780 W boreal-laser.com REMOTE PRECISION. SURE DECISION.

This manual was written to be compatible with the following firmware versions:

DSP v1.3.8, IPM v1.0.9, LDD 1v034, PLD 1v2a

CAUTION: TO PREVENT THE RISK OF ELECTRIC SHOCK, DO NOT REMOVE COVER (OR BACK). NO USER SERVICEABLE PARTS INSIDE. REFER SERVICING TO QUALIFIED SERVICE PERSONNEL ONLY.

SAFETY INSTRUCTION:

Please read all the instructions herein.

Please heed all safety warnings.

Please retain this manual for future reference.

Please install in accordance with these instructions.

WARNING

TO REDUCE THE RISK OF ELECTRIC SHOCK:

• Servicing is required when the unit has been damaged in any way, such as the power supply leads are damaged, liquid has been spilled or objects have fallen into the unit, the unit does not operate normally, or the unit has been dropped.

• Refer all servicing to qualified personnel only.

Disclaimer

Boreal Laser Inc. assumes no liability or responsibility for issues or harm resulting from the use of this equipment.

 Ph.+1 780 488 5173 Fax +1 780 488 0780 E-mail support@boreal-laser.com

Contents

Product Warranty

Boreal provides a standard warranty with all Boreal manufactured GasFinder units. The warranty covers the GasFinder laser analyzers plus Boreal manufactured items supplied with the GasFinder laser analyzers. The standard warranty does not cover items manufactured by third parties and supplied as components of a system, such as: cables; reflector elements; enclosures; scanning mounts; meteorological instruments; etc.

For items covered by the standard warranty, Boreal guarantees that, during the first 12 months following delivery, there will be no charges for parts or service required to correct:

- Equipment breakdowns
- Equipment malfunctioning
- Repeated or recurring faults or errors in the system.

Instrument shipping and/or travel expenses for on-site service will be charged at cost.

For the warranty to be valid the equipment must be registered, installed, commissioned, and operated within Boreal's performance specifications.

This warranty does not apply to situations whereby system performance has been compromised as a result of customer negligence or abuse or damage resulting from natural disasters.

Boreal software is provided 'As Is' without any express or implied warranty of any kind. Boreal is not liable for any damages (including, without limitation, lost profits, business interruption, or lost information) arising out of use of or inability to use Boreal software products.

Enhanced Warranty

Boreal can quote Enhanced Warranty on a project specific basis to include some or all of the following:

- Include all non-Boreal manufactured items supplied on a specific job.
- Extended warranty if a delay is expected from the time of delivery to the time of installation and commissioning.
- Include a specified number of site visits during the warranty period - highly recommended for development projects.
- Extend warranty on GasFinder systems beyond the standard 12 month period.

Procedures for Returning a Unit to Boreal Laser

These instructions are to be followed when preparing to return a Boreal Laser Instrument.

- A Service Tech at Boreal Laser must be contacted in order to receive an RMA number
- When possible, please return the Boreal Laser Instrument in its original packaging
- Mark the container "Fragile" and "Electro-Static Sensitive" to ensure proper handling
- If required, ensure proper DG documentation is completed
- Mark the RMA number clearly on the outside of the container
- Please ensure the commercial customs cost for the shipment is the same as the original value when purchased. Ex. If the original cost of the Gas finder was $35,000.00, that cost must be used for customs purposes when the unit is returned.
- The "Country of Origin" MUST be stated as CANADA. This is VERY important for customs clearance into Canada

If you do not have the original packaging materials please follow these guidelines:

- Wrap the instrument securely in heavy duty bubble pack or similar foam
- Use a strong double-wall container made for shipping instrumentation. 350-lb.test material is adequate
- Use a layer of shock absorbing material 70 to 100mm (3 to 4 inch) thick around all sides of the instrument. Protect the control panel with cardboard
- Seal the container securely
- Mark the container "Fragile and "Electro-Static Sensitive" to ensure proper handling
- Mark the RMA number clearly on the outside of the container
- Do not ship more than one unit per box

Important Declarations for Customs Purposes:

- Indicate in commercial invoice notes section "Equipment being RETURNED to manufacturer for SERVICE. Equipment will be returning to shipper after this has been completed. No sale was made on the shipment of this product. All Values are for customs purposes only.".
- FULL original unit cost required for customs.
- Country of origin MUST be stated as CANADA.
- If you are wishing to have Boreal Laser clear your freight through Canadian customs a copy of the signed documents (commercial invoice, Air waybill, DG declaration (if required) must be sent to our Shipping Manager at scarey@boreal-laser.com as soon as the product has been dispatched. There is a $75.00 fee attached to this clearance on top of billing back of clearance costs. Unsigned, or incorrectly filled out documents can cause a delay in this clearance process
- Boreal Laser does NOT recommend the use of DHL to ship equipment back to us for service. We base this recommendation on experience and delays involved.
- Please reference the attached commercial invoice for pertinent information that will help your freight arrive here quickly and efficiently.
- Please reference the attached DG declaration sample for use in declaring HF based shipments.

Return Shipping Address:

Boreal Laser Inc.
Service Department – [RMA# xxxxx]
12846 – 146 Street NW
Edmonton, Alberta
Canada, T5L 2H7
Tel: +1-780-488-5173

Commercial Invoice

Invoice No.	RMA#

Date of Exportation	Page 1 of 1

Shipper/Exporter	Consignee
Shippers Address here	**Boreal Laser Inc. 12846- 146 Street Edmonton, AB Canada T5L 2H7 Tel: 1-780-488-5173 Ext.101 Attn:Scott Carey**
Country of Export	Purchase Order
Clients Home Country	**If Applicable**
Consignee Contact	End –User P.O
Scott Carey	**If Applicable**
Total Number and Type of Packages	Total Shipping Weight
1 box = 23 x 20 x 10 inches(Dangerous Goods if applicable)	**30lbs**
Freight Carrier	International Air Waybill Number
TBD	**TBD**

Country of Origin	Description of Goods	Qty	Unit Value	Total Value
Canada	**Gasfinder Detection Monitoring System – S/N HFFC-2079**	**1**	**$25,000.00**	**$25,000.00**
	HS#9027.80.00			

Currency of Value	**USD**	*INVOICE TOTAL*	**$25,000.00**

Reason for Export

Equipment being RETURNED to manufacturer for SERVICE. Equipment will be returning to shipper after this has been completed. No sale was made on this shipment of this product. All Values are for customs purposes only.

I declare that, to the best of my knowledge, all information contained in this invoice to be true and correct.

Signed: _____ Date: _____

Name: _____ Title: Shipper

SHIPPER'S DECLARATION FOR DANGEROUS GOODS

Shipper

Shippers Address

Air Waybill No.

Page 1 of 1 Pages

Shipper's Reference Number RMA#16055 *(optional)*

Consignee

Boreal Laser Inc.
12846- 146 Street
Edmonton, AB
Canada T5L 2H7
Tel: 1-780-488-5173 Ext.101

For optional use for Company logo name and address

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non-applicable)*

PASSENGER AND CARGO AIRCRAFT [redacted]

Airport of Departure:

Airport of Destination: Edmonton

Shipment type: *(delete non-applicable)*

NON-RADIOACTIVE [redacted]

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification				Quantity and type of packing	Packing Inst.	Authorization
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Packing Group			
UN3363	Dangerous Goods in Apparatus	9		1 Fibreboard box x 0.02.Net Qty = 0.02L	962	

Additional Handling Information

24 Hour Emergency Contact Telephone Number: TBD

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. I declare that all of the applicable air transport requirements have been met.

Name/Title of Signatory

Certifier and Title

Place and Date

Signature *(see warning above)*

General Warnings and Cautions

This symbol draws attention to warning statements. These statements indicate a potentially hazardous situation which, if not avoided, may result in serious injury or death.

Warning, explosion hazard. This equipment is suitable for use in Class 1, Zone 2, or non-hazardous locations only. Substituting components may impair the suitability for Class 1 Zone 2 environments. For a list of certifications see the Specifications section.

Explosion hazard. Do not connect or disconnect equipment unless power has been switched off in the area or the area is known to be non-hazardous.

Always disconnect the main power to the instrument before attempting any repair.

This symbol indicates important information concerning the operation or installation of the instrument.

Failure to follow directions may result in damage or malfunction of the analyzer.

The instrument's function, proper installation, operation, and maintenance are beyond the control of Boreal Laser Inc. and are the responsibilities of the analyzer system designer/integrator and end user. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the manufacturer may be impaired.

Disclaimer

Boreal Laser Inc. assumes no liability or responsibility for issues or harm resulting from the use of this equipment.

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Section 1: System Description

Introduction

Boreal Laser's patented (US patent 5,637,872) TDL (Tunable Diode Laser) used in the GasFinder3-OP (Open Path) measures gas concentrations through the internally mounted optical transceiver that forms the active measurement path. A schematic representation is shown below in Figure 1.

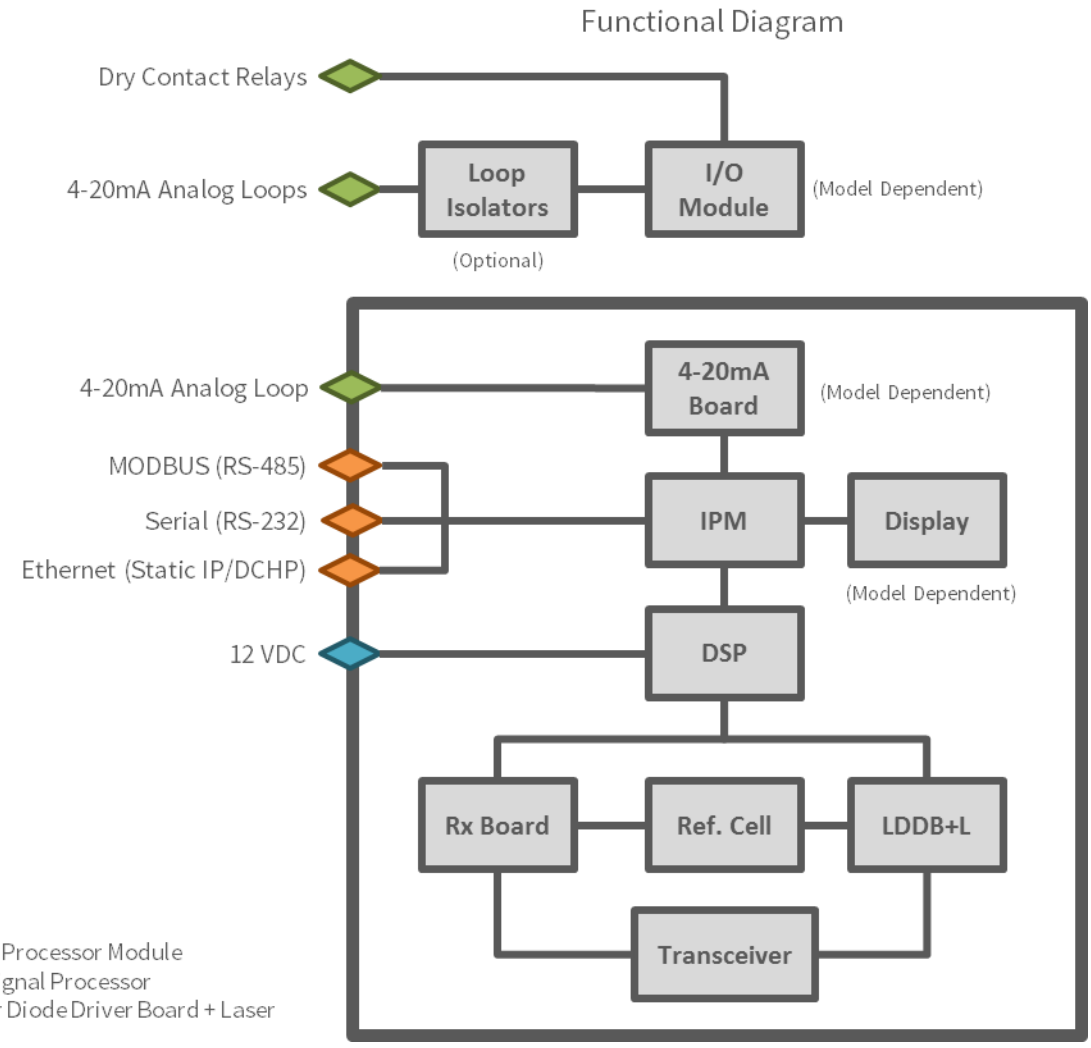


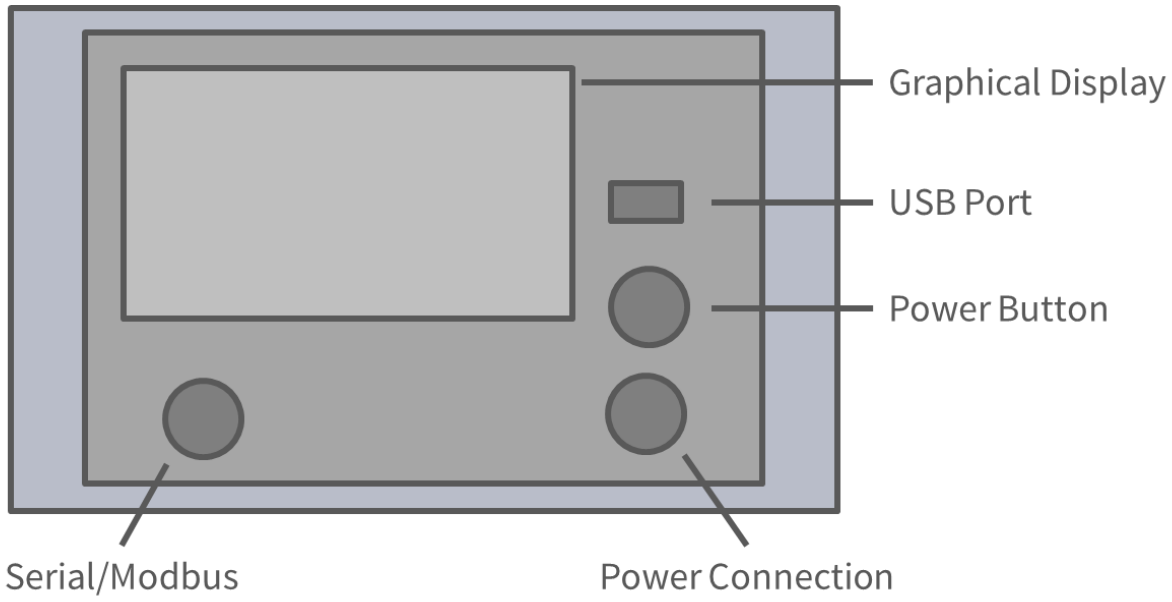
Table:
IPM: Interface Processor Module
DSP: Digital Signal Processor
LDDB+L: Laser Diode Driver Board + Laser

The GasFinder3-OP (Open Path) monitoring system is a gas detector intended for use in general purpose environments. It is based on a digital analyzer core and uses second harmonic tunable diode laser absorption spectroscopy. The analyzer is housed in a IP65 rated aluminium extrusion enclosure.

GasFinder3-OP Model Descriptions

The GasFinder3-OP is technically and economically capable in leak detection, and ambient monitoring applications. Three different GasFinder3-OP models have been created to allow customers to self-select which functionality is appropriate for their application and budget. While the all the models have the same performance specifications, there are some physical and functional differences. Listed below is an in-depth explanation of these three models and a table with the list of features.

Basic GasFinder3-OP Model:



No other technology or vendor has a local touchscreen display that enables field personnel to see ppm(-m) concentrations, light level, and active status in real-time. This means that operators and maintenance personnel have local indication of actual gas concentrations in normal or, more importantly, in emergency scenarios.

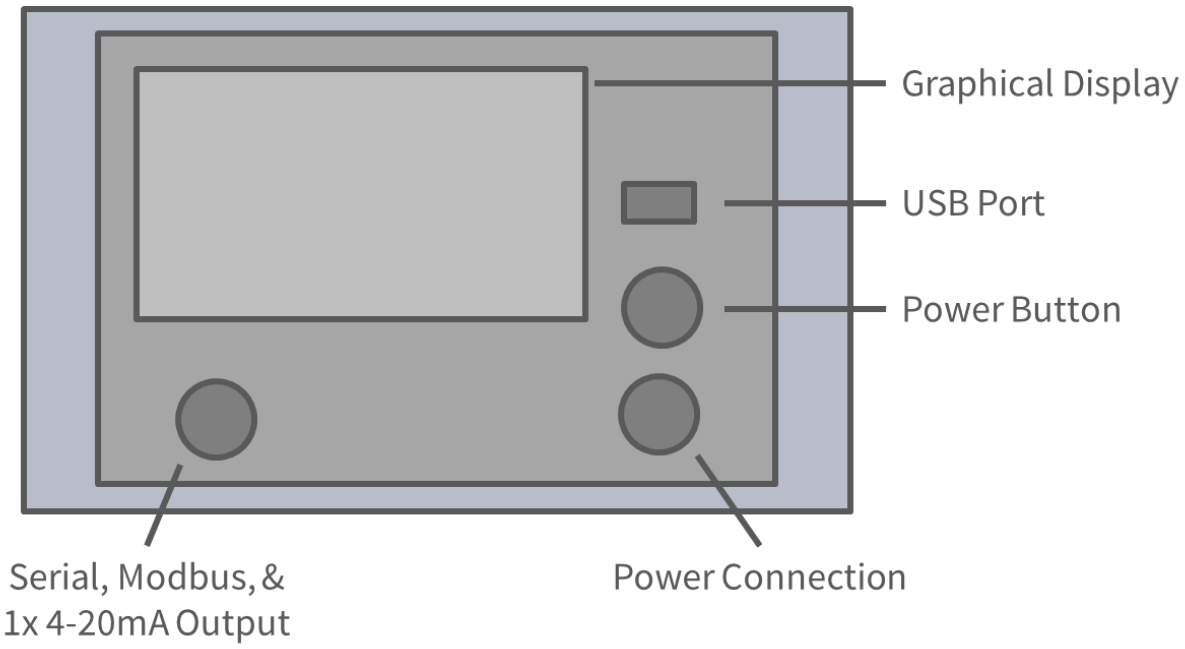
The GasFinder3-OP has internal data logging capabilities to collect and store all the GasFinder generated data for around 20 years.

The Standard model can be interfaced locally by the user with the GasView Software or via the HMI Touchscreen.

All GasFinder3-OP models have internal data logging capabilities to collect and store all the GasFinder generated data for around 20 years. The customer can interface with the analyzer using the included GasView Software. GasView is a Windows based program for remote interfacing over the USB port or via the Serial Connector. GasView enables the user to set basic path parameters, view real-time data, initiate logfiles (daily accumulation of all collected data) and initiate array transfers (visualize snapshots of waveforms and other diagnostic data).

The Basic GasFinder3-OP model has two output options: MODBUS (RS-485) and Serial (RS-232). Both outputs are available via the Serial/Modbus Connector and Data Cable. The customer may purchase the Basic model and upgrade to the Standard or Enhanced models by purchasing an upgrade package later.

Standard GasFinder3-OP Model:

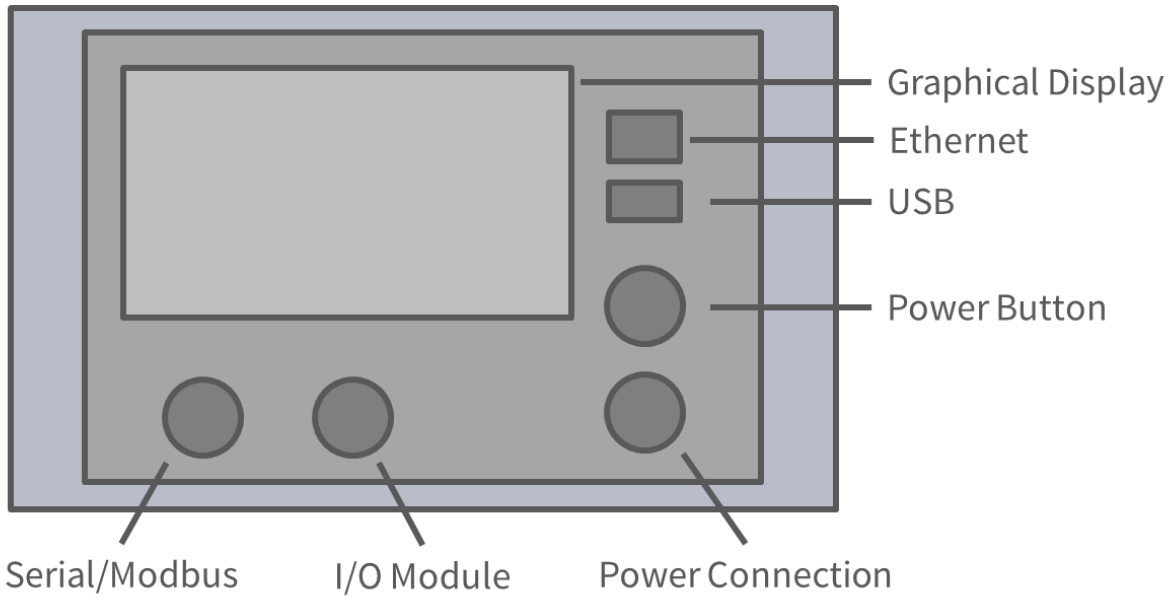


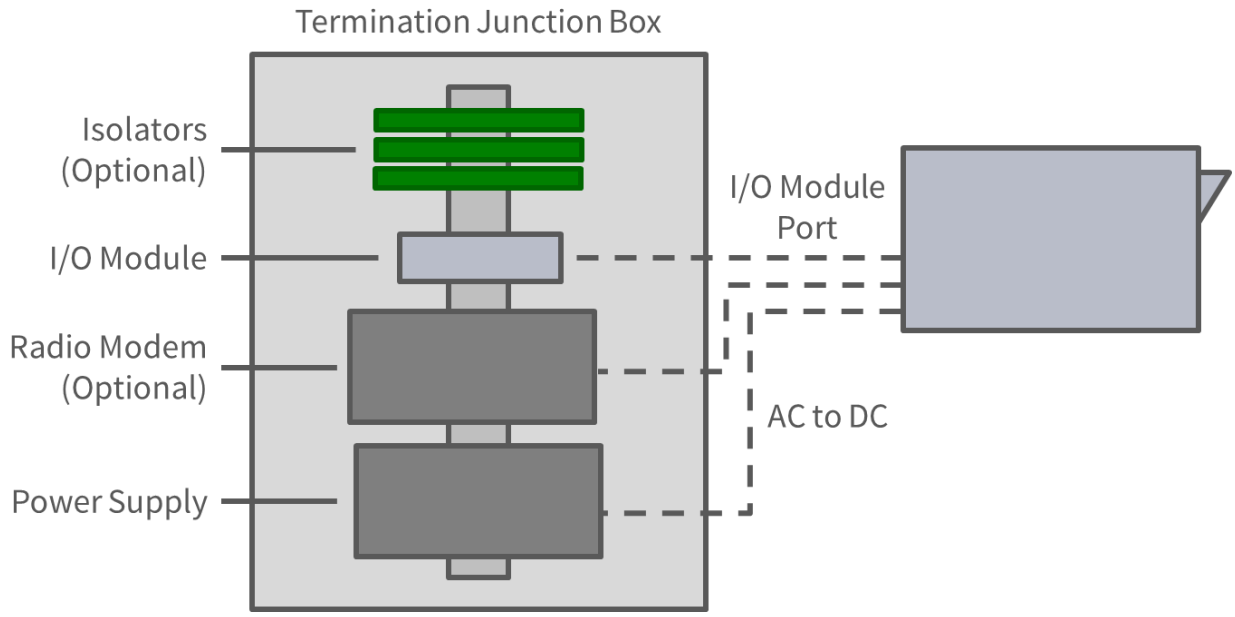
This model has improved output capabilities with the addition of one (1) 4-20mA Analog Loop. The 4-20mA output is user configurable and are most often used for ppm-m concentration. This model also includes the additional diagnostic data that is provided on the 4-20mA loop such as low light status (2.7mA) and system fault (3.6mA).

The added functionality of the HMI Touchscreen allows the user to set configurable alarm levels for the outputs. With the HMI Display it is possible to view real-time GasFinder3-OP serial string data and view de-bug statements.

The customer may purchase the Standard model and upgrade to the Enhanced model by purchasing an upgrade package later.

Enhanced GasFinder3-OP Model:





The Enhanced Model is the top-of-the-line GasFinder3-OP. This model has full functionality and is designed to be a ruggedized and industrial version for use in general purpose applications.

TDL technology is susceptible to effects caused by changes to the pressure and temperature of the gas matrix being measured. Boreal Laser has therefore developed active pressure and temperature compensation to correct for both the Universal Gas Law (Physical) and Absorption Line Strength (Spectroscopic) effects. Boreal Laser's GF3 technology possesses industry leading internal laser temperature stability (controlled to 0.0001C). This means that there is practically no temperature related measurement drift over that an ambient temperature range from -40 to 50C and that the

analyzer does not need to be housed in an environmentally controlled building or cabinet. Therefore, the GasFinder3-OP-E provides the best Raw Uncorrected Results in the industry.

It is possible to provide real-time pressure and temperature inputs from the active measurement path to enable dynamic P+T compensation. With the use of the P+T Inputs and firmware available in the Enhanced GasFinder3-OP, the system automatically corrects the raw results to have P+T compensation. This and other capabilities make the GF3-OP Enhanced Model the most advanced off-the-shelf TDL analyzer in the industry.

The Enhanced model of the GasFinder3-OP has full User Interface and Output options. The Graphing Display has real-time ppm/time, ppm-m concentration, light level, R2 confidence factor, and status. With the HMI Touchscreen the user can locally program all the functions that GasView has but has the additional capability set alarm level parameters and to visualize the snapshot of the waveforms.

All output options are available on the GasFinder3-OP-M. The Enhanced Model includes one (1) I/O Module that enable three (3) 4-20mA Loops & Dry Contact Relays, along with the output and interface protocol options: Serial (RS-232 & Micro USB), Ethernet (Static IP or DCHP), and Modbus (RS-485).

The GasFinder3-OP-M is a Microsoft Excel Macro used to visualize collected data: ppm(-m)/ Time, R2/Time, Light Level/Time, R2/ppm-m Curve, Status/Time, & Debug (internal temperature, offset, ref cell quality, reference R2, reference status, supply voltage, system status, date time, and checksum).

Complete List of Model Functionality

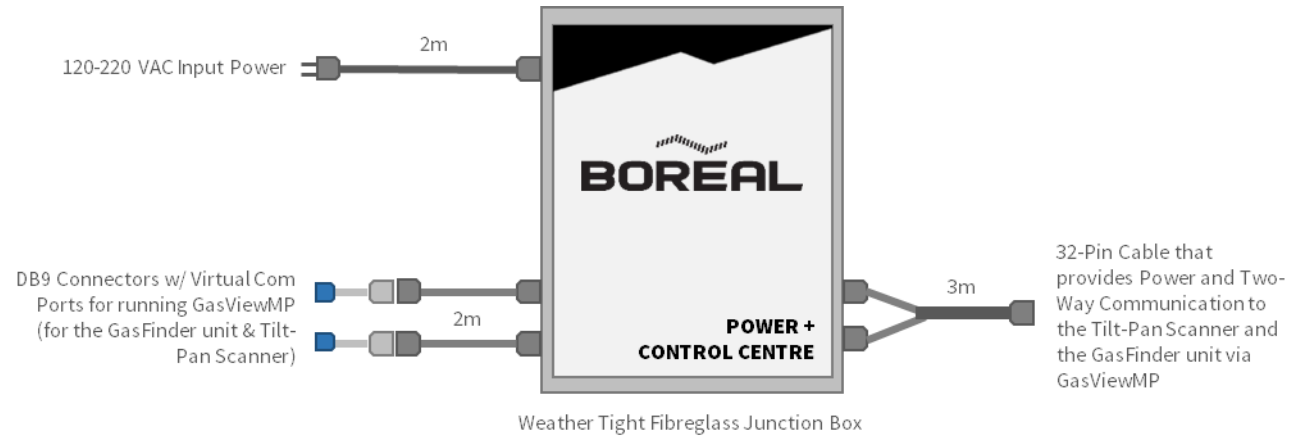
S = Standard O = Optional X = Included in Model - = Not Available within Model	Basic Model (Good)	Standard Model (Better)	Enhanced Model (Best)
Display/Interface Options			
HMI Touchscreen & GasView Software	S	S	S
View Real-Time Serial String Data	S	S	S
HMI Numerical Display	S	S	X
HMI Graphing Display	-	X	X
View Waveforms on HMI	-	-	X
Communication Options			
Update Firmware through USB port	S	S	S
Modbus (RS-485)	S	S	S
Serial (RS-232)	S	S	S
Ethernet (Static IP or DCHP)	-	X	X
1x 4-20mA Loop Output per Channel	-	S	X
3x 4-20mA Loop Outputs per Channel	-	-	X
3x Dry Contact Relays per Channel	-	-	X
2x 4-20mA Inputs (Real-Time P+T Compensation)	-	-	X
Analog Loop Isolation			
Non-Isolated Loops (Active)	S	S	S
One (1) Isolated Analog Loops (Active & Passive)	-	-	O
Two (2) Isolated Analog Loops (Active & Passive)	-	-	O
Three (3) Isolated Analog Loops (Active & Passive)	-	-	O
Retro-Reflector Enclosure Options			
Heated Fibre Glass Retro-Enclosure	S	S	S
Non- Heated Fibre Glass Retro-Enclosure	O	O	O
Heated Stainless Steel Retro-Enclosure	O	O	O
Non-Heated Stainless Steel Retro-Enclosure	O	O	O

Accessories:

There are many accessories available for the use with the GasFinder3-OP. While the list is not exhaustive, it does provide the end-user with an indication of what is available.

Tilt-Pan Scanner: This accessory can be used with the GasFinder3-OP for two main purposes. The first is to create more active measurement paths by using one GasFinder3-OP to move to obtain alignment on 1-8 retro-reflectors. The second is to have the Auto Light Optimization functionality to maintain the optimal light level. The Tilt-Pan Scanner requires one of two Control Centre's to operate: Power + Control Centre or the Remote Monitoring + Control Centre. For more information please reference the Tilt-Pan Scanner + Control Centre's brochure.

Power + Control Centre: Is one of the Control Centre options available for communicating with the Tilt-Pan Scanner. The Power + Control Centre has two main purposes: 1) Supply power to both the Tilt-Pan Scanner and the GasFinder unit. 2) Enables the supplied GasViewMP Software to communicate locally with both the Tilt-Pan Scanner and the GasFinder unit. For more information please reference the Tilt-Pan Scanner + Control Centre's brochure.



Remote Monitoring + Control Centre: Is used primarily with long term ambient monitoring installations to provide power, log data, and allow remote communications (cellular and radio modems) with a

GasFinder, meteorological instruments (3D sonic anemometer + met station), Tilt-Pan Scanner (via GasViewMP software), Relays (can be used to remotely cycle the power), and Webcam (useful tool for verifying weather conditions). Measurement campaigns can thus be monitored remotely without having to physically visit the installation. Depending on the accessories the operator can remotely intervene with the installation if necessary. For more information please reference the Remote Monitoring + Control Centre brochure.

Radio Communication Module: This module allows for the one-way communication of the GasFinder3-OP serial string data. For more information please reference the Radio Communication Module brochure.

Response Cells: Are typically used in leak detection installations where the target gas is not normally present in the ambient atmosphere. Response cells are used for quality assurance purposes to validate that the GasFinder instruments is responding appropriately to a nominal concentration of the target gas. The validation using a response cell is NOT a field calibration. For more information please see the Response Cell Brochure.

120-220 VAC Power Supply: The GasFinder3-OP is designed to accept 12 VDC. If the customer prefers to power the system with 120-220 VAC power then a 120-220 VAC Power Supply is an included accessory with the assembly.

Rain/Dust Enclosure: Some applications that include heavy settling dust or water deluge may want to install the GasFinder3-OP inside a Rain/Dust Enclosure to prevent the returned laser light being returned to an un-usable level.

Specifications

Application Data

Target Component	Can choose from one of the following: • "Lo-Range" or "Hi-Range" Hydrogen Fluoride (HF) • "Lo-Range" or "Hi-Range" Methane (CH_4) • "Ultra Lo- Range", "Lo-Range" or "Hi-Range" Carbon Dioxide (CO_2) • "Lo-Range" or "Hi-Range" Carbon Monoxide (CO) • Hydrogen Sulfide (H_2S) • Ammonia (NH_3) • Hydrogen Cyanide (HCN) • Hydrogen Chloride (HCl) • Acetylene (C_2H_2) • Ethylene (C_2H_4) • Oxygen (O_2) NOTE: There may be other gases or ranges that are measurable by OP-TDL that are not listed. Please check with Boreal Laser for more information.
Calibrated Range	Gas and Application Dependent (please see calibration sheet)
Full Range	Gas and Application Dependent (please see calibration sheet)
Typical Accuracy	0.5% of Reading
Response Time	~1 Second
Detection Principle	Tunable Diode Laser Absorption Spectroscopy (TDLAS)
Modulation Technique	Wavelength Modulation Spectroscopy (WMS)
Environmental Temperature Range	-40°C to +50°C for GasFinder3-OP (Analyzer/CCU) – General Purpose -40°C to +85°C for Measurement Heads
Ingress Protection	Weathertight (IP65 Equivalent)
Enclosure Material	Powder Coated Aluminium Extrusion
Humidity	0-100% RH (Non-Condensing)
Certification	General Purpose.

Electrical Data

Nominal Input Required	24 VDC @ 20 W	
Max Input Rating	24 VDC, 4 A	
Communication Output	Serial (RS-232) Serial (Micro USB) Ethernet (TCP/IP) MODBUS (RS-485)	±12 VDC, ±35 mA 5 VDC, 0.5 A 5 VDC, 50 mA ±12 VDC, ±250 mA
Analog Outputs	4-20mA Outputs 1 to 3 per Channel (Model Dependent) Output #1 Example: ppm-m (or ppm) Concentration Output #2 Example: Light Level (Rx) Output #3 Example: Confidence Factor (R^2)	24 V, 2 to 20 mA
Analog Isolation	Non-Isolated Active (Standard): GasFinder3-OP powers loop Isolated Active (Optional): GasFinder3-OP powers loop Isolated Passive (Optional): Field powers loop	
Alarm Relays	NC/NO Dry Contact Relays 1 to 3 per Channel (Model Dependent) Relay #1 Example: High Alarm Relay #2 Example: High-High Alarm Relay #3 Example: Fault	20 W max.
Display Options	Display Options are Model Dependent • **Basic:** Numerical Display (ppm-m, light level, and fault) • **Standard:** Numerical Display & Graphical Display (ppm-m over time, ppm-m, light level, confidence factor, and fault) • **Enhanced:** Numerical Display & Graphical Display (ppm-m over time, ppm-m, light level, confidence factor, and fault)	

Physical Data:

GasFinder3-OP (Core Analyzer)

Net Product Weight	5.0 kg [11.0 lbs.]
Tare Weight	5.0 kg [11.0 lbs.]
Gross Shipping Weight	10 kg [22 lbs.]
Dimensions (L x W x H)	260 x 200 x 160 mm [10.2 x 7.9 x 6.3inch]
Mounting	1x 3/8”-16 NPT Hole 4x 5/16” Through Holes

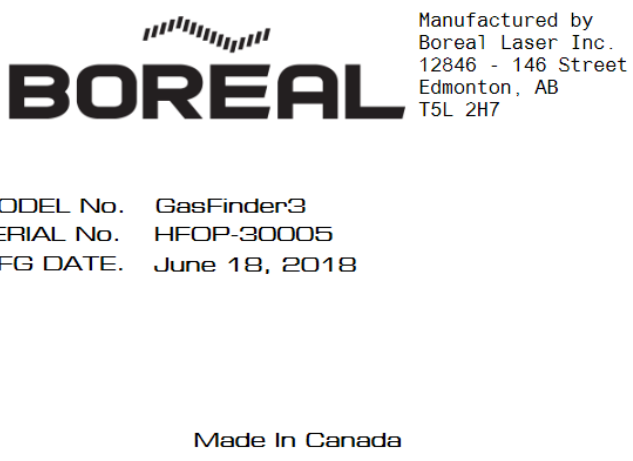
X-Y Aiming Mount

X-Y Mount Weight	1.15 kg [2.5 lbs.]
Total Dimensions (L x W x H)	260 x 160 x 95 mm [10.25 x 6.25 x 3.75 inch]
Mounting	1x 3/8”-16 Thread for temporary installations (Tripod). 4x 5/16 Through Holes for permanent installations.

120-220 VAC Power Supply

Total Weight	3.2 kg [7 lbs.]
Total Dimensions (L x W x H)	260 x 159 x 83 mm [10.25 x 6.25 x 3.25 inch]

Labels



This label is affixed to the body of the GasFinder3-OP and gives the instrument serial number, manufacturing date, power requirements and area usage classification.

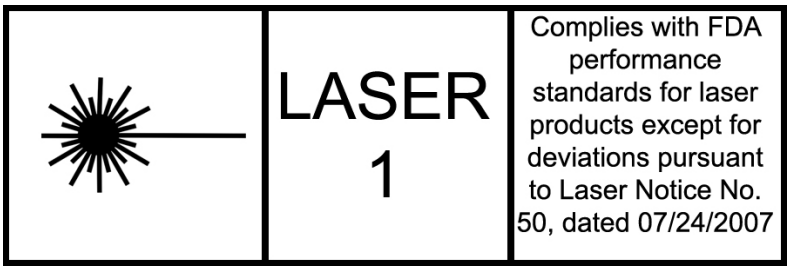
There is also a label indicating the following (see below):

COMPLIES WITH FDA PERFORMANCE STANDARDS FOR LASER PRODUCTS EXCEPT FOR DEVIATIONS PURSUANT TO LASER NOTICE NO. 5, DATED 07/24/2007

Warning labels are described in a later section.

Safety Concerns

Boreal Laser's GasFinder3-OP contains an invisible (infrared) laser source that conforms to Class 1 as per IEC 60825-1 and is eye-safe. It does not require the use of protective eye wear, protective equipment, or outdoor control measures. There is no optical ignition hazard presented by lasers of this type.



Caution: The infrared laser output from the GasFinder3-OP has very low power (conforms to Class 1 as per IEC 60825-1) and will not damage eye tissue. However, it is the recommendation of Boreal Laser Inc. that, as with ANY LASER SYSTEM, the user/ operator should avoid staring directly into the output aperture.

Technical Note 17-3

The Boreal Laser GasFinder product line meets or exceeds the requirements to be listed as Class 1 laser products under the IEC 60825-1 standard.

The IEC 60825-1 standard defines Class 1 as any laser product which during operation does not permit human access to laser radiation (accessible emission) in excess of the AEL of Class 1 for applicable wavelengths and emission durations.

The Boreal Laser GasFinder product line operates in the NIR (Near-Infrared) wavelength region for purposes of gas detection. The appropriate ranges for wavelength and duration have been considered to ensure that products meet or exceed these requirements.

Boreal Laser makes use of a NIST (National Institute of Standards and Technology) traceable testing program to ensure the NIR thresholds are not exceeded during setup and production of GasFinder products.

For export into the United States of America, Boreal Laser products are classified as Class 1 and are compliant with the testing, record keeping and reporting requirements of the CDRH (Center for Devices and Radiological Health) which operates under the FDA (Food and Drug Administration). Boreal Laser complies with performance standards for laser products except for deviations pursuant to Laser Notice No.50, dated 06/24/2007.

Section 2: Pre-Installation Checks

All equipment leaving the factory is inspected prior to shipment for quality and completeness. It is recommended that the shipment be inspected by the end user or system designer after receipt of the equipment from the Boreal Laser factory and prior to installation.

The contents of the shipment should include:

- GasFinder3-OP OP-TDL Gas Analyzer
- X-Y Aiming Mount (w/ Quick Release Plate & Swivel Mount)
- Data Cable
- 120-220 VAC Power Supply
- 12 VDC Alligator Battery Cable
- Any applicable accessories
- This manual
- Calibration documents
- Product Registration Card

If any of these items are missing from the shipment, notify Boreal Laser immediately.

Inspecting the GasFinder3-OP and Accessories

Make note of any large or obvious damage on the external cardboard shipping container before unpacking the instrument. Report any damage to the freight carrier and Boreal Laser and photographically document the damage.

- The GasFinder3-OP should be placed on a flat surface for inspection
- Check for any large dents or deformities in the instrument enclosure

Open Path Installations

A site survey should be undertaken to check the following points have been considered:

- Factors that Determine Path Length:
  - Determine the monitoring area:
    - Identify the desired locations of the GasFinder3-OP (transceiver) and Retroreflector.
    - Ensure there is a clear line-of-sight from the GasFinder3-OP and Retroreflector.
    - Determine the physical path length between the GasFinder3-OP and Retroreflector.
  - Expected Gas Concentrations:
    - Concentrations Under Normal Operating Conditions.
    - Worse Case Concentrations during Upset and/or release.
    - Desired High and High-High Alarm Levels.
    - Other gases that could be present.
  - Environmental Conditions:
    - Is rain, snow, sleet, dust, steam, or other particulate matter commonly present that can block the beam?
    - Over the desired path length, is the retroreflector visible from the transceiver?
    - Temperature Range: (-40 to 50C)
    - Pressure Range:
- GasFinder3-OP Mounting Structure:
  - Is the GasFinder3-OP and Transceiver safety accessible?
  - Is the operator/maintenance personnel access structure separate from the GasFinder3-OP or Retroreflector mount?
  - Is the mounting structure affected by vibration?
  - Will the materials that have been used cause misalignment by diurnal temperature changes?
    - Can non-expanding materials be used?
    - Can the mounting structure be insulated?
    - If installed in a cold weather environment, is the pile installed below the frost line?

Mounting locations outside where sun can strike directly on the mount structure may require additional insulation to prevent movement due to differential heating.

Retroreflectors (Retros)

Retroreflector locations should be chosen to limit paths to the suitability of the remote head and be in areas that are safely accessible for cleaning when necessary. The Retroreflector can tolerate small vibrations and movement, but the reflector enclosure should be attached with the front window perpendicular to the path. There should be no obstructions in the path between the retroreflector and the head. All retro enclosures include heaters and rain/dust shields to ensure the end user has all the tools necessary to maintain maximum up time.

Section 3: Installation

Required Hardware

Listed below are the hardware compatibility requirements for properly connecting and mounting the GasFinder3-OP. Specific part numbers have not been listed due to different requirements and/or preferences from site to site.

- Junction box for landing pre-wired cables from GasFinder3-OP
- Conduit, as necessary
- Suitable cable for power connections of up to 4 A at 24 VDC, as required*
- Suitable cable for data & I/O connections, as required*

Required Tools

Depending on the system configuration requested, some or all of the following tools will be required to install the instrument.

- Screwdriver sets
- Hand drill/bits
- Level
- Pencil/grease pencil
- Socket wrench set
- Adjustable spanner (Crescent wrench)
- Allan key set (Imperial)

Optional: Range Finder Binoculars

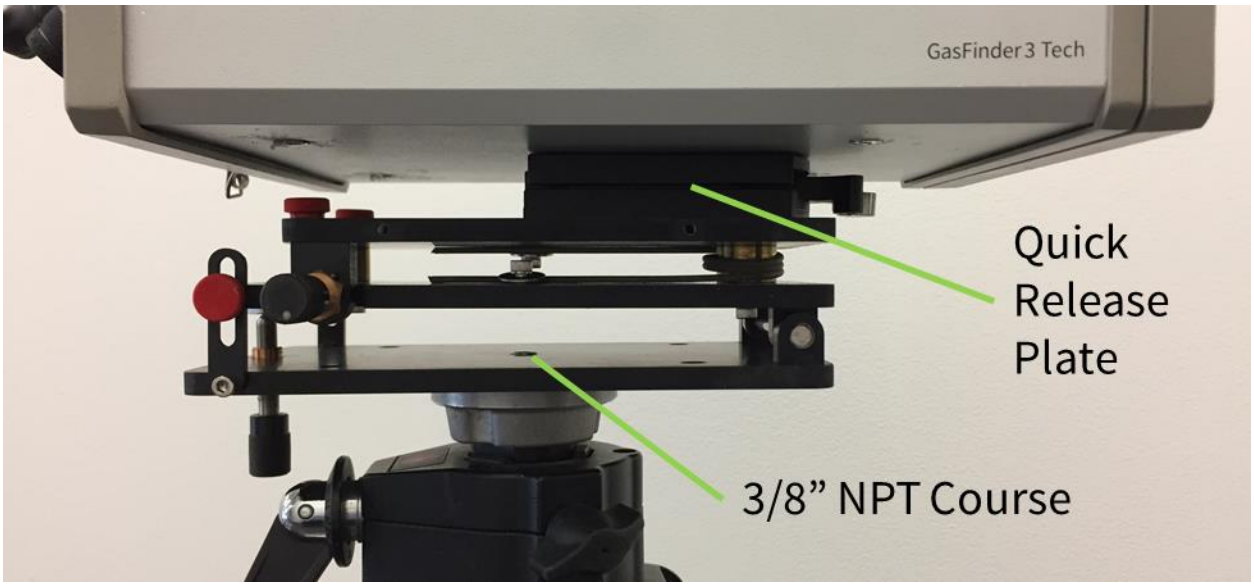
Installation Sequence

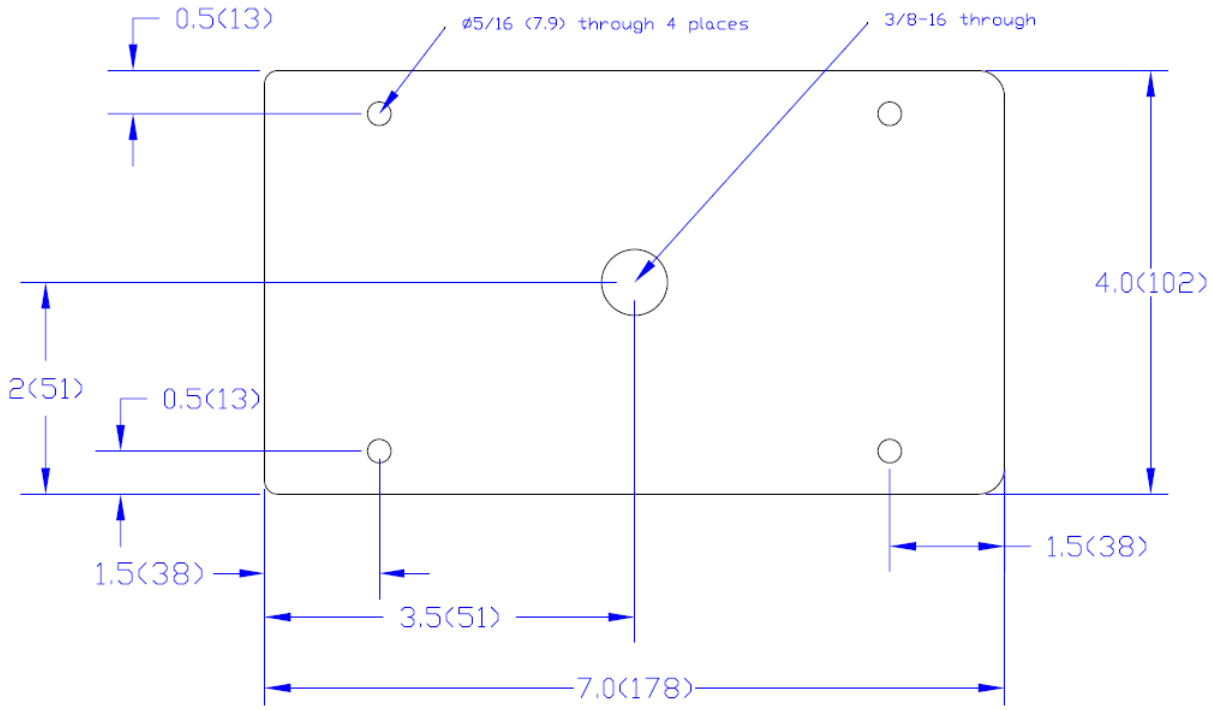
The preferred sequence is to install the Retroreflector(s) and then the GasFinder3-OP. This ensures that when the measurement head(s) are installed, it/they can be aligned at the same time.

Mounting Requirements

The GasFinder3-OP can be mounted anywhere in a facility where there is a need to monitor ambient gas concentrations, provided the area falls under general purpose classification.

The GasFinder3-OP is attached to the X-Y Aiming Mount by a Quick Release Plate. The X-Y Aiming Mount can be mounted to the support structure with the one (1) 3/8”-16 NPT (Course) threaded hole or with the four (4) 5/16” through holes.





In hot climates care should be made to locate the instrument out of direct sunlight or use the Boreal Laser Rain/Dust Enclosure accessory (Part # BL-OPRD). Care should be taken to keep the GasFinder3-OP under 50C. Mount the GasFinder3-OP a suitable distance away from adjacent equipment to allow for conduit routing and access. Ensure there is sufficient space in front of the analyzer in order to allow for operation and maintenance. A dimensioned drawing is shown in Appendix A.

Mounting the GasFinder3-OP

1. Select a suitable location to mount the instrument.
2. Decide the mounting option on the X-Y Mount:
    a. One (1) 3/8-16 NPT Thread (and the Swivel Mount)
    b. Four (4) 5/16 Through Holes
3. Connect the GasFinder3-OP to the X-Y Mount via the Quick Release Plate

See Appendix A for bolt mounting pattern and dimensions.

Mounting the Retroreflectors

The retroreflector is a vital part of the system and choosing the correct type is necessary for the correct operation of the system. Refer to the following page for details on choosing a retro. For short paths where reflective tape is used (0-20m), the tape can be attached to the back of an enclosure which is fitted to a tripod or placed on a wall in any convenient location. The angle of the tape can be adjusted to give an adequate signal return provided this does not degrade the R2 value.

- Where Retros are used on longer paths, these may be mounted in an enclosure on a tripod, or the enclosure placed in any convenient location.
- Purge air may be required for Retros used in ducts.
- Where long paths are measured in metal buildings, the Remote Head may go out of alignment as a result of solar heating deforming the structure. The preferred solution is to use multiple Retros.
- The GasFinder3-OP does not require any changes when different path lengths are measured unless ppm values are needed on the serial output, in which case the distance must be set in the instrument menus. Otherwise, ppm values can be obtained by setting upper and lower 4-20 mA limits with the help of a trained Boreal technician.

Path Length Retro Table

Path Length	Retro-Reflector Configuration
1-5m	Red/White Tape
1-20 m	Grey Tape
20-45 m	1 Corner Cube
45-75m	3 Corner Cube Array
75-200m	7 Corner Cube Array
200-350m	12 Corner Cube Array
350-500m	19 Corner Cube Array
500-625m	27 Corner Cubes Array
625-750m	40 Corner Cube Array

Light Values

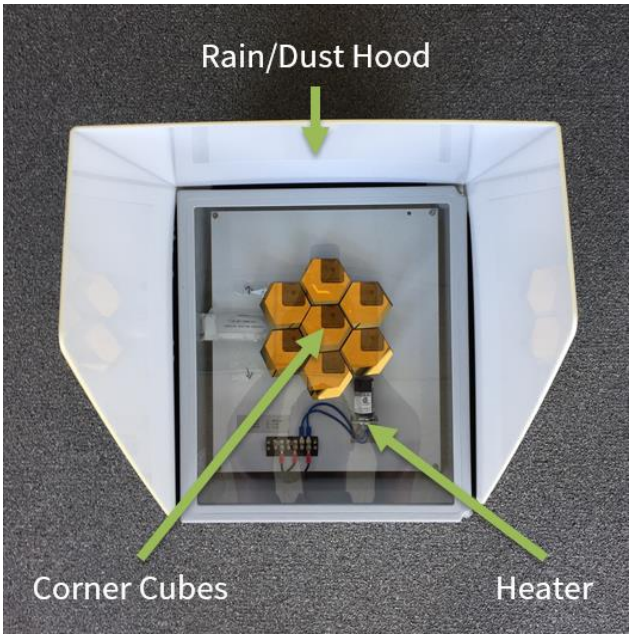
The type of Retro used will depend on the path length, atmospheric conditions such as dust or fog, the type of head and the type of laser. When choosing a Retro, the prime concern should be to keep the returning light level value at a reasonable value.

IMPORTANT: The Light Level values in the GasFinder3-OP are quite different from those used in the previous GasFinder2-based technology. There are important reasons for this explained on the following pages. Failure to understand these differences can result in poor setup and compromised performance of the system.

Condensation

Condensation on the surface of the window is caused by the window temperature falling below the dew point. This may occur in areas of high humidity or large temperature differences between day and night. The enclosures are sealed but condensation can sometimes occur inside the window. Condensation can usually be controlled by the following measures:

- Fasten the included rain/dust hood over the enclosure to shield the window from radiation cooling at night. This also prevents rain from striking the window.
- Use a desiccant pack to prevent condensation inside the enclosure.
- Place a heater in the enclosure. The heater can be 12W to 50W depending on the size of the enclosure and the operating conditions and is controlled by a thermostat to prevent overheating. The heater raises the enclosure temperature and prevents condensation either inside or outside of the window. To minimize heat loss the enclosure is insulated. This option requires power to be supplied and there are heaters available for use in hazardous areas.

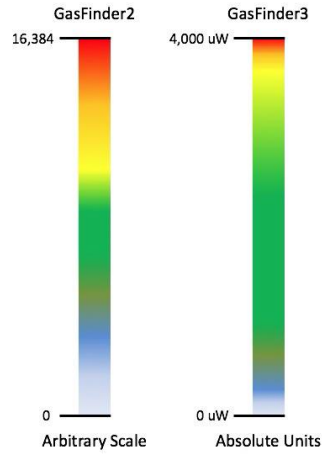


Why the light level appears lower in GF3 tech compared to the GF2

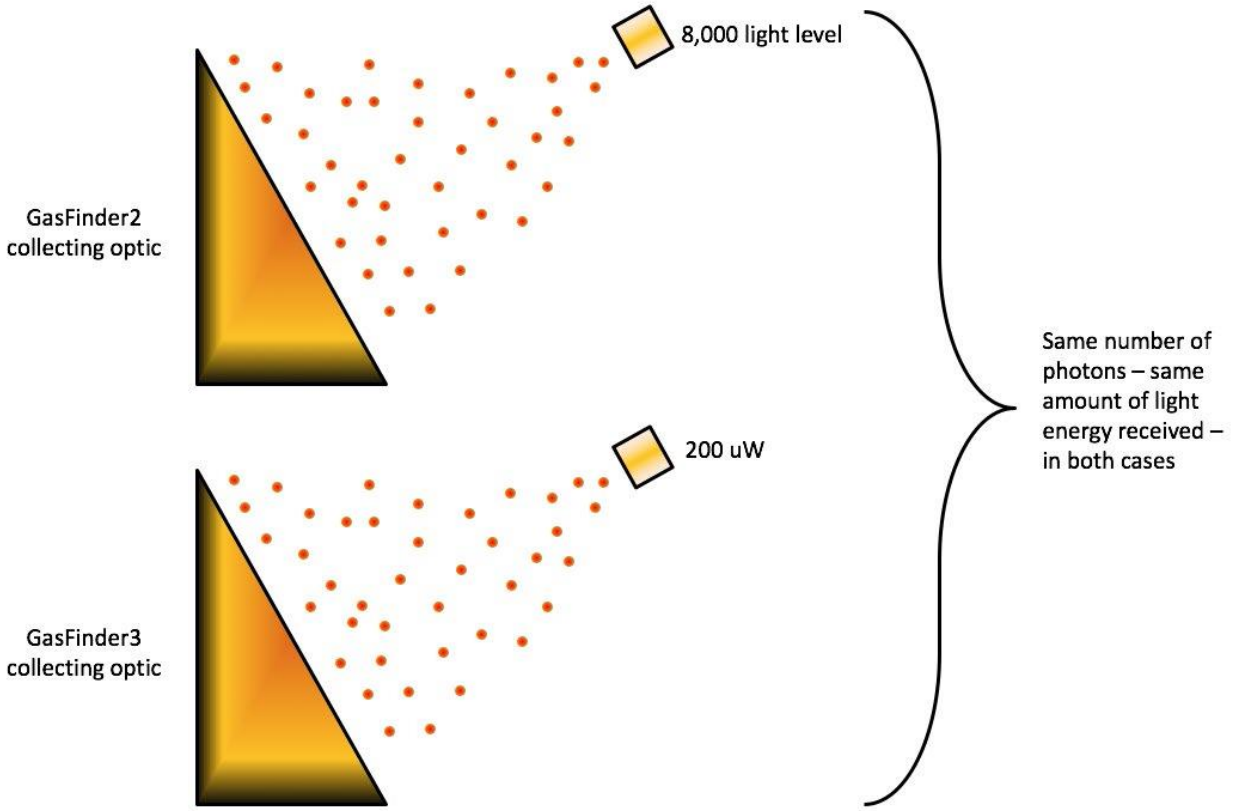
One of the first major differences you may notice when you first set up your GF3-based gas detector is that the light level is now called “Rx”. This is short for Received Power, and it is named differently for some important reasons explained below. The second aspect you will notice when you align your system is that the Received Power has a much lower numerical value than that of a GF2. Your first reaction may be to say that the GF3 is receiving much lower light than the GF2.

Different Units

The light level in Boreal's GasFinder units are inferred through an indirect measurement of modulated received light. With the GasFinder2 technology, we made efforts to try and ensure that systems were built consistently with a "good light level" being somewhere 6,000– 10,000. This was an arbitrary dimensionless scale based on the 14-bit measurement the electronics would make of the light level (a dynamic range from 0 to 16,384), and we chose and arranged for mid-scale to be a good light level.

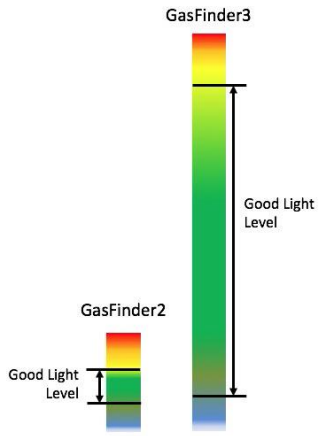


With the GasFinder3 technology, we developed a better method of calibrating the received light in real physical units –microwatts (uW). The number you see displayed as Rx on the GF3 is light level calibrated in microwatts (uW). With the new technology, you now have a better sense of what you're receiving back from a retroreflector, and we can more reliably state when you are above the required signal-to noise ratio for good system performance. While the number for the GasFinder3 Received Power is lower, that is no indication that it is less effective at collecting light. The receiving optics in both the GF3 and the GF2 are nearly identical, so both are equally effective at collecting returned light from a retroreflector. We've simply changed the number so that it means something real and physical.



What is "Good Light"?

With the GasFinder3, we properly set the minimum threshold for light level to be 50 uW. The system performs quite well and reliably above this threshold. The maximum amount of light that can be obtained is 3,000. This is because the 3,000 Received Power on the GF3 corresponds to 3,000 uW, or 3 mW of returned light**. The "Good Light" range on a GF3 is anywhere between an "Rx" of 50 to 3,000,** this range has been calibrated and optimized for best performance.



One of the great benefits of the GasFinder3 is that it now has a much higher dynamic range of acceptable returned light before saturating amplifiers and/or the photodiode. The GasFinder2 technology would saturate at what would be a few hundred microwatts on the GasFinder3. The GasFinder3 therefore has an entire order of magnitude greater range of acceptable light levels.

What does this mean for you? It means that you don't need to keep swapping out retros or attenuating light to reach a narrow sweet spot of light where the system is happy. It means you can use corner cubes at short distance as well as long. You can take a single type of retroreflector and use it for nearly all your application needs.

Optical alignment

Once the GasFinder3-OP is mounted and fastened, adjust the two alignment screws on the X-Y mount so that the Retro appears in the centre of the cross hairs in the alignment scope. Verify that the entire Retro is clearly visible and there are no obstructions in the path. Ensure that the GasFinder3-OP is powered on. Adjust the XY mount with the horizontal and vertical adjustment screws so that the light level reading on the analyzer is as high as possible. Gently tighten the 4 red locking screws on the mount, ensuring that the light level on does not decrease. If the retroreflector is not visible in the alignment scope or difficulty is experienced getting a reading, switch on the visible laser. Using the continuous red beam now being emitted from the GasFinder3-OP, the mount can be adjusted so that the red beam is reflected back from the retroreflector. As soon as the analyzer registers a reading, the visible laser use can be discontinued and the analyzer used alone for precise alignment.

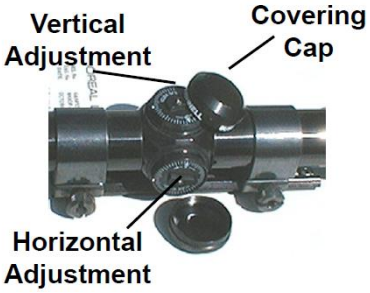
Note: do not stare into the reflected beam of the visible laser through the aiming scope.

Adjusting the Aiming Scope

Cross Hairs

Once the OPX is aligned, if the cross hairs on the scope do not line up with the centre of the retroreflector, they can be adjusted by unscrewing the covering caps in the centre of the scope and adjusting the rectangular-headed screws underneath. This enables quick and easy system realignment in the future. The factory setting is made so that the cross hairs are parallel to and thus above the laser beam.

It is better to start by adjusting the mount for maximum signal by maximising the light value reading and then centre the cross hairs in the centre of the Retros by adjusting the cross hairs with the scope adjustment screws. Note that the scope is made for a rifle where the eye is always at a fixed position determined by the stock at a set distance behind the scope. If you are not at the correct distance from the eye-piece, moving the eye laterally will cause the cross hairs to move across the Retro.



- Remove the caps covering the adjustment screws.
- Turn the zoom on the scope to a maximum.
- Focus the eye-piece so the retros are sharp.
- Position your eye so that all the apertures in the scope are concentric and open the full diameter.
- Depending on your eyes, this may be about 6 inches away from the eye-piece. Then the cross hairs intersect on the centre line and will not move laterally.
- Turn the horizontal and vertical screws as necessary to position the cross hairs in the centre of the retro.
- Replace the covers.

Focus and Zoom

- The two adjustable rings at the front of the scope can be turned to adjust the focus and zoom. When cold these rings are extremely stiff.
- The zoom is used at a minimum when locating the Retro and at a maximum when checking for movement and aligning the cross hairs.
- Focus the eye-piece so the Retros are sharp.
- When all adjustments to the scope are finished, tighten all the locking screws.

Note: Make sure that these adjustments do not misalign the system.

Data Cables

The data cables are optional accessories to transmit the RS-232 serial data from the GasFinder3-OP back to a computer or serial logger. It is easily integrated with the GasView program to interact with the GasFinder3-OP remotely. The cable length should not exceed 30m as the data is communicated via RS-232. If a longer distance is required, other options may be available. Contact Boreal Laser Support for more details.

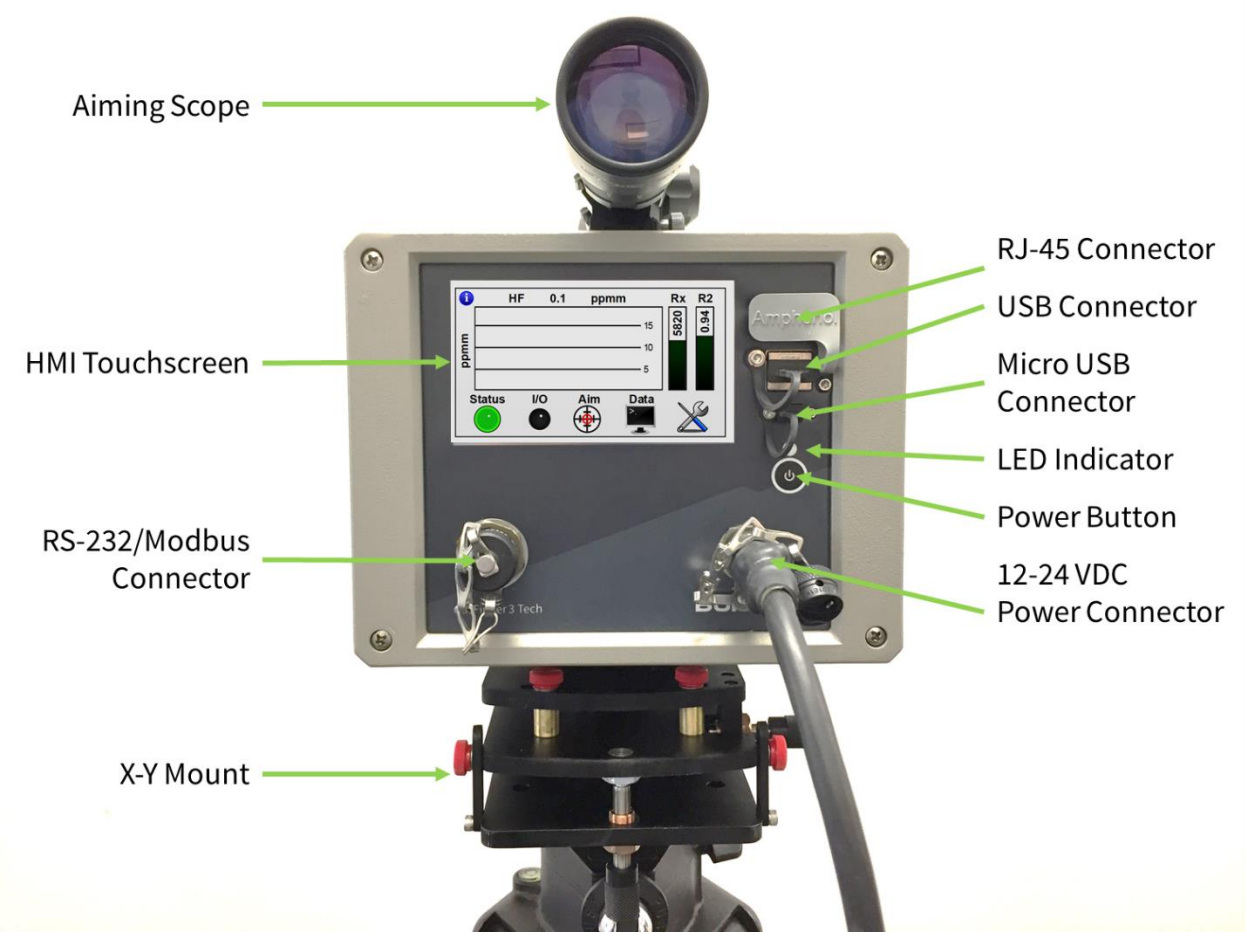
Data Input / Output

The serial data cable uses the standard serial TX/RX/GND pins for DB9 RS-232 connections. The micro-USB serial data cable requires USB drivers which should install automatically on most Windows Operating Systems. Contact Boreal Laser if you have difficulty getting the correct drivers.

Note: I/O equipment may be connected or disconnected while the system is operating. Caution should be observed that data may be compromised during transition.

Connecting Electrical Power to the GasFinder3-OP

The GasFinder3-OP is shipped configured for 12-24 VDC with a barrel connector. All electrical work must be performed by qualified personnel. Water tight conduit seals should be used in compliance with local regulations.



The GasFinder3-OP operates from a regulated,12VDC, 5A supply. This can be from a 12V battery or a power supply module which converts the local supply voltage (110V/220VAC) to 12VDC. The GasFinder3-OP has a built-in membrane switch on the front panel.

Connect the power cable between the socket on the rear of the Gasfinder3-OP and the 12V power supply and connect the power supply to a power source. Turn on the power supply (if required).

Power Button
The membrane switch embedded in the GasFinder3-OP operates in the following manner:

Power On: If there is adequate voltage, the system can be powered on by a short press of the power button.

Power Off: The system can be powered off by a 3-second press of the power button.

Power-on Mode: The GasFinder3-OP will require a button press to power on every time power is disconnected and reconnected. You can change this to make the GasFinder automatically power on every time there is adequate power by doing the following: Press and hold the power button for 15 seconds or longer. The LED indicator will flash at a high frequency to indicate the power-on mode has been changed. A power cycle is required to see the change.

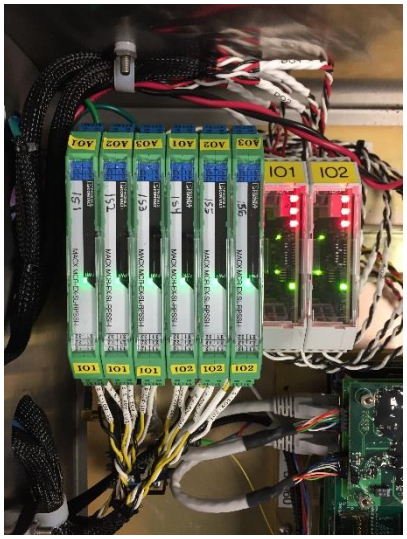
LED Indicator: The green LED indicator light will illuminate and flash when the voltage is adequate to power the GasFinder3-OP (+12VDC). If the system is in standby mode, the illumination period will be long, and the off period will be short. During operation, the LED indicator light will flash for short periods, with long off periods.

Make sure to connect the protective conductor terminal flying lead, with a green insulation jacket, to earth. The protective conductor lugs inside the enclosure are also labeled (right).

Connecting the Output Signals, 4-20 mA.

The GasFinder3-OP can come equipped with three 4-20 mA outputs, and three dry contact relay outputs per channel (model dependent).

Removing or modifying the connections on the system will compromise the alarm response of the instrument.



All user 4-20 mA connections are pre-wired as labeled flying leads from either from the I/O Module or the (optional) the Phoenix Contact Isolators (left). None of these wires should be removed or altered. They should be connected to an external Termination Junction Box through an appropriate 3/4" liquid tight flex conduit. Altering these wires can compromise the response of the instrument. The loop is configured at the time of ordering by the customer and can be either powered by the GasFinder3-OP instrument or the customer's loop. Three flying leads per 4-20 mA output are provided to allow for "Active" or "Passive" configuration. For complete details of the electrical connection layout, refer to Appendices B and C.

For the 4-20mA loops, the ppm scale is determined by the gas type and application at time of order or can be user configurable with the HMI Touchscreen. If it is a low light fault the loops will output 2.7 mA. If it is a system fault the loops will output 3.6mA. Relays used are 1 Form C, single pole double throw and provide Normally Open and Normally Closed contacts. During normal run mode the relays for the normally open contact will be closed and vice versa. For low light faults the relay will switch if configured for Rx uW fault on a specific channel. For a communication failure or system fault, the relay will switch if configured for system fault. When the fault has cleared, the relays and 4-20mA loops will return to normal conditions. Table 2 shows the various levels of the 4-20mA loops and the normally open relay contacts under normal operating condition, low light and system fault.

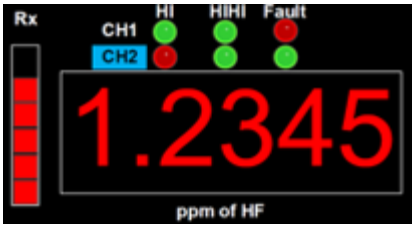


Table 2.

Front Panel	Example Error	Analog #1 CH1 ppm(-m)	Analog #2 CH1 Light Level	Analog #3 CH1 R^2	Relay #1 CH1 High-High	Relay #2 CH1 Rx uW	Relay #3 Fault
0 ppm	Normal	4.0mA	16-17mA	4mA	Closed	Closed	Closed
Yellow Highlight	Low Light	2.7mA	2.7mA	2.7mA	Closed	Open	Closed
Red Fault LED	Communica-tion Failure	3.6mA	3.6mA	3.6mA	Closed	Closed	Open

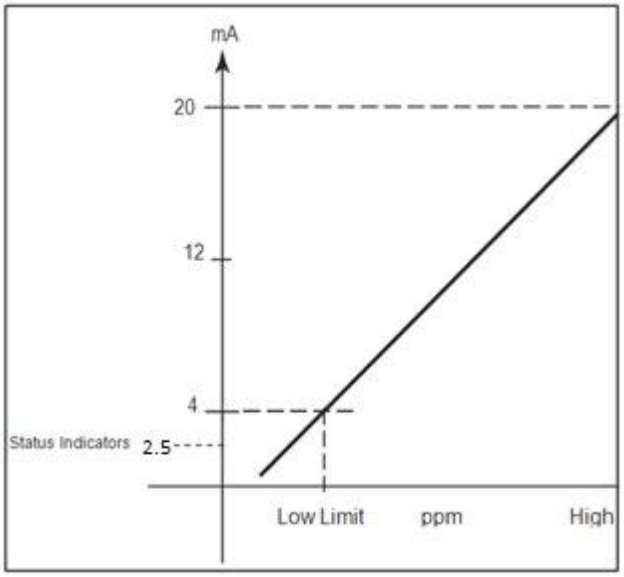
4-20 mA Details

- 4 mA is equivalent to the lowest programmed value of gas concentration, 0 ppm.
- >4 mA and <20 mA varies proportionally to the gas concentration.
- 20 mA is equivalent to the maximum gas concentration (varies with gas type and application).
- Gas concentration higher than maximum setting will display 20 mA.

Current levels <4 mA are usually used for status indicators as follows:

- A Low Light status sets the PPM loop currents to 2.7 mA.
- A Communication Failure status, or other faults sets the PPM loop current to 3.6 mA.

This relationship is illustrated in Figure 6.



When the GasFinder3-OP is integrated into a client's control system via the 4-20 mA and relay outputs, the installation instructions and wiring diagrams specified in Section 3 must be followed. Failure to do so may compromise the performance of the instrument. Adherence to the instructions will ensure that system integration does not affect GasFinder3-OP performance.

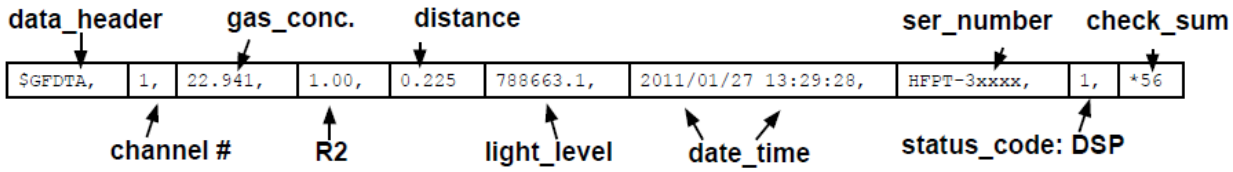
Serial Data Output

The serial data output in a GasFinder3-OP uses the RS232 format and is made up of two different types of strings: data strings and debug strings. Both are comma-delimited ASCII strings. All data are logged internally on the SD card.

Format of Data Strings

These data strings are comma-delimited (,) and an asterisk (*) signifies the end of the string. Each string is terminated by a carriage return and a line feed.

$GFDTA



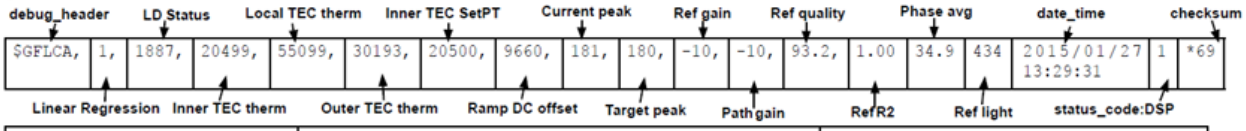
Explanation

data_header	Header designating the type of data	String
Channel #	Designates channel origin of data (1 or 2)	Number
gas_concentration	In ppmm (parts per million meter)	Number
R2 (confidence factor)	Decimal between 0 and 1 (percentage)	Number
distance	Factory-set path length in meters	Number
received_light	Rx Light received on the photodiode	Number
date_time	Current date and time	YYYY/MM/DD hh:mm:ss
ser_number	Identification number of the system	String
status_code DSP	Code giving system operating status from the DSP	Integer (hexadecimal)
check_sum	Checks the data stream for errors	String

Format of Debug Strings

Periodically, strings containing line-centering data ($GFLCA) are transmitted giving details of the GasFinder3-OP operation. The $GFLCA string is output whenever the system performs a line-centering check and/or adjustment.

$GFLCA



Debug header & Record ID	Line centering data string	String ('$' + 5 letters)
Linear regression	Linear Regression Algorithm Enabled (0 | 1)	
LD Status	Laser Diode Status	
Inner TEC therm	Inner Thermal Electric Cooler Thermistor* m^{0}C	Number Integer
Local TEC therm	Local Thermal Electric Cooler Thermistor* m^{0}C	Number Integer
Outer TEC therm	Outer Thermal Electric Cooler Thermistor* m^{0}C	Number Integer
Inner TEC SetPT	Inner Thermal Electric Cooler Setpoint* m^{0}C	Number Integer
Ramp DC Offset	Line centering position control variable	
Curr Peak	Laser offset current** (Line centering control variable)	
Targ Peak	Line centering target peak location	
Ref Gain	Reference cell receiver gain (dB)	
Path Gain	Path receiver gain (dB)	
Ref Qual	Reference cell quality percent	Number (float)
Ref R2	Least Squares R2	Number (float)
Phase Avg	Phase Average	Number (float)
Ref Light	Reference cell received light level calibrated in uW	
Date/Time	Current system date and time (24h)	String (YYYY/MM/DD HH:mm:ss)
DSP Status	Code giving system operating status from the DSP	Number (hexadecimal, 32 bit)
Checksum	Used to validate the data for transmission errors	8 digit hexadecimal number

*The thermistor values are given in milli-celsius. Example: 30193 in an LCA statement corresponds to 30.193^{0}C.
**The laser offset current is given roughly in 10s of uA. Example: 2395 in an LCA statement is 23,950 uA, or 23.95 mA

Section 4: Operating Instructions

Equipment Warnings

The following warnings are also located on the side of the GasFinder3-OP enclosure in both French and English.

WARNING – EXPLOSION HAZARD. DO NOT DISCONNECT WHILE THE CIRCUIT IS LIVE OR UNLESS THE AREA IS FREE OF IGNITIBLE CONCENTRATIONS.

Safety of HF Reference Cell (if applicable)

The HF reference cell used in Boreal Laser GasFinder3-OP systems configured for HF gas detection is a 1½ cm wide, completely-sealed Teflon™ bottle containing about 2 ml of aqueous (35%) HF. This bottle is mounted in a solid aluminum block which is bolted to the GasFinder3-OP base-plate. Teflon is the ideal material for an HF reference cell as it is both non-reactive with HF and transparent to the laser IR radiation at the wavelength used to measure HF.

Under normal operating conditions, the reference cell will remain completely sealed and does not pose a risk. Under extreme conditions outside of normal operation, it may be possible for the reference cell's integrity to be compromised.

The vapour phase in the bottle is in thermal equilibrium with the aqueous solution. Typically, the reference cell concentration is 60 ppm-m in an effective path length of 1 cm—so the actual vapour phase concentration is 6000 ppm.

The reference cell and GasFinder3-OP instrument enclosure represent a double containment system for the HF. If the reference cell is compromised, the HF gas in the cell would dilute within the surrounding air. The volume of vapour in the ref cell is about 8ml. The internal volume of the GasFinder3-OP is about 40cm x 35cm x 15cm = 21,000 ml. At least 75% of this internal volume is air—so the dilution factor resulting from an HF ref cell rupture would be approximately 2000:1. This means that the average HF concentration inside the instrument, resulting from a rupture, would be less than 3 ppm. The majority of the HF will likely react with the aluminium reference cell mount and base plate inside the enclosure, further reducing any residual ambient HF gas.

It is important to note that Boreal Laser has very few failures of the reference cell. Because of the way the HF reference cell is mounted, it would require a deliberate action to rupture the reference cell – and even then, the consequences, as described above, would be restricted to collateral damage of adjacent internal components.

More details on the design and construction of the HF reference cell used in Boreal Laser GasFinders can be found in US Patent No. 6,121,627, "Calibration cell for reactive gases": https://www.patexia.com/us-patents/06121627 For details regarding the shipping of GasFinder systems with HF reference cells, see sample DG Declaration in Appendix J.

How to spot a compromised HF Reference Cell

The first indications of a compromised HF reference cell will most likely be in a reduction of the reference cell quality (see debug statement format for more information). A visual inspection may reveal obvious deformations or punctures to the reference cell, and the surrounding components may be spotted white from HF acid burns.

Immediate Actions

Ensure the appropriate Personal Protective Equipment (PPE) is worn whenever handling a GasFinder3-OP with a compromised HF reference cell. See below for further details. Contact Boreal Laser, and consult your local safety officer to perform a risk assessment on the instrument. If no significant risks are presented by removing the analyzer and moving it to a secure, well-ventilated area, do so while wearing appropriate PPE and following local safety protocols. Await further instruction from Boreal Laser support.

Personal Protective Equipment (PPE)

The following minimum Personal Protective Equipment must be worn during operations involving HF. Note that some sites may have additional specific requirements:

- Eye/face protection: Splash-proof chemical goggles with plastic face shield. Contact lenses should not be worn.
- Gloves: long, Best Ultraflex Neoprene 32 gloves over Best NDex 8005 nitrile gloves. Double-gloving is required when working with HF. Inspect gloves frequently. Change gloves frequently and immediately whenever contaminated, punctured or torn. If gloves are to be reused, rinse thoroughly after use and then dip them into a saturated solution of sodium bicarbonate.
- Wash hands immediately after removing gloves.
- A standard or disposable laboratory coat or disposable coveralls. A standard laboratory coat may be reused before laundering if it has not been contaminated with HF. A chemical-resistant apron with attached sleeves should be worn over the laboratory coat.
- Closed-toed, leather shoes (not fabric or mesh). Alternatively, boots made of polyvinyl alcohol (PVA) may be worn.

Powering-up the GasFinder3-OP

The instrument will power up immediately when power is connected.

When the GasFinder3-OP system powers up, it will enter a warm-up mode and display the Cold message while the system and laser are warming up. At 20°C the system takes approximately two (2) minutes to warm up. In extreme cold it may take up to 10min.

During the warmup cycle, the concentration and light level will not be transmitted on the 4-20 mA bus; they will be at the system fault level.

After the warm-up cycle, the system will immediately start detecting gas without user interaction.

Powering Down the GasFinder3-OP

There are no special requirements for powering down the instrument.

A Power Button is located on the GasFinder3-OP:

Front Panel Display and Touchscreen

The touchscreen on the GasFinder3-OP responds to finger taps or touches with a stylus or other non-sharp items.

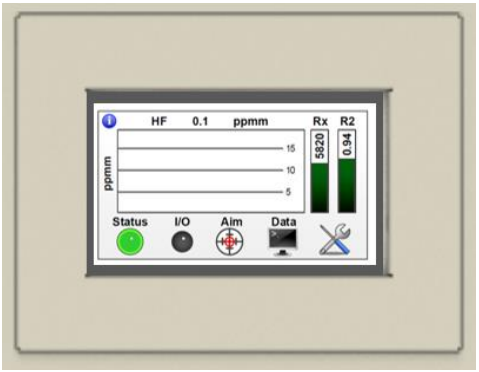
Display/Interface

The front panel display will differ depending on the GasFinder3-OP model purchased. Below is an explanation of the functionalities of the two displays:

Basic Model

With the **Basic GasFinder3-OP Model**, the system has a Touchscreen Human Machine Interface (HMI). In real-time, the numerical display shows the ppm(-m) concentration, light level (Rx), which channel is active, alarm status, and fault status. The user also has the ability to view the real-time serial string on the HMI.

Standard/Enhanced Model



With the **Standard & Enhanced GasFinder3-OP Models**, the system also has a Touchscreen HMI. This model has a graphical display that plots the real-time ppm(-m) over time relationship, ppm(-m) concentration, light level (Rx), Confidence Factor (R^2), and status indication. The numerical display is also available and user configurable with the Standard & Enhanced Models.

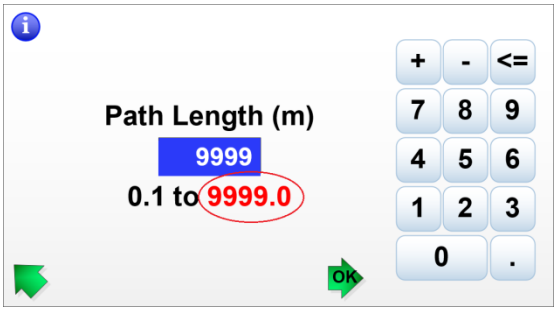
NOTE: At any time, the end-user may purchase an upgrade package to move up-to a different GasFinder3-OP Model.

The touch screen interface uses a number of icons to help the user navigate through the system's pages.

	Home	Return to the home page.
	Left Return	Return to the previous page. When in parameter entry mode, this exits without saving any changes or values entered.
	Up Return	Return to the previous page.
	Page Arrows	Switch to next/previous page.
	OK Arrow	Accept the value entered or displayed, and return to the previous page.

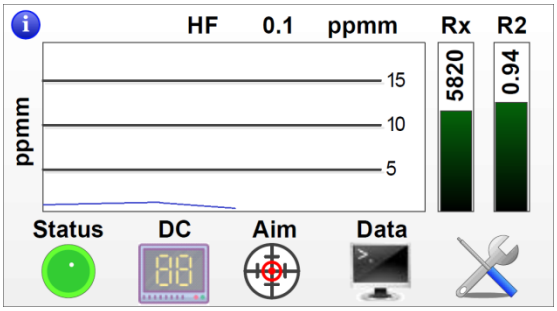
Changing the Setting Values

Press the setting's current value to change that setting. Either a pop-up menu will appear or the display will switch to a page with a keypad. When entering values that are outside the allowed range for that setting, the allowable limit will be highlighted in red. Use the touchpad backspace key (<=) to delete the entry and re-enter a valid value.



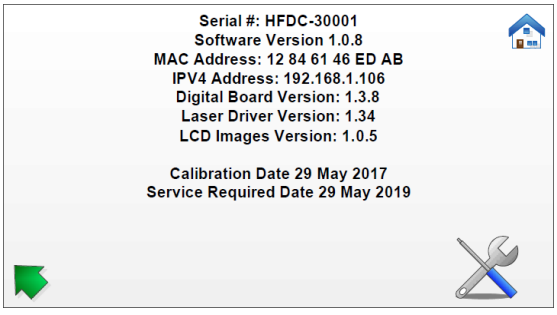
Home Page

The home page has a number of touch sensitive areas that allow access to the features and settings of the GasFinder3-OP unit. Press the icons or scale on the main menu to switch to the additional screens.



Info Screen

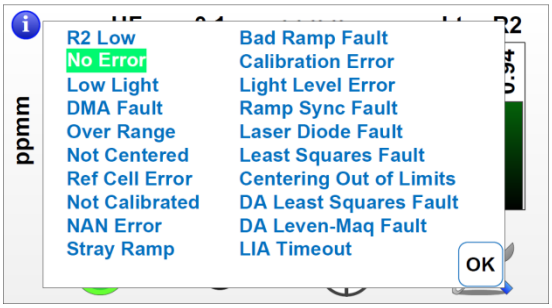
Pressing the blue "i" icon will switch to the info screen. This screen displays the unit's serial number and gas type, software version, MAC address, IPV4 address, hardware board versions, calibration date and recommended next service required date.



Status Page

The color of the status button will change if there is a change in the system status codes:

- Green: No alarm codes
- Blue: Line-centering (normal)
- Yellow: Warning code(s)
- Red: Alarm code(s)

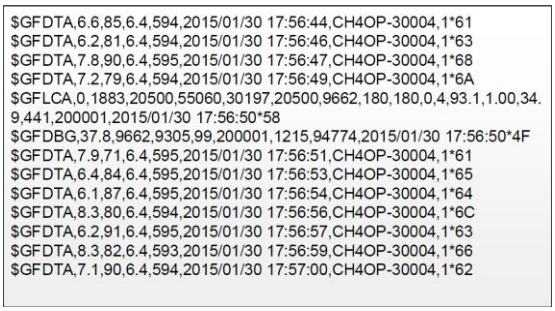


Pressing the status button icon will switch to the status code page.

Codes that generate a warning or alarm will be highlighted with inverse text in yellow or red. Multiple codes may be highlighted at the same time. The information indicated on the status page is also encoded in the Status Word field in the serial data strings. For more information on how to decode the Status Word, see Appendix D.

Data (View GasFinder Data)

This button allows the GasFinder3-OP serial data to be seen live on the LCD screen as the system operates. Pressing anywhere on the screen exits to the previous menu.

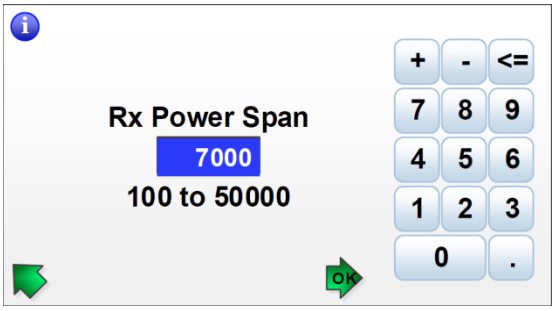


NOTE: The LCD screen does not have memory, so by going to this screen the historical trend on the home-screen graph will be lost.

NOTE: Array dumps are not plotted on this screen.

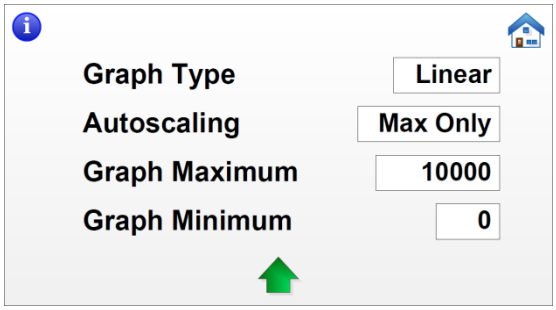
Received Power Scale

Pressing anywhere on the Rx power bar from the home menu page, or anywhere on the graph on the aim page will switch the display to the Rx Power Scale Page. Enter a new value for the maximum value that the bar will display, or go back to leave it unchanged. Values changed will change the displayed height of the light bar on the home page.

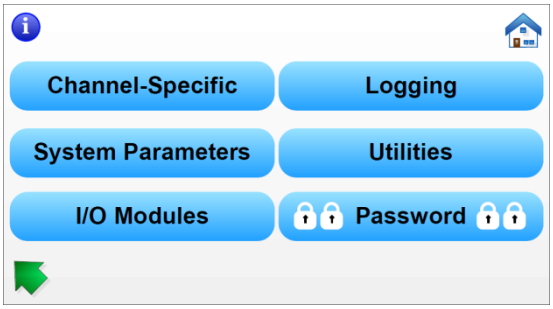


Gas Graph Setup

Pressing anywhere on the graph image from the home menu page will switch the display to the gas graph setup page. Press the setting's current value to change that setting. Values changed on this page will be reflected in the gas graph on the home page.



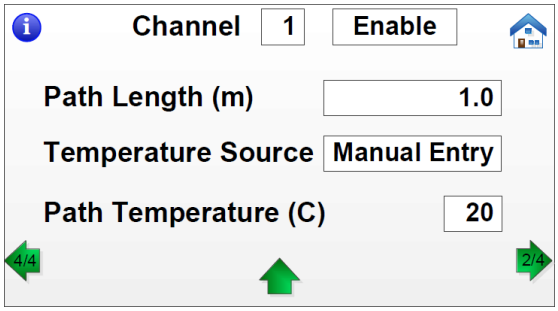
Main Setup Menu Page

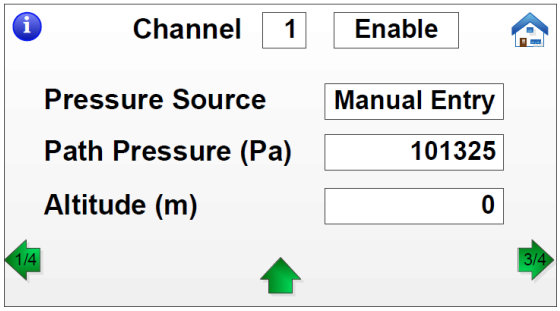


The main setup menu page allows access to the system configuration settings:

- Path Parameters
- System Parameters
- I/O Modules
- Logging
- Utilities
- Password (factory-protected menus)

Channel Specific Parameters





Here you can Enable/Disable channels and adjust settings for each enabled channel. Press a setting's current value to change that setting.

Path Length (m)

Enter the length of the target path in meters. This value is used to calculate ppm values.

Path Temperature (C)

Set this value to the average temperature of the active measurement path (distance between the transceiver and retro).

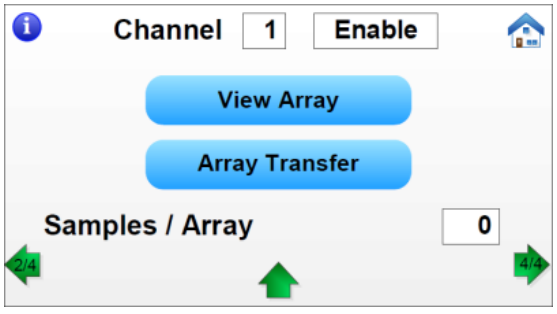
Path Pressure (Pa)

Set this number to the absolute atmospheric pressure of the path. If the absolute is entered the nominal pressure is automatically calculated and displayed.

Path Altitude (m)

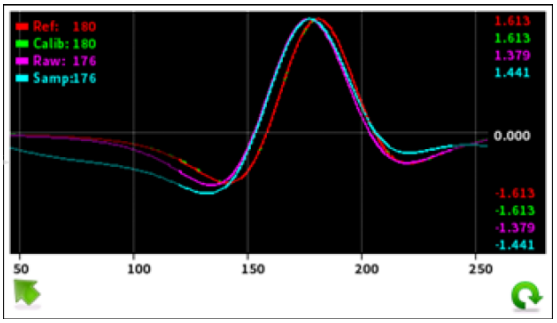
Set this value to the altitude of the path above sea level. If the correct absolute atmospheric pressure is known and entered for the path pressure, the nominal altitude is automatically calculated and displayed. Entering the correct absolute atmospheric pressure is the preferred method.

Array Transfer & Samples / Array



This setting adjusts how long the system waits between creating array transfers by number of readings. Set this value to 0 if you do not want array transfers. Press the Array Transfer button to instantly transfer an array on demand. This will be visible out of the serial ports.

View (Array)

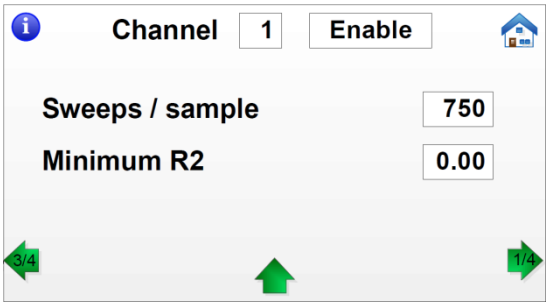


Press the View button to capture and display an array on the screen of the GasFinder3-OP. This will take a few seconds as the system needs to acquire and draw four distinct graphs, described below. Note that the waveforms can be refreshed by tapping the circular arrow button in the bottom-right corner.

This is a plot of the second harmonic gas absorption signal produced by the wavelength modulation spectroscopy method used in the GasFinder3-OP.

- **Raw (Red):** This is the raw waveform captured in the sample path, without any post processing.
- **Samp (Green):** This the wavefrom from the sample path with some post-processing done.
- **Reference (Purple):** This is the live reference waveform from the on-board reference cell in the GasFinder3-OP.
- **Calibration (Blue):** This is the stored calibration waveform that was captured in the factory.

Sweeps/sample



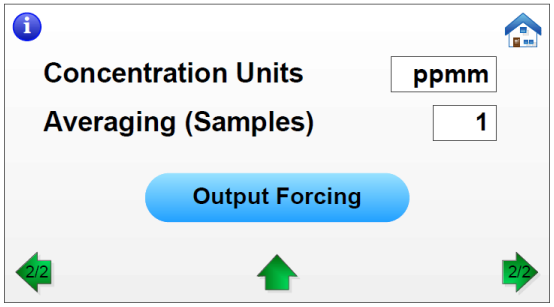
This item selects the number of times the sample path input data is averaged before the analysis and data output occur. The factory setting varies but it should not be necessary to change this value. Contact the factory before changing this value.

Minimum R2

This item allows the user to check the value of the confidence factor below which the concentration is deemed to be insignificant. Operators can adjust this value to reduce the occurrence of “noisy” readings in the presence of factors such as steam, traffic or thermal scintillation. Boreal Laser Inc. should be consulted before changing this value from the factory setting.

System Parameters

Concentration Units



This item displays the units chosen to display the concentration for the gas graph on the home display. The units can be adjusted to display:

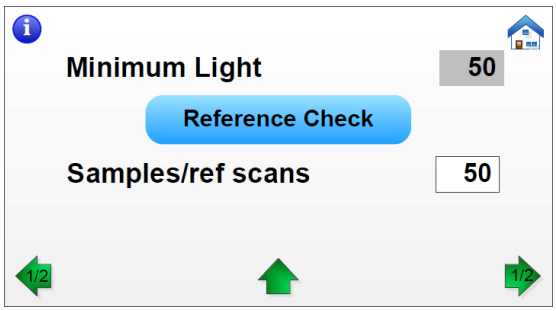
- **ppm-m** (parts per million - metre): the total amount of gas along the path.
- **ppm** (parts per million): average concentration along the path.
- **mg/Nm3** (milligrams per normalised cubic metre).

Averaging (Samples)

The number of samples collected that are used in the moving average calculation.

Minimum Light

The minimum light value is set by the factory and is displayed for reference only.



Reference Check

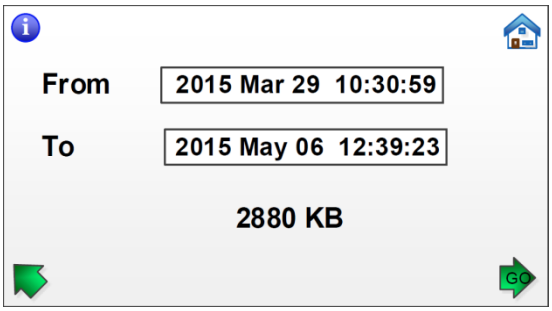
The reference check page displays the values from the internal reference cell's readings. These settings cannot be adjusted.

Samples/ref scans

This item selects the number of times the sample path is measured before the reference cell is checked. It should not be necessary to change the factory setting from the factory default value. Contact the factory before changing this value.

Logging

This menu will display the date range of the internal logs, and the estimated total file size of the date range specified. When first entering, it will pause on calculation screen shown below.



The date range of interest can be adjusted by touching the separate fields, delimited by the gray borders. When a USB storage device is plugged into the GasFinder3-OP, the "GO" arrow in the bottom right corner should be visible. After selecting the date range of logs files you desire, you can touch the "GO" button to begin data transfer to the USB storage device. The transfer speed is approximately 256 kB/s, and may take longer depending on the number of files being transferred.

WARNING: Do not remove the USB device while data are being transferred.

IMPORTANT: The USB storage device must be formatted as FAT32 with 4096 byte allocation. These are typical settings, but should be checked prior to beginning the USB dump of internal logs. After dumping, the files will be in a folder named by the last four bytes of the system's MAC address.
Example: "C0F03946"

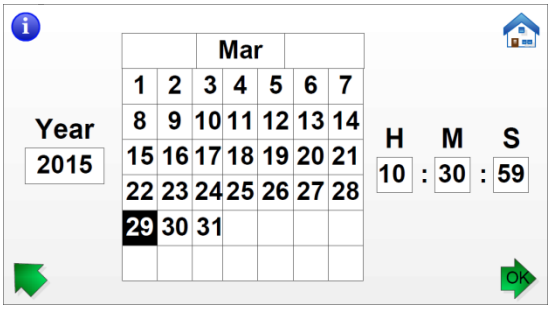
Utilities

The following feature has not yet been implemented and is currently grayed out:

- Screen Calibration

Clock Settings

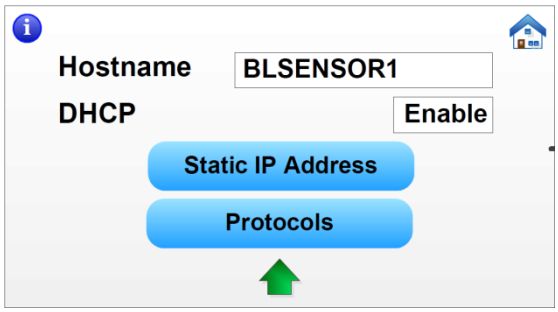
Enter the correct year, month, day, hour, minute and second settings.



Network Settings

Hostname:

From this menu you can assign a hostname to the GasFinder3-OP device, which is the label that will appear when the device is connected to a computer network.



DHCP:

Select whether or not DHCP (Dynamic Host Configuration Protocol) is enabled. With DHCP enabled, the GasFinder3-OP will automatically be assigned an IP address and other related configuration information such as the subnet mask and default gateway.

Static IP Address:

If you want to assign the IP-related configuration information yourself as fixed values, you can do so in the Static IP Address Menu.

Protocols:

This menu contains information and settings for other network communication protocols.

FTP

From the File-Transfer Protocol (FTP) menu, you can enable or disable the protocol, as well as assign a username and password to the GasFinder3-OP.

Telnet

From the Telnet menu, you can enable or disable the protocol, as well as assign a username and password to the GasFinder3-OP device.

HTTP

Not yet implemented.

Brightness

You can adjust the brightness of the LCD screen in this menu.

Beeper Volume

You can adjust the volume of the beeper of the LCD screen in this menu.

Update Software

Software updates can be done through the USB port in the GasFinder3-OP.

- IPM (Interface Processor Module)
- DSP (Digital Signal Processor)
- LDD (Laser Diode Driver)
- LCD (Liquid Crystal Display)

The screen will display No USB Drive Found if there is no USB device inserted when the menu button is pressed. If the USB device is not formatted properly, this message will also be displayed.

IMPORTANT: The USB storage device must be formatted as FAT32 with 4096 byte allocation. If a USB device is inserted and the software update is not found in the root directory, the message Valid Update File Not Found will be displayed. The filename of the update must match exactly to those given below:

- For IPM updates: ipm-upd.hex
- For DSP updates: dsp-upd.bin
- For LDD updates: ldd-upd.bin
- For LCD updates: lcd-upd.bin

If the correctly-named file is found in the root directory of the USB device, the system will spend some time checking the file. Then it will list the current version and the new version on the USB device. Updating the software is irreversible unless you have the .hex or .bin file of the older version.

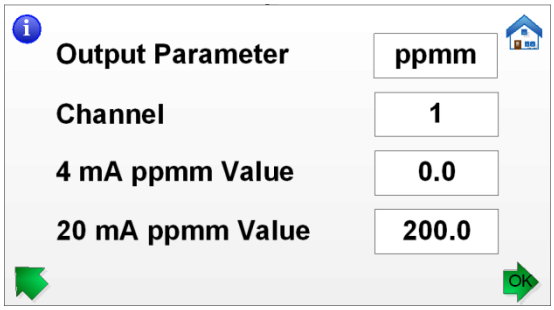
Pressing “Proceed” will begin to load the update. This may take a few minutes.

When the update is loaded, the system will prompt the user to power-cycle the instrument. Doing so will reboot the GasFinder3-OP into normal operation. Checking the software version on the info screen should reveal that the new version is now installed.

I/O Module

This menu contains the configuration settings for the Analog, Digital and Serial Outputs available in the GasFinder3-OP.

Analog Outputs



This menu allows configuration of the 4-20 mA output of the I/O Module. The outputs are labeled **IO*X*-AO*Y*** where **X** is the I/O Module number and **Y** is the output number (1 to 3). You must press the "OK" button on the bottom right corner of the screen to save any changes.

Output Parameter: Selects the quantity to report.

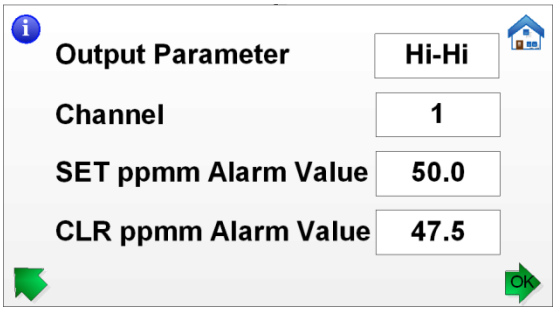
ppmm: Gas concentration in parts per million metre
ppm: Gas concentration in parts per million
Rx uW: Received light in microwatts
R2: Confidence factor of the gas concentration readings

Channel: Selects appropriate channel (path) in a dual channel setup.

4 mA Value: Sets the low span of the output.

20 mA Value: Sets the high span of the output.

Digital Outputs



This menu allow configuration of the dry contact relays of the I/O Module. The outputs are labeled **IO*X*-DO*Y*** where **X** is the I/O Module number and **Y** is the output number (1 to 3). You must press the "OK" button on the bottom right corner of the screen to save any changes.

Output Parameter: Selects the quantity to alarm.

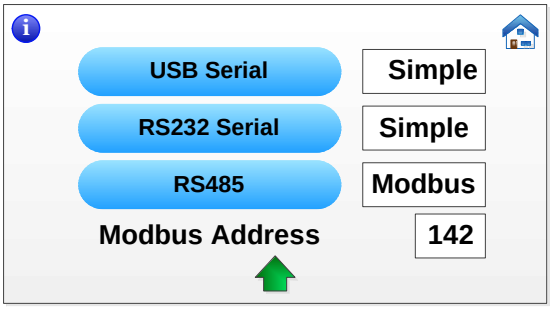
Hi-Hi: Gas concentration – units are in ppm-metre
Hi: Gas concentration – units are in ppm-metre
Rx uW: Low light alarm – threshold set by factory
Fault: Reports system faults – channel is disregarded for this option

Channel: Selects appropriate channel (path) in a dual channel setup if applicable.

SET Alarm Value: Relay alarm will activate when equal to or greater than this value. Setting this value will automatically adjust **CLR** to 95% of the **SET** value.

CLR Alarm Value: Relay alarm will clear when equal to or less than this value. This value may be adjusted to any value less than the **SET** value.

Serial Outputs



This menu adjusts settings for serial output through the micro-USB port, the 6-pin RS-232 port and MODBUS.

USB Serial / RS232 Serial:
Selecting the mode in the box on the right will allow "Simple" and "Enhanced" serial outputs to be disabled or selected between for the USB serial and RS-232 serial ports, respectively. "Simple" serial output is the standard (recommended) serial output for viewing regular data strings. "Enhanced" serial output is a special output mode designed specifically for use with the GasFinder3 Scope application.

Touching the USB Serial or RS232 Serial (blue button) will open up the menu where the following settings can be adjusted for that specific serial port. Note that if using the micro-USB port, the computer will require the appropriate virtual COM port driver (see Appendix D for details).

Bit Rate: The bit rate specifies how fast data are sent over a serial line.
NOTE: For "Enhanced" output to GasFinder3 Scope, the USB Serial bit rate is 230,400.
Data Bits: This determines how many bits constitute a packet. It is not adjustable from 8.
Parity: This low-level error checking bit can be set to odd, even or none.
Stop Bits: This is the bit that marks the end of a packet.

RS485:
Selecting the mode in the box on the right will allow "Serial" and "Modbus". Serial output on RS 485 is currently not available. Modbus allows the RS 485 output to function as a Modbus slave in binary/RTU.

Touching the RS 485 (blue button) will open up the menu where the following settings can be adjusted for that specific serial port.

Bit Rate: The bit rate specifies how fast data are sent over a serial line.
NOTE: For "Enhanced" output to GasFinder3 Scope, the USB Serial bit rate is 230,400.
Data Bits: This determines how many bits constitute a packet. It is not adjustable from 8.
Parity: This low-level error checking bit can be set to odd, even or none.
Stop Bits: This is the bit that marks the end of a packet.

Modbus address will set the device address when Modbus mode is selected.

Standard Modbus Output Registers for GasFinder Analyzers
Mode: Slave, Binary/RTU, Decimal Integers.
Comport Out: RS485 1/Variable Baud/8/N/1

Register assignments GAS A (RS485):

Channel	ppmm High	ppmm Low	ppmm Decimal	R2	Distance Decimeter	Light	Seconds	Status High	Status Low	ppm	ppm Decimal
0*	41000	41020	41040	41060	41080	41100	41120	41140	41160	41180	41200
1	41001	41021	41041	41061	41081	41101	41121	41141	41161	41181	41201
2	41002	41022	41042	41062	41082	41102	41122	41142	41162	41182	41202

$GFDBG	Internal Temp	Internal Temp Decimal	DC Offset	Ref Qual	Ref R2	Ref Status High	Ref Status Low	Supply Voltage	Amb Pressure High	Amb Pressure Low
	41300	41301	41302	41303	41304	41305	41306	41307	41308	41309

ppmm – Concentration of gas will be represented with 32-bits and an extra 16-bits for decimal.
R2 – Confidence factor from 0-100.
Distance in decimetres – Path length measured in **decimeters** for integer values.
Light – Received power as reported by the IPM.
Seconds – Heartbeat indicator. This is “seconds” in Date/Time field of the DATA statements. 0-60.
Status – 32-bit of Status Code from the DATA statements.
ppm – Path averaged gas concentration. 16-bit for the whole number and extra 16-bit for decimal.

Internal Temp – Internal temperature. 16-bits for whole number and 16-bits for decimal.
DC Offset – Ramp DC Offset.
Ref Qual – 16-bit of Reference Quality.
Ref R2 – Reference Confidence Factor from 0-100.
Ref Status – 32-bit of Status Code after Line Centering.
Supply Voltage – Supply voltage is displayed as x100 (volts) to display in integers.
Amb Pressure – 32-bit of Ambient Pressure.

Section 5: Maintenance

Note: If the GasFinder3-OP is working well it is best to leave it alone while keeping a check on the parameters mentioned below.

The GasFinder3-OP requires little maintenance and there are no user-serviceable parts. Note that batteries located in the electronics of the system are not user replaceable. A system check is done automatically at periodic intervals with an on-board reference cell.

Cleaning and Decontamination

The GasFinder3-OP analyser is equivalent with ingress protection of IP65. The windows on both enclosures are made of Mylar.

Wipe down the enclosure with a cloth dampened with water. The windows should be sprayed with water from a spray bottle and gently dried with a soft cloth to prevent scratching. If required, the window may be cleaned with any typical household ammonia window cleaner if chemically compatible with the local environment.

After checking chemical compatibility with the enclosure alloys and window material, the system enclosures can be decontaminated wiping down with a cloth soaked with the appropriate decontamination solution or spraying the enclosures using any typical laboratory spray bottle.

Validating the GasFinder3-OP

Automatic System Validation:

Every Boreal Laser GasFinder unit contains an integral, internal Reference Cell containing a small amount of the target gas species. Boreal Laser has a patent on its particular Reference Cell configuration (US Patent Number 6,121,627). The Reference Cell serves two primary purposes:

1. It provides a reference position for the line locking of the laser diode onto the wavelength required for the target gas and,
2. It is used as a built-in concentration reference for the measurement to ensure that the instrument always remains in calibration and does not drift.

Approximately once per minute the GasFinder will interrogate an internal Reference Cell which contains a sample of the target gas to ensure a high level of performance and increased reliability and safety.

The GasFinder unit needs to successfully answer these three questions in order to generate a ppm-m concentration (and not a fault code):

1. Is the laser on and is there enough laser light to perform an analysis?
    - There are four possible light level scenarios: no light, low light, good light, and too much light.
2. If so, has a Sample Waveform been generated?
    - If enough of the target gas in present in the active measurement path then a Sample Waveform should be generated.
3. If so, does the Sample Waveform look appropriate?
    - The Sample Waveform is compared against the Calibration Waveform by linear least squared regression to give a R2 Confidence Factor.

Boreal's On-Board Diagnostics will: determine if it gets a proper response from a real sample, make any adjustments necessary to eliminate drift, and collect additional system diagnostic information to ensure the analyzer is operating within required parameters. If any of these conditions is not met then the analyzer will enter an identifiable fault condition.

User System Validation:

While the system automatically performs its own advanced and sophisticated diagnostics, user preventative maintenance procedures may require additional testing to ensure operability. The user can manually force the ppm-m concentration to simulate different operating conditions on the customer's DCS or PLC. The system can provide a graphical representation of the calibration, reference, and sample waveforms. The user can verify that the analyzer responds to the target gas by checking the internal reference cell quality. When monitoring atmospheric gases like CH4 and CO2, the system constantly "sees" the gas of interest and outputs the actual concentrations of the gas. For applications where the target gas is not commonly present, the self-check performed every minute verifies the system does indeed respond to the gas of interest. If this isn't enough to satisfy the customer's PM program requirements then they can perform their own system challenge with a response cell. Response cells are used for quality assurance purposes to validate that the GasFinder instruments are responding appropriately to a nominal concentration of the target gas. While the GasFinder instruments are designed to report any instrument or measurement errors, this response test provides an independent validation of the instrument's operation.

Response Cell

The response cell is typically used in leak detection installations that are monitoring for a gas that is not present in the ambient atmosphere. Response cells are used for quality assurance purposes to validate that the GasFinder instruments is responding appropriately to a nominal concentration of the target gas. The validation using a response cell is NOT a field calibration.

The response cell is a completely sealed unit that contains the specific target gas that the GasFinder Instrument has been configured to detect. The OP-TDL GasFinder instruments are designed to "count" the number of molecules of the target gas in the active measurement path. Since the response cell has a concentrated number of molecules within the cell it can replicate or simulate a release of gas that would be similar to a loss of containment. The small amount of gas contained in response cell does not present a health hazard to the user.

One cannot expect identical readings from the response cell every time it is put into the path as it has an anticipated repeatability around +/- 20%. Repeatability of the response cell is affected by two factors: Depending on how the response cell is held in the active measurement path, the path length through the response cell (and number of counted molecules) can change and therefore so will the indicated reading and optical effects from the response cell windows. It is recommended that response cells be returned to Boreal Laser for factory re-certification every two years or within the frequency required by facility quality assurance and safety procedures.

To "bump" or "challenge" the system, the response cell needs to be placed in the active measurement path. The active measurement path is between the transceiver and the retro-reflector.

Line-of-Sight

The GasFinder3-OP relies on a clear optical path to obtain accurate readings of gas concentration. Dust settling on the windows must be cleaned off whenever it degrades the instrument's performance. The average value for the light level should be kept between the recommended values set at the time of installation. Regularly inspect the equipment and remove all obstructions such as bird nests, cobwebs, etc. Only if necessary clean the windows. The time between cleaning can only be determined from experience. See the cleaning procedure on the next page.

If movement of the mounts has occurred, re-alignment may be necessary. In areas with a lot of dust and/or humidity, some lubrication of the X-Y mount may be required. If the GasFinder3-OP is consistently moving out of alignment, the structural stability of the mount supports should be reassessed.

Cables

Both the signal cables are best left alone if the equipment is operating well.

Retroreflectors

The Retroreflectors have no moving parts and the only maintenance required is to clean the windows when absolutely necessary. The window material is typically Lexan which is a soft plastic and great care must be used when cleaning to avoid scratches. The need for cleaning will be indicated by a consistent loss of light, which may result in poor gas-concentration readings. Difficulty in obtaining an adequate light level may indicate that the GasFinder3-OP has moved out of alignment and should be checked first.

Note: The instrument relies on a clear optical path to obtain readings of gas concentration. Dust settling on the window of the Retro enclosure must be cleaned off whenever it degrades the system's performance. The average value for the light level should be kept at the recommended values as determined at the initial installation. It is difficult to clean the windows without scratching them and should only be done if adequate light levels cannot be obtained by re-alignment.

Many dusts, especially aluminium oxide, are very abrasive, and care must be taken not to scratch the windows when cleaning them. The recommended procedure for cleaning is as follows:

- Blow off any dust using canned compressed air (Cans of compressed air are available from camera and electronic stores). Note that compressed "shop" air may contain oil from the compressor, and should not be used without a filter or oil trap.
- If the window is streaked with rain-deposited particles, wash the window with substantial amounts of water, using a spray bottle, (laboratory or other type) and clean fingers.
- Gently wipe with a soft tissue.
- Spray a small quantity of anti-static solution on the window. A suitable anti-static solution is "Novus™ No.1" used by plastic fabricators and it can be obtained directly from Boreal Laser Inc.
- Gently wipe clean with a dry, soft tissue.

Calibration Certificate Extension

While there is no Boreal Laser requirement for any inherent re-calibration, the recommended service interval is every two (2) years. Service should include some level of the recommended Preventative Maintenance. If the GasFinder unit continues to operate without fault codes, the system is still within calibration and will continue to provide accurate and reliable data. In some applications, customers' preventative maintenance and/or regulatory reporting obligations may require that proof-of-calibration and/or re-certification documentation have a "current date" and not just the date provided at calibration.

With the Quarterly Data Review Package, it is possible to get a Calibration Certificate Extension with a "current date" without sending the GasFinder unit to the factory by providing certain diagnostic data to Boreal Laser's Technical Support Team to perform a health-check that uses key diagnostic data to ensure operability.

The **Quarterly Data Review Package** requires the following diagnostic data from the customer: Boreal Laser provided Preventative Maintenance Sheet, 3-7 Daily Logfiles, and at least 1 Array Transfer. This information is to be sent to support@boreal-laser.com every three (3) months. At all four (4) quarterly data reviews, Boreal Laser's Technical Support Team will provide email confirmation of GasFinder units performance.

While there is no limit to the number of Calibration Extensions available per GasFinder unit, it is recommended that the equipment is to be returned to the factory every five (5) years. Boreal Laser's Technical Support Team's determination on the frequency of returning the GasFinder unit to the factory depends on and will be dictated by the individual GasFinder unit performance and not by the recommended factory service interval. In addition to check-up and calibrations there may be hardware, software, firmware, or analysis algorithms updates available to improve the performance of the analyzer that can only be performed at the factory or with a re-calibration.

Customer Training:

Training On-site: in conjunction with the system installation and commissioning (or at any point) Boreal Laser's engineers or technicians will provide training to customer technical personnel on-site on basic system maintenance, operation and troubleshooting after system installation is completed. A training certificate can be issued upon request for professional development purposes. Normally this training program takes one-man day, charged at standard rates, plus travel expenses.

Training at our Edmonton Facility: Boreal Laser will train customer technical personnel at our Edmonton facility, on system theory, operation and maintenance. The training includes hands-on experience and typically takes one day. Boreal Laser suggests that such training is carried out on the customer's system and in conjunction with a Factory Acceptance Test (if requested). A training certificate can be issued upon request for professional development purposes. The charge for training at Boreal Laser in Edmonton is $1200 per day for training (4 persons max). Customer is responsible for the salary, travel and subsistence expenses of their personnel during the training.

Preventative Maintenance

Our customers can obtain preventative maintenance services from either Boreal Laser or an approved local distributor. While the preventative maintenance sequence of activities can change from installation to installation, there are common set of tasks that form a Service Interval and they can include: monitoring diagnostic data (performance indicators) by analysis of log files and array transfers, monitoring the alignment of each channel, performing a system challenge with a response cell. Boreal Laser or one of our authorized distributors may be able to provide any available field updates (hardware, software, firmware, or analysis algorithm). Boreal Laser or our approved local service providers can provide an estimate upon request.

Required Preventative Maintenance Schedule

Action	Minimum Frequency
Confirming the system is running without fault codes	At least once a month
Fill-out the Preventative Maintenance (PM) Sheet	At least once a month
Visual Inspection of Entire System	At least once a year

Additional and Optional Preventative Maintenance Tasks

Action	Minimum Frequency
Quarterly Data Review	At least once every three (3) months
User System Validation (as mentioned above)	At least once a year
Calibration Certificate Extension (from Boreal Laser only)	Once a year
On-Site or Factory Training	At least once every five (5) years
Factory Calibration and Check-up (from Boreal Laser only)	At least once every five (5) years

Section 6: Data Interface

RJ45 Connector

The RJ45 connector is used to connect the GasFinder3-OP to a local area network. The GasFinder3-OP has the capability for an IP to be assigned via DHCP or static IP address. To access the Network Settings, see the Utilities menu section. Once the IP address of the GasFinder3-OP is known, the serial data can be accessed via telnet, and the fi les transferred via FTP. The IP address can also be found by pushing the 'i' button on the info screen.

Serial Data via Telnet

1. On a networked computer, open a command line interface (on Windows 7, searching for "cmd" will bring up the appropriate "cmd.exe" application).
2. Type "telnet [SPACE] [IP Address]". The system should start outputting serial data to the terminal window.

NOTE: If Telnet is not enabled on Windows 7, contact your system administrator or do the following:

To enable Telnet command line utilities:

1. Click Start > Control Panel.
2. Click Programs and Features.
3. Click Turn Windows features on or off.
4. In the Windows Features dialog box, check the Telnet Client check box.
5. Click OK. The system installs the appropriate files. This will take a few seconds to a minute.

Connecting via FTP

1. Note the IP Address of the GasFinder3-OP by going into the info screen. This can be done by touching the "i" button at the top left of the main screen. If there are problems with the IP address format for your network, you can assign static or DHCP in the Network menu (Utilities > Network Settings). Protocols for user names and passwords can be set in Utilities > Network Settings > Protocols.
2. On a networked computer, open a command line interface (on Windows 7, searching for "cmd" will bring up the appropriate "cmd.exe" application).
3. Type ftp [SPACE] [IP Address]. "ftp 192.168.1.112"
4. If you have assigned a user name and password for the GasFinder3-OP, you will be prompted to enter that information. If you have not, you can simply hit ENTER twice to bypass the user and password prompts.
5. You are now connected to the GasFinder3-OP micro SD card, and standard FTP commands will enable you to access the data stored there. Some useful FTP commands are listed in Appendix D.

USB Connector

The USB connector is used to attach a USB storage device to the GasFinder3-OP. The user can then extract the system's internal logs from the system's micro SD card onto the USB storage device.

IMPORTANT: The USB storage device must be formatted as FAT32 with 4096 byte allocation. These are fairly typical settings, but are worth checking prior to beginning the USB dump of internal logs.

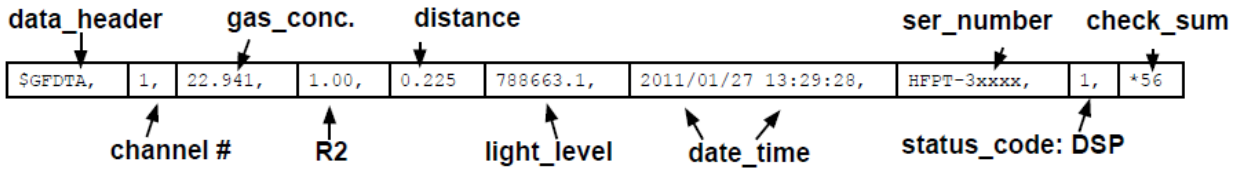
For more information and instructions on how to do this, see the menus section.

Serial Communications

The GasFinder3-OP transmits serial data via the micro USB port and the 6-pin RS-232port. The output settings can be adjusted in the Utilities menu, under Serial Outputs (see the menu section for more information). Note that if using the micro-USB port, your computer will require the appropriate virtual COM port driver (see Appendix D for details).

Data String Specification

$GFDTA



Explanation

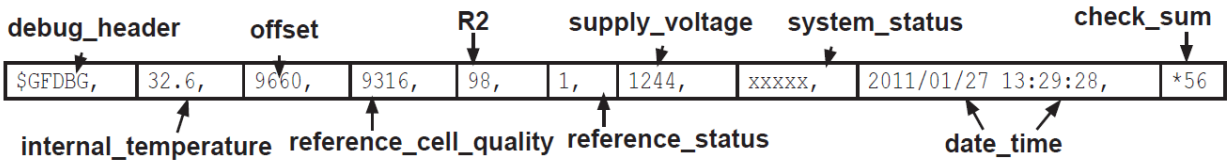
data_header	Header designating the type of data	String
Channel #	Designates channel origin of data (1 or 2)	Number
gas_concentration	In ppmm (parts per million meter)	Number
R2 (confidence factor)	Decimal between 0 and 1 (percentage)	Number
distance	Factory-set path length in meters	Number
received_light	Rx Light received on the photodiode	Number
date_time	Current date and time	YYYY/MM/DD hh:mm:ss
ser_number	Identification number of the system	String
status_code DSP	Code giving system operating status from the DSP	Integer (hexadecimal)
check_sum	Checks the data stream for errors	String

These data strings are comma-delimited (,) and an asterisk (*) signifies the end of the string. Each string is terminated by a carriage return and a line feed.

Debug String Specification

The $GFDBG string is output whenever the system performs a calibration check.

$GFDBG

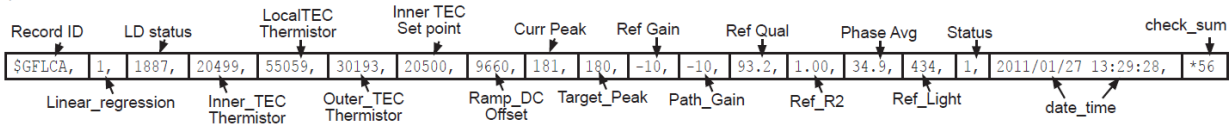


debug_header	Header designating the type of data	String ('$' + 5 letters)
internal_temperature	Internal temperature of GasFinder in degrees C	Number
offset	Setting to enable array peaks to line up	Number (integer)
reference_cell_quality	Reference cell quality as a percentage x 100	Number (integer)
reference_R2	Reference cell R2	Number (integer)
reference_status	Code giving reference system operating status	Number (integer)
supply_voltage	System input voltage in 10's of millivolts	Number (integer)
system_status	Internal_system_status	Number (hexadecimal, 32 bit)
date_time	Current date and time	String (YYYY/MM/DD HH:mm:ss)
check_sum	Checks the data stream for errors	'*' + 2 digit hexadecimal number

Line Centering Data String Specification

Periodically, strings containing line-centering data ($GFLCA) are transmitted giving internal details of the GasFinder3-OP operation. The $GFLCA string is output whenever the system performs a line-centering check and/or adjustment.

$GFLCA



The format of the $GFDBG string is as follows:

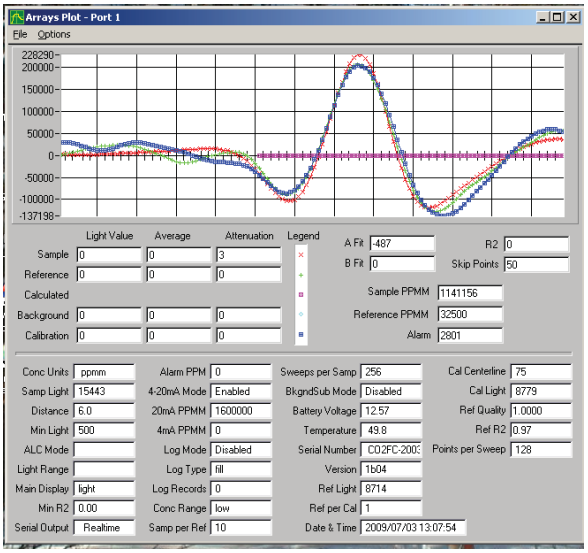
Record ID	Line centering data string, gas A	String ('$' + 5 letters)
Linear Regression	Linear Regression Enabled (0 | 1)	Number (integer)
LD Status	Laser Diode Status	Number (integer)
Inner TEC Thermistor	Inner Thermal Electric Cooler Thermistor	Number (integer)
Local TEC Thermistor	Local Thermal Electric Cooler Thermistor	Number (integer)
Outer TEC Thermistor	Outer Thermal Electric Cooler Thermistor	Number (integer)
Inner TEC Set Point	Inner Thermal Electric Cooler Set Point	Number (integer)
Ramp DC Offset	Line Centering position control variable	Number (integer)
Curr Peak	Line Centering current peak location	Number (integer)
Target Peak	Line centering target peak location	Number (integer)
Ref Gain	Reference cell receiver gain	Number (integer)
Path Gain	Path receiver gain	Number (integer)
Ref Qual	Reference cell quality percent	Number (float)
Ref R2	Least Squares R2	Number (float)
Phase Avg	Phase Average	Number (float)
Ref Light	Reference cell receiver power level (uW)	Number (integer)
Status	Line centering/reference cell status	Number (hexadecimal, 32 bit)
Date/Time	Current system date and time (24h)	String (YYYY/MM/DD HH:mm:ss)
Checksum	Used to validate the record data for transmission errors	'*' + 2 digit hexadecimal number

Section 7: Troubleshooting

Array Transfers

The internal arrays and the various parameters stored internally in the GasFinder3-OP are very important diagnostic tools. In cases of suspected problems with the equipment, data from an Arrays Transfer, together with at least 30min of .gvl data should be sent (emailed) to support@boreal-laser.com. A diagnosis and solution can often be made quickly and without the need to return the system to the factory. These internal arrays can be accessed by downloading an array transfer file to an external computer. The GasView software can be used to record the file.

To download the arrays:



- Connect the GasFinder3-OP to a computer and run the GasView program.
- Click on Options and then click Arrays Plot Enable.
- At the GasFinder3-OP enter the menu and in the Channel Specific Menus the first item is:
- 'Internal Arrays Transfer'.
- Press Enter. The display will read - Acquiring, Transferring. The computer screen will show a series of curves.
- The file containing the data can be saved by clicking on File in the top left of the tool bar and saving it to a specific location. It can then be sent to Boreal Laser Inc. for analysis.

If the user does not have the GasView program, the Arrays Transfer and Data files can be viewed and downloaded using the Serial Commands with any compatible terminal program.

Stability of Support Structures

The diameter of the laser beam when it exits the Remote Head is about 1.5mm and the divergence is approximately 1.5 mrad (milliradians). This means that at a distance of 100m the beam diameter is 1.5 x 100 = 150mm (6"). Similarly, at a distance of 1,000m, the beam diameter would be 1,500mm (59"). The beam intensity falls off towards the edge of the beam spot.

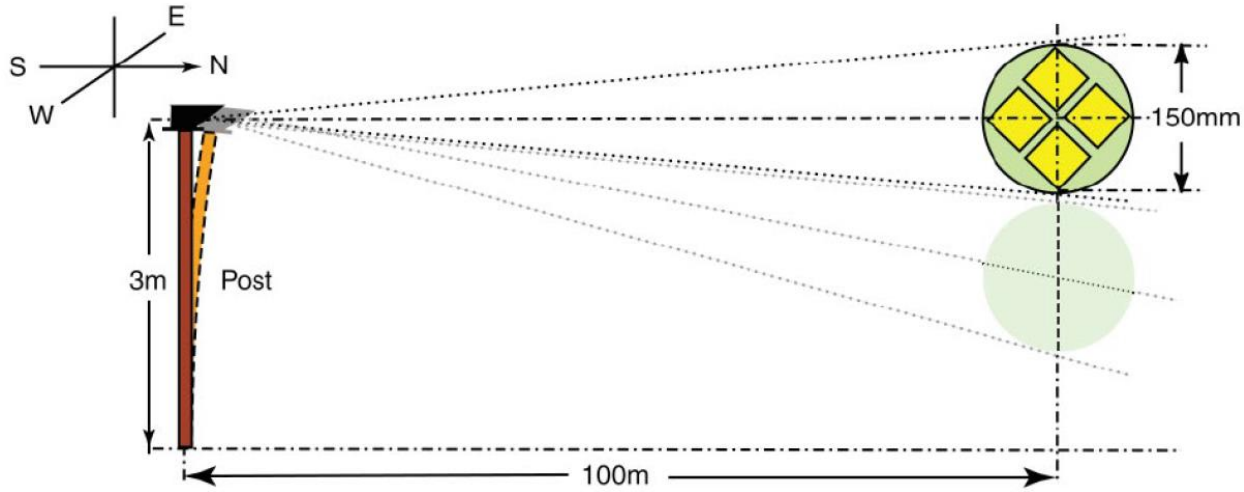
The Remote Head can be mounted on a tripod, post, or platform, and directs the laser beam to a reflector, which can be from a few metres to several hundred metres distant. This article deals with the stability requirements for the mounting structure.

Calculating the Effects of Movement

The table below is a general guideline of the size of a "typical" laser dot at certain path lengths (actual size may vary per application):

Path Length	"Typical" Laser Dot Size
50m	0.1m
100m	0.2m
250m	0.5m
500m	1m
750m	1.5m
1,000m	2m

Consider the example of a 150mm diameter retro array located 100m due north of the Open Path Measurement Head.



The post, and therefore the Open Path Measurement Head, can move vertically or horizontally 150mm (6") either side of the centreline before the beam will move completely off the retro array. This movement is referred to as translational. In practice, significant translational movement is unlikely to occur, as the post is usually fastened to a solid base; however, because it is fixed at the bottom, torsional or bending movement is much more likely, due to wind loading or thermal distortion. Any East - West bending (i.e. perpendicular to the centreline) is manifested as a lateral motion and will have a minimal effect. Conversely, any North - South bending will have a serious negative effect: the top of a 3m (~10') tall post can only move 4.5mm (0.177") before the beam will have moved 150mm all the way off the retro. For a 500m path length, with the retro array doubled in diameter to 300mm (12"), the top of the 3m post can only move 1.8mm (0.071") before the beam will completely miss the retroreflector. A 10m post can move 6mm (0.236") and cause the same result.

Note: Movement of the retros has little effect compared to movement of the Remote Head. The retro support does not require the same structural stability as that required by the Remote Head support.

Types of Supports

All posts require a solid concrete base. In areas where freeze/thaw conditions occur, the base of the concrete needs to be well below the frost level and an air space left between the base and the surrounding earth down to the frost level. Above ground, the post can be concrete (preferred) or metal. A 100mm x 100mm (4”x 4”) metal post can be used for heights up to 2m; above 3m, torsion limits the path length to 100m.


Solid metal support

Longer distances or higher supports require a wider base. This can be obtained by using self-supporting lattice towers or a number of posts joined at the top and well braced.

Provided it is in the correct location, a building can often provide a very stable support for an GasFinder3-OP. However, it should be noted that the metal roof structures of long buildings oriented east-west are very susceptible to diurnal movement caused by solar heating.

Scaffolds can be used for temporary mounting structures but they must be ‘CupLock’, ‘Z-Lock’ or other rigidly braced types. The clip-together types are not stable enough. To comply with safety regulations, the height of a scaffold cannot exceed three times the width of the narrowest base dimension. This gives a very stable platform however the alignment will often move slightly when the operator descends. The scaffold can also be placed on adjustable legs to accommodate different ground elevations.

Thermal Effects

Differential heating of support legs can cause diurnal variations in alignment. This is very common on long paths (over 100m) and can be minimized by shading, insulating the legs, or using non-metallic materials such as concrete, wood, or fibreglass. The effect can be seen by looking at the light level history over a number of sunny days. A sinusoidal variation is an indication of solar heating. In severe circumstances a dispersed retro array may be the only solution.

Wind Effects

On outside paths wind effects can be minimised by using open member supports. Note that guy wires can sometimes oscillate and cause movement.

Platform Separation

It is critical that the platform for the Remote Head is not connected to the same platform that the operator stands on for installation or maintenance work. This may preclude the use of scaffolds for long paths.


Remote Head separated from the work platform

Alignment Procedures for a Moving Building

All buildings move. Some move more than others depending on the external and internal forces. In most cases, this movement goes unnoticed until cracks form in concrete or a small piece of plaster flakes off. Movement can occur over years as the building foundations settle, or over seconds as wind forces or cranes move the structure. Settlement over a long time is too slow to cause an alignment problem, because any movement is incrementally small, and can be compensated for with periodic adjustments. When the movement is caused by wind, the structure returns to its previous position once the wind has passed. In the same way, the shaking motion produced by the movement of overhead cranes is not usually a problem as the structure quickly returns to its original position when the crane has stopped. Movement caused by thermal expansion due to solar heating is different. Metal structures are particularly susceptible to deflection when the solar heating produces large differential forces, which result in a twisting or warping motion of the structure. This is seen, especially on sunny days, as a diurnal variation in the GasFinder3-OP light level. This variation is caused by the expansion and contraction of the metal structure carrying the laser mount, which twists with respect to the longitudinal axis of the original laser path. This causes the laser beam to move away from the retros and results in a drop in the returning light level. The amount of movement will vary considerably with the orientation of the building and the attachment of the mount within the building and the length of the path.

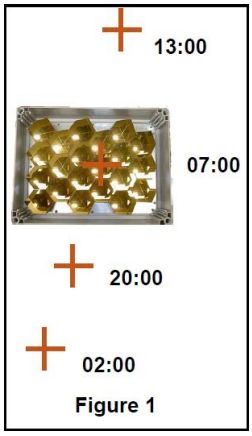


Figure 1

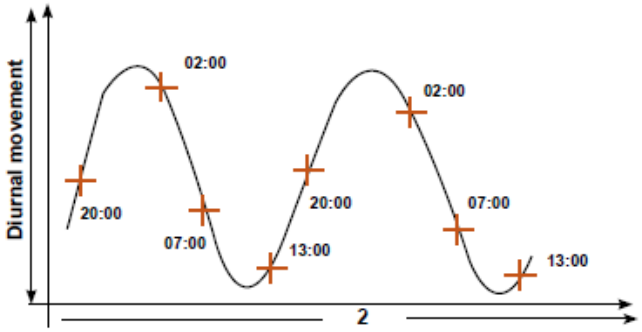


Figure 2

If movement is suspected, it can be verified and measured as follows: Arrange to have access to the mount where the Remote Head and telescope are located, and plan to make observations through the telescope at least four times throughout the day. Movement is usually at a maximum on bright, sunny days. At each observation, note the time and the position of the cross hairs in the telescope with respect to a part on the retro. Shining a flashlight beam on the retro will make it easy to see at long distances. Do not adjust any alignment screws. At the end of the day, you should have a number of points showing the different positions of the cross hairs. This difference will indicate the amount and direction of movement of the laser beam. See Figure 1.

The observations can be made over a shorter time period, but the results may not give an accurate picture of the movement. A plot of the positions over time will yield a graph similar to Figure 2. This graph can be used to estimate the maximum movement of the beam.

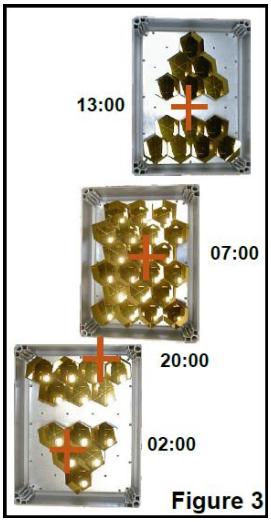
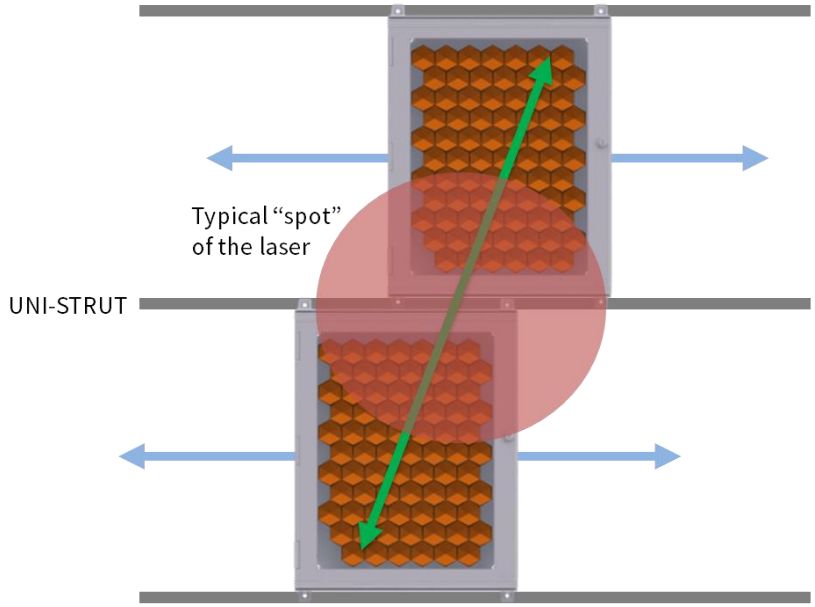


Figure 3

Rather than use a motorized mount to adjust the alignment of the Remote Head, the preferred to solution is to use a dispersed array of retro reflectors.

In the preceding example, the final retro array will be similar to the shape shown in figure 3.



This adjustable retro configuration allows for movement of the laser path due to the buildings structure expanding and contracting throughout the day.

Typically, the alignment will move in a diagonal fashion with mostly a vertical component.

The number of retros may have to be increased from the number used in the single enclosure, and their spacing will also have to be changed. Contact Boreal Laser for more specific details.

Centering the Cross Hairs with the Centre of the Laser Beam

At 400m, the diameter of the beam is about 600mm, so the area of the beam may be larger than the enclosure. To find the edges of the beam, the Remote Head has to be traversed horizontally and vertically until the light level drops. Note where the cross hairs are in the scope relative to the retro at these positions, (see Figure 4) and position the Remote Head, so that the cross hairs are in the centre of the travel. In the example shown, the cross hairs would be at the top right corner of the retros when the beam is centred on the retro.

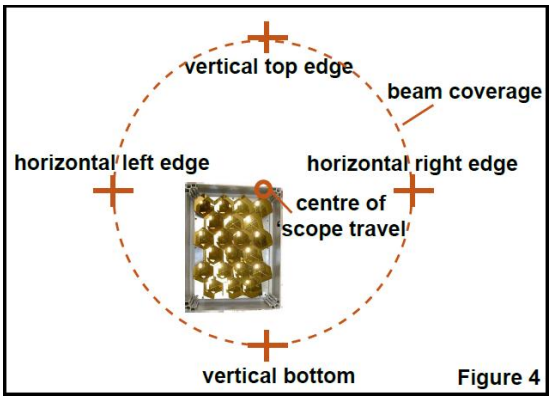
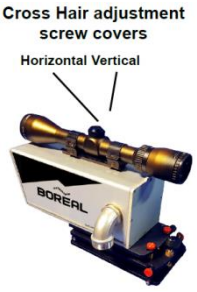


Figure 4

Looking through the telescope, and without adjusting the alignment of the Remote Head, adjust the crosshairs to the centre of the reflector. This is done by removing the two cover caps in the centre of the scope body and turning the screws underneath so that the cross hairs are centred on the middle of the retro. The vertical cross hair is adjusted by the screw on the top, and the horizontal cross hair is adjusted by the screw on right.



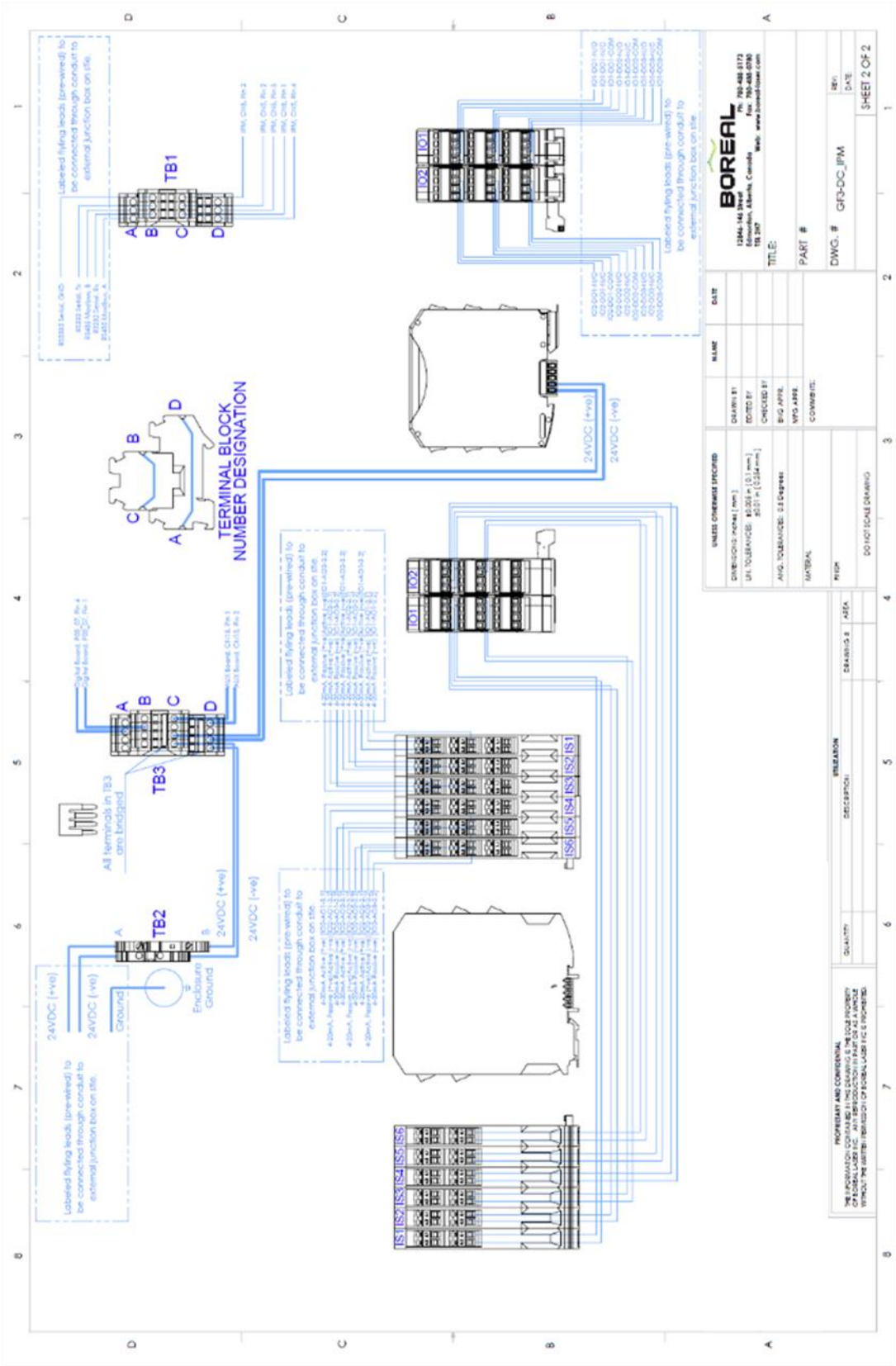
Section 9: Appendices

Appendix A: Physical Dimensions

Net Product Weight	5.0 kg [11.0 lbs.]
Tare Weight	5.0 kg [11.0 lbs.]
Gross Shipping Weight	10 kg [22 lbs.]
Dimensions (L x W x H)	260 x 200 x 160 mm [10.2 x 7.9 x 6.3inch]
Mounting	1x 3/8”-16 NPT Hole 4x 5/16” Through Holes

<INSERT DRAWING>

Appendix B: Electrical Component Layout – Isolated Analog Loop



Appendix C: Digital Signal Process (DSP) Status Code

The DSP status code (or status word) is a hexadecimal value that can be converted to binary (32 bits wide) to determine which DSP errors are present from the table below.

Format of the DATA and LCA statement's STATUS WORD

BIT Name	BIT Position	Comments
NO_ERROR	0	Normal operation, no errors.
GAS_HIGH	1	Not used.
NAN_NUMBER_ERR	1	A NaN Number was detected during: acquiring data, data processing, or during FLASH memory read-back (this one must show-up combined with "FRAM_RW_ERR") operations then DO NOT ALLOW line-centering!... This bit is new in v1.2.4e.
NOT_CTRD	2	Laser is not line centered.
R2_LOW	3	R2 lower than limit set.
LOW_LIGHT	4	Light lower than set point.
BADRAMP_FLT	5	The bad ramps counter overflowed the set maximum count value during a sample computation. This event raises the error bit flag.
LT_LV_ERR	6	Signals that the AGC controller was not able to set the specified light level because the gains chip is at the maximum/minimum gain setting..
DA_LS_FLT	7	**This bit applies to Direct Absorption only (DA):** Indicates that DA Least-Squares algorithm failed to fit the ramp. This event raises the error bit flag.
OVERRANGE	8	The signal in the inputs of the ADC is larger than the reference voltage.
DA_LM_FLT	9	**This bit applies to Direct Absorption only (DA):** Indicates that Levenberg-Maquardt algorithm failed to fit absorbed gas signal. This event raises the error bit flag. (note: for IPM descriptions you may shortened its name to "Lev-Marq")>
CALIB_ERR	10	Ref quality < min ref qual, ref quality > max ref qual, or ref R2 < min Ref R2.
MENU_MODE	11	Not Used.
LOW_BAT	12	Not Used.
NOT_CALIB	13	System is in the line centering loop, the Ramp DC offset may be adjusted but system is not yet centered.
LIATIMEOUT_FLT	14	The LIA task was pendant on semaphore for too long… the system will re-trigger (force) a new ramp AND clean error conditions (also system does not allow line-centering under these conditions).

REFCELL_ERR	15	A fatal error was found during the line centering process. System cannot line center under these conditions. Bit is set if any below is true: • DCoffset found out of limits • LD_FLT • Low Light in REF Cell • Overrange in REF Cell • DMA_FLT • RAMPSYNC_FLT • LINECENTRING_FLT (when in user mode trying to capture a stored calibration waveform, this bit is mirrored by DSP from ISSW, system will try to center normally if possible but still will signal this flag if an error happened during storing a calibration waveform)
LD_FLT	16	Laser Driver Fault detected (communication error with the currently active Laser Driver).
LEASTSQUARES_FLT	17	The inverse matrix could not be computed
DMA_FLT	18	Operational error could not be computed
CENTERING_OUTOFLIMITS	19	The Ramp DC offset current needed to move the "Line" is below the minimum limit or maximum limit allowed.
RAMPSYNC_FLT	20	Ramp sync signal is missing or DSP was not able to recover the last incoming Ramp.
Rsvd0	21	Reserved for future use.
STRAYRAMP_FLT	21	A not expected Ramp was received but DSP was not expecting it. The Ramp was thrown out. This bit is new in v1.2.4e.
Rsvd1	22	Reserved for future use.
FRAM_RW_ERR	22	An error was detected in the last read, write or erase operation with the FLASH memory. This bit mirrors the value of a bit of same name found in the Internal System Status Word (ISSW), please see more details on ISSE in the next table ---
Rsvd2	23:31	Not available for use.

The **LOW_LIGHT** and **R2_LOW** status bits contain information for sample and ref cell in the sample status word, and ref cell only for debug word.

Bit 13 NOT_CALIB

This means that the system is not centered and in some cases that DSP is still in the line centering loop, for example: the DSP have just checked the reference center peak position and adjusted the offset but system is not at center yet!, therefore DSP is going to loop again.

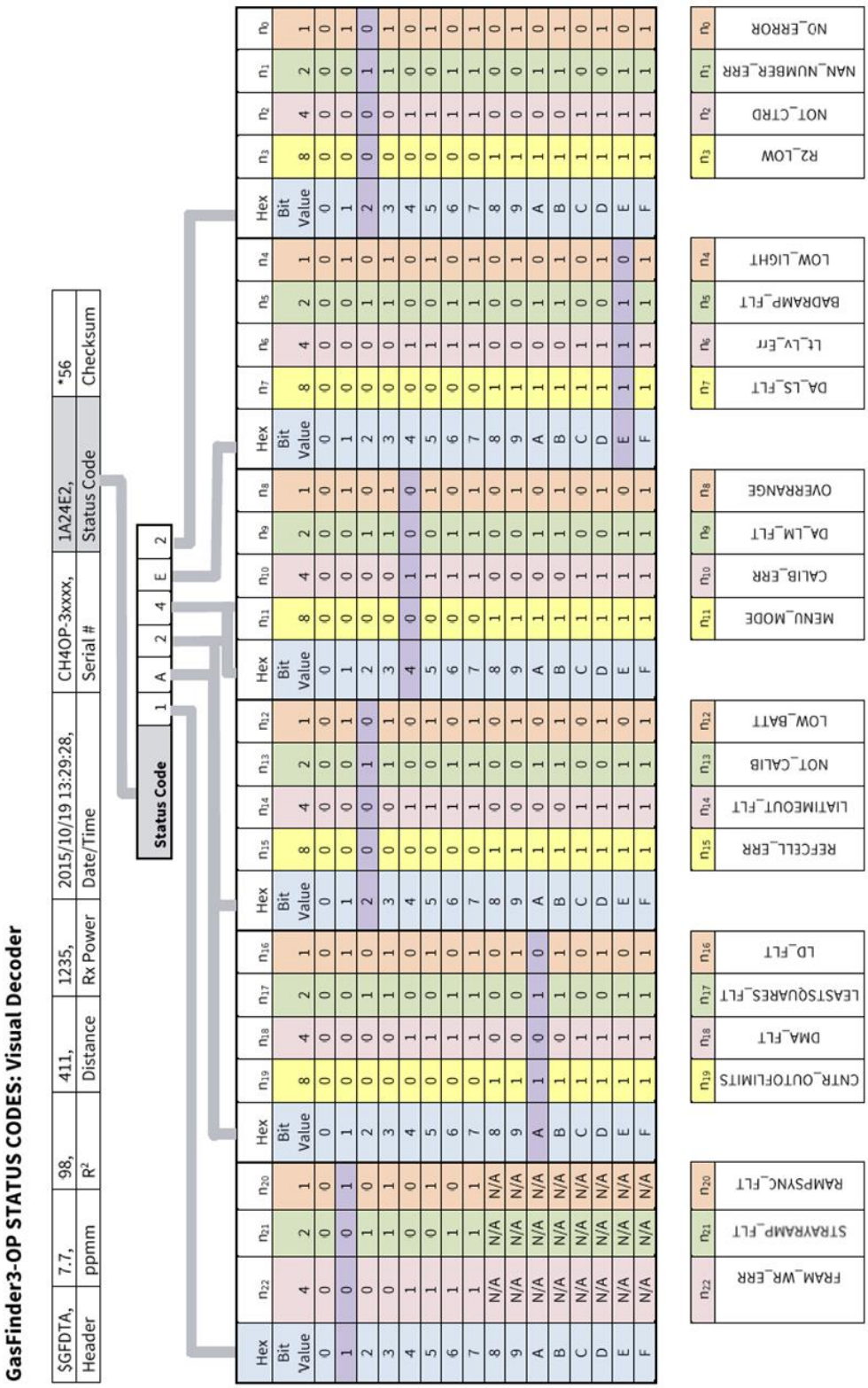
For this particular case in which the DSP still looping through line centering routine, the system will set bit NO_ERROR = 1 (unless that another error was detected!) to announce user that this is not a permanent error until line centering loop ends. If line centering loop ends and system still not centered "NOT_CALIB=1" then bit NO_ERROR will drop to "zero" announcing error was detected and will propagate the error conditions into the DATA strings too.

Bit 15 REFCELL_ERR

There are six conditions that activate this bit if any of these events is active then bit 0 "NO_ERROR" will drop to "zero" indicating a fatal error has occurred. Please see below:

1. LOW_LIGHT
2. OVERRANGE
3. DMA_FLT
4. CENTERING_OUTOFLIMITS
5. RAMPSYNC_FLT
6. LINECENTERING_FLT (during a stored calibration waveform capturing process and condition was not cleared by user)

Appendix D: GasFinder3-OP Status Codes, Visual Decoder



GasFinder3-OP STATUS CODES: Visual Decoder

$GFDTA,	7.7,	98,	411,	1235,	2015/10/19 13:29:28,	CH4OP-3xxxx,	1A24E2,	*56
Header	ppmm	R^2	Distance	Rx Power	Date/Time	Serial #	Status Code	Checksum

Status Code	1	A	2	4	E	2

Hex	n_{22}	n_{21}	n_{20}	Hex	n_{19}	n_{18}	n_{17}	n_{16}	Hex	n_{15}	n_{14}	n_{13}	n_{12}	Hex	n_{11}	n_{10}	n_9	n_8	Hex	n_7	n_6	n_5	n_4	Hex	n_3	n_2	n_1	n_0
Bit Value	4	2	1	Bit Value	8	4	2	1	Bit Value	8	4	2	1	Bit Value	8	4	2	1	Bit Value	8	4	2	1	Bit Value	8	4	2	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1
2	0	1	0	2	0	0	1	0	2	0	0	1	0	2	0	0	1	0	2	0	0	1	0	2	0	0	1	0
3	0	1	1	3	0	0	1	1	3	0	0	1	1	3	0	0	1	1	3	0	0	1	1	3	0	0	1	1
4	1	0	0	4	0	1	0	0	4	0	1	0	0	4	0	1	0	0	4	0	1	0	0	4	0	1	0	0
5	1	0	1	5	0	1	0	1	5	0	1	0	1	5	0	1	0	1	5	0	1	0	1	5	0	1	0	1
6	1	1	0	6	0	1	1	0	6	0	1	1	0	6	0	1	1	0	6	0	1	1	0	6	0	1	1	0
7	1	1	1	7	0	1	1	1	7	0	1	1	1	7	0	1	1	1	7	0	1	1	1	7	0	1	1	1
8	N/A	N/A	N/A	8	1	0	0	0	8	1	0	0	0	8	1	0	0	0	8	1	0	0	0	8	1	0	0	0
9	N/A	N/A	N/A	9	1	0	0	1	9	1	0	0	1	9	1	0	0	1	9	1	0	0	1	9	1	0	0	1
A	N/A	N/A	N/A	A	1	0	1	0	A	1	0	1	0	A	1	0	1	0	A	1	0	1	0	A	1	0	1	0
B	N/A	N/A	N/A	B	1	0	1	1	B	1	0	1	1	B	1	0	1	1	B	1	0	1	1	B	1	0	1	1
C	N/A	N/A	N/A	C	1	1	0	0	C	1	1	0	0	C	1	1	0	0	C	1	1	0	0	C	1	1	0	0
D	N/A	N/A	N/A	D	1	1	0	1	D	1	1	0	1	D	1	1	0	1	D	1	1	0	1	D	1	1	0	1
E	N/A	N/A	N/A	E	1	1	1	0	E	1	1	1	0	E	1	1	1	0	E	1	1	1	0	E	1	1	1	0
F	N/A	N/A	N/A	F	1	1	1	1	F	1	1	1	1	F	1	1	1	1	F	1	1	1	1	F	1	1	1	1

n_{22}	FRAM_WR_ERR
n_{21}	STRAYRAMP_FLT
n_{20}	RAMPSYNC_FLT

n_{19}	CNTR_OUTOFLIMITS
n_{18}	DMA_FLT
n_{17}	LEASTSQUARES_FLT
n_{16}	LD_FLT

n_{15}	REFCELL_ERR
n_{14}	LIATIMEOUT_FLT
n_{13}	NOT_CALIB
n_{12}	LOW_BATT

n_{11}	MENU_MODE
n_{10}	CALIB_ERR
n_9	DA_LM_FLT
n_8	OVERRANGE

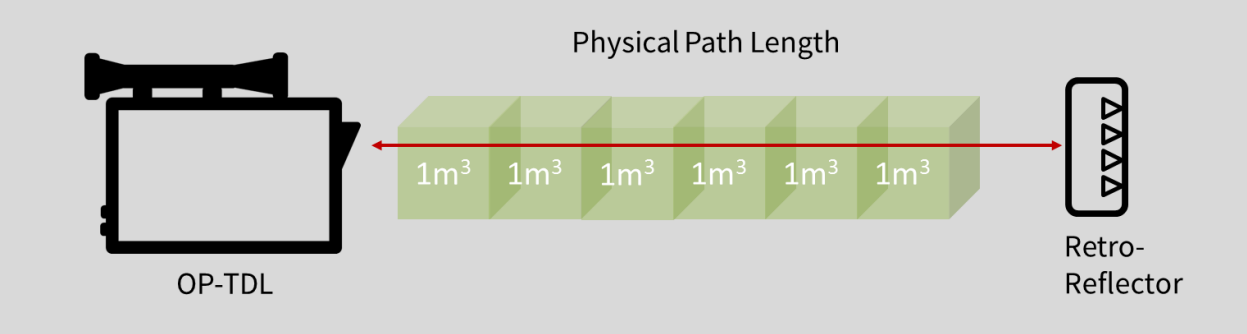
n_7	DA_LS_FLT
n_6	LT_LV_Err
n_5	BADRAMP_FLT
n_4	LOW_LIGHT

n_3	R2_LOW
n_2	NOT_CTRD
n_1	NAN_NUMBER_ERR
n_0	NO_ERROR

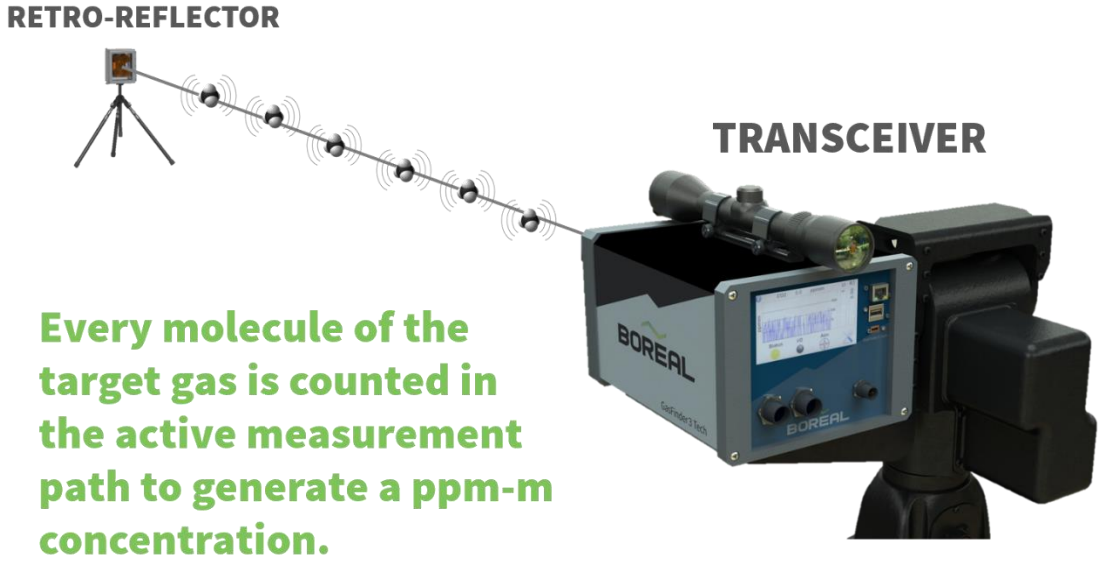
Appendix E: Explanation of ppm-m

Gas concentration is measured in ppm, 'parts per million' by volume. If a room measuring 100m x 100m x 100m (1 million cubic metres) has 10 cubic metres of air replaced by a pure gas, then the gas concentration is expressed as 10ppm. A point sensor measures directly in ppm. Open path monitors, like the GasFinder3-OP, measure the total amount of a specific gas, for example HF, in the path of the laser beam between the transmitter unit and a reflector. This is a 'total path' measurement. The units are 'parts per million metres', or 'ppmm'.

Open-path measurements are slightly different from the traditional point measurement. A good visualization of the how open-path measurements work is stacking the one square meter that we're used to. The standard unit of measure for an open-path instrument is Parts Per Million – Meter (ppm-m).



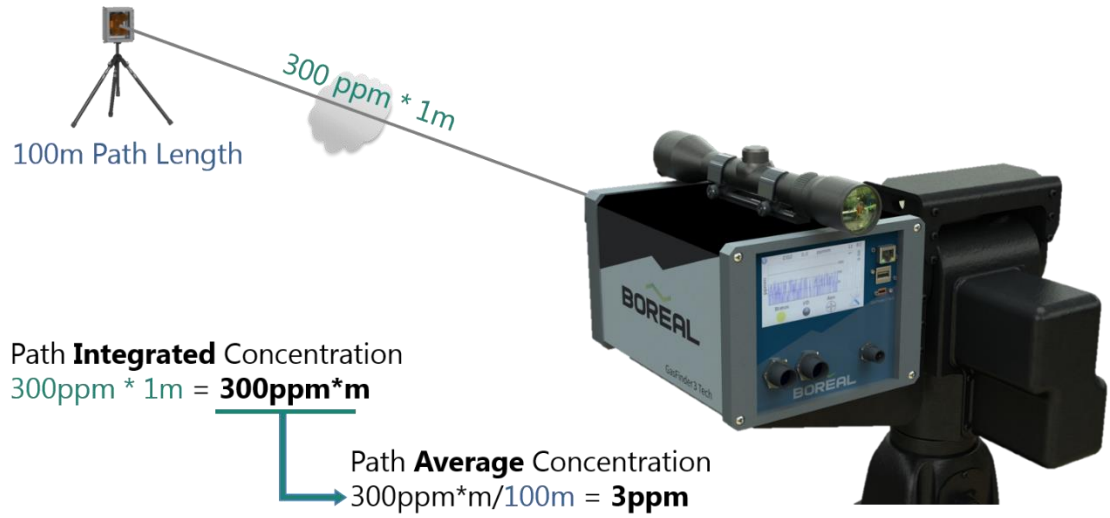
Remember, OP-TDL technology simply counts the number of molecules in the active measurement path (the distance between the transceiver and retro-reflector).



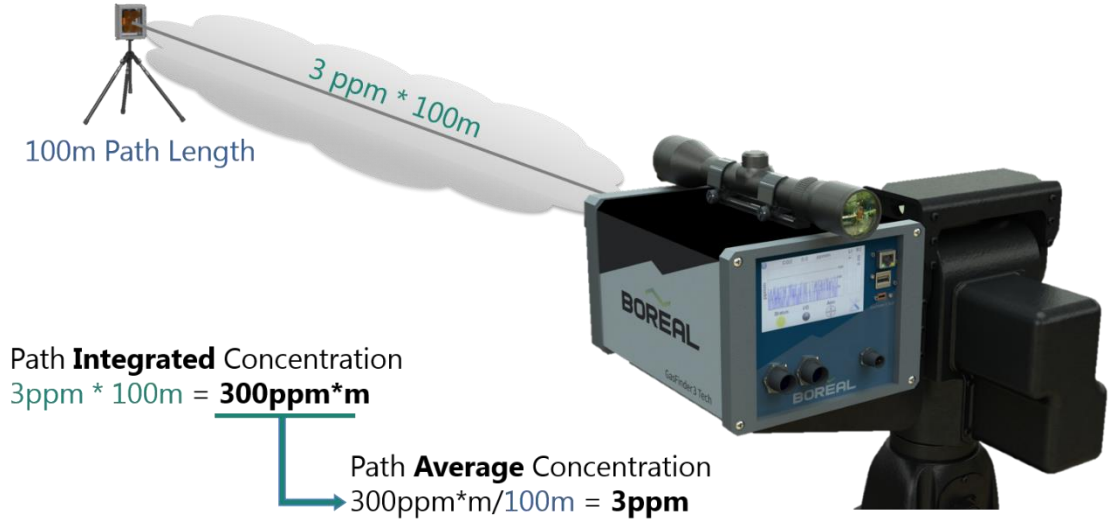
There are two common ways to discuss to open-path measurements: **Path Integrated Concentration (PIC)** and **Path Average Concentration (PAC).**

- Path Integrated Concentration (PIC) units of measure is ppm-m and a good way of thinking of PIC is simply the OP-TDL counting the number of molecules in the active measurement path.
- The Path Average Concentration (PAC) is the PIC divided by the physical path length (or the length of the active measurement path) to give a ppm concentration.

Small & Highly Concentrated Plume:

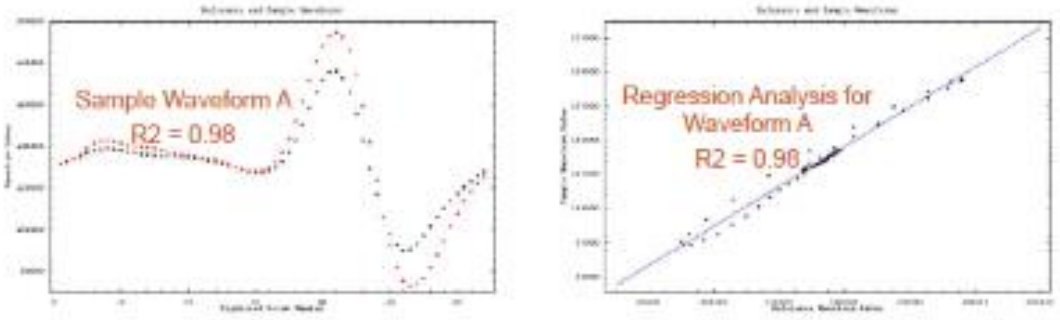


Large Dispersed Plume:

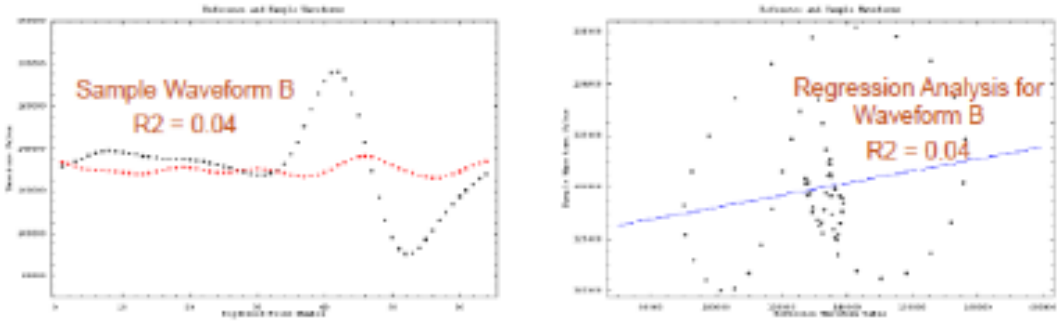


Appendix F: Explanation of R^2

When the GasFinder3-OP receives the returning laser signal after it has passed through the sample gas, the electronics convert it to the shape of a specific waveform or curve. This is the sample waveform. The GasFinder3-OP also has a similar signal from the calibration waveform. These curves are then digitised and compared as two numeric arrays.



An accepted mathematical procedure to compare curves or numeric arrays is the Linear Least Squares Regression analysis. This analysis results in a measure of the similarity (R2), between the waveform of the sample gas and that of the reference cell gas. A perfect similarity would give a value for R2 of 1.0, and a total mismatch would be 0.0.

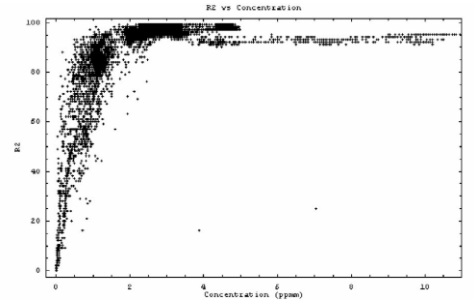


The blue line represents the Linear Least Squares fit of the data and is the best fit of a straight line between the reference (X) and sample (Y) data points. The slope is a component in the ratio-metric calculation of gas concentration.

A typical plot of concentration versus R2 will give the following graph: With lower levels of sample gas, the R2s decrease, and equal zero when there is no gas present. As the signal from the gas becomes stronger, the effect of noise, both electronic and optical, is reduced and the R2s will increase (i.e., the signal to noise ratio will increase). The general shape of the plot is the same for all gases; however, the x-axis values will depend on the sensitivity of the instrument to the gas species being observed.

Use of R2

The point at which the bend or 'knee' of the curve occurs in the plot of R2 / ppmm can be used to determine the sensitivity of the instrument to the gas concentration measurement. This varies with the instrument and the type of gas but an R2 of 0.85 is generally considered to be the point at which the readings can be considered valid. Below this the readings should be treated with suspicion.



Appendix G: Conversion from ppm to mg/m³

Parts per million to milligrams per cubic metre

To convert from ppm to mg/m³ the following equation is used and follows the EPA Air Emissions Monitoring Guidance Note #2 (AG1):

$$\text{Concentration } \left(\frac{\text{mg}}{\text{m}^3}\right) = \frac{\text{Concentration (ppm) x molecular weight (g)}}{\text{Molar volume (L)}}$$

In the following example Hydrogen Fluoride (HF) is used to illustrate the conversion:

HF reading from GasFinder = 1ppm at STP*
Molecular weight of HF = 20.006 g/mole
At STP the molar volume of an ideal gas = 22.41 litres

$$\text{Therefore the concentration} = \frac{1 \text{ x } 20.006}{22.41}$$

1ppm HF = 0.8927 mg/m³ at STP

*STP refers to:
Standard Atmospheric Pressure (P) = 101.325 kPa
Standard Temperature (K) = 273.15 K

If the measurement is not taken at STP then an additional correction is required to adjust to STP.

$$\text{Concentration } \left(\frac{\text{mg}}{\text{m}^3}\text{at STP}\right) = \frac{\text{Concentration } \left(\frac{\text{mg}}{\text{m3}}\right) \text{x T x } 101.325}{273.15 \; x \; P}$$

where T is the path temperature (Kelvin)
P is the absolute path pressure (kilopascals)

Eg. With a reading of 11 ppm, a path temperature of 30°C and path pressure of 94.34 kPa:

$$Actual\ Concentration = \frac{11 \; x \; 0.8927 \; x \; 303.15 \; x \; 101.325}{273.15 \; x \; 94.34} mg/m^3$$

= 9.8197 x 1.11 x 1.074 mg/m³

11 ppm of HF = 11.71 mg/m³

Note: If the measured ppm values have already been corrected for pressure and/or temperature using either the onboard compensation or the supplied compensation curves, then in the above equation use T = 293.15 K and/or P = 101.325 kPa; not the sample measurement conditions.

Appendix H: Serial Communication Commands

GasFinder3-OP supports commands over the serial interface ports (R-S232, USB device and Telnet). Commands may execute a function or access a system parameter and generally mimic a GasFinder menu. All commands adhere to the following format:

gf[<cc>][<n>][? | = [<m>]]

The lowercase 'gf' preceeds all commands. <cc> is a 2 character command acronym. <n> is a single digit channel number. Parameter access commands are followed by '?' or '=' for get and set respectively. Set commands take a parameter <m>. There are no white space characters to keep the interface lean. All commands are terminated by carriage return (Enter). Commands are responded to using the GasFinder3-OP check summed output line convention "$GF{CER | COK[,<n>]}*XX" where "XX" is the hexadecimal checksum, e.g. "$GFCER*55" for an unrecognized, malformed or out of range command.

Serial commands will be echoed using a GasFinder3-OP wrapper (as described above) in the following format: '$GFCMD,"<cmd>"*XX'. The '<cmd>' portion is the actual command string entered. This will provide confirmation of what was received by the GasFinder serial port as well as provide a record of serial line transactions when logging.

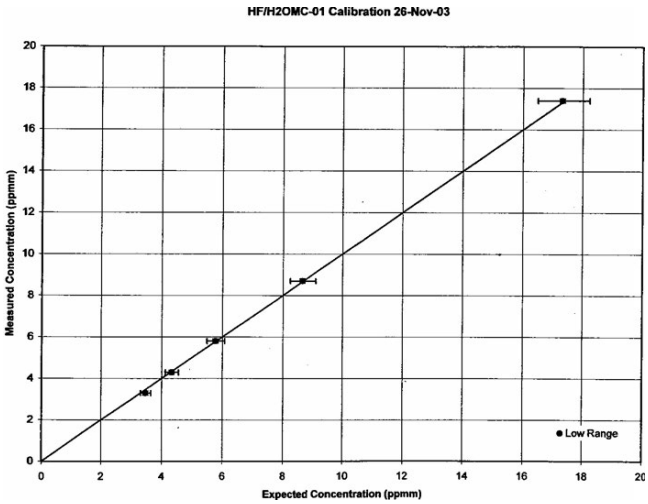
GasFinder3-OP Commands:

Command	Response	Description
gf	$GFCOK*46	Check for command interface
gfal?	$GFCOK,{0|1}*XX	Aiming laser status, '0' for off and '1' for on
gfal={0 | 1}	$GFCOK,*46	Aiming laser control, '0' for off and '1' for on
gfam?	$GFCOK, <d>*XX	Get altitude in meters
gfam=<d>	$GFCOK*46	Set altitude in meters
gfip?	$GFCOK,<n>.<n>.<n>.<n>.<n>*XX	Current static IPV4 address
gfpa?	$GFCOK,<p>*XX	Get pressure in Pascels
gfpa=<p>	$GFCOK*46	Set pressure in Pascals
gfpat=<p>	$GFCOK*46	Set pressure in Pascals (not saved to non-volatile)
gfpl?	$GFCOK,<d>*XX	Path length query, <d> is path length in decimeters
gfpl=<d>	$GFCOK*46	Set path length to <d> in decimeters
gftc?	$GFCOK,<c>*XX	Get path temperature in degrees Celsius
gftc=<c>	$GFCOK*46	Set path temperature in degrees Celsius
gftct=<c>	$GFCOK*46	Set path temp in C (not saved to non-volatile)
gfvn	$GFCOK*46	Firmware version query
gfxd	$GFCOK*46	Arrays dump

Appendix I: Calibration

The GasFinder3-OP is shipped already calibrated and can only be recalibrated at a Boreal Laser facility and not in the field.

The calibration of the GasFinder3-OP is done by passing a known concentration of gas through a test cell, which is placed in the path of the laser beam. Gases which are very reactive or unstable, such as hydrogen fluoride, are generated at the time of use with a permeation tube. The tube is placed in a temperature-controlled chamber and emits the calibration gas at a known rate. A measured flow of inert dilution gas creates a concentration of gas which is traceable to NIST standards. The calibration data are stored in the instrument's software as a standard reference waveform.



During operation, the GasFinder3-OP's internal reference cell is compared with this stored waveform at frequent intervals. Any significant deviation generates a status code to alert the user to a potential calibration problem. The GasView software can be used to check the reference cell, as well as to download sample, reference, and calibration waveforms (System Menus/Internal Arrays Transfer) to verify that the internal calibration system is functioning correctly.

A technical note detailing the calibration procedure and quality assurance is available from Boreal Laser Inc.

Appendix J: Customer Preventative Maintenance Checklist

Recommended Monthly Preventative Maintenance

support@boreal-laser.com

BOREAL

Serial Number:	

	Rx Light	Diagnostic Information ($GFDBG)				Reading	
Date	Rx Light	Int Temp	DC Offset *less than 200 from initial value	RefQual >90	Ref R2 >85	ppmm	R2

Recommended Monthly Preventative Maintenance

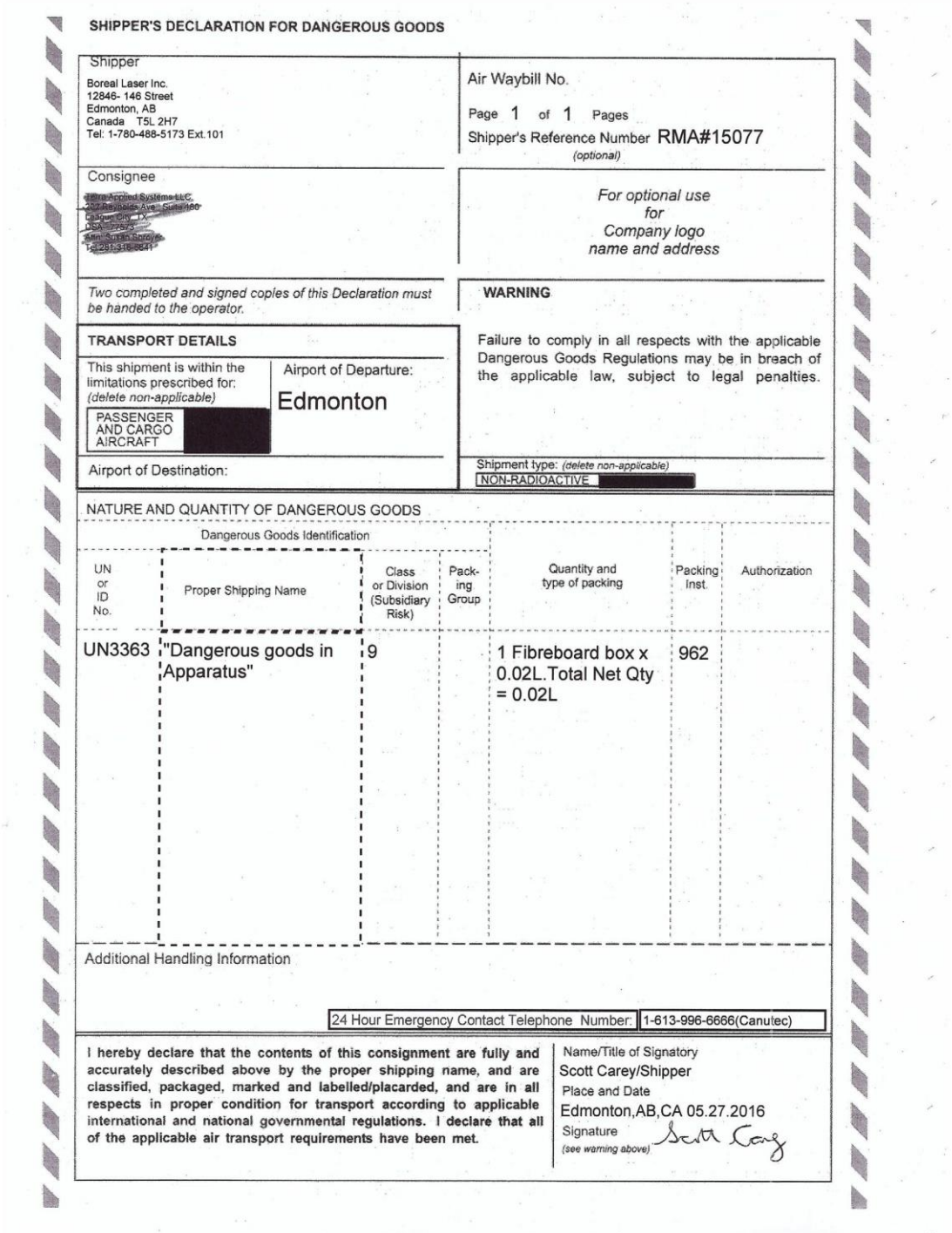
support@boreal-laser.com

BOREAL

Serial Number:	

Date		Diagnostic Information				Reading Information		
		Int Temp	DC Offset *less than 200 from initial value	RefQual >90	Ref R2 >85	Rx Light	ppmm	R2
	$GFDBG							
	Ch1							
	Ch2							
	$GFDBG							
	Ch1							
	Ch2							
	$GFDBG							
	Ch1							
	Ch2							
	$GFDBG							
	Ch1							
	Ch2							
	$GFDBG							
	Ch1							
	Ch2							
	$GFDBG							
	Ch1							
	Ch2							

Appendix K: Dangerous Goods Declaration Form



SHIPPER'S DECLARATION FOR DANGEROUS GOODS

Shipper
Boreal Laser Inc.
12846- 146 Street
Edmonton, AB
Canada T5L 2H7
Tel: 1-780-488-5173 Ext.101

Air Waybill No.
Page 1 of 1 Pages
Shipper's Reference Number RMA#15077
(optional)

Consignee
[redacted]

For optional use for Company logo name and address

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING
Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.

TRANSPORT DETAILS
This shipment is within the limitations prescribed for: *(delete non-applicable)*
PASSENGER AND CARGO AIRCRAFT [redacted]
Airport of Departure: Edmonton
Airport of Destination:
Shipment type: *(delete non-applicable)*
NON-RADIOACTIVE [redacted]

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification						
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Packing Group	Quantity and type of packing	Packing Inst.	Authorization
UN3363	"Dangerous goods in Apparatus"	9		1 Fibreboard box x 0.02L.Total Net Qty = 0.02L	962	

Additional Handling Information

24 Hour Emergency Contact Telephone Number: 1-613-996-6666(Canutec)

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. I declare that all of the applicable air transport requirements have been met.

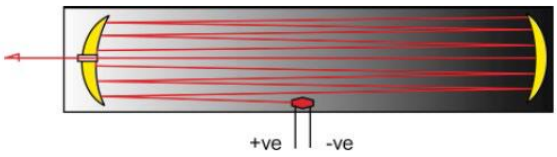
Name/Title of Signatory
Scott Carey/Shipper
Place and Date
Edmonton,AB,CA 05.27.2016
Signature *(see warning above)* Scott Carey

Below is a sample Dangerous Goods (DG) declaration form for the shipping of a GasFinder3-OP System with an HF Reference Cell.

Appendix L: The Basics of Laser Gas Detection

Tunable Diode Laser

Laser is an acronym for: **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation

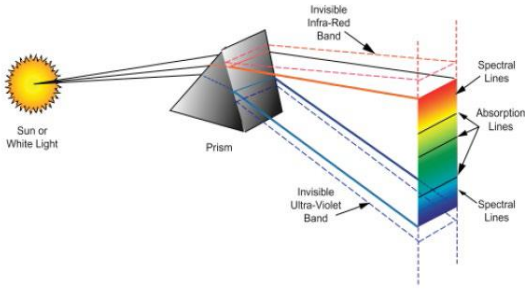


In principle, the laser is a tube with a mirror at each end. In the tube is a crystal or gas mixture which is induced to emit radiation by stimulating it with electricity. The radiation in the tube bounces between the two mirrors and starts a chain reaction. The chain reaction, or light amplification, would cause the device to burn up if continued indefinitely. For this reason, a small amount of the reflective coating on one mirror is removed or a small hole placed in it. This causes a small stream of identical photons to be released through the hole. The emitted stream of photons is identical in both time and space. This is the 'coherent' radiation characteristic of a laser. A crystal or gas is selected which will emit radiation at a specific wavelength. A ruby crystal emits a visible red beam with a wavelength of 6500 angstroms or 650 nanometers.

Gas Laser

A **Diode Laser** works on the same principle except that the tube, mirrors, and crystal are all combined in a small package using semiconductor technology. The diode laser is composed of a pn junction, as in the light emitting diode (LED), and specially cleaved mirror facets that form the optical cavity. The output wavelength is fixed. The size of the laser and focusing optics is similar to the size of a pencil eraser.

A **Tuneable Diode Laser (TDL)** can have its wavelength altered very slightly while it is operating. This can be done by changing the operating temperature or the drive current.



Absorption Lines

If a beam of sunlight is sent through a prism, a spectrum of colours can be seen leaving the prism, which can be projected onto a screen. Blue, which has a shorter wavelength, is bent more than the red. The visible spectrum is only a small part of the emissions. Extending beyond the blue is the ultra-violet and beyond the red is the infra-red.

If the projected spectrum is sharp and defined, a number of black lines may be seen at various locations. These lines are absences of light where atoms and molecules of gas in the sun or the light beam path have absorbed the light at a particular wavelength. This results in a black line on the display. These lines are called absorption lines.

Gas Detection with a Laser

Every gas is composed of atoms or molecules. If the target gas is hydrogen fluoride, then one atom of hydrogen would have combined with one atom of fluoride to give one molecule of hydrogen fluoride. These molecules have various frequencies or wavelengths at which they resonate or vibrate. See Figure 1. These are known as the absorption wavelengths, because when the molecules absorb a portion of the light energy, they vibrate at these wavelengths. Because molecules of other gases have different atomic weights, these gases absorb light at different wavelengths from the target gas. Wavelengths for laser gas detection are chosen in regions where the absorption of the target gas is not interfered with by the absorption wavelength of any other gases that may be present. See Figure 2.

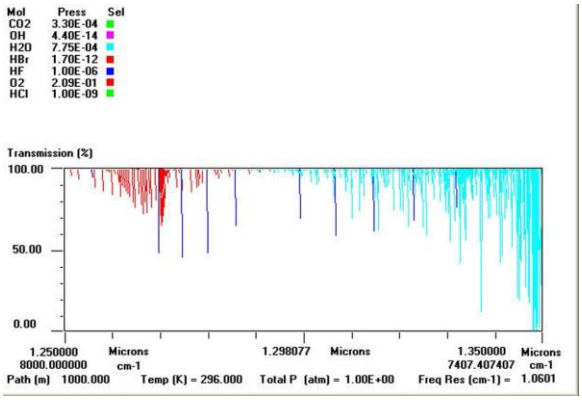


Figure. 1

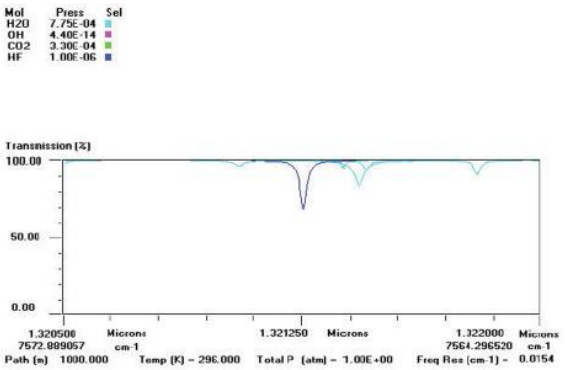
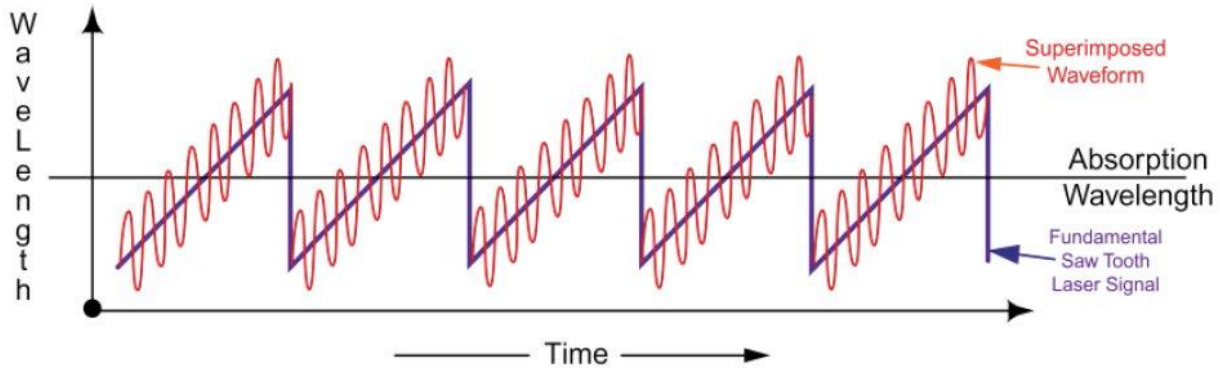


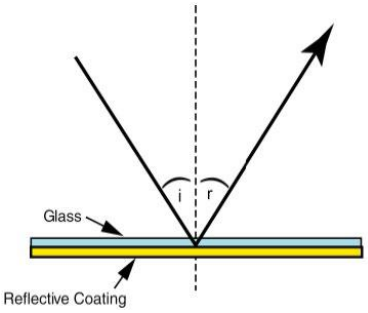
Figure. 2The laser operating wavelength is kept stable by housing it in a temperature-controlled box. A fluctuating (saw-tooth) current is used to drive the laser, and this causes the wavelength to change slightly so that the laser scans across the absorption wavelength.



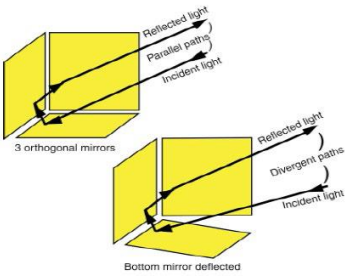
The laser beam has a signal superimposed on it at a different frequency. See Figure 3. When the gas molecule is struck by the laser beam, the molecule vibrates. These vibrations affect the laser beam by changing this superimposed frequency. This difference is detected by a receiver in the instrument, when the laser beam is reflected back. The difference in the superimposed signal, together with the intensity of the returning beam, is used to obtain a measurement of the target gas concentration. The laser operates in the near infra- red spectrum (1300 to 1700 nanometers) and cannot be seen with the eye. It has a line width of about 0.3nm and is concentrated and very intense. For the same power output, it is able to penetrate dust and steam better than a visible laser.

Retroreflectors

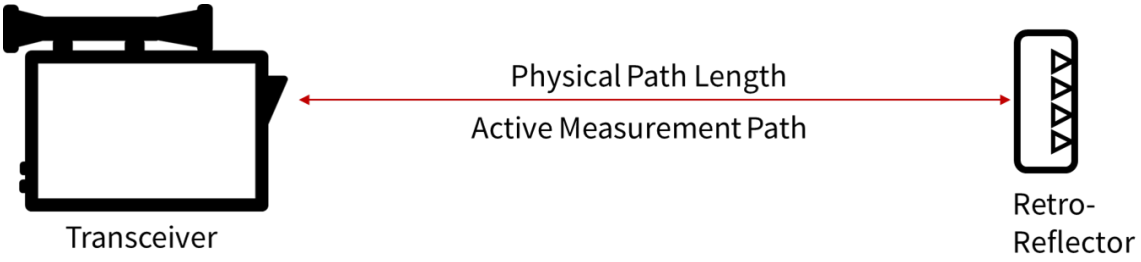
The laser beam is transmitted to a retro made with a special type of corner cube arrangement. This causes the signal to be reflected directly back to the detector in the transmitter enclosure. With the appropriate number of retros, path lengths up to 750m can be traversed.

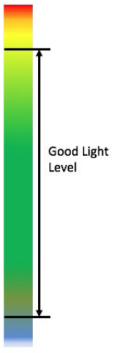


Most mirrors reflect light the same way as a flat, glass bathroom mirror, where the angle of incidence(i) = the angle of reflection(r). A bathroom mirror has the reflective coating on the rear, behind the glass. See figure 4.



A retro is different in that the reflected light returns in the same direction as the incident light. The beam is reflected 180 degrees. A retro is like a section through a corner and has three faces that form the inside corner of a cube. Some highway reflectors are everyday examples. See figure 5. Because retros used for laser gas detection have the reflective surface on the front, the base material can be glass or metal. The surface coating is usually a very thin layer of gold or sometimes silver. This means that cleaning the fragile coating is very difficult and is done with an air brush to avoid touching the surface.





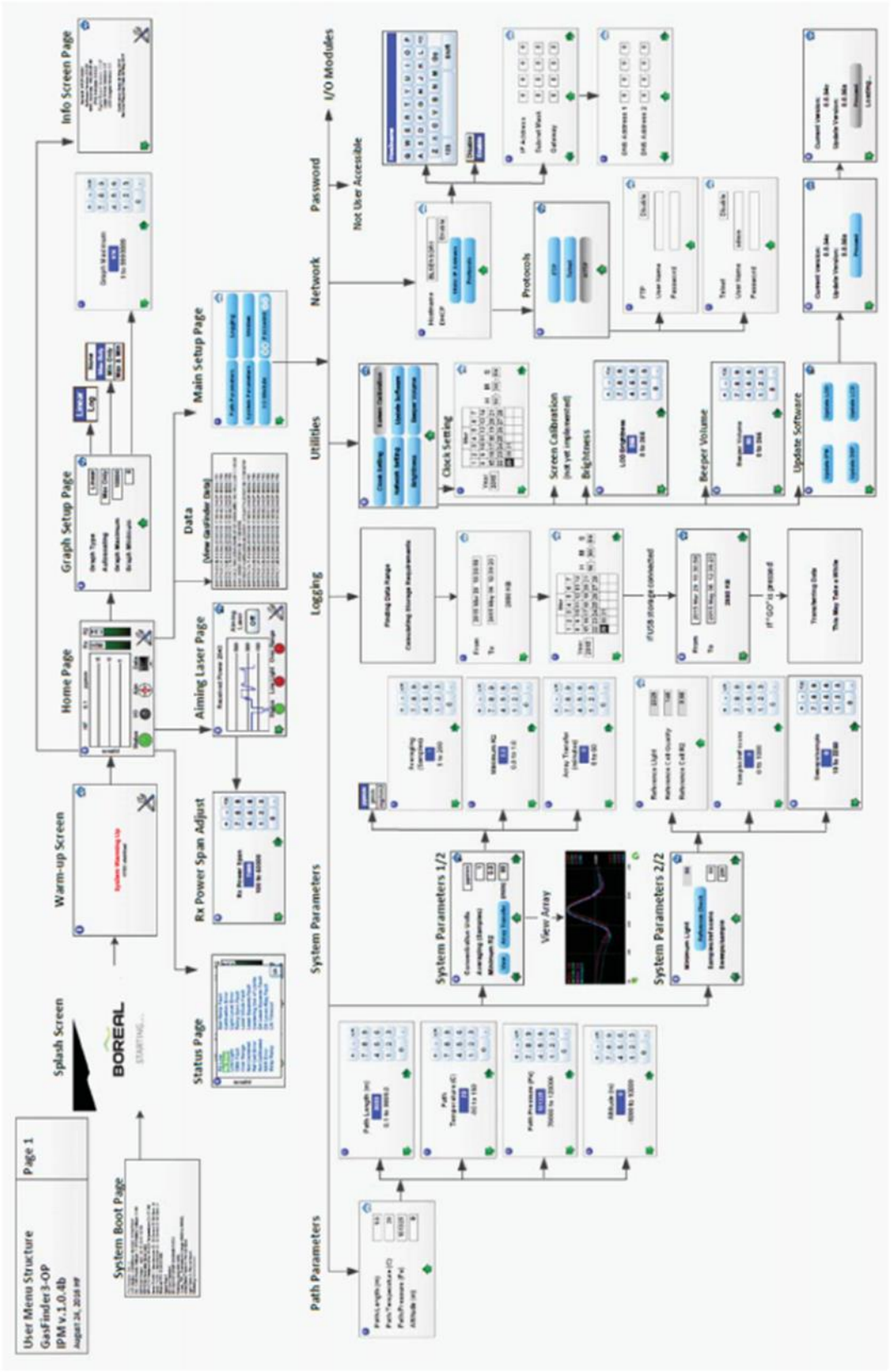
DIFFERENT SCENARIOS

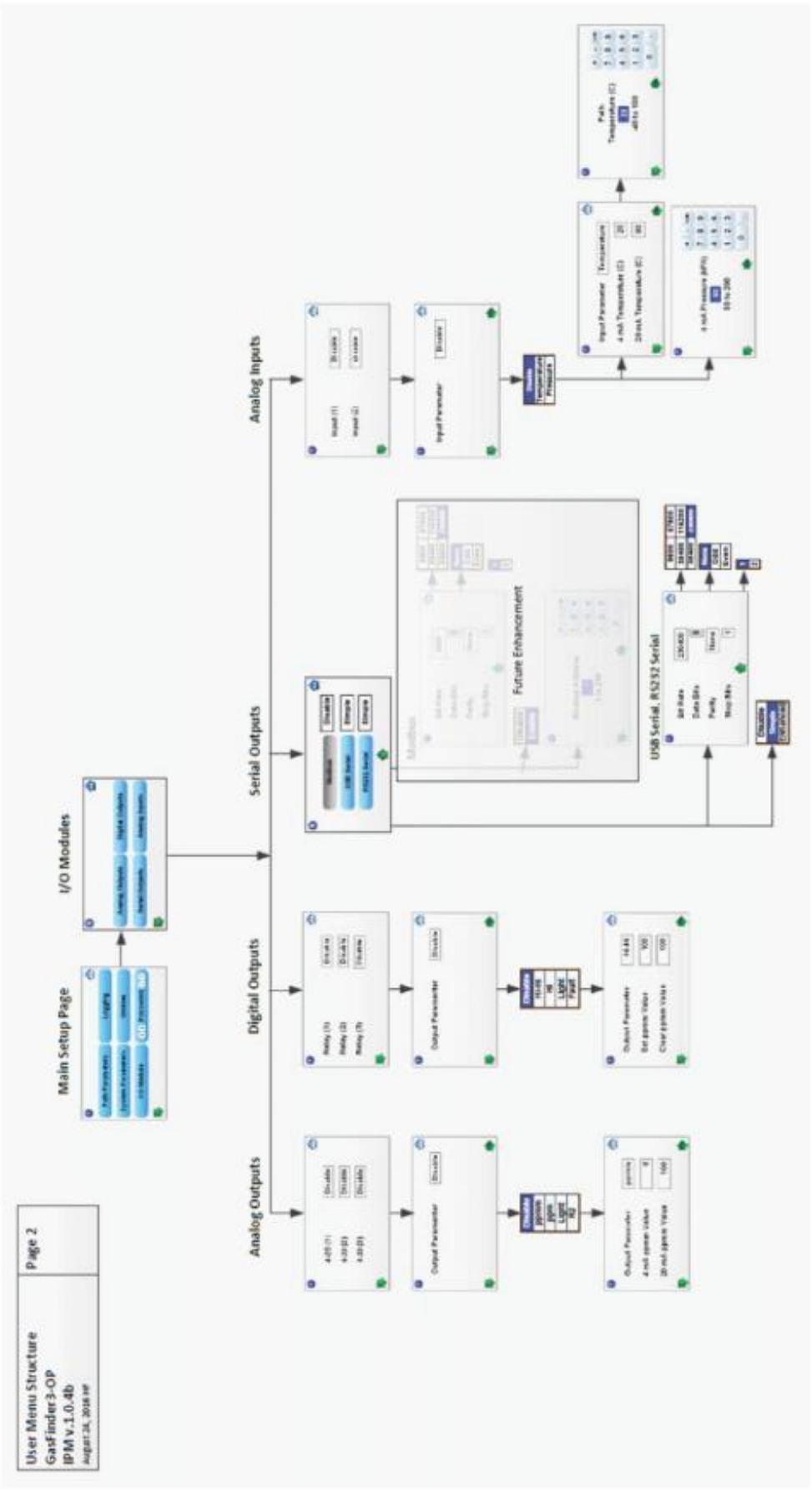
- **NO LIGHT:** Laser is either not on or the beam is blocked
- **LOW LIGHT:** Misalignment or opacity issues present
- **GOOD LIGHT:** The system can perform its analysis
- **TOO MUCH LIGHT:** Too many retros; too close to the transceiver

Appendix M: Glossary of Common Terms and Abbreviations

Term/Abbreviation	Description
Absorption	Dark lines in the spectrum due to absorption of the light.
Absorption Wavelength	The wavelength at which a gas absorbs light.
Angle of Incidence (i)	The angle to the perpendicular that a beam makes.
Angle of Reflection (r)	The angle to the perpendicular that a reflected beam makes.
Angstrom	Measurement of wavelength 0.000 000 000 1 part of a meter.
Arrays	A group of graphs or curves.
Corner Cube	Special type of reflector surface (see retroreflector).
Coherent	Having the same frequency and phase.
Digitised	Represented by numbers.
Facets	Sides or faces.
Frequency	Number of repeated oscillations a wave makes in a set time.
Inert	Not reactive.
Infra-Red	Long wavelength electromagnetic radiation.
Laser	Light Amplification by Stimulated Emission of Radiation.
Microcontroller	A small device using a microcomputer.
Microcomputer	A small computer the size of a postage stamp.
Micron	0.000 001 part of a meter.
Modulated	Like a wave.
Molecule	A collection of atoms bonded together
Multimode	A light beam containing many different frequencies.
Nanometer	0.000 000 001 part of a meter.
NIST	National Institute of Standards and Technology.
OTDR	Optical Time Domain Reflectometer.
Orders of Magnitude	Multiples of ten.
Permeation Tube	A device to generate a gas at a known and controlled rate.
Photo Diode	An electronic device used to detect light.
ppm	parts per million.
ppmm	parts per miliion metre.
ppb	parts per billion.
Retro	A device to reflect a beam back to where it came from.
Retro Arrays	A group of retro reflectors.
Saw-Tooth	Serrated, or shaped like the teeth on a saw.
Singlemode	A light beam containing only one frequency.
Spectroscopy	Measurement of different radiation spectra.
TDLS	Tuneable Diode Laser Spectroscopy.
Tunable Diode	A diode (emitter) that can have its wavelength altered.
Wavelength	Distance between the same points in two consecutive waves.

Appendix N: HMI Touchscreen Menu Map




User Menu Structure
GasFinder3-OP
IPM v.1.0.4b
Page 2
Main Setup Page
I/O Modules
Analog Outputs
Digital Outputs
Serial Outputs
Analog Inputs
Future Enhancement
USB Serial, RS232 Serial

Appendix O: Product Registration

For the purpose of initiating your warranty and for the notification of safety alerts or product recalls we kindly ask you to register your GasFinder Unit.

Please email registration@boreal-laser.com and include the following information:

- Serial Number (Found on the GasFinder Unit):
- Installation/Commissioning Date:
- Contact Information:
    - Company:
    - Facility Address:
    - Facilities Phone Number:
    - Unit/Area where the Equipment is installed:
    - Assigned Facilities ID or TAG #:
    - Department/Group who is responsible for the GasFinder Unit:
    - The most applicable Position within the Department/Group whom to contact:
        - Position/Title:
        - Name:
        - Phone #:
        - Email:

Appendix P: Boreal Laser Inc. Software License Agreement

This Software Licensing Agreement (the "Agreement") made between Boreal Laser Inc. ("Boreal") and the Customer, which Customer has purchased one or more of the various products listed below from Boreal as part of an overall contract which includes this Agreement.

This Agreement applies to any and all software products, programs and applications and any manuals and materials whether in hard copy or electronic and any support related systems and services (the "Software") that are provided to the Customer in connection with any Boreal products, including but not limited to the GASVIEW2, GASVIEWOP, GASVIEWMP, GASMAP and GASVIEWMC products (the "Boreal Product").

Use of the Software by the Customer constitutes the Customer's acceptance of the terms of this Agreement.

GRANT OF LICENSE

Boreal grants to the Customer a non-exclusive license (the "License") to utilize the Software in connection with the Customer's personal use of Boreal Product it has purchased from Boreal. The Customer is authorized to make copies of the Software for its own personal use. Without limiting the restrictions implicitly contained in the License, the Customer shall not distribute, license or in any way provide the Software to third parties without Boreal's express written consent, which consent may be withheld at Boreal's sole and unfettered discretion. The Customer shall not reverse engineer, decompile or disassemble the Software.

NO WARRANTIES

There are no warranties or representations, whether written or verbal, given by Boreal in relation to the Software, and the Customer acknowledges that is has not received any warranties or representations in relation to the Software. Without limiting the generality of the foregoing, Boreal makes no claim with respect to, and the Customer places no reliance on, the fitness, usability, functionality or accuracy of the Software.

LIMITATIONS OF LIABILITY

Boreal shall not be liable, whether in contract, tort or any other basis, with respect of any problem or issue with the Software whatsoever.

COPYRIGHT

Save and except for the limited rights granted to the Customer by the License, Boreal retains all rights and title it has to any and all intellectual property contained in or related to the Software. Any rights not expressly granted to the Customer by this Agreement are retained by Boreal.

TERMINATION

Upon the Customer's failure to maintain compliance with this Agreement, Boreal may at its option terminate this Agreement. Upon said termination, the Customer shall cause to be destroyed all copies of the Software in its possession or control. Said termination shall be without prejudice to any other rights Boreal may have. Failure to exercise said option to terminate shall not constitute a waiver of any of Boreal's rights.

GENERAL

This Agreement is governed by the laws of the Province of Alberta and the Parties hereby attorn to the jurisdiction of the Courts of Alberta. The Parties agree that Boreal shall be entitled to a full indemnity for any and all costs and legal fees incurred in connection with any action brought by Boreal against the Customer for breach of this Agreement.

Appendix Q: FTP Commands

dir

Lists all folders and directories.

```
ftp> dir
200 OK.
150 Data.
-rw-r--r-- 1 502 502 2459 Sep 13 2015 params.ini
drwxr-xr-x 1 502 502 0 May 29 2015 LOGFILES
226 OK.
ftp: 95 bytes received in 0.20Seconds 0.48Kbytes/sec.
ftp>
```

cd [NEW DIRECTORY]

Change directory to destination.

```
ftp> cd LOGFILES
250 Dir changed.
ftp>
```

```
ftp> cd LOGFILES/2015
250 Dir changed.
ftp>
```

get [FILENAME]

Retreives the file from the GasFinder3-OP and places it in the local directory (the one that was connected to the FTP before).

```
ftp> get LOGFILES/2015/20150529.LOG
200 OK.
150 Data.
226 OK.
ftp: 259009 bytes received in 0.33Seconds 789.66Kbytes/sec.
ftp>
```

lcd

Displays the local directory if typed alone or if a path is typed after the lcd it will change the local directory.

```
ftp> lcd
Local directory now C:\Users\hfriesen\ti.
```

```
ftp> lcd c:\Users\hfriesen
Local directory now C:\Users\hfriesen.
```

send OR put

Sends a local file to an FTP client.

```
ftp> send TEST.LOG
200 OK.
150 Data.
226 OK.
ftp: 259009 bytes sent in 1.30Seconds 198.78Kbytes/sec.
ftp>
```

quit OR bye

Exits the FTP connection.

mget *

This command will get all the files in the current directory. Its intended use is to avoid having to individually get separate logfiles. To streamline this process it is best to disable "interactive mode". When the interactive mode is enabled, the system will ask the user y/n for each file (so a "y" has to be typed each time). This is not helpful when using mget to get many files without supervision.

There are two options to disable the interactive mode:

Option 1:

1. Start ftp using the 'i' option:
   ftp -i [ip address]

2. Navigate to the directory:
   cd LOGFILES
   cd 2015

3. Send the mget command:
   mget*

The files will go to the directory that was started in the command prompt.
(default C:\Users\[name]\)

Option 2:

1. Enter ftp normally:
   ftp [ip address]

2. Navigate to the directory:
   cd LOGFILES

3. Disable interactive mode:
   Prompt

4. Send the mget command:
   mget *

For more information, type "?" and see a full list of commands.

Virtual COM port Drivers

In order to be able to receive serial data over a mirco-USB cable, the computer in question must have the FT230X Full Speed USB to Basic UART driver. It can be found at the following web address on the FTDI site:

http://www.ftdichip.com/Drivers/VCP.htm