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Casting Emission Reduction Program

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Second Verification of SIVL: Triboelectric Particulate Monitors - Monitor A

Technikon # 1411-234-A

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(Revised for public distribution)

EPA United States Environmental Protection Agency

CISA

AFS

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

USCAR

DAIMLERCHRYSLER Ford Motor Company GM General Motors

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Second Verification of SIVL: Triboelectric Particulate Monitors – Monitor A

Technikon # 1411-234-A

This report has been reviewed for completeness and accuracy and approved for release by the following:

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Executive Summary

As part of the Systems Integration and Validation Laboratory (SIVL) project, monitoring instruments for measuring particulate emissions from typical foundry processes that included metal pouring, cooling and shakeout (PCS) were installed in the emissions stack of Technikon's Research Foundry. Two monitors utilizing the triboelectric effect for particulate detection were chosen for the purpose of qualitatively evaluating their responses to PCS emissions from foundry operations.

These monitors were operated during three greensand mold tests with each test incorporating different molding materials. These included molds made from greensand containing a premix without seacoal and with the pattern coated with a release agent containing graphite (Test GL); an uncoated hotbox core set in a mechanically-produced clay, water, a greensand mold also without seacoal (Test GH); and molds from an uncoated baked oil sand core that was set in a mechanically-produced clay, water, and seacoal-less greensand mold (Test GM). Molds used were 4-on step-core, and a 4-on coreless star for tests GM.

Of the two monitors, Monitor A was found to have a lower noise level and was more sensitive to particulate producing events. Monitor profiles were found to parallel the time profile of major emission events that have been verified by the well characterized E-Bench total hydrocarbon (THC) monitor. Monitor A's responses were consistent and reproducible during all runs from an individual test, as well as between different tests. This behavior suggests it may be used as a continuous emission monitor provided it is calibrated through isokinetic sampling against standard particulate matter of defined size and mass.

Particulate matter Monitor B is specifically designed as a bag leak detector, and as is consistent with this function it was found to have a more stable response, with slight variance during furnace events, and responding mostly to mold shakeout. Neither monitor responded significantly to metal pouring, suggesting that most emissions associated with this event are of a fume or gaseous nature, rather than being in particulate form.

This report describes and summarizes the testing, data and results for tribo Monitor A.

A comparison report, Technikon # 1411-234-B, describes the testing, data and results for Tribo Monitor B.

It must be noted that the results from any testing performed are suitable only for evaluating the relative emissions and emission profiles associated with the materials, equipment, or manufacturing processes tested herein. The emissions are unique to the specific castings produced, materials used, and testing methodology associated with these tests. These measurements should not be used as the basis for estimating emissions from actual commercial foundry applications.

1.0 INTRODUCTION

1.1.Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The parties to the CERP Cooperative Research and Development Agreement (CRADA) include The Environmental Research Consortium (ERC), a Michigan partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation; the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC), a laboratory of the United States Army; the American Foundry Society; and the Casting Industry Suppliers Association. The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data.

1.2.Technikon Objectives

The primary objective of Technikon is to evaluate materials, equipment, and processes used in the production of metal castings. Technikon's facility was designed to evaluate alternate materials and production processes designed to achieve significant air emission reductions. The facility has two principal testing arenas: a Research Foundry designed to measure airborne emissions from individually poured molds, and a Production Foundry designed to measure air emissions in a continuous full scale production process. Each of these testing arenas has been specially designed to facilitate the collection and evaluation of airborne emissions and associated process data.

It must be noted that the results from any testing performed are suitable only for evaluating the relative emissions and emission profiles associated with the materials, equipment, or manufacturing processes tested herein. The emissions are unique to the specific castings produced, materials used, and testing methodology associated with these tests. These measurements should not be used as the basis for estimating emissions from actual commercial foundry applications.

1.3.Objectives of This Study

Two particulate monitors utilizing the triboelectric effect for particulate detection were installed in the emissions stack of Technikon's Research Foundry for the purpose of qualitatively evaluating their responses to particulate emissions from foundry operations including metal pouring, cooling, and shakeout. This report describes and summarizes the testing, data and results for tribo Monitor A. Details of monitor operation and setup may be found in Appendix A of this report. A brief description of the operating principle used for the monitors follows.

Description of the Triboelectric Effect

The triboelectric effect is the transfer of electric charge between dissimilar materials (electrostatic charge). Generally, if two materials collide, then the further they are separated on the triboelectric series, the more charge will be transferred. Electrostatic charges from the friction of particles contacting the particulate monitor probe will electrify the probe, causing the production of a small current in the probe. A small current may also be induced in the probe when charged particles pass by.

One type of triboelectric device measures the DC current produced by the charge transfer when particles strike the probe. The current is proportional to the momentum of the particles. A direct correlation exists between the signal strength and particulate concentration in a pipe or duct when the velocity and the material being monitored are relatively constant. Other tribo devices use the AC component of the induced current in the probe caused by charged particulate pass by, rather than the charge created by contact with the probe. Because the signal produced by these monitors may be affected by several factors, the instrument output must be correlated to manual gravimetric measurements if quantitative data are needed. Some of the factors that may affect the relationship between particle mass and the monitored signal are particle velocity, particle characteristics (composition and size), and particle charge. Probe electricification does not work well in wet gas streams with water droplets or when the particles are subject to a varying electrical charge. The AC component of the induced current is used to minimize the effect of velocity on the measurement.

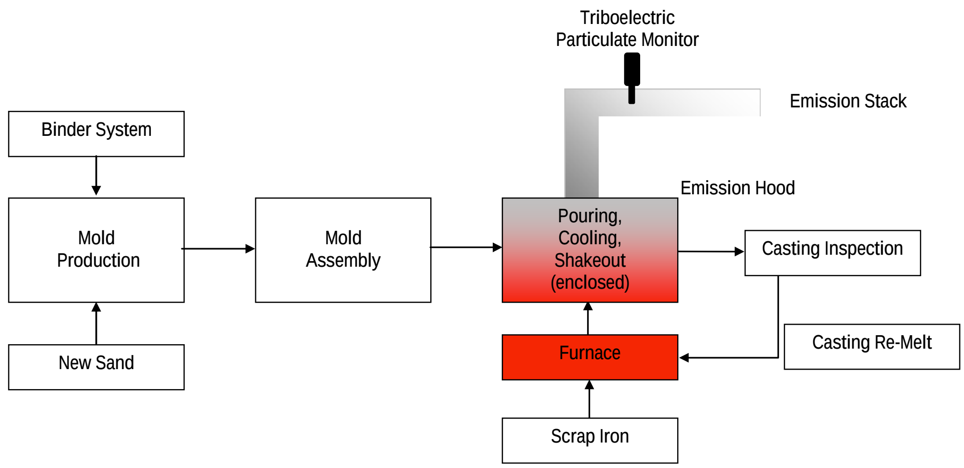
2.0 TEST METHODOLOGY

Technikon has developed the capability to reproducibly generate emissions from mold production, core making, metal melting, and mold pouring, cooling and shakeout processes under controlled conditions. Technikon has a general purpose, non-automated metal casting plant, which has been adapted to generate, collect and measure emissions, using methodologies based on EPA protocols for pouring, casting cooling, and shakeout processes on discrete mold and core packages under tightly controlled conditions not feasible in a commercial foundry.

2.1.Description of Process and Testing Equipment

This research foundry utilizes cored and un-cored greensand and No-Bake® molds. In order to obtain reproducible emission samples, a number of process parameters are carefully controlled. Process and stack parameters include the weights of the casting, mold, seacoal additions, core and binder; loss-on-ignition (LOI) values for the mold prior to the test and at shakeout; LOI for the core; percent clays and metallurgical data. Stack parameters measured include temperature, pressure, volumetric flow rate, and moisture content. The process parameters are maintained within prescribed ranges in order to ensure the reproducibility of the tests. A layout of the Research Foundry with the location of the particulate monitor indicated is provided in Figure 2-1.

Figure 2-1 Research Foundry Process Flow



Emission samples for the evaluation of the triboelectric monitors were generated through the melting, pouring, cooling and shakeout periods of three greensand mold tests, each of which used different molding materials. The emissions duct is clearly visible (covered with white insulation) at the top of the foundry emission hood where these processes occur, as shown in the photograph in Figure 2-2. Figure 2-3 shows the metal initially being poured into the mold contained in the hood, the event that signals the beginning of a run. The emissions duct connects to the main emissions stack behind the hood, as does the furnace vent at a point slightly downstream from where the emissions duct enters. The triboelectric instruments detected particulate originating from both of these sources. The location of the monitors installed on the stack is shown in Figure 2-4.

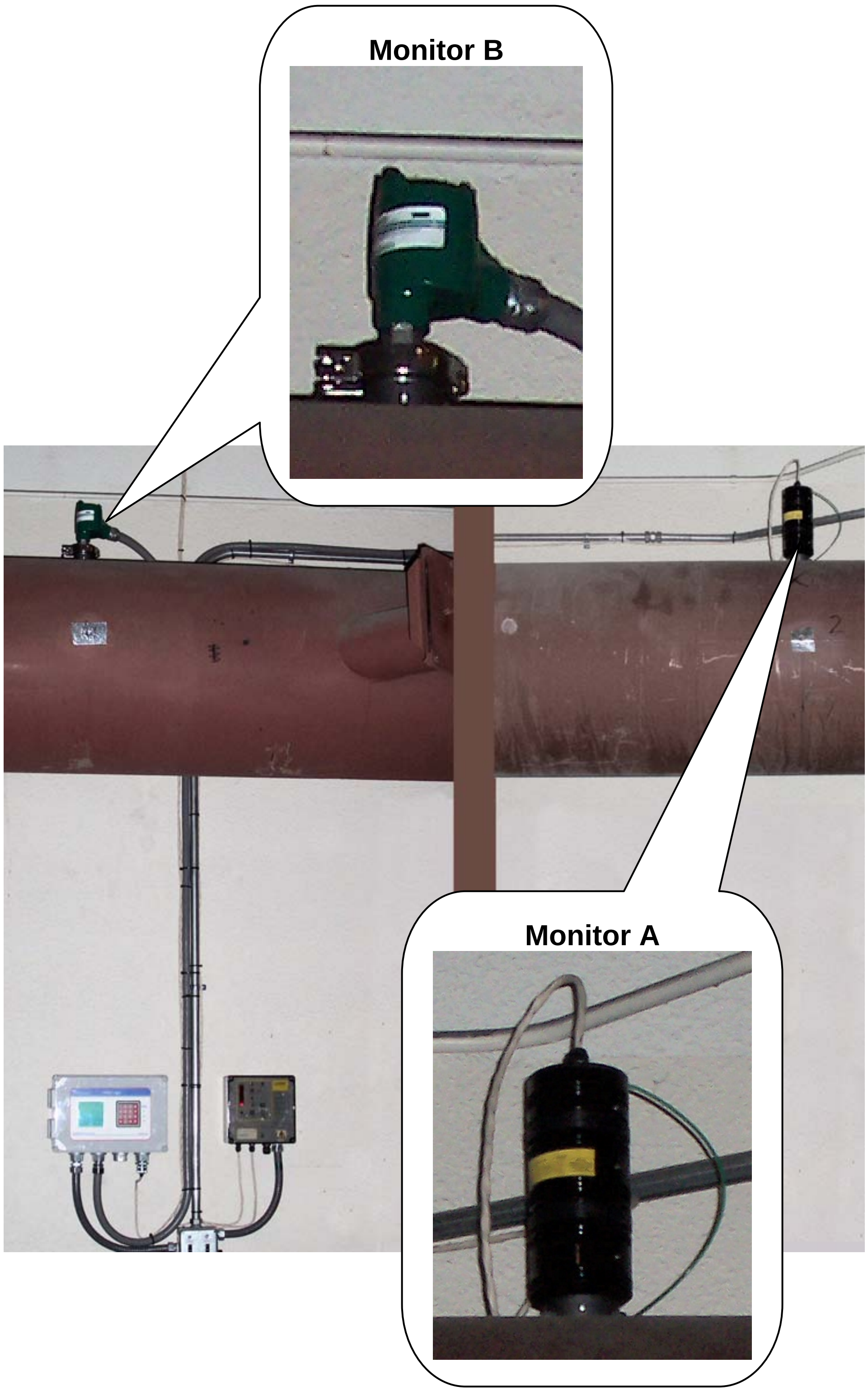
A particulate monitor consisted of a sensor head with a detachable probe was inserted into the stack. The tribo monitors were installed in a vertical position on the main 20 inch diameter emissions stack in a fixed sampling location downstream of any obstructions or other impediments to flow, and upstream of the baghouse. The sampling locations were selected after conducting a full traverse following the protocols established in EPA Method 1.

Each remote sensor head was connected to a main control panel. The control panel was equipped with a real time display, either in a bar graph or line graph form, ranging from one second to two minutes resolution. The data were also output using a 4-20 mA connection to a DAQ Book/260 data logger that recorded data every second. This enabled recording of a permanent record for subsequent examination of potential particulate producing events prior to and during an individual PCS run. Potential particulate producing events were noted and recorded as they occurred by laboratory or floor personnel. Not all events were able to be anticipated or noted, but sufficient data were collected to characterize the monitors during the PCS foundry operations.

Figure 2-2 Technikon Research Foundry Emission Collection Hood

Figure 2-3 Metal Pouring into Test Casting Molds

Figure 2-4 Triboelectric PM Monitors Installed On Stack



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3.0 TESTING RESULTS

Tabular event summaries for relative time of occurrence for tests GH, GL and GM are in Tables 3-1, 3-2, and 3-3, respectively.

Table 3-1 Test GH Events

Test	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009
Event	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	Data counts (sec)
Data file Start time	1	1	1	1	1	1	1	1	1
Additives (C, Si)	1221	ND	ND	2422	ND	ND	ND	ND	ND
Furnace exhaust up for back pour	1638	ND	3186	3582	ND	541	1513	2287	2563
Furnace exhaust down after back pour	1728	15:01-1560	3250	3688	ND	624	1575	2359	2626
Metal returned to furnace	1922	15:01-1560	3260	3888	2017	635	1586	2371	2637
	1952	1569	3292	3943	2023	657	1608	2404	2657
Furnace exhaust up for tap	2258	ND	3429	4246	2161	657	1810	2716	2869
Metal into ladle	2295	ND	3450	4264	2221	843	1825	2738	2900
	2322	ND	3469	4291	ND	863	1830	2753	2916
Test Start Time	2486	1987	3697	6945	2396	1018	2012	2846	3097
Furnace exhaust down after tap	2531	1741-1800	Pig Out	ND	ND	Pig Out	2054	2887	Pig Out
Metal returned to furnace	2556	1875		ND	ND		2079	2912	
	2587	2086		ND	ND		2096	2929	
Shakeout start	5186	4687	6397	9645	5096	3718	4712	5546	5797
Shakeout stop	5486	4987	6697	9945	5396	4018	5012	5846	6097
Test Stop Time	6989	6487	8197	11445	6896	5518	6510	7346	7597

ND=Not determined

Table 3-2 Test GL Events

Test	GL001	GL002	GL003	GL004	GL005	GL006	GL007	GL008	GL009
Event	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)
Data file Start time	1	1	1	1	1	1	1	1	1
Additives (C, Si)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Furnace exhaust up for back pour	6231	5523	7682	ND	4792	4339	5122	3659	3589
Furnace exhaust down after back pour	6283	5693	7743	ND	4956	4442	5177	3820	3649
Metal returned to furnace	6295	5703	7748	ND	4994	4450	5185	3828	3657
	6327	5757	7769	ND	5017	4469	5195	3844	3674
Furnace exhaust up for tap	6540	6145	7974	4445	5441	4732	5409	4185	3946
Metal into ladle	6558	6170	7996	4469	5463	4758	5432	4211	3969
	6577	6189	8017	4486	5482	4782	5452	4229	3991
Test Start Time	6750	6314	8149	4609	5651	4940	5607	4367	4133
Furnace exhaust down after tap	Pig Out	6364	8208	Pig Out	5699	4982	Pig Out	4407	Pig Out
Metal returned to furnace		6447	8241		5712	5005		4426	
		6470	8255		5727	5020		4439	
Shakeout start	9450	9014	10849	7309	8351	7640	8307	7067	6833
Shakeout stop	10050	9614	11449	7909	8951	8240	8907	7667	7433
Test Stop Time	11250	10804	12649	9109	10151	9440	10107	8867	8633

ND=Not determined

Table 3-3 Test GM Events

Test	GM001	GM002	GM003	GM004	GM005	GM006	GM007	GM008[1]	GM009
Event	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)	data counts (sec)
Data file Start time	1	1	1	1	1	1	1	1	1
Additives (C, Si)	4556	ND	ND	ND	ND	ND	ND	ND	ND
Furnace exhaust up for back pour	5288	ND	2333	5046	1202	1136	253	ND	2181
Furnace exhaust down after back pour	5368	ND	2440	5145	1280	1279	336	ND	2260
Metal returned to furnace	5371	ND	2514	5150	1308	1377	341	978	2263
	5401	ND	2561	5185	1346	1440	361	998	2280
Furnace exhaust up for tap	5625	ND	2835	5407	1732	1702	652	ND	2454
Metal into ladle	N/D	ND	ND	ND	ND	ND	ND	ND	ND
	N/D	ND	ND	ND	ND	ND	ND	ND	ND
Test Start Time	5944	1373	3087	5610	1936	1939	911	1380	2669
Furnace exhaust down after tap	5986	N/D	Pig Out	N/D	ND	Pig Out	979	ND	Pig Out
Metal returned to furnace	6012	N/D		N/D	2011		996	ND	
	6042	N/D		N/D	2034		1009	1453	
Shakeout start	8644	4073	5787	8310	4636	4639	3611	4080	5369
Shakeout stop	8944	4373	6087	8610	4936	4939	3911	4380	5669
Test Stop Time	10444	5873	7587	10110	6436	6439	5411	5880	7169

ND=Not determined

[1] Furnace exhaust up during entire run

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4.0 DISCUSSION OF RESULTS

The triboelectric particulate monitors were operated during three greensand mold tests with each test incorporating different molding materials. These materials included molds made from greensand containing a premix without seacoal and with the pattern coated with a release agent containing graphite (Test GL); an uncoated hotbox core set in a mechanically-produced clay, water, and greensand mold, also without seacoal (Test GH); and molds from an uncoated baked oil sand core that was set in a mechanically-produced clay, water, and seacoal-less greensand mold (Test GM). Molds used were of two types: a 4-on step-core for tests GH and GL, and a 4-on coreless star for test GM.

Of the two monitors, particulate Monitor A was found to have a lower noise level, was more sensitive to particulate producing events, and to parallel the time profile of major emission events that have been verified by the well characterized E-Bench THC monitor. Its responses were found to be consistent and reproducible during all runs from an individual test, as well as between different tests. This behavior suggests it may be used as a continuous emission monitor provided it is calibrated against standard particulate matter of defined size and mass through isokinetic sampling. Particulate Monitor B is specifically designed as a bag leak detector, and as is consistent with this function, it was found to have a more stable response, with minimal variance during furnace events, and responding mostly to mold shakeout. Neither monitor responded to metal pouring, suggesting that most emissions associated with this event are of a fume or gaseous nature, rather than being in particulate form.

<u>Particulate Events</u>

For Monitor A, all evident particulate events apparent during PCS exhibited a rapid rise followed by a rapid decay. Returning the metal to the furnace after both back pouring and tapping, and mold shakeout were the most prominent events. All events were short lived (on the order of seconds) except for the shakeout, which is described below.

The monitor's baseline was consistent both during a run and between each run in the test, even after a particulate event that caused a peak or spike, with the trace returning to the same level after the event. Additionally, the instrument responded in a similar manner to similar events for each run.

The particulate profiles were found to parallel the time profiles of major emission events that have been verified by the well characterized E-Bench THC monitor. The initial pouring of metal into the mold, which signaled the beginning of a run, was always a few seconds before the THC response, and was a small event as far as particulate generation, being barely indicated on any of the run profiles. For the THC, however, the run start generates a large peak starting with a rapid rise that is followed by a decay not quite to baseline, then a slow rise to a second broad peak with a slow decay never reaching back to baseline – indicating a large initial emission of hydrocarbons followed by the release of additional compounds with continual hydrocarbon emissions. Because the particulate monitor did not respond significantly to metal pouring, it suggests that most emissions associated with this event are of a fume or gaseous nature, rather than being in particulate form.

If a run was started after metal was returned to the furnace, there were generally no other visible particulate events, except for run GH005. The source of the extra events in this run is unclear, but is most likely furnace related. During run GH004, there were several additional occurrences of metal returning to the furnace due to difficulties meeting parameter requirements needed for actual pouring. There are consistently one or two hydrocarbon events in between pouring and shakeout, during the phase of metal cooling.

At shakeout both the particulate monitor and the THC monitor responded simultaneously. The hydrocarbon profile indicated a single large peak which began to rapidly decay after 1 - 2 minutes, but then asymptotically approached the baseline background. In the particulate case, the response started with an initial small peak with a rapid rise followed by a rapid decrease, followed by larger multi-spiked peaks which lasted for the complete duration of mechanical shaking. As soon as the shakeout was physically stopped, there was an immediate rapid decrease back to baseline.

After the last run at the end of a day, the metal was pigged out. As a consequence, the final run had no influence from events surrounding the furnace after the metal was poured. Tests where this occurred are indicated in Tables 3-1 through 3-3. These tests tend to have fewer and smaller particulate peaks. To isolate the effect of furnace particulate events from the monitor, the furnace vent was left disconnected for the entirety of run GM008. It was clearly seen in the monitor profile from this run that there was much smaller and fewer peaks than in the other runs.

APPENDIX A EQUIPMENT SPECIFICATIONS

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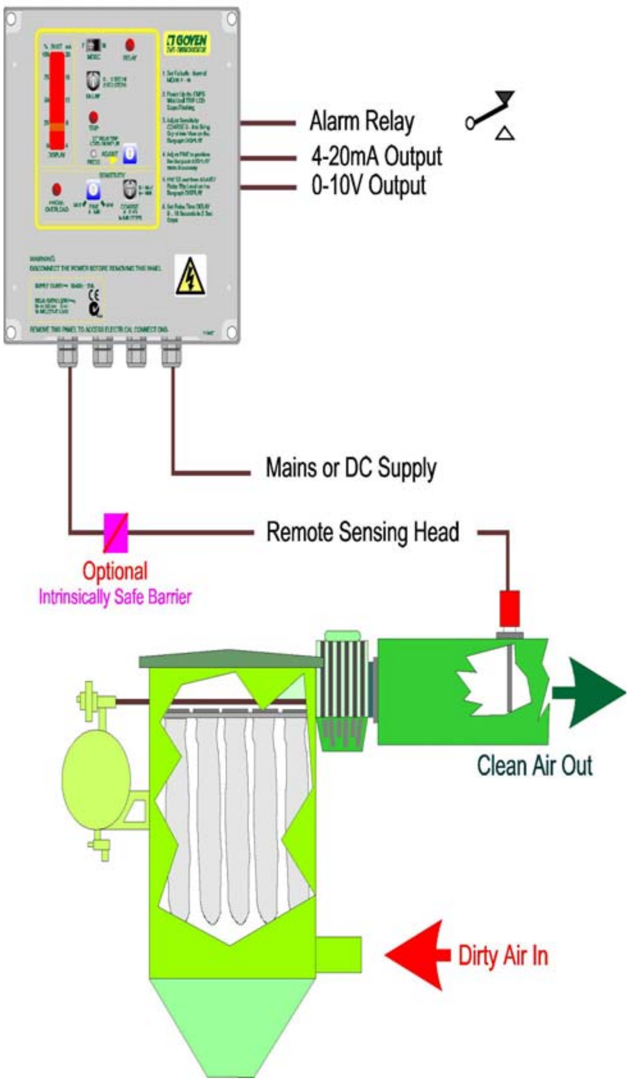
Monitor A

GOYEN ELECTRONIC .. **EMP5** TECHNICAL SPECIFICATIONS

EMISSION MONITOR



The Goyen *EMP5* Emission Monitor is designed to interact with hardware as detailed in the Technical Specifications.

EMP5 Main Control Unit

Power Requiremen (AC TYPE)	95-265V ~ 50/60Hz 12VA
Fuse	For wiring protection use a 2 AMP (Slow Blow)
Power Requiremen (DC TYPE)	18-32Volts DC 0.3 AMP MA
Fuse	For wiring protection use 0.5 AMP (Slow Blow)
Alarm Relay Rating	Isolated SPCO - 8A Resistiv Load, 1A Inductive Load, 250V ~
Ambient Operating Temperature Range	0oC - 60oC
4-20mA Output	Max Loop Resistance 470 Ohms
0-10V Output	Source Resistance 1000 Ohms
Enclosure	IP65

EMP5 Remote Sensing Head

Cable Specification	4 Core Screened Data Cable (Belden 9534 or Equivalent)
Sensing Head	Insertion Temperature. Up to 80oC Part Number (P2-45210)
Sensing Head	Insertion Temperature. Up to 200oC Part Number (P2-45220)
Sensing Head	(Consult Supplier for applications over 200oC)
Air Purge	1/8" Gas thread on the side the unit 1-10cfm at 10-60psi
Standard Sensing Element Length	300mm x 12mm OD Stainles Steel M8 Male Thread

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APPENDIX B ACRONYMS & ABBREVIATIONS

ARDEC	U.S. Army Armament Research, Development and Engineering Center
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CEMS	Continuous Emissions Monitoring Systems
CERP	Casting Emission Reduction Program
CISA	Casting Industry Suppliers Association
CO	Carbon Monoxide
COR	Contracting Officer's Representative
CRADA	Cooperative Research and Development Agreement
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
ERC	Environmental Research Consortium
PCS	Pouring, Cooling, Shakeout
PM	Particulate Matter
SIVL	System Integration Validation Lab
THC	Total Hydrocarbon Concentration
US EPA	U.S. Environmental Protection Agency
USCAR	U.S. Council for Automotive Research