DANIELI NEW POT GRATE TESTING FACILITIES: A CASE STUDY – AHMSA PELLET PLANT*

Luca Tommasi[1]
Selena Tiburzio[2]

Abstract

Danieli complemented its wide range of production plants for the iron and steel industry with a further step upstream into iron ore pelletizing and beneficiation. Danieli has engineered and constructed a state of the art and fully automated pilot plant facility – pot grate and sinter box – at Altos Hornos de Mexico S.A. (AHMSA) Pelletizing Plant, Monclova, Mexico. Installation and commissioning were completed in October 2009. Key features of the pot grate include the avoidance of the need for operator intervention during the test, automatic system preheat, absence of dead time, heat recuperation system with an air/air heat exchanger, oxygen control in pre-heating and firing with zirconia oxygen analyzer, possibility to test deep beds up to 625 mm. A series of projects have been accomplished by AHMSA availing of the pot grate facility with the aim to enhance pellet plant productivity and to reduce operating costs. The results obtained by use of Danieli pot grate combined with the experience and skill of plant operators has shown significant technical and economical benefits thus fully justifying the initial investment made by AHMSA and confirming the importance of having an in-house testing facility in order to optimize industrial plant operations.

Keywords: Pot grate; Productivity enhancement; Pelletizing plant.

---

[1] *Chemical Engineer, Director Process and Technology – Iron Ore Processing Dept., Danieli & C. S.p.A., Buttrio, Italy.*

[2] *Chemical Engineer, Process Engineer – Iron Ore Processing Dept., Danieli & C. S.p.A., Buttrio, Italy.*

** Technical contribution to the 45º Seminário de Redução de Minério de Ferro e Matérias-primas, to 16º Simpósio Brasileiro de Minério de Ferro and to 3º Simpósio Brasileiro de Aglomeração de Minério de Ferro, part of the ABM Week, August 17th-21st, 2015, Rio de Janeiro, RJ, Brazil.*

1 INTRODUCTION

The present work concern on the results obtained at AHMSA pellet plant using the Danieli pot grate testing facilities.

The pot grate is a pilot plant which allows firing the green pellets according to defined firing patterns, simulating the actual conditions that occur on the moving strand of a induration machine. The application is the evaluation of the effects of ores, additives and firing patterns on fired pellets properties and the design of new firing machines. For the straight grate pelletizing process, world-class plants operate at as much as 25% over the designer's name plate capacity [1]. The pot grate testing allows pushing even more the pelletizing plants towards the increase of productivity.

The managers of the plants are reluctant to implement radical changes as they can result in a risk on product quality or productivity of the plant and therefore optimization paths are not always explored. The pot grate pilot permits to carry out a research activity without affecting the production plant. The low capital cost of the pilot plant results indeed into a fast return on investment.

The main research activities of the pilot plant facilities can be summarized as follows:

- Optimization of the Pelletizing Process
- Possibility of testing different blends of raw materials
- Evaluation of additives (binders, fluxes and solid fuels)
- Determine the oxygen required for the most complete oxidation of magnetite to hematite [2]
- Increase productivity in the industrial plant
- Define the process conditions of the pellet plant configuration, minimizing the operating costs
- Validate the basis of design for new pellet plants or future expansion projects

One of the main interests is the possibility of testing new raw materials composition. This allows being independent from selected iron ore suppliers and being able to process lower quality and cheaper materials, without decreasing the product quality.

An additional saving can be the utilization of local additives of lower quality but more readily available and less costly.

Bentonite is the most common used binder in the agglomeration process. However, in some cases the fact that bentonite increases pellet silica and alumina content is not desired by iron ore producers/consumers. In this case, the behavior of organic binders (natural or synthetic polymers that have a low content of impurities) will be tested in pilot plant facility, identifying the optimum binder dosage which satisfies the pellet physical and mechanical properties. [3]

The below diagram (Figure 1) shows the pot grate testing facility philosophy. The test campaign starts with the objective of evaluating a new feed material composition (iron ore mixture or different additives) or some operating parameters of the induration machine. The fired pellet produced during the test will be then characterized in terms of chemical, physical and metallurgical parameters. The results can then be applied into the real plant.

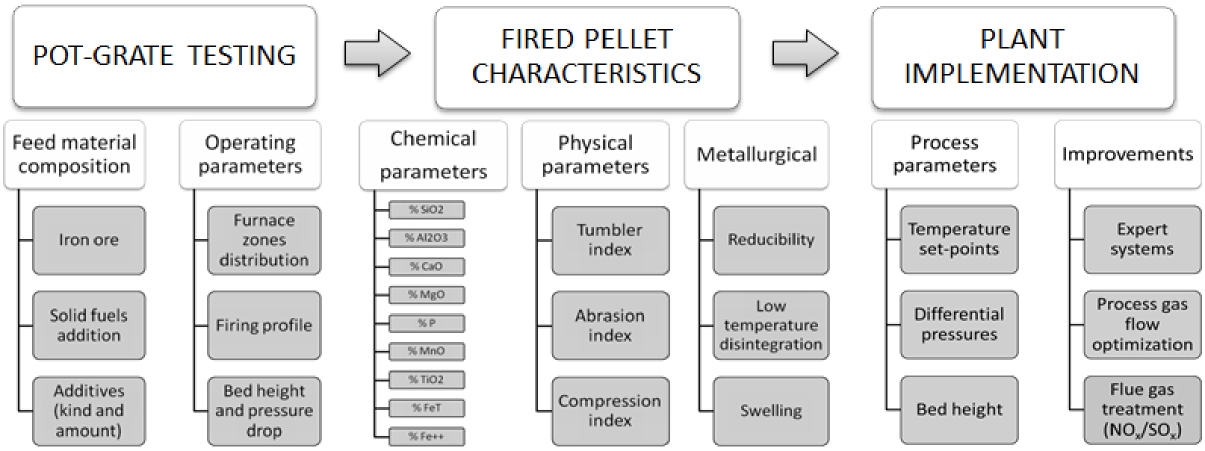

Figure 1 - Pot grate testing philosophy

AHMSA pellet plant, located in Monclova, Coahuila province - Mexico, has reached important results since the installation of the Danieli pot grate facilities in 2009. The pelletizing plant has been design for an installed capacity of 3 Mtpa of pellet product. It started its operation in 1984 for the agglomeration of hematite and magnetite fines coming from the concentrator plants of Hercules, Coahuila and La Perla. The pellet feed is received via slurry pipeline and filtered to 10.5% moisture approximately. The additives (dolomite, limestone and bentonite) are added just before the mixer. The agglomeration is made with six balling discs and screened onto a double deck roller screen before entering the induration machine with a reactive area of 464 m^2.
During 1996, the activities of technological suitability developed in to the increase of the capacity to 3.55 Mtpa. Plant productivity increased year by year from 19.83 ton/day/m^2 (design) to 29.2 ton/day/m^2 in 2012.

2 MATERIAL AND METHODS

Danieli pot grate is the core part of the pilot plant (footprint about 135 m^2) for the production of the fired pellets under controlled conditions, starting from iron ore concentrate.
The main component of the testing facilities is the pot-grate itself which consists of a refractory lined steel pot fitted with high temperature resistant grate bars, on which the percentage of free area is similar to that of the industrial scale plants. The pot has a cylindrical shape with an internal diameter of 357 mm and can be charged up to a height of 625 mm, allowing the production of more than 100 Kg of fired pellets. In this way side effects are reduced compared to small pot.
Hearth layer and green pellet are manually loaded in before the beginning of the test. A charge separator is placed on the top of the hearth layer to avoid mixing with the new product when emptying the pot after the test. The filled pot is then positioned between a windbox and firing hood by means of a trolley and held in position by a pneumatic jack to seal the pot to the combustion chamber and windbox. The pot section is placed into and removed from the rig and is jacked into position. The pot is not moved during the test, whilst the gases may pass up or down through the bed at a give pressure and temperature, in order to simulate the different sections of the induration machine (UDD, DDD, Pre-heating, Firing and After Firing, Cooling).

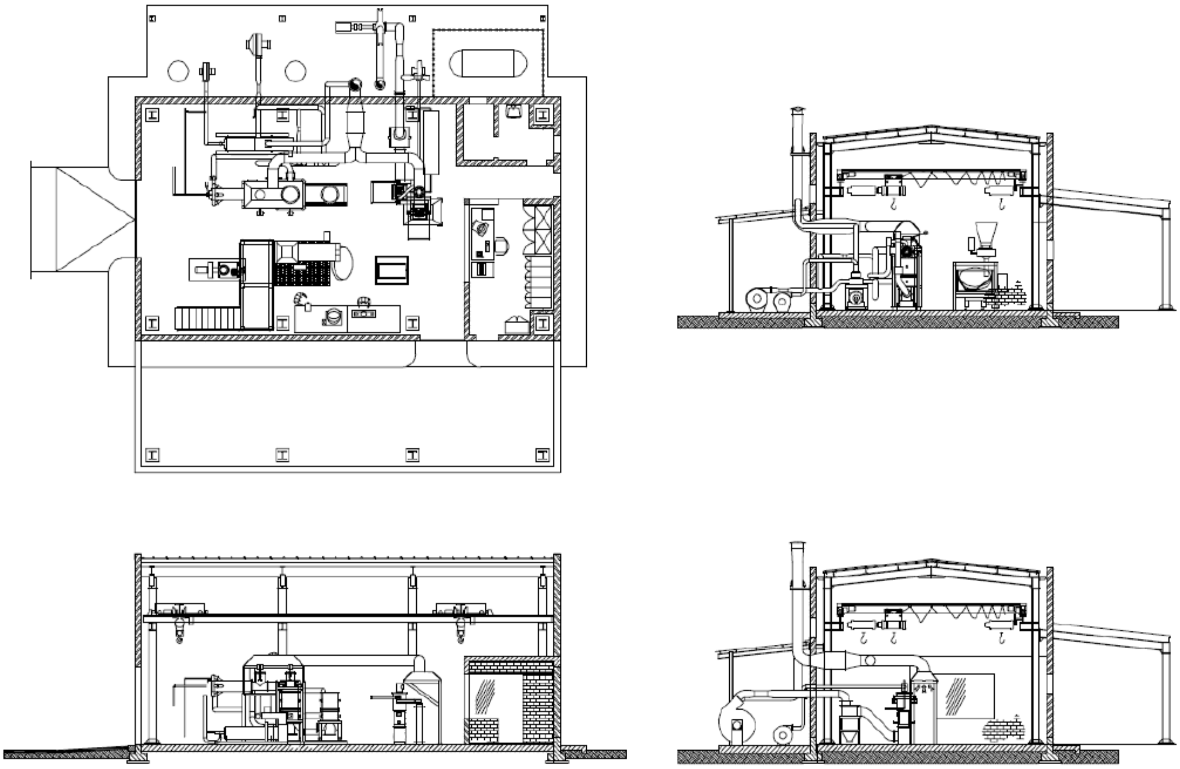

Figure 2 – Pot grate facilities layout (not including areas for chemical, physical and metallurgical tests)

Thermocouples are located in the ductwork and at various points inside the bed to record the temperature profile during the test and in the gas streams entering and leaving the bed. A suction system in the hood and windbox with an ejector enables a faster response of the thermocouples and ensures measurement of the temperature of the process gas itself without being influenced by any radiation effects.

In order to be heated up to reach a firing temperature up to 1300°C, the process air passes through an air/air heat exchanger and a primary combustion chamber. The secondary combustion chamber produces a hot flue gas in order to provide the necessary heat to the indirect heat exchanger, through which the process gas passes and is preheated up to 450°C. In this way the heat recuperation process typical of the cooling section of the straight grate is partially simulated. The temperature of the gas exiting the heat exchanger is raised up to the desired set-point value in the primary combustion chamber. During this stage, oxygen addition is performed in order to reproduce the same oxygen content as in the furnace during all the process phases and to ensure the complete combustion of the fuel inside the chamber. The oxygen analyzer is a sensible instrument in order to guarantee high accuracy even at 1300°C. Incorporated into the main combustion chamber there is a special high-temperature gate valve, able to isolate the chamber from the pot section. This valve consists of tailor made silica carbide trim moved by two pneumatic pistons capable to withstand very high firing temperature. The main combustion chamber is fitted with a stack cap to allow the burners to be fired to atmosphere and to preheat the surrounding refractory before beginning the test and to slowly cool down the refractory at the end of the heating phase. The hood above the pot is provided with a stack cap to allow exhausting of process gas during Up Draught Drying and Cooling phases. The cylinders of these stack caps are pneumatically operated, as well as the butterfly valves into the process ductwork. The refractory parts are made of castable alumina refractory.

The gases may flow up and down through the pellet bed at given pressure and temperatures, thus simulating the process gas flow conditions occurring on the industrial scale plant. This change in gas flow direction is made by opening and closing the appropriate valves (the pot is not moved during the test).

Danieli pot grate is a fully automated unit in which most of shut off and control valves are controlled directly by the PLC. The typical pot grate test sequence starts with the gas preheating, followed by the ignition of the main burner. The test pot, charged with hearth layer and green pellets, is then put into position. All the firing profile set points are entered by operators through the HMI and the PLC controls the process through each phase of the firing cycle.

The green pellets are produced from a mixture of iron ore, binder, fluxes and solid fuel in the preparation area, which consists of a horizontal high intensive mixer and a 0.9 m diameter balling disc having a fully adjustable angle, speed of rotation and spray water addition.

Inside AHMSA laboratory, DANIELI supplied also a sinter box test unit, with a dedicated sinter preparation area and physical properties testing facility.

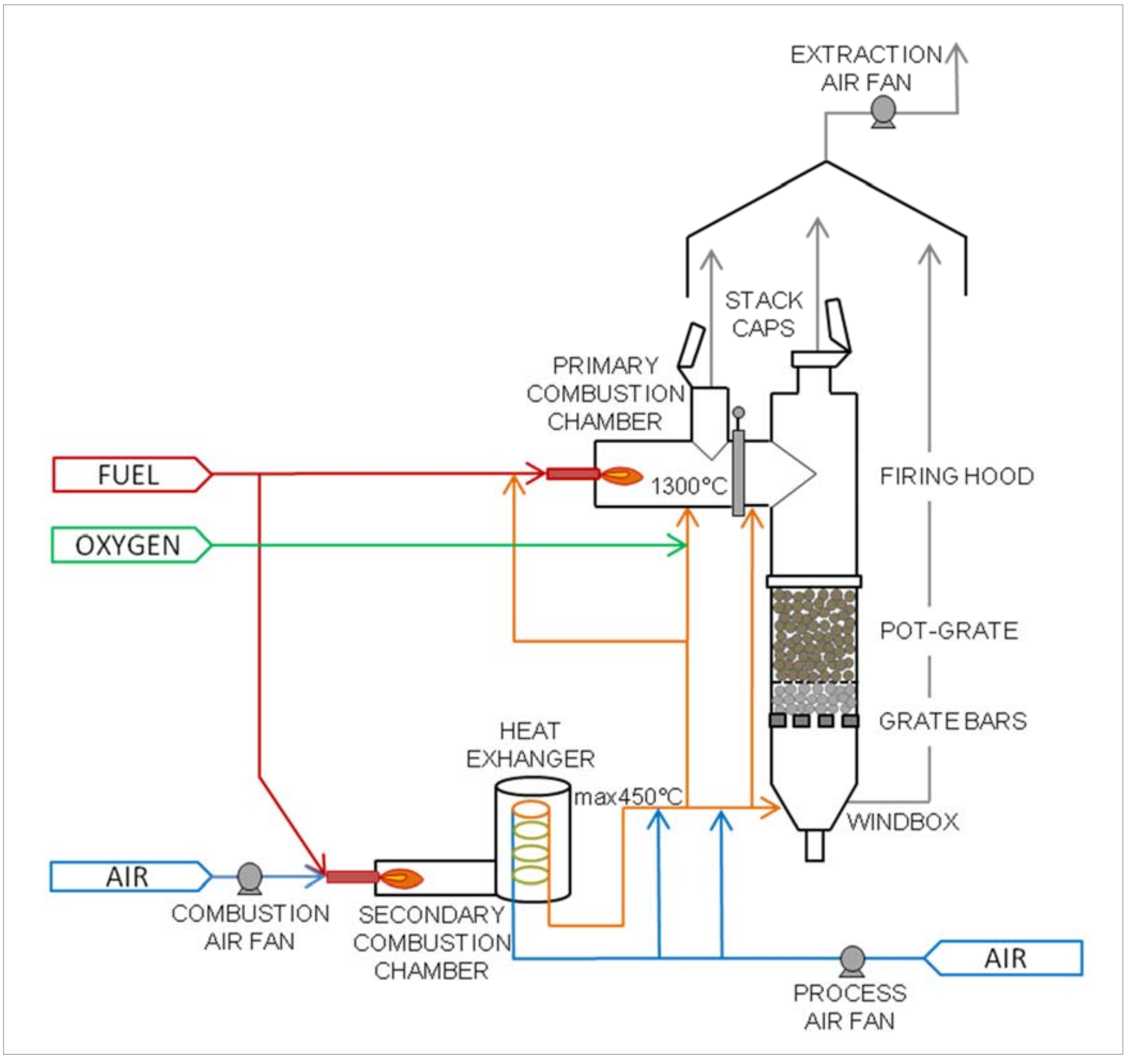

Figure 3 – Pot grate simplified process flow diagram

Figure 4 - AHMSA Pot Grate Installation

3 RESULTS AND DISCUSSION

This section presents the tests carried out and the obtained results; the results are presented divided in several sections.

3.1 Testing New Iron Ore Blends

A testing program has been carried out to find the proper process conditions in order to substitute high quality Brazilian iron ore with cheaper and lower quality ore. The table below (Table 1) shows the main results of the test campaign, in which the fired pellets obtained with a feed material composition containing 17% North American iron ore source and different additives has been evaluated in terms of chemical, physical and metallurgical properties.

Table 1 - Iron ore blend testwork data

Description	Unit	1910 PG	1510 PG	1610 PG	1710 PG	1810 PG	2010 PG
MINERAL SOURCE							
Hercules	%wt	77	77	77	77	77	77
Durango	%wt	6	6	6	6	6	6
Brazil	%wt	17	0	0	0	0	0
North America	%wt	0	17	17	17	17	17
ADDITIVES							
Dolomite	%wt	3.90	3.95	3.95	3.95	3.95	3.95
Hydrated lime	%wt	1.40	2.10	1.60	1.85	1.55	1.00
Bentonite	%wt	0.5	0.5	0	0.5	0.5	0.5
Coke breeze	%wt	0.82	0.82	0.82	1.20	0.86	0.89
GREEN PELLET							
Moisture [%]	%	9.25	9.50	9.50	9.85	9.00	9.50
Fixed Carbon [%]	%	0.70	0.70	0.70	1.02	0.73	0.76
Wet compression strength	Kg/pellet	2.03	2.40	2.07	2.09	2.05	1.82
Dry compression strength	Kg/pellet	4.69	4.40	4.28	4.18	4.28	4.36
Drop number	-	10	6	6	12	6	7
FIRED PELLET							
Chemical composition							
SiO_2	%wt	2.95	3.67	3.58	3.82	3.79	3.89
Al_2O_3	%wt	0.74	0.67	0.74	0.74	0.69	0.82
CaO	%wt	3.70	4.27	3.89	4.20	4.10	3.69
MgO	%wt	1.10	1.06	1.10	1.05	1.10	1.10
P	%wt	0.119	0.118	0.115	0.123	0.121	0.129
MnO	%wt	0.18	0.22	0.21	0.21	0.22	0.22
TiO_2	%wt	0.34	0.35	0.30	0.32	0.30	0.33
Fe_{tot}	%wt	63.70	65.53	63.52	61.94	62.33	62.51
Fe^{++}	%wt	1.20	6.12	2.46	3.16	3.00	2.18
S	%wt	0.005	0.007	0.003	0.029	0.005	0.004
IB2		1.25	1.16	1.09	1.10	1.08	0.95
Physical properties							
Tumbler index	%	92.92	92.90	93.80	93.74	94.69	95.13
Abrasion index	%	6.73	6.50	5.85	5.84	4.34	4.25
Compression strength - Top	Kg/pellet	256	198	188	144	181	217
Compression strength - Middle	Kg/pellet	246	180	187	142	131	263
Compression strength - Bottom	Kg/pellet	221	125	123	124	140	190
Compression strength - Avg.	Kg/pellet	241	168	166	137	151	223

The formulation 2010PG with North American iron ore replacing the Brazilian one (1910PG) was held as acceptable results in terms of physical quality of the product pellet.

Suitably, by modifying the additives amounts and operational parameters of the induration process, adequate physical properties of the product pellets were achieved, in comparison to the reference formulation used with the Brazilian ore.

3.2 Bed Height, Pressure Drop and Process Gas Flow Optimization

The pellet bed permeability determines the pressure drop along the pellet bed and, therefore, the gas flow inside the bed. A lower pressure drop across the pellet bed will lead to higher gas flow through the bed, a higher productivity and also a decrease of the specific power consumption [4].

According to the concept of deep bed technology an increase of the bed height allows lower gas flow through the bed, but increases the efficiency of the heat transfer, due to longer residence time of pellet inside the machine. An optimum bed height exists according to the green pellet quality (amount of fines, particle size distribution, compression strength, drop number) and installed capacity of the process fans. A deeper bed will increase material pressure in the lower layer of the bed and deformation of the pellets may occur reducing the permeability. If the quality of the green pellets is not good enough, a deeper bed will not necessarily result in an efficiency improvement.

Via pot grate testing (Table 2), it has been shown that without modifying the installed capacity of the process fans, the optimum green pellet bed height for AHMSA pellet plant operation, with current raw materials, is around 500 mm. Considering this bed height, in order to ensure an adequate tumbler index of the product pellet, a ratio of, at least, 2.4 ta/tp (tons of air per tons of pellet) is required in order to transfer sufficient heat to the pellet (Figure 5).

Table 2 - Bed height test campaign

TEST	Unit	1	2	3	4	5	6	7	8	9	10
Production	Mtpa	5.1	5.2	5.3	5.6	5.3	5.1	5.23	5.1	5.3	5.35
Velocity	mm/s	37.9	40	50.2	51.7	50.5	40.4	60	54	52.3	52.3
Mineral	%wt	93.63	93.63	93.63	93.63	93.63	93.63	93.63	93.63	93.63	93.63
Dolomite	%wt	4	4	4	4	4	4	4	4	4	4
Hydrated lime	%wt	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Coke breeze	%wt	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Heat equivalent magnetite	%	100	100	100	100	100	100	100	100	100	100
Green pellet height	mm	630	630	550	550	550	550	500	500	500	500
Firing temp.	°C	1300	1280	1300	1300	1300	1300	1280	1300	1300	1300
UDD flow(*)	Nm^3/min	9825	10437	10830	11034	10907	11209	11483	11768	10756	11023
Exhaust windbox flow(*)	Nm^3/min	8052	8829	8430	8233	9167	9202	9716	8810	9100	9087
Recup. windbox flow(*)	Nm^3/min	6506	7056	8776	8133	8795	7567	9408	8149	8445	8411
ΔP UDD	Pa	4900	4900	4900	4900	4900	4900	4800	4800	4800	4800
ΔP Exhaust windbox	Pa	5000	5500	5000	5000	5500	5000	5500	5500	5500	5500
ΔP Recup. Windbox	Pa	6000	6500	6000	6000	6500	6000	6000	6000	5800	5800
ta/tp	rel	2.21	2.3	2.29	2.17	2.40	2.52	2.56	2.54	2.40	2.40
Tumbler Index	%	90.23	90.1	90.97	91.68	92.57	93.50	90.30	93.50	93.20	93.10
Abrasion Index	%	7.5	6.1	6.80	5.80	5.10	4.30	6.50	3.80	4.50	4.60

(*) pilot plant flows have been scaled according to indurating furnace areas.

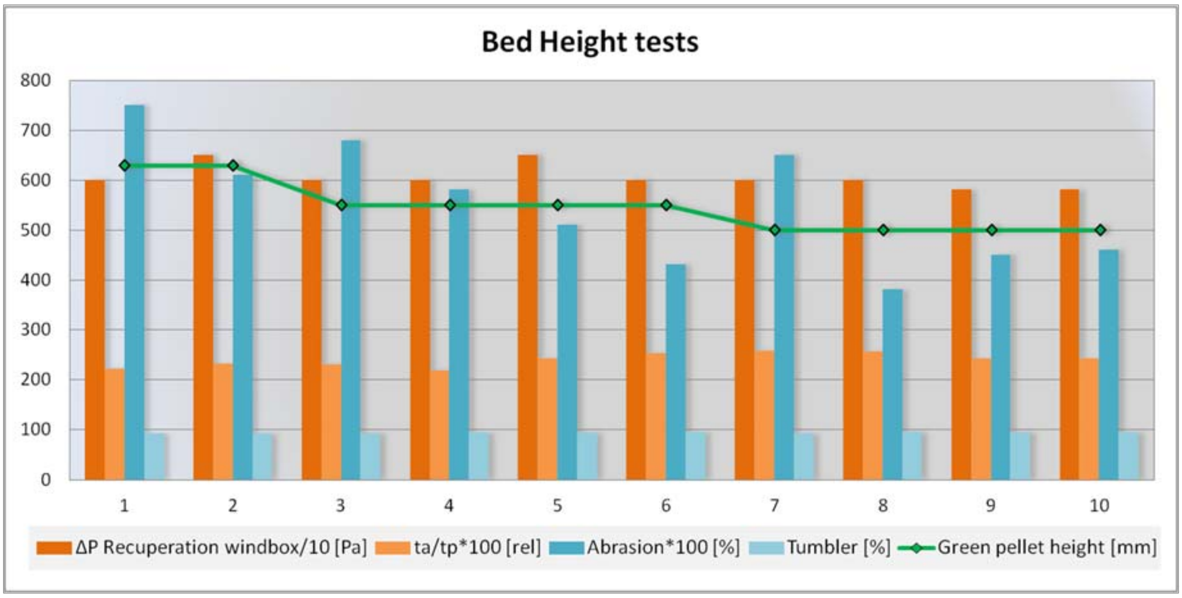

Figure 5 - Fired pellet characteristics in different green pellet bed testing campaign

Temperature and flowrate of process gas together with the duration of the firing phase must to be controlled with care in order to obtain pellets with high compression strength and adequate porosity [5].

Figure 6 - Pitot tubes inside / outside the ductwork

A series of pot grate testing activities have been carried out in order to optimize the process gas flow configuration comparing the values read by on-field Pitot tubes to the flows measured during pot grate firing test - a total of 15 tailor-made Pitot tubes have been installed to measure the flows in the ductworks in correspondence of each process fan. As a result of the increased productivity, optimization of bed height and process gas flow distribution, a significant reduction in pelletizing plant specific electrical consumption has been observed (Table 3).

Table 3 - Specific electrical consumption referred to entire pelletizing plant area

Year	Specific Consumption kWh/t	Saving %
2009	52.76	-
2010	47.10	10.7
2011	46.94	11
2012	44.08	16.5

3.3 Firing Profile Optimization

During many pot grate test campaigns, different feed mixtures with different values of magnetite equivalent % (%M.E.) have been evaluated. For a particular mineral mixture it is possible to elaborate the required temperature profile for the specified pellet product quality. The control of additives amount, especially in the case of solid fuel, it is very important in obtaining a good physical and chemical quality. The below table (Table 4) reports the several induration zones and temperatures as a function of magnetite equivalent ranges.

Table 4 - Indurating zones and relevant temperatures

%M.E	UDD	DDD	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	After firing
65-69	250	140	450	1200	1320-1340	1320-1340	1320-1340	1310-1330	1000-1100
70-74	250	140	450	1150	1310-1330	1310-1330	1310-1330	1300-1320	1000-1100
75-79	250	140	450	1100	1300-1320	1300-1320	1300-1320	1290-1310	1000-1100
80-84	250	140	450	1050	1290-1310	1290-1310	1290-1310	1280-1300	1000-1100
85-89	250	140	450	100	1280-1300	1280-1300	1280-1300	1270-1290	1000-1100
90-94	250	140	450	1000	1119-1210	1270-1290	1270-1290	1260-1280	1000-1100
95-99	250	140	450	950	1180-1200	1260-1280	1260-1280	1250-1270	1000-1100
100-104	250	140	450	900	1170-1190	1250-1270	1250-1270	1240-1260	1000-1100

3.4 Production Increase

All of the improvements listed above (optimizations) enabled the achievement of an increase in plant production.

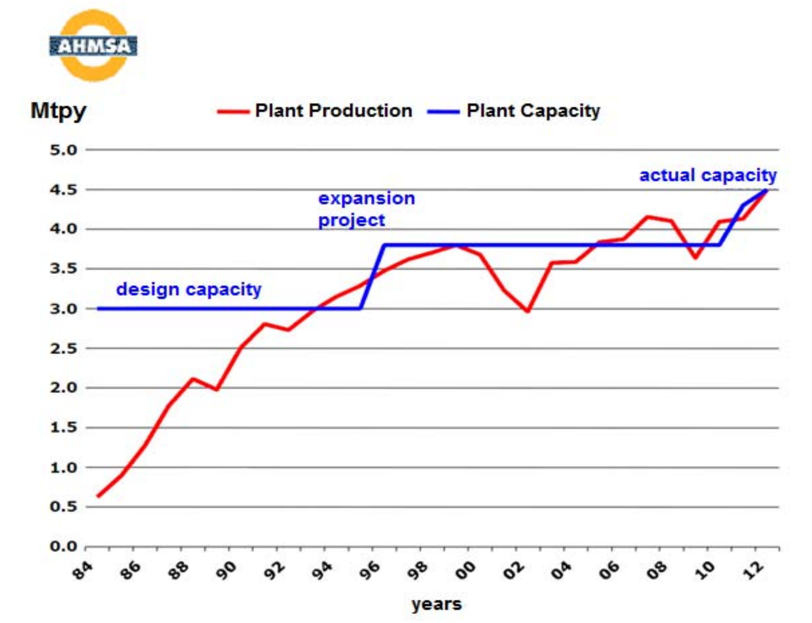

Figure 7 - Pellet plant production through the years

4 CONCLUSIONS

The results reported above confirms the benefits that an in-house installation of a pot grate testing facility can bring, along with the experience and skill of the pellet plant operators.
With particular reference to AHMSA pellet plant, via a specific testing program carried out in the pilot plant prior to trials in the industrial plant, it has been identified the most advantageous blend of iron ore and the optimum pellet bed height thus achieving remarkable results both from technical and economical point of view and namely:

1. Productivity increase from 27.1 to 29.2 ton/m^2 day;
2. Reduced production cash costs due to the use of a blend of cheaper iron ores;
3. Reduction of specific electrical consumption of 16.5% by production increase and bed height optimization;
4. Fuel saving in the order of more than 22 million m^3/year of COG;
5. CO_2 emission reduction of about 18,760 tons, as consequence of item 4 above.

Acknowledgments

The authors would like to acknowledge all the people of AHMSA pelletizing department for the provided information and cooperation: in particular to Gerardo Rivera Garza and Norma Mayela Carreon Villareal.

REFERENCES

1 Huerta M, Cameron I, O'Learly K, Mourao JM, Medeiros UV. Guidelines for Selecting Pellet Plant Technology. AISTech 2013 Proceedings.
2 Meyer K. Pelletizing of Iron Ore. Dusseldorf: Springler-Verlag; 1980.
3 Halt JA, Komar SK. Review of Organic binders for Iron Ore Agglomeration; 2013
4 Nordgren S. Energy Analysis of Pelletising in a Straight Grate Induration Furnace [Licentiate Thesis]. Luleå, Sweden: Luleå University of Technology; 2010.
5 Barati M. Dynamic simulation of pellet induration process in straight-grate system. Int. J. Miner. Process. 2008; 89:30-39.