Laser in Situ Online Gas Analysis System

Application Guide for the Steel Industry

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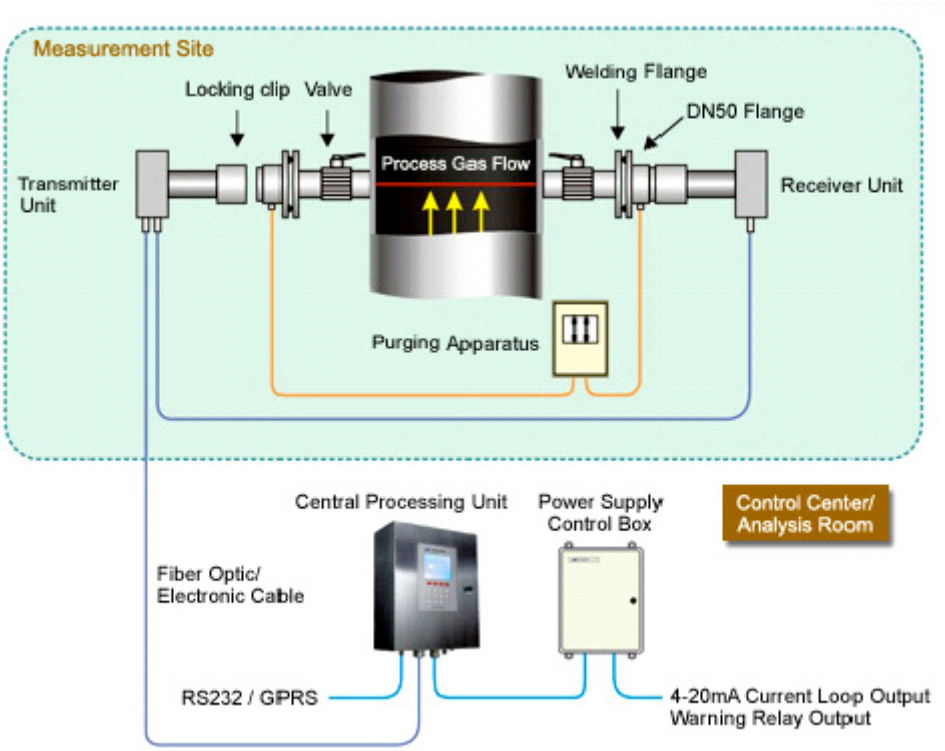
1. Introduction

1.1 System Configuration

A Laser in-situ online gas analysis system comprises of a transmitter, a receiver and a central processing unit. The transmitter launches a laser beam across the diameter of the industry flue or conduit under test onto the receiver placed at the other end. The resulting electrical signal is then sent to the central processing unit and analyzed to yield the gas concentration information.



Main Parts:

- **Transmitter**
  - Components: laser launching device, optical assembly, transmitter unit box and etc.
  - Function: generates and launches a collimated modulated laser beam across the gas environment under test and onto the receiver.
- **Receiver**
  - Components: opto-electronic sensor, optical assembly, signal amplifier, receiver unit box and etc.
  - Function: collects the laser beam from the transmitter, converts the light intensity into electric signal and sends it real-time to the central processing unit.
- **Connecting Unit**
  - Components: valve, welding flange, instrument flange and etc.

Function: mounts the transmitter and receiver units onto the industry flues/conduits under test.

- **Central Processing Unit**

  Components: power supply board, signal processing board, user interface board, central processing unit case, and etc.

  Function: processes the spectral signal from the Receiver, performs display, data communications and operation management.

- **Purging Apparatus**

  Components: precision filter, decompression valve, flowmeter, case, and etc.

  Function: blows clean industry gases such as N2 into the connecting unit to form a air wall before the optical window that prevents process gas flow from contaminating it.

- **Calibration Unit**

  Components: Calibration tube, needle valve, and etc

  Function: Used for calibration.

- **GPRS wireless communication system**

  Components: GPRS module, control circuit, case, and etc.

  Function: enables online data analysis, remote diagnosis, instrument management, and remote software upgrade.

1.2 Gas Species

Regular gas species and their measurement indicators

Gas	Lower Limit	Range	Highest Pressure	Highest Temperature
O_2	0.01% Vol.	0-1% Vol., 0-100% Vol.	10 bar abs.	1500°
CO	40 ppm	0-8000 ppm, 0-100% Vol.	2 bar abs.	1300°
CO_2	20 ppm	0-2000 ppm，0-100% Vol.	2 bar abs.	1500°
H_2O	0.03 ppm	0-3 ppm, 0-70% Vol.	2 bar abs.	1500°
H_2S	2 ppm	0-200 ppm,0-30% Vol.	2 bar abs.	400°
HF	0.01 ppm	0-1 ppm,0-1000 ppm	3 bar abs.	600°
HCl	0.01 ppm	0-7 ppm,0-8000 ppm	2 bar abs.	500°
HCN	0.2 ppm	0-20 ppm,0-1% Vol.	2 bar abs.	500°

NH_3	0.1 ppm	0-10 ppm,0-1% Vol.	2 bar abs.	500°
CH_4	10 ppm	0-200 ppm, 0-10% Vol.	5 bar abs.	500°
C_2H_2	0.1 ppm	0-10 ppm，0-70% Vol.	-	-
C_2H_4	1.0 ppm	0-100 ppm，0-70% Vol.	-	-

Note: Specific ranges can be custom made.

1.3 Technical Specifications

Technical Features	Optical path length (OPL)	≤ 12m
	Response time	< 1s
	Linear accuracy	≤ ± 1% FS
	Span drift	≤ ± 1% FS (within a maintenance interval)
	Zero drift	Negligible
	Warm-up time	< 1hour
	Maintenance interval	< 4 times/year (no replacement parts)
	Calibration interval	<4 times/year
Input & Output Signal	Analogue output	4~20mA current loop, 500Ω Max, isolated
	Digital output	RS232/GPRS
	Relay alarm	3-Channel (Relay Specification: 220V, 0.5A)
	Analogue Input	4-20mA environment gas temperature, pressure input (optional)
Operation conditions	Environment temperature	-20° to 50° (adjustable upon customer request)
	Protection class	Transmitter/ Receiver: IP65
	Power supply	220 VAC, 50Hz, <30W
	Purging gas	N_2, etc.
Installation	Mounting method	Use DN50/PN2.5 flanges to install transmitter and receiver

Dimension and Weight	Transmitter/Receiver Unit	260×200×150mm, 10kg
	Connecting Unit	385×150×160mm, 10kg
	Central processing unit	400×320×170mm, 10kg

Note: Specific indicators can be adjusted.

1.4 Models

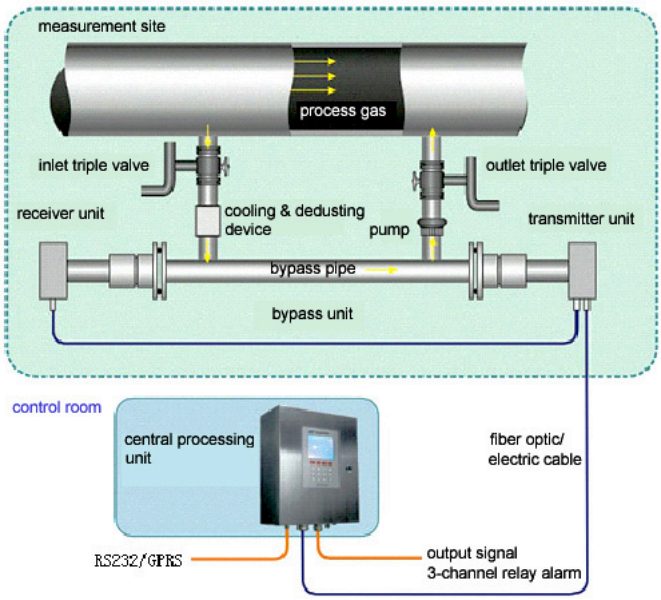
（1）Standard Model

- Applicable scope: The temperature and pressure is in the measurement range, as well as the dust concentration is lower than 80g/m^3.
- Configuration: Mainly comprises of the transmitter unit, receiver unit, central processing unit, connecting unit, purging apparatus and the calibration unit.
- Features: The receiver unit and the transmitter unit can be directly installed onto the gas flow flue under test, and realizes in situ measurement and analysis.

（2）Bypass Model

• Applicable scope: Dust, temperature and pressure exceed the standard model's range. The customer's field installation requirement will not allow opening holes in multiple locations while several gas species needs monitoring.

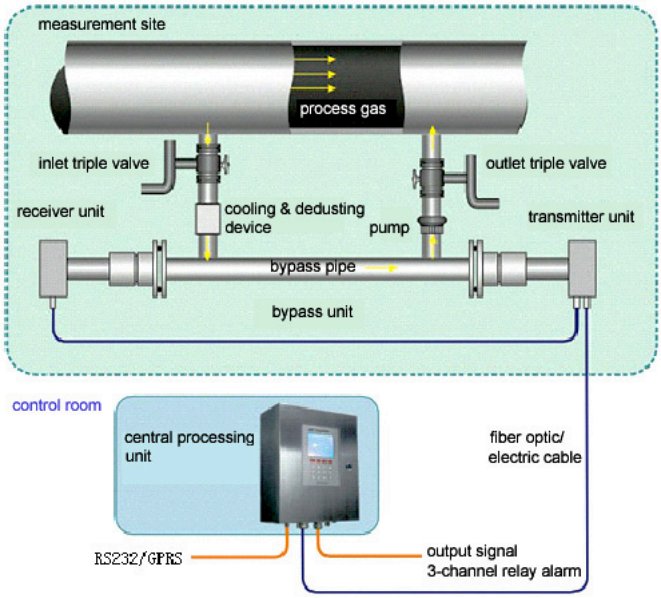
• Configuration: As depicted in the figure, a bypass unit is added. The bypass unit comprises of feed gas pipe, gas pretreatment system, electric ball valve, electric pump, bypass measurement pipe, calibration gas inlet and off gas pipe. The configuration may vary from application to application.



• Features: The bypass unit extracts the gas from the process flue. After cooling, de-pressurization, dust

removal, and other simple pretreatments, the gas enters the bypass measurement pipe where the gas is analyzed. By using the special bypass unit invented by TAI, quality field measurements can be achieved.

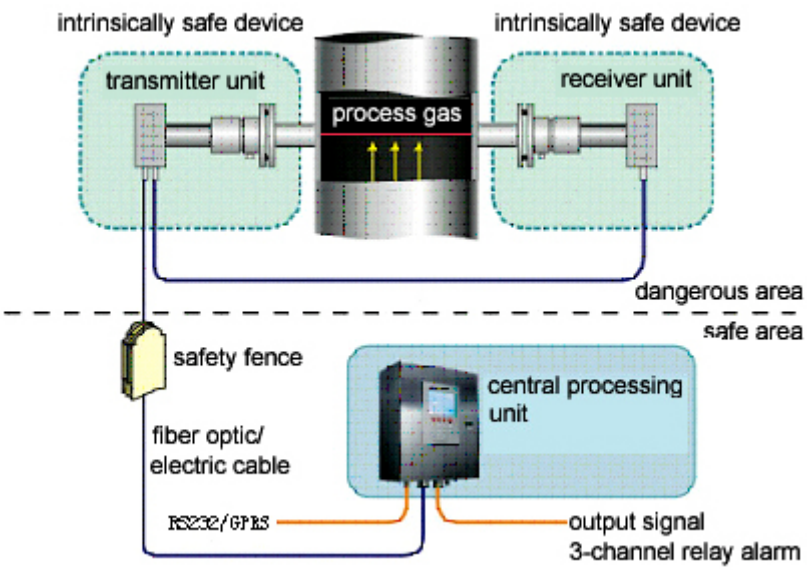
（3）Fiber Model



- Applicable scope: The fiber system is suggested when it is not suitable to put the diode laser in-situ, due to operational constraints, or for situations when monitoring the same gas at multiple points,
- Configuration: Different from the standard model and the bypass model, the diode laser is put in the central processing unit, and the laser is transmitted to the receiver unit via the fiber.
- Features: Resistance to electromagnetic interference is very high; the central processing unit can be put in better environments, thus increasing its ability to work effectively in poor environments.

Using the fiber model, TAI can construct distributed fiber laser in situ online gas analysis system, measuring gas at different locations. In the distributed fiber laser in situ online gas analysis system, several monitoring points share one central processing unit and laser, thus greatly reducing the cost. Compared to traditional gas analysis system, the system configuration is more flexible, and the price point is better in most customer applications.

（4）Explosion Proof Model



- Applicable scope: TAI provides intrinsically safe and positive pressure explosion proof models, which meet or exceed all explosion proof requirements. Use the intrinsically safe cables with relative small distributed capacity and distributed

inductance in dangerous areas. The positive pressure explosion proof model's central processing unit can be installed in dangerous areas.

• Configuration: All electrical wiring between the transmitter unit and the receiver unit is intrinsically safe. During the installation, a safety fence with limited current and pressure to the cable is added between the central processing unit and the transmitter unit.

2. Technical Principle

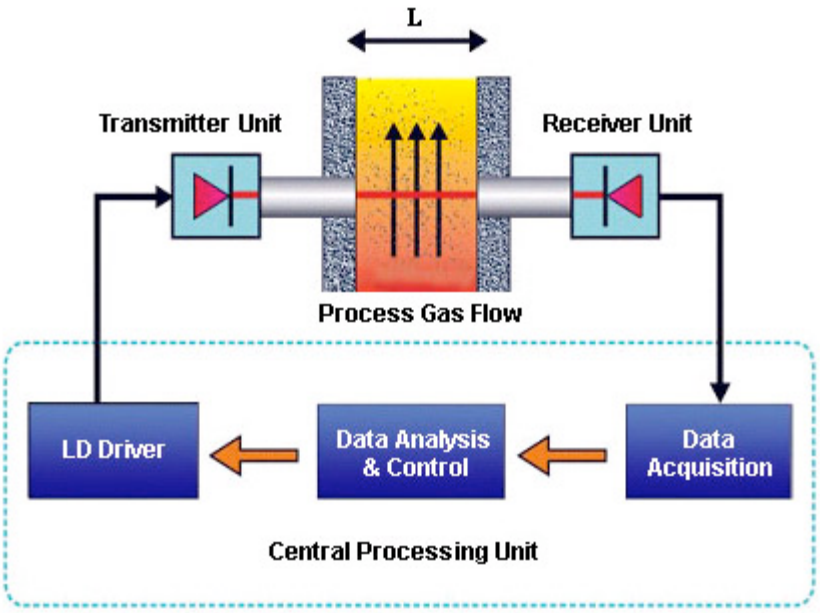
2.1 Brief Introduction of DLAS

TAI's Laser in-Situ Online Gas Analysis Systems are based on TAI's proprietary Diode Laser Absorption Spectroscopy (DLAS) technology.

TAI is a major leader in DLAS analysis instruments and systems. It has built a complete portfolio of intellectual property in relevant areas such as quantitative laser spectrum technology, feeble signal detection, optical fiber technology, simultaneous and digital electro circuit design, micro controller technology, and software. Its analyzers have been widely installed in the metallurgy, petrochemical, environmental protection, biochemical, aeronautics and astronautics, and etc. fields.

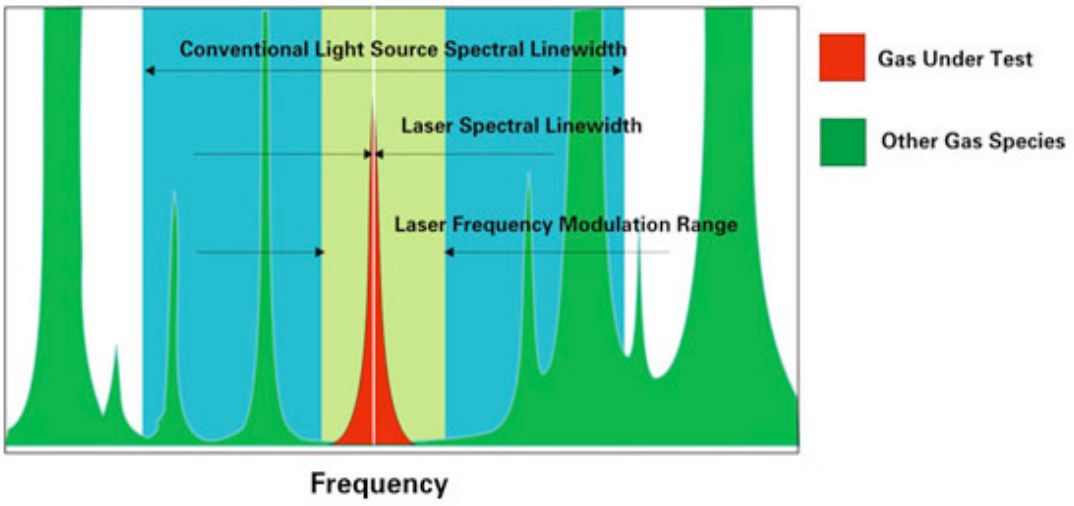
2.2 Technical Principle of DLAS

DLAS is short for Diode Laser Absorption Spectroscopy. Light from a diode laser passes through the environment under test and gets selectively absorbed. By detecting and analyzing the absorption spectrum, TAI's DLAS analyzers can measure gas concentrations, flow velocity, temperature, and etc.



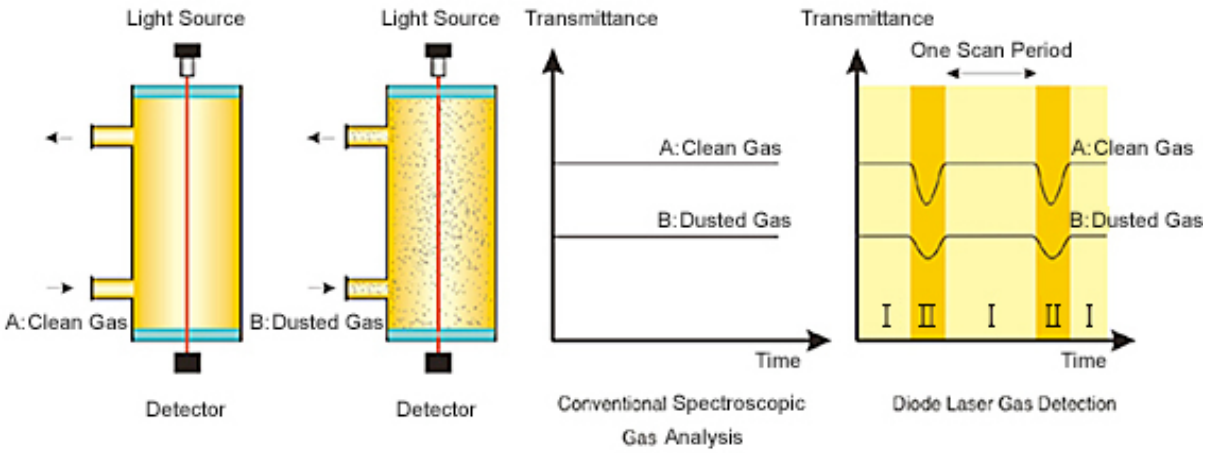
The special gas analysis technology of DLAS solves three major problems in process gas analysis, cross interference of background gas, dust and window contaminations, and influence of the environment parameters of the gas under test. Thus it makes in situ online analysis possible, and avoids pretreatment.

■"Single-line" Spectroscopy Technology—no cross interference from background gas species



Schematic of "Single-line" Spectroscopy Measurement Principle

Conventional infrared spectroscopy light sources are normally non-laser and have very broad line-widths. The absorption spectrum encloses not only the spectral line from the gas under test, but also those from background gas species, and introduces cross interference. DLAS gas analyzers uses diode lasers, which have line-widths of less than 0.0001nm, or only 1/106 of that of the non-laser sources. By selecting a laser emitting near a specific absorption line of the gas under test and tuning its wavelength through changing its temperature and driving current, an absorption spectrum that only covers a single line of the gas under test can be obtained to eliminate cross interference.



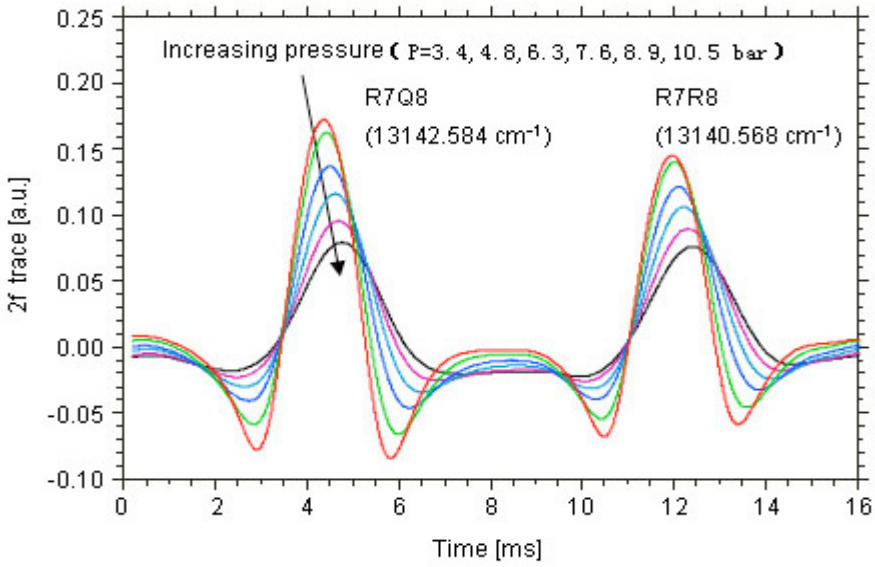
■ Laser spectral scanning technology—automatically correct for dust, water vapor and optical window contamination

Spectroscopic gas analysis technologies in general measure light transmittance to yield the gas concentration information. Conventional gas analyzers use fixed broad-spectrum light sources and measures total light transmittance, Tgd, that also counts for absorptions and deflections caused by dust, water vapor, optical window contaminations etc., and can not differentiate the transmittance of the gas under test, Tg, and that of dust, water vapor, and optical window contaminations, Td. As a result, measured gas concentration will be higher than the real data when dust density in the environment increases.

DLAS gas analyzers use the laser spectral scanning technique. They periodically scan the gas under test with a modulation frequency range larger than the gas absorption spectral line-width such that, within one scan period, there are two distinctive areas. Area I is unaffected by the gas absorption and gives Td, whereas area II is and gives Tgd. The transmittance of the gas under test is then calculated accurately by Tg = Tgd /Td. The interference from dust and optical window contamination is, therefore, automatically screened out.

■ Automatic compensation for the spectral line broadening—eliminates the influence of gas environment parameters (temperature and pressure) variance

When the gas temperature and pressure change, the width and height of the measured gas absorption spectral line will change accordingly. It affects the accuracy of the measurement. By having a 4-20 mA process temperature and pressure input, TAI's LGA-3500 and LGA-3000 analyzers automatically compensate for them with TAI's proprietary algorism to ensure measurement accuracy.



The evolution of absorption spectral line as a function of gas environment parameters.

2.3 Technical Advantages of DLAS

Compared to conventional analysis system, this laser online gas analysis system has the following advantages:

Item	**LGA-3500 *in situ* laser online gas analyzer**	**Conventional online gas analyzers**
Pretreatment	Not required	Required
Measurement Method	*In Situ*, continuous, real-time	Discontinuous
Gas Environment	Applicable to adverse environments such as high temperature, high pressure, high dust density, high water vapor density, high flow velocity, high corrosiveness	Only applicable to dry, dust-free gas samples with constant temperature, pressure, and flow velocity
Response Speed	Fast, only limited by instrument electronics response, less than 1 sec.	Slow, limited by gas sampling, transport, and instrument electronics response, 20+ sec.
Reliability	Average concentration along the optical path, *in Situ*, real-time; no cross interferences from other gas species, dust, and gas parameter fluctuations	Gas concentration at the tip of the sampling probe only, affected by gas influence, absorption, and leakage during gas sampling and transport; cross interferences from other gas species, dust, and gas parameter fluctuations

Continuous	Continuous	Discontinuous; not functioning during reverse purging
Dependability	No moving parts, highly reliable	Quite a lot of moving parts, low reliability
Measurement Parameters	Gas concentration, temperature, flow velocity, and etc. simultaneously	Gas concentration only
Medium Interruption	No cross interferences from background gas species; automatic correction for dust and optical window contamination	Vulnerable to background gas cross interference, unable to compensate for dust and optical window contamination
Sample Gas Discharge	None	Frequent, dangerous and pollutant
Calibration & Maintenance	Calibration: 3~4 times /year Maintenance: 4 times/year, system prompt	Calibration: 2~3 times /month Maintenance: often
Operation Cost	No spare parts, only electricity	Quite a lot of spare parts, ~20% of the equipment cost per year

3. Installation & Operation

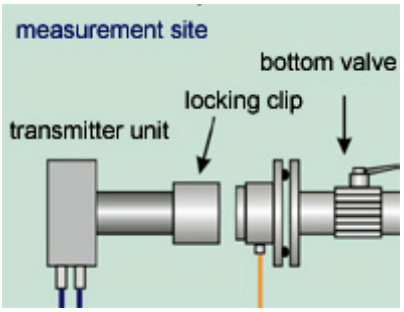
3.1 Installation

The installation is easy. Open up two round holes at the two ends of a diameter of the process gas flow flue under test, weld a DN50 flange on each side, mount a valve (optional) and an instrument flange subsequently, and then install and tighten the transmitter unit and receiver unit to the instrument flange by mounting nuts. The central processing unit is placed in an Instrument Control Center or an Analysis Room (instrument rack).

3.2 Standard Working Flow

- Keep the bottom valve open, certain frequency laser transmit from the transmitter unit to the receiver unit, when crossing the gas pipe, it attenuats as a result of absorption. Afer receiving the attenuated laser, the sensor in the receiver unit sends the signal to the central processing unit for analysis and computing the concentration of the gas under test.
- To prevent dust and other contaminations from assembling in the window, it is necessary to purge the inlet continuously with industry N_2, forming a section of N_2 curtain between the optical window and industry gas.

3.3 Calibration & Maintenance



It is easy to calibrate and maintain the system. The typical maintenance interval is 3 months.

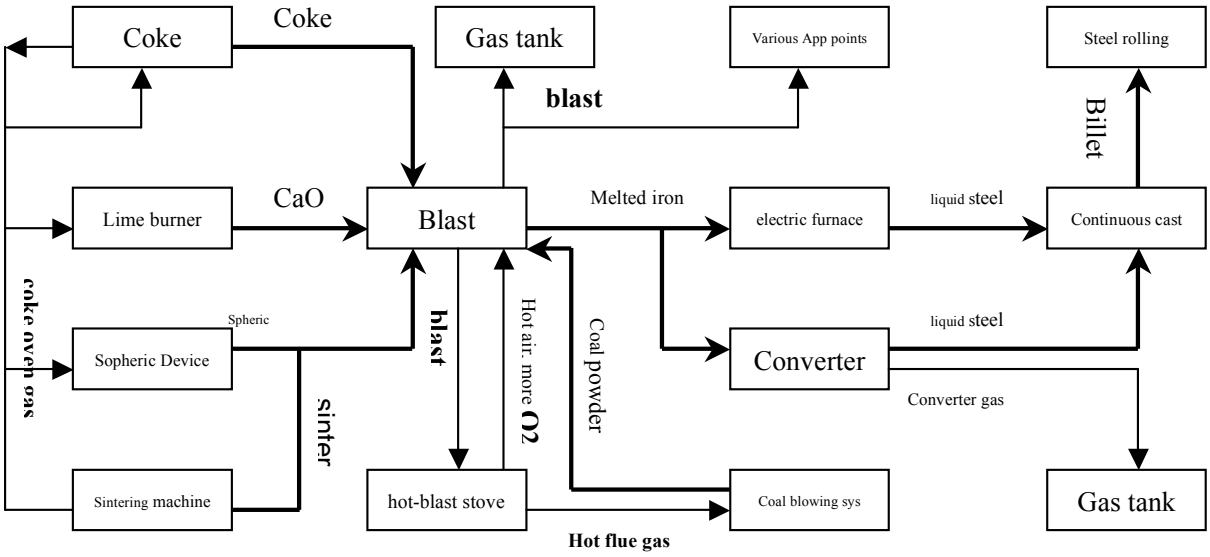
When maintaining, first close the bottom valve (no influence to production), then screw down the locking clip, clean the optical window, and then screw up the locking lip. It is shown in the right figure.

When calibrating, first close the bottom valve (no influence to production), then screw down the locking clip, and install the transmitter and receiver unit on the calibration pipe, and inlet the calibration gas. And calibration can be finished while operating the central processing unit or PC menu.

4. Applications in Steel Industry

4.1 Purposes

The basic process in modern steel industry is indirect fused smelting. Reduction smelting and oxidizing are the two basic steps in this process. The following figure is the sketch map for this process.



Note: In the above figure, bold arrow represents the flow direction of material and half finished product, and normal arrow represents gas flow direction.

During the smelting process, many gases will be generated. It is important to analyze and monitor these gases' concentration.

1. Optimize production process: such as blast furnace gas analysis system, converter/ electric furnace gas analysis system, and etc.
2. Recycle of fuel gas: such as converter gas recycling and analysis system, coke oven gas recycle and analysis system, and etc.
3. Environment protection & energy saving: such as flue gas analysis system after hot-blast stove, sintering/ lime burner flue gas analysis system, thermoelectric flue gas analysis system, and etc.
4. Safety control & analysis, such as blast furnace coal blowing analysis system, electrostatic tar filtering safety analysis system, electrostatic filtering safety

analysis system, and etc.

4.2 Typical Applications

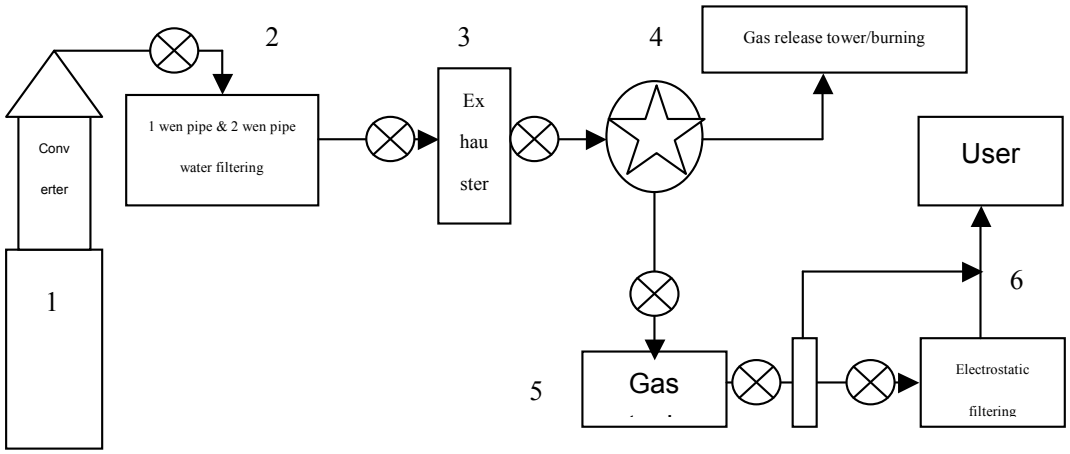
Plant	Monitoring Point	System Name	Gas under test	Process Purpose
Iron-making Plant	Gas pipe after gravity dust separator or after bag-type dust remover	Blast furnace gas analysis system	$CO/CO_2/O_2/H_2/CH_4$	Control the furnace status, optimize production process, safe production
	Mill inlet and outlet, cloth screen outlet, coal powder barn	Blast furnace coal blasting safety analysis gas	O_2/CO	Safety monitoring, explosion proof
	Hot-blast stove outlet gas flue	Hot-blast stove flue gas analysis system	O_2	Burning efficiency analysis
Steelmaking Plant	Before/after Exhauster	Converter gas recycle and analysis system	CO/O_2	Gas Recycle
	Electric furnace outlet gas flue	Electric furnace gas analysis system	CO/ CO_2	Optimize process
Gas Plant	Before/after gas tank	Before/ after gas tank safety analysis system	O_2	Safety Monitoring
	Before electrostatic filtering	Electrostatic filtering safety analysis system	O_2	Safety Monitoring
Coke-oven Plant	Before recycle fan	CDQ recycle gas analysis system	$O_2/CO/CO_2/H_2$	Control process, safe production
	Before coke oven electrostatic tar filter	Electrostatic tar filtering safety analysis system	O_2	Safety Monitoring
Thermal Electricity Plant	Blast furnace/ converter main gas pipe	Gas analysis system	CO	Gas content analysis
	Furnace outlet gas flue	Thermal electricity plant gas analysis system	O_2/CO	Burning efficiency analysis

4.3 Typical Cases

（1）Converter gas recovery

Converter is the main device for steel making. The gas produced by combustion reaction in the converter changes periodically. The periodic time of smelting is about half an hour. During the 10 minutes in the middle, much CO is generated, with high economic value of recovery. Generally, 50-100 m^3 gas can be recovered per ton of steel. The key is the control of recovery time and gas quality.

OG is one of the most popular methods for gas recovery. The temperature in the converter could reach 1400°C, the dust concentration could be higher than 200g/m^3, and recovery can only be conducted after cooling and dust removal. After that, use exhauster to extract the gas, when CO concentration has reached a certain valve, normally above 30%, open the 3-channel valve and store the gas in gas tank. Otherwise, burn it through the by-pass valve. The gas in the gas tank can be conveyed to users after electrostatic filtering.



1. Converter 2. OG cooling & de-dusting system
3. Exhauster 4. 3-channel valve 5. gas tank 6.electrostatic

During the steel making and fuel gas production process, the following segments need gas analysis system:

1. Converter gas recovery analysis system

By analyzing converter gas before/after exhauster, it helps judging whether the gas has reached recovery standard, then it is possible to control the 3-channel valve, to recover or to evacuate. 50-100m^3 gas can be recovered per ton of steel for converter smelting. Thus converter gas recovery has high economic value. During the gas recovery process, recovery time and gas quality are the key parameters, thus online analysis of CO and O_2 concentration is necessary, providing parameters for recovery control.

2. Gas safety analysis system

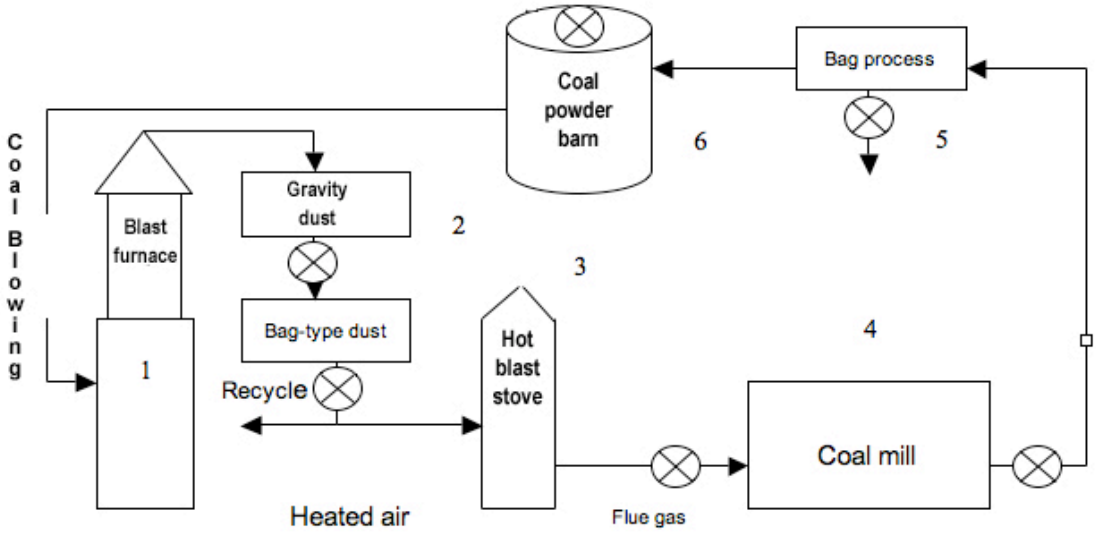
Coal gas is a very flammable gas. When mixed with certain amount of O_2, it will explode when heated to a certain degree. It is thus necessary to inspect O_2 concentration to avoid explosion. By analyzing O_2 concentration before/after gas tank and before electrostatic filter, O_2 concentration in the coal gas can be calculated, then gas quality can be known, and further operation, whether to bypass or not can be determined to avoid explosion.

Gas and environment parameters, measurement requirements required by steel making process:

Monitoring point	Temperature (^oC)	Pressure (Mpa)	Dust (mg/m^3)	Gas under test	Process purpose
Before exhauster	<75	Negative pressure	150	CO/O_2	Recycle control
After exhauster	<75	30mbar	150	CO/O_2	Recycle control
Before gas tank	<75	30mbar	150	O_2	Safety monitoring
After gas tank/ before electrostatic filter	Room temperature	30 mbar	150	O_2	Safety monitoring

TAI's laser in situ online gas analysis system has the following features:

- Response time < 1s，8-10Nm^3 gas can be recycled per ton of steel
- Accurate measurement data, good quality of recycled gas
- Conduct safety control in time
- Easy to use and maintain, low operation cost
- No sampling & pretreatment system, high dependability



1. Blast furnace 2. Gravity dust separation and bag type dust remover
3. Hot blast stove 4. Coal mill 5. Bag process 6. Coal powder barn

（2）Blast furnace and coal blowing system

During the iron making process, the following areas require gas analysis system:

1. Blast furnace gas analysis system

Gas analysis at the top of blast furnace can provide important information. Gas concentration is also a key parameter of blast furnace's mathematical model. During blast furnace smelting, whether CO_2 or CO concentration varies according to general smelting patterns is an important indicator showing the blast furnace status. Therefore, during normal smelting, most factories draw gas curves to observe the blast furnace status. If disrupted, different parameters can be adjusted to make the blast furnace work at its best. By analyzing $CO/CO_2/O_2/CH_4/H_2$ concentration in the off gas of blast furnace after gravity dust separation or bag-type dust removing, it helps judging the combustion status in the blast furnace and iron ore reaction status, then to control air blowing, coal blowing, iron ore feeding time, speed and quantity, to optimize burning, save fuel and cost, and improve iron making quality.

（2）Hot-blast stove residue O_2 analysis

By conducting residue O_2 analysis in the off gas generated in the hot-blast stove, it helps

to judge the combustion status in the hot-blast stove. By controlling the air & coal blowing speed, combustion efficiency can be increased.

（3）Coal blowing system safety analysis

Blast furnace coal blowing analysis system is a typical safety control device. By analyzing O_2 concentration at the inlet of coal mill, outlet of coal mill and outlet of bag, it helps controlling the O_2 concentration entering the coal mill and coal powder barn. When O_2 concentration exceeds 10%, blow N2 to dilute it, to avoid explosion in the coal mill. As the gas in the coal powder barn is the off gas lead from the flue after hot-blast stove, high concentration of CO and O_2 will cause explosion. Therefore, real time inspection of off gas in the coal powder barn is required, to make alarms and N_2 dilution in time.

Gas and environment parameters, measurement requirements required by iron making process:

Monitoring point	Temperature (°C)	Pressure (Mpa)	Dust (mg/Nm^3)	Water g/Nm^3	Gas under test	Process purpose
After gravity dust separation	<400	Normal	20000	50	$O_2/CO/CO_2/H_2/CH_4$	Process control
After bag-type dust remover	200	Normal	10	50	$O_2/CO/CO_2/H_2/CH_4$	Process control
Hot-blast stove outlet	<300°C	Normal	20	——	O_2	Burning control
Coal mill inlet	<450°C	Normal	10	——	O_2	Safety monitoring
Coal mill outlet	<450°C	Normal	$200g/Nm^3$	——	O_2	Safety monitoring
After cloth screen	<150°C	Normal	50	——	O_2	Safety monitoring

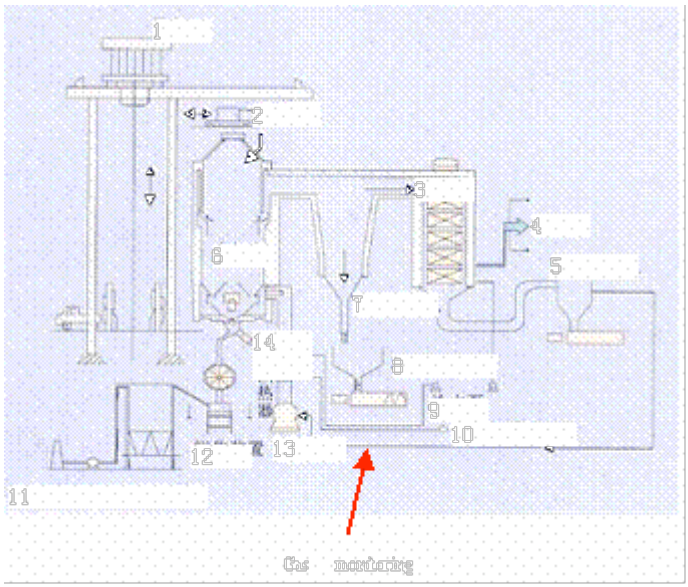
Coal powder barn	<100°C	Normal	200 g/Nm^3	——	CO/O_2	Safety monitoring

TAI's gas analysis system has the following features:

- Quick response, response time is shorter than 1s, can conduct process & safety control in time
- Accurate measurement data
- Increase blast furnace process control level
- High dependability, small maintenance & calibration workload
- Lighten operators' workload
- Lower device operation cost

（3）CDQ recycle gas analysis

The purpose of analyzing O_2, CO, CO2, and H_2 concentration in the CDQ recycle gas is to optimize process, control coke product quality, provide accurate and dependable data for safety control, and give alarms in time.



1-crane; 2-tar tank; 3-boiler; 4-environment; 5-2nd dedusting; 6-cooling room; 7-1st dedusting 8-dust discharge device;9-water supply pump; 10- recycle gas fan; 11-environment dedusting & control of dust pipe; 12-de-tar device; 13-recycle gas fan; 14- cool water pre heater

Gas and environment parameters, and measurement requirements required by CDQ process:

Monitoring point	Temperature	Pressure	Dust	Gas under test	Process purpose
Before recycle fan	<170°C	3.4KPa	1 g/Nm^3	CO/CO_2/O_2/H_2	Control coke quality, safe production

（4）Electrostatic tar filtering safety analysis

Electrostatic tar filter is an effective electrostatic filter, can reduce the tar fog mixed in the coke oven gas. Coke oven electrostatic tar filter has to monitor O_2 concentration continuously to avoid safety problem generated by high O_2 concentration. The O_2 analysis system is critical to the filter operating rate and safe plant operation. Conventional O_2 analysis system can hardly deal with the tar fog. Besides, temperature control part and other parts need replacement periodically, thus conventional ones have high inspection cost. However, Laser in situ online gas analysis system do not need any sampling or pretreatment system, thus needs small maintenance workload and low operation cost。

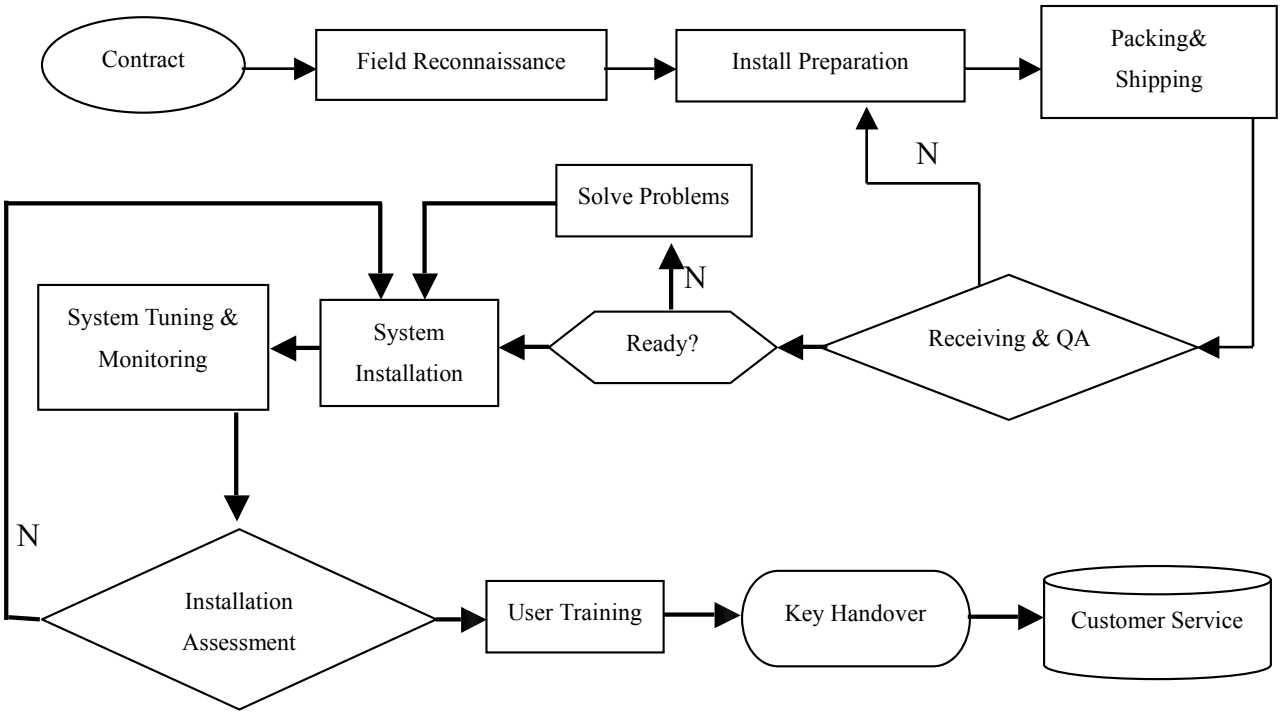
Gas and environment parameters, measurement requirements required by electrostatic tar filtering process:

Monitoring point	Temperature	Pressure	Dust	Tar	Gas under test	Process purpose
Before electrostatic tar filter	22°C	Slight negative pressure	Micro dust	Before electrostatic tar filtering: 80-120mg/m^3 After electrostatic tar filtering: 10 mg/m^3	O_2	Safety analysis

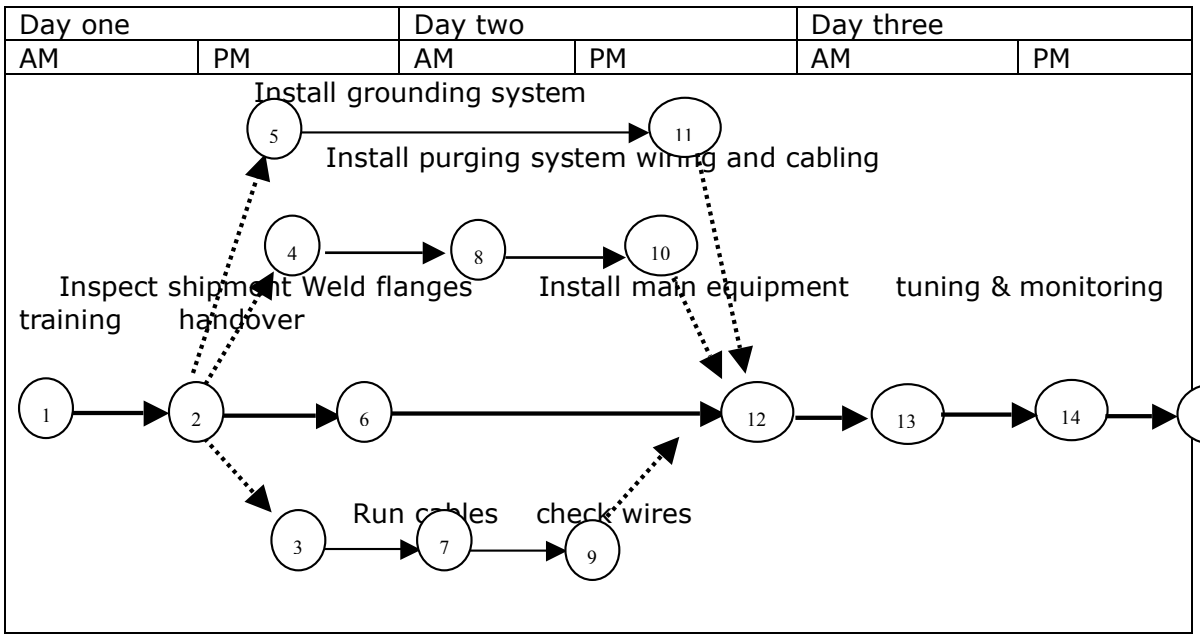
5. Project Implementation & After Service

5.1 Project Flowchart

TAI acknowledges the importance of product support and training at the commissioning stage. Therefore, TAI has developed a thorough set of flow charts to ensure the best long-term interests of the customers, ranging from customer project initiation to installation to assessment and handover to after-sale services.



5.2 Field Application Schedule



5.3 Service

Technical Support

TAI is dedicated to providing customers with the best pre/post-sale services, and helping them to optimize their project designs to achieve the ultimate performance-to-cost ratios.