Utilization of COG Excess to RhF Without A Gas Holder By An Automatic Control System For Mixing Combustion of COG & NG

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~ ABSTRACT ~

Coke Oven Plant (COP) is an upstream factory facility in Krakatau Steel (KS) that supplies coke for the needs of Blast Furnace Plant (BFP) operations and volatile material in the form of Coke Oven Gas (COG) of 27,800 Nm^3/h. The calorific value of COG is relatively high (4,000 $kcal/Nm^3$), so this gas is used for the internal needs of COP of 16,000 Nm^3/h, and the excess is used for the needs of other factories of 11,800 Nm^3/h. In ideal conditions, utilization of COG should use a Gas Holder so that the gas pressure to the user is more stable. But in KS, COG is utilized without using a Gas Holder & Booster Pump and replaced with a Water Seal Tank to increase gas pressure. Energy costs in the Reheating Furnace (RhF)-Hot Strip Mill (HSM) rank second after raw materials in the production cost structure, so there is an initiative to use excess COG to be used as a substitute for Natural Gas fuel and as a company initiation in emission reduction programs.

One of the exciting and distinctive things related to the utilization of COG to RhF in KS is the use of a dual-mode control system, namely full Natural Gas fuel mode and mixing NG with COG. The control system with gas mixing mode is based on no burner modification because the existing burner design is sufficient to accommodate COG, the calorific value is relatively high, or half the calorific value of natural gas (8,400 $kcal/Nm^3$), and CO_2 emissions are lower (0.65 kg/Nm^3) than NG (2.29 kg/Nm^3). The working system of the burner control is based on the set point temperature to be achieved in the furnace. The algorithm system will convert the input temperature to the amount of heat required in the available COG flow, and the amount of incoming natural gas flow will adjust based on the heat liberation in each zone. The amount of combat air supply will adjust the Air Fuel Ratio of each gas. The fuel gas mixing design is only implemented in 4 zones out of 9 zones due to COG limitations.

Realization of savings in NG usage from COG substitution that has been used in HSM from January 2020 - March 2021 on average 1,250 kNm^3/month or 32% of NG consumption in 2017. With COG utilization to RhF-HSM operating yield still achieved, it does not affect the production process and product results, equipment remains conducive and more environmentally friendly, with a reduction in CO_2 emissions of 32,550 kT of the use of COG.

Keywords: COG, Gas Holder, Water Seal Tank, air fuel ratio, heat liberation, emission reduction.

I INTRODUCTION

To ensure business continuity, the availability of energy sources, prices, and the stability of energy supply are the main issues for the steel industry. Natural gas is the primary energy source used in the gas-based steel industry. The price of natural gas continues to increase significantly. On the other hand, natural gas has become the most widely used alternative energy source at a time of high oil prices, resulting in a limited supply of natural gas to the steel industry.

Krakatau Steel (KS) has production facilities for ironmaking Blast Furnace Complex (BFC) consisting of Raw Material Handling, Sinter Plant, Coke Oven Plant, Blast Furnace Plant, Hot Metal Treatment Plant, and Pig Casting Machine. Where the Coke Oven Plant (COP) is a production facility that produces coking coal, this coke will later be used as raw material for combustion in the Blast Furnace Complex area. The production process at COP produces Coke Oven Gas (COG) which is used for the internal combustion process at BFC.

Currently, only COP and support processes are operating at BFC. When the COP operates with a maximum capacity (73 push/day), it can produce COG of 27,800 Nm^3/h. The COG requirement for internal COP is 16,000 Nm^3/h, so there is an excess COG of 11,800 Nm^3/h.

In ideal conditions, clean COG utilization should use a Gas Holder and increase the gas pressure using a booster pump from 6 kPa to 12-15 kPa, so that the system pressure to several plants is more stable and burned in the Bleeding Tower if there is excess gas. However, the utilization of COG in several plants is constrained by the unpreparedness of the Gas Holder & Booster Pump operation due to non-technical problems that have not been resolved so far. In increasing the system pressure to 8.5 kPa, only the Water Seal Tank is used, as the minimum operating pressure requirement.

From here came the initiation to utilize the remaining COG to the Reheating Furnace (RhF) Hot Strip Mill (HSM) to replace natural gas as fuel gas to the furnace, due to several considerations, including:

- In the production cost structure, energy costs in HSM rank second (4.81%) after raw material costs (94.49%), as shown in figure 1.1 below.
- The calorific value of COG is relatively high (LHV 4,000 kcal/Nm^3) or half the calorific value of natural gas (LHV 8,400 kcal/Nm^3) or 1 Nm^3 of COG substituted by 0,47 Nm^3 of NG
- The existing burner capacity is still able to accommodate COG and natural gas
- A feasibility study was carried out before the implementation of the use of COG to RhF by an external party from LAPI ITB.
- Company initiatives in reducing emissions due to the production process

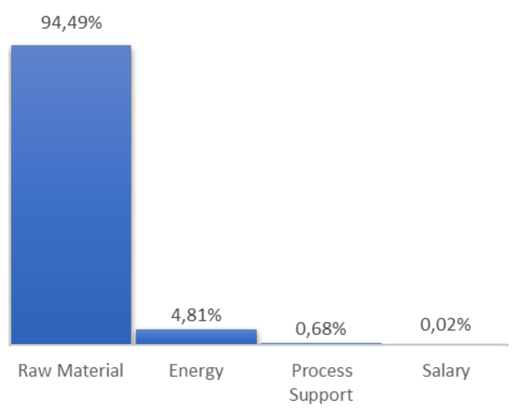

Figure 1.1 HSM Cost Production in 2022

II PROCESS PRODUCTION

A. Coke Oven Gas

Coke Oven Plant (COP) is an upstream factory facility in Krakatau Steel (KS) that supplies coke for the needs of Blast Furnace Plant (BFP) operations and volatile material in the form of Coke Oven Gas (COG) of 27,800 Nm^3/h. The calorific value of COG is relatively high (4,000 kcal/Nm^3), so this gas is used for the internal needs of COP of 16,000 Nm^3/h, and the excess is used for the needs of other factories of 11,800 Nm^3/h. In ideal conditions, utilization of COG should use a Gas Holder so that the gas pressure to the user is more stable. But in KS, COG is utilized without using a Gas Holder & Booster Pump and replaced with a Water Seal Tank to increase gas pressure.

The following is the process flow diagram of the Coke Oven Plant production:

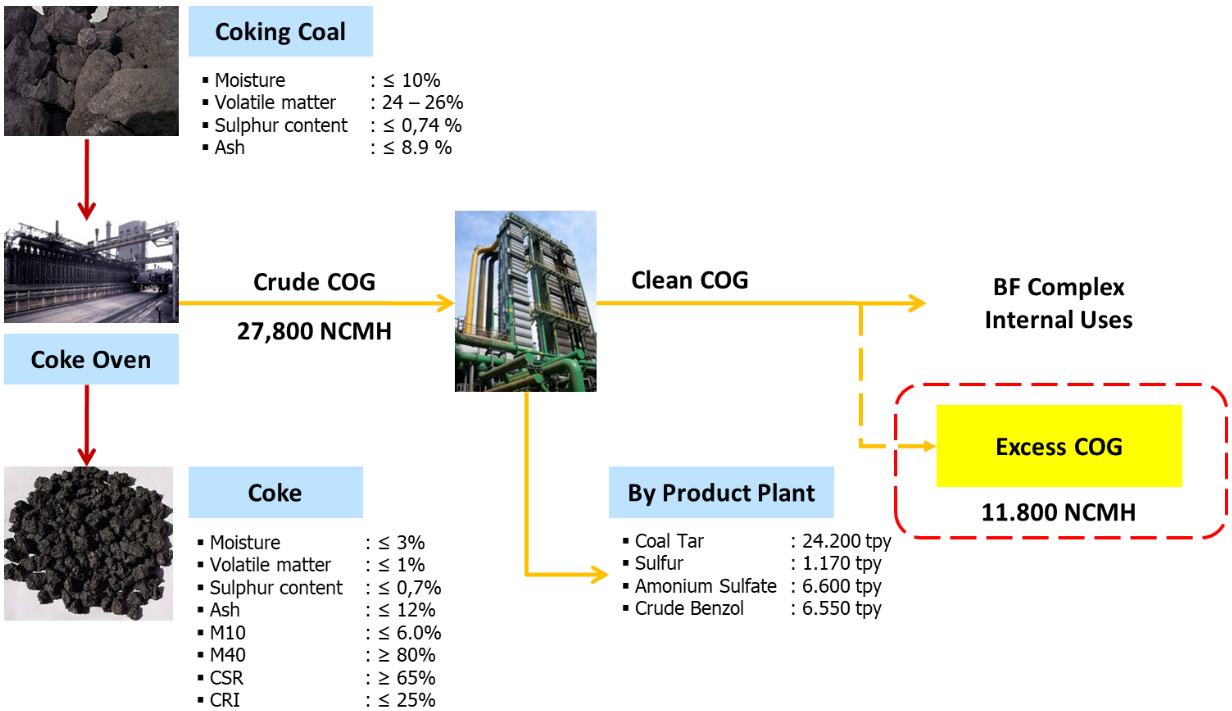

Figure 1.2 Coke Oven Plant Process Diagram

The Gas Holder is a large gas storage tank, and the volume is 50,000 m^3 with gas pressure slightly above atmospheric pressure (6 kPa) at ambient temperature. The gas pressure in the holder is relatively constant according to the weight of the movable cap, which is set with the addition of several weights that can be adjusted to the desired gas pressure setting.

The gas holder also functions as a gas accumulator. Suppose the gas output from the holder is greater than the gas input. In that case, the moveable cap/piston deck will decrease; otherwise, if the gas output from the holder is smaller, the piston deck will be lifted, and the pressure will remain stable during this process. Operation level piston deck between the minimum-maximum level. At the same time, the function of the booster pump is to increase the gas pressure as needed. The following is a figure of Gas Holders generally installed in several factories:

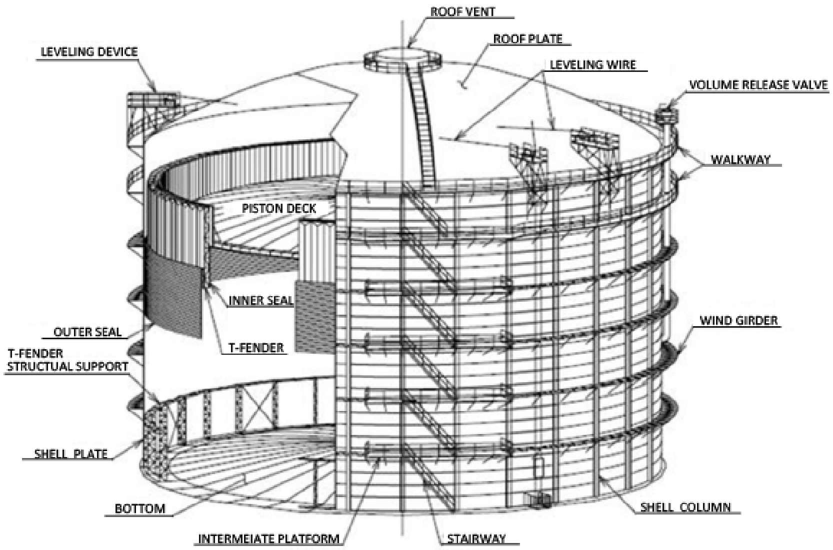

Figure 1.3 Coke Oven Gas Holder

The basic principle of increasing or decreasing the COG system pressure is to regulate the COG output in the Bleeding Tower using a Water Seal Tank (WST). Adjust the COG output pressure from the Bleeding Tower, which can be done by adjusting the water level and valve overflow. The way it works is to increase the gas pressure by manually closing the fluid flow path in several valves so that the flow to the route will be limited, and the pressure can be adjusted as needed, with a range of 4.5-9.5 kPa. The following is a figure of the Water Seal Tank at the General Facility:

Figure 1.3 Water Seal Tank COG

B. Hot Strip Mill

HSM factory is an inseparable part of the series of production processes at Krakatau Steel, as a hot sheet steel forming factory, it processes slab raw materials with a thickness of 200 mm to be developed into sheet steel, both in hot rolled coil (HRC) products and sheet products with a thickness of up to 2.0 mm. The main equipment in the formation of sheet steel consists of a Reheating Furnace, a furnace to heat the slab, and a Roughing Mill, which serves to reduce the thickness of the steel to the desired size, as shown in figure 1.4 below:

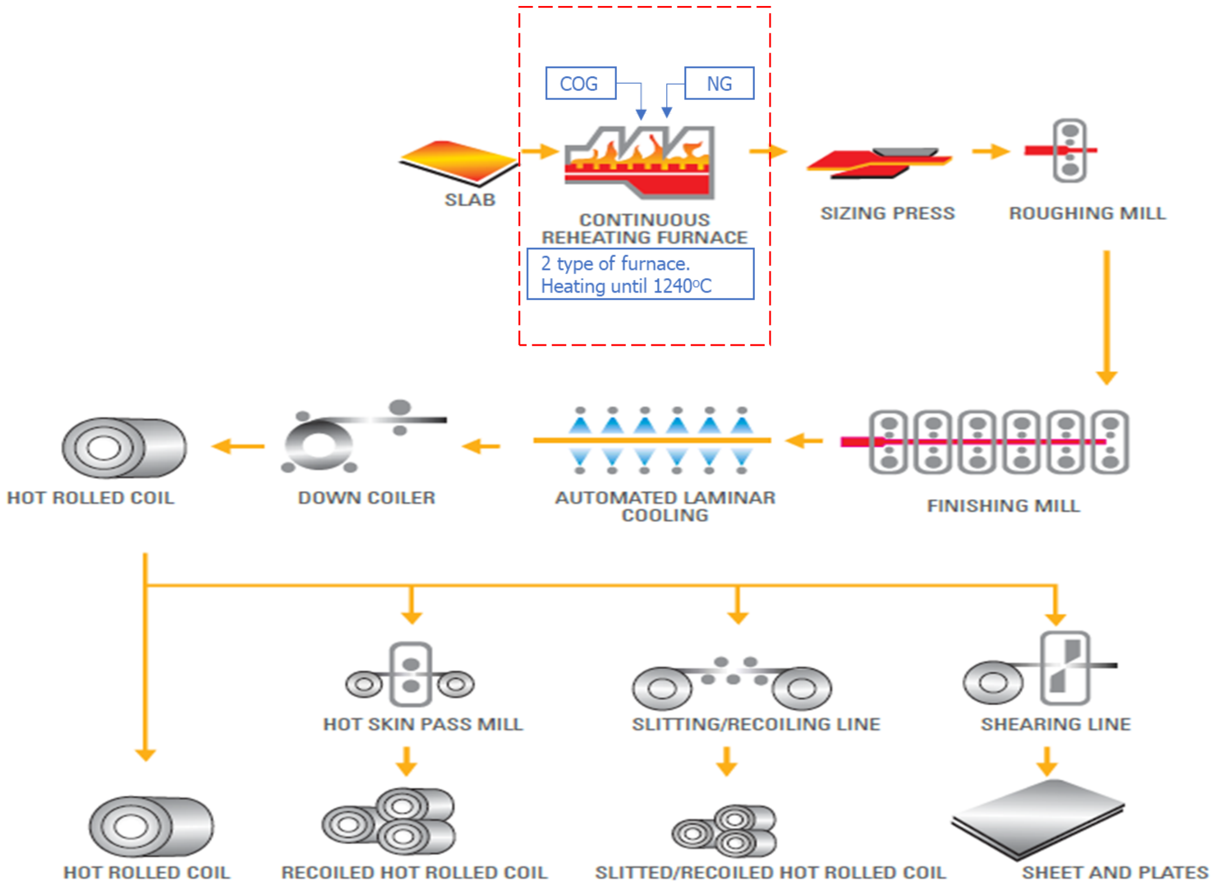

Figure 1.4 Hot Strip Mill Process

HSM produces thin sheet steel into coil, plate, and sheet. The process begins with heating the slab to a temperature of ± 1250°C using a Reheating Furnace and then hot rolling at the Roughing Mill.

C. Control System

The control system in the RhF HSM is like the steel heating process in general, which uses a pusher type.

C.1 Combustion Process and Reactions

Combustion has various definitions, but in general, it can be defined as a chemical reaction process between a fuel and an oxidizing agent, releasing energy in the form of heat as output. The rate of combustion is the rate of oxidation because it requires oxygen in the reaction. Fuel can be defined as any substance that releases heat when oxidized and generally contains the elements Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), and Sulfur (S). While the oxidizing agent is any substance that contains oxygen, for example, air, which will react with the fuel.

In the combustion process, the phenomena that occur include the interaction of chemical and physical processes, such as the release of heat from the energy of chemical bonds, the process of heat and mass transfer, and fluid movements inside.

The combustion process occurs if there are factors that cause it, namely: 1. fuel, 2. oxygen, and 3. chemical reactions. This process follows the stoichiometric equation combustion of CxHy (hydrocarbons) below:

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 + 3,76\left(x + \frac{y}{4}\right)N_2 \rightarrow xCO_2 + \frac{y}{2}H_2O + 3,76\left(x + \frac{y}{4}\right)N_2$$

The value of oxygen content in the air is 21%, and nitrogen is 79%, so the number 0.376 is obtained in the above equation, which compares oxygen levels to nitrogen levels in the air. The levels of other substances are ignored because the percentage is less than one percent in the air. Equality This is an equation simplified with various neglect because it is very difficult to obtain an exact equivalent ratio of air, one place to place differs from the ratio of the equivalent air mixture. In incomplete combustion, it will not produce CO_2 and H_2O, but CO_2 is formed, which can damage the body and other hydrocarbons such as formaldehyde.

C.2 Air Fuel Ratio (AFR)

This method is the most frequently used method in defining a mixture and is the ratio between the mass of air and fuel from the point of view. Symbolically, AFR is calculated as:

$$AFR = \frac{m_a}{m_f}$$

Where:

AFR : The ratio of air to fuel in the stoichiometric state
Ma : Number of Moles of Air
Mf :Number of Moles of Fuel

III. PROCESS DESCRIPTION

The data used from table 1 to compare existing conditions are existing data (max) which can be compared with table 2 in high-rate furnace conditions because it has comparable heat liberation values.

Table 1. Comparison of NG Fuel In Each Zone

Zone		Zone No	No. Of Burner	Design flowrate (Nm^3/h)	Max existing (Nm^3/h)	Heat Liberation (kcal/h)
Preheating	Top	1	10	3,858	2,315	20,138,760
	Bottom	2	8	4,585	2,751	23,933,700
Heating	Top	3	10	3,141	1,885	16,396,020
	Bottom	4	10	4,188	2,513	21,861,360
Soaking	Top	5	5	617	370	3,220,740
	Bottom	6	5	617	370	3,220,740
	Top	7	3	727	436	3,794,940
	Bottom	8	3	727	436	3,794,940
Soaking Discharge	Top Bottom	9	2	285	291	2,531,700
Total				18,745	11,367	98,892,900

If the design uses COG 3,000 Nm3/h, the total natural gas consumption in each zone will be reduced.

Table 2. Comparison of NG Fuel and NG-COG Mixture On Each Zone

Zone	Desain Flowrate Burner	Existing Flowrate NG (Max)	Project Design(COG+NG) (Nm^3/h)	
	(Nm^3/h)	(Nm^3/h)	COG	NG
1	4000	2315	3000	935
2	4000	2751	3000	1372
3	4000	1885	3000	505
4	4000	2513	3000	1133
5	620	370	-	370
6	620	370	-	370
7	720	436	-	436
8	720	436	-	436
9	500	291	-	291
TOTAL	**18.945**	**11.367**	12.000	5.849,8

Savings from decreasing natural gas consumption in zones 1, 2, 3, and 4 are 5,517 Nm^3/h or 3,177,907 Nm^3/month assuming the Gas price is 6 USD/MMBtu, Effective working days 24 days, total saving is 114.288 MMBtu/month or 9.6 Billion IDR/month.

Since December 2019, trials have been conducted to mix natural gas with COG using existing burner facilities. The use of burners without replacing existing facilities is based on the tip hole of a natural gas burner that can still accommodate COG based on the calorific value. The gas mixing design is only implemented in 4 zones out of 9, due to the availability of the remaining COG. The following is a figure of COG utilization desain concept:

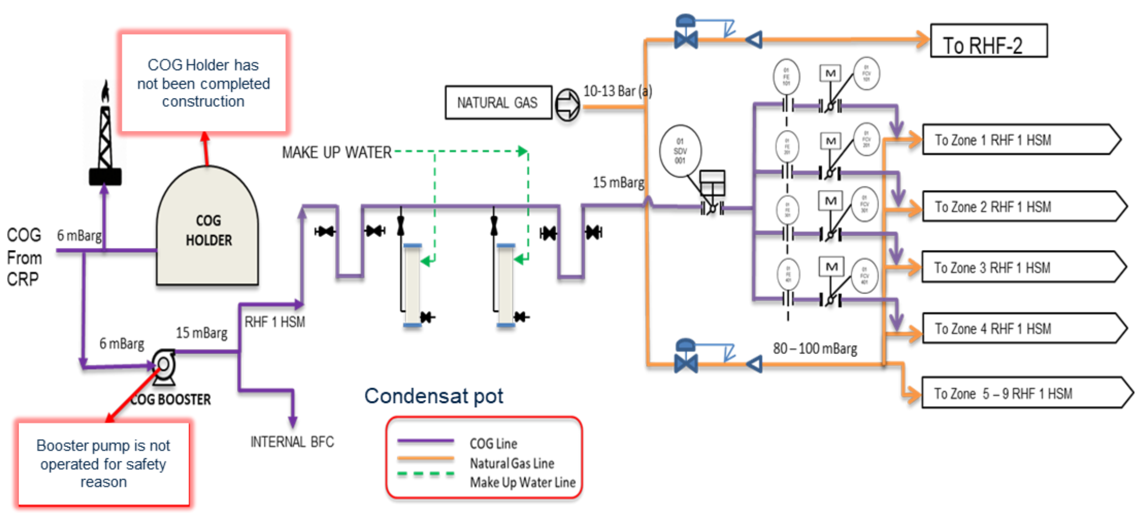

Figure 1.5 COG Utilization Design Concept

In addition to new COG pipes, DP orifice flowmeters, control valves, and manual valves are also installed on each line. Shut-off valve is only installed in the COG supply pipe header. Condensate pots are also installed along the COG gas path, this is to prevent the liquid fraction carried by the gas, which can interfere with the combustion process. Preventive maintenance is carried out every shift to ensure the level of condensate water until it overflows.

The slab output temperature and the exit gas temperature in the Reheating Furnace when using natural gas will be relatively lower than COG. However, the use of COG as a substitute for natural gas does not affect the quality of the process or product so that orders are maintained.

The latest data from January 2020 - March 2021 shows that COG utilization depends on the production process at COP, production stability can be seen from the number of pushes in a day, with an average of 45 pushes per day. The use of COG in HSM is not optimal due to an unstable supply. The minimum flow needed in Bleeding Tower is 1,500 Nm^3/h to maintain system safety to maintain positive pressure. In May - July 2020, and April - May 2021 HSM did not consume due to a shortage of raw materials.

If the average use of cog as a substitute for natural gas is 1,250,000 Nm^3/month or 32% of the natural gas consumption at the time of operation in 2016/2017. In 2020 the decrease in natural gas from the use of COG by 11.890×10^6 Nm^3 or equivalent to 2.5×10^6 USD, and in 2021 by 310×10^3 Nm^3 or equivalent to 650×10^3 USD. The total savings from the initiation of COG utilization from 2020 - 2021 was recorded at **3.15×10^6 USD.** Assuming the price of natural gas is 6 USD/MMBtu government subsidies.

One of the exciting and distinctive things related to the utilization of COG to RhF in KS is the use of a dual-mode control system, namely full Natural Gas fuel mode and mixing NG with COG. In addition to modifying the control system, it also adds new pipelines and the installation of field instruments. The gas mixing process in zones 1-4 is carried out in the pipeline before entering the furnace.

It can be seen in the following figure 1.5 that the process of mixing COG and NG in RhF in zones 1, 2, 3 & 4. The existing natural gas line is added with a new pipeline for cog with a pipe header diameter of 10 inches, the percentage of the mixture of cog with natural gas has been simulated by an LAPI ITB consultant, because the gas mixing process is carried out in the pipe, the results of gas mixing are homogeneous, and some are less homogeneous, but this has less effect on the temperature of the combustion results.

The dual-mode control system makes it easy to operate, where when COG is available to substitute natural gas, the mixing mode can be selected by the operator in the Slab heating process, but if COG is not available, it can return to full natural gas mode.

The working system of the burner control in the Reheating Furnace is based on the set point temperature achieved at the HMI by the operator. From the input target the temperature will be changed by the algorithm system in the PLC into the required amount of heat in the form of the COG flow value. Then the amount of natural gas flow that enters will adjust based on the heat liberation in each zone. The amount of combat air supply will adjust the Air Fuel Ratio (stoichiometry theory) of each gas. Each zone is installed with a flowmeter for COG, NG, and combustion air. The following is a flowchart of the temperature control system process:

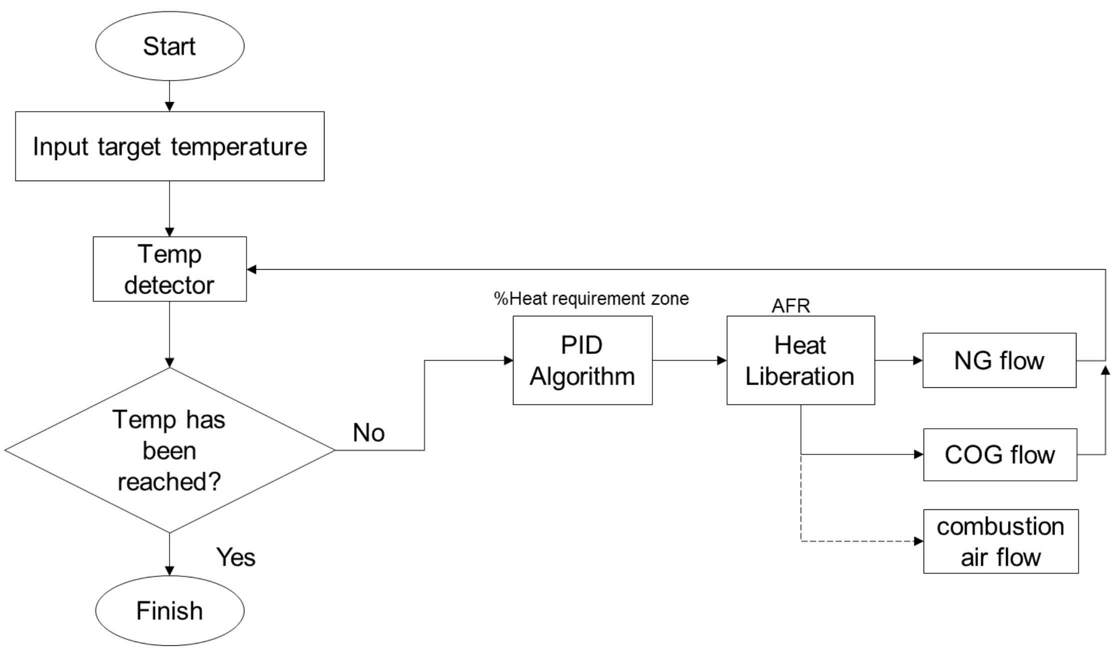

Figure 1.6 Flowchart of the Temperature Control System Process

A. Efforts in Optimizing COG

In the short term, the efforts that have been carried out and scheduled are to carry out preventive maintenance on the condensate pots along the COG pipeline from General Facility BFC to Furnace HSM. Checks are carried out on each shift by looking at the water level where the pot overflow occurs. This function is so that during COG usage, there are no issues related to water condensation or impurities carried by gas.

In the medium term, KS's efforts in optimizing the remaining COG to RhF HSM are by upgrading the burner and pipe capacities in zones 1 and 2, from 3,000 Nm^3/h to 3,500 Nm^3/h, so that COG uptake into HSM can be even more than now, namely of 7,000 Nm^3/h.

Then in the long term, after KS's efforts to build the infrastructure of a Gas Holder facility with a capacity of 50,000 m^3 and a Booster Pump to increase the pressure to 12-15 kPa, it will modify the burner with a full COG or full natural gas design, where changes to pipes and supporting equipment are also adjusted. With the design of each burner has a capacity of 6,000 Nm^3/h, so the COG utilization target can be reached at 12,000 Nm^3/h or fully utilized.

IV CONCLUSION

From the initiative to utilize excess COG as a substitute for NG fuel at RhF HSM Krakatau Steel, with the operation of the combustion system automatically, the following results were obtained:

1. Energy cost reduction using natural gas substitution achieved savings of 32% or 3.15 Million USD.
2. HSM Productivity remains optimal, the use of COG and automation can optimize energy efficiency to run HSM factory production.
3. Yield is achieved, orders are maintained, used COG as a natural gas substitute does not affect the quality of the process or product.
4. H_2 content of more than 50% makes COG more environmentally friendly, an initiative to reduce emissions from COG consumption in RhF HSM by 32,550 kTon/year.

5. Utilization of excess COG can be implemented into the Reheating Furnace by mixing gas mode, but it will be more optimal if a Gas Holder is built and a burner replacement.

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