Technical Note

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		Our ref:	Email 19 January 2021
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Title: **Dark Smoke Monitoring Methodology**

1. Introduction

1.1 Background

Flexible Generation Limited obtained a permit to operate fourteen 3.5 MWth diesel fuelled compression ignition engines (one 49 MWth Specified Generator). These engines are operated via a balancing services contract on a short-term basis meeting peak demand or short falls in generation within the electrical distribution network.

The permit (number PAN-005837) has been issued by Natural Resources Wales (NRW) in 2019 and include the following condition in relation to 'dark smoke' monitoring (see section *3-Emissions and monitoring* of the permit):

- *There must be no persistent emission of 'dark smoke' as defined in section 3(1) of the Clean Air Act 1993.*

Table S1.4A of the permit provide a description of NRW requirements:

- *Within 1 month of permit issue, and before the commencement of operations, the Operator shall submit to Natural Resources Wales and obtain written approval for a report detailing a proposed methodology for undertaking the monitoring of dark smoke.*

Flexible Generation Ltd requested Wood to provide technical support in defining a monitoring approach to comply with the aforementioned condition.

2. Monitoring Methodology

The apparent darkness of a smoke depends upon the concentration of the particulate matter in the effluent, the size of the particulate, the depth of the smoke column being viewed, and natural lighting conditions such as the direction of the sun relative to the observer.

Since the generators are provided with have jacket water heaters for increased cold-starting capability, the likelihood of black smoke is limited, and 'persistent emissions of black smoke' are considered highly unlikely.

However, to comply with NRW requirements the following approach is proposed:

- Flexible Generation Ltd staff will perform visual inspections when the generators are in operation.
- The first observation will commence at start-up and, if dark smoke is observed, the visual inspection will continue, with regular observations repeated at one-half minute intervals.
- Dark smoke will be assessed using a Ringelmann chart and results will be reported in a log-book.
- If the dark smoke is clearly visible (see Section 2.1 and Figure 1) for more than one hour, the plant manager will be informed, and the incident will be reported to NRW.

2.1 Ringelmann chart

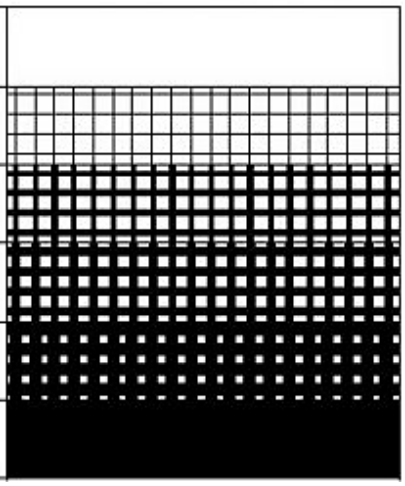
The Ringelmann chart is used to define dark smoke. The Ringelmann chart uses a scale for measuring the apparent density or opacity of smoke. The scale has 5 levels of density inferred from a grid of black lines on a white surface which, if viewed from a distance, merge into known shades of grey. Shade 1 is slightly grey and is usually categorized by air pollution boards as acceptable. It corresponds to an opacity of 20%. Shades 2, 3, 4 and 5 correspond to opacities of 40%, 60%, 80% and 100% (completely black) and are usually considered to be "black smoke".

In use, the observer views the plume at the point of greatest opacity and determines the corresponding Ringelmann Number. A Ringelmann 0, 1, 2, 3, 4 and 5 are equivalent to an opacity of 0, 20, 40, 60, 80 and 100.

To determine average smoke emission over a relatively long period of time, such as an hour, observations should be repeated at one-half minute intervals. The readings are then reduced to the total equivalent of No. 1 smoke as a standard. No. 1 smoke being considered as 20 percent dense, the percentage "density" of the smoke for the entire period of observation is obtained by the formula:

$$\frac{\text{Equivalent units of No. 1 smoke} \times 0.20 \times 100}{\text{Number of observations}} = \text{percentage smoke density.}$$

Figure 1 – The Ringelmann Scale

Ringelmann 0	0% opacity – clear	
Ringelmann 1	20% opacity – barely visible	
Ringelmann 2	40% opacity – clearly visible	
Ringelmann 3	60% opacity – somewhat transparent	
Ringelmann 4	80% opacity – barely transparent	
Ringelmann 5	100% opacity – black	

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