

## **Blasting soft, plastic mineral inside a silo at a copper mine**

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### **ABSTRACT**

Metallurgical testing at Cobre Las Cruces prior to production at the mill was done with overburden gossan. Some of that test gossan was a very fine material, wet by the water conditions at the bottom of the pit. When processed and stored wet at the fines material 3000 tonne (3307 tons) silo, this material cemented in a very unusual manner.

At one side, it was a very soft, clay-like material that would absorb all mechanical energy provided by pneumatic hammers. On the other side, it would be extremely cohesive, keeping an 80° angle with horizontal without falling. All three feeders would not extract material from the bottom of the silo due to the bridging of the material on top.

The mill had to go into production in few days and almost 3000 tonnes of material needed to be removed soon. For liberating the feeders, a set of smooth, pyrotechnical charges were placed in the feeders, on top and the side door of the silo throughout several days. The holes needed to place these charges were drilled with compressed air up to 1,5 m (5 feet) length maximum. Stemming those crumbling, horizontal holes was not possible due to safety and operational restrictions. In order to direct explosive energy in adequate manner, charges were placed in steel tubes and stemmed with a gypsum-cement mix.

Shooting at feeders, the lateral access door of the silo and top of the material from the roof of the silo through several days resulted in enough material evacuated that allowed crews to access and clean safely the rest of the material left. Production of the mill was possible at the projected date.

### **Introduction**

On May 2009, Inmet's operation Cobre Las Cruces, was ready to go into production. In order to test the mill and provide iron to the SX-EW circuit, aggregate rock and gossan ore was run through the mill circuit.

The gossan ore was a fine, wet material that, during the time into the fines silo, developed enough internal cohesion that stopped its free flowing characteristics. Along with crushed rock previously run through the mill, the mix revealed to have turned into a situation hard to solve. 1000 tonnes of that material were stocked at the fines silo, with no flowing through any of the 3 feeders located at the base of this concrete structure.



*Figure 1: Fines silo of 3000 tonnes that contained wet, fine gossan ore that hardened due pressure and humidity, preventing flow at the feeders*

Access to the silo was very limited, with only one gate at a side, and openings at the flat roof. Safety was a first priority, and first attempts to shake the material with the use of concrete vibrators or compressed air spears were unsuccessful. The wet, fine gossan material was hard enough to hold negative angles and high pressure air, and still plastic enough to withstand vibration without crumbling or flowing.

Blast Consult S.L. was called in to apply any blasting procedure that could both ensure the integrity of the silo and feeders and also help on reaching a safe state at which workers could be sent in the silo and work with a bob cat or mini excavators.

After studying the work and considering legal and security restrictions on the use of standard explosives, a set of pyrotechnic tools were chosen. Those are safe to use in open air, behaving like a flare with a slow burning rate. But, under compression, the reaction rate increases and the gas produced is released at a pressure enough to displace and fracture rock, concrete or any other confining material immediately surrounding it.

### Phase 1. Feeders and first shots

First attempts to start moving the gossan were performed at the feeders, which were all bridged up at few inches above the conveyor belt. The only access to place 100 gram cartridges inside the material

trapped on the feeders was using a 20 cm x 20 cm (7,9" x 7,9") window on each side which harbors a fill sensor. Also, iron "needles" used to regulate the falling rate of the material under normal circumstances were removed at even locations along the feeders. Holes were performed with the help of compressed air spears and first charges were located and fired.

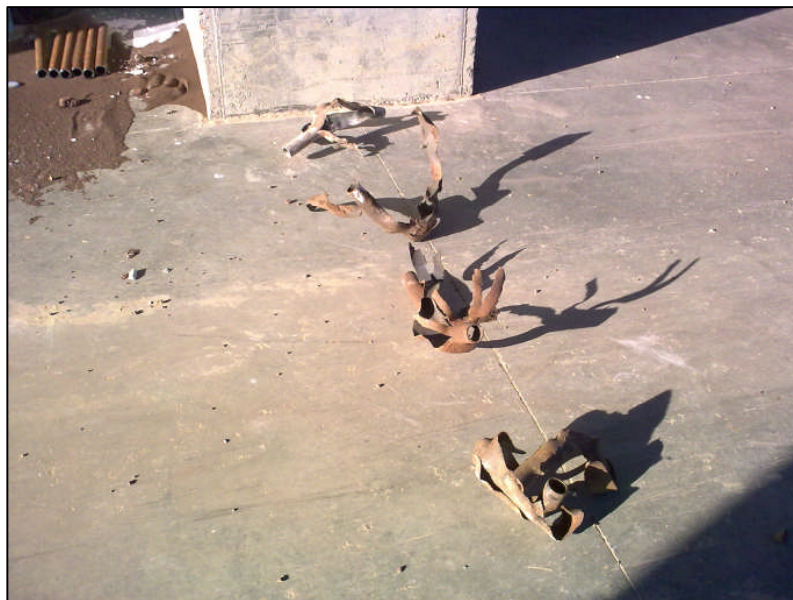
First shots were unnoticeable. The charges did go off, but since the use of compressed air made holes of much greater diameter of the cartridges, and because of the soft, plastic nature of the wet gossan, the gas generated at the charges simply did not reach any usable pressure and was lost in filling the holes. Therefore, a way to increase confinement was needed.

### Higher confinement of charges

A mix of gypsum and cement was prepared as a fast reaction stemming material that would fill the surroundings of the hole. Although this was useful at some point, the best results were achieved by introducing pyrotechnic cartridges into metal tubes and stemming them with gypsum on both ends.

This latter design proved very useful in confining gasses and raising their pressure before it was released. An increase of charge diameters of around 5 times was detected by the recovery of blasted steel tubes after shooting. This was enough to push and displace gossan around the holes and resulted in the clearing of the 3 feeders.

Unfortunately, the gossan on top did follow until reaching surface, but the cone angle of the material was too steep and would still not fall into the feeders, leaving the silo still out of order.



*Figure 2: Some of the metal tubes recovered at the feeders after shooting*

### Side attack on the silo

Using the lateral door on the lower first third of the height of the silo proved to be a difficult task. Unpredictable falls of large tonnages of the gossan happened and reached outside the door, with a potential of hurting or killing workers digging their way to the closest feeder with the use of compressed air.

Again, as a way to minimize the time inside the silo and maximize gossan collapse under controlled circumstances, pyrotechnical charges were placed in holes drilled horizontally on the gossan.

These charges were modified in the length of stemming so higher lengths will confine the exit of gasses at the collar of the holes, thus diverting the highest amount of pressure backwards and creating more excavation of material from the bottom of the holes.

In order to ensure safety, it was not allowed to place by hand at the face of the area to be blasted the cartridges. Instead, charges were placed at the end of poles which helped inserting them to the end of the holes from outside the silo. This was a slow, delicate maneuver, as it was easy to break electric cables and/or have the charge falling outside the hole.



*Figure 3: Once the cavity progressed upwards and into the silo, the only safe way to place the cartridges was attaching them to a long pole and inserting them in holes drilled with long compressed air spears.*

### Liberating feeder number 1 from the side

After few blasting rounds at the face of the gossan by the side door, feeder number 1 was reached. A high, vertical wall of 10 m (30 feet) wet mud-like material stood without falling, ready to collapse at any, unpredicted moment that could take from minutes to weeks, with a whole mill of a 600 million euro project waiting for it.

The feeder was turned on several times to transport all blasted material that fell into it. At point was reached in which feeder number 1 was completely empty and almost vertical walls stood on the sides of it without any more material falling into it.

A large number of charges were used simultaneously on the larger face achieved, with the possibility of placing a simple pattern of holes of 2 rows maximum, creating a cutting wedge on the gossan as when chopping down a tree.

Few minutes after firing this larger round of 8 charges, several tonnes of gossan fell on the feeder number 1, filled it and pushed through the door until it was full to the ceiling. Had any worker being there at that time, it would have been under a serious safety situation.



*Figure 4: Minutes after shooting several charges at once at the bottom of the gossan wall, a large amount of ore collapsed into the feeder and overflowing through the side door*

## Top charges

An additional and complementary way tested to increase the collapse of material was placing a charge on top of the crests over cones created under the feeders and had reached surface.

Since there was no way to drill from the roof of the silo, a charge design that would direct the effect of the explosion downwards was created with hand ready items. This charge had to be self stemmed and stable in order to prevent rollover of it. The result of this design was two pyrotechnical charges on steel tubes on the side of a gypsum barrel.



*Figure 5: A self stemmed double charge was created to be placed on top of the ore. This had to have side stabilizers to prevent rollover and ensure downward actuation*



*Figure 6: Placing the double charge on top of the crests created in between feeders. It was lowered with the help of a long rope. It had limited effect, although helped on collapsing part of the crest and, by air blast, shake the surrounding ore.*

## Results

Pyrotechnical charges modified to specific site-conditions proved a useful tool to safely excavate and remove plastic material. Although slow and with limited power, it ensured no damage was done to any silo structure.

Combined efforts from up downwards and from the bottom upwards resulted in the liberating of feeders and progress on the side of the silo to clear enough material that it became safe of a bob cat to get in and do the mucking of remaining gossan.

This allowed for the full clearing of the silo and the load of copper ore in order to start production.

## Acknowledgements

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