REDUCING/ELIMINATING GAS EMISSIONS FROM PIERCE SMITH CONVERTERS

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1. INTRODUCTION

We have a moral responsibility towards the world to reduce the harmful deposits we emit into the environment arising from beneficiation technologies. Industry has not willingly spent money to limit these emissions because it affected their profit margin with the end result of emitting harmful elements into the environment. Governments have thus rightly stepped in and enforced systematic reduction of these emissions through legislation.

In the past beneficiation of sulphur bearing ores was typically done through hydro-metallurgical concentration, smelting, followed by Sulphur removal by converting processes like the Pierce Smith converter. The latter two processes emitted substantial quantities of Sulphur into the atmosphere. Spiralling costs and legislation have resulted in the quest to develop more efficient and environmentally friendly processes to achieve the same end results. New hydro-metallurgical processes like the ActiVox process has completely eliminated the pyro-metallurgical processes. Kansanshi are also operating a similar process. It however elicits other ground water and spillage pollution hazards and problems of it's own. Various improvements has also been made to the pyro-metallurgical stages, examples being combined smelting and converting with the Noranda reactor, the Codelco CMT furnace, one step flash smelting/converting or the Mitsubishi continuous smelting, converting and slag cleaning process. The new converting processes are also normally enhanced using oxygen leading to higher SO_2 gas strength with only a marginal increase in off-gas volume. These processes have led to better efficiencies and a more controlled environment that reduces pollution, but does not eliminate it completely.

The fact that there are still more than 70 existing Pierce Smith converter plants throughout the world that needs to be replaced or upgraded at tremendous capital cost, means that we will have the environmental problems for some time to come. The need thus exists to cost effectively get these existing plants into a state where they meet the new environmental regulations, community and safety requirements.

This paper will concentrate on just one aspect of this quest, i.e. reduction/removal of off-gasses emanating from the converting of non ferrous sulphur mattes to achieve higher or specialised grades of refined metals.

2. OFF-GAS CAPTURE IN THE PAST

In past air cooled hoods were used, with large amounts of infiltration air for cooling. As people tried to capture and fixate the sulphur the associated plant for the huge gas quantities was excessive and the need to reduce the infiltration air became important.

Lower infiltration rates led to higher temperatures and gas strength in the off gas system which failures due to high temperatures and thermal fatigue. The air-cooled hoods were also prone to accretion build-up, making the capturing hood unsafe to operate when these accretions dislodged unpredictably.

Figure 1 – Accretion Build-up on Air Cooled Back Flap

Hence the development of water-cooled hoods onto which the accretions do not adhere. The accretions then fell off the hood behind the converter mouth and end up behind the converter on the punching platform. This, together with fear of water leakage into the converter presented major safety and operational concerns, but it stopped accretion build-up and associated unpredictable dislodging. Even though water leakage never really manifested itself as a constant and re-occurring danger, it is still an underlying safety concern that can be eliminated with proper design and maintenance.

Environmental requirements further required capture of fugitive gasses while the converter is out of stack, which led to the installation of secondary hoods. This led to weak SO_2 concentrations in the secondary hood systems which were not very successful in treating/converting to acid until recently where weak gas strength could be treated through other processes than metallurgical acid plants.

These new low concentration fixation plants however require huge capital outlay. The secondary hoods also require high crane rails, a luxury not too many existing plants have. These two factors have resulted that there are not many secondary hoods that are operating successfully today.

Early water-cooled hoods also attempted to make steam to improve waste heat recovery, but with tremendous capital outlay and maintenance/operational problems, especially in low pressure systems.

The earlier open circuit systems of water-cooling had corrosion on the hot side plates due to acid condensation on the surfaces, corrosion on the waterside due to oxygen in water, and high pumping costs of numerous water circuits. Various materials were also tried with even the most exotic materials failing quickly.

3. LATEST DEVELOPMENTS

To make the remaining Pierce Smith converter hoods, and even the newer generation technologies, conform to legislation, and be cost effective, the following criteria need to be satisfied:

- Must be able to fit onto existing converter installations
- Must capture all gasses during the blowing cycle
- Must have a tight seal onto the converter to facilitate low infiltration air
- Must add to the safety of the inherently dangerous converting operation
- Must have a long life in excess of ten years
- Must not be maintenance intensive
- Must have a low operating cost component
- Must be easy to manufacture
- Must be easy to install

To achieve this a new generation of water cooled hoods and associated cooling systems were developed by Drummond Technical Services and refined and improved by HG Engineering in Canada.

3.1 Hood Design

With careful design the hoods can be retrofitted onto any existing set of Pierce Smith converter. The concept can also be adapted to fit onto the newer technologies such as the Norando reactor, CMT furnaces, or even the ISA and AUS Smelt technologies, utilising higher water pressures to prevent boiling of the cooling media. Each application is however a design on its own taking into consideration factors like aisle configuration, crane rail height limitations, crane approaches, ladle sizes, number of converters, connection into existing gas handling systems, air infiltration, velocity to pressure conversion in the hood, etc.

Typical hood design parameters considered are :

- Aim for low mouth velocities, i.e. if we have the chance, install larger mouth

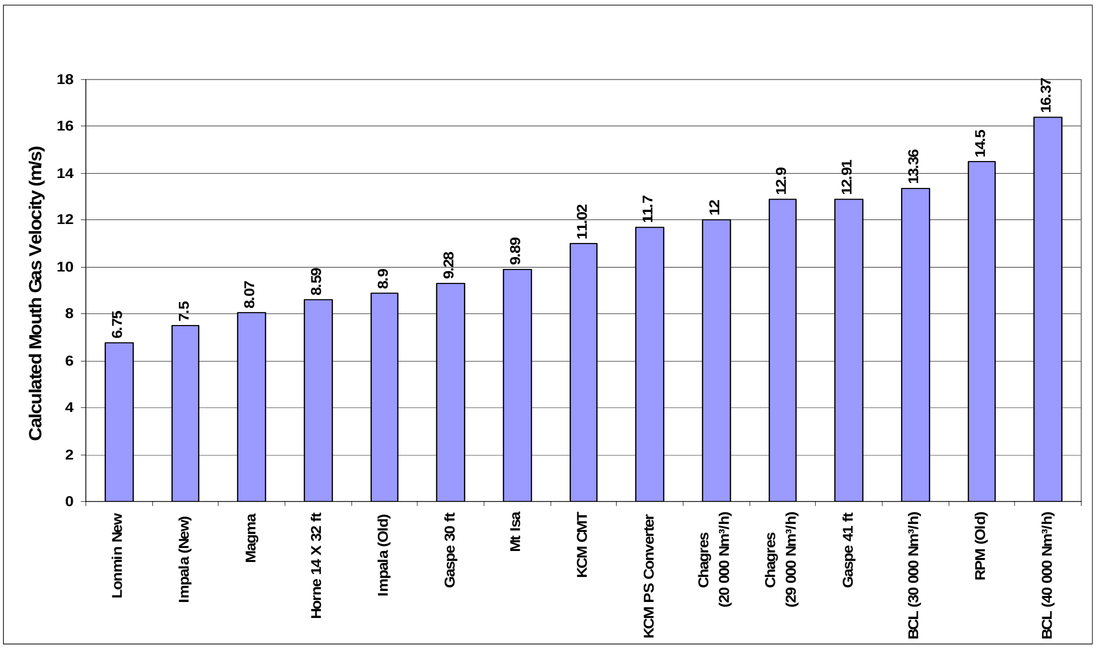


Figure 2 – Typical Mouth Speeds

- Design to have sufficient draft to maintain capture velocities and the required infiltration air quantities. The velocity at the bottom of the hood must be greater than that of the converter mouth exit velocity.

- Eliminating mouth velocity impact on door . This can be done by decreasing the mouth velocity with a bigger mouth or moving the mouth, or both. This must be done with care so as not to create other problems like increased heat loss or excessive build-up on the mouth.

Figure 3 – Effect of High Mouth Velocity

- Maintain the same hood gas velocity at converter mouth exit and at the top of the hood.

- Optimising flow into the hood by varying the blowing angle or by moving the mouth. Computational Fluid Dynamic model (CFDs) can assist with flow dynamics in the hood.

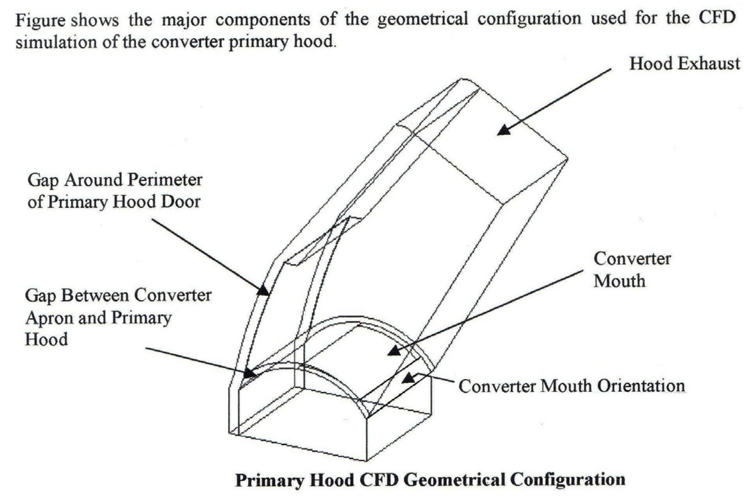


Figure 4 – CFD Elements Considered (Ref 3)

The results shown below shows dynamically where the pressures are positive or negative and by altering the mouth position and blowing angle, one can keep pressures negative in critical areas around the door.

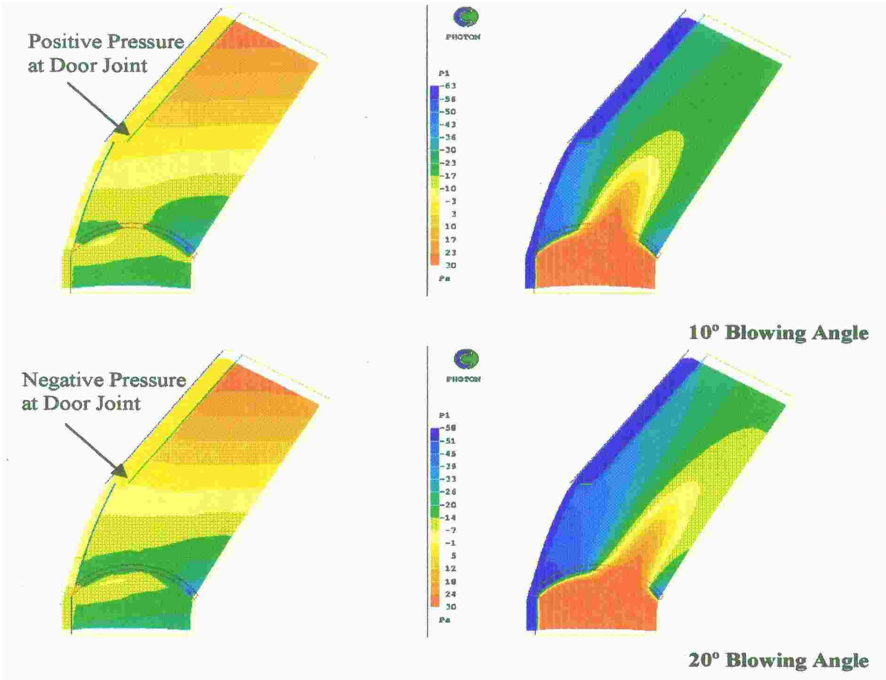


Figure 5 – CFD Pressure and Temperature Profiles at Varying Blowing Angles (Ref 3)

- Eliminate velocity to pressure conversion before the door seal. There must not be any convergence of the hood until after the top door opening to prevent positive pressure at the door seal.

- Can accommodate any door configuration

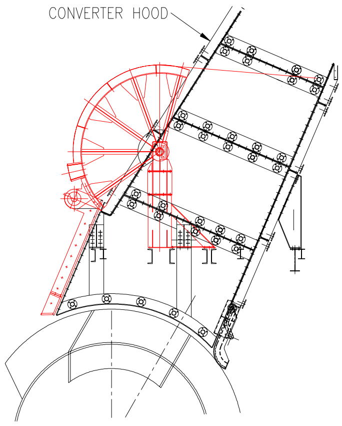


Figure 6 – Quadrant Type Door

Quadrant doors have direct metal to metal seals in the closed position, but cannot seal positively onto the converter shell. Typically these doors are not water cooled.

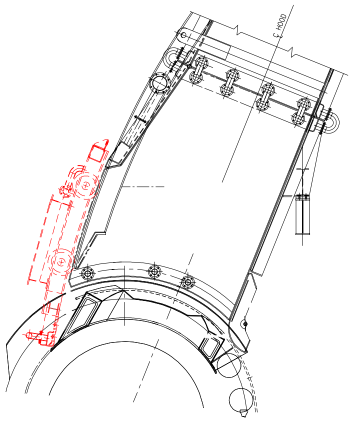


Figure 7 – Sliding Type Door

Sliding doors do not have tight sealing seals around the peripheral, and can be used to control infiltration air. These doors can be water cooled to take the punishment of a direct blast emanating from the mouth of the converter

- Small clearance to converter seal plate. This assists in achieving lower infiltration volumes. The seal can also be improved by placing a ceramic fibre seal in between the seal plate and the hood. Depending on infiltration rate required this clearance can be as little as 50mm.The seal plate must be 1.5 times higher than the stack base to prevent splash build-up on the seal plate itself.

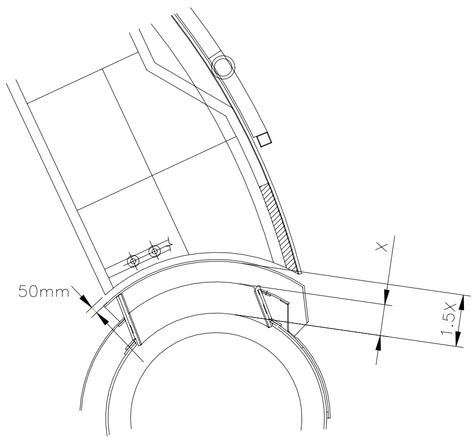


Figure 8 – Clearance Between Seal Plate and Hood

- A back lip liner can be installed onto the converter. With the alignment distance between the lip liner and the back of the hood kept to a minimum, the bulk of the splash and airborne sand will return back into the mouth of the converter, drastically reducing spillage behind the converter. Proper sized flux will also reduce air borne sand. This feature contributes hugely to the safety aspect of the hood where hot metal splash is to a large degree eliminated at the punching platform.

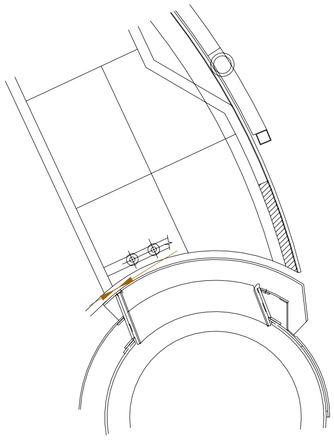


Figure 9 – Clearance Between Back Liner and Hood

- Water cooled back flap is essential (Fixed as above or Movable)

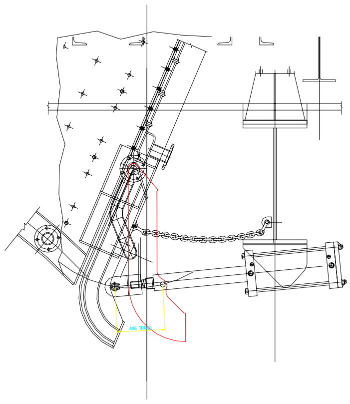


Figure 10 – Movable Backflap

- Ensuring easy ladle loading and discharge of converter product

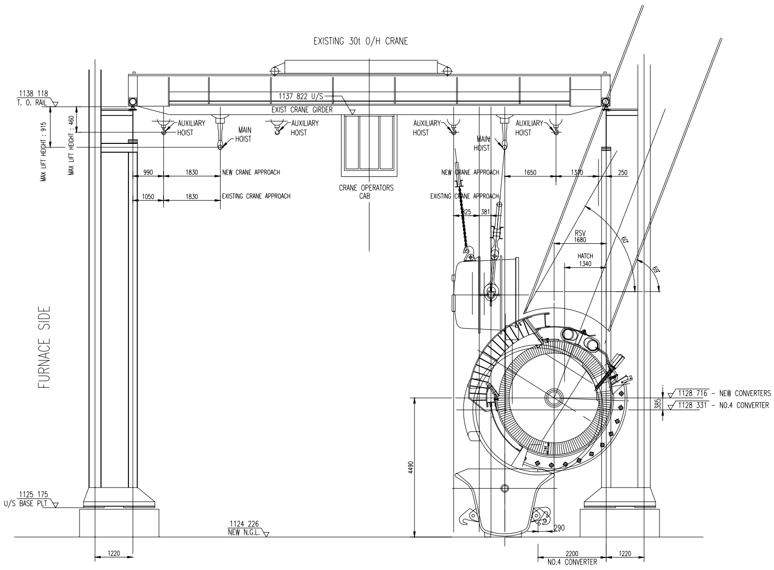


Figure 11 – Loading and Discharge of Ladles

- Water will be fed through a header at bottom of the hood, while the collecting header is at the top to remove any steam generated from the hood

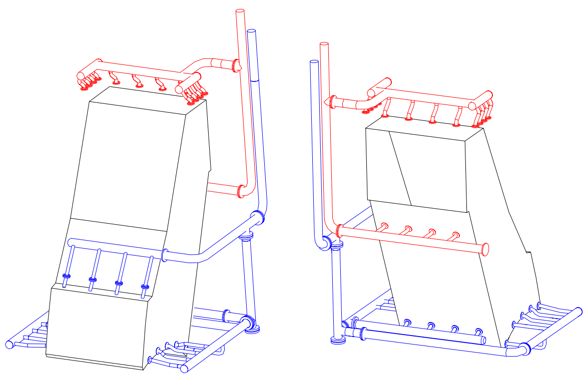


Figure 12 – Inlet and Outlet Piping

- **The hood has an inherently sturdy construction and therefore requires no frame**

- **Each application designed on its own merit to fit in under rails**

- **The hood is easy to install in one or two pieces**

Figure 13 –Lifting of Hood – Stages 1 & 2

- **Quick and easy commissioning of the system as a whole**

3.2 Panel design

In order to make the individual panels cost effective, the principal design considerations for the panel design is ease of fabrication using low cost material. The following other factors are taken into consideration

- **Water velocity through panel should be consistent with burnout criteria in a gap between the hot plate and cold plate of only 20mm. This configuration permits neucleoid boiling where a small steam bubble is formed and immediately swept away from the hot plate. Once loose from the hot plate the bubble immediately collapses again. This mechanism of allowing neucleoid boiling exponentially increases the heat transfer rate from the hot plate to the water, but in essence the system is non-boiling.**

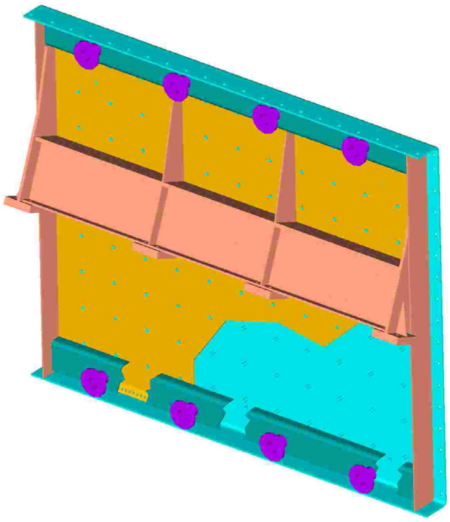


Figure 14 – Typical Panel Manufacture

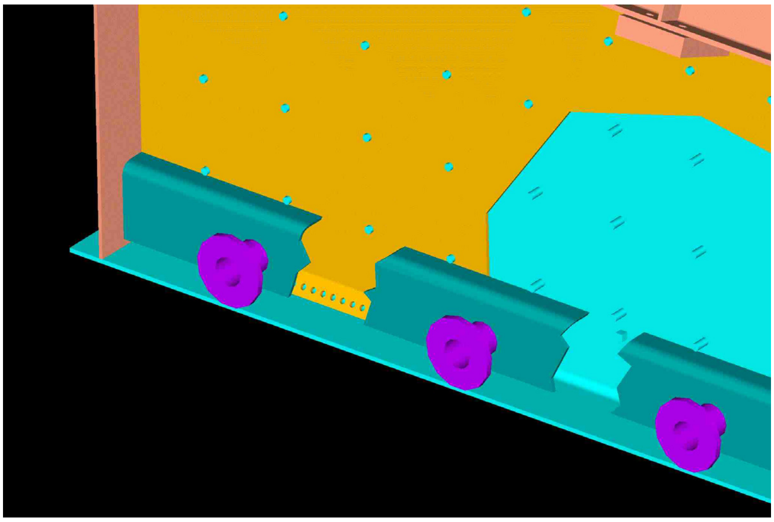


Figure 15 – Water Distribution in Panel

- **Bending of sides must be made where possible. If not possible, the connection plates can be welded on the waterside of the hot plate. Only in absolutely impossible circumstances must welding to the hot face be allowed, but heat treatment is then required to stress relieve the welding to prevent accelerated corrosion on the weld.**

- **Studding and spacing onto the hot face eliminate the need for welding on the hot face. The studding also has an insignificant heat affected zone, so preventing annealing and weakening of the hot plate. Typically 600 to 1000 studs can be done in one day, which is more than the requirement of a complete hood. Also with 20mm studs sufficient weld strength is achieved on the joint to the hot face plate for studs to go into yield failure before the weld fails.**

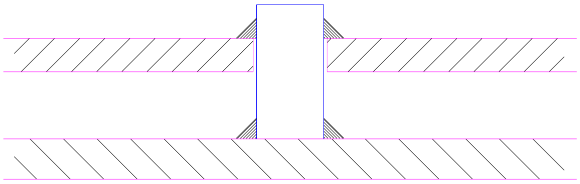


Figure 16 – Typical Stud Weld

Figure 17 – Photo of Stud Failure and Weld

- **Tolerances of three millimetres for end-to-end plate dimensions can easily be achieved. This usually takes a bit of practice, but once achieved can be easily maintained.**

- **No stress relieving of the panel is required**

- **The panel is designed for pressure vessel standards. This is not necessary due to the inclusion of a standpipe in the piping system.**

- **Materials of construction are standard mid range boilerplate for the hot plate and mild steel for all other sections. The combination has good weld ability characteristics. Corrosion will be discussed later**

- **The panels are designed for worst case of low air infiltration, radiation and convection heat.**

3.3 Process Design

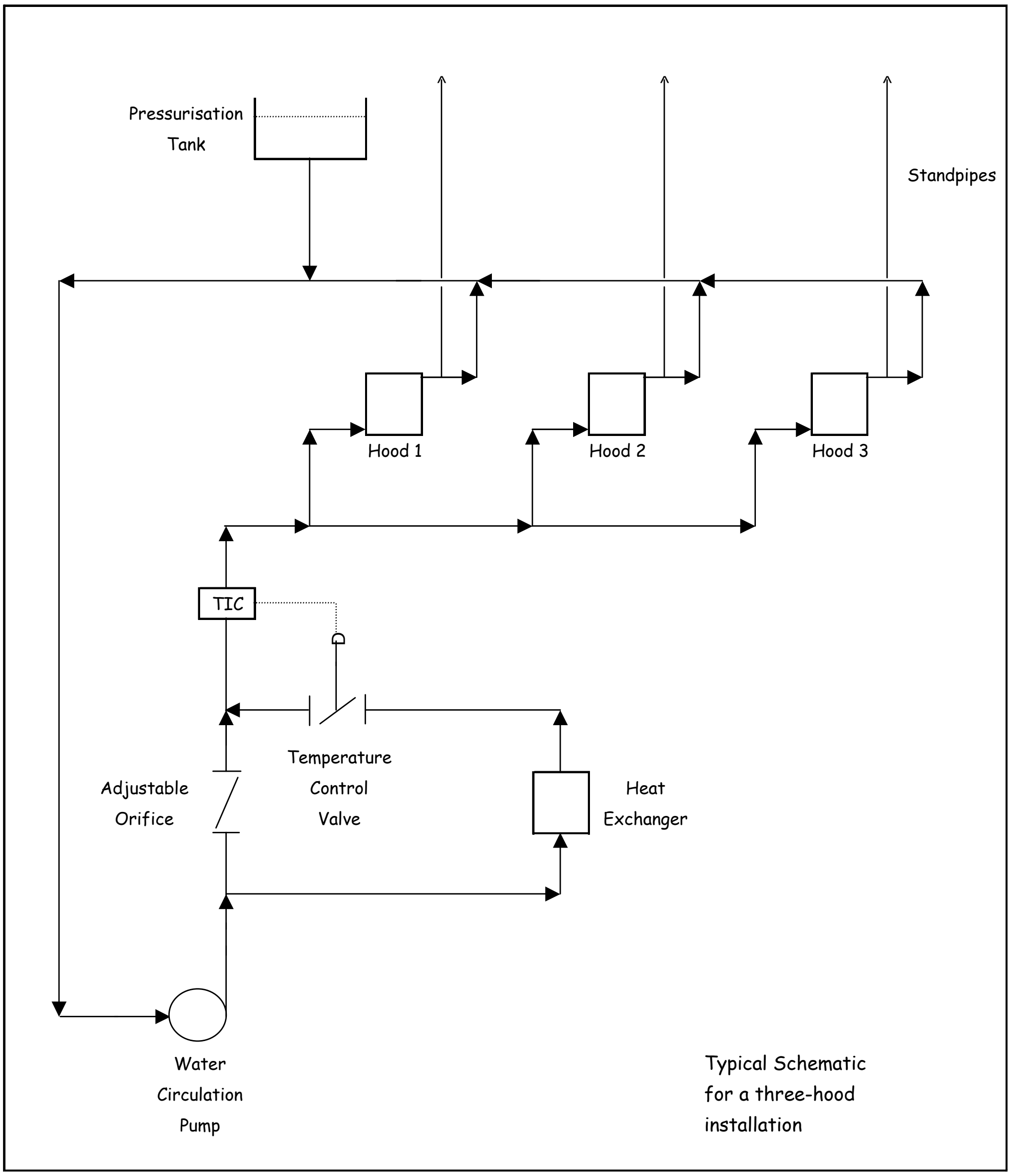


Figure 18 – Simplified PFD

The concept utilises a totally closed circuit water circulation concept whereby the circulating water does not come into contact with air. The closed circuit water therefore only has oxygen entrapment in the initial fill and once this is oxygen depleted, inside corrosion on the water circuit is virtually eliminated.

- Parallel circuit with up to 4 hoods in a single closed circuit configuration.
- Does not make bulk steam.
- Nucleonic boiling allowed but scrubbed off with high water velocities before boiling occurs
- Cooling of water can be done through various types of heat exchangers, e.g. plate heat exchangers or tube bundle evaporative coolers. Provision must be made for sufficient cooling capacity in the cooling circuit for maintenance of

equipment without stopping the complete system. Only about 33% of the circulating load goes through the coolers.

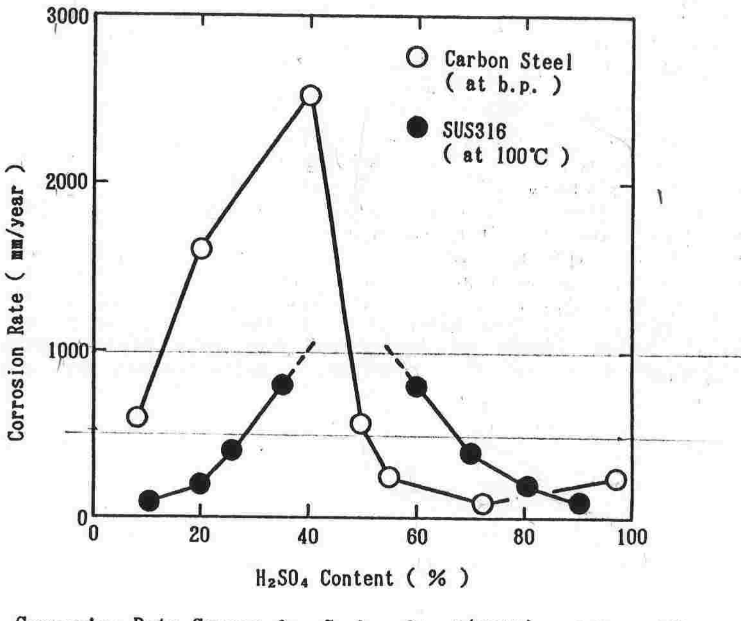
- A single control valve controls the temperature of the complete cooling water system.

- A variable orifice is inserted into the cooling circuit to create pressure drop to force water through the coolers.

- Standpipes are inserted into each hood system to prevent pressure build-up in the circuit due to steam formation. Steam formation is not expected in this design and the installation of the standpipes is for safety reasons only.

- A single pressurisation tank is installed to pressurise the closed circuit water stream to increase the boiling point slightly, preventing boiling in the circulating circuit.

- The temperature of the closed circuit circulating water is controlled at 70 degrees Celsius. According to the During diagram below, the partial pressures of SO3 and partial pressure of water is balanced at this temperature so that strong acid is formed on the hot plate when moisture and process gasses are brought together. With the strong acid formed, the corrosion rate of carbon steel is then drastically reduced. Note that the corrosion rate for carbon steel is much lower than that of 316 stainless steel at this acid strength, hence the choice of normal mild steel boiler plate for material of construction.



Corrosion Rate Curves for Carbon Steel(SS41) and Type 316 Stainless Steel(SUS316)

Figure 19 – Corrosion vs. Acid Strength (Ref 4)

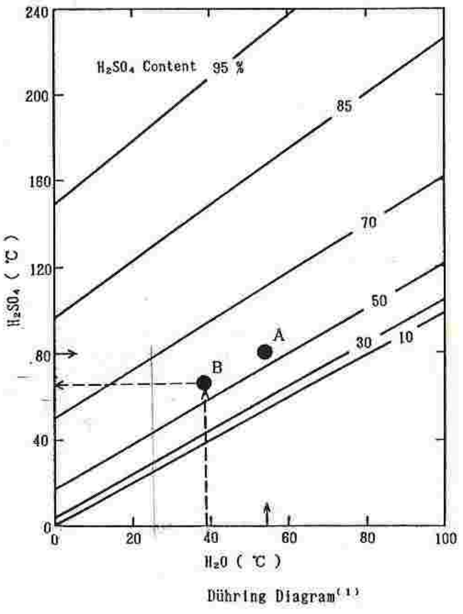


Figure 20 – Formation of Acid vs. Temperature (Ref 4)

- **Initial water treatment of the circulation water is critical, thereafter virtually no further water treatment is required due to the closed circuit concept**

3.4 Design Successes and Problems Encountered

- **Tuticoren**
- **RPM with panel life in excess of 8 years**
- **Palaborwa Mining, problems due to water replacement and lack of water treatment**
- **Impala Platinum, hoods installed for 5 years without problems to date, but currently problems with top panel due to heat impingement and blasting effect of high mouth velocities**
- **Kennicott, hoods making steam**

4. Conclusion

It is the responsibility of industry to conserve our environment and create a safe working environment for its employees to work in. With PS converters still operating, and liable to operate for some time to come until better processes can be viably developed and constructed, better off-gas capture hood solutions need to be developed and/or improved where the bulk of the SO_2 emissions occur. Safety and environmental protection must be the overriding considerations and must be everyone's mission.

5. References:

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2) **Heat Transmission, William H.McAdams, Third Edition**
3) **Effective Design of Converter Hoods, Paper by Paykan Safe, Sam Matson and John Deakon**
4) **Water Cooled Jacket System for Waste Gasses Containing SO_2, Paper by Y Maeda, T Suzuki & R Togashi**