Measurement of Pot Gas Exhaust Flowrate and Heat Loss

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Abstract

Pot duct exhaust flowrate is an important parameter in the control of pot emissions and pot heat balance. The exhaust flowrate must be sufficient to create large enough under-pressure in all areas under the hood to prevent the escape of under-hood gases to the potroom in regular operation as well as during anode changing and tapping. The exhaust gas temperature must also be acceptably low for the scrubbers. Pot exhaust rates and temperature are measured at regular intervals to confirm compliance with these requirements. The exhaust rates are determined from gas velocity measurements in the duct using Pitot tube at a certain number of traverse points across the duct diameter, which should follow international standards, such as ISO 3966:2008. In practice, to save time, the number of traverse points is most often fewer than required by standards, which depend on flow disturbances at the measurement location caused by nearby flow control damper and duct bends. In this paper, the measurements of duct flowrate according to the ISO 3966:2008 standard are compared with abridged ones used for regular flowrate control and the duct heat loss is determined as a function of duct flowrate in DX Technology pots, operating in Potline 8 at DUBAL – an operating subsidiary of Emirates Global Aluminium ("EGA").

Keywords: Aluminium electrolysis pot exhaust; measurement of duct gas velocities; ISO 3966:2008 standard; heat loss through pot gas exhaust duct.

1. Introduction

The main purpose of pot hooding and gas extraction is to capture cell emissions and reduce fugitive emissions into the potroom. The minimum gas flowrate required is that which allows no gas leakage from the pot to the potroom during steady operation with all hoods closed and also during pot operations, such as anode change, tapping and anode dressing, in which pot doors or hoods are open. Pots are usually designed for increased suction during these operations. Pot suction has to provide under-pressure in all under-hood volume, which is the most difficult to achieve at the top of the under-hood space at the exit of anode rods from the hood since buoyancy lifts the air to the top of the volume. This difficulty increases when anode cover is thin as there is more heat lost from the anodes, which provides more buoyancy.

The second role of pot gas flowrate is to take away the heat lost through the anodes and generated inside the hood. It is generally assumed that the heat loss through the duct is proportional to the gas flowrate and that this can be used for pot heat balance control. This is why the duct gas flowrate is measured regularly. In [1] it was shown that in the particular case studied, 74 % of cell heat loss from the anode assembly was taken out through the gas duct. With increased gas flowrate, the calculated heat loss increased at the rate of 21 kW/(1 000 Nm^3/h) in the range of 2 000 Nm^3/h to 7 500 Nm^3/h in [1]. Similarly, in another case, the measured heat loss increased at the same rate of 21 kW/(1 000 Nm^3/h) in the measurement range of 2 000 Nm^3/h to 6 000 Nm^3/h in 170 kA pots [2]. This result is not applicable to the high amperage cells analysed in this paper with a gas flow range from 7 000 Nm^3/h to 16 000 Nm^3/h, which was substantially outside the range in [1, 2]. In this paper the measurements gave a heat loss increase of 11 kW/(1 000 Nm³/h) in Potline 8 DX Technology pots for the gas flowrate of 7 000 Nm³/h to 16 000 Nm³/h.

The third role of gas flowrate is to lower exhaust gas temperature to a maximum of 140 °C to 145 °C, which is limited by the Gas Treatment Centre ("GTC"). If the duct gas temperature is higher, some means of gas cooling between the pots and GTC has to be installed [3]. In [1], the modeling gave approximately 9 °C/(1 000 Nm³/h) temperature decrease, whereas in [2] the measurement gave 13 °C/(1 000 Nm³/h). In this paper, the measurements gave 4 °C/(1 000 Nm³/h) in Potline 8 DX Technology pots for the gas flowrate in the range of 7 000 Nm³/h to 16 000 Nm³/h.

This paper describes the measurements of the gas exhaust flowrate, duct temperature and duct heat loss in Potline 8 DX Technology pots. The duct flowrate measurements according to the ISO 3966 standard [4] are compared with two simplified methods used in this pot technology.

2. Standards for Gas Flow Measurements in Ducts Using Gas Velocity.

Gas flow in a straight duct is not uniform across the cross-section. The velocity profile is parabolic for laminar flow and rectangular for turbulent flow. The latter is practically flat across most of the cross-section for highly turbulent flows and decreases logarithmically to zero near the wall of the duct. In velocity measurement methods, the flowrate is determined from a certain number of velocity measurements along the diameter of the duct, called duct traverse. The average velocity can be calculated as the algebraic average of these local velocities, if the velocity profile near the wall is taken into account by proper, non-uniform spacing of the traverse points. To this effect, several methods exist and are regulated by international standards in order to guarantee universal applicability of these methods. One of these standards is ISO 3966 [4], which was used in this work.

According to the standards, the minimum number of duct traverse points depends on the distance between the measurement site, and upstream and downstream flow disturbance – as shown in Figure 1.

In pot exhaust ducts, there is an obvious problem – the disturbances upstream and downstream from the measurement site are much closer than required by the standards for a well defined flow profile. In Potline 8 DX Technology pots the damper upstream is about 2 duct diameters away and the duct bend is about 4 diameters away. In DX+ Technology pots, the damper upstream is about 2 duct diameters away and the disturbance downstream about 2 diameters also. This would require 16 traverse points on each diameter and a lot of time for each measurement. A compromise of 8 traverse points was chosen according to ISO 3966 . The relative positions of the traverse points are shown in Figure 2 and the ISO 3966 traverse points are given in Table 1. The measurements were made along two perpendicular diameters, vertical and horizontal. These were compared to the simplified method of 2 traverse points in Potline 8 DX Technology pots; and 5 equally spaced traverse points along vertical diameter only used in another pot technology in DUBAL.

With typical velocities of 14 m/s and duct diameter of 600 mm, which gives Reynolds number of about 350 000, the gas flow in the duct is turbulent and has a flat velocity profile across the diameter if there are no obstructions in the duct. In the wall boundary layer, the velocity decreases from bulk value in a logarithmic way to 0 as per Equation (1).

The ISO 3966 standard (or any other similar standard) for flow measurement cannot be fully satisfied because upstream and downstream flow disturbances are too close to the measurement location. However, the accuracy of the measurements is reasonable if the number of traverse points is a minimum of 8 along 2 diameters.

In these measurements, the duct heat loss increased with the flowrate increase, but the bath temperature did not decrease. Therefore, using gas flowrate to control thermal balance of the pot appears to be ineffective especially at high gas flowrate ranges (7 000 Nm^3/h to 16 000 Nm^3/h) . Also, pot-to-pot and day-to-day variability is too great to hope for uniformity in the potline if the flowrate is changed for thermal balance control.

Exhaust duct gas temperature decreases with gas flowrate increase, but in these measurements much less rapidly than reported in the quoted references.

The numerical results obtained in these measurements are specific to this technology and to the state of this technology at the time of measurements and should not be used as universal.

6. References

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