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TMS Paper Selection

MEASUREMENT OF FUGITIVE PARTICULATE AND SULPHUR DIOXIDE EMISSIONS AT INCO'S COPPER CLIFF SMELTER

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MEASUREMENT OF FUGITIVE PARTICULATE AND SULPHUR DIOXIDE EMISSIONS AT INCO'S COPPER CLIFF SMELTER

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Summary

The Copper Cliff Smelter, housing 6 reverberatory furnaces, 1 flash furnace and 19 converters, has approximate dimensions of 440 m x 100 m x 55 m high. Emissions from operations carried out within this building, not captured by the process hooding are vented to atmosphere via 44 major ventilators (combined area of approximately 1000 m^2). As part of a program to measure fugitive emissions from the Smelter, a measuring system has been built and tested on a ventilator situated above a copper converter (natural draft 7.6 m x 5.7 m, 3-5 m/s, 20-40°C). The gas was collected via a 12-probe grid and analyzed continuously by filtration for particulates and by absorption and titration for SO_2. Average dust loadings were obtained every 1-2 hours, and SO_2 every 2-30 minutes. The majority of emissions (70%) were recorded during the blowing cycle; concentrations of sulphur dioxide varied from 1-2 g/m^3 during matte addition, 0.5 to 1.5 g/m^3 during blowing to 0.2 g/m^3 when skimming. Particulate concentrations varied from 100 to 300 mg/m^3 during concentrate addition, 30 to 130 mg/m^3 during blowing to less than 10 mg/m^3 during delays.

Introduction

The Copper Cliff Smelter component of the Ontario Division of Inco Metals Company, in Sudbury, is the largest non-ferrous Smelter in the world. It combines under one roof both Nickel and Copper Smelting facilities, consisting of 6 reverberatory furnaces, 1 flash furnace and 19 Pierce-Smith converters. The metallurgical operations of the Smelter have been adequately described in previous Inco publications (ref. 1,2,3). It is sufficient to note that the Smelter produces, from its unit operations, both sulphur dioxide and metal containing dusts, most of which are adequately captured and treated in the process flue systems provided. In fact, it is conservatively estimated that over 95% of these gases are captured, dedusted in electrostatic precipitators and exhausted via the 380 m chimney. Advances in the handling of the process gas streams have led to highly significant reductions in the local ground level concentrations of both gaseous and particulate pollutants associated with the Smelter operation. It is now recognized that it is time for similar advances to be made in the reduction of the so-called fugitive emissions from the Smelter building, as these emissions are responsible for most of the residual concentrations of pollutants now found in the vicinity of the Smelter.

In the previous 10 to 15 years, limited attempts have been made to measure emission from some of the Smelter ventilators, principally from those immediately above the converter aisle itself. Results obtained by a continuous traversing, single probe technique, have indicated that the gas flow and fugitive emission rates through the ventilators are highly variable and stratified. However, testing was sufficiently precise to indicate that the total flow of gas through all the converter aisle ventilators was of the same order as that up the 380 m chimney, about 100 000 m^3/min, and that the sulphur dioxide fugitive emissions were less than 5% of total production. No data was forthcoming relating the emission rates to the production cycle nor rate of production, nor to the individual units responsible for generating them.

Objectives

The objectives of the on-going series of testwork, partially described in this paper, are therefore to:

(1) identify the sources of all fugitive emissions from the Smelter,

(2) quantify the emissions in terms of sulphur dioxide and particulate,

(3) relate the fugitive emission rates to the unit operations and the throughput of the Smelter, and

(4) assess the impact of the quantity and rates of the fugitive emissions on the local environment and provide direction in the attempts to curtail them.

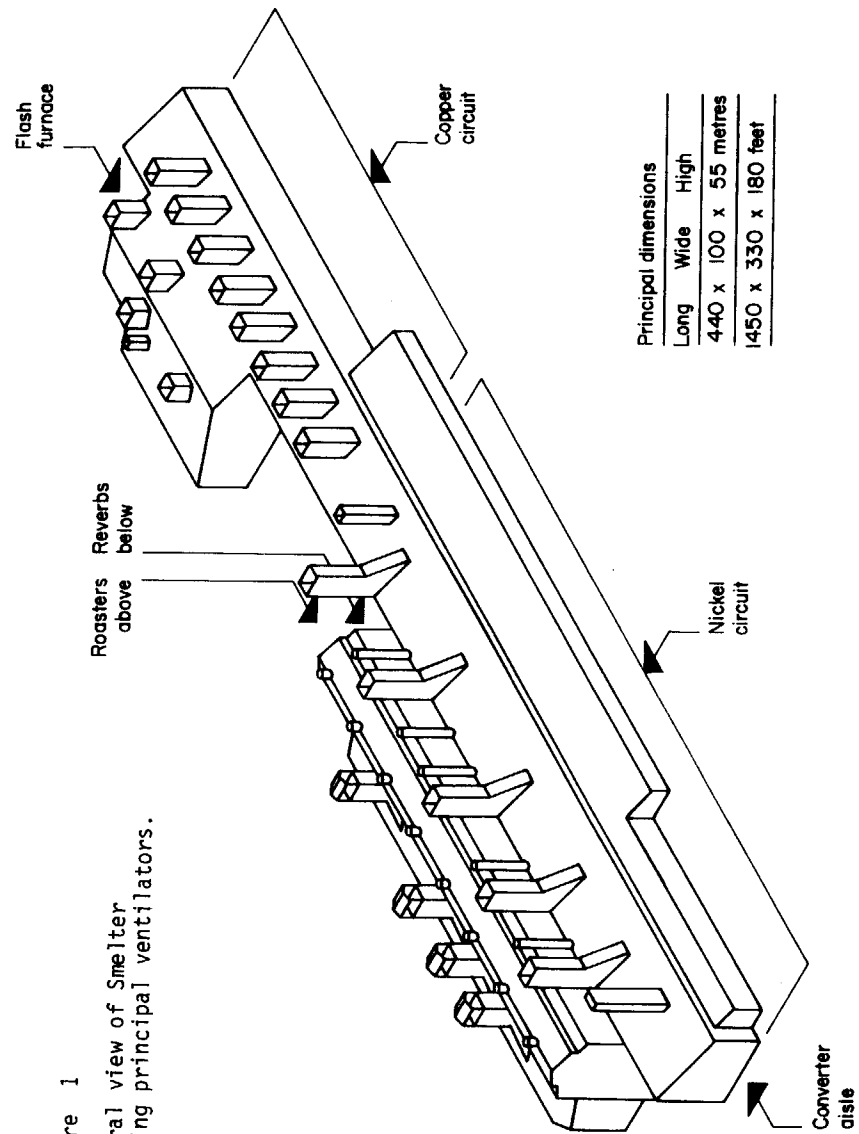


Figure 1
General view of Smelter showing principal ventilators.

Experimental

Preliminary Fieldwork

A survey of the Smelter revealed a total of 44 major roof ventilators with a combined area of some 1000 m^2. Their positions are located in Figure 1, together with the general dimensions of the Smelter building, namely 440 m x 100 m x 55 m high. The ventilators were found to fall in two categories, designated type "A" and "B".

The type "A" units are typified as fan forced, high velocity, uniform cross-section ventilators and are amenable to conventional testing procedures for enclosed gas streams such as EPA Method 5 or the ASTM technique. The type "B" units are large cross-section, gravity flow, with non-uniform profiles and are not amenable to conventional measurement techniques. This type of unit represents the majority of the Smelter's ventilation volume; the development of measurement techniques for these ventilators is the subject of this paper.

As the initial type "B" ventilator was to be tested, one situated directly above the copper converters was chosen. Figure 2 indicates its position above the aisle and its approximate size; there are 12 similar units above the converter aisle, each having a cross-sectional area of some 44 m^2.

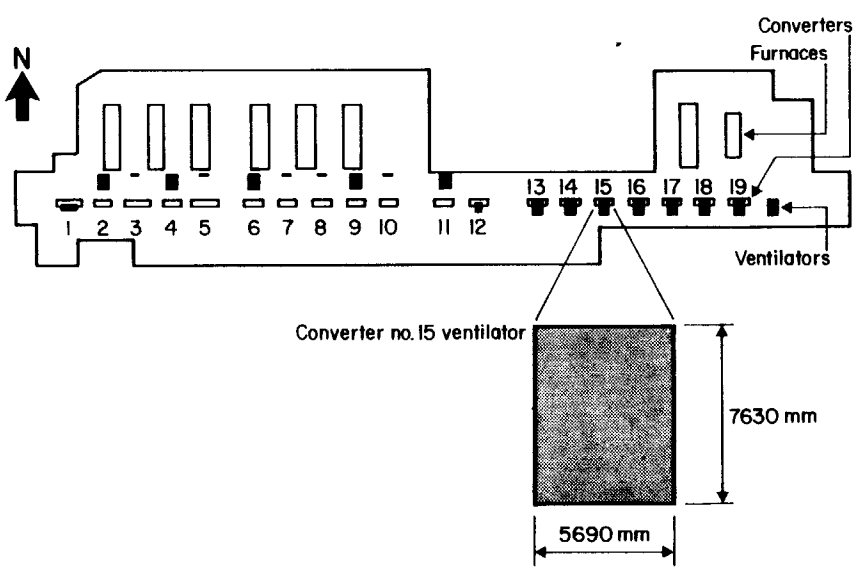
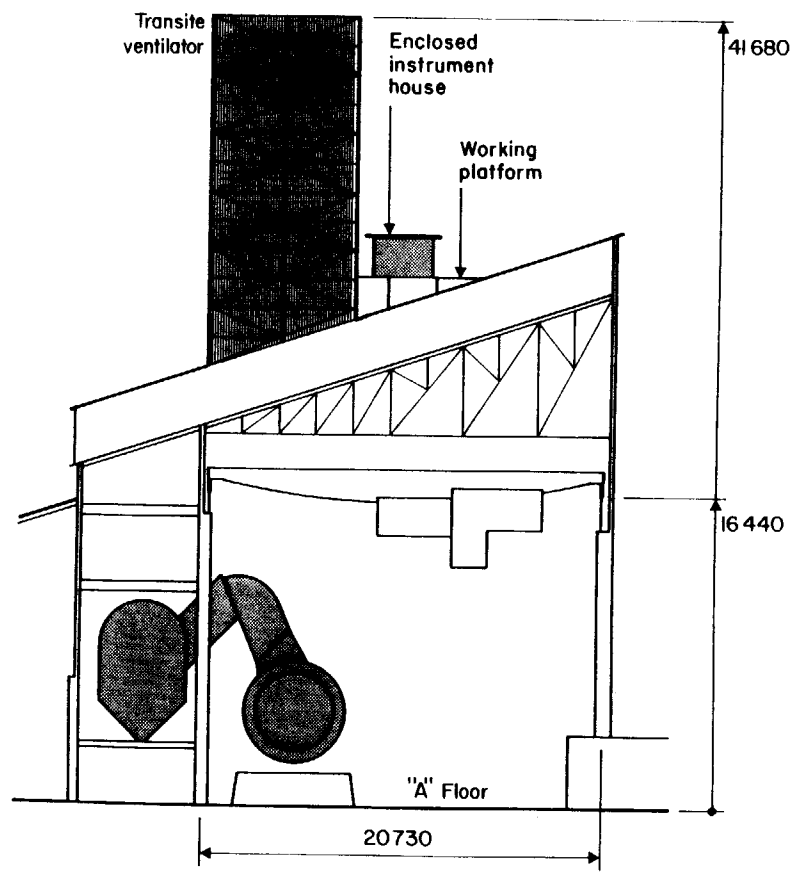


Figure 2
Location of roof ventilators over converter aisle.

Figure 3 shows the relative vertical positions and displacements of the ventilator, converter hood and flue systems and the overall dimensions of the converter aisle at this point. It is obvious, as was in fact observed, that gas and dust emanating from the mouth and hood area of the converter will tend to rise directly up to the ventilator directly above with minimum of loss to and interaction with adjacent units. In fact, the testwork indicated these interactions to be less than 10% of the total emissions, a very important conclusion in assessing the overall accuracy of the work.



All linear dimensions are in mm

Figure 3
Cross section through converter aisle - copper converter.

Figure 4 shows a general view of the roof ventilators above the copper converters. The position of the sampling platform and analysis station that were constructed can be seen, as can the relative positions of the adjacent ventilators. The necessity for the secure platform and enclosed station will be readily appreciated when one considers the time required to make the measurements, the exposed location of the sample point and harsh Canadian winter climate.

Ventilator Velocity Profile and Temperature Determination

The first phase of testwork was a study of the temperature and velocity profiles in the ventilator. A precalibrated remote readout vane anemometer and a type "K" thermocouple were traversed on a 54-point grid pattern across the ventilator section. The grid consisted of 7 parallel guy wires with 8 "stations" located symmetrically on each wire. From these traverses, it was apparent that the ventilator flow was symmetrical about its north-south horizontal axis and that it would be possible to select a fixed location for the anemometer and thermocouple that would represent the average flow through the ventilator. Figure 5 shows a typical velocity profile measured in the ventilator. It is to be noted that, as anticipated, the highest velocities and temperatures are towards the back of the ventilator (south) and directly above the converter.

In order to locate the positions of the multiple fixed probes to be used in sampling, the velocity profiles were reworked into a cumulative flow diagram as shown in Figure 6. Using this technique, the centers of 6 equal areas of volumetric flow were established in a south-north direction. In the profile shown, the total flow is 8600 m^3/min and each equal slice embraces a flow of 1430 m^3/min. A probe system of two identical 6-hole units, connected to a common header and symmetrical about the north-south axis, was then constructed as shown in Figure 7.

The locations of the thermocouple and anemometer are also shown. The accuracy of positioning of these instruments is indicated in the following tables,

	Total Volume (m^3/min)			
	Traverse	Single Point	Difference	% Difference
Test #1	9250	9530	+ 280	3.0
Test #2	9060	9310	+ 250	2.7

	Temperature (°C)			
	Traverse	Single Point	Difference	% Difference
Test #1	23	24	1	4.3
Test #2	23	23	0	0

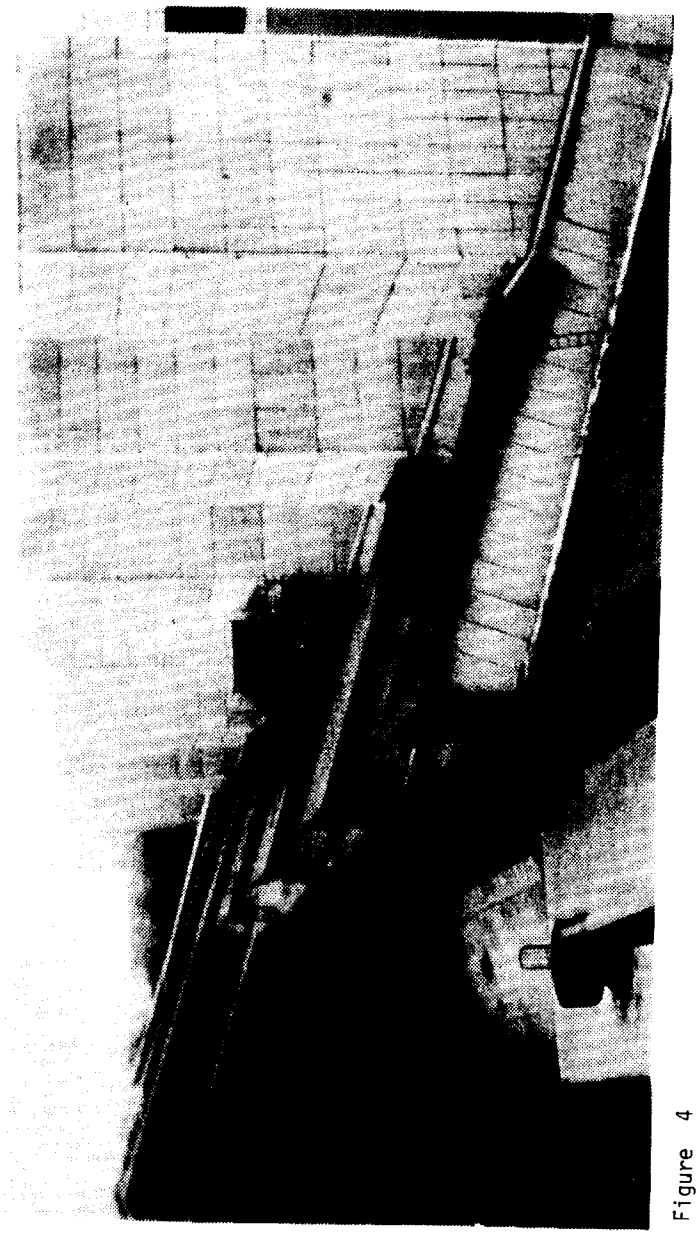
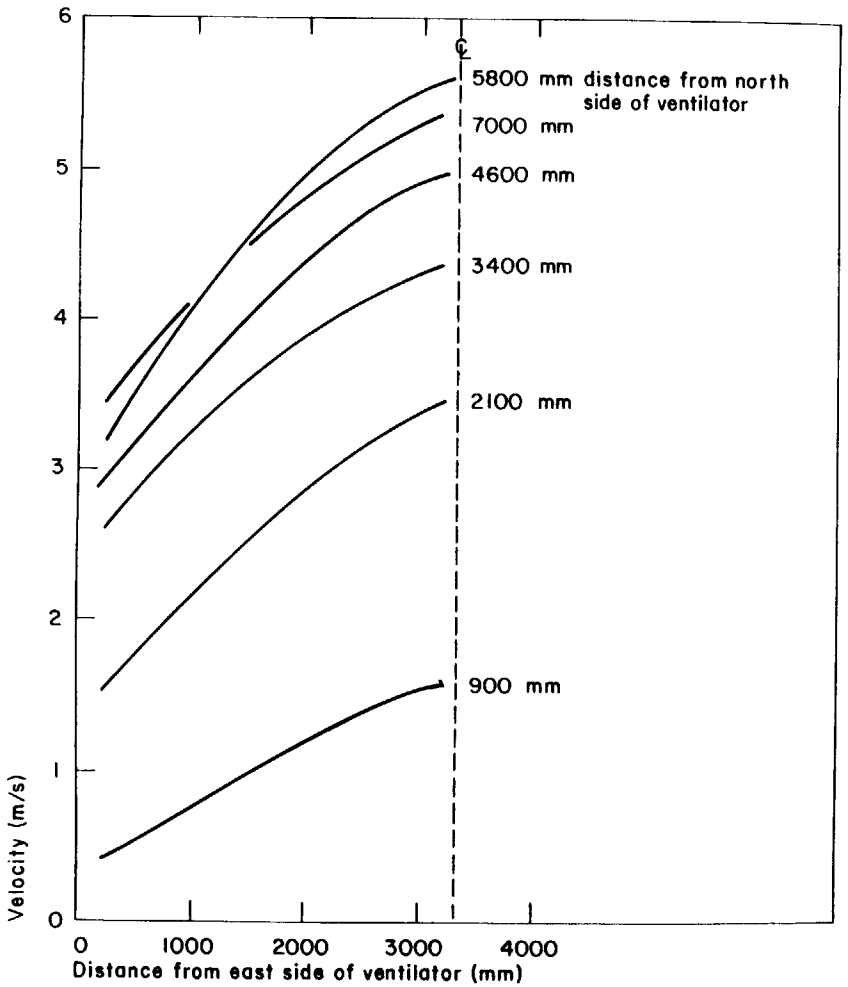


Figure 4
Copper converter roof ventilators.



Note: velocities assumed to be symmetrical about north-south centreline of ventilator.

Figure 5
Velocity profiles in six sections of ventilator.

in which the flow data from the predetermined fixed anemometer and thermocouple was compared to traverse data taken at the same time. It was concluded to be within ± 5% of the traverse data and consequently well within the projected accuracy of the total test of +10%.

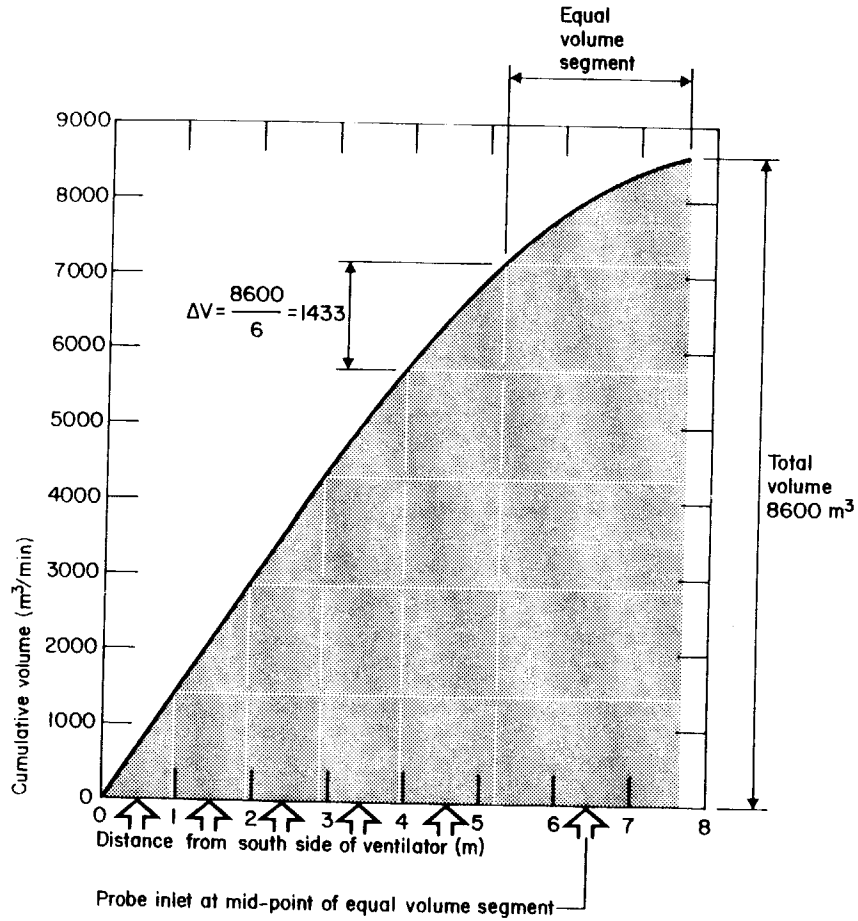


Figure 6
Cumulative gas volume in ventilator from south to north side.

Probe Design and Measurement Techniques

A fixed multipoint probe system, rather than a traversing probe, was developed for this testwork as it was both more convenient to use in an extended test and, due to the cyclical nature of the emissions, judged to be more accurate. The probe was constructed from ABS plastic piping, connected to a common header and vacuum pump (Figure 8). Flow to the individual arms of the probe

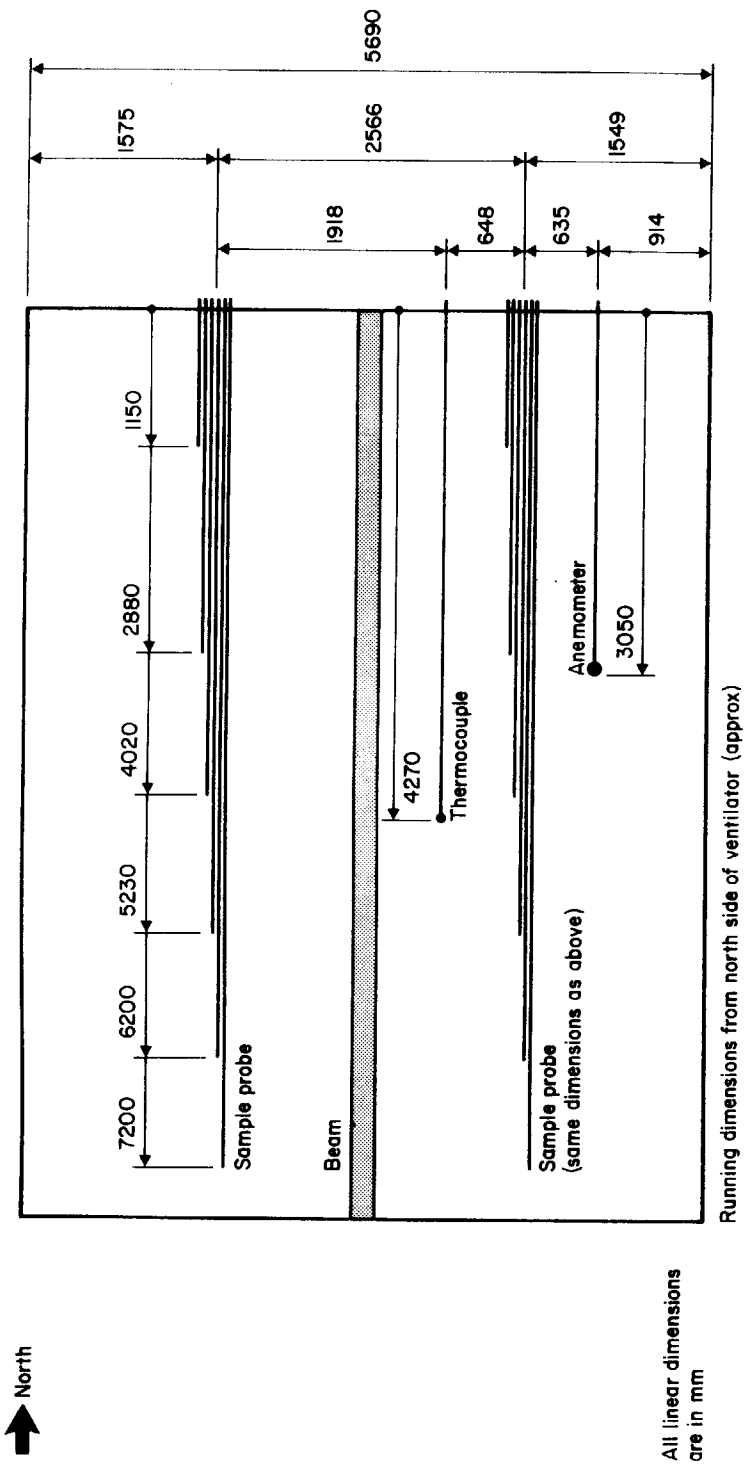


Figure 7
Location of anemometer, thermocouple and sample probes in ventilator.

was metered by precalibrated differential pressure measurement and controlled by individual pinch valves. The total flow through the system was indicated by an orifice plate and controlled by varying the speed of the pump.

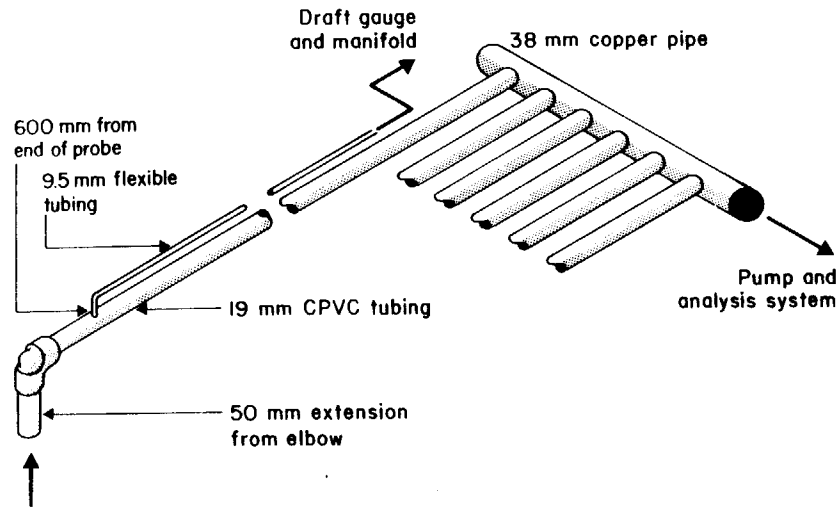


Figure 8
Probe sample tip and draft measurement location.

The overall schematic of the sample probe assembly in position in the ventilator is presented in Figure 9. After collection by the header, the total sample was passed through a filter for particulate removal and measurement. The filter, a Staplex type "S" paper filter, was exposed for between 1-3 hours before changing in order to obtain enough dust for assay. Typically, 1-5 grams of dust were recovered, weighed and analyzed.

Sulphur dioxide was analyzed for by a chemical technique in which a metered side stream of 2-4% of the total sample flow (of 40-60 m^3/h) was continuously drawn through a dilute hydrogen peroxide solution. The resulting sulphuric acid generated was semi-continuously titrated in the field to pH 4.6 with sodium hydroxide (Figure 10). The final solution, after partial depletion of the hydrogen peroxide, was transferred to the lab for total sulphur determination. Independent tests indicated 99% sulphur dioxide absorption and an excellent correlation between the cumulative titration and the final total sulphur assay. Differential particulate emission rates could be thus determined over a 1-3 hour interval and sulphur dioxide emission rates every 2-30 minutes, depending on flows and loadings.

In order to effectively operate this equipment and to accurately correlate with converter and other relevant activities in the aisle below, it was necessary to have three operators, two on the sample platform above and one below in the aisle, and in constant communication by two-way radio. A detailed logging procedure

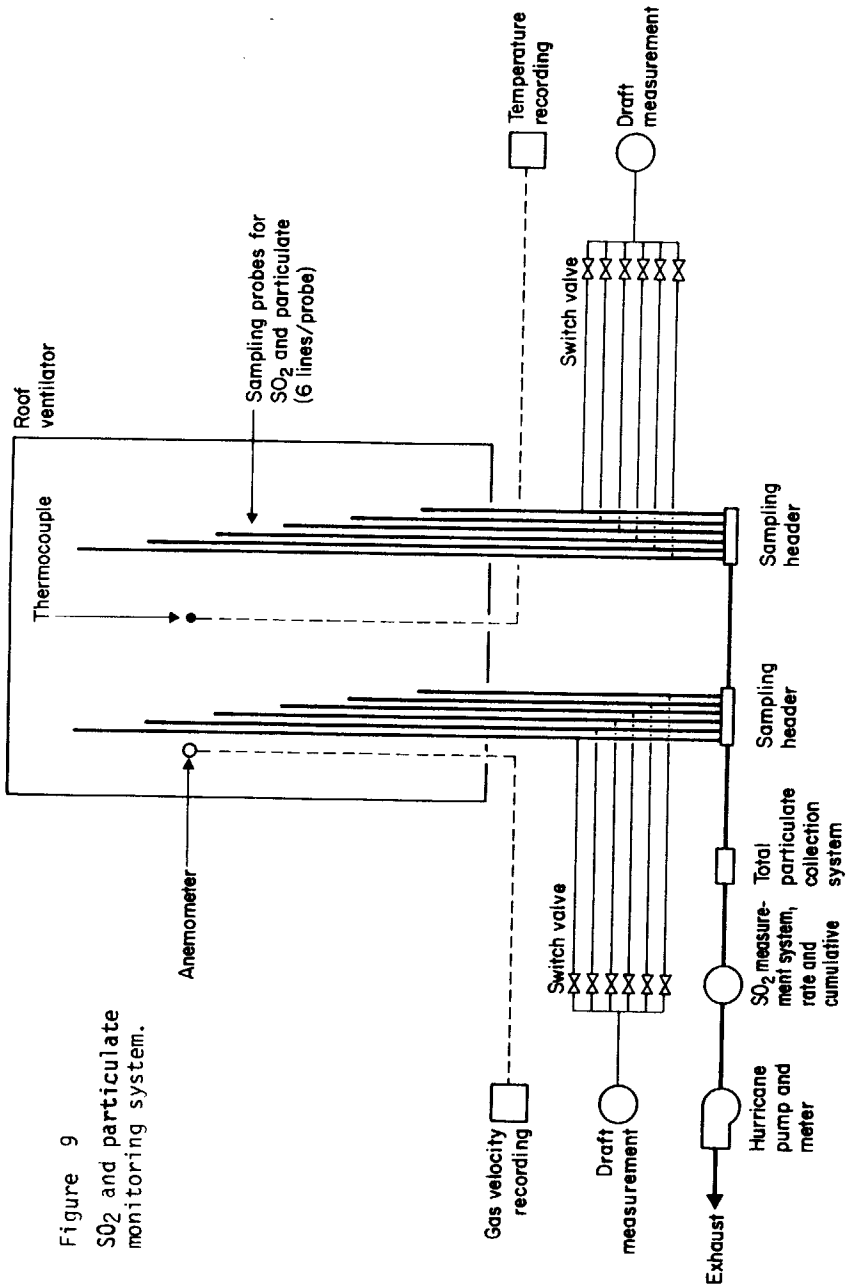
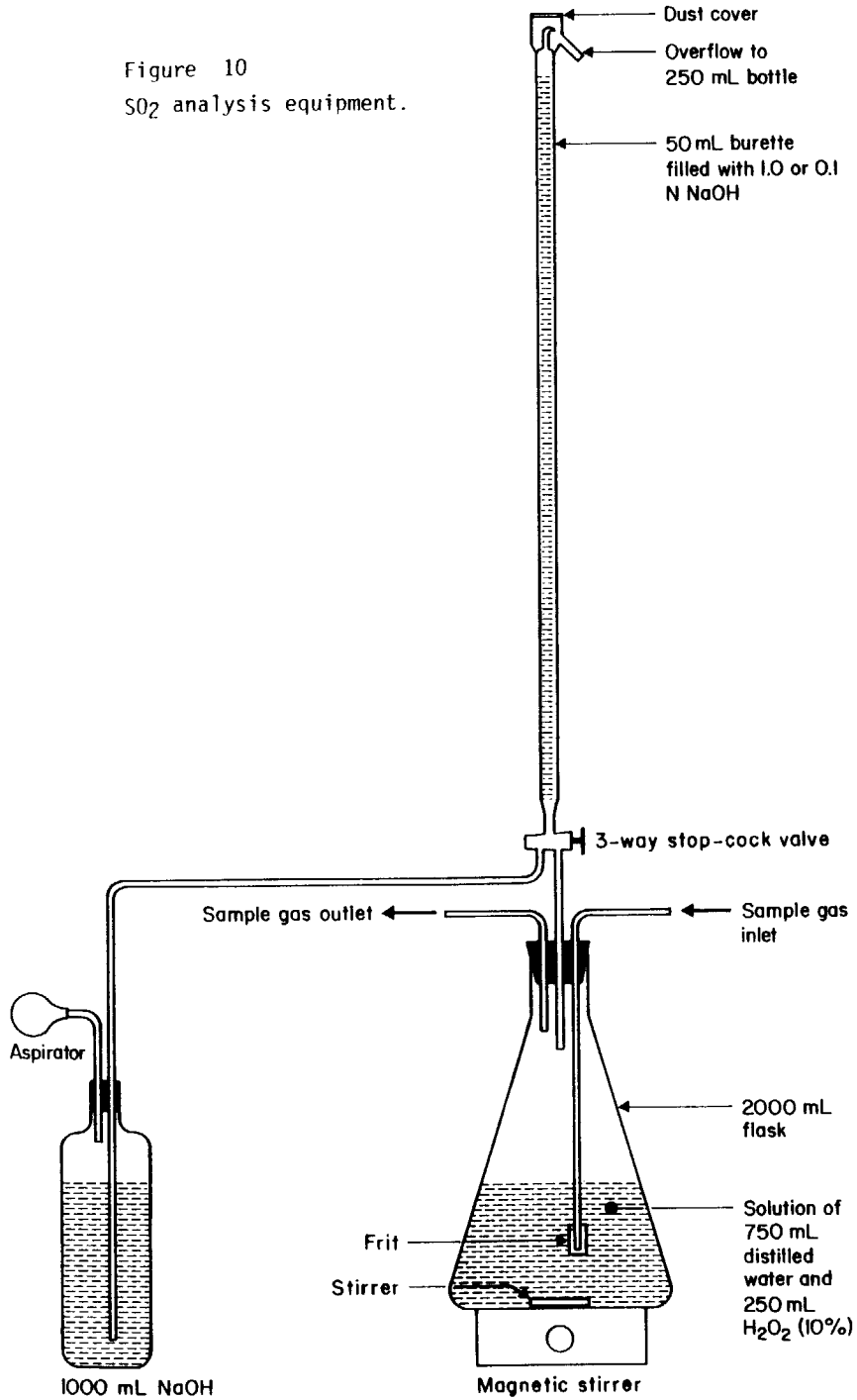


Figure 9
SO_2 and particulate monitoring system.

Figure 10
SO_2 analysis equipment.



for all relevant aisle activities was developed to record both aisle activities and emission parameters on a minimum 2-minute basis. Since a copper converter production cycle at Inco takes about 24 hours, it was necessary to follow the emissions round-the-clock and it was found expedient to follow several back-to-back cycles to get adequate coverage. In fact, this phase of the testwork culminated with a continuous period of 8 days, covering 5 consecutive charges and involving some 66 man-days of direct effort.

Experimental Results

In order to understand the terminology used in describing the results, some explanation of Inco copper converting practice is in order. Apart from the conventional copper converting phase in which 40-45% copper matte is blown to blister copper, there are two unconventional phases in the converter operation. In the first, a chalcocite concentrate containing about 70% Cu is added periodically to the blowing converter at about 70-80% weight of the final blister product. This fine recycled material is the result of Inco's unique copper-nickel separation metallurgy. Secondly, due to the relatively high nickel content of Inco's copper feeds to the converters, a large amount of semi-solid nickel containing mush is left in the converter at the end of the cycle, after the blister copper has been decanted. This mush is solublized and transferred to the nickel circuit by the careful addition of nickel reverberatory furnace matte to the converter, blowing and transfer of the resulting fluids. This is known as the nickel washout procedure. Currently there are about 0.6 nickel washouts per copper charge, determined by the quantity of nickel input to the converter.

During the period embraced by the testwork, there were three separate phases defined by the state of the converter hood repair. Initial tests were carried out with the hood in somewhat poor condition. The hood was then repaired and during the interim period, tests were carried out with the converter down. Consequently, ventilator emission data was recorded with the converter operating for two states of hood repair and also with the converter out of operation.

Sulphur Dioxide Emissions

In terms of sulphur dioxide emissions, the results are summarized in Figure 11 for a typical cycle, including nickel washout and with the hood in repaired condition. The following conclusions can be made.

The copper cycle proper produces over 93% of the total emissions, the remaining 6.7% being produced during the nickel washout. Within the cycle, blowing produces over 72% of the total fugitive emissions. Nearly three-quarters of the total measured SO_2 emissions were escaping from the converter hood system when the converter was in the blowing position.

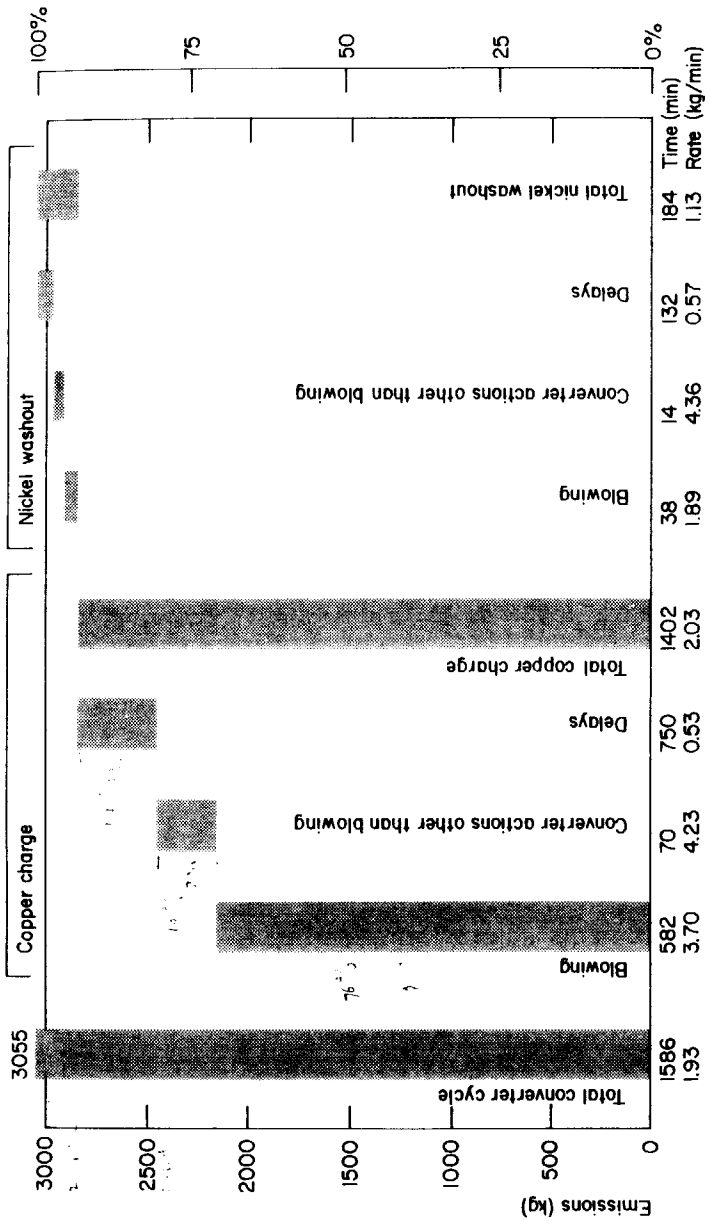


Figure 11
Magnitude of SO_2 emissions during converter cycle.

The remaining 28% are escaping when the converter is turned out of the hood and not blowing, and are divided into two groups, namely those produced by (a) addition and removal of materials to the converter (11%), and (b) delay periods within the cycle during which the converter is quiescent and waiting for service (17%).

Rates of SO_2 emission were highest during addition to the converter; somewhat lower at 80% of the rate during addition, but more sustained during blowing, and much less, 10% of the rate during addition, during the delay periods. These emission rates produce concentrations of SO_2 up to 1000 to 2000 mg/m^3 at the peaks during matte additions, dropping to low values of less than 30 mg/m^3 after extensive delays.

Particulate Emissions

Analogous data for particulate emissions is shown in Figure 12.

It is clear that total emissions are split 94 to 6% between the copper cycle and the nickel washout, and that 71% are generated during the copper blowing. No data was available for the washout blow due to the shortness of the blowing time compared to the average measuring filter change cycle. It is obvious that the breakdown of the particulate emissions between blowing and not blowing is extremely similar to the SO_2 emissions. In fact, they retain a constant mass ratio of between 10 to 20:1 throughout the cycle. Particulate emissions are highest during the concentrate charging part of the cycle, dropping to 40% of this rate during the normal blow, even though flux is being added during this latter part of the cycle.

Delays produce low, but significant, rates of 10% of the rate during charging, suggesting continuous elutriation of previously settled dusts around the ventilator steelwork. Corresponding concentrations are up to 100 to 300 mg/m^3 during the chalcocite charging, but this reduces to approximately 5 mg/m^3 during long delays, which is several times greater than the ambient Smelter environment dust loading. Analysis of the particulate showed greater than 50% Cu content.

In Figures 11 and 12, the converter cycle shown has been constructed to represent the typical average cycle and as such, produces 112 Mg of blister copper. The ventilator emissions can be expressed in terms of copper throughput in the Smelter.

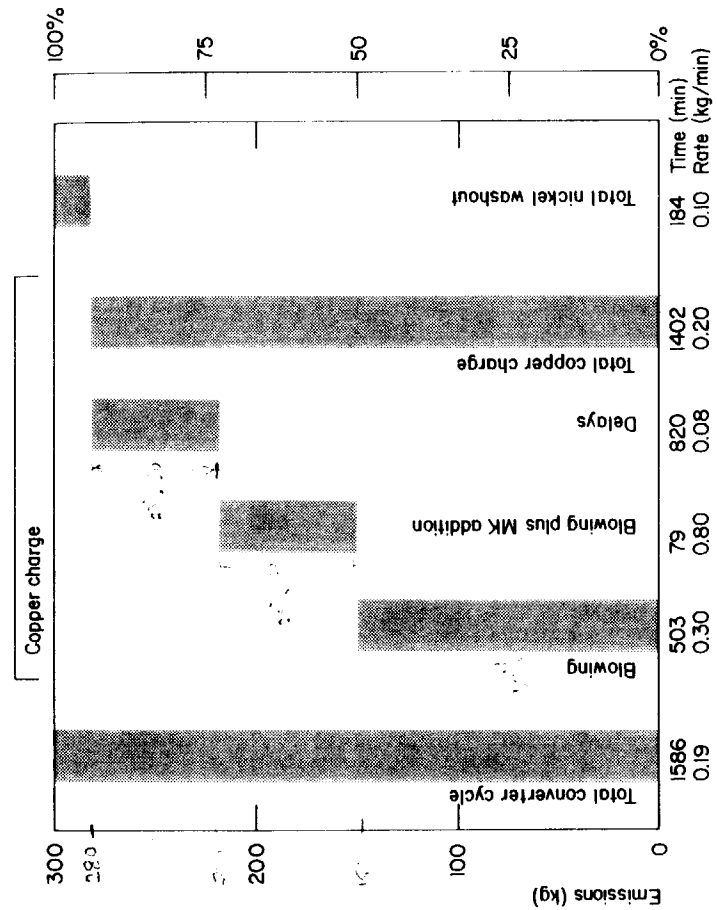


Figure 12
Magnitude of particulate emissions during converter cycle

Conclusions

It is felt that for the converter-ventilator pair tested, a procedure has been established for measuring fugitive emissions for both total gaseous sulphur (recorded as sulphur dioxide) and filterable particulate at about the ± 10% level of uncertainty over an extended period of time. Further, we have been able to distinguish emission rates down to the 2-minute average interval for SO_2 and 1-hour average for particulate using simple analytical techniques. These rates and totals have been related to actual converter operation and can be extrapolated to different production rates.

Future Work

On-going efforts in the program are aimed at developing more refined instrumentation and data correlating techniques. Since this work was completed, a second major campaign has been carried out on a different ventilator and in the course of this, techniques have been developed to continuously record and integrate velocity and temperature as volumetric throughput. This is to be coupled to a direct reading SO_2 analyzer and give integrated emission rates of sulphur dioxide continuously. Also, a primary data collection system has been designed to record the relevant aisle events in such a way as they can be rapidly transferred to a computerized data system. In this way, much of the very laborious and time-consuming data manipulation is being eliminated and it is anticipated that improved accuracy and reduced man-power will be required for the on-going studies on the other, type "B", ventilators in the Copper Cliff Smelter.

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Acknowledgements

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