GAS FLOW IMPROVEMENT IN A PELLETIZING PLANT [1]

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Abstract

Vale, the largest diversified mining company of the Americas, has decided to build a new pelletizing plant, next to the iron ore beneficiation plant at Vargem Grande, in Nova Lima – MG – Brazil. The plant was designed to produce 7.0 Mt/y of pellets with expected start-up in 2008. This paper shows the gas flow distribution rearrangement done during the design phase of the project. The gas flow pattern suggested in the conceptual study for that plant was quite similar to other plants. However, because of demand for more productivity and due to higher altitude than other plants located at sea level, the calculated volumetric flows for the furnace process fans have become quite large. It was decided then to divide the cooling air flow into three fans and to reuse the last part of the heated cooling air in the beginning of the first cooling zone. Due to recuperation air temperature increase, it is expected that fuel consumption can be reduced by 20%. In addition, due to updraft drying temperature increase, it is expected that productivity can be increased by 5% to 8%, depending on the quality and availability of the iron ore supplied to the plant.

Key words: Pelletizing; Gas flow; Energy savings.

MELHORIA DE FLUXO DE GASES DE USINA DE PELOTIZAÇÃO

Resumo

A Vale, maior empresa mineradora diversificada das Américas, decidiu construir uma nova usina de pelotização de minério de ferro junto à instalação de tratamento de minérios denominada Vargem Grande, no município de Nova Lima – MG. A usina de pelotização foi projetada para produzir 7,0 Mt/a de pelotas, com previsão de início de operação em 2008. Este trabalho mostra a redistribuição do fluxo de gases do forno de pelotização realizada durante o projeto. O fluxo de gases previsto no estudo conceitual dessa usina era semelhante ao de outras usinas. Contudo, com uma maior produtividade exigida e uma maior altitude que outras plantas localizadas ao nível do mar, as vazões volumétricas calculadas tornaram-se bem maiores. Decidiu-se então dividir o fluxo de ar do resfriamento por três ventiladores e reaproveitar a última parte já aquecida do ar de resfriamento no início do resfriamento. Em função do aquecimento do ar de recuperação, espera-se que o consumo de combustível possa ser reduzido em até 20%. Em função do aumento de temperatura do ar de secagem ascendente, espera-se um aumento de produtividade do forno entre 5% e 8%, dependendo da disponibilidade e da qualidade do minério fornecido à planta.

Palavras-chave: Pelotização; Fluxo de gases; Economia de energia.

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1 INTRODUCTION

Vale is the second-largest metals and mining company in the world and the largest in the Americas, based on market capitalization, and is also the world's largest producer of iron ore and iron ore pellets.[1] After an internal location study, Vale has decided to build a new pelletizing plant next to the iron ore beneficiation plant at Vargem Grande in the city of Nova Lima, Minas Gerais State – MG – Brazil.
In general, for a pelletizing plant, the bulk of the operational costs and capital expenditure are concentrated in the furnace and ancillary equipment. Any modification after the erection of a plant demands significant investment and time, causing production and earnings losses. For that reason, it's very important to dedicate attention to the furnace and peripherals equipment design in order to have the best possible configuration, in terms of high productivity and energy savings.
The gas flow pattern suggested in the conceptual study for the Vargem Grande Pelletizing Plant (VGP) was quite similar to other plants. However, having higher productivity demand and higher altitude than other plants located at sea level, the calculated volumetric flows for the furnace fans have become quite large. Thus, this plant has the largest furnace in the world in terms of steel structure and refractory, although its reaction area is the same of some other plants (768m²).
After the conceptual study of VGP, when the heat and mass balance was thoroughly analyzed, it was verified that a considerable part of the heat recovered in the cooling zone was supposed to be lost as excess gas, bypassing the updraft drying zone. Another problem that arose was that the required cooling air fan had become quite large. It was decided then to divide the cooling zone into three; each one assisted by one process fan. It was also decided to recycle the recuperated hot air of the last and third cooling zone to the beginning of the first cooling zone.
This paper presents some aspects of the Vargem Grande Pelletizing Plant taking into consideration the whole process flow sheet, equipment and, specially, the new gas flow pattern of the indurating machine.

2 MATERIALS AND METHODS

2.1 Project Premises

The new pelletizing plant is part of a project comprehending mining, concentration, pelletizing and infrastructure measures. The pelletizing plant is a green field installation close to the existing concentrator Vargem Grande. The budget for the pelletizing plant, including engineering and erection, is 461.5 million dollars.
The layout considers the possible future installation of a second plant. Viable synergies were considered and potential conflicts were eliminated. Any of the two indicated plants could be installed first. The arrangement of the individual areas is shown on a simplified plot plan, in Figure 1.

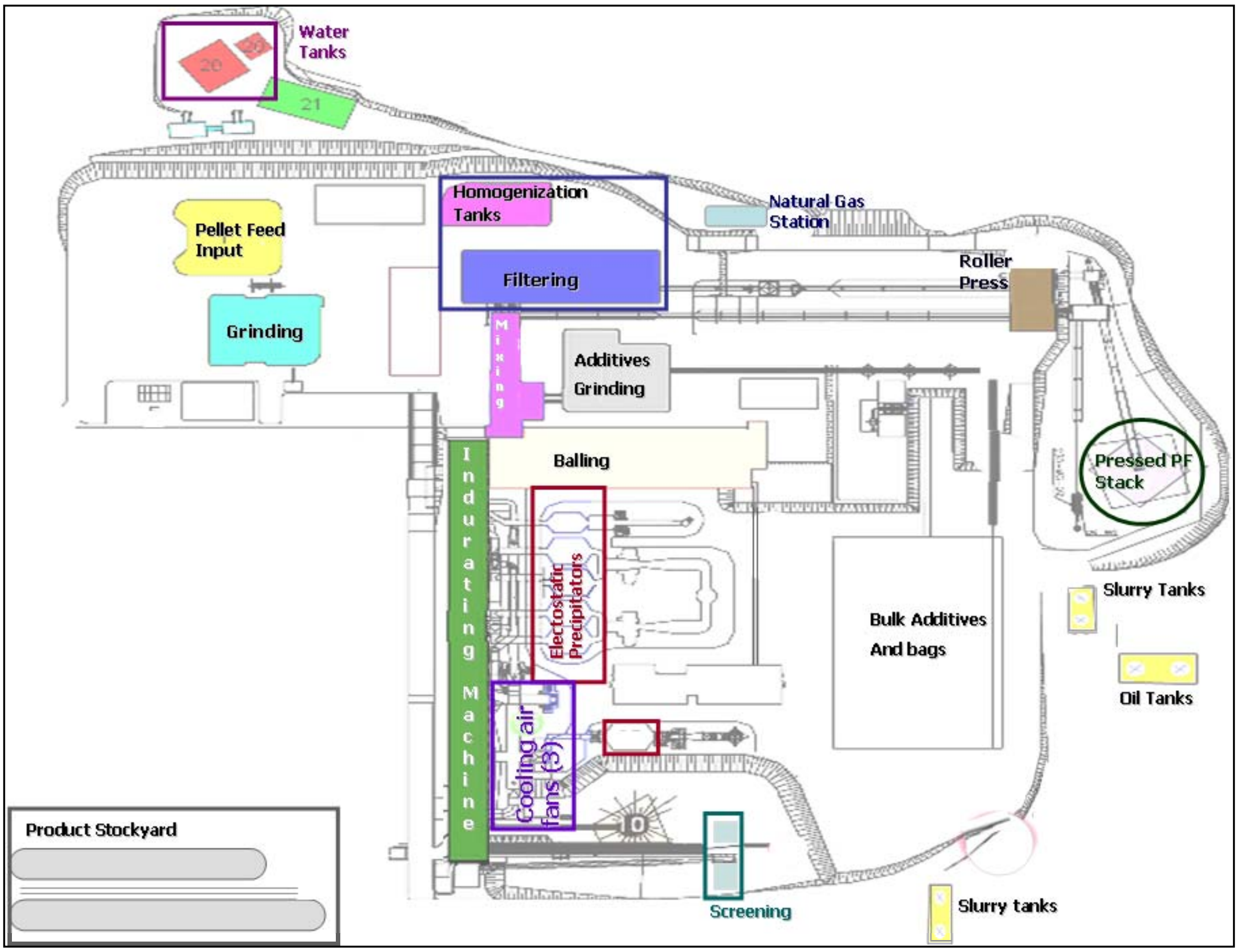

Figure 1 - Pelletizing plant lay out

The equipment was designed with a safety factor of 20%, with few exceptions. The proposed design fulfils the demand on productivity, product quality, safety, health and environmental aspects for operation. It reflects the state of the art of pelletizing technology.
The product stockyard is connected to the existing product stockyard of Vargem Grande. The entire plant is located at a slope beside the existing Vargem Grande concentrator. The flow of material through grinding, filtration, induration, screening and storing follows the natural gradient. The area below the discharge end of the indurating machine is used for product screening, which allows for a compact plant arrangement. All downhill discharge from the plant is easy to collect in the existing tailings pond.
Automatic process control has been considered in the process areas. Modern plant design and automatic control elements help to improve the plant availability and to decrease the specific production costs.

2.2 Process Description

The ore concentrate is supplied to the plant as slurry. Two iron ore concentrates sources are considered, Pico and Vargem Grande. The plant can produce the required product quality with each concentrate individually or both concentrates in mixture, although individually, no one is enough to achieve the target production.

A brief description of the pelletizing process can be seen in Figure 2 that shows the flow diagram of the Vargem Grande Pelletizing Plant. The iron ore slurry passes through the following areas to become fired pellets

i. Tanking – 6 slurry tanks, 3150 m^3 each.
ii. Grinding – 2 ball mills, open circuit, 6,1 x 14m, 9MW each.
iii. Filtration – 12 disc filters – 120 m^2 filtering area each.
iv. Roller Press Comminution – 1 roller press, 2000mm diameter x 1500mm width.
v. Mixing – 2 horizontal drum mixers, 20 m^3 each.
vi. Green Pelletizing – 11 balling discs, 7.5m diameter, each.
vii. Induration – 768 m^2 grate area (4x192m), 32 wind-boxes.
viii. Product Screening – 3 screens (1 stand-by).

Also the following areas and systems are required in order to make fired pellets:
ix. Additives grinding and transport (1 roller mill; 1 ball mill).
x. Thickening.
xi. Pond.
xii. Utility system for water (Cooling-, Gland-, Process Water).
xiii. Utility system for air (Compressed-, Instrument Air).
xiv. Utility system for fuel (Oil and natural gas supply).
xv. Utility system for coating.

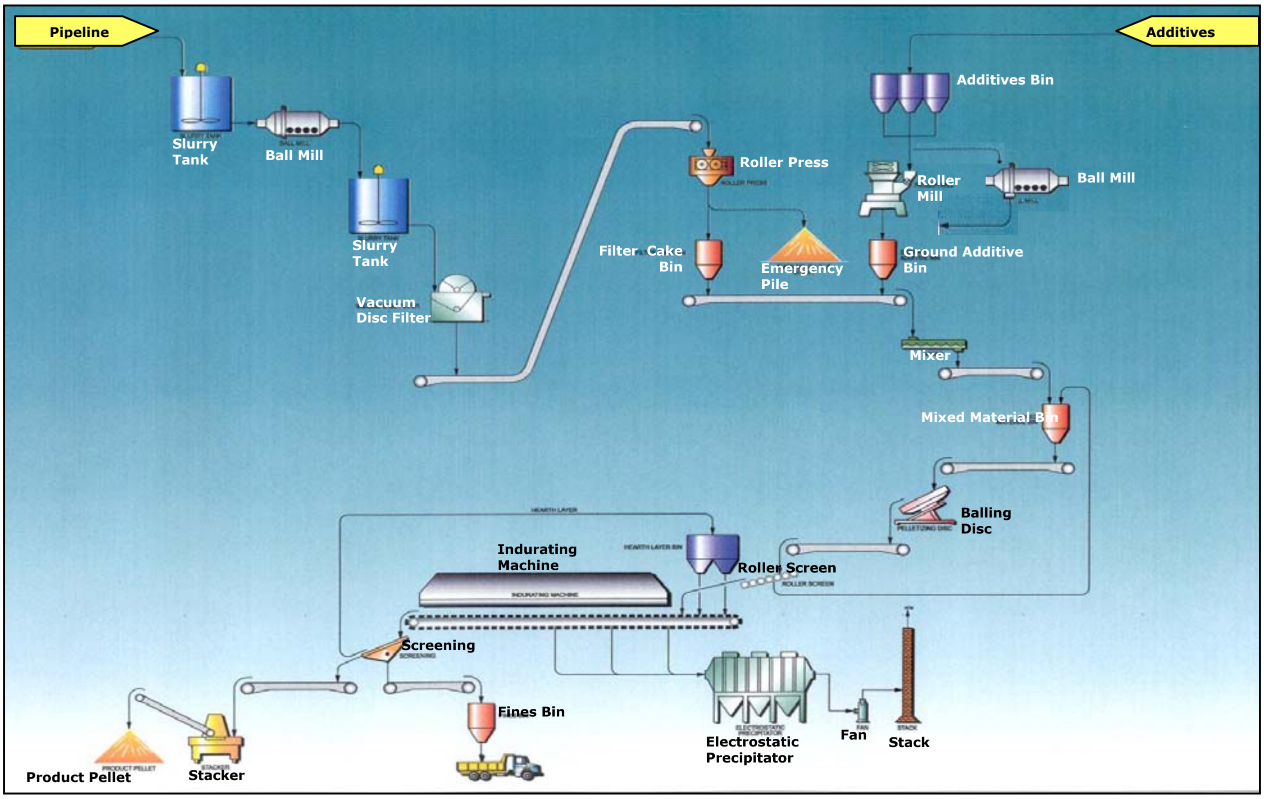

Figure 2 - Pelletizing plant simplified flow diagram

2.3 Process Description – Furnace Area

The traveling grate machine on which the green pellets will be heat treated, indurated and cooled has a reaction area of 768 m² (4 m wide and 192 m long). This traveling grate consists of an endless chain of pallets, which continuously travel. One of the process pre-requisites for obtaining a uniform product quality is a uniform bed height. This is ensured by automatic control of the traveling grate speed as a function of the ultrasonic level measuring devices installed after green pellets are charged to the traveling grate.

The following text is a brief description of the process gas flow distribution of VGP, as it was first conceived according to the principle of Lurgi-Dravo traveling grate induration system.[2] Figure 3 illustrates qualitatively the typical temperature profile over the length of the indurating machine and Figure 4 illustrates this description.

Intake and circulation of the air and gas required for the process is ensured by the application of various fans. The induration process is characterized by the recovery of maximum heat from cooling of the hot pellets by applying the direct recuperation principle, which means transportation of recovered hot air from the first cooling zone to the preheating and firing zone without a fan. The cooling air fan VP-05 sucks in ambient air through a silencer and blows it through an air duct into the wind-boxes of cooling zones 1 and 2.

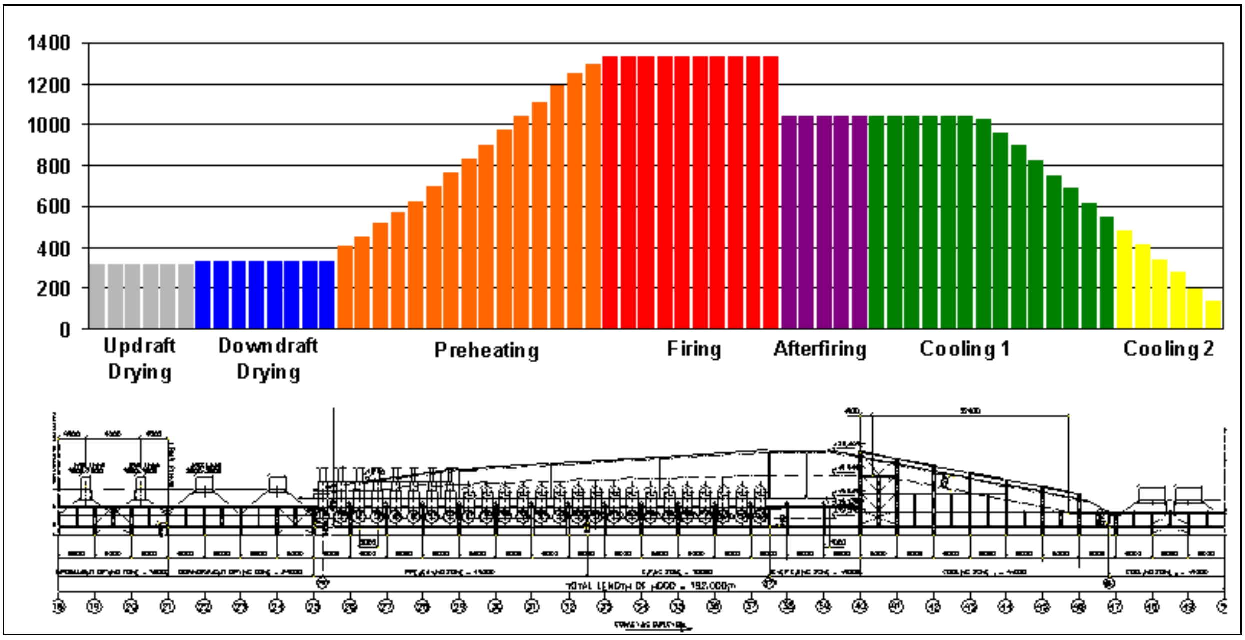

Figure 3 - Typical temperature profile over the length of the indurating machine

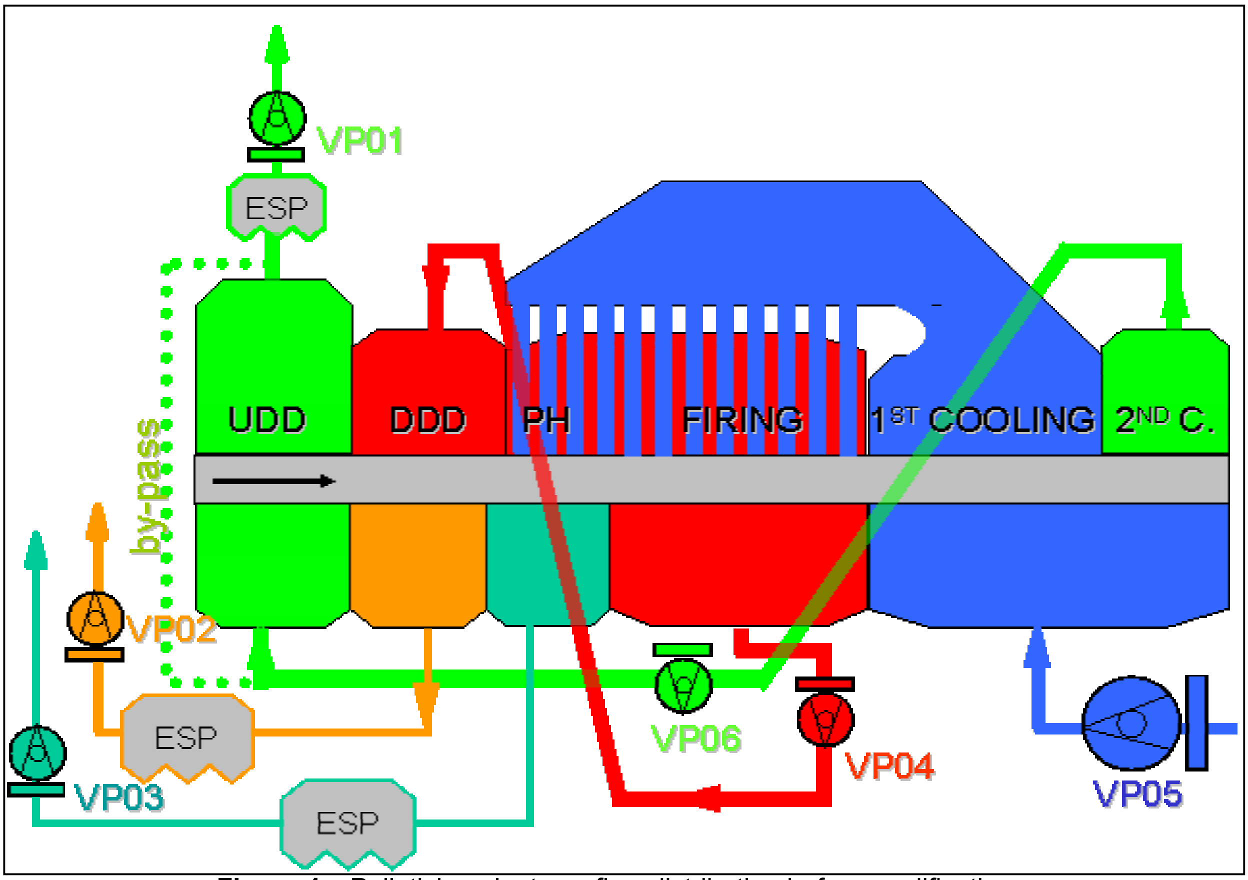

Figure 4 – Pelletizing plant gas flow distribution before modification

The cooling air, which is heated after passing through the hot pellets in the pellet bed, is collected in the first and second cooling hood. These hoods are installed directly above the traveling grate. The heated air streams recuperated are recycled to the process as a "heat carrier".
Hot air collected in the second cooling hood and hot process gas from the wind-box recuperation system is extracted by the updraft drying fan VP06 and forced into the wind-boxes of the updraft drying zone. Wind-box pressure in the updraft drying zone is automatically controlled by a damper, which leads excess air to the hood exhaust gas system through an electrostatic precipitator by process fan VP01 to a stack and then to the atmosphere.
The hot gases recuperated from the downdraft drying, pre-heating and firing zones are sucked in through the pellet bed and then through electrostatic precipitators by fans VP02 and VP03. The function of these electrostatic precipitators is to clean the gases before finally exhaust to a common stack and then to the atmosphere.
The hot combustion gases from the last section of the firing and the after-firing zone are recycled as drying gases in the downdraft drying zone. They are sucked through the pellet bed by the wind-box recuperation fan VP04 and then forced via gas ducts into the hood above the downdraft drying zone.
An appropriate temperature profile in the preheating zone is essential for the production of high quality oxide pellets. At the same time, an adequate control strategy for all the fans is critical to have a stable operation and low energy consumption.[3-5]
The temperature profile can be adjusted easily by mixing controlled flow of second cooling air/wind-box recuperation air, supplied by fan VP04, to the down-comers

above wind-boxes 8 to 11. A by-pass between the wind-box recuperation and the updraft drying system allows the passing of heat from the one to the other route.
The hood exhaust fan VP01 sucks off the humid exhaust air from the updraft drying hood. Hot excess gas from the recuperation fan is added in order to raise the temperature of this air and to control the pressure in the downdraft hood. The exhaust gas is cleaned in an electrostatic precipitator and conveyed to the atmosphere via a stack.
Hot combustion gases enter the firing zone by the direct recuperation principle. Burners are arranged opposite to each other on the longitudinal sides of the preheating and firing zone. Arrangement and sizing of the burners and process fans ensure a uniform hot gas passing through the width of the pellet bed.
Since the burners are individually controlled, a different temperature profile can be adjusted in each side of the machine thus permitting an optimum heat treatment of the pellets. There are two burning systems designed and installed in the plant, one to burn heavy fuel oil and other to operate with natural gas. These systems can operate alternatively, turning out the plant with high and strategic flexibility in terms of fuel consumption. The temperatures in the individual control zones of the preheating and firing zone are measured with thermocouples and indicated by the central control system; they serve as control variables for the automatic fuel flow control to the burners.

2.4 Gas Flow Pattern Rearrangement

Since the middle of the last century, many pelletizing plants have been designed with some different configurations of the gas flow [6]. After the Seventies, few modifications in the well established way of pelletizing have been made. The Vargem Grande Pelletizing Plant would not be different in its conceptual study and so it was conceived, as a copy of another Vale's Pelletizing Plant, located in São Luís – MA – Brazil. However, after the conceptual study of VGP, when the heat and mass balance was thoroughly analyzed, it was verified that the energy efficiency of the furnace could be improved by some changes, mainly in the cooling zone.
The first reason to rearrange the gas flow distribution was the motivation to reduce the cold air flow forced into firing zone through the down-comers. With more than one fan, it should be possible to use the first one to supply the required mass of air to the combustion chambers and heat transfer to achieve required temperatures at the pellet bed, while using the second one to improve the pellets cooling. With only one fan it is not possible to have the best operational control of the fired pellets cooling and, at the same time, the optimization of necessary air to transfer heat to the pellet bed at the firing zone. For instance, if the process conditions require increasing the pellets cooling, at the same time it is necessary to inject more cool air in the firing zone. Conversely, if the process conditions require reducing the flow inside the furnace in order to optimize fuel consumption, it is necessary to reduce the total cooling air flow and because of that, pellets temperature at cooling zone increases.
The second reason to improve the gas flow distribution was the excess of air coming from the second cooling zone bypassing the updraft drying zone to the exhaust system. Reducing that hot recycled air flow would reduce thermal energy losses. A third fan was proposed then to complete the cooling of fired pellets and instead of exhaust it to the atmosphere, it was proposed recycle it to the beginning of the first cooling zone as a hot cooling. With this third fan it is possible to better control the

pellet discharge temperature since this air flow becomes independent from the firing and drying process.
After several discussions, in order to mitigate risks of such a big modification, it was decided to provide the furnace with valves that permit a furnace operation in any way between the new and the old gas flow configuration.
As a mining company, Vale has long been concerned with the impact of its operations on the environment. The gas flow pattern rearrangement, together with the flexibility to use natural gas as fuel, also makes a significant contribution to fight against climate change. These benefits are in addition to the already known advantages of the use of pellets in the steelmaking chain [7]. As a company that produces many of the basic mineral commodities that are components of the products we enjoy in daily life, Vale made its core mission the transformation of minerals into prosperity and sustainable development.
Figure 5 presents the gas flow pattern after modifications. The benefits of the new gas flow distribution will be discussed in the next section (Results and Discussion).

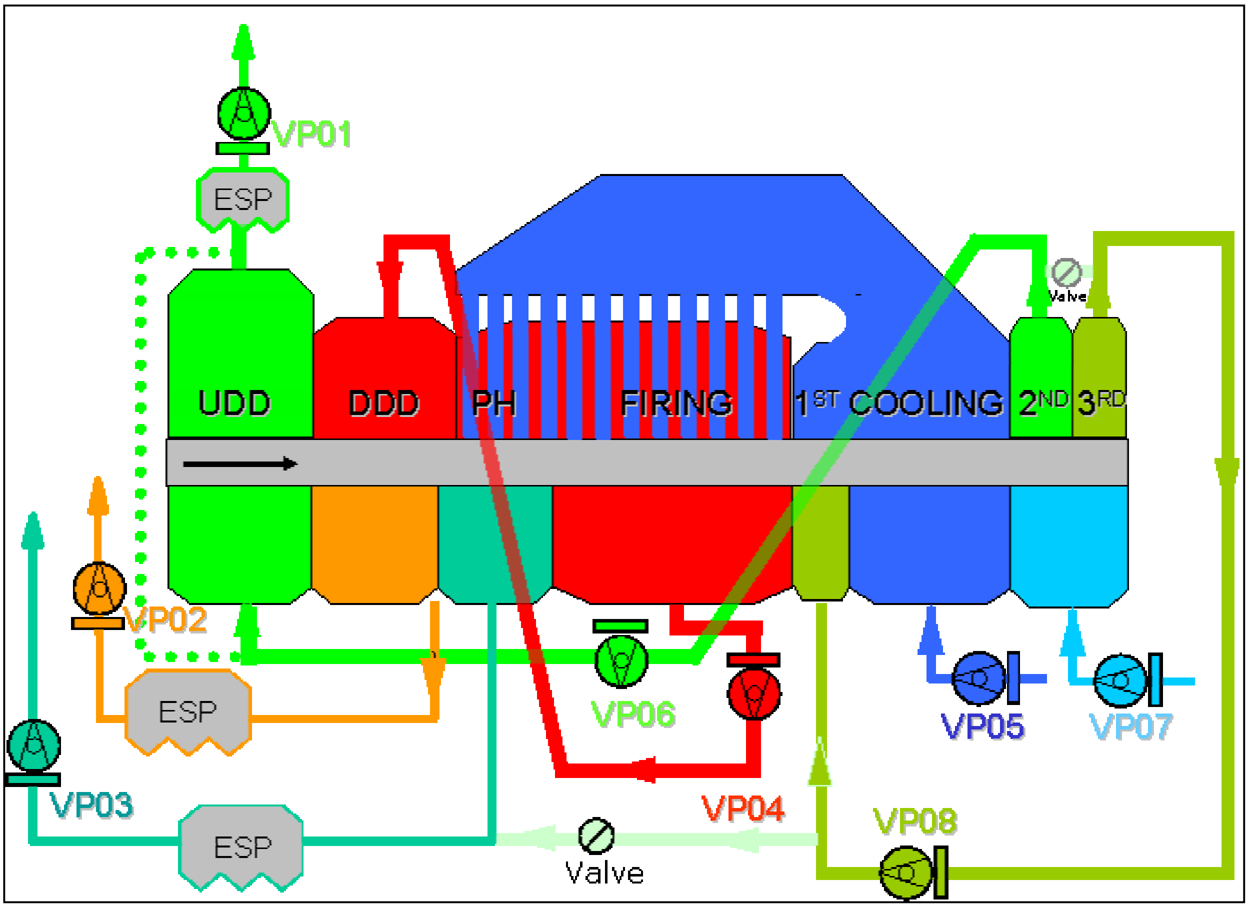

Figure 5 – Pelletizing plant gas flow distribution after modification

3 RESULTS AND DISCUSSION

Since the plant is not operational at the time of the submission of this paper, the presented results are derived from the heat and mass balance of the furnace after the modification and from data of a pot grate test.
With the updraft drying being made without the colder part of the flow from the cooling zone (last part), it was possible to estimate an increase in its temperature

from 340ºC to 420ºC, which is the maximum average gas temperature that the fans can handle. Part of the hot air coming from the colder section (third cooling zone) is now being used in the beginning of the first cooling zone instead of being wasted. Hence it is expected less gas volume in the stacks and less energy loss.
A test in laboratory showed that if the temperature of updraft drying is increased from 340ºC to 420ºC it is possible to reduce the drying time in 8%. This means that, if the duration of the other zones of the furnace can also be decreased keeping quality of fired pellets, the productivity of the furnace can be increased by the same 8%. After the modifications and some process considerations, it was assumed that the actual design of the machine and its zones would absorb the timing reduction and the plant nominal capacity was increased from 7.0 to 7.5 Mt/y depending on the quality and availability of iron ore supplied to the plant.
Using the heat and mass balance, it was possible to estimate the influence of the recuperation temperature in the fuel consumption, shown in Table 1. The expected fuel reduction consumption is the impressive number of 20%.
The negative impacts of the modification were the increase in the capital expenditure of about 7.5 million dollars and the increase in specific electric energy consumption, estimated in 2.1%, although far compensated by the benefits

Table 1 – Expected fuel consumption before and after modification.

Type of Gas Flow	Direct recuperation temperature (ºC)	Required heat in pre-heating + firing (Gcal/min)	Natural Gas Consumption ($Nm^3/t_{pellets}$)	Oil Consumption ($kg/t_{pellets}$)	Decrease (%)
Values before modification	887	2.14	17.7	16.2	-
Expected values after modification	950	1.71	14.1	12.9	20%
Possible values after modification	980	1.51	12.5	11.4	30%

One expected benefit, but not yet quantified, is the downdraft drying temperature increase. As the first cooling zone will receive hot air (230ºC, estimated) the common leakages between it and the last after-firing zone (short circuit) will be also hotter. Because of that, another expected, but not quantified benefit, is the thermal shock reduction, once the expected air temperature in the beginning of the cooling zone is higher than in the conventional process.
The new fans configuration makes the operation more stable and secure, once it makes possible to compensate thermal fluctuations by changing the speed of the third cooling air fan (VP08) alone, without disturbing the firing zone, as it would be if with only one cooling air fan available.

4 CONCLUSIONS

The rearrangement of the gas flow pattern has the following impacts:
- Increase in the plant productivity in about 8%.
- Reduction in oil consumption in about 20%.
- Increase in electric energy consumption in only 2.1%.

- Increase of the updraft drying air temperature from 340 to 420ºC.
- Increase of direct recuperation air temperature from 887 to 950ºC.
- Reduce the pellet thermal chock on the beginning of the cooling zone.
- Increase of downdraft drying gas temperature.
- Reduction of exhausting gas to the stacks – reduction of energy loss and carbon emission.
- Better control of fired pellet discharge temperature – improve operational security.
- Improvement and flexibility of indurating machine operational control.

As a global company, Vale seeks to expand the boundaries of sustainable development and find the right balance between the economic growth and the mandate to preserve our precious resources for future generations. The global dimensions of the climate change threat require all humankind to strive for new levels of innovation and cooperation.

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