MAJOR REDUCTION OF THE ENVIRONMENTAL FOOTPRINT IN CONCENTRATE DRYING

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ABSTRACT

Non-ferrous metal concentrates contain typically 7 – 12% water when received at the smelter. Removal of this water prior to smelting is always economically feasible because unnecessary heating of vapour (from 100 °C to 1200 °C) in the smelting furnace can thus be eliminated. This results in major reduction in CO₂ emission and direct annual savings of several millions of dollars due to improved energy efficiency. Next step to further improve the energy efficiency, to gain substantial savings and simultaneously cut emissions is to select modern technology for the drying process. Consequently, all CO₂ emission will be completely eliminated (from 40,000 tpy down to 0 tpy), NOₓ emission will be negligible, and the SO₂ emission will be reduced by over 99%. Switching of conventional direct heated drying technology to modern indirect steam drying brings, in addition to dramatic emission reduction, additional savings due to further improved energy efficiency. Direct energy savings count for 900 – 1300 MJ/t H₂O, which depending on the concentrate feed rate and its moisture load can be worth several millions of dollars every year. Additional savings in operational expenses related to drying and gas cleaning may be worth a few million dollars more. Sustainability is a key issue today, and major savings together with significant emission reduction are readily available by proper technology selection for concentrate drying.
INTRODUCTION

Sustainability is a decisive principle in any process industry accompanied with emissions and high amount of energy. This is of significant importance in metal processing, including concentrate drying, where minimum impact on the environment, people and community are targeted, and all this with minimum cost, effort and resources. Therefore, special attention is paid to high energy efficiency, low energy consumption with preferable utilization of waste energy, safety issues, availability, level of maintenance, cost of maintenance, and emissions among other things.

Non-ferrous metal concentrates can be dried using various techniques. Conventional drying based on direct heating, and use of fossil fuels for drying energy has almost entirely been replaced by steam drying. It is based on indirect heating and it has become the most dominant drying technology for copper concentrates during the last decade with over 90% of the market share of all new dryer installations. Among the steam dryers the Kumauna Steam Dryer is the most pre-dominant technology with some 70% of all new dryer installations world-wide.

BENEFITS OF USING DRY CONCENTRATES IN SMELTING

Removal of water from the concentrate is very energy intensive thus having a significant environmental impact. However, drying prior to smelting is always economically feasible and very often viable also from the perspective of process operations.

Whether drying can, or cannot be applied depends primarily on the smelting technology. All flash furnaces and in-flight reactions strongly prefer or even necessitate the use of dry concentrates to allow oxidations reactions to take place within seconds. On the contrary, all TSL reactors prefer or even necessitate the use of wet concentrate in order to prevent excessive dust load from the TSL furnace. Also agglomeration, like pelletizing may therein be required. Other bath reactors are a bit more flexible with the moisture content in the concentrate.

Main benefit in removing the water prior to smelting is the lower operational expenses and lower emission. The lower expenses relate to the fact that when water is removed down to 0.2 – 0.3% H₂O prior to smelting, some 2700 MJ/t H₂O of energy is required for each ton of water as water heating, water evaporation and vapour heating require 377 MJ, 2 256 MJ and 47 MJ, respectively, as can be seen in Figure 1.

![Figure 1 - Heat required for water removal](image)

Evaporation of water consumes by far the biggest portion (84%) of the energy related to the water content in wet concentrates. Heating of liquid water counts for 14% of this energy and heating of gaseous water vapour for 2%.
In such case when separate drying prior to smelting is not practiced, all of the water vapor needs to be heated up to the smelting temperature. Therefore, energy of 47 MJ (2%) encountered for heating the evaporated water in drying (100 °C => 125 °C) increases drastically to 2,167 MJ (125 °C => 1250 °C), being of equal magnitude with that of evaporation.

Depending on the price of energy, smelter capacity and moisture content in the concentrate, an economic loss of 75 – 300 M USD in 30 years lifetime due to use of wet concentrate in smelting could easily be encountered. Although a portion (65%) of this energy incorporated in vapour heating could be recovered in a waste heat boiler, minimum savings of 30 – 100 M USD would make separate drying economically very feasible.

Furthermore, operation of the furnace and the waste heat boiler becomes much easier and more predictable and more easily controlled with dry concentrate in the feed mixture. Additionally, size of the gas line can be significantly reduced having positive effects on both CAPEX and OPEX (capital expenses and operational expenses, respectively) of the smelter. Dry concentrate may also have positive effects on the acid plant and smelter capacity. Therefore, the use of dry concentrate in primary smelting has operational, economic and environmental benefits resulting in significantly smaller environmental footprint in smelting.

**BENEFITS OF STEAM DRYING**

Although concentrate drying prior to smelting is beneficial, it can be carried out by various methods; some being more energy efficient and environmentally friendly than the others. Currently the most beneficial of all drying technologies is steam drying (Chen et al., 2006; Talja et al.; 2011, Talja et al., 2012).

**Energy Efficiency in Concentrate Drying**

Drying is a very energy intensive process. However, it is always favourable, because when it is not applied prior to smelting the amount of energy required for water removal and successive heating of the vast amount of water vapour in smelting would be doubled (Talja et al., 2012).

The high amount of energy associated with drying is primarily due to high enthalpy of vaporization, approximately 2,260 kJ/kg water. Additionally heating of water, heating of concentrate and very importantly the gas flow rates (depending strongly on drying technology) play a major role therein.

Overall heat needed for drying depends primarily on moisture content, specific heat capacity of the solids to be dried, ambient temperature (and pressure), residual moisture content, final drying temperature and most importantly, drying technology.

Effect of moisture content on specific heat per ton concentrate (MJ/t concentrate) and on specific heat per ton water (MJ/t H₂O) in steam drying is presented below in Figure 2. Correlation between the moisture content and heat in drying can be clearly seen in Figure 2. Heat required for one ton of concentrate increases almost linearly with increasing moisture content. On the contrary, the specific heat required to evaporate certain water content in concentrate is only slightly dependent on the moisture content, especially at moisture levels of 7 – 12 % which are typically found in concentrates.

Required heat in steam drying is typically 3,700 – 3,900 MJ/t water. This consists of heating the water and concentrate from ambient 10 °C to 100 °C, requiring 377 and 509 MJ/t H₂O, respectively. Evaporation at 100 °C requires approximately 2,260 MJ/t H₂O, and additional heating of the water vapor and concentrate from 100 °C to drying temperature adds some 50 and 80 MJ/t H₂O, respectively. This makes a total of some 3,300 MJ/t water. There are also heat losses which require some 200 MJ/t H₂O making a total of approximately 3,500 MJ/t H₂O (Talja et al., 2011; Talja et al., 2012).
Figure 2 – Effect of moisture content on specific heat required in steam drying

In addition to the given figures, more heat is required for heating up the purging and leakage gases and the large quantities of combustion gases incorporated in drying. Herein, the selected drying technology plays a major role in energy efficiency due to significant difference in gas quantities.

When we combine the overall heat required in drying we end up to figures of 3,700 – 3,900 MJ/t H₂O in steam drying and 4,700 – 5,000 MJ/t H₂O in conventional drying, as can be seen in Table 1.

Table 1 – Effect of drying technology on energy efficiency

<table>
<thead>
<tr>
<th>Drying Technology</th>
<th>Heating 10–100 °C</th>
<th>Evaporation 100 °C</th>
<th>Heating 100–125 °C</th>
<th>Concentrate 10–115 °C</th>
<th>Heating 10–125 °C</th>
<th>5% Losses MJ</th>
<th>Heat Total MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Dryer</td>
<td>377</td>
<td>2,256</td>
<td>47</td>
<td>593</td>
<td>279</td>
<td>178</td>
<td>3,730</td>
</tr>
<tr>
<td>Rotary Drum Dryer</td>
<td>377</td>
<td>2,256</td>
<td>47</td>
<td>593</td>
<td>1,253</td>
<td>226</td>
<td>4,752</td>
</tr>
<tr>
<td>Flash Dryer</td>
<td>377</td>
<td>2,256</td>
<td>47</td>
<td>424 (85 °C)</td>
<td>1,627</td>
<td>237</td>
<td>4,968</td>
</tr>
</tbody>
</table>

Conventional dryers like rotary drum dryers and flash dryers, are operated using fossil fuels, and thus have very high gas flow rates due to combustion gases. Therefore, the energy efficiency of conventional dryers is significantly lower than that of steam dryers. Additionally, energy efficiency in gas cleaning subsequent to drying stage depends primarily on dryer gas flow rate. This is also in favour of steam drying (30,000 Nm³/h) compared to that of conventional drying technologies (90,000 – 125,000 Nm³/h) for 160 t/h wet concentrate at 10% initial moisture.

Use of Waste Heat for Drying Energy

From both the energy and economics perspective steam drying is the most favourable as it requires some 20 – 30% less energy than conventional dryers. Furthermore, the energy used in steam drying is 100% waste energy from primary smelting, thus having a minimum impact on the environment. This is due to the fact that the hot gases from primary smelting must be cooled before directing them to sulfuric acid plant. Herein the waste energy is captured in the form of steam and part of it is used in the drying process while the surplus of steam can be used for other purposes, e.g. heating or electric power generation.
There is often a debate on steam drying benefits versus a possible loss of power generation in case part of the steam would be alternatively used for drying. This is very true, but only partially. It is worth noticing that shifting conventional drying to steam drying would affect the following:

- Energy required for drying decreased by 20 – 30%.
- OPEX due to energy and maintenance costs would be reduced by some 30 – 40%
- OPEX and CAPEX of gas cleaning would be reduced by some 70 – 75%
- Gas emissions would be practically fully eliminated
- Problems in gas cleaning, like burning of filter bags would be significantly reduced
- Conversion of surplus steam to electric power has reasonably low efficiency (less than 40% plus additional superheating), whereas that of steam for drying has efficiency very close to 100%
- Availability of drying could be significantly increased, as in case of the Kumea Steam Dryer there would practically be no down time initiated by the dryer to the smelter.

All these benefits should then be compared with the main drawback, i.e. the value of steam, which is out of the power generation. All the combined benefits of using steam drying would easily overcome the loss of possible power generation of about 3 – 6 MW. However, this comparison should always be made on case by case basis taking into account the prevailing conditions, price and availability of steam, fuel and electricity, drying and smelting capacity with relevant OPEX, etc.

**Gas Emission – CO₂, SO₂, NOₓ**

The most important factor in determining the environmental footprint of drying is the drying technology itself. This is due to the fact that drying technology affects the amount of energy needed in drying, the type of fuel used in drying, and thus the quantity and type of gaseous emission.

**Carbon Dioxide CO₂**

The use of steam benefits other than just decreased energy consumption and utilization of waste energy. It is very favourable in sense of gaseous emission, as no carbon dioxide is generated. Therefore, there is a significant difference in CO₂ emission between steam drying and conventional drying with emission rates of zero versus some 40,000 tons CO₂/year, respectively, at an average size smelter at 1 Mtpy concentrate. Also possible future carbon credits are expected to force the smelters to decrease the existing CO₂ emission, and steam drying technology is one way to achieve such goals.

Summary of the CO₂ emission is presented in Table 2. Therein the total heat for particular drying technology, its ratio over thermodynamic heat (see Table 1), an equivalent amount of energy from heavy oil and its successive CO₂ emission, actual specific CO₂ emission and annual CO₂ emissions (for 1 million ton of treated wet concentrate at 10% moisture) are presented.

<table>
<thead>
<tr>
<th>Drying Technology</th>
<th>Total MH₂O</th>
<th>Excess Heat MH₂O</th>
<th>Excess Heat Val %</th>
<th>Heavy Oil Emissions CO₂/mt H₂O kg</th>
<th>CO₂ Emissions kg</th>
<th>CO₂ Emissions tpy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Dryer</td>
<td>3,730</td>
<td>19%</td>
<td></td>
<td>91</td>
<td>286</td>
<td>0</td>
</tr>
<tr>
<td>Rotary Drum Dryer</td>
<td>4,752</td>
<td>51%</td>
<td></td>
<td>115</td>
<td>365</td>
<td>365</td>
</tr>
<tr>
<td>Flash Dryer</td>
<td>4,968</td>
<td>58%</td>
<td></td>
<td>120</td>
<td>381</td>
<td>38,120</td>
</tr>
</tbody>
</table>
Conclusions from Table 2 are as follows:

- Steam drying is clearly the most energy efficient due to low gas flow rates.
- In steam drying only 19% of excess energy is consumed compared to a thermodynamic minimum value calculated at a drying temperature of 100 °C without any purging gases.
- Conventional drying technologies, drum drying and flash drying need significantly more energy with the excess amount exceeding 50% of the required minimum. Thus neither drum drying nor flash drying can be considered as energy efficient processes.
- An equivalent amount of heavy oil needed in drying varies between 90 and 120 kg per one tonne of evaporated water.
- Conventional drying technologies generate annual CO₂ emissions of 36,000 and 38,000 tons, whereas emissions from the steam drying remain at zero (when heat recovery is applied).

**Sulphur Dioxide SO₂**

Due to low drying temperature of about 120 °C, low and controlled atmosphere with typical partial pressure of oxygen 8 – 12%, there is no ignition of even fine dry sulphide particles. Furthermore, as the fuel (steam) doesn’t contain any sulphur, the total SO₂ emission is very close to zero mg/Nm³. This is very different from conventional dryers, in which levels up to 1,000 mg/Nm³ can be detected (Chen et al., 2006). In addition to the SO₂ gas elimination, operation of the gas cleaning in conjunction with the steam drying is more convenient with significantly reduced probability of burning the bags, decreased maintenance expenses and less down-time of the smelter.

**Nitrogen Oxides NOₓ**

Due to the prevailing conditions inside the dryer (no combustion of fossil fuels, low temperature of about 120 °C in the gas phase), NOₓ emission is zero.

**Dust Emission**

Dust emission depends primarily on the dryer technology and its subsequent off-gas flow rate as well as on the dust cleaning technology, e.g. bag house, ESP, scrubber.

Conventional dryers have gas flow rates typically three or four times greater than in the steam drying due to indirect heating. Due to the fact that dust emission is determined by mg/Nm³, it is practically directly a function of gas flow rates, and not really dependent on the actual dust load entering the bag house filter.

The lowest dust emission rates can be achieved by steam dryer technology, primarily due to significantly low gas flow rate together with a bag house filter. By such means dust emission rates at less than 5 mg/Nm³ can easily be achieved. Furthermore, low emission means also better metal recovery with savings of up to 0.5 M USD.

It is also worth noticing that due to the significantly smaller gas flow rates in steam drying, the gas cleaning device can be made three to four times of smaller size than for conventional dryers. Similar downsizing occurs also for the fan. Both of these matters do strongly affect the costs of gas cleaning and may decrease the direct costs therein by a factor of 3 to 4.

With a combined use of steam drying and a bag house filter, the dust emission can be easily kept below all regulations with typical emission rates being 1 – 3 mg/Nm³.
Safety Issues

Steam drying is based on indirect heating by steam, which is generated in the waste heat boiler where an excessive amount of chemical energy from sulphide smelting is captured as waste energy. Part of this steam is further utilized as an optimum heating media for drying.

Due to the nature of indirect heating, the temperature profile and gas atmosphere inside the dryer can be properly controlled. This is important as the tendency for ignition of dry fine sulphide or even elemental sulphur particles can thus be significantly decreased or even fully eliminated.

Conversely, the conventional dryers have very high inlet temperature of combustion gases (500 – 750 °C) resulting in much higher tendency for ignition and subsequent CO₂, SO₂ and NOx emission and problems in gas cleaning.

ADDITIONAL BENEFITS OF THE KUMERA STEAM DRYER

Main benefits of steam drying relate to sustainability, enhanced energy emission, and very low emission, if any. However, in addition to all these nice features, there are several reasons why the Kumera steam dryer is currently the most highly recognized concentrate dryer on the market.

Availability, Operational Expenses and Maintenance

Energy efficiency, safety and environmental issues in drying are all in great favour of steam drying over conventional drying technologies. However, there are major differences in availability, operational expenses and maintenance expenses within steam dryers. This is very important for the sake of smelting operation and overall smelting economics.

Very little maintenance is needed in the Kumera Steam Dryer. This is based on the original dryer design, specifically made for abrasive materials i.e. concentrates. Consequently, simultaneous rotation of the drum shell, individual heating elements and concentrate at the same pace result in minimum slip velocity (i.e. velocity difference between the heating element and concentrate particles), minimum friction, and thus minimum wear.

Circular rotation and movement of the concentrate inside the dryer result also in a high heat transfer coefficient, which enables a very high drying capacity in a small unit with low capital expenses. This results in the best Capacity/CAPEX ratio, the lowest OPEX/t concentrate and the lowest maintenance costs USD/t concentrate in the industry. Principles for high heat transfer and low wear are presented in Figure 3 (Chen et al., 2006).

![Figure 3 – Principles for high heat transfer and low wear in the Kumera Steam Dryer](Image)
Drying can also have a significant impact on smelting economics and smelting process performance in either securing or ruining the smooth operation of the subsequent smelting process. The Kumera steam dryer enables uninterrupted operation of the smelting process together with high product quality at consistent optimum moisture content together with minimum costs. High availability with minimum maintenance breaks enables a minimum down time, if any, for the smelter. The down-time initiated by the Kumera steam dryer is in most of the cases significantly less than 1%.

High availability (i.e. very small need for any maintenance) is the key factor in low maintenance costs. The Kumera steam dryer is known to have maintenance costs several magnitudes smaller than other steam dryers. Scheduled maintenance break are suggested to be carried out only once or maximum twice per year, with a duration of 16 hours at a time. This means a total downtime of only some 20 – 30 hours per year.

Capacity and References

Current references of the Kumera steam dryer deliveries are listed in Table 3. As we can see from Table 3 there has been a clear trend in a demand for increasing capacity over the years. Currently, the biggest dryers have a feed rate capacity well above 200 t/h of wet concentrate, which in practice means a water removal capacity in excess of 20 t/h in a single unit. Consequently, due to both the very high capacity and very high availability, smelters treating approximately 1 million tons per year of concentrate can manage with just one Kumera steam dryer.

<table>
<thead>
<tr>
<th>Start-up Year</th>
<th>Smelter Site</th>
<th>Country</th>
<th>Initial Capacity, wet t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Hamburg</td>
<td>Germany</td>
<td>82</td>
</tr>
<tr>
<td>2001</td>
<td>Pirdop</td>
<td>Bulgaria</td>
<td>90</td>
</tr>
<tr>
<td>2001</td>
<td>Pirdop</td>
<td>Bulgaria</td>
<td>90</td>
</tr>
<tr>
<td>2003</td>
<td>Toyo</td>
<td>Japan</td>
<td>160</td>
</tr>
<tr>
<td>2004</td>
<td>Hibi Kyodo</td>
<td>Japan</td>
<td>80</td>
</tr>
<tr>
<td>2006</td>
<td>Yanggu</td>
<td>China</td>
<td>160</td>
</tr>
<tr>
<td>2006</td>
<td>Jinlong</td>
<td>China</td>
<td>160</td>
</tr>
<tr>
<td>2006</td>
<td>Guixi</td>
<td>China</td>
<td>160</td>
</tr>
<tr>
<td>2007</td>
<td>Harjavalta</td>
<td>Finland</td>
<td>136</td>
</tr>
<tr>
<td>2008</td>
<td>Onsan</td>
<td>China</td>
<td>125</td>
</tr>
<tr>
<td>2011</td>
<td>Zijin</td>
<td>China</td>
<td>180</td>
</tr>
<tr>
<td>2012</td>
<td>Tongling</td>
<td>China</td>
<td>180</td>
</tr>
<tr>
<td>2012</td>
<td>Tongling</td>
<td>China</td>
<td>180</td>
</tr>
<tr>
<td>2012</td>
<td>Zhuzhou (Pb)</td>
<td>China</td>
<td>82</td>
</tr>
<tr>
<td>2012</td>
<td>Guixi</td>
<td>China</td>
<td>220</td>
</tr>
<tr>
<td>2013</td>
<td>Baiyin</td>
<td>China</td>
<td>240</td>
</tr>
<tr>
<td>2013</td>
<td>RTB BOR</td>
<td>Serbia</td>
<td>80</td>
</tr>
<tr>
<td>2013</td>
<td>Sarchemeh</td>
<td>Iran</td>
<td>220</td>
</tr>
<tr>
<td>2014</td>
<td>Glogow I</td>
<td>Poland</td>
<td>160</td>
</tr>
</tbody>
</table>

Experience and Improvements

Because of large number of dryer deliveries, we have been in a position to get lots of feedback from the users. Furthermore, practically every new delivery comes with new features and improvements. It has enabled the Kumera Corporation and its Technology Centre to keep its position as a leading global supplier of the state-of-the-art drying equipment for concentrate drying today.
CONCLUSIONS

Separate drying prior to smelting is favourable due to a number of benefits relating to savings, operational expenses, operation of the smelters and significantly reduced environmental footprint.

Currently there is technology on the market to significantly decrease the environmental footprint related to concentrate drying. Amongst the drying technologies steam drying is recognized to be the best practice today. It consumes significantly less energy to remove the water out of the concentrates while gas emissions can be nearly entirely eliminated. Simultaneously the dust emission can be substantially reduced also enhancing the metal recovery for better profit.

Because of the main design and number of deliveries of the Kumera steam dryer, also additional operational benefits are available enabling high capacity, high availability and high energy efficiency with simultaneously reduced operational and maintenance expenses at practically zero gas emission.

REFERENCES

