Problems and approaches for solutions in modern injection technologies

There are many hot metal desulphurisation injection designs around the world, dependant on equipment supplier, technology available at the time, material cost and availability, and steel plant requirements. Many of these plants are not operating at maximum efficiency or lowest cost. Almamet provides assistance to steel plant managers to reduce costs and improve efficiency through plant design and performance assessment followed by optimisation of operations.

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A modern injection system, as it pertains to desulphurisation of hot metal, comes in several different forms. The most common and widely accepted is co-injection of reagents lime and magnesium, this being the most cost-effective and efficient overall. That being said, not all co-injection systems operate in the same manner and at their full potential. This paper will outline some of the methodology for solutions when analysing problems with co-injection systems, including quality of reagents, distribution and injection of reagents, and analyses of sulphur results data.

The typical problems can be separated into the following categories:

- Pneumatic transport
- Injection, pressure and flow setpoints
- Control of the injection system
- Injection optimisation
- Injection sequencing
- Injection reagent charts
- Maintenance of the system
- Variable vs. fixed orifice

PNEUMATIC TRANSPORT

Pneumatic transport of desulphurising reagents can be in dense or dilute phase. Dilute systems transport air and material at the same rate. In dense phase, material velocity is much slower than air velocity. Dilute phase has a solids to gas ratio of up to 8:1 or 15:1, while dense phase is higher than 8:1.or 15:1.

For the above, it is important to know that fluidised lime with typical specifications of 75µ @ 900kg/m^3 and magnesium <850µ @ 850kg/m^3 have very different flow characteristics. Together, these two products must co-exist simultaneously in the same transport pipe at a constant ratio and rate.

Ladle size (t)	Mg rate (kg/ min)	Lime rate (kg/ min)
80-150	6-15	20-45
150-300+	15-23	35-45

Table 1 **Typical co-injection rates**

A co-inject system must first have excellent lime flow characteristics as lime is the carrier for the Mg into the hot metal. The ferro-static pressure at the lance tip at 3m below the hot metal bath will be at approximately 2 bar. This pressure on the lance must be overcome for the material to flow.

The Mg vapourisation reaction takes place as far from the end of the lance as possible. This reaction creates stirring action to allow the interaction with sulphur at an efficient level without incurring hot metal splashing.

Table 1 shows a range of possible rates with many variables, including hot metal temperature, lance type, lance depth, orifice size, material conditions, transport pipe arrangement and sizing, vessel pressures and transport gas flow rates.

Ideally, the final goal of a pneumatic transport co-inject system is to fall within the following criteria:

- Maximum efficient Mg flow rate
- Minimal lime flow rate
- Turbulence for ideal stirring
- Low ratio for cost reduction
- Zero lance blockages
- Minimal injection time
- No splashing

INJECTION, PRESSURE AND FLOW SETPOINTS

The setting of suggested pressures and transport flow rates for different ladle sizes is shown in *Table 2*.

Ladle size, t	Freeboard <450mm	Freeboard 450-610mm	Freeboard >610mm
Lime	Pressure, bar	Pressure, bar	Pressure, bar
80 to 150	5.5	5.5-6.8	6.2-6.8
150-300+	5.5-6.8	6.2-6.8	6.8 max
Mg	Pressure, bar	Pressure, bar	Pressure, bar
80 to 150	4.8	4.8-6.2	6.2 max
150-300+	4.8-6.2	5.5-6.2	6.2 max
Gas flow	Nm^3/h	Nm^3/h	Nm^3/h
80 to 150	17-19	17-34	34
150-300 +	17- 25	17-34	34

Table 2 **Co-injection pressures and transport gas flow rates**

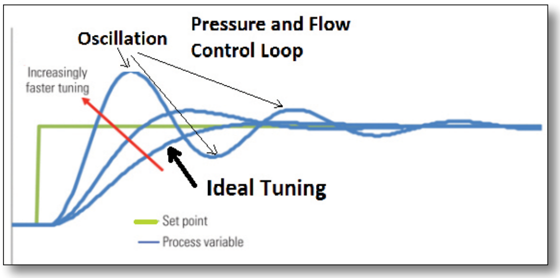

Fig 1 **Pressure or flow control loops**

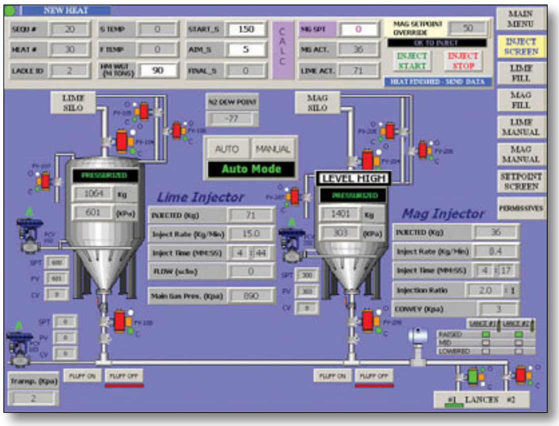

Fig 2 **Standard co-injection system operator display**

A properly tuned Proportional Integral Derivative (PID) control loop intended to control within a certain setpoint should not overshoot the pressure or flow setting and must be tuned to react smoothly to changes in the setpoint or to disturbances of the process variable (see *Figure 1*).

When excessive oscillation of the process pressure or flow variable occurs this can create turbulence in the hot metal bath or clogging of the lance. Unless a system is designed to monitor this oscillation, it is not possible to identify whether there is a problem. Tests should be performed to eliminate the possibility of poor loop control by the PLC processor.

CONTROL OF THE INJECTION SYSTEM

Control and monitoring of the co-injection system is imperative when determining issues that may arise.

Some of the control and monitoring interfaces designed with desulphurisation co-inject systems do not allow for complete solutions to situations. There are several reasons that may account for this lack of control.

- Third party design; poor understanding of process.
- Steel plants only need minimum operator interaction, which means they cannot manipulate parameters in changing situations.
- Poor operator training.
- Inflexible system control.
- No trending to review historical or real-time data.
- Availability of relevant screen information.

Figure 2 depicts a standard co-injection system display allowing for a complete view of all parameters

To eliminate down time, lance plugging, splashing of hot metal and troubleshooting, operators must have the proper training and understanding of the fundamental behaviour of the reagents, the injection parameters and troubleshooting of problems, in order to minimise costs and increase production. This includes modifying pressures, flows, lance depth and viewing real-time trends of all parameters.

(Basic operation of the control system should be designed to minimise key strokes or mouse movements to come as close to a single button start injection as possible, thus reducing set-up time for a ladle treatment.)

INJECTION OPTIMISATION

The example shown in *Table 3* indicates setpoints and operating parameters for a typical large ladle size in order to achieve a ratio of lime to magnesium of 2:1 on a bottom port lance.

Most systems lack a lance pressure monitoring transmitter. This is an important tool in recognising the behaviour of the injection and lance condition.

In the past it was thought that low ratios are not possible and would be detrimental to the injection process. In North American systems, these ratios are possible even on hot metal ladles as low as 200t.

The cost savings and return on investment to make the appropriate changes far outweigh the initial time and cost required for consulting knowhow, modifications to equipment, PLC programming and parameter adjustments.

INJECTION SEQUENCING

An injection sequence is designed and programmed in the PLC to allow the processor to perform tasks identically in every injection.

The function of a well-planned injection sequence is to:

- Eliminate lost time due to human functions
- Reduce cycle time
- Perform each step identically
- Identify each step
- Track parameters
- Identify problems
- Distinguish between equipment and material issues
- Prevent clogging of the lance
- Allow for quick recovery of the injection.

Specific understanding of the PLC program and the capability of the system are required to make appropriate changes, saving both time and money.

Below is an example of a standard injection sequence along with *Figure 3* depicting the area of description in the system.

1. **OK TO INJECT** indicator is visible
2. **INJECT START** is pressed to start sequence
3. Lance starts to lower
4. Transport Gas tracks **HIGH FLOW** Setpoint
5. Lance reaches the **ABOVE BATH** position
6. Lance reaches position just below surface of hot metal. *(Optional: to prevent fines in the bag house and steel shop)*
7. Lime Injector Material Valve opens
8. The following lime values increment accordingly: Injected Reagent, Inject Rate, Inject Time, Gas Flow
9. Transport Gas tracks **LOW FLOW SETPOINT**
10. The lance stops at **LOWERED** position
11. Mg Injector Material Valve Opens
12. The following Mg values increment accordingly: Injected Reagent, Inject Rate, Inject Time, Ratio
13. Mg material Setpoint reached
14. Mg material valve closes
15. The Transport Gas tracks **HIGH FLOW SETPOINT**
16. Lime material valve closes after 20kg once Mg valve has closed.*(To clear Mg in transport line)*
17. Lance raises to **ABOVE BATH** position
18. Lance purge cleanout cycle initiated.
19. Lance raised to Top/Parked position, Injection Complete

Setpoint/ parameter	Value
Lime pressure setpoint	5.8 bar
Lime orifice diameter	7.5mm
Mg pressure setpoint	5.2-5.3 bar
Mg orifice diameter	11mm
Lime injection rate	~ 4-45kg/min
Mg injection rate	~ 20-22kg/min
Lance pressure during injection	2.9-3.0 bar
High flow setpoint	$50Nm^3/h$
Low flow setpoint	$17Nm^3/h$

Table 3 **Example setpoints and operating parameters for a 280t ladle**

Fig 3 **Co-injection system depicting sequence numbering**

INJECTION REAGENT CHARTS

Steel plants have standard sulphur targets or aims required for a grade of steel. The desulphurisation sulphur charts are maintained or reside on a Level II system that relays the amount of Mg to consume to the PLC Level I system.

Sulphur charts are magnesium/t of hot metal curves based on different start sulphurs for a given aim, and can be static or dynamic. Dynamic self-evolving sulphur charts that predict the amount to inject, examine and track historical variables. Adjustments make it very difficult to account for changes in ratios, differences in lance design, reagent additives, flow rates, etc. The result of this is a variation in consumption for a given aim from month to month.

Easy access to modification of sulphur charts should be provided to avoid over-consumption. Almamet provides a detailed evaluation on injection performance by examining all aspects of reagent consumption. Historical raw data collection identifies areas of cost savings.

Figure 4 shows a scatter plot of a particular aim where the steel plant has been over-consuming far below the aim tolerance. The resultant final sulphur should be between the aim sulphur and the tolerance for that given aim. This indicates either a final sulphur measurement problem or a need to adjust the Mg/t additions of reagent.

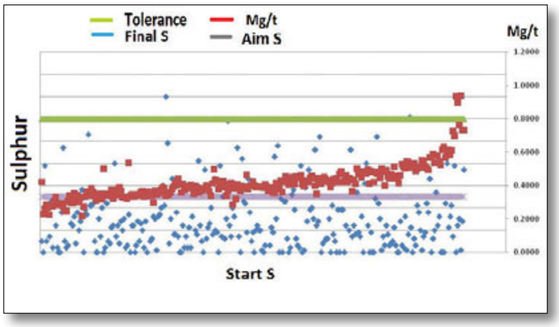

Fig 4 **Sulphur final in relation to aim and tolerance**

MAINTENANCE OF THE SYSTEM

Maintenance generally applies to hardware such as valves, instruments, piping and spares. Maintenance, as it pertains to desulphurisation systems, includes software, reagent consumption charts, operator interface screens, optimisation of the system and reagent modifications. All of the above must work in conjunction with each other to maintain a seamless operation and reduce overall cost per tonne of hot metal.

On an injection system, there are certain valves that require more frequent changes than others. Replacement of valves and the area to work in to accomplish this, means more down time for the equipment. A well-designed injection system allows for easy access to valves and instruments.

Fig 5 **Good design**

Fig 6 **Poor design**

Figure 5 below shows a system where the need for ease of maintenance has been anticipated, and *Figure 6* shows a system where poorly designed spacing makes it difficult to service the equipment without adequate down time.

In addition, smaller actuator and valve body sizes makes the process of changing required valves easy and less time-consuming.

VARIABLE VS FIXED ORIFICE

The decision to either install a variable orifice to control reagent material flow rates or a fixed one, is entirely dependent on the application and comfort level of the steel plant. A comparison is shown in *Table 4*. On sequential systems that inject Mg, lime and CaC_2 or other additives, the delivery of the reagent with respect to time of the treatment generally justifies the need for varying the rate of material for CaC_2.

In recent years, plants that maintain a fixed material flow rate with a requirement for minor changes to rate when desired, have selected to go to a fixed orifice with a simple quick clean-out port.

CONCLUSIONS

There are many hot metal desulphurisation injection designs around the world. Depending on the equipment supplier, technology available at the time, material cost, availability and steel plant requirements, Almamet has extensive knowledge and experience in injection technology and provides assistance to steel plant managers to reduce costs and improve efficiency through plant design and performance assessment followed by optimisation of operations. The need for solving problems within existing systems is the aim, wherever possible. **MS**

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Variable orifice	**Fixed orifice**
Constant injector pressure	Variable injector pressure
Variable % opening size	Fixed opening size
Expensive	Inexpensive
Complex control	No control
Difficult installation	Simple installation
No down time to vary % opening	Requires stopping system to change out orifice ball size
Clean out requires stopping system and dismantling	Clean out requires stopping system. No dismantling
Good for questionable material.	Not good for questionable material
Ratios and rates can be varied easily	Ratios and rate changes require injector pressure and orifice size variations
Can work as variable or fixed	Only works in a fixed position

Table 4 **Variable vs fixed orifice**