

Confidential



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Stack Emission Test Report

Monitoring objective: Sampling of **Airflow**

Monitoring deviations/ special requirements: None

Trial Ref 20.002.7
Client Connollys Red Mills
Address Grange Lower, Goresbridge, Co Kilkenny .R95EKH4
Contact Name John Rea
Date of test 21/02/2020
Dryer Name A2-9, Flaker Cyclone
Powder Name Animal Feed

Contents:

Section	page
1. Executive summary	2
2. Method and apparatus	3
3. Plant conditions	4
4. Field measurements	5



Authorised by Eoin.Murphy
Technical Manager

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Airflow

1. Executive Summary

Trial Reference: 20.002.7
Client: Connollys Red Mills,
Address: Grange Lower, Goresbridge, Co Kilkenny .R95EKH4
Date of test: 21/02/2020
IPPC Licence no: P1069-01
Emmission Limit: 50 mg/m³

Airflow of stack A2-9
on dryer A2-9, Flaker Cyclone

The air flowrate was measured as 8,713 m³/hr of moist air at 57 °C or
7,006 Nm³/hr of dry air under standard conditions, equivalent to
7,120 m³/hr under standard conditions on a wet basis (Note 2)

Notes:

1. Standard conditions are 0°C and 1013 mbar barometric pressure. The figures expressed as ± mg/m³ are expanded uncertainty values (confidence level 95%). We do not claim uncertainty values for results that are less than the limit of detection.
2. IPPC 4.2.1 expresses emissions under standard conditions on a wet basis for non-combustion gases. See comment at end of Explanatory Note.
3. This report refers only to the items identified herein.

Airflow



2. Method for monitoring Airflow to atmosphere

A series of velocity head readings are taken using a Pitot tube at intervals across the stack, from which the individual velocities at those points are calculated, The Pitot assembly for velocity measurement is mounted on the lance that is normally used for sampling air for particulates, together with a built-in thermocouple. A handheld datalogger reads the stack temperature (from the thermocouple), ambient temperature and barometric pressure. An Airflow type 5 manometer is used to take readings from the Pitot tube. Velocity measurement normally takes place along 2 sampling lines at right angles, according to EN 13284. The report gives total airflow on a wet and dry basis. The calculations are outlined in the Explanatory Note.

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Airflow

Plant Conditions

<i>Trial Reference</i>	20.002.7
<i>Dryer:</i>	A2-9, Flaker Cyclone
<i>Duct</i>	A2-9
<i>Powder:</i>	Animal Feed
<i>Start time</i>	15:20:00
<i>End time</i>	15:55:00
<i>Production Rate:</i>	6 tonnes/h
<i>Feed Solid level:</i>	86%
<i>Product moisture:</i>	14%
<i>Inlet temperature:</i>	15°C
<i>Outlet Temperature</i>	58.6°C

Sampled By: Donal Rawle
 Experimental officer

Team Leader:

eoin.murphy
 Research officer

Comment on plant conditions

Normal Conditions
 Angle of flow (>15deg) due to turbulence

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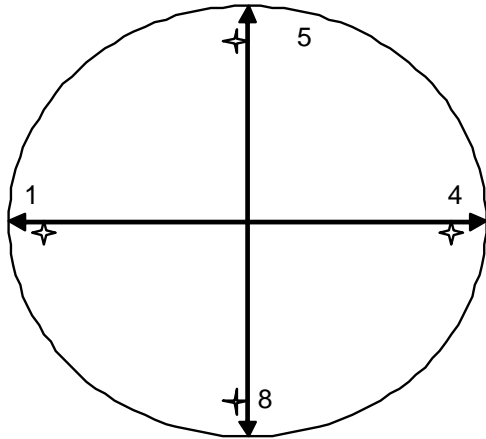
Airflow

Field Measurements

Airflow Determination

Stack: A2-9

Circular Duct
Two Sampling Lines at 90°



Pitot Readings
(see table below)

Pitot Readings No.	(N/sq m)	Edge Distance (m)	Sample Point	Temperature (°C)
1	293	0.027	<input type="checkbox"/>	58.6
2	302	0.100	<input type="checkbox"/>	58.2
3	287	0.300	<input checked="" type="checkbox"/>	57.5
4	276	0.373	<input checked="" type="checkbox"/>	57.4
5	308	0.027	<input type="checkbox"/>	57.2
6	293	0.100	<input type="checkbox"/>	57.5
7	283	0.300	<input checked="" type="checkbox"/>	57.4
8	224	0.373	<input checked="" type="checkbox"/>	57.1

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Airflow

Field Measurements

Stack Temperature:	57 °C
Static Pressure (relative):	-34 Pa
Barometric Pressure (outside stack):	1002.0 mbar
Barometric Pressure (in stack):	1001.66 mbar

Diameter (m)	0.400
Area (m²)	0.1257
Velocity (m/s)	19.3
AirMoisture (g/kg)	10

Air Flow			
Mass flow	9,144 kg/h;	8,713 m ³ /h moist air (Note 3);	7,006 Nm ³ /h dry air
7,120	m³/h moist air under standard conditions (Note 4)		

Note 1: Stack temperature is an average of temperatures across sampling plane

Note 2: Flowrate was determined by subdivision of cross section area into anular rings in the case of a circular duct and rectangles in the case of a rectangular duct. The summation area accounted for was 0.1257 m²

Note 3: At stack conditions, density 1.0495 kg/m³

Note 4: Moist air volume under standard conditions as per 4.2.1 of IPPC for non-combustible gases.

Note 5: No wall effect factor applied.

Note 6: Velocity and flow are determined from the sample points

Sampling

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Max/Min Ratio of pitot readings	Ratio < 9:1 OK
Isokinetic ratio	0.0 %
Leak Test < 2%	<input checked="" type="checkbox"/>
Ambient temperature	19 °C
Weight of water collected in moisture trap	g

Comment on Sampling:

Angle of flow normal (<15°)

Airflow

6. Explanatory note on Stack Emission Report for Total Particulate

1. The *average air velocity* v is calculated as follows:

A cross-sectional area a_i is associated with each point, where a Pitot reading is taken and where air is sampled for particulate. The velocity v_i in each segment is calculated as a function of the Pitot pressure and the temperature. The flow q_i through each segment (associated with each point of measurement) is calculated as:

$$q_i = a_i \cdot v_i \quad [\text{m}^3/\text{s}]$$

$$\text{The total flow of moist air, } Q = \sum q_i \quad [\text{m}^3/\text{s}]$$

$$\text{and the average velocity, } v = Q/A, \quad [\text{m/s}]$$

where A is the cross-sectional area of the stack, e.g. $A = \pi (D/2)^2$ for a circular stack.

2. Air density for moist air is determined from first principles as a function of temperature, pressure and water vapour content. The relationship between volumetric flow of moist air in duct, Q_h [m^3/h], mass-flow of moist air in duct, m_h [kg/h], and flowrate of dry air in duct under reference conditions, Q_{nh} [Nm^3/h], is:

a. Flowrate per hour (m^3/h): $Q_h = 3600 Q$, where Q is in (m^3/s)

b. Mass flowrate (kg/h): $m_h = Q_h \rho$, where ρ = the density of air at the actual temperature, pressure and moisture in the stack.

c. To convert from volumetric flow of moist air to moist air under standard pressure and temperature:

$$Q_{mh} = Q_h \times \frac{P_s}{1013} \times \frac{273}{273 + T_s}$$

d. Convert from volumetric flow of moist air to dry air under standard conditions:

$$Q_{nh} = Q_h \frac{(100 - B_{ws})}{100} \times \frac{P_s}{1013} \times \frac{273}{273 + T_s}$$

where B_{ws} = air moisture in % v/v (= Air Moisture in g/kg x 0.151). Air Moisture in g/kg is determined from the weight of moisture absorbed by the desiccant [g] and the volume of sampled air recorded by the gasmeter and converted to mass [kg], as follows

$$\text{Mass of dry air at reference conditions, } M_{ad0} = \frac{V_m \times 273}{T_m + 273} \times \frac{P_m}{1013} \times \rho_0 \quad [\text{kg}]$$

where P_m = barometric pressure at gasmeter [mbar].

$$\text{Humidity ratio, } x = \frac{w_w}{M_{ad0}} \quad [\text{g}/\text{kg of dry air}]$$

where w_w = weight of water absorbed by desiccant.

Airflow

3. A gasmeter is used to measure the sampled air volume. Measured concentration of particulate is:

$c = w \times 1000/V_{mo}$ [mg/Nm³], where **w** is total weight [g] of dried sample (including washings) and **V_{mo}** is the cumulative flow of sampled air measured by the gasmeter, corrected for temperature and pressure.

The total loss **L** [kg/h] is calculated as **c** times the estimated flowrate of dry air in the stack at standard conditions (0°C and 1013 mbar), divided by 10⁶ for unit conversion (mg to kg).

4. *Isokinetic ratio* is calculated as $100 \times V_{mo}/V_{no}$ %, where **V_{no}** is the target cumulative flow of dry air at the sampling nozzle during sampling, calculated from the Pitot readings **P** as $0.84\sqrt{(2P/\rho)}$ for an S-type Pitot tube, and corrected for moisture removal, stack temperature and pressure to standard conditions. The isokinetic ratio should be between 95 and 115% for total particulate.

5. Summary of notation:

A	Cross-sectional area of the stack ($= \pi(D/2)^2$ for a circular stack of diameter D).
a	Sampling nozzle cross sectional area
a_i	Cross-sectional area is associated with each point.
B_{ws}	Water vapour content on a volumetric basis, i.e. volume of water vapour / volume of moist air.
c	Gravimetric dust concentration [mg/Nm ³]
ELV	Emission limit value
GasmeterCF	Gasmeter calibration factor
L	Total loss [kg/h] i.e. estimated mass of powder being lost in stack
m_h	Total mass flowrate of air in stack [kg/h] = $Q_h \rho$
P	Pitot tube reading, Pa
P_s	Barometric pressure in stack, mbar. P_m = barometric pressure at gasmeter
Q	Total airflow in stack = $\sum q_i$, m ³ /s
Q_h	Total air flow per hour [m ³ /h] = 3600 Q
q_i	Flow associated with each point = $a_i v_i$
Q_{mh}	Total air flow expressed as moist air corrected for standard pressure and temperature [m ³ /h]
Q_{nh}	Total air flow expressed as normal cubic metres (dry air) per hour [Nm ³ /h] = m_h/ρ_o
t	Sampling duration
T_m	Gasmeter temperature (°C); T_s Stack temperature, °C
v	Average air velocity = Q/A
v_i	Velocity at any point (function of the Pitot pressure and the temperature).
v_s	Mean velocity at the sampling points
V_m	Volume of air measured by gasmeter (m ³),
V_{mo}	Cumulative flow of sampled air measured by the gasmeter, corrected for temperature and pressure (Nm ³).
V_{no}	Target cumulative flow of dry air at the sampling nozzle during sampling, calculated from the Pitot readings and corrected for moisture removal, stack temperature and pressure to standard conditions (Nm ³).
w	Sample weight; w_w weight of water absorbed by desiccant
x	Humidity ratio (g/kg of dry air)
ρ	Density of air at the actual temperature
ρ_o	Density of dry air = 1.2928 kg/m ³ at standard conditions (0°C, 1013 mbar)

Airflow