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Recent Improvements in Integrated Zinc Control and Dust/Sludge Recycling at China Steel

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Abstract: In an integrated steel mill, zinc (Zn) inputs from raw materials and steel scrap are enriched in the dusts and sludges collected from gas and water cleaning systems. The reuse of these dusts and sludges must be controlled within certain limit to avoid Zn accumulation and related operational problems in blast furnace. An integrated system has been established at China Steel Corporation (CSC) to enhance the internal reuse of Zn-containing dust/sludge while keeping Zn input within control limit. However, the performance of this system has not been very satisfactory until one and half years ago when a rationalization process was initiated. The essence of this rationalization process, the recent improvements in Zn control and dust and sludge reuse are reported and discussed.
Keywords: Zinc, Control, Dust, Sludge, Reuse.

Introduction

In the steel industry, dusts and sludges are originated from various processes when wastes gases and wastewater are cleaned for emission control. This dusts and sludges are internally reusable by nature since their major components are similar to the raw materials for iron and steel making. However, there are two prime limitations:

(I) High Levels of Undesirable Impurities: This is the primary limitation for the reuse of dust and sludge inside a steel mill. For example, the direct water sludges with concentrated lubricant or rolling oil is not acceptable to sinter plant since its electrical precipitator (EP) can be damaged when oils accumulate inside. Another example is the zinc (Zn) and lead (Pb) contents of reused dust and sludge. Zn and Pb contents of dust and sludge can be more than 1,000 times higher than raw materials due to enriching effect. When Zn and Pb are charged into a blast furnace (BF), they become vapors circulating in the upper stack and fostering scaffold formation. This will result in Zn and Pb accumulation, deteriorated gas permeability and damaged hot blasting tuyeres (when scaffolds fall down).

(II) Difficult Handling and Reusing Properties: Dry dust can easily become polluting if not properly stored or handled, whereas wet sludge is sticky and not easy to discharge from storage bins. They could induce other operational problems due to the very small particle size.

Therefore, proper handling and treatment of these dusts and sludges is quite important before they can be properly recycled. Various technologies have been developed to solve these problems and some already adopted in the steel industry [1-6]. However, some Zn-rich sludges remain difficult to recycle, and have to rely on stockpiling or landfill. Taking China Steel Corporation (CSC) as an example, it has built up a series of units to reuse dusts and sludges [7-8]. An external recycling path was also established. These recycling activities, composing an integrated recycling system inside and outside CSC, can be divided into 4 paths as shown in **Table 1** and **Figure 1**.

Although this integrated system has been built up since few years ago, its performance was not satisfactory. Only a couple years ago CSC suffered badly from overloaded sludge yards and had to send out sludge for land reform. Therefore, there was a strong need to improve the sludge recycling activities. This was why CSC seriously considered the Rotary Hearth Furnace (RHF), a process to separate Zn from dust/sludge as a ZnO product and to reduce iron oxides into metal, as some Japanese and American mills has adopted recently.

Table 1: Description of the Integrated 4-Path Sludge and Dust Recycling System.

Path (1):	Directly reuse Basic Oxygen Furnace (BOF) slurry in sinter plants without de-watering operation, since this slurry contains slow-settling solids and can be transported for a long distance.
Path (2)	Directly reuse low Zn sludges in mini-pellet plant and reuse biological and cold rolling sludges in industrial waste incinerator (IWI) (without stockpiling and reclaiming). The former takes fine dusts as well.
Path (3)	The remaining low Zn sludges are stockpiled, naturally dried, sized and reused in X-mix plant together with coarse dusts, while they are reused in Y-mix plant with slump materials.
Path (4)	The Zn-rich and oil-containing sludges are blended with coal fly ash and sold to cement-making plants.
Residue	The ultra high Zn cold rolling sludge from electrical galvanizing line (EGL) is solidified and landfilled (a recycling path to Zn smelting is being developed).

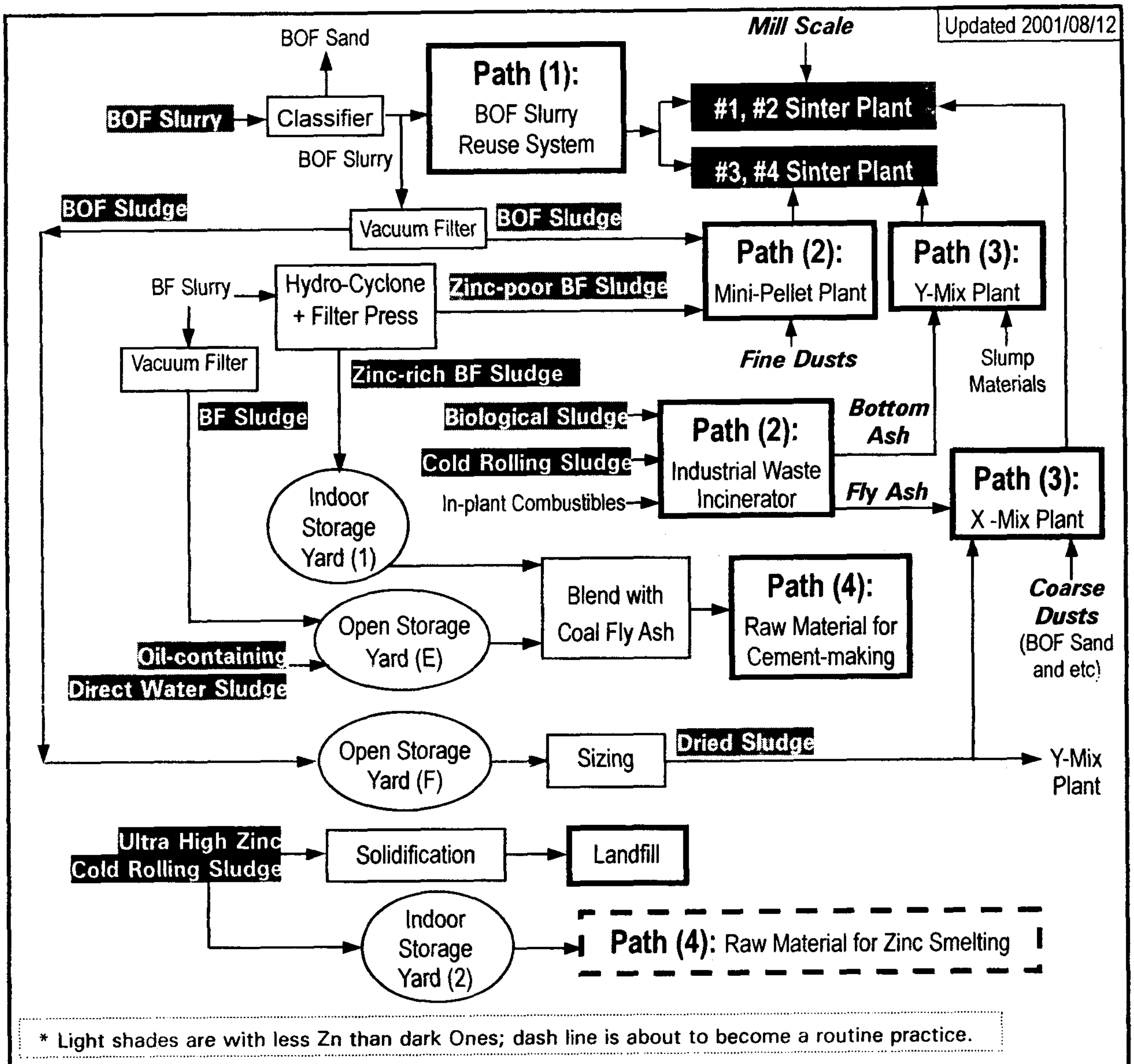

Figure 1: The Integrated 4-Path Dust/Sludge Recycling System of CSC (Simplified Flow Sheet).

While CSC was considering the RHF technology, two other projects were also promoted to deal with the immediate sludge problem. The first was to rationalize the existing integrated system to improve Zn control and to enhance internal reuse of sludge. The other was to expand the sludge market in cement making industry. Thanks to the success of these two projects, the sludge yards have been reduced quickly since one year ago, and the need of RHF has diminished.

In this paper, the rationalization process and the performance of the improved integrated dust/sludge recycling system at CSC are briefly reported and discussed.

Experiment

Since the Zn-bearing dusts of CSC are not easy to stockpile or recycle elsewhere, they are reused in CSC immediately after generation. This left the Zn-containing sludges the one to be managed and controlled in this integrated system. It is generally accepted that Zn and Pb have similar adverse effects on BF operation with Zn playing a more dominating role. Therefore, it is sufficient to just control the Zn input of BF.

The rationalization procedures and the major actions taken in CSC are summarized as shown in **Table 2**. For step (2), the Zn inputs for BF were calculated from all its input materials i, i=1....n, based on the following mass balance equation:

$$\text{Zn Input} = \sum_{i=1}^{n} [\text{Zn}(i) \times \text{Input Rate}(i)]$$

Where Zn(i) was the Zn content of ith input material to BF, and Input Rate (i) was its feed rate. Their Zn contents were analyzed using Induction Couple Plasma

(ICP)-Atomic Emission Spectrometer following the standard procedures. Similar procedures were used for the outputs of BF, namely BF sludge, BF flue dust, BF stock house dust, hot metal and slag. The input and output rates as well as the Zn contents of the materials used in mid-March 2000 were the basis for this Zn balance analysis. This calculation was also applied to the major Zn sources of BF such as Sinter, Mini-Pellet and Y-Mix (was in a similar condition as # 3 BF) to have a better understanding of the origins of Zn inputs for #4 BF. This procedures were also applied to # 2 BF (was in a similar condition as #1 BF) to have a similar understanding.

Table 2: Procedures and Tasks to Enhance Integrated Zn-Control and Sludge Recycling.

Procedures	Outlines
(1) Identify Current Problems and Limiting Factors	• Zn input to BF was out of control too frequently resulting in complaints from BF shops. • Reusing BOF slurry in sinter plant is limited by the water content of raw mix. • Availability and capabilities of some reusing units were not satisfactory. • Too much sludge was stockpiled in yards waiting for a better recycling solution. • Critical information was not made available for Zn control and sludge reuse.
(2) Construct Zn Input and Output Model to identify key Controlling Points for Improvement	• Set up an easy Zn balance model with graphical display. This model can provide a much better understanding of sludge-reusing rate and the resulting Zn input to BF. • Use Zn balance model to identify proper controlling points for Zn input and sludge reuse. • Reduce Zn inputs from their origins and adjust the sludge-reusing rate accordingly.
(3) Modify System Units and Operation to Enhance Reusing Rates	• Separate low-Zn sludges for complete internal reuse (not to be mixed with others). • Modify reusing units to enhance their capabilities in sludge reuse. • Adjust and maximize sludge-reusing rate to keep Zn input slightly below controlling limit.
(4) Set Daily Targets for Sludge Reuse and to Keep Zn Input under Control	• Set daily operation targets for each reusing unit, adjustment is provided when needed. • Setup an "Information Proving and Sharing system" for quick analyses, reporting, sharing and communication by using an internal web site.
(5) Better Management of Sludge Flow, Storage and Reuse	• Design a "**Balance Sheet**" to keep track of the flow, storage and reclaiming of sludge. • Periodic review of progress and determine corrective actions.
(6) Continual Improvement	• Minimize solidification and landfill for environmental concern and cost saving. • Setup a cyclic pattern for raining and dry seasons (lower targets for raining season results in a small pile of sludge to be used up in dry season). • Reduce the amount sent to cement making.

Results and Discussion

1. Zn Input and Output of BF

The calculation of Zn inputs for #4 BF was extended to its feed materials, Sinter, Y-Mix and Mini-Pellet, shown in **Tables 3 and 4.** All these Zn inputs were combined as an integrated Zn input model for #4 BF shown in **Figure 2.** Similar results for #2 BF was shown in **Figure 3**. For # 2 BF, the difference was the Y-Mix is replaced with X-Mix whereas the Mini-Pellet was not in the system any more.

Figures 2 and **3** indicate that: (I) The Zn-inputs of #2 BF and #4 BF were both over the control level, 200 gm/THM, at the time of analysis. (II) The major Zn inputs came from IWI fly ash and BOF slurry. The Zn input from IWI fly ash was so high (92 gm/THM) that the yard sludge was barely reused in X-Mix. Consequently, to reduce the Zn contents of IWI fly ash and BOF slurry was a good starting point.

Table 3: Calculation of Zn Inputs for #4 BF and #4 Sinter Plant of CSC.

Zn inputs for	Input Materials	Input Rate (kg/THM)	Zn Content (%)	**Zn Input (gm/THM)**	% Contribution
#4 BF	Coke	375	0.0016	6	2.9
	Pulverized Coal	119	0.0010	1	0.5
	Lumpy Ore + Pellets	380	0.0020	8	3.9
	Fluxes	4	0.0012	1	0.5
	Sinter	1,178	0.0160	**188**	**92.2**
	Sub-Total	2,056	----	**204**	100.0
#4 Sinter	BOF Slurry	14	0.415	**58**	**30.4**
	Coke Breeze	48	0.003	1	0.5
	Fluxes	68	0.005	3	1.6
	Y-Mix	64	0.058	**37**	**19.4**
	Raw Mix (without BF Return Fine)	1,211	0.004*	48	25.1
	Mini-Pellet	26	0.170	**44**	**23.0**
	Sub-Total	1,431	----	**191****	100.0

* Slightly different from the Zn input to BF (188) due to disturbances from sampling, analyses etc.

Table 4: Calculation of Zn inputs for Mini-Pellet Plant and Y-Mix Plant of CSC.

Zn inputs for	Input Materials	Input Rate (kg/THM)	Zn Content (%)	Zn Input (gm/THM)	% Contribution
Mini-Pellet	BF Flue Dust	8	0.105	8	18.2
	BF Cast House Dust	2	0.239	5	11.4
	Hot Metal Pretreatment Dust	0.4	1.111	4	9.1
	BOF Dust	1	0.698	7	15.9
	BOF Sludge	3	0.418	**13**	***29.5***
	Zn-Poor BF Sludge	1.3	0.289	***4***	***9.1***
	EP Dust	10	0.033	3	6.8
	Lime Dust	1	0.005	~0	~0
	Subtotal	26.7	---	**44**	100.0
Y-Mix	Dried Yard Sludge	3	0.900	**27**	***73.0***
	Slump Materials etc	64	---	10	27.0
	Subtotal	67	---	**37**	100.0

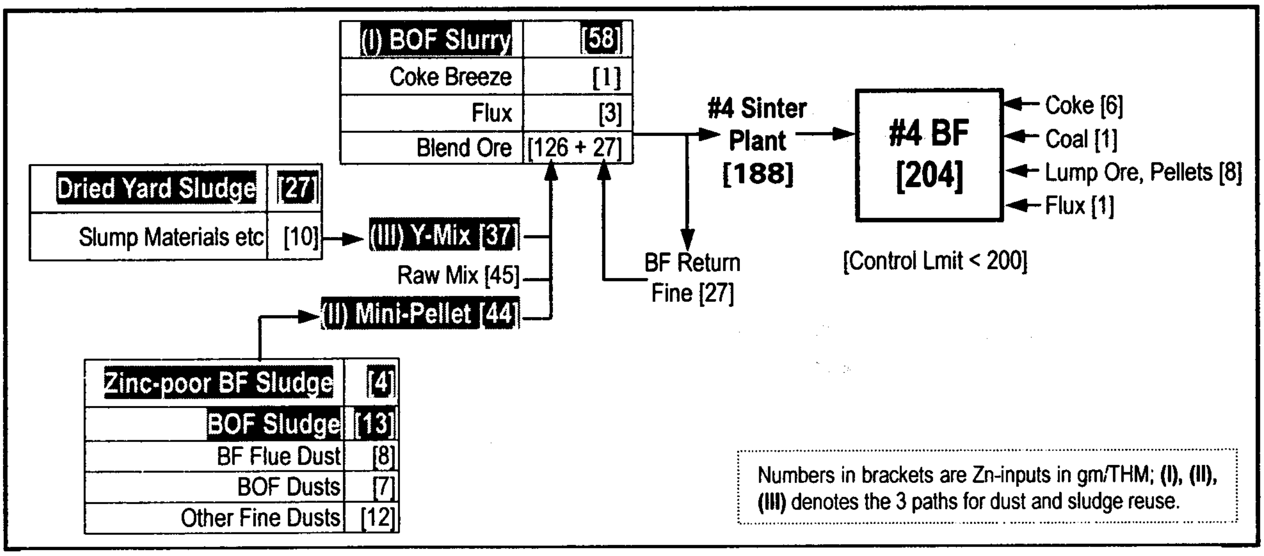

Figure 2: Calculated Zinc Inputs of #4 BF (Similar to #3 BF).

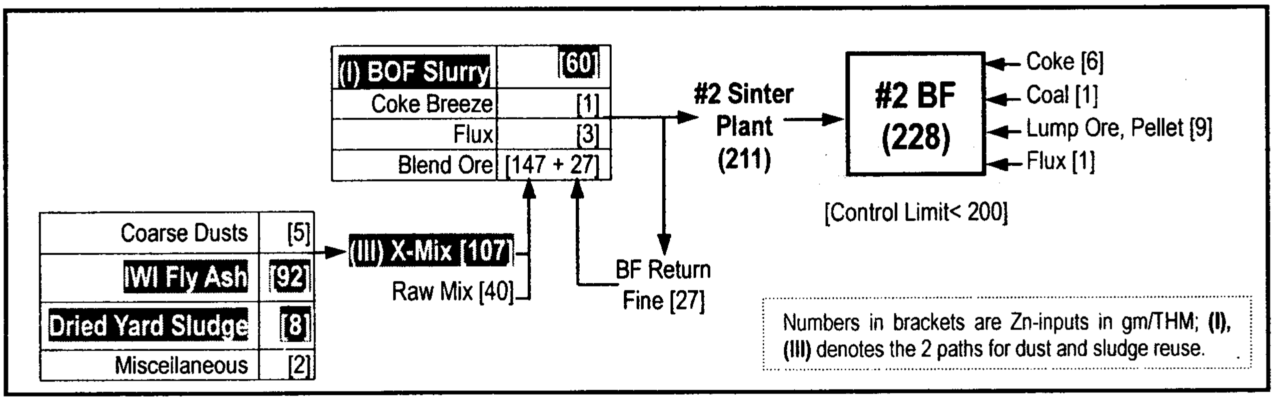

Figure 3: Calculated Zinc Inputs of #2 BF (Similar to #1 BF).

The calculation of Zn outputs for BF was relatively straightforward. The analyses made during the same period showed that the major output was BF sludge (>80%), others include BF flue dust and cast house dust (5-10%), hot metal and slag (5~10%). However, the total Zn output from BF was much lower than the input. The possible reasons for this are: (I) There was an increased Zn accumulation in BF (i.e. it was not at a steady state). (II) There could be significant disturbances in sampling and analyses. (III) There was a pronounced time lag phenomenon. For practical purpose, only the Zn input data was used for operation control and routine checkup.

2. Zn Control and Improved Sludge Reuse

The controlling points and the major actions to increase sludge reusing rate under controlled Zn input are outlined in **Table 5**. It is worth mentioning that CSC has multiple production lines for its 10M ton steel production per annum. This results in a complicated sludge system at containing 19 generation units, 8 internal reusing units, 4 storage yards and 2 external recycling routes. Therefore, a "Sludge Balance Sheet" was designed to have a good picture and to have a close control of the sludge flow in the mill, especially for the yard sludges to be recycled after drying.

Table 5: The Zn Controlling Points and Major Actions for Improved Sludge Reuse.

	Controlling Points	Major Actions
All BF	BOF Slurry to Sinter BOF Sludge to Mini-Pellet	• BOF slurry/sludge has a wide effect on Zn inputs and sludge reuse at CSC. • Try to reduce their Zn contents by better quality control of the scraps purchased and used in BOF shops • Alert for proper adjustment when the scrap quality apparently deteriorates.
	BOF Sludge to Yard then to X-Mix & Y-Mix	• BOF sludge has relatively low Zn content. Modify system to separate the remaining BOF sludge for storage, natural drying and reuse. • Analyze Zn content at least once a week to control its reusing rate and Zn input.
#1 & #2 BF	IWI Fly Ash to X-Mix (Has a predominant effect on Zn input)	• Completely separate the high Zn cold rolling water to generate ultra high Zn cold rolling sludge, and to reduce the Zn content of other cold rolling sludge. • With this adjustment, the Zn content of IWI fly ash was reduced from 5-6% to 1-2%, and a lot of room was provided for sludge reuse. • The ultra high-Zn cold rolling sludge is sent to solidification and landfill.
#3 & #4 BF	Zn-poor BF Sludge to Mini-Pellet	• Zn-poor BF sludge has the lowest Zn content of all. • Enhance the capability and availability of the hydro-cyclone and filter press unit to separate more Zn-poor BF sludge for reuse is beneficial.

After the Zn balance analyses and rationalization process, controlling and improving actions were initiated in June 2000. The operational results before and after are shown in **Figure 4** that can be summarized as follows:

(I) The % of working days that Zn input was over the BF control level (200gm/THM) averaged 19.8% for the first 6 months of 2000. It dropped quickly to 3.4% for the rest of the year (**Figure 4** (a)) showing the effectiveness of the Zn control task.

(II)The reuse of sludge for the first 5 month of 2000 averaged 17,370 ton/month. It increased to 21,360 for June and averaged 23,199 for the rest of the year (**Figure 4** (b)). This means that not only the Zn input was in better controlled but also the reused sludge was increased by 5,829 ton/month. As a result, the monthly balance of sludge became largely negative (**Figure 4** (c)), and the accumulated sludge storage quickly dropped from 103,650 to 54,670 ton by the end of 2000 (**Figure 4** (d)).

3. Continual Improvement

(I) Minimize Solidification and Landfill: The ultra high Zn cold rolling sludge sent to solidification and landfill was increased from 53.4 ton/month to 115 ton/month for the year 2000 (**Figure 5**). This has helped a great deal to cut down the Zn inputs to #1 and #2 BF and to increase sludge reuse capacity by >3,000 ton/month. However, the extra 61.6 ton/month sludge for solidification and landfill was an added cost. Moreover, solidification and landfill was not an environment-friendly solution. An on-going project was to control the water treatment process to upgrade the Zn content of ultra high Zn cold rolling sludge (up to ~50% or more) so that it can be used as a raw material for Zn smelting. There has been some success in this project and it is expected to become a routine practice soon.

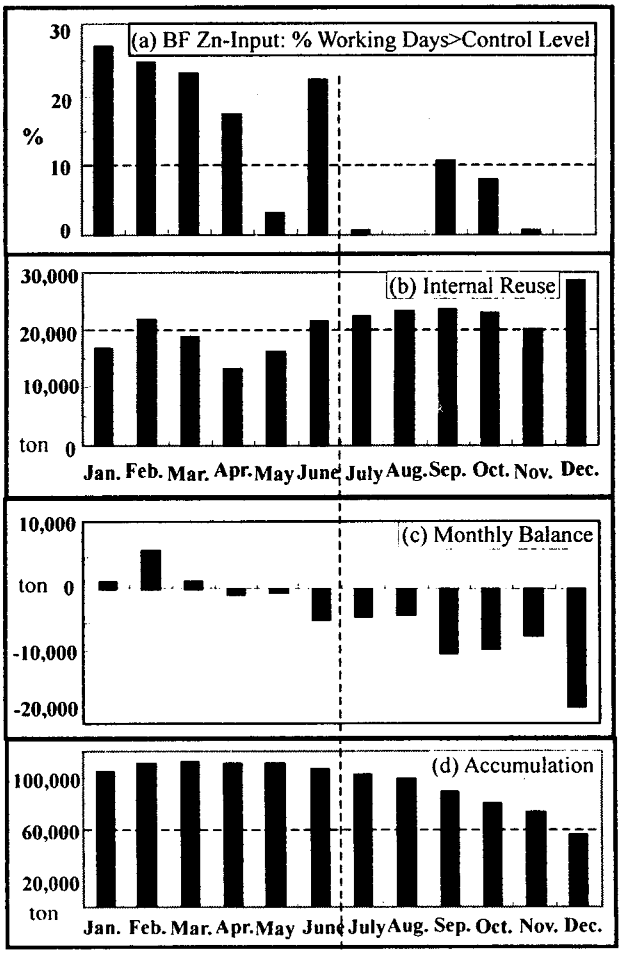

Figure 4: (a)% Working Days that BF Zn-Input Was Over Control Level, (b)Internal Reuse,(c)Monthly Balance, (d)Accumulation of Sludge in 2000.

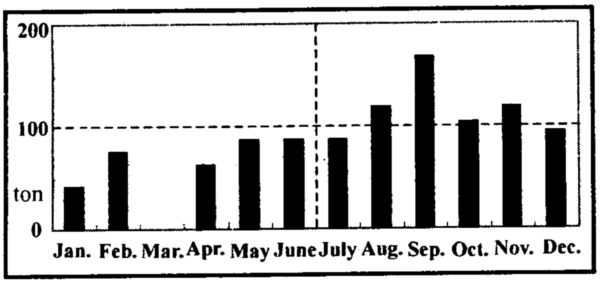

Figure 5: The Amount of Ultra High Zn Cold Rolling Sludge Sent to Solidification and Landfill in 2000.

(II)Cyclic Sludge Reuse Pattern for Raining and Dry Seasons: In raining season, the reuse of BOF slurry is limited by the high moisture content of raw mix, and the reuse of dried yard sludge is not always possible. Hence it is necessary to set lower targets in raining season for these units before better countermeasures are developed. This results in ~15,000 ton of excess sludge in raining season to be used up in dry season.

(III)Reducing the Quantity to Cement Making: The "sludge and fly ash blend" sent to the cement-making plants on East Coast of Taiwan was sold at a low price. Since CSC has to pay the incurred handling fee and high freight cost, this recycling path is quite costly compared to the reuse inside CSC. Therefore, to enhance the internal reuse furthermore and to reduce the quantity sent to cement making is an important means for cost reduction.

(IV)Other Areas for Further Improvement: There are other parts that could be further improved in this integrated Zn control and dust/sludge recycling system. Several projects are being studied or tested right now.

Conclusion

1. Significant improvement has been achieved at CSC in its integrated Zn control and dust/sludge recycling system. This was realized through a rationalization process starting from an integrated Zn balance analysis, followed by a close control of Zn inputs and sludge flow, and a tailored reuse of sludge in the mill.

2. The % of working days that BF was overloaded with Zn inputs averaged 19.8% in the first half of 2000. It dropped to 3.4% in the latter half.

3. The internal reuse of sludge increased from 17,370 ton/month to 23,199/month in 2000. The difference of 5,829 ton/month resulted in quickly reduced sludge storage and a significant cost reduction.

4. Continual improvements are under way. Examples include: to convert high Zn cold rolling sludge to a raw material for Zn smelting, to set up a cyclic reuse pattern for raining and dry seasons, and to increase the quantity of sludge for internal reuse and thus reduce the quantity for cement making.

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