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Project Summary

Evaluation of an Air Curtain Hooding System for a Primary Copper Converter

Chuck Bruffey, Paul Clarke, Thomas Clark, Mark Phillips, and John O. Burckle

This report presents the results of tests conducted to evaluate the effectiveness of a full-scale air curtain capture system installed on a primary copper smelter converter for capture of low-level fugitive particulate, including trace metals and sulfur dioxide. The test work was performed onsite at ASARCO's Tacoma Smelter on the first domestic full-scale prototype system, resulting in the first published evaluation of a full-scale fugitive capture system based upon the air curtain approach as applied to a primary copper converter.

The installation of the air curtain hooding system has permitted a quantitative approach to the direct measurement of the fugitive emissions from a primary copper converter for the first time. In this program, the fugitives captured by the air curtain were measured at a downstream sampling point in the exhaust side of the air curtain system during the various portions of the converter cycle. Emission factors were established for sulfur dioxide, filterable particulate (Method 5), inhalable particulate, and selected trace elements.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Copper converting is a batch operation conducted in two stages to convert copper matte produced in a smelting furnace into blister copper. The Peirce-Smith converter, used in all but one U.S. smelter, is acknowledged to be the major source of fugitive emissions in the smelter. These fugitive emissions first enter the workplace and, because they are present in relatively high concentrations, are considered hazardous to worker health. They are emitted from the smelter at relatively low elevations through roof monitors and other openings in the building. These emissions cause deterioration of the air quality and are believed to pose adverse health risks to the general population suffering prolonged exposure. While some dispersion and dilution of the fugitive emissions occur upon leaving the smelter workplace, the resulting ambient concentrations are high relative to a well-dispersed emission from a tall stack.

A number of approaches to controlling these emissions have been attempted by industry with unsatisfactory results. The major barrier to the development of an acceptable secondary hood has been the inability to design a system capable of permitting crane and ladle access while simultaneously providing for reasonably effective capture of fugitive emissions.

The air curtain (Figure 1) is formed by blowing air from a supply plenum or a row of nozzles which is especially designed to form an air sheet, or curtain, with as little turbulence as possible. This curtain is directed over the open space, well above the converter, which permits crane access. On the opposite side of the space, the curtain and entrained air are captured by an exhaust system. Fumes which rise

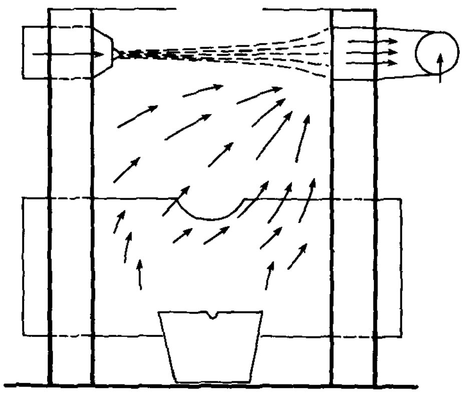


Figure 1. Air curtain operating concept.

from the source are directed into the suction plenum by the curtain. Air is also pulled into the curtain from both above and below. Since all air flow is inward, into the curtain, a high capture efficiency is achievable with a properly designed and operated curtain.

In the past it has been possible to estimate only very approximately, the quantity and composition of the converter fugitives for defining control strategies and needs, making actual design and selection of equipment somewhat risky.

Because the fugitive emissions are effectively captured by the air curtain and are collected by ducting, it becomes possible to completely characterize these emissions with a much higher degree of confidence in order to provide actual engineering data for design.

The tests described in the full report were conducted jointly by the U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards and the Office of Research and Development in cooperation with ASARCO, the Puget Sound Air Pollution Control Agency, and the EPA Region X Office.

Test Program

The test program was designed to achieve two major objectives: to estimate the effectiveness of capture of the converter fugitives not controlled by the primary hood and to characterize the captured fugitives by the "quasi-stack" method.

Capture Effectiveness

The effectiveness of capture was evaluated using three techniques.

- Mass balance using hexafluoride as a tracer
- Opacity of emissions escaping through the slot
- Observation of visible emissions

Tracer Experiments

Sulfur hexafluoride was injected into various points within the air curtain control volume, defined by the top, sides and front of the air curtain structure and the converter and primary hood which formed the back of the structure. The tracer experiments were of two types, those in which the tracer was injected into the air curtain volume above the converter (the upper portion of the air curtain control volume) and those in which the tracer was injected below the plane of the top of the converter and near the front of the air curtain side walls (the lower portion of the air curtain control volume).

The recovery efficiencies measured in the first test for individual tracer releases above the converter varied from 69 to 119 percent, and the overall average efficiency for the 45 tests was 94 percent. The port through which the releases of the tracer were made did not have any effect on the average collection efficiency. The average collection efficiency of all releases made through a given port ranged from 93.0 percent for Port C-6 to 95.4 percent for Port C-1. This difference was not statistically significant. The variability between the average collection efficiency of the replicates made at a given position (between the jet side and the exhaust side) was statistically significant. The greatest difference occurred at Port D-1, where the average collection efficiency ranged from 83.3 to 105.7 percent. The average collection efficiencies for Positions 1 and 2 (near the exhaust side) were approximately 96.6 percent and were generally higher than those for Positions 3 and 4 (near the jet side) which were approximately 91.6 percent.

The tracer recovery efficiencies for the various converter operating modes were also measured. With the exception of cold additions, the average recovery efficiency was not affected by the operating mode of the converter; averages varied from 92.8 percent during blowing to 95.0 percent during slag skimming.

For the second experiment above the converter, the overall average tracer recovery efficiency was 96.0 percent. Again, the port through which the tracer releases were made had no effect on the average tracer recovery efficiency of the air curtain hood. The average efficiency varied from 94.5 percent at Port C-6 to 98.0 percent at Port B-2 (Figure 2). For positions within the matrix, the average collection efficiency varied from 80.7 percent at Position 4, Port D-1, to 106 percent at Position 2, Port D-1. As in the first test series, the recovery efficiencies were consistently higher for positions near the exhaust side than for positions near the jet side (Figure 3). Again, the operating mode had no adverse effect on the recovery efficiency measured.

Two special tests were conducted during slag skimming where the tracer was injected just above the top of the converter at the front of the jet side baffle wall. The average collection efficiency measured was 94.5 percent, which is comparable to that reported for the releases on the three-dimensional matrix in the space above the converter.

For the third experiment, several series of tests involving the release of the tracer into the lower portion of the air curtain control volume near the front of the air curtain side walls were conducted. The first series (three tests) involved the release of the tracer material at a location slightly above the ladle near the jet side of the hood. The average recovery efficiency was 64.3 percent.

For the second series (six tests), the tracer was released at a location slightly above the ladle and very close to the wall on the exhaust side. During slag skimming, the recovery efficiency measured (four tests) ranged from 52 to 79 percent for an average of 63.5 percent. During matte charging, the average recovery was 68.5 percent.

In the third series of tests, the tracer material was also released at a location slightly above the ladle, but farther from the wall on the exhaust side. The collection efficiency measured for the seven tests ranged from 30 to 89 percent, with an overall average of 58.7 percent. It should be noted that the samples for tests conducted during the operation in the blowing mode yielded the lowest recovery efficiencies, i.e., 32, 33, and 33 percent. These values would be expected because the hooding system was in the low flow mode and there was no thermal lift which causes air to be drawn into the air curtain control volume from the front and carried to the upper control volume, a phenomenon which enhances the collection efficiency.

In the final series of tests, the tracer was released very near the ladle on the exhaust side of the hooding system. Recovery efficiencies were determined for 53 releases of the tracer material and

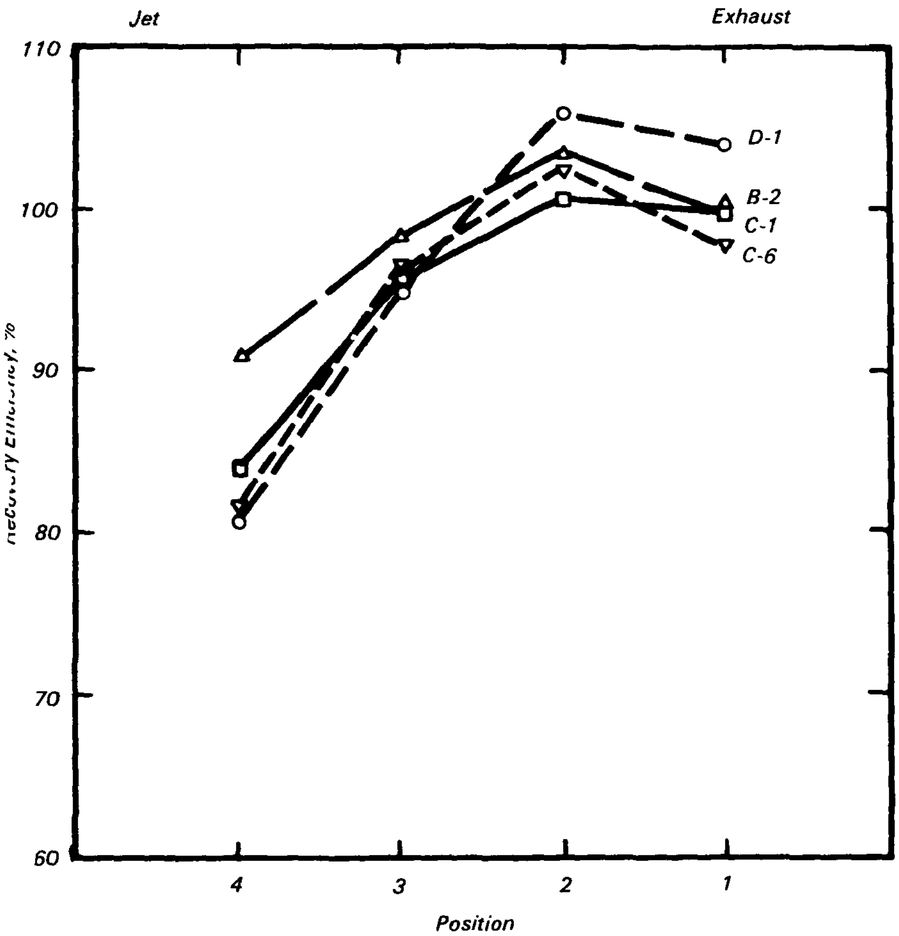


Figure 2. Effect of injection port on recovery efficiency.

ranged from 27 to 128 percent, with an overall average of 70 percent. Recovery varied from 38 percent for the 6 tests performed during blowing to 84 percent for the 28 tests performed during slag skimming. The difference between average collection efficiencies for the several operating modes is statistically significant.

Opacity Measurements

An opacity monitor was mounted on the top of the air curtain below the crane rail in order to obtain information on emissions escaping capture by the air curtain and passing through the slot. A total of 86 discrete observations was made with results ranging from 2 to 54 percent opacity for the major converter operations. During slag and finish blowing, no attenuation of the monitor's light beam was observed resulting in zero percent opacity. The instrument output range was 0 to 20 milliamps which corresponds with 0 to 98.4 percent opacity. The relationship of the instrument output to opacity was exponential, with 5 milliamps corresponding with 50 percent opacity. Therefore, emissions during the test program were in the lower end of instrument response. No correlation between opacity and capture effectiveness could be made because of emissions from the front of the air curtain system.

Visual Emissions

Two observers visually monitored the air curtain capture effectiveness by noting the location, approximate opacity, duration, and significance of visible emissions. Their estimates of capture efficiency were within 5 to 10 percent with only a few exceptions. Most variability in the estimates occurred for those operations involving rapid evolution of emissions over a short period, such as roll-in, roll-out, and pouring. The average of the observations for the various converter operating conditions displayed the same trends as the tracer experiments and indicates a reasonably effective capture of fugitives.

Conclusions

In summary, the visual observation and tracer recovery data indicated that the fugitive emissions capture effectiveness of the secondary hood is greater than 90 percent, averaging about 94 percent overall. The capture effectiveness during converter roll-in, roll-out, and slag skimming operations is more variable than other converter modes, since fugitive emissions generated during these events are dependent upon converter and crane operations. It is also evident that capture efficiencies of 90 percent or better are achievable for these events under the proper crane and converter operating conditions to minimize fume "spillage" into the converter aisle.

Thermal lift plays a significant role in increased collection efficiencies for fume generated in the lower portion of the control area. Also, the lower tracer recovery efficiencies for the various converter roll-out modes are indicative of fume "spillage" outside of the control area.

It is believed that no practical correlation can be made between opacities recorded by the observers and the transmissometer. The transmissometer was mounted perpendicular to the longitudinal axis of the slot, whereas the position of the visual observers was such that their view was parallel to the longitudinal axis of the slot, which resulted in a considerably longer path length through the escaping emissions. The apparent opacity increases as the path length through the emissions increases. Also, when positioned in front of the converter, the overhead crane interfered with visual observations above the slot area.

Emission Characterization

The capture of the fugitive emissions by the air curtain permitted their characterization by the "quasi-stack" method using standard EPA stack sampling techniques in the exhaust duct. The converter is a batch operation comprised of a number of steps requiring the roll-out, charge or pour, and roll-in of the converter. The generation of fugitive emissions occurs primarily during these operations because the primary hood is raised and the draft to the primary hood is closed off to prevent dilution of the strong sulfur dioxide gases processed in the acid or liquid SO_2 plants. During the blowing phase of the operation, some small

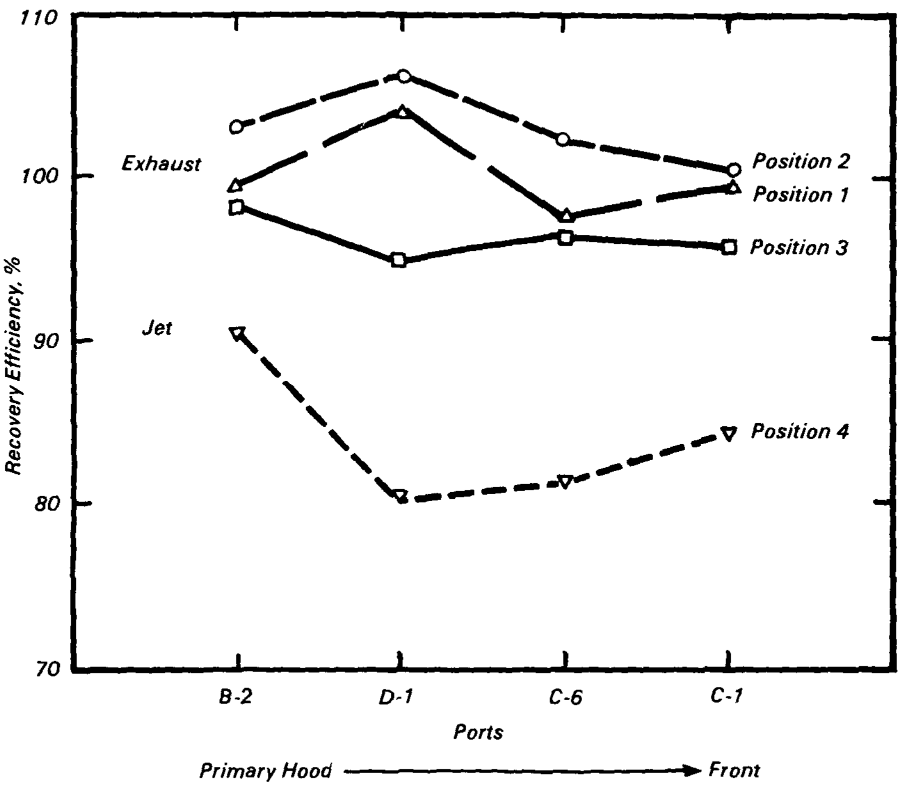


Figure 3. *Effect of injection position on recovery.*

quantities of fugitive emissions are seen to occasionally escape the primary hood. Because of the large number of different operations -- i.e., roll-in and roll-out; charging of matte, anode slag, various reverts, and scrap; slag skims; copper pours; and blowing and holding--we recognized that we could not characterize emissions for each individual condition. Therefore, the test was structured to provide composite data for selected operations.

Sulfur Dioxide Emissions

The concentration of sulfur dioxide in the air curtain exhaust was monitored by a continuous emission monitor. More than 470 individual data points were utilized to characterize the converter emissions, resulting in an emission factor of 3.0 kg/Mg of blister copper for the total converter cycle and 0.1 kg/Mg when the converter was in the blowing or standby mode.

Particulate Emissions

Total filterable particulate was sampled using EPA Method 5. For each of the three converter cycles, a sample was taken compositing all emissions over the total converter cycle by traversing the exhaust duct. Single point sampling was used to obtain a composite sample representing the emissions during those converter operations where the primary hood was open, i.e., charging or discharging. The emission factor for the total cycle was calculated as 0.45 kg/Mg of blister copper for the total cycle and 0.43 kg/Mg for those operations where the converter was rolled out.

Particle Size

Particle size samples were taken by impactors to define the particle size distribution within the inhalable particulate range of 10 μm and less by aerodynamic size. The tests were conducted at points of average velocity simultaneously with,but at points different from, those at which the particulate samples were taken. The sampling was conducted in such a manner so as to provide a composite over a converter cycle for each major converter operating condition.

- Charging mode which consists of all additions to the converter such as matte, anode slag, and cold additions such as scrap

- Skimming mode, which consists of slag skimming and pouring of blister copper

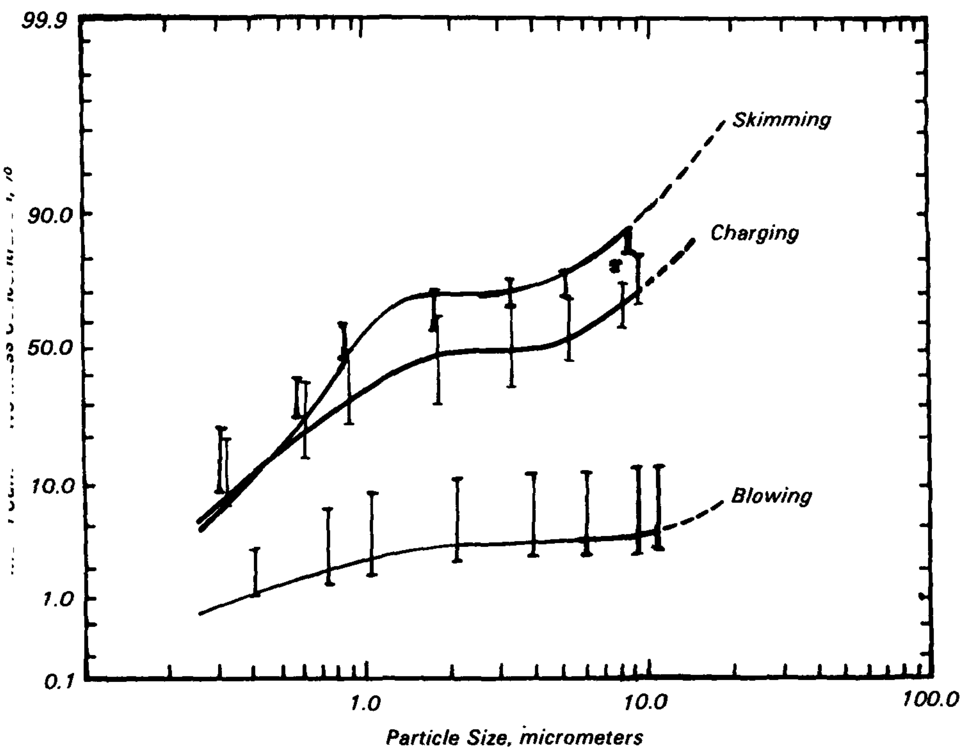
- Blowing mode, which consists of all operating conditions during which the primary hood is closed, including the slag, cleanup, and finish blows

The average particle size distribution for each mode indicates that: 1) the bulk of the particulate (88 to 98 percent) is above 10 μm during blowing; 2) the particulate is composed of both fine and coarse particulate (70 to 84 percent less than 10 μm) during charging; and 3) the particulate during skimming and pouring is predominantly (86 to 92 percent less than 10 μm) in the inhalable range (Figure 4).

Trace Metal Emissions

Arsenic, emitted in the form of arsenic trioxide, was measured to determine both the filterable particulate and gaseous emission rates (Table 1). The filterable arsenic fraction represents material collected in the sample probe and on the filter, both of which were heated to approximately 121°C (250°F). The gaseous arsenic fraction represents material that passed through the heated filter and condensed or was trapped in the impinger section of the sample train, which was maintained at a temperature of 20°C (68°F) or less. In retrospect, the sampling train should have been operated at the temperature of the stack gas, i.e., 15° to 30°C, to prevent revolatilization of arsenic trioxide and passage through the filter. Should revolatilization occur, the amount of arsenic reporting as gaseous would be increased, which could lead to a false conclusion regarding the amount that could be removed by dry collectors.

During Test 2, the gaseous arsenic concentration was considerably greater than in the other tests. During this test, the loss of draft in the primary hood caused by operational problems at the chemical plant resulted in frequent releases of smoke and fumes from the primary hood. Significant quantities of heavy smoke escaped the primary hood systems, and much of these emissions were captured by the secondary hood. Sampling continued throughout these intermediate upsets, but was finally stopped when the air curtain control system became overwhelmed by continuous and heavy emission discharge from the primary hood. Therefore, it is reasonable to conclude



'igure 4. Average particle size distribution for converter operating modes.

hat fugitive emissions generated by the nalfunctioning primary hood draft conributed to the higher arsenic concentraions observed during this second cycle est.

›onclusions

The bulk of the fugitive sulfur dioxide ·missions (over one-half) was emitted uring those converter operations ıvolving the rolling in or out of the onverter and the charging of cold dditions, particularly anode slag. The emaining operations in order of ignificance were matte charging; slag kimming; and copper pouring and ·lowing, including standby and idle. The results of the total particulate sampling indicated that the bulk of the fugitive particulate emissions occur during those operations occurring when the converter is charging or discharging. This suggest that the primary hood system is quite effective in preventing the escape of emissions during blowing.

The particulate size information leads to the conclusion that the bulk (90%+) of the fugitive particulate emitted during blowing is greater than 10 μm, while that emitted during the charging or discharging is predominately (70 to 90 percent) in the inhalable range. Emissions which occurred during a process upset in the blowing mode exhibited an increase in the proportion of emissions in the fine (less than 2.5 μm) particle range, in addition to the increase in total loading.

The trace metals contained in the particulate emissions comprise an appreciable portion of the total, some 12 to 40 percent by weight for charging and pouring, but only a small part (5 percent) during blowing. The bulk of the trace elements emitted in the fugitives tends to occur in the inhalable range with a very considerable contribution from the fine (less than 2.5 μm) range.

The trace metal emissions were dominated by arsenic and lead that are present in high quantities in the concentrate and carry through to the matte which is processed in the converter. The potential for trace metal fugitive emissions is then greatest during the charging of matte followed by he charging of reverts, scrap, matte skimming, copper pouring and finally blowing. Because of the greater variability of the trace element content of the feed materials, the content of the emissions during charging is the most variable, followed by slag skimming and then copper pouring. then copper pouring.

'able 1. Summary of Arsenic Emission Data

Converter cycle No.	Test	Mass emission rate, kg/h (lb/h) Filter	Gas	Emission factor kg/Mg (lb/ton)
1	TC	0.33 (0.73)	0.04 (0.08)	0.03 (0.06)
	SM	0.99 (2.18)	0.20 (0.44)	0.03 (0.07)
2	TC	0.61 (1.35)	0.72 (1.59)	0.09 (0.20)
	SM	1.97 (4.35)	0.99 (2.18)	0.05 (0.12)
3	TC	0.21 (0.47)	0.07 (0.16)	0.01 (0.03)
	SM	1.48 (3.26)	0.05 (0.11)	0.01 (0.02)

This Project Summary was authored by staff of PEDCo Environmental, Inc., Cincinnati, OH 45246.
***John O. Burckle** is the EPA Project Officer (see below).*
The complete report consists of two volumes:
"Evaluation of an Air Curtain Hooding System for a Primary Copper Converter: Volume I" (Order No. PB 84-160 514; Cost: $17.50, subject to change).
"Evaluation of an Air Curtain Hooding System for a Primary Copper Converter: Volume II. Appendices" (Order No. PB 84-160 522; Cost: $53.50, subject to change).
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