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# ALTA 2012 NICKEL/COBALT/COPPER CONFERENCE

**MAY 28-30, 2012**
**BURSWOOD CONVENTION CENTRE**
**PERTH, AUSTRALIA**

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# CHUQUICAMATA RETROFIT AND FRANKE - RECENT CU SOLVENT EXTRACTION PROJECTS IMPLEMENTED BY OUTOTEC

By

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## ABSTRACT

Development of Outotec VSF® technology dates back to the 1970's, the first commercial application being Kokkola Mo SX Plant in Finland (1977). Zaldívar in Chile was the first Cu SX plant to utilize the technology (1995), which has gone through several versions and incremental improvements from the first projects to the most recent. The latest projects are retrofit project of Chuquicamata Oxide Plant Train A (start-up in 2008), Franke Cu SX-EW (2009), Assarel Cu SX-EW (2010), Tia María Cu SX-EW (start-up date unknown), Caserones Cu SX-EW (2012), a confidential U SX project (2012) and a confidential Co/Ni SX project (after 2015).

The objective of this paper is to discuss the experiences of the Chuquicamata and Franke projects and specifically the results of technological improvements implemented in them. The Chuquicamata retrofit project was the first of its kind executed by Outotec, with incorporation of VSF technology in an existing, operative solvent extraction train to increase its PLS processing capacity. Downtime required for the installation of VSF equipment was minimized by incorporation of by-pass pipelines to the separate stages and installing the VSF equipment stage by stage, keeping the train in operation during the whole intervention sequence. In the Franke Project, a new concept of combined Washing stage and Loaded Organic tank was utilized for the first time, providing approximately 15% CAPEX reduction for the SX plant. Additionally, Outotec® Reverse settler design was utilised in order to further optimize the plant layout in terms of operational ergonomics.

## INTRODUCTION

The existing VSF® (Vertical Smooth Flow) solvent extraction plants account for about 30% of the total world-wide copper solvent extraction capacity[1, 2] and about 15% of the global cobalt solvent extraction capacity[3].

VSF technology includes three main equipment units:

- DOP® (Dispersion Overflow Pump) pumping unit,
- SPIROK® mixing unit,
- Outotec® Compact or Reverse settler with DDG® (Dispersion Depletor Gate) fences

Principal distinctive features of VSF technology are:

- Separated pumping and mixing
- Low head overall design resulting in low tip speeds of the DOP pumps
- Mixing with the helicoidal SPIROK agitators, which create a vertical flow pattern in the mixer tanks
- Compact, deep settler design with DDG fences and high settling rates

One of the beneficial characteristics of the overall VSF design is that the generated dispersion has narrower droplet size distribution and larger average droplet size, when compared to conventional SX plant design. This has been demonstrated by droplet size measurements made in industrial plant conditions. Some measurement results are shown in Figures 1 and 2.

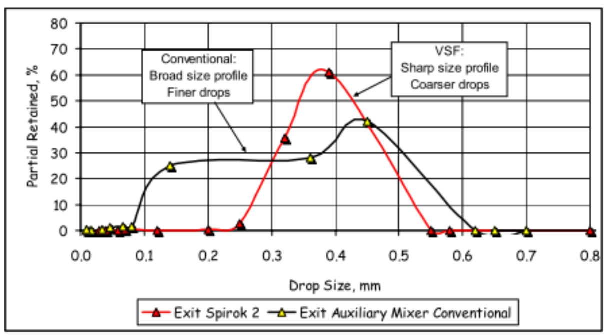


**Figure 1: Dispersion Droplet Size Distribution after Mixing[4]**

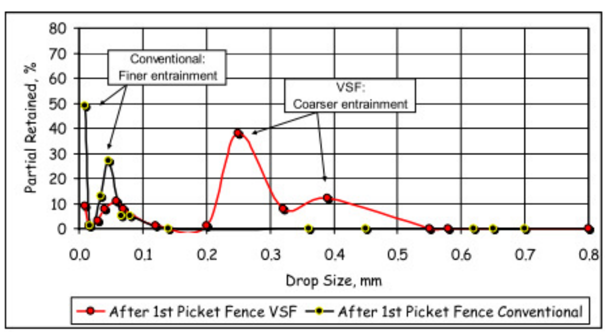


**Figure 2: Dispersion Droplet Size Distribution after First Coalescing Fence[4]**

The operating principle of DDG® fences has not been extensively discussed in the earlier publications made by Outotec[5, 6], so that the principle and operating features of the DDG fences are described briefly here. A schematic illustration of DDG fence operation is shown in Figure 3.

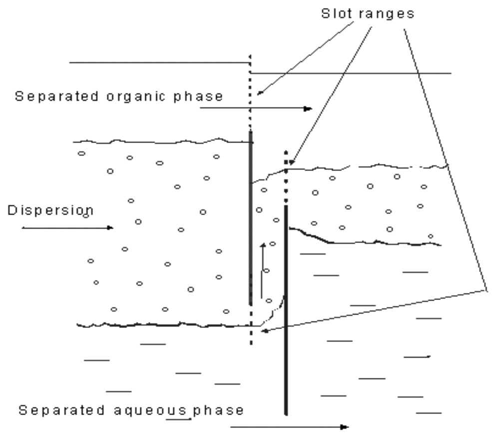


**Figure 3: DDG Fence Operation (Side View)**

Dispersion flowing towards the discharge end of the settler is accumulated behind the first, solid plate of the DDG fence (on the left hand side in Figure 1) and is forced to flow under the first plate and over the second plate, through a vertical slot in between the plates. Due to this structure, DDG fences distribute the dispersion flow efficiently along

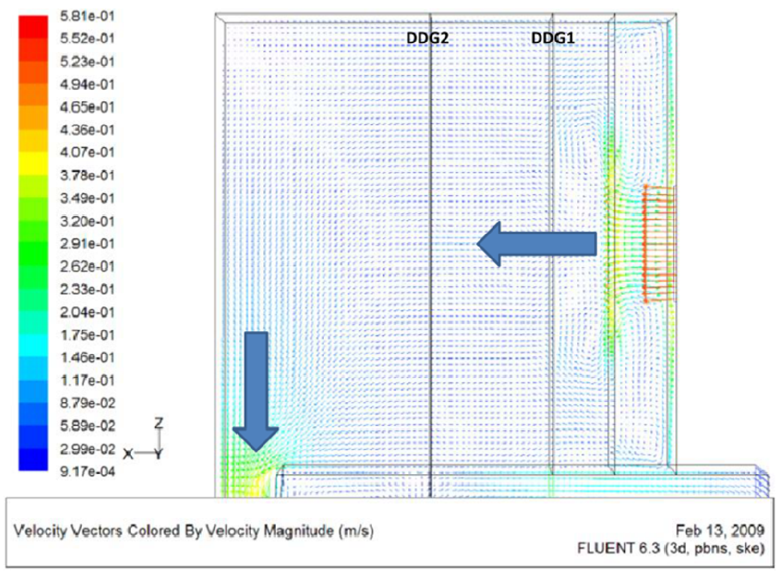


**Figure 4: CFD Model Velocity Profile for Outotec® Reverse Settler Feed Side with DDG Fences**

the width of the settler, even though their principal duty is to enhance phase separation and removal of fine droplets from the continuous phase. In addition to the operating DDG® fence installations, this distributing influence can be observed also in one-phase CFD models made by Outotec. An example of the results of a simulation made for Outotec® Reverse settler is shown in Figure 4.

Dispersion accumulated upstream of the fence acts as a “filter” for the small droplets of discontinuous phase, enhancing their coalescence. Separated organic phase gets to flow over the DDG fence through a slotted section of the first plate and the same principle is applied for the separated aqueous flow below the fence. In this way the pressure drop of the fence can be minimized, which contributes to the overall low-head design of a VSF plant.

DDG fences and Outotec settler design have also been optimized to tolerate conditions, where gypsum precipitation or very high PLS solids loading may occur. It has been demonstrated at Outotec reference plants, that the deep settler design provides more flexibility to tolerate such extreme conditions, as may be seen in the Picture 1. At this plant the PLS solids and calcium concentrations have consistently been well above the maximum operational limits. However, it has been possible to operate the plant with normal flows during prolonged periods.

**Picture 1:** E1 settler of Outotec reference plant being cleaned of precipitated gypsum. Prior to the maintenance shutdown, the plant was operated with >1 m thick gypsum layers in the settlers.

Outotec VSF® technology has been developed in several steps from the first projects to the latest, which are the VSF retrofit project of Codelco´s Chuquicamata Oxide Plant Train A (start-up in 2008), Quadra Mining´s Franke Project (2009), Assarel (2010), Southern Perú Copper Corporation's Tia María (start-up date unknown), Minera Lumina Copper's Caserones (2012), a confidential U SX project (2012) and a confidential Co/Ni SX project (after 2015). The objective of this paper is to discuss the experiences of Chuquicamata and Franke projects and specifically the results of technological developments implemented in them.

## METHODOLOGY

Information presented in this paper has been collected from Outotec's internal reports, engineering documents in the reviewed projects, operational data of actual operations received from the plant operators and public external sources.

CFD modelling reviewed in this paper has been made with FLUENT 6.3 software.

O/A entrainments discussed in this paper (Chuquicamata project) were analyzed with Horiba analyzer using the Horiba standard method. A/O entrainments were measured with "Chuquicamata-type minicoalescer", which is used at several SX plants in Chile.

## RESULTS AND DISCUSSION

### Chuquicamata Retrofit Project

Codelco's Chuquicamata Oxide Plant Train A was converted from conventional to VSF® technology in 2008. The plant was originally started up in 1987 and solvent extraction had become a production bottleneck due to gradual decrease of PLS copper content. Therefore, the main objective of the retrofit project was to increase the Train A flow capacity. The project was implemented as an EPC delivery by Outotec and included replacing the old picket fences with DDG® fences, the original pump-mixers with DOP® pumps and the secondary and tertiary blade mixers with SPIROK® mixers in each of the four stages of the train. The project scope included also some additional works, like pipeline diameter modifications and installation of new by-pass pipelines and valves in order to be able to implement the project while the train was in operation. E1 stage of the modified train can be seen in Picture 2.

Stage configuration of the train was maintained, consisting of four stages 2E+2S in series. In order to minimize the impact of modifications on production, the train was operated in three-stage configuration while the fourth stage was in the process of being modified (2Ep+S during the modification of extraction stages and 2Es+S while the stripping stages were being retrofitted).

Sequence of intervention was E1→E2→S2→S1, the total duration of installations being three months (during July-October 2008). As soon as the modification of each stage was completed, it was started up again, leaving the next stage out of operation and to be modified. Calculated production rate during the works is presented in Table 1. Once the installations were completed, Train A began to operate with the new nominal flow values, which are 36% higher than before the retrofit.

Performance guarantees were part of the project scope and performance tests were conducted during 24 hours of continuous operation with nominal flow values, after which the flows were increased to design values for a period of three hours (PLS flow of 1,750 $m^3/h$, which is 60% higher than before the retrofit). Results obtained in the performance test are presented in Table 2.


**Picture 2:** E1 stage of Chuquicamata Oxide Plant Train A after the retrofit project (the new DOP® pump at the front).

**Table 1: Calculated Production Before, During and after Chuquicamata Retrofit Project Implementation.**

| Phase | PLS Cu [g/l] | PLS flow [$m^3/h$] | Cu production [t/d] |
|---|---|---|---|
| Initial | 8.0 | 1,100 | 189 |
| Modification of E1 | 8.0 | 1,000/500 | 169 |
| Modification of E2 | 8.0 | 1,000/500 | 169 |
| Modification of S2 | 8.0 | 1,500 | 243 |
| Modification of S1 | 8.0 | 1,500 | 243 |
| Final | 8.0 | 1,500 | 254 |

**Table 2: Results of Chuquicamata VSF® retrofit project performance test**

| Parameter | Average in guarantee test | Range of acceptance |
|---|---|---|
| PLS flow [$m^3/h$] | 1,500 | 1,500 ±5% |
| Cu in PLS [g/l] | 9.4 | 7.0-9.0 |
| $H^+$ in PLS [g/l] | 7.4 | 5.0-7.0 |
| PLS temperature [°C] | 20 | 19-22 |
| Solids in PLS [ppm] | 38 | < 20 |
| O/A entrainment in Raffinate [ppm] | 16 | < 35 |
| O/A entrainment in RE [ppm] | 18 | < 35 |
| A/O entrainment in LO [ppm] | 40 | < 350 |

## Franke Project

Quadra FNX Mining's Franke Project in Chile is located approximately 1,000 km north from the city of Santiago and at an average elevation of 1,700 masl. Operations include open pit mining and treatment of ore by means of primary, secondary and tertiary crushing, curing, agglomeration, leaching in dynamic heaps, solvent extraction and electrowinning to produce 30,000 t/a of LME A grade copper cathodes.

The project implemented by Outotec included an EPC delivery of SX-TF-EW plant, upstream scope limit being PLS inlet to SX. The plant was designed to be expanded in the future, to be able to produce 45,000 t/a in a first expansion stage and up to a maximum of 60,000 t/a in later phases. Due to this requirement, all pipelines were designed based on the flow rates required to produce the eventual maximum capacity. Furthermore, settler design considered installation of additional DDG® fences in the future to accommodate higher flow rates. Another important design consideration was the estimated project lifetime of < 9 years and therefore one of the objectives in engineering was to minimize the plant CAPEX, while still maintaining high plant availability and product quality targets.

Franke SX plant is equipped with VSF® technology in series-parallel configuration E1+E2+Ep+WLO+S. General arrangement of the SX plant considered a space reserved for future installation of an additional mixer-settler which could be used as S or W stage. A new concept of combining Washing Stage and Loaded Organic tank was utilized, and thus the circuit includes a so-called Washing Loaded Organic Tank (Outotec WLO)[7]. This way the SX plant footprint and consequently CAPEX could be reduced by approximately 15%. The SX plant layout is presented in Figure 5 and WLO general arrangement in Figure 6.

By utilizing reverse settlers, all the main pipelines and operational area could be concentrated along the central maintenance walkway and trench, located in the middle of the SX train. The layout was compacted further for example by utilizing only one mixer in each stage, while still maintaining the required contacting times in mixing.

WLO operation can be described as follows: LO flows into the tank through a DOP® pump and a SPIROK® mixer, from where the generated dispersion (LO with recirculated wash water) flows to settler area, which is equipped with a distributor fence, DDG fences, a turn fence, aqueous recirculation pipelines, an overflow wall, organic outlet manifold and an aqueous bleed outlet. The volume of organic solution after the overflow wall and in the settler part (area between the settler inlet from the mixer and the overflow wall) provide the required organic inventory in the tank, organic band thickness in the WLO being higher than in the other mixer-settlers. On the other hand, recirculation of aqueous wash solution via the DOP and SPIROK create the required washing effect.

Several design features also in the Tank Farm area and EW tankhouse were selected to minimize the plant CAPEX, one of the examples being that the EW tankhouse was designed without walls to facilitate natural ventilation. Also semi-automatic crane and Full Deposit Stripping Machines were selected to reduce the investment cost.

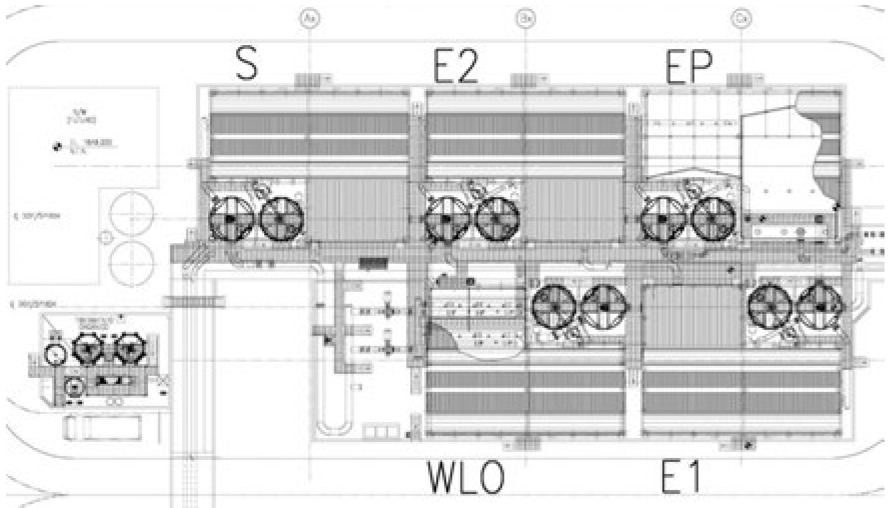


**Figure 5: Franke SX Plant Layout**.

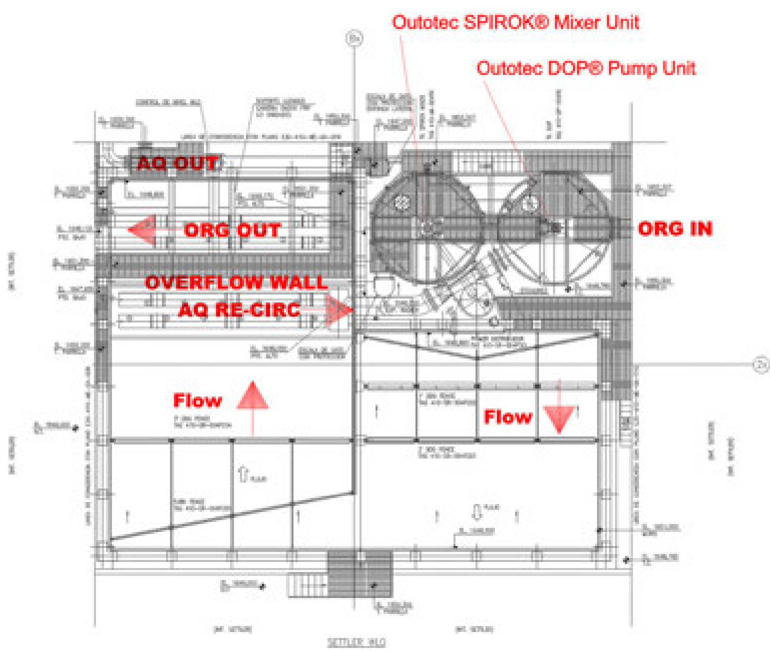


**Figure 6: Franke Washing Loaded Organic tank General Arrangement Drawing**

The Franke plant was started up in July 2009. Due to variations in ore grade and lower than planned recoveries in leaching, operation of the SX plant had to be adjusted after the start-up, in order to facilitate processing higher flows with lower PLS copper concentrations than those considered in design phase of the project (below 3.5 g/l versus 5.0 g/l, respectively). Subject to these conditions, the Franke SX plant has been able to operate with high PLS flows without having to be modified (up to 10% over the design value of 870 $m^3/h$ total PLS flow), achieving copper recoveries over 90%, with production averages of 60% to 70% of nominal values considered in the initial project. The measured O/A entrainment values have been extremely low, in the range of few ppm.

## CONCLUSIONS

Outotec has been gradually developing its VSF® solvent extraction technology since the first projects in the 1970's. One of the recent developments is introduction of DDG® fences to enhance the phase separation and flow distribution in the settlers. Furthermore, SX plant CAPEX and operational ergonomics have been improved by combining Washing Stage and Loaded Organic tank into a so-called Washing Loaded Organic tank (WLO), utilization of Outotec® Reverse settlers and general development of the overall plant layout design.

By utilization of WLO alone it is possible to obtain a CAPEX reduction of the SX plant of about 15% (exact saving depending on the stage configuration). It is also possible to design an SX plant in such a way, that the potential future needs to modify the operational parameters (flowrates, stage configuration, etc) are taken into account in the very beginning of the project.

VSF technology can also be implemented in retrofit projects, for example when there is a need to increase an existing SX plant flow capacity. In addition to copper SX plants, it is also possible to retrofit SX plants processing other metals (like Co, Ni or U). The execution sequence of such a retrofit can be planned in a way, which minimises the downtime and consequent production losses caused by the modifications.

## REFERENCES

1. **Brooke Hunt**, Metals Market Service, Long Term Outlook – Copper, December 2010

2. **ICSG**, Directory of Copper Mines and Plants, September 2010

3. **Raw Materials Group**, Raw Materials Data, Version 2011.01.17

4. **Menacho, J.,** *Industrial Practise and and Control of Entrainments and Degradation in Chilean SX Plants,* Pre-Conference Short Course, Copper 2007

5. **Karcas, G., Laitala, H., Palmu, L. & Tuuppa, E.** (2007) *The Advantages of Concurrently Design and Engineering of Copper Solvent Extraction and Electrowinning Plants*, COM 2007 Conference, 25-30 August, Toronto, Canada

6. **Laitala, H., Pekkala, P. & Rodriguez, C.** (2007) *Innovations in the Outotec's VSF® Cu SX Process to Reduce Total Investment Cost While Maintaining High SX Process Efficiency*, HydroCopper 2007 Conference, 16-18 May, Viña del Mar, Chile

7. **Saarenpää, T., Laitala, H. & Pekkala, P.** (2009) *System for Decreasing Amount of Organic Solution in the Liquid-Liquid Extraction Process*, PCT Pat. Appl. no: WO 2009/138563 A1