Department of Engineering – Risk Assessment Ref No. B871

Title of project/experiment/activity
Use of Kenosistec Gas Characterisation System

Location of activity	**Start and end dates**
EEDBA Annexe : Ink Lab	01/09/2015 - continuous

Brief description (or attach procedure/protocol)
This system is used to test samples as resistive gas sensors. Samples are placed in a climatic chamber, connected to 2 or 4 electrical probes and sealed from the outside environment.
During testing, a picoammeter will detect the resistance response of the sensor exposed to different atmospheres (e.g. gas type, humidity, temperature). This is a commercial system and must be used in accordance with the manufacturers instructions.
System also comprises:

- Rotary and turbo pump for evacuating the test chamber
- 6 mass flow controllers: 2 air (to give dry and wet air) and 4 for other gases, with a valve system to distribute gas mixture flow.
- A thermoregulated humidifier, to provide 100% wet mixture.
- A thermoregulated condenser to eliminate extra humidity.

Various samples can be tested e.g. graphene, 2d materials, metal oxides, etc. (user should refer to personal risk assessments for sample handling). Samples should not be highly conductive since the system is based on resistive sensing.

The system has a max flow rate of 1000 sccm. Gases will be diluted with dry air, using flow rates ranging from 10 to 500 sccm.

Although toxic gases are to be used, they are to be supplied from pre-mixed gas cylinders where the contents have been diluted to a safe level.

Gas cylinders will be located next to the instrument in a floor standing rack. Changing of cylinders should only be done by someone having previously attended a recognised course (BOC does these).

The system can be used overnight only when testing as a humidity sensor (no heating).

This process is carried out in the Ink Lab in the EEDBA and performed a few times per week.

The following gases may be used:
Dry Air
Oxygen, O2
Nitrogen, N2
Carbon dioxide, CO2 [redacted]
Ammonia, NH3 (<100 ppm in air)
Nitrogen dioxide, NO2 (<100 ppm in air)

"Inert" gases such as N2 and CO2 can cause asphyxiation if released in quantity.

Ammonia, NH3:
Colourless gas. Ammonia-like odour. Can decompose at high temperatures forming very flammable hydrogen

gas. VERY TOXIC. Fatal if inhaled. Corrosive to the respiratory tract. CORROSIVE. Causes severe skin burns and eye damage.

Nitrogen dioxide, NO2:
This gas mixture is colourless and has a pungent, suffocating odor. NO2 is VERY TOXIC. Exposures to this gas mixture may result in severe irritation and burns of eyes, skin, mucous membranes, and any other exposed tissue. Delayed pulmonary damage and breathing difficulty may occur. Severe over-exposures can be fatal.

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Hazard	Effect	Control measures	Residual risk
General hazards in lab	Inhalation of solvents	Other lab users will be using solvents with appropriate extraction in place. (Likelihood: 1, Severity: 1) Gloves, eye protection and lab coat must be worn whilst in the laboratory. The Ink Lab rules will be respected.	Low risk
Compressed gases	Serious injury	Gases under pressure may explode if heated (Likelihood: 1, Severity: 3). General conditions to avoid: open flames, sparks, static discharge, heat and other ignition sources.	Low risk
Full gas release	Inhalation of potentially toxic gases Long-term exposure limit TWA 8 hr period: O2 : N/A N2 : N/A CO2 : 5000 ppm NH3 : 25 ppm NO2 : 3 ppm	The gas cylinders to be used with this equipment will be 10 L volume (e.g. AV type). O2, N2 and CO2 → Pure gases. NH3 and NO2 → 100 ppm diluted with air. In the event of a complete venting of a cylinder the size of the room means toxic levels will never be reached. However, there must NEVER be usage of cylinders >60 L, or concentrations > 600 ppm (@10 L volume), as this could lead to concentrations > 3ppm. Leakage of a pure CO_2 cylinder will generate a room concentration of 5371 ppm, however, due to lab air exchanges (8 per hour), this release will be well below the 8 hr TWA exposure limit. (Likelihood: 1, Severity: 1)	Low risk

Gas leakage from the instrument	Inhalation of potentially toxic gases	This is most simply performed by observing the instrument software flow rates going into the system and exiting the Exhaust mass flow controller. Most leaks will typically occur at the climatic chamber if it is not properly sealed. The system must always be checked for leaks prior to experiment using the compressed air gas cylinder. (Likelihood: 2, Severity: 1) If a sample is removed whilst the climatic chamber is filled with a toxic gas, there is a risk of inhalation by the user. (Likelihood: 2, Severity: 1) *? Training involves ensuring the user will purge the system with vacuum and then air prior to removing samples.	Low risk
Substrate heating	Risk of burns	Climatic chamber substrate can be heated to ~300°C. If a sample is removed whilst the substrate holder is still hot, there is a risk of burns to the user. (Likelihood: 2, Severity: 1) Tweezers should be used to place and remove samples. The equipment will have a safe operating procedure set of rules so that the burns risk and exposure to chamber contents is avoided as long as the users follow the rules.	Low risk
Mechanical damage	Damage to equipment	The sample stage is very delicate and needs to be removed and re-inserted carefully not to damage electrical connections. (Likelihood: 2, Severity: 1) A torq-wrench is required to tighten the screw fittings to ensure a leak-free sample chamber.	Low risk

Personal Protective Equipment required [*eye/face protection, respiratory protection, gloves, lab coat etc*]

Lab coat, gloves (purple nitrile) and eye protection (safety specs) required in the lab at all times

Emergency Instructions & First Aid

General advice: Consult a physician. Show this risk assessment to the doctor in attendance.

In the case of inhalation of a significant quantity of toxic gas (e.g. during full cylinder release): Take precautions to ensure your own safety before attempting rescue (e.g. wear appropriate protective equipment). Move victim to fresh air. If breathing is difficult, trained personnel should administer emergency oxygen. DO NOT allow victim to move about unnecessarily. Symptoms of pulmonary edema may be delayed. Immediately call a Poison Centre or

doctor. Treatment is urgently required. Transport to a hospital.
Any special monitoring required [*e.g. hearing test, vibration monitoring, health surveillance*] Keep a record of CO_2, NH_3 and NO_2 usage (i.e. emissions)
Further control measures required? If yes, list with actions. Waste Disposal Procedures: Gaseous exhaust and vacuum pump exhausts extracted via in-house extraction system. In the case of equipment malfunction/failure: an emergency shutdown button located on the rear side. This should be pressed if the system is malfunctioning.
Biological/Laser/Radiation Approval [*requires relevant Specialist Safety Officer signature and date*] N/A
Out of hours/Lone working The system cannot be used overnight when using potentially toxic gases or substrate heating. Overnight runs can only be run using water vapour (moisture sensing). Requires permission from the Head of Division.

Signature to confirm that this is a suitable and sufficient assessment of risk and that stated control measures are in place. This risk assessment should be reviewed if additional risks not covered in this assessment are identified or if there is any reason to indicate that the control measures are insufficient.

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Name of Supervisor Prof. Andrea Ferrari	**Signature**	**Date** 04/08/2015

Local Safety Coordinator	**Signature** D Hurley	**Date** 6/8/15.
Departmental Safety Office IAN SLACK	**Signature**	**Date** 9 NOV 2015