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Title – Comparison of a Networked Multi-head AC Coupled Triboelectric Digital Dust 'Transmitter' system to other 'traditional' dust monitoring systems.

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ABSTRACT

Legislative pressure to monitor ever-smaller sources of emissions has resulted in the need for economic high performance solutions to many emission monitoring requirements. For particulate measurement traditional optical systems are proving to have too high a cost of ownership for applications with multiple emission points. Triboelectric instruments have gained considerable acceptance as an economically viable technology. Goyen, a pioneer of AC coupled triboelectric technology, have developed a totally digital AC coupled system with high-level communications capability which approaches the simplicity and 'user -friendly' performance of a simple transmitter.

This paper describes the components of a typical AC coupled networked triboelectric dust 'transmitter' system and compares the performance and cost to both traditional optical instrumentation and DC coupled triboelectric systems. Data from typical application examples will be used to demonstrate the performance of typical systems e.g. emission from a municipal waste incinerator and filter system 'break through' monitoring. The data shows very clearly that an AC coupled triboelectric dust monitoring system where the function of the instruments has been so simplified that they can be reasonably described as dust transmitters, can more than adequately comply with European legislative demands for reproducibility, accuracy and reliability.

The system, which operates fully digitally, can be directly integrated into SCADA and DCS systems. Its outputs can also be simply converted from the RS485 half duplex network to RS232 for small simple systems allowing a low cost PC to be used to evaluate the results and carry out regulatory requirements of data storage and averaging.

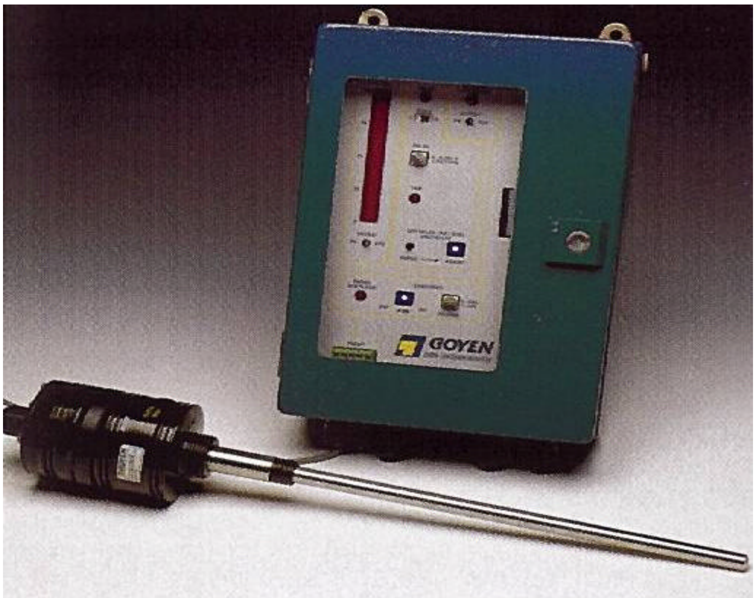
INTRODUCTION

There is a clear growing desire on behalf of regulators to monitor medium and small sized industries dust emissions on a continuous basis. Economic pressures have in the past made this unrealistic as even low cost transmisometer opacity system were not 'low enough' in price and as the quality levels for dust dropped rapidly throughout Europe (typically below 20 or even 10mg/m3); they could not be used as their lower detection limit is 20 or 30mg/m3n depending of course and duct size and to a lesser extent on particle size distribution.

Triboelectric probes have become much more accepted over the last years, particularly 'AC tribe'(the difference between DC and AC triboelectric probes is explained in a later section of this paper) but whilst the cost of obtaining a signal which is proportional to the dust has been reduce the cost of installation temperature including control boxes, AC power to all the heads, data acquisition systems etc has meant that the real saving has not been as large as expected when only the cost of the dust monitoring hardware was taken into consideration.

The illustrations below show clearly the amount of 'excess hardware' necessary to make a complete system.

Typical Previous generation Triboelectric Monitor



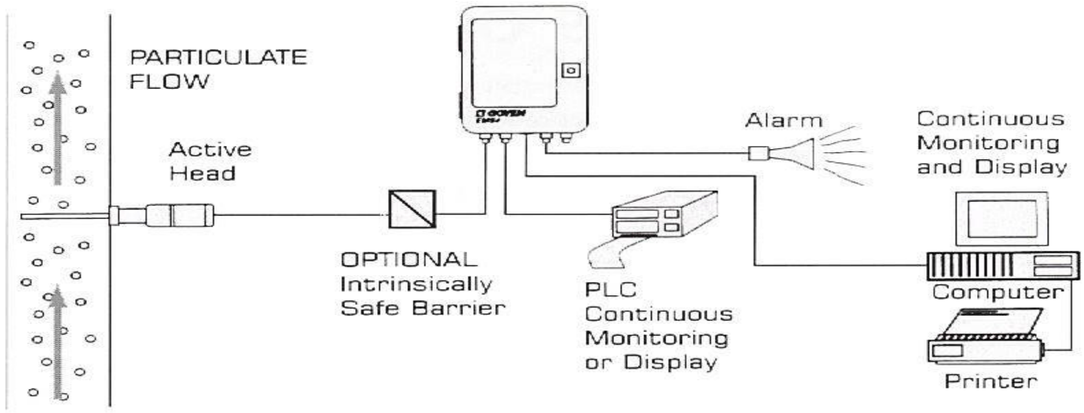


Fig 1 Schematic showing the extent of hardware needed by an earlier generation Triboelectric dust monitoring system.

AC Coupling vs. DC Coupling

The "triboelectric" effect is the transfer of electric charge on contact between dissimilar materials, traditionally by rubbing. All moving particles acquire a small charge by this mechanism from collisions with the duct, dampers, filter elements, other particles and even with air. When particles collide with or pass close to the probe of an AC triboelectric emission monitor , a small electric current is induced in the probe by one of these mechanisms:
induction (charged particles produce a varying electromagnetic field, which induces current in the probe), or
electrostatic transfer (from charged particles to the probe when they touch), or
triboelectric generation (from all particles which collide with the probe).
These effects are not dependent on whether the flow is turbulent or laminar. However increased turbulence can lead to higher effective velocity at the probe, and even to recirculation of particles past the probe, so for best accuracy, probes should be mounted at least 5 diameters from any bend or other discontinuity.

The electric current collected by the probe is highly random by nature, and always includes both a steady (DC) component and a varying (AC) component. A DC coupled electronic circuit will pass both of these components, but the detection circuits in a typical DC coupled emission monitor will ignore the AC component. AC amplifiers, however, are usually considered to be more predictable, and AC triboelectric signals to be more meaningful.

An AC coupled emission monitor will typically include a number of stages of amplification, coupled together by capacitors which pass only AC signals, with filters to exclude unwanted frequencies, and high overall gain. A "detector" then converts the amplitude of the amplified and filtered AC signal into a DC signal, which is either transmitted as 4-20mA, or further processed in a microprocessor, and transmitted via a network. The total combination of all these issues produces a certain characteristic which is often given a specific name, and the characteristic adopted for the EMS and EMP series emission monitors is termed "tribo-kinetic".

Parameters Which Influence the Signal

‘most competitive techniques decry Triboelectric a as a temperature sensitive velocity measurement’

The sensitivity of a Triboelectric Emission Monitor depends on a number of parameters. In most industrial processes these parameters are well controlled, and hence the output from EMS6 will also be very consistent. However when one or more of these parameters varies substantially, the emission signal may also vary. In most cases the user need not be aware of any of these parameters, however there are some situations where the user should be aware of the potential impact of the parameters, in order to obtain optimum accuracy from the Emission Monitor. The following explanations are intended for those situations.

CONNECT software and most SCADA systems can be configured to display emission values in any required units. Gas velocity has negligible effect on a Triboelectric Emission Monitor’s "natural" output of particulate flow rate, e.g. mg/s or kg/hr. For any given particulate mass density (mg/m^3), increasing the gas velocity will increase the particulate flow rate, and hence the Emission Monitor output. An emission signal calibrated in such units can be totalled over a period to produce the total mass emitted over that period. Also, such a signal is independent of any excess air introduced. For example, if the gas stream were diluted with an equal flow of air, the velocity would double, the particulate mass density would halve, but the Emission Monitor measurement would correctly remain approximately constant. In summary, a Triboelectric Emission Monitor measures emissions in terms of mass flow rate, so if mass flow rate units such as kg/hr are used, the signal will be relatively immune from velocity effects, and can be averaged or summated meaningfully over a period of time.

Many users, however, prefer to display emissions in mass density (e.g. mg/m^3) rather than mass flow rate. Triboelectric Emission Monitors are commonly calibrated in such units, and when gas velocity varies only a little, as in most plants, the calibration will still remain valid. If the gas velocity varies substantially from the velocity at calibration, however, the effective mass density sensitivity will vary, and summations over time become less meaningful. This will be seen as velocity sensitivity, which may be an important consideration.

Particle size affects the sensitivity of a Triboelectric Emission Monitor to create substantial effective differences in sensitivity between different sites. Within most sites, however, there is usually a wide and reasonably constant distribution of particle sizes, so the effect is not seen. Particle size variations affect the available accumulated particle charge (due to different energies, momenta and physical interactions), and in the inherent sensitivity of the AC Triboelectric Emission Monitor (due to the masking effect of many small particles on each other). However the variations are often advantageous. For example, the exhaust from a properly functioning bag filter system contains mainly very small particles, but when a bag begins to rupture, the mean particle size increases, which increases the sensitivity of the Triboelectric Emission Monitor. At the same time, the output from a Triboelectric Emission Monitor is usually somewhat less than proportional to actual mass flow rate, but in this situation, the two effects tend to cancel, the result being much closer to linear.

Material chemistry; each material has a unique position in the triboelectric series. When two materials interact, the signal generated is related to their separation in the triboelectric series. In the case of Triboelectric Emission Monitoring, the particulate matter interacts with the duct, the filter medium, the gas and the probe, and all these interactions affect the final signal.
Material physics; the processing of a material (particularly combustion) affects it's structure, which in turn determines the physical properties of the surface such as hardness, flatness, malleability, etc, all of which affect the way in which a particle interacts with other particles. Furthermore, most processed particulates are heterogeneous, so the composition of the surface may differ from that of the interior, leading to different triboelectric properties.
Moisture content can affect both the material chemistry and material physics, and hence the sensitivity, particularly if the moisture is concentrated at the surface. This is especially significant for monitoring the output of wet scrubbers, far less so for the output of combustion processes.
Gas temperature has little direct effect on triboelectric monitoring, however temperature may affect the moisture content of the particles, and even the material physics, and therefore indirectly affect the sensitivity. Ambient temperature has no effect on triboelectric monitoring, provided it is within the specified range.
Turbulence has no direct effect on sensitivity, except that turbulent flow will generally be seen as a higher velocity, and therefore a higher sensitivity. In extreme cases, such as when a probe is positioned just after a bend on the inside, there may be sufficient local recirculating eddy currents that the Emission Monitor sees a particulate level which is both artificially high and remains long after the particulate flow has ceased.
Probe geometry: the recovered electrical signal from the probe depends on the effective coupling from the particulate to the probe, and in particular the frontal surface area of the probe exposed to the flow. Varying the probe size and geometry is a convenient way to increase the sensitivity when the particulate is very insensitive and in low concentrations, or vice versa. The probe can vary from a few cm long "stub" to a conventional wire extending perhaps 60% across the duct, to a welded mesh screen across most of the duct area (e.g. 5mm stainless steel wire in a 100mm mesh). The most critical issue with such large geometry probes is the need for additional support, because the insulation at the supports may be degraded by high temperatures or surface pollution by product deposits. Both of these potential problems can be minimised by mounting the insulators out of the gas stream in, say, tubular ports through which cool clean air is allowed to enter the stack.

A Triboelectric transmitter

A new generation tribo developed which is an integrated probe and digital monitor, avoiding the inevitable noise, signal loss, linearity loss and microphonics of a passive probe with separate electronics.
Probes mount to nodes via a standard M8 thread, and so can be replaced easily if damaged, or to adjust coverage. Standard probes are 300mm stainless steel wire rope, but many variants are available to suit different applications, including various lengths of rigid rod, telescopic tube and plain wire rope, plus custom wire rope arrays and custom materials such as Tungsten Carbide.
Purge Air facilities to clear particulate build-up from the probe in hostile environments.
Robust machined alloy housing, with inserted parts of stainless steel.
An open architecture with simple industry-standard Modbus RTU ™ compatible communications protocol, so the user can alternatively purchase monitors only, and easily interface them to either a Modicon™ or other compatible PLC, or any central SCADA system. Modbus™ documentation, support and expertise are plentiful, so customers will not feel isolated.

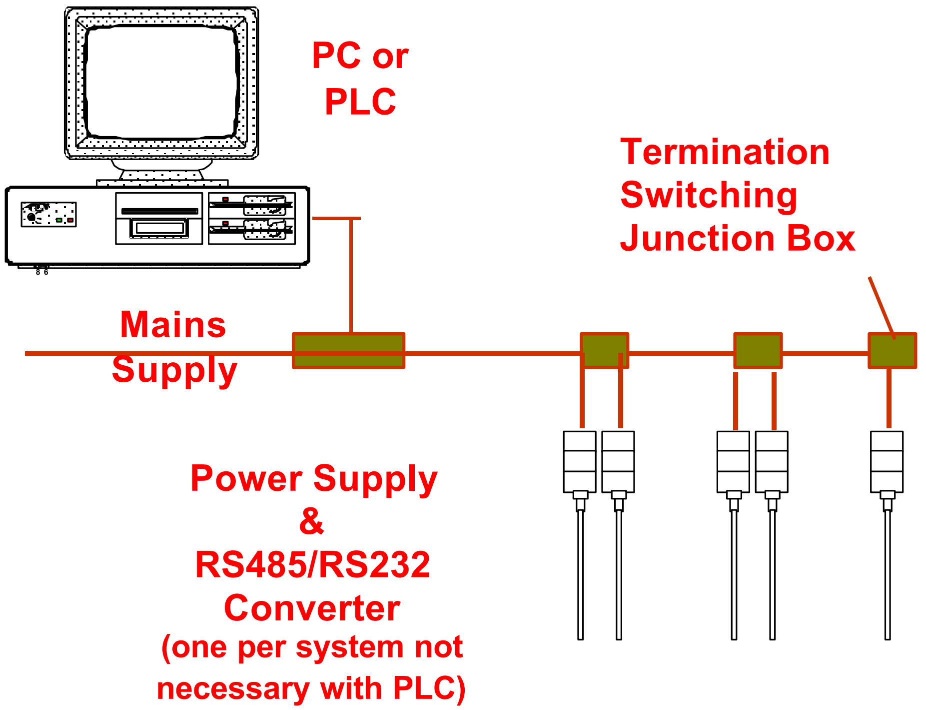


Fig 2 Schematic of AC Tribo Multi-head Transmitter system

The new generation of low energy electronics gives the new transmitter a very low power consumption, only 5mAmp per node! up to 29 EMS6s can be connected to and powered from a single "daisy chained" network, covering up to 1km, and making wiring easy. There is no need for separate power supply for each transmitter. There is no limit to the number of networks.

Monitors can be assigned a Network ID and Gain via selector switches, and all other configuration and operation is remote; there is no need for ongoing access to tapping points, so commissioning and maintenance are easy. The unit can also support changes to Network ID and Gain via the network, avoiding the need to access the instrument physically except for a 6 month probe cleaning in most applications.

SYSTEM COMPONENTS

The lack of AC power installation, simple junction boxes plus the ability to add other older dust monitoring systems from any manufacturer to the system so long as they have a voltage or a 4 to 20mAmp analogue output using an small access card means that the previous generation of triboelectric monitors' high 'system' cost is eliminated. The connect access card shown below can also allow the introduction of other parameters such as oxygen, differential pressure etc to be included in the data logging system.

APPLICATION EXAPMPLES

1- Municipal Incinerator

The trace shows two probes mounted at different probes on a Municipal Waste Incinerator where the average levels were considerably lower than 1mg/m3. The spikes show the reverse air cleaning pulses of the individual rows of filter bags – Trace I which follows
Trace 2 shows and expanded portion of trace 1 clearly showing that despite the low levels of emissions there are varying levels of filter performance in the 'baghouse'.

2-Steel Works

Large filter plant with low velocities, 2 to 3 m/second and with discharge direct to the atmosphere present a challenging monitoring problem as. the discharge does not narrow to a stack or duct have always presented problems the ability of the new 'transmitter' to accommodate large complex sensor and provide more than acceptable results is clearly shown in trace 3. The initial peaks are the checks with small dust quantities that all parts of the sensor are equally responsive the second half of the trace shows a scrap melt with 2 complete cleaning cycles of the filter. The base line drift is low and results from an incre3ase in gas temperature from ambient to 130degrees c,

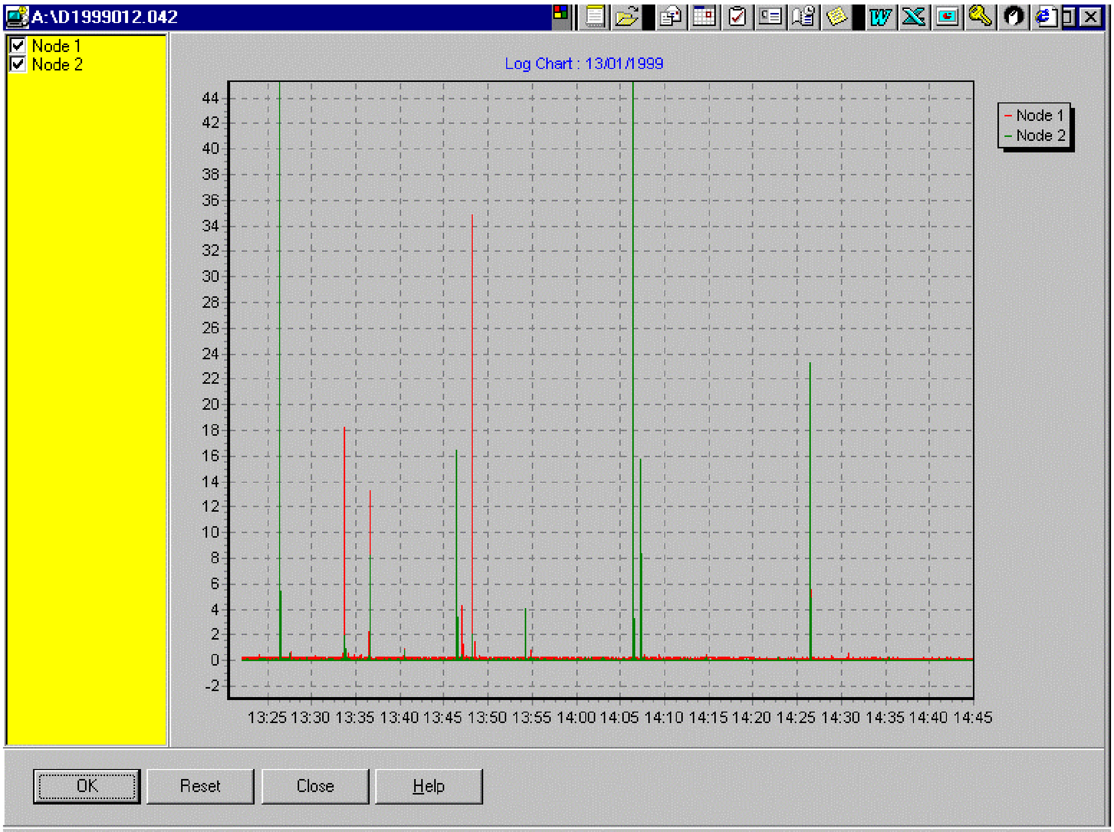
3 Broken Bag Discrimination

Using access cards on the RS485 bus it is possible to distinguish which row of bags is responsible for a peak emission. Fig 5 shows a schematic and also clearly indicates how older generations of monitors can be included in the bus system.

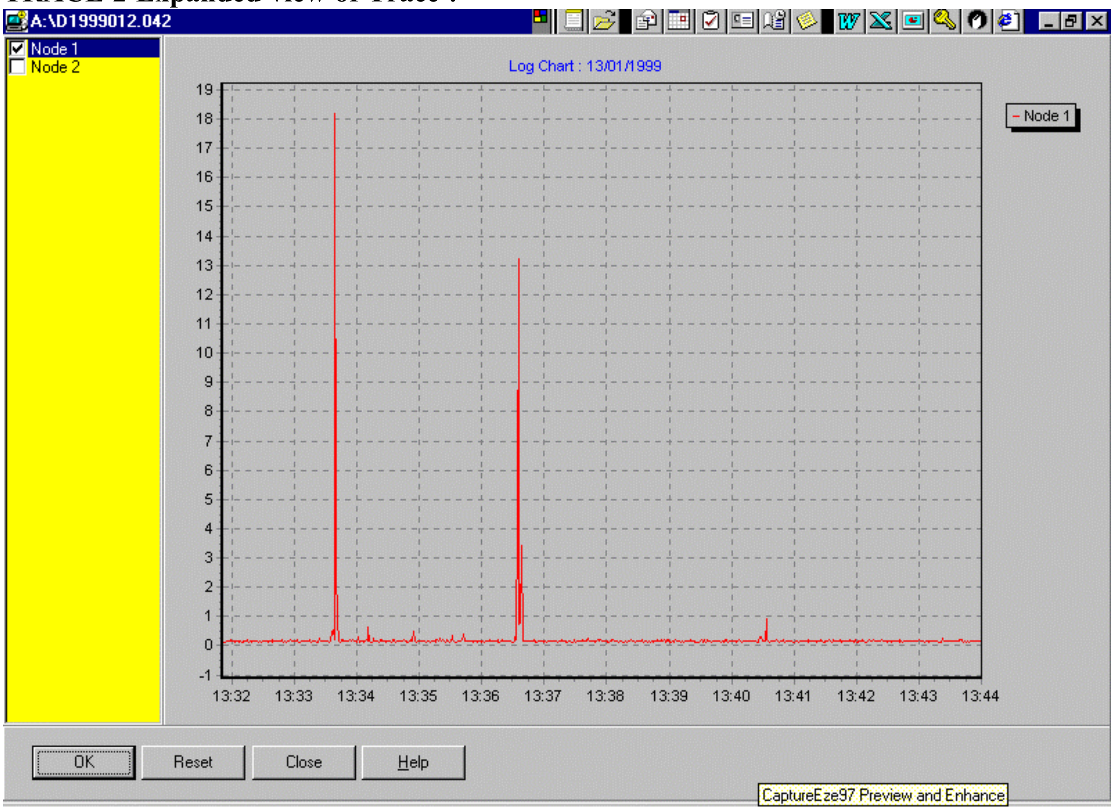
CONCLUSION

The use of low cost dust transmitters and access cards allow cost effective monitoring systems for complex applications. Easy economic installation with low cost of ownership.

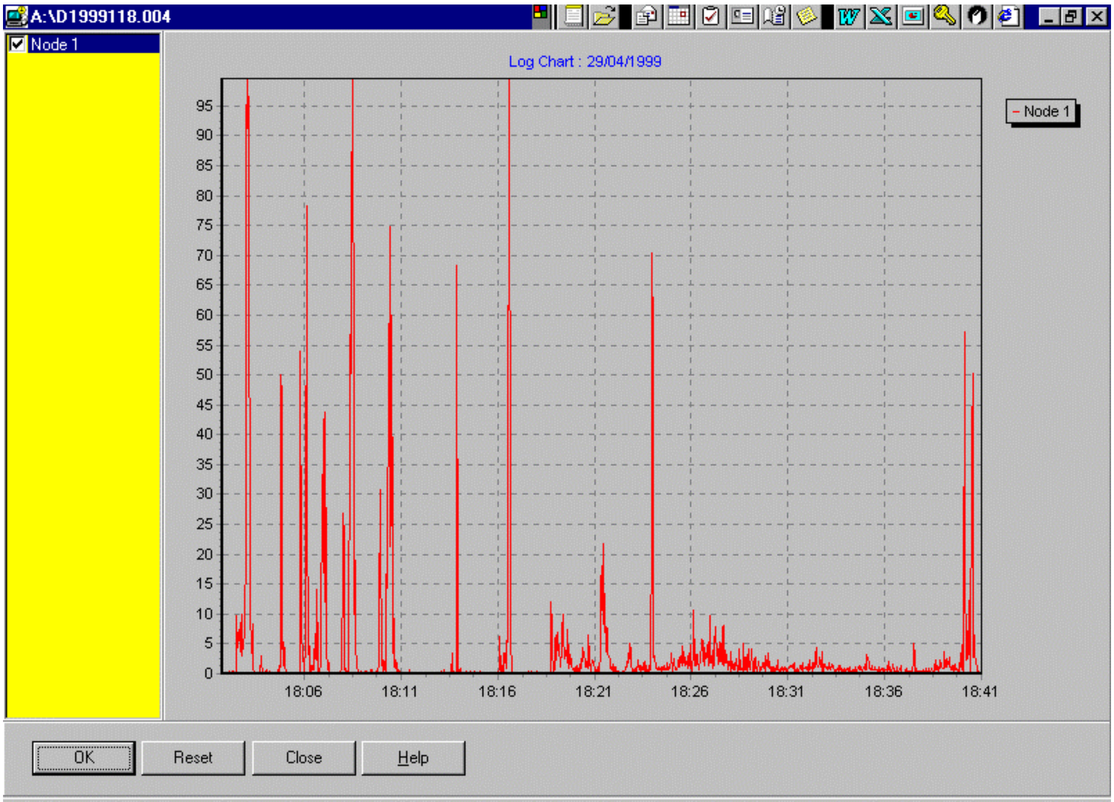
TRACE 1 Municipal Incinerator



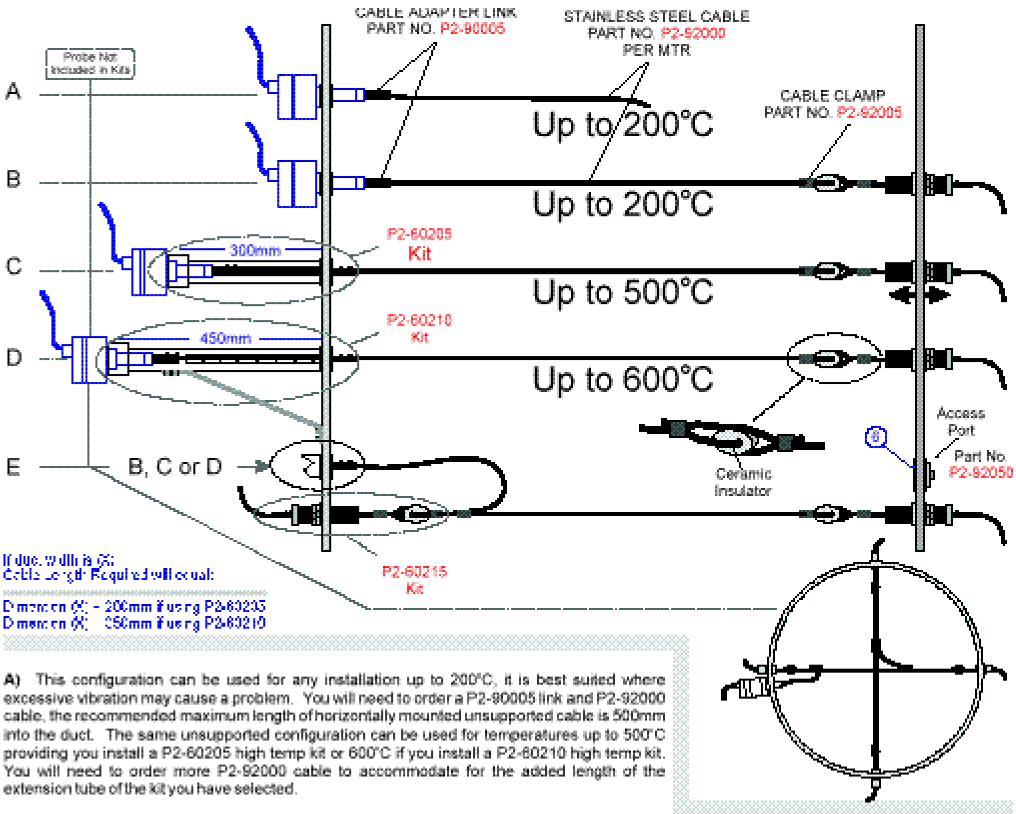
TRACE 2 Expanded view of Trace !



TRACE 3 Steel Works Reverse Air Filter

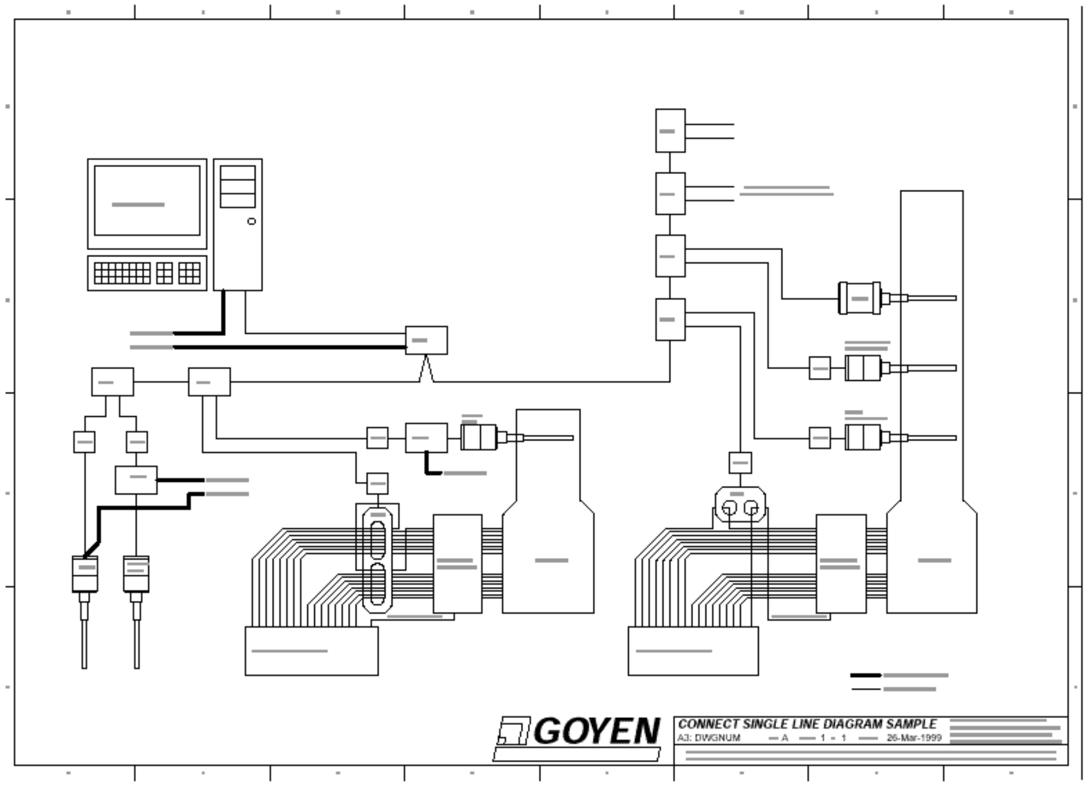


Varied Geometry Probes



A) This configuration can be used for any installation up to 200°C, it is best suited where excessive vibration may cause a problem. You will need to order a P2-90005 link and P2-92000 cable, the recommended maximum length of horizontally mounted unsupported cable is 500mm into the duct. The same unsupported configuration can be used for temperatures up to 500°C providing you install a P2-60205 high temp kit or 600°C if you install a P2-60210 high temp kit. You will need to order more P2-92000 cable to accommodate for the added length of the extension tube of the kit you have selected.

Fig 5



Typical Multi Sensor system.