Firecracker Emission Testing Facility for Measurement of PM and Gaseous Pollutants

Emission chambers are normally used for testing emissions from fossil fuels. Various designs and structures are available for testing emissions of particulates and gaseous pollutants from fossil fuel burning such as crop residues, forest fires, and grassland fires based on the continuous burning source (Tian et al., 2008; Kamalak et al., 2005; Lusini et al., 2014; Christian et al., 2003; Soares et al., 2011; Zhang et al., 2008). Firecrackers use is open and is majorly ground cracker and few of them in air. With a view to bring uniformity, all tests have been confined to a close room so that conventional and improved systems can be compared in a similar way. Bursting of firecracker is a spontaneous activity and therefore, a firecracker emission testing facility (FETF) has been designed for emissions of particulates (PM_{10} and $PM_{2.5}$) and gaseous pollutants SO_2, NOx, etc. from various types of firecrackers. A schematic diagram of FETF is shown in Figure 1. These emissions, however, may result in varying levels of ambient concentrations based on wind speed, direction, temperature, humidity, topography etc.

A new Firecracker Emission Testing Facility (ETF) using dilution method has been set up recently and the details are as follows:

Description of Firecracker Emission Testing Facility (ETF)

FETF designed in our study, consists of bursting chamber (approximately 14 m^3) and dilution chamber (approximately 1 m^3). The details are as follows:

- Dimension of Bursting chamber in **dilution method** : 2m X 2m X 3.5m
- Dimension of small dilution chamber in **dilution method**: 1m X 1m X 1m
- For **dilution chamber method**, the total volume of chamber is (14 m^3 + 1m^3) = 15 m^3.

It has 1) the provision for diluting the emissions and to homogenize the same before the start of monitoring. 2) can control air change rate and outlet flows and 3) provided with sampling ports and sufficient throughput to accommodate multi-pollutant measurements. 4) can accommodate different types of firecrackers due to its volume.

The bursting chamber has fixed dimension and a volume of approximately 15m^3. It is provided with electric fan for mixing the emissions within the chamber. It is also provided with a lamp and a glass window to have visibility of the activity. The thermo-anemometer is provided to measure gas velocity and temperature in the chamber. Sampling ports in the chamber allow for extraction of the exhaust for measurement of various pollutants. The dilution air inlet is preceded by High Efficiency Particulate Air (HEPA) filters and an air blower. Cracker is placed at the center of the chamber during the tests, and ignited. Emissions released after bursting of firecrackers are diluted by passing the filtered air into the bursting chamber and sent in the dilution chamber through duct. Homogenized emissions are monitored in dilution chamber.

Methodology

Tests will be carried out to evaluate the emissions. The chamber will be completely evacuated before starting the monitoring to remove residual aerosol and gases. Optimization of sampling period will be done for different types of firecrackers. Sampling will be conducted after homogenizations of emission for specific time depend on type of firecracker.

For testing the homogeneity of sample, emissions will be diluted by passing the air and allowing to mix it with fan provided in chamber. After approximately five minutes, emissions will be allowed to pass into the dilution chamber. Dust track will be used to measure the concentration level with respect to time intermittently till the concentration reaches to minimum. Data generated will be plotted against the time versus mass concentration to know the homogeneity and also time requires reaching concentration to its minimum level. Sampling of PM_{10} and $PM_{2.5}$ emissions will be carried out by Low Volume Sampler (LVS) by collecting the particles on filters. Dilution was carried out with blowing air in the bursting chamber (volume 14 m^3) at 125 LPM for two hours with simultaneous transfer of diluted gaseous emissions into the dilution chamber (volume 1 m^3). Accordingly, dilution factor was calculated and used. Gaseous pollutants such as SO_2, NOx, CO, CO_2 etc. will be monitored by flue gas analyzer. Characterization of PM_{10} and $PM_{2.5}$ samples will be carried out for specific metals such as Al, Ba, Fe, K, Sr, Cd, Cu, Cr and Mg by ICP-OES and EC/OC by EC/OC analyzer and using standard methods.

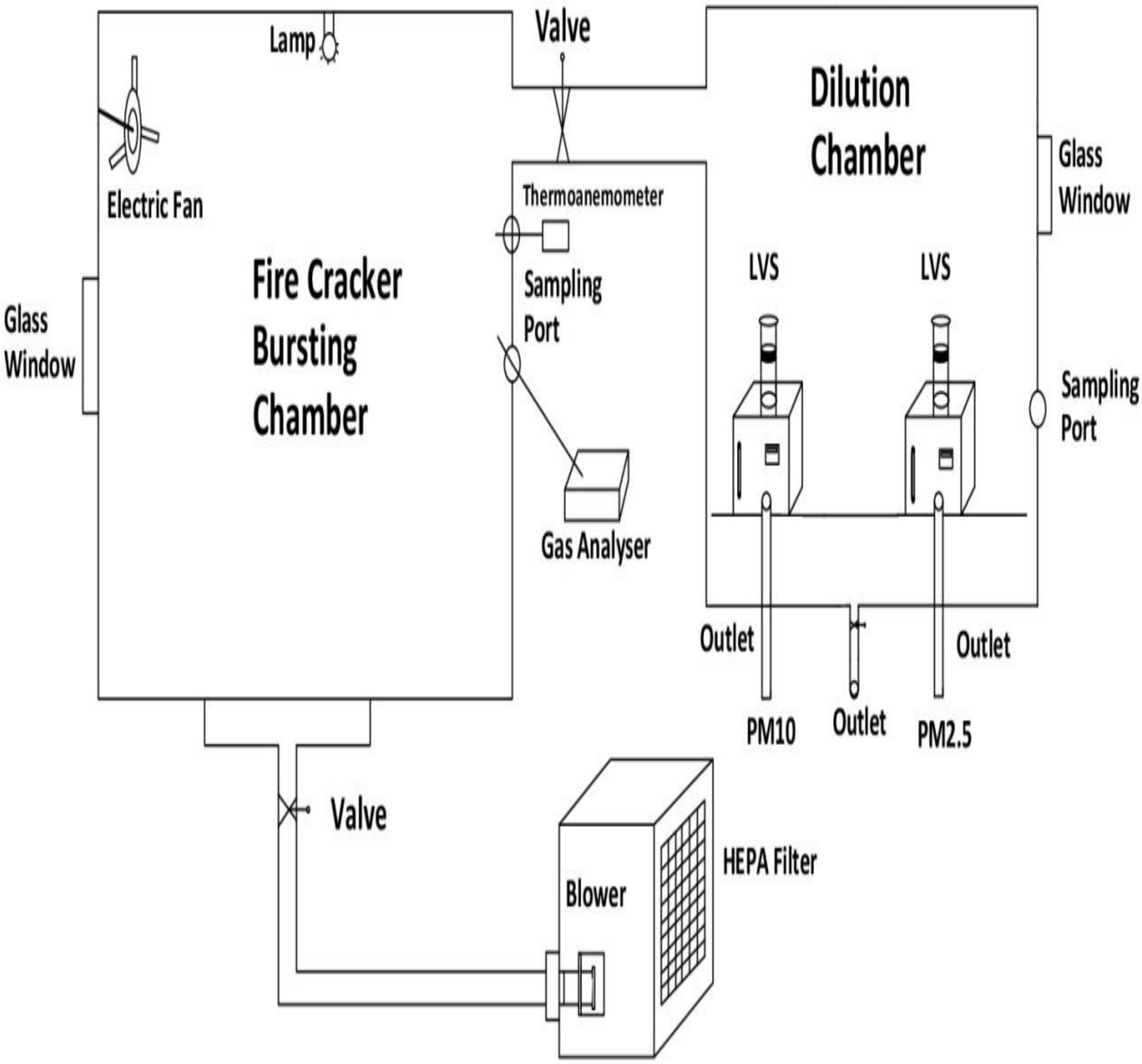


Fig 2: Schematic design of firecracker emission testing facility

Details of Instruments Used for Analysis & Monitoring

Airmetrics manufactures the MiniVol™ TAS, which samples ambient air at 5 liters/minute for particulate matter (PM10, PM2.5, TSP). While not a reference method sampler, the MiniVol™ TAS gives results that closely approximate data from Federal Reference Method samplers. Lightweight and portable, the MiniVol™ TAS is ideal for remote areas or locations where no permanent site has been established.

Sampler Features

The **Standard PM-2.5 MiniVol™ TAS includes**

- **2 PM-2.5 Impactors**
- **2 PM-10 Impactors**
- **2 Multiple Impactor Adapters**
- **2 Louvered Inlets**
- **2 Filter Holder Assemblies**
- **2 Li-ion Battery Packs**
- **1 Battery Charger**
- **1 Universal Mounting Bracket**
- **1 All-Weather Transport Case**

Basic Operation

Particulate Sampling

The MiniVol™ portable air sampler can be configured to collect either $PM_{2.5}$ PM_{10}, or TSP samples - but only one type at a time.

The MiniVol's pump draws air at 5 liters/minute through a particle size separator (impactor) and then through a 47mm filter. The 10 micron or 2.5 micron particle separation is achieved by impaction, or a TSP sample can be collected by removing the impactor(s). Gas samples can be taken simultaneously with particulate matter samples.

Technical Specifications

Pump

- Double-diaphragm with laminar flow valve technology
- Rated for 10,000 hours continuous operation
- Ironless core motor with precious metal commutation
- Flow range 0-10 LPM

Physical

- Polypropylene copolymer weatherproof sampler case
- Dimensions: 10" x 12" x 7"
- Weight: less than 10 lbs. fully configured
- All in one transport case
- Dimensions: 19.75" x 12" x 18"
- Weight: less than 40 lbs. with all accessories

Timer

- Programmable 7-day timer with battery backup
- Up to six sample periods per day

Pre-separator/Cassette Filter Holder Assembly

- Non-directional louvered inlet design
- Easily removed for cleaning
- Standard 47mm filter holder
- Nominal 10 micron or 2.5 micron "cut-point" at 5 liters/minute sample rate

Electronics

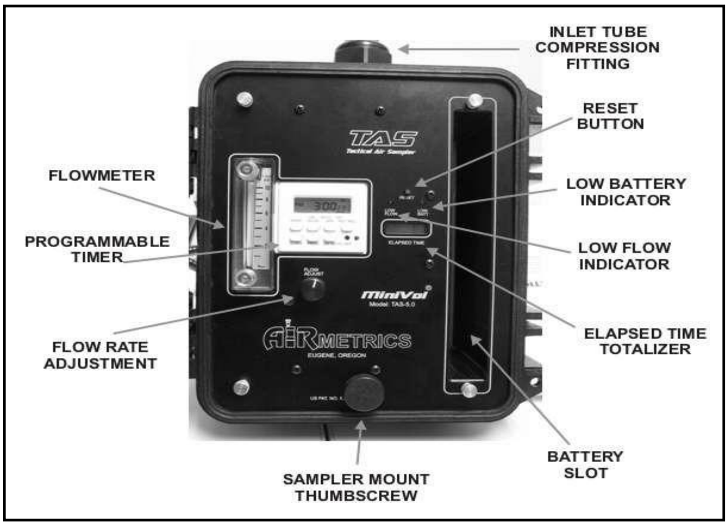
- Constant flow control circuit
- AC or DC operation
- Variable flow adjustment
- Elapsed time totalizer
- Low battery indicator and shut-off
- Low flow rate indicator and shutoff

Battery Pack

- Litium Ion batteries
- 14.8V / 118 Watt Hours
- 1.2 amp external battery charger
- Full recharge in less than 6 hours

The particulate sample is caught on the filter, which must be weighed pre- and post-exposure with a microbalance accurate to one microgram. Sampling results are reported in micrograms/cubic meter. Airmetrics offers filter weighing services to complement use of the MiniVol™.

The MiniVol™ comes equipped with low flow and low battery shut-offs and operates from a rechargeable, lead-acid battery. The battery can power the sampler for 24 hours of continuous sampling before the battery pack must be exchanged for a freshly charged one



The MiniVol™ also features a 7-day programmable timer, an elapsed time totalizer, and rugged PVC construction.

A new, corrected indicated flow rate must be established for each sampling project. This calibration ensures that the sampler has an ambient flow rate of 5 liters per minute and that there is consistent performance of the inertial size separator. The calibration accounts for the differing air temperatures and atmospheric pressures due to elevation and seasonal changes.

Specification of Flue Gas Analyzer(model Testo 350)

Sr.No		Specification of Flue Gas analyzer
1	Primary Sensor (range) Additional sensor (range)	O_2(0-25%), SO_2(0-5000 ppm), CO(0-10000 ppm), CO_2(0-500 vol %), NO(0-4000ppm), NO_2(0-500 ppm), CH_4(100-5000 ppm),Propane (100-21000 ppm), Butane(100-18000 ppm), H_2S(0-300 ppm)
2	Accuracy	For low range (up to 200 ppm) of SO_2 ,the resolution should be 0.1 ppm For low range of NO(up to 300 ppm) of NO, the resolution should be 0.1 ppm For high concentration of SO_2(up to 5000 ppm) the resolution should be 1 ppm CO_2 should follow IR measurement techniques with resolution of 0.01 volume % and can measure (0-50 volume %)
3	Versatility and range of application	- Dew point calculation up to 90 degree Celsius(Temperature at which droplet formed) - Single dilution for high range of gaseous concentration dilution factor up to 40 times (range extension up to 40 times for all sensor)
4	Features	Air fuel ratio adjustment facility should be provided in order to produce a complete combustion event. Positive pressure + 40 mbar or greater Negative pressure -200 mbar or below -Inbuilt Peltier chiller for removing water precipitate for enhancing life of sensor.
5	Weight	Light in weight up to 6 kg which can easy to manage during transportation and stack monitoring application
6	Probe	- Temperature measurement up to 1200 degree Celsius .length more than 1 m. - It should be used for stack monitoring application. - Stack gas sampling probe should be more than 1 m - Preheated probe for low conc. of gases
7	Battery life	5-6 hrs or more
8	Data logging	USB data logger with user specific interval choice.

The testo 350 flue gas analyzer comprises two units

- **The testo 350 Control Unit** (separate product) with a clear graphic display, allows you to control emissions measurement. Operation is really easy: burner, gas turbine, engine and user-defined applications are available for selection in the menu. The Control Unit enables remote control of the analyzer unit even when there is a spatial separation of the flue gas pipe and the setting location – particularly recommended for emissions measurements on large plants.
- **The testo 350 analyzer unit** is just what you need for carrying out emissions measurement, because it contains all the sensor technology and electronics. The testo 350 analyzer unit includes an O_2 gas sensor as standard, but at least one additional sensor must be connected for commissioning (can be used with a maximum of 6 sensors). When connecting the optional sensors, you can choose between gas sensors for CO, CO_2, NO, NO_2, SO_2, H_2S or CxHy.

The measuring range extension enables unrestricted measurements to be carried out, even when there are high gas concentrations. In order to protect the sensor technology, the measuring range extension (dilution) is automatically activated when there are unexpectedly high gas concentrations. The measuring range of a selected sensor can be extended by a specific factor. The service opening on the underside of the instrument allows fast access to all relevant serviceable and wearing parts, such as pumps and filters, enabling users to clean or replace these. In addition, the testo 350 has numerous instrument diagnosis functions. Instrument notifications are output in cleartext, making them easy to understand. The current status of the flue gas analyzer is constantly displayed.

The equation to calculate the mass of fine particulate matter collected on a Teflon filter is as below:

$M_{2.5}$= (Mf - Mi) mg x 10^3 µg

Where, $M_{2.5}$ = total mass of fine particulate collected during sampling period (µg)

Mf = final mass of the conditioned filter after sample collection (mg)

Mi = initial mass of the conditioned filter before sample collection (mg)

10^3 = unit conversion factor for milligrams (mg) to micrograms (µg)

Field records of PM samplers are required to provide measurements of the 2.5 total volume of ambient air passing through the sampler (V) in cubic meters at the actual temperatures and pressures measured during sampling.

Use the following formula if V is not available directly from the sampler: -

V = Q_{avg} x t x 10^{-3} m Where,

V = total sample value (m)

Q_{avg} = average flow rate over the entire duration of the sampling period (L/min)

t = duration of sampling period (min) 10^3 = unit conversion factor for liters (L) into cubic meters (m^3)

$PM_{2.5}$ mass concentration: $PM_{2.5}$ = $M_{2.5}$/ V Where,

$PM_{2.5}$ = mass concentration of $PM_{2.5}$ particulates (µg/m^3)

V = total volume of air sampled (m^3)

Ref. CPCB documents National Ambient Air Quality Series: NAAQMS/36/2012-2013

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