Efficient heating of heap leaching solutions to minimize GHG emissions and cost of energy

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Abstract

Inproheat is a 56 year old privately held Western Canadian based company who specializes is combustion technology and applied heat transfer. For the past 38 years, we have continued to apply our proprietary Heat Transfer Technology, namely SubCom™ to a diverse range of aggressive solutions used in the mining sector.

Submerged combustion offers the highest possible thermal efficiencies, 99% on an HHV basis and resultant lowest GHG's for heating aggressive liquids with combination of high TDS.

Our presentation will focus on the application of heating an aggressive low pH 1.0 to 2.0 Raffinate Solution at a copper heap leach operation. It will discuss the technical design challenges that had to be overcome to utilize submerged combustion as the heating method and the resulting benefits realized. These challenges included selection of the most appropriate materials of construction for the tank and internal combustion chamber alloys. The Raffinate flow rate was 130 USGPM and was heated from 15°C to 35°C in an effort to increase its leaching potential as this high altitude operation was subject to extreme colder ambient conditions. The location of the Heap Leach Operation was remote and at an elevation of 2,600 MASL and all required diesel fuel to run the operation had to be trucked to site. Based on this location, the operation wanted to ensure they achieved the maximum efficiency from their diesel fuel energy supply.

Introduction

This paper describes the design process and outcomes of a raffinate heating system, using submerged combustion technology, at a copper heap leach mining facility in Chile. The purpose of heating the raffinate was to improve the leaching performance during the cooler evenings and winter months.

Traditional heating methods include indirect Boilers/heat exchangers which typically operate at thermal efficiencies of around 75% to 85% in optimal conditions and require regular maintenance to ensure safety, due to the high-pressure operation. The thermal efficiencies of boiler systems tend to decrease with time as the heat exchangers foul. Furthermore, boiler systems require condensate return systems to maintain a reasonable efficiency; adding more components requiring maintenance. Steam and condensate piping must be insulated for heat conservation and personnel protection, adding to the cost.

Submerged combustion is a proven technology in several heavy industrial applications, and perhaps most notably in the liquid natural gas (LNG) industry where it has been used for over 50 years to heat seawater for the vaporization of LNG. Relatively unknown in the mining industry, submerged combustion has the advantage of being able to heat any type of non-combustible liquid to near boiling point at thermal efficiencies approaching 100%, and with low maintenance requirements. Submerged combustion is a process in which the products of combustion directly contacted with the liquid to be heated. The energy transfer occurs directly between the liquid and the hot gases, resulting in high efficiencies with no fouling issues. Figure 1 is a graph of thermal efficiencies for heating water in single stage contact and with a heat recovery system.

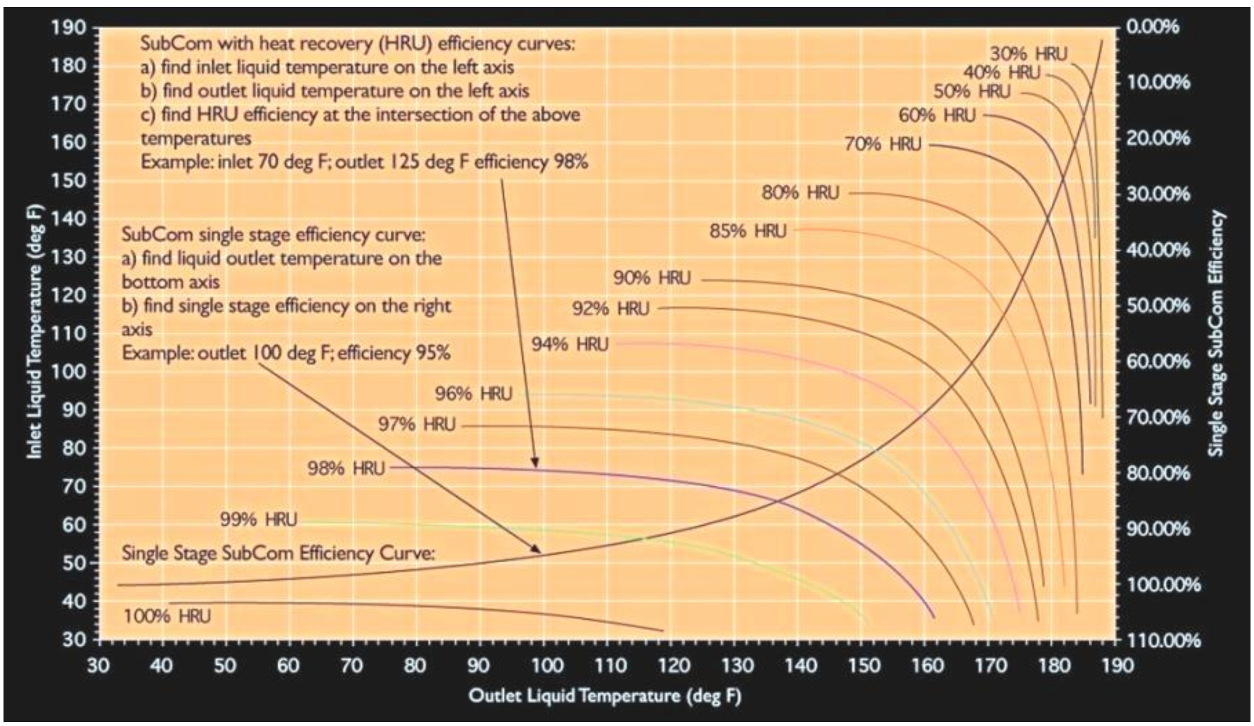

Figure 1: Thermal efficiency vs. liquid discharge temperature

Submerged combustion technology

The Raffinate heating system highlighted in this paper is trademarked SubCom™ and was developed by Inproheat Industries in the early 1970's in response to the global energy crisis. A SubCom™ liquid heating system consists of a fuel burner mounted at the top of a combustion chamber, which extends down from the top of a tank containing the liquid or slurry to be heated, as shown in **Figure 2** below. The burner is connected to a blower that provides air for combustion as well as heat transfer. Pressure from the blower purges the liquid from the combustion chamber allowing the flame to burn in a dry atmosphere without impingement, for complete combustion of the fuel. The products of combustion are vented through a series of carefully designed orifices around the lower circumference of the combustion chamber. The heat transfer takes place between the combustion gases and the liquid to be heated. An inherent property of the technology is that the temperatures of the exhaust gases that are released from the liquid are at the same, or close to the same, temperature as the heated liquid, which means high heat transfer efficiencies.

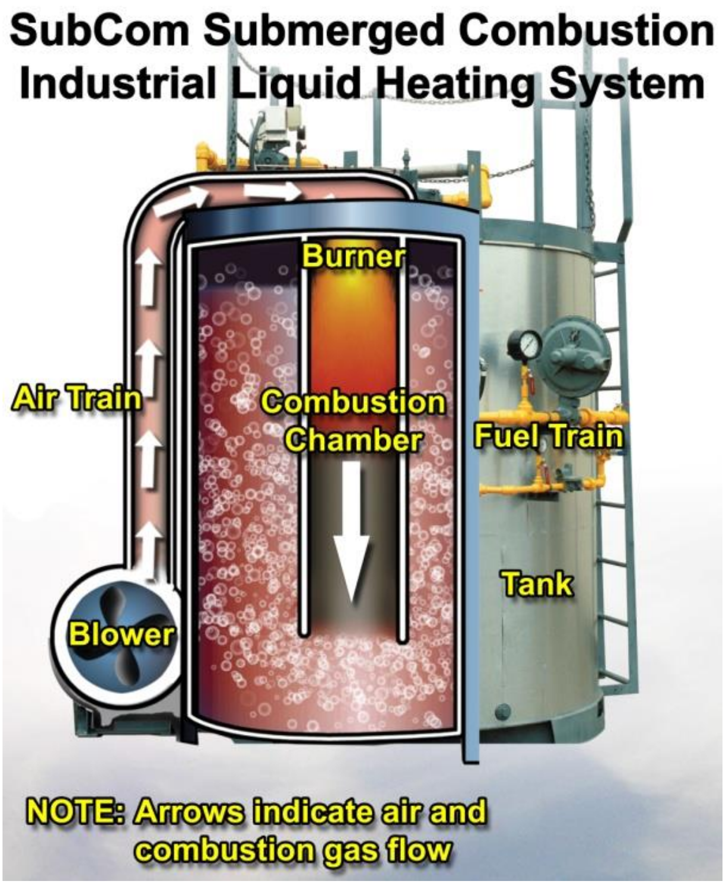

Figure 2: Typical Subcom system cutaway

GHG Reduction with Submerged Combustion

Because SubCom™ is more efficient than alternative liquid heating technologies, such as steam boilers with indirect heat exchangers, there is a significant gain in thermal efficiency. This thermal efficiency advantage can be 20% or more. This translates into a directly proportionate reduction in fuel consumption and concomitant CO_2 emissions from the burning of fossil fuel.

SubCom™ Applications in the Mining Industry

SubCom™ systems have been and are being used in a variety of applications in the mining industry.

A multi-burner system originally comprising ten 13 MM Btu/h burners was installed at the PCS Patience Lake potash operation in 1992. The system was modernized and upgraded with the addition of four more burners to bring the installed capacity to 182 MM Btu/h. The system heats brine to enable solution mining of potash from the former underground workings after the mine flooded in 1984. Without the heating of the brine, the operation would not be economically viable.

Recently a five burner SubCom™ system was installed at an integrated steel plant in Mexico to heat iron ore concentrate slurry with 65% solids content. The burners were installed in an existing 15 m diameter x 15 m high agitated tank. The heating improves the slurry filtration performance in the pelletizing plant.

SubCom™ heaters have been used in mine water treatment to maintain the water temperature during winter months in cold climates.

Project overview

In 1995 Inproheat was approached to evaluate if submerged combustion could be applied to heat raffinate solution. The primary objective was to minimize the high consumption of diesel fuel oil at the mine.

Run-of-mine ore is trucked to crushing circuits with primary, secondary and tertiary crushers. Crushed ore is screened and 13-19 mm material is sent to stackers that construct the leach pad. The ore is stacked to a height of 6 - 8 m. Fines are sent to agglomerating drums in which marble- to golf-ball-size ore nodules are formed with sulphuric acid to cure the pellets. The nodules are stacked for 15 or 30 days for oxide and sulphide ore respectively to activate bacteria and consolidate pellet strength. The cured pellets are then are conveyed to the heap pads.. Raffinate solution is constantly circulated to the heaps through an irrigation system. As the acidic raffinate percolates through the heap and it contacts the ore it leaches the copper along with other impurity metals. Pregnant Leach Solution (PLS) flows from the bottom of the heap on lined pads into ditches that take the PLS to collection basins and then to covered ponds. From there, the PLS flows by gravity to the SX/EW distribution point. Copper separation and recovery are done by conventional SX/EW to produce high grade copper cathode. Raffinate from the SX plants is heated from 15°C to 35°C (60°F to 95°F) before being pumped to the leach pads to increase its leaching potential. The primary source of energy for the mine is No. 2 diesel fuel.

The challenge

Raffinate is a mild solution of sulfuric acid with a pH of between 1.2 and 2.0. An investigation into suitable materials of construction for the system was required for the combustion chamber, tank, piping and valves. Typical of mining operations in Chile, the water contains chloride which can cause pitting and stress corrosion cracking in "standard" Austenitic stainless steels. In this case, there could be up to 2 gpl of chloride in the raffinate.

Inproheat's experience at the time with existing installations was limited to gaseous fuels. Using No. 2 diesel fuel had to be researched.

The elevation of the site, at 2,600 MASL, had to be taken into consideration when designing and selecting the combustion system components. The unit was to be mounted outside and capable of automatic operation with remote start/stop from the control room.

The requirement for high efficiency was dictated not only by economics but also by the logistics of trucking diesel fuel to the remote mine location.

The solution

Inproheat designed and manufactured a 10MM Btu/h (2.5MM kcal/h) submerged combustion system for raffinate heating. Metallurgical corrosion tests were undertaken to establish the best material for the combustion chamber. Carpenter 20Cb-3 alloy was selected for all combustion chamber components. The tank, vent stack and piping were made of fiberglass using an acid resistant Derakane 411-45 resin. To handle corrosive raffinate Inproheat selected Durco valves and a pump made of CD4MCu duplex stainless steel alloy. Propane was used as the burner pilot fuel and No. 2 diesel as the main fuel.

The unit was skid-mounted, pre-packaged and prewired, including the heating tank, submerged combustion burner, combustion air blower, propane pilot fuel train, diesel oil main fuel train, inlet water shutoff and control valve, discharge pump, and control panel. The fiberglass vent stack was shipped separately. The client provided raffinate inlet and outlet connections and fuel supply. Raffinate is fed by gravity from a large storage tank adjacent to the heating system. An inlet flow control valve maintains the liquid level inside the heater tank via a level control loop. On the discharge side, a centrifugal pump removes heated raffinate from the heater.

Figure 3: Twin 10 MM Btu/hr Subcom Raffinate heaters

To address the technical uncertainties of the project Inproheat decided to simulate system operation with water in the Vancouver factory. The system was tested for approximately two weeks. A 50 Hz generator was used to match the frequency of power supply in Chile. A cold water supply of approximately 30 m^3/h was connected to the heater, and high altitude operation of the combustion air blower was simulated by installing a restrictor plate on the inlet of the blower.

Initially, a problem of vortexing developed in the round-domed fiberglass tank. This problem was quickly resolved by the addition of baffles installed on the interior tank wall. Performance of the diesel oil burner exceeded expectations. Initial concerns of potential oil residue in ther were alleviated by water discharge quality tests. All system functions and performance were tested before shipment to Chile.

Inproheat commissioned and started the system up in November 1995. A number of combustion tests were conducted. The raffinate discharge temperature was set at 35°C, with stack temperatures between 34°C and 36°C. The resulting overall system efficiency was calculated at 93% of the diesel oil higher heating value, with USD$12/h (approx. USD$100,000/y) savings compared to the original conventional boiler / heat exchanger system which was rated at 64%. GHG emission was reduced by 31%.

Conclusion

The application of direct contact solution heating for aggressive mining solutions is ideally suited for optimizing energy utilization with minimal GHG generation. Small scale pilot projects could be utilized to prove out benefits where indirect heating systems have been the norm.