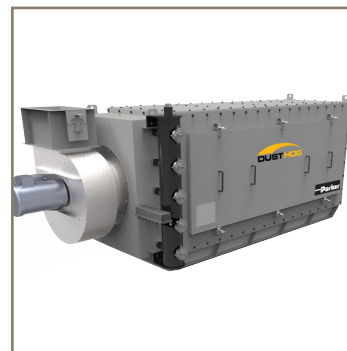




Reducing Air Pollution in a Lime Plant with Conveyor Filtration System:

Improvements and Benefits Case Study of the
China Linda Plant in Cajamarca, Peru



ENGINEERING YOUR SUCCESS.



Abstract

The process of crushing and grinding huge amounts of raw materials at Yanacocha's China Linda lime plant meant that the generation of fine nuisance dust was inevitable. The situation presented some key challenges that had to be addressed:

- The conveyor belt system transporting the materials from point A to point B was over-burdened.
- Regulations for outlet emissions had become more and more demanding, and dust collection technology had to deliver more effective solutions.

If not resolved, these issues could have impacts on the environment, productivity, safety, equipment maintenance and company profitability.

Yanacocha and Parker Hannifin (previously GE Environmental Services), worked together to address these issues, evaluate alternatives and find a better approach for dust collection: installation of horizontal dust collectors, or the DustHog® Conveyor Filtration Systems.

To measure the solution's success, dust emissions were recorded in different areas in the lime plant to establish a baseline. After the installation of the equipment and almost a year of operation, dust emissions were recorded for comparison.

This study describes implementation of the solution and analyzes how remarkably low emission results were achieved. A similar approach may be applicable to other mining operations.

Outline

1. Situation
2. Evaluation and selection of solution
3. Installation
4. Performance of the plant after the installation and collected data
5. Conclusions

Situation

The China Linda lime kiln plant of Newmont Gold (Compañía Minera Yanacocha in Perú, "Yanacocha") has two vertical lime kilns, which were supplied by Cimprogetti and Cornei in the late 1990s and 2005 respectively. One kiln produces 180 ton/h while the other produces 60 ton/h. All of the

lime produced is used in the Yanacocha gold processing plant. Yanacocha also obtains additional lime material from outside producers to meet their internal demand.

The lime produced by each lime kiln is transported through an individual conveyor belt system to two storage silos. Each silo has a holding capacity of 300 tons. The lime is discharged into lime storage trucks and transported to the process areas.

Yanacocha was having problems with pollutions created from the transfer conveyor belts and from material discharged from the lime kilns onto the conveyor belts. They were looking for a solution that would address both environmental and housekeeping issues. Yanacocha turned to the Parker Hannifin team for analysis and recommendations of possible solutions.

Evaluation and Selection of Solution

Several alternatives were evaluated before deciding on the use of point vent dust collection systems.

The water option

Spray water was the first possible solution considered. However, it was discarded because water could create an undesirable thermal reaction, raising the temperature of the lime and affecting operator performance.

The traditional vertical dust collector option

A second solution considered was a traditional vertical dust collector. This option would involve installation of a conventional centralized dust collector with filter bags and cages. However, proper duct routing was going to be difficult to achieve because of space requirements. Numerous elbows also would be needed to get around structures.

A significant problem with more elbows in ducting is increased wear on the system and a higher static pressure loss in the ductwork. System wear can lead to increased maintenance work and patching to prevent air leakage. Higher static pressure loss typically requires more horsepower to operate the dust collector fan. In addition, multiple point vent dust collector systems are more difficult to balance, often leaving vent points over- or under-vented. The particulate collected by the dust collector is then returned to the belt conveyor that is being vented.

At China Linda, the two existing lime kilns and the transportation conveyor belt systems are not always in simultaneous operation. If this solution were implemented, all venting points would work whenever the system was on—regardless of whether or not lime materials were on the conveyor belts or not.

The best option

A variation of the dust collector solution was determined to be the preferred option. Parker Hannifin recommended the installation of two, smaller, horizontal, insertable dust collectors. This solution was relatively new but very cost effective.

The concept relies on the installation of a small and compact pulse jet dust collector at each of the lime kiln discharge points. Key advantages of this solution are that no ductwork, hoods and ductwork supports are needed. These horizontal units also work only when the conveyor belt is running, and no extra dust handling equipment and no access platform and ladder are required.

At first glance, it may appear that a traditional dust collection system could be the more economical option because it only requires one collector. However, the total cost of installing the smaller Conveyor Filtration System was actually even less than going with one larger unit. But more importantly, the cost to maintain the smaller units was determined to be about 30 percent to 40 percent less than a larger, single, traditional dust collector.

At Parker Hannifin's recommendation, Yanacocha further investigated and evaluated Conveyor Filtration System technology. The company sent plant personnel out to visit a cement plant nearby where several of these Conveyor Filtration Systems were in use. After watching the technology at work and seeing its results first-hand, Yanacocha decided to pursue the Conveyor Filtration System for China Linda.

Installation

Calculating proper airflow

The guidelines of the Industrial Ventilation Manual that is used worldwide were used to calculate the gas flow. The correct calculation is essential for the following reasons: Under-sizing the flow will not ventilate the equipment properly; Oversizing the flow will collect the fine and gross particles, recirculate the material, and create an inefficient system by increasing energy use unnecessarily.

To calculate the correct gas flow for venting the discharges of the lime kilns onto the 2 ft. (61 cm) wide conveyor belts, the following calculation was used:

$$(2 \text{ ft. width of belt} \times 500 \text{ cfm/ft.}) + 700 \text{ cfm} = 1,700 \text{ cfm}$$

Compensating for altitude

Note that the preceding equation is valid for standard conditions (70°F = 21°C) at sea level. However, the elevation of the lime plant is about 4,100 meters (13,500 ft.) over sea level. Therefore, in order to achieve the same air density as standard conditions, engineering increased the gas flow as follows:

$$1,700 \text{ cfm} \times 1.61 = 2,737 \text{ acfm}$$

Compensation of Air Density Due to Elevation

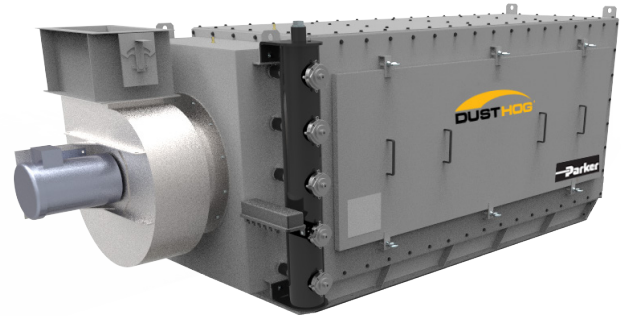
| Elevation in feet | Elevation in meters | Factor |
|-------------------|---------------------|--------|
| 0 | 0 | 1.00 |
| 2,000 | 610 | 1.08 |
| 4,000 | 1,220 | 1.16 |
| 6,000 | 1,830 | 1.25 |
| 8,000 | 2,440 | 1.35 |
| 10,000 | 3,050 | 1.45 |
| 12,000 | 3,660 | 1.53 |
| 14,000 | 4,270 | 1.62 |

It was reported that the operating temperature of the flow was 49°C (120°F), therefore the compensation for temperature was:

$$2,737 \text{ acfm} \times \frac{(460^\circ + 120^\circ)}{(460^\circ + 70^\circ)} = 3,000 \text{ acfm} = 5,100 \text{ Am}^3/\text{h}$$

The dust collectors were sized to have 20 high efficiency pleated filters providing a total filtration area of 1,035 ft².

Therefore, the Air-to-Cloth ratio of each of the dust collectors was: 2.90 acfm/ft².



DustHog Conveyor Filtration System (CFS)

Another factor considered in the final design of the equipment was the noise level of the fan assembly. Based on Peruvian regulations, the selection of the fan for the noise level was a maximum of 85 dBA at 5 ft. The fans selected have 78.9 dBA noise levels at 5 ft. The brake horsepower was 5.93 (4.42 kW). The nominal horsepower of the electrical motors was selected to 10 (7.5 kW).

The two lime kilns discharge onto two different inclined conveyor belts. The slope of the inclined belts is about 18°, which caused the material to slip back and made it difficult to control and reduce dust. Another challenging issue was overhead space restriction right after the discharges. Both inclined conveyor belts reduced the overhead space up to 30 cm (1 ft.) in certain areas, which made it impossible to install the collectors nearby.

Both of the new dust collectors were installed behind the restricted overhead areas at least 10 meters (30 ft.) from the discharges. A very tight enclosure was installed before and after the kiln discharges in order to maximize the negative pressure created below the dust collectors. The goal was to successfully transfer the negative pressure all the way down to the tail of the inclined conveyor belt. Virtually no dust leakage occurred when the dust collectors were installed. Additionally, the dust collectors were installed on the top of the enclosure at 305 mm (12 in.). This clearance allowed gross particles – usable lime – to settle on the belt conveyor and prevent it from being pulled into the collector. Flexible seals were installed between the top of the conveyor belt and the enclosure to minimize the amount of outside air pulled into the enclosure. Government visitors that inspected the area after several months of operation could not believe the conveyor belts were working because their emission monitors did not register any readings.

In order to obtain the proper 3,000 acfm designed gas flow, the outlet damper was adjusted based on the amperes demanded by the motor:

Based on the Full-Load Currents enclosed table, the ratio between Amps/HP for a 460 volt motor and 10 hp motor is: 1.40.

Relationship Between Horsepower and Amperes in Motors

(Table courtesy of Electrical Engineering Pocket Handbook)

Full-Load Currents

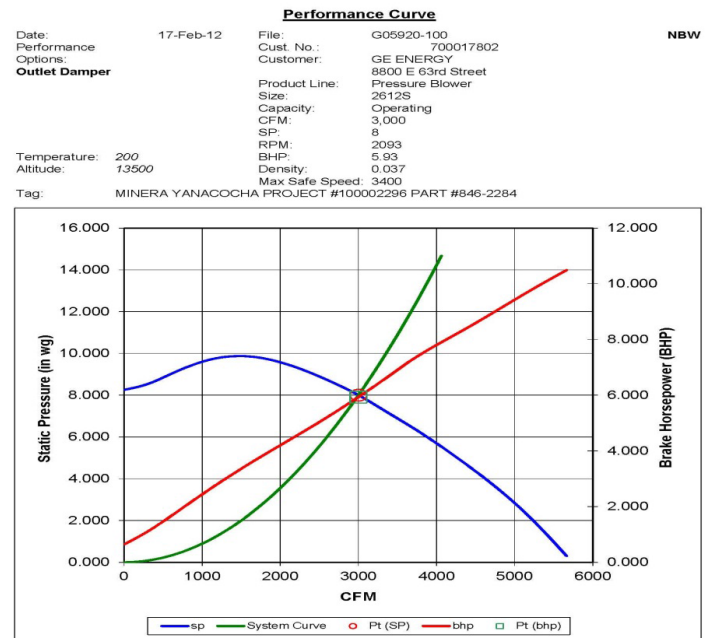
Three-Phase A-C Induction Type - Squirrel Cage and Wound Rotor Motors*

*For conductor sizing only.

| HP | 115V | 200V | 230V | 460V | 575V | 2300V | 4000V |
|-------------------------------|------|------|------|------|------|-------|-------|
| ½ | 4 | 2.3 | 2 | 1 | .8 | | |
| ¾ | 5.6 | 3.2 | 2.8 | 1.4 | 1.1 | | |
| 1 | 7.2 | 4.15 | 3.6 | 1.8 | 1.4 | | |
| 1 ½ | 10.4 | 6 | 5.2 | 2.6 | 2.1 | | |
| 2 | 13.6 | 7.8 | 6.8 | 3.4 | 2.7 | | |
| 3 | | 11 | 9.6 | 4.8 | 3.9 | | |
| 5 | | 17.5 | 15.2 | 7.6 | 6.1 | | |
| 7 ½ | | 25 | 22 | 11 | 9 | | |
| 10 | | 32 | 28 | 14 | 11 | | |
| 15 | | 48 | 42 | 21 | 17 | | |
| 20 | | 62 | 54 | 27 | 22 | | |
| 25 | | 78 | 68 | 34 | 27 | | |
| 30 | | 92 | 80 | 40 | 32 | | |
| 40 | | 120 | 104 | 52 | 41 | | |
| 50 | | 150 | 130 | 65 | 52 | | |
| 60 | | 177 | 154 | 77 | 62 | 15.4 | 8.8 |
| 75 | | 221 | 192 | 96 | 77 | 19.2 | 11 |
| 100 | | 285 | 248 | 124 | 99 | 24.8 | 14.3 |
| 125 | | 358 | 312 | 156 | 125 | 31.2 | 18 |
| 150 | | 415 | 360 | 180 | 144 | 36 | 20.7 |
| 200 | | 550 | 480 | 240 | 192 | 48 | 27.6 |
| Over 200 HP Approx Amps/HP | | 2.75 | 2.4 | 1.2 | .96 | .24 | .14 |

On the enclosed fan curve, we see the BHP (brake horsepower) is 5.93 for the 3,000 acfm. By using the ratio 1.40, we can figure out that when the motor draws 8.26 amps, the fan assembly is set up in the desired operating point. In order to achieve the 8.26 amps, the outlet damper was modulated properly.

Fan Curve



The New York Blower Company <http://www.nyb.com>

2/17/2012 Page 1

The first insertable dust collector was installed in June 2012 and the second one in September in 2012. The cleaning system was set to clean the filters on demand. This means the filters are cleaned only when needed. This approach contributes to longer filter life and lower compressed air consumption.

The delta P or differential pressure in the dust collectors was 4.0" w.c. and the interval time between pulse about 30 seconds.

Performance of the Plant After the Installation and Collected Data

Compañía Minera Yanacocha decided to evaluate the result after the installation and conducted a series of tests.

Two monitoring tests made were: First, breathable dust concentration in a 12 working hours (TWA) period, and the second one was for Crystallized Silica dust (Quartz, Cristobalite and Tridymite).

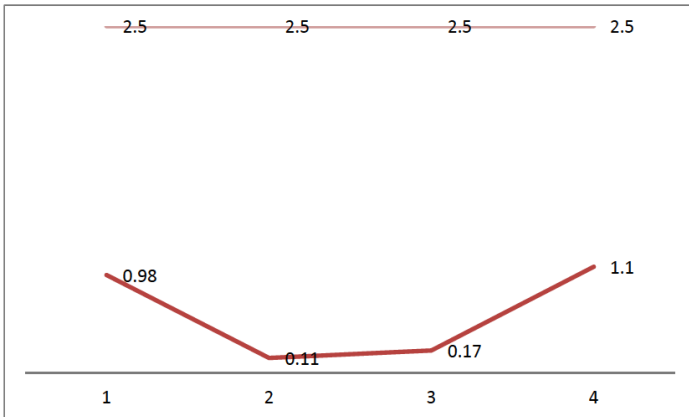
Because the dust created by the discharge of the lime from the lime kiln is more crystallized silica, these readings are more representative of the efficiency of the Conveyor Filtration Systems.

BREA Breathable Dust Test Results

| Samples | TWA - 12 hours (mg/m ³) | Exposure = (Concentration * 100)/TLV | |
|----------------------|-------------------------------------|--------------------------------------|--------------|
| Plant Operator | 0.980 | 39 | Low Probable |
| Maintenance Operator | 0.110 | 4 | Rarely |
| Plant Operator | 0.170 | 7 | Rarely |
| Maintenance Operator | 1.100 | 44 | Low Probable |
| | TLV(mg/m ³) 8 hours | 3 | |
| | TLV in 12 hours | 2.5 | |

TLV=Top Limited Value, established by AACGH 2012 (American Conference of Governmental Industrial Hygienists) TWA = Total Weight Average

| | | | |
|-------------------------------|------|---------------------|-------|
| Number of Samples (n): | 004 | % over TLV: | 0.0 |
| Maximum (mg/m ³): | 1.10 | Average: | 0.59 |
| Minimum (mg/m ³): | 0.11 | Standard Deviation: | 0.522 |

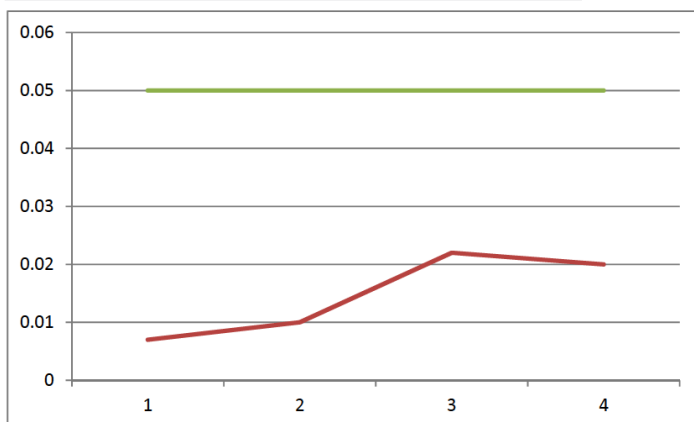


None of the samples surpassed the permissible limit of breathable dust of 2.5 mg/m³ for a working week of 48 hours.

| Samples | TWA - 12 hours | | | Exposure | | | | | |
|----------------------|----------------|--------------|-----------|----------|--------------|--------------|--------------|-----------|--------------|
| | Quartz | Cristobalite | Tridymite | Quartz | | Cristobalite | | Tridymite | |
| Plant Operator | 0.007 | 0.004 | 0.004 | 17 | Low Probable | 10 | Low Probable | 10 | Low Probable |
| Maintenance Operator | 0.010 | 0.004 | 0.004 | 23 | Low Probable | 10 | Low Probable | 10 | Low Probable |
| Plant Operator | 0.022 | 0.004 | 0.004 | 53 | Low Probable | 10 | Probable | 10 | Low Probable |
| Maintenance Operator | 0.020 | 0.0045 | 0.005 | 48 | Low Probable | 11 | Low Probable | 11 | Low Probable |

| Samples | TLV | | |
|--|--------|--------------|-----------|
| | Quartz | Cristobalite | Tridymite |
| TLV (mg/m ³) 8 Hours | 0.007 | 0.004 | 0.004 |
| TLV (mg/m ³) for atypical work hours | 0.0417 | 0.0417 | 0.417 |

Number of Samples (n): 004
 Maximum (mg/m³): 0.022
 Minimum (mg/m³): 0.007
 % over TLV: 0.0
 Average: 0.015
 Standard Deviation: 0.007



None of the samples surpassed the permissible limit of crystallized quartz dust of 0.05 mg/m³ for a working week of 48 hours.

Conclusions

Recent developments in point vent collectors have made Conveyor Filtration System technology a practical and cost-effective filtration system solution for applications, such as conveyor belts and air slides, where dusty conditions and space restrictions may be a concern. Point-venting with the Conveyor Filtration Systems may present significant practical advantages—as well as operational and energy savings— over other dust abatement options such as water suppression or traditional vertical dust collection.

Following the installation of point-venting equipment at the China Linda plant and after almost a year of operation, dust emissions were remarkably low. This success could be replicated in other parts of the materials transportation systems in a mine.

As filtration technology evolves, it is important to remember that sometimes the best solutions come in simple, small packages.



Providing Clean Air Solutions

Parker Hannifin is committed to providing clean air solutions that protect your employees, improve plant performance and enable you to realize your operating goals.

State-of-the-Art Labs and Advanced Filtration Research for Optimized Performance. Purpose-built labs and test facilities with the latest equipment allow our engineers and technicians to quickly and accurately assess filter capabilities and develop innovative new medias.

High Performance Filters & Specialized Equipment Solutions. With decades of experience manufacturing high performance original equipment and aftermarket

filters to meet a variety of system types and configurations, we can satisfy whatever requirement is needed including customized solutions.

World-class Manufacturing Processes with a Global Footprint. We produce top quality filtration solutions through stringent manufacturing processes.

Application Expertise for Any Filtration Challenge. Our ability to design a solution to fit your application begins with engineering expertise proven by hundreds of global installations.

Industrial Applications

- Abrasive Blasting
- Carbon Black
- Cement
- Chemicals
- CNC Machining
- Coal-Fired Boilers
- Cold Heading
- Die Casting
- Food Processing
- Lime
- Metals
- Metalworking
- Pharmaceutical
- Plasma & Laser Cutting
- Plastics Processing
- Powder Paint
- Thermal Metal Spraying
- Utility
- Waste-to-Energy
- Welding
- Woodworking
- Other Applications
- Custom or OEM Applications

Acknowledgements

Parker Hannifin's Air Filtration team thanks Carlos Choque, Lisban Caballero, Luis Escobedo and Danyer Girón from Compañía Minera Yanacocha for their assistance and contributions during the installation, start-up and operation of the dust collectors, and their input to develop this paper.

References:

- Industrial Ventilation Manual – 23rd Edition ACGIH

