Methodological Analysis of Process Technology in Engineering Projects Implementation

by

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SUBMITTED TO THE SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN MANAGEMENT
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2007

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Submitted to the Sloan School of Management
on May 12, 2007 in partial fulfillment of the
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ABSTRACT

This thesis will evaluate the utilization of process management tools in the implementation of a major engineering project in a steel plant of Gerdau Group in the city of Charqueadas, Brazil. The project consisted of an increase in capacity of the electric arc furnace in order to improve the availability of liquid steel to the subsequent processes in the Melt Shop.

The evaluation will be performed according to the Approach to Developing Process Technology Strategy (Beckman, S.L. and Rosenfield, D.B., *Operations Leadership Competing in the New Economy*, Irwin McGraw Hill, 2007) methodology and it will assess to what degree the company covered the six recommended steps of the methodology:

Step 1 – Understand the Business Strategy and Competitive Environment
Step 2 – Understand the Technology Trends in the Industry
Step 3 – Understand the Internal Capabilities of the Company
Step 4 – Identify and Assess Process Technology Investment Alternatives
Step 5 – Develop an Implementation Plan and Implement
Step 6 – Implement, Assess and Measure Results

The evaluation will not prioritize the technical depth of the process technologies analyzed, but rather will focus on the strategic and tactical aspects of the projects' implementation process. The major goal will be to assist the company in improving its engineering projects managerial system.

The actual methodology utilized in engineering projects, although covering most of managerial aspects of implementation, does not represent a formal approach to the process technology decisions required. The utilization of process management tools will provide less variability in the achievement of project performance goals, allowing the company to achieve the expected benefits related to its investments in installations and infrastructure quickly and consistently.

The conclusions will be used to develop recommendations for the implementation of future projects and the evaluation will also address the organizational aspects for a possible replication of the project in other steel plants outside Brazil.

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NOTE ON PROPRIETARY INFORMATION

In order to protect Gerdau Group proprietary information, the data presented throughout this thesis has been modified, scaled or minimized and do not represent actual values used by Gerdau Group.

1) LIST OF CONTENTS

2) LIST OF FIGURES AND TABLES

CHAPTER 1 - THESIS OVERVIEW

The Introduction, Chapter 2, describes the company operations within the steel business industry the role of the Aços Especiais Piratini as the only specialty steel plant in Gerdau Group at that time. The chapter includes the assessment of the company's managerial processes related to engineering investments implementation and the implementation structure, and its links to all levels of hierarchical responsibilities within the company. Also, the chapter includes the project goals and scope definition as described in the project plan.

Chapter 3 is dedicated to Business Strategy and Competitive Environment analysis. It will analyze the business strategy adopted by Aços Especiais Piratini plant and the positioning relative to the main strategic drivers through the Delta Model methodology (Hax, A. C and Wilde II, D. L., *The Delta Project*, Palgrave 2001), which clarifies the company's strategic choices and priorities. A major part of Gerdau Group operations is related to the production and commercialization of common steel business, while the Aços Especiais Piratini plant focuses on the specialty steel production. This chapter will describe how the business strategy impacted the focus definition and potential trade-offs.

Chapter 4 covers the main technology trends for electric arc furnace equipment and processes at the time of the project implementation and describes their main features. The electric arc furnace equipment and processes are very specialized and tailored for each new installation. The process of a supplier proposal demands close interaction between the company's engineering departments and the potential suppliers. For this scope of engineering project the company utilizes outsourced world class suppliers which normally have already developed their proprietary technologies, but the degree of customization of each project influences deeply the competitiveness of the potential suppliers' offers. The chapter also presents a brief description of the electric arc furnace process and the available process technology alternatives are described, considering the risks and tradeoffs involved in their implementation.

Chapter 5 is dedicated to the assessment of the organization's internal capabilities related to process technology development and management. The methodology utilized to support the assessment is the Porter's Five Forces Model (Porter, M. E., *Competitive Strategy*, New York Free Press 1980). The electric arc furnace process defines important intrinsic steel properties and is considered a core capability in the specialty steel business and, as such, it can provide the company with a competitive advantage. As the number of technology suppliers and customers is limited and there is a strong tendency towards reduction, the flow of critical information from the customer to the suppliers has to be controlled in a very strict way to avoid loss of intellectual property.

Chapter 6 performs the identification and assessment of process technology alternatives and evaluates the fit of the choices to the company's strategic needs. The product-process matrix and Learning Curve tools are applied to help the decision making process. The role of automation is discussed considering labor, business, operational, socio-political and regulatory issues and their influence in the company's environment. Chapter 9 also presents a unifying framework for process technology decisions assessment, putting together the conclusions obtained from the Chapters 6, 7, 8 and 9 in a practical tool to help the evaluation of the quality of the implementation plan.

Chapter 7 describes the implementation plan developed for the project according to the methodology PMI (Project Management Institute) adopted and customized by the Aços Especiais Piratini engineering department. The methodology implementation steps are detailed, as well as the focus of tasks and expected results.

Chapter 8 performs the assessment and measurement of the new process technology results, making a comparison between the achieved benefits and the planned goals for costs, quality, availability, innovativeness and environmental conformity. Besides the performance check, the chapter analyzes the fit of the process implementation outcomes to the company's overall strategy.

Chapter 9 draws the conclusions about the effectiveness of the company's engineering projects implementation practices compared to the recommended six-step approach employed in its evaluation. The improvement opportunities uncovered generated a set of recommendations to be implemented in engineering projects within the whole organization. The recommendations also will address the organizational aspects in case of their implementation in other business units of the Gerdau Group, through the three perspectives on organizational analysis action (Ancona, D. et al., *Three Perspectives on Organizations*, South-Western College Publishing, 2005).

CHAPTER 2 - INTRODUCTION

a. COMPANY

The Gerdau Group is the largest producer of long steel in the Americas, with mills in Brazil, Argentina, Canada, Chile, Colombia, the United States, Peru and Uruguay; it also holds a 40% stake in the Spanish steel company Sidenor. Currently, Gerdau has an installed capacity of 19.1 million metric tons of steel per year. In 2006, the Gerdau group exceeded US$ 13 billion in sales revenues from the production of 15.6 million metric tons of steel, generating net profits of 1.7 US$ billion.

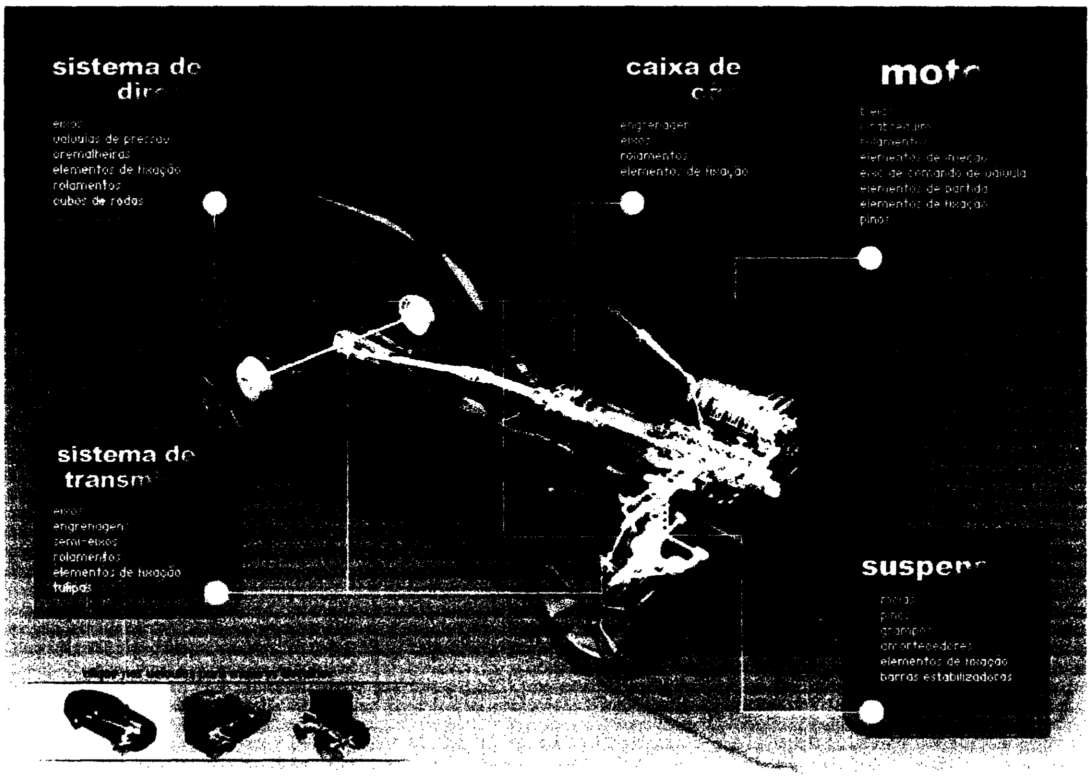
Gerdau Aços Especiais Piratini is a mini mill steel plant focused on the production of specialty long steels developed primarily for the automotive industry. Throughout the years, the Gerdau Group has invested in the mill's technology and equipment, giving it the means to offer superior quality products that are developed based on the specific needs of each customer. Technical training, aligned with world class management practices, has made Gerdau Aços Especiais Piratini one of the most modern and efficient steel mills in the world.

The company's production capacity reached 500,000 metric tons/year of crude steel, and its constant concern and investment in the modernization of the production and environmental control are reflected by the different awards it has received during its history. An example is the ISO 9002 quality certification (1993), the National Quality Award (2002), the ISO TS 16949:2002 (granted in 2003) and, more recently, the ISO 14001 certification (May 2005) and the nomination for the ISO TS 16949:2002 recertification (June 2006).

The Gerdau Aços Especiais Piratini (AEP) plant produces engineering steel and stainless or tool steel grades for applications which demand materials with more restricted guidelines for chemical composition, mechanical and metallurgic properties.

The engineering steels are used in the machining, cold forging, hot-forging and cold drawing processes. They are utilized mainly in the manufacturing of auto parts for steering and suspension systems, power trains, gears and axles of speed boxes and engines. Some examples of the engineering steel application in cars are shown below:

Figure 2.1 – Specialty Steel Applications in Cars (highlighted parts)



The tool steel is used in the manufacturing of sawing tools, die tools to plastic and metal injection as well as to forging dies.

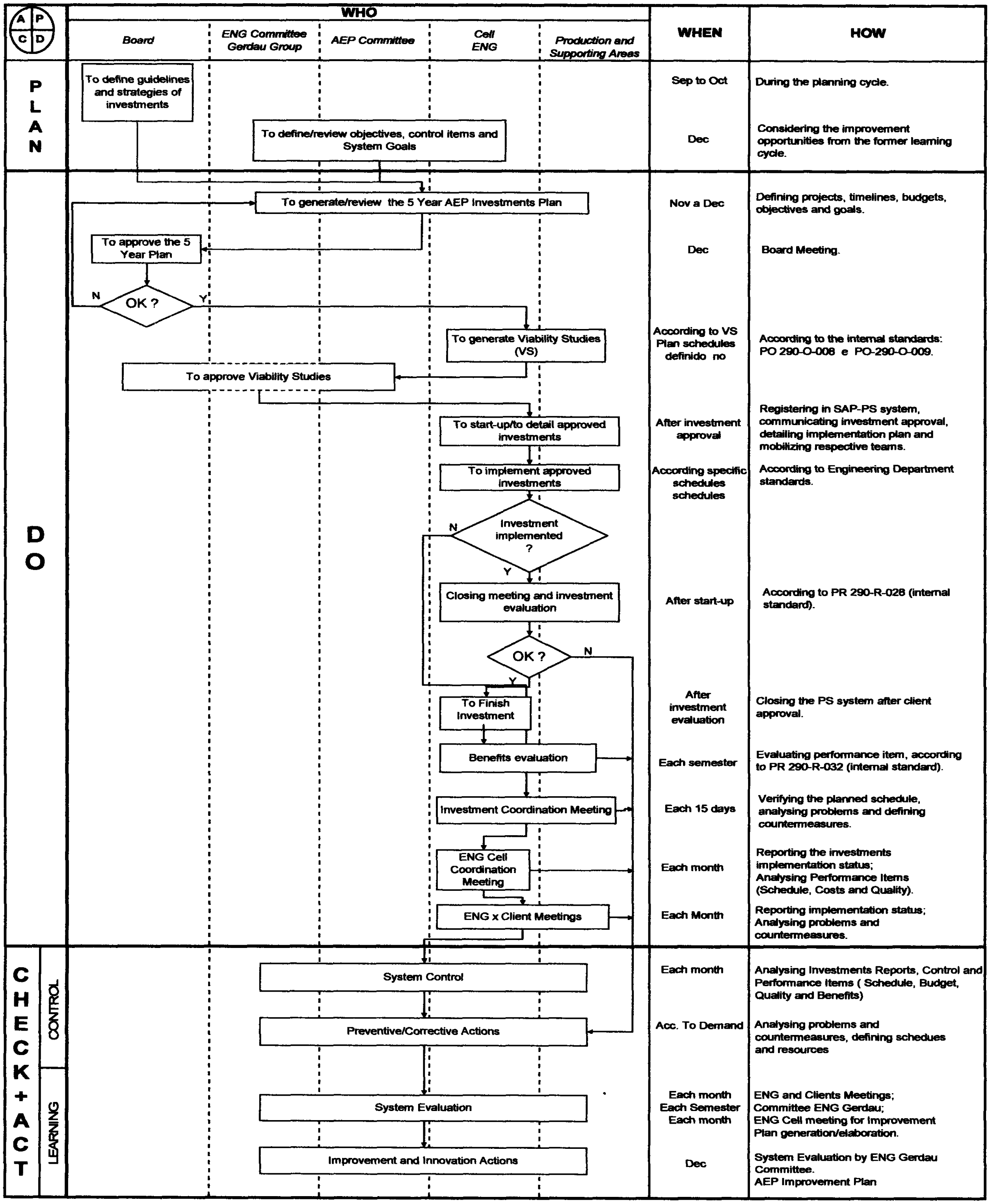
The stainless steel is used in the machining, forging and cold drawing processes. They are widely used in the manufacturing of parts and accessories for the oil, chemical, food, dental tools and medical industry.

Differently from the common steel business units and due to its products specificities, the Aços Especiais Piratini plant adopts the “make-to-order” production strategy. The variety of its final product and steel metallurgical compositions prevents the plant from carrying respectively high levels of finished goods and work in process inventory. It means that there are almost no production buffers to compensate any plant stoppage. In the case of automotive industry, the problem is amplified by the just-in-time production strategies adopted by the parts manufacturers and by the automotive industry. In order to meet the strict production schedules, the plant utilizes sophisticated production management systems and developed unique related skills which consist of a company's competitive advantage.

b. ENGINEERING PROJECTS

The PDCA cycle of engineering investments is shown in the Figure 2.2 – Investment Implementation Flow, which clearly defines all steps and responsibilities for engineering projects implementation. The five-year strategic plan is detailed at the industrial units' level, with the participation of the Gerdau Group engineering committee, and approved by the board of the company. After the strategic plan approval, the engineering departments perform studies in order to confirm the viability of each potential investment. According to competence levels, the projects are approved and then the engineering departments are in charge of the entire project's management. Usually each industrial unit has its own engineering department, like the case of Gerdau Aços Especiais Piratini plant, which is responsible for all steps of the projects implementation.

FIGURE 2.2 - INVESTMENT IMPLEMENTATION FLOW



Remarks Preventive/Corrective actions, generated by the Control and Learning System Processes, are identified and implemented in the "ACT" step of the PDCA cycle.
Preventive/Corrective actions are related to the "DO" step (System Execution).
Improvement actions cover the whole PDCA cycle

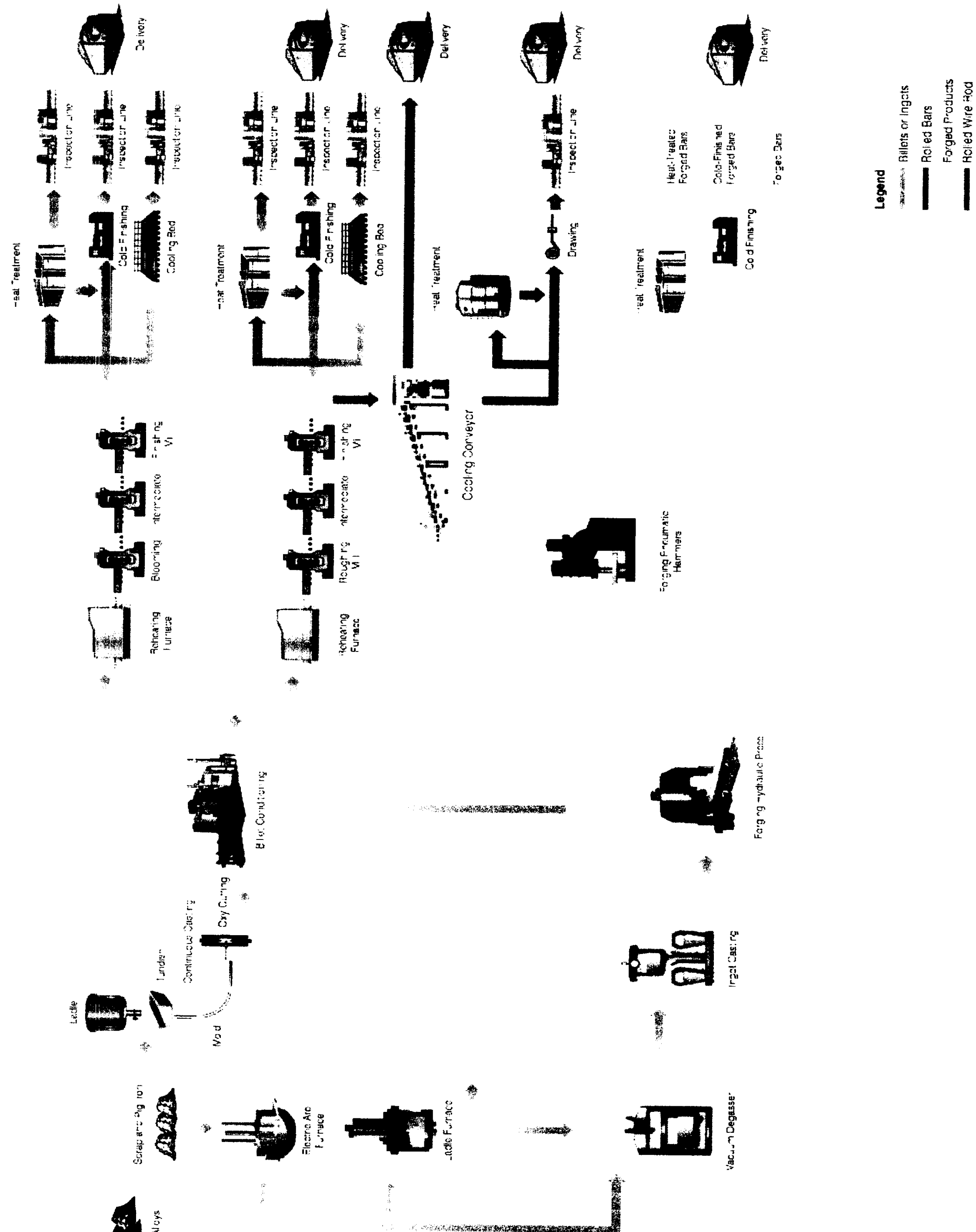
The engineering departments are structured in order to provide the whole installation of new systems, performing mainly activities related to installation projects and equipment assembling. Each project has its assigned coordinator and the investment coordinators team has representatives from each major field of engineering expertise, such as power, automation and instrumentation, mechanics, utilities and construction engineering. Although the engineering departments have technical designers, they are used to covering basic demands for minor projects and the interfaces between existing systems with new ones, outsourcing most of the installation projects. In the case of equipment, the company maintains technical expertise and considers this a core competence, but nearly all equipment is manufactured by external suppliers.

c. ELECTRIC ARC FURNACE PROJECT

As mentioned before, the engineering project to be evaluated is the increase of capacity of the sole plant's electric arc furnace. This chapter describes the general scope of the project, with the detailed evaluation performed in Chapter 9, where the process technology alternatives are compared.

Figure 2.3 – AEP Production Flow shows the simplified operation processes in the Gerdau Aços Especiais Piratini plant in order to illustrate its impact in the company's operation. It is important to observe that the arc furnace is the only source of liquid steel for the next processes and its stoppage causes the same effect to the subsequent processes.

Figure 2.3 – AEP Production Flow



From the viability study, the main project features are described below:

PROJECT SCOPE

OBJECT

- Installation of new shells, roofs and baskets
- Installation of a new hydraulic systems, new electrode regulator and automation
- Substitution of the sub and superstructure of the furnace
- Installation of a new control room

GOALS

- Increase EAF production capacity from 27,500 to 30,500 ton/month
- Reduce the tap-to-tap time (TTT)
- Reduce maintenance and operational delays
- Increase operational safety
- Reduce energy, electrodes and refractory costs
- Reduce maintenance costs

PREVIOUS SITUATION

Furnace shell: the previous shell had a 4,860 mm diameter, too short in comparison with the ladle capacity of 65 ton, generating the need of 3 or 4 charging operations and the consequent set up times. The delays caused by overcharging (high scrap level into the furnace) due to the reduced shell size were equal to 0.89 minutes/heat, causing low electric power average and high refractory consumption.

Sub and superstructure: highly deformed and fragile due to the overload, because it was operating at a taping load of 65 ton when originally projected for 40 ton.

Furnace movements: the speed of roof opening and roof elevation with the actual equipment presented lower speed than the world standards; causing loss of production.

Table 2.1 - EAF Hydraulic Movements

[illegible]	[illegible]	[illegible]	[illegible]
Electrode elevation	45 (6,6m/min)	20	25
Electrode lowering	38	--	0
Roof elevation	12	12	0
Roof lowering	10	10	0
Roof opening	36	20	16
Roof closing	27	20	7
[illegible]			[illegible]

Buckets: previous capacity was 30 cubic meters per bucket, causing higher number of chargings.

Electrode regulator: Ferrari design, very outdated. The dynamic response did not allow the achievement of low energy or low electrode consumption. Also, there was no availability of spare parts.

Control room: inappropriate layout caused poor visualization for the operators, proximity of the furnace provoked serious safety risks and electromagnetic interference, and inadequate construction caused poor acoustic insulation and internal air contamination.

Automation: the furnace movements were controlled by electro mechanic relays which presented no reliability and high maintenance costs. Also, auxiliary systems were added to the furnace without planned integration, preventing the operational optimization of the furnace and subsystems as well as of the whole melt shop. In addition, all delays' controls (power offs) were done manually and subjected to mistakes.

PROPOSED SITUATION

SCOPE

Furnace shell: replacement of the former ones by shells with 5,200 mm of diameter and consequently the former roof should be replaced.

Furnace structure: redesign to adequate to the new shell capacity.

Hydraulic movements: substitution of the whole hydraulic system in order to eliminate the time losses listed in Table 2.1 – EAF hydraulic movements

Buckets: Manufacturing of two new buckets with 51 cubic meters of capacity to allow the reduction of the number of charges from three or four to two per heat.

Bucket transfer cars: both former cars would be refurbished with the addition of a new weighing system in the line B.

Electrode control system: installation of an entire new one.

Control room: construction of completely new one, placed in a way to allow better visualization and safety.

Automation: automation of the whole furnace movements and complete integration of the furnace subsystems and production control.

Table 2.2 – Projected benefits shows the expected results from the project implementation and will be used as guidance for the return of the investment.

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
- Power on	min	48,3	46,0	43,7	2,3
- Charging time	min	9,0 (1)	9,0 (1)	4,0 (2)	5,0
- Maintenance delays	min/heat	6,8	3,0	2,0	1,0
-Delays from overcharging	min/heat	0,89	0,89	0,50	0,39
- Tap-to-tap time	min/heat	86,2	78,4	70,8	7,6
- Electrode consumption	kg/ton	2,8	2,6	2,4	0,2
- Energy consumption	kWh/ton	421	410	395	15
-Refractory consumption	kg/ton	4,8	4,4	3,4	1,0
- Maintenance costs	US$/ton	11,6	10,6	9,0	1,6

(1) Considering 3 charges of 3 minutes.

(2) Considering 2 charges of 2 minutes.

EXCLUSIONS

New scrap transfer line (structure and rails) in the “A” line

Improvements in the tapping car

Improvements in the lime addition system

Increase in capacity of the carbon injection silos

Improvements in the platform car (manipulator)

The most critical aspect of the project was the fact that the plant had only one electric arc furnace and its stoppage could result in the interruption of the whole plant shop production if some buffers were not created.

As the company’s main customer is the automotive industry, with 80% of the production destination, any planning mistake could cause the stoppage of whole vehicle assembling lines of different manufacturers in Brazil.

Additionally, the other Gerdau steel plants are only able to produce less sophisticated grades of steel, not being alternative suppliers to Gerdau Aços Especiais Piratini products.

CHAPTER 3 - UNDERSTAND THE BUSINESS STRATEGY AND COMPETITIVE ENVIRONMENT

The specialty steel business has features that make its analysis unique in comparison with the common steel business, which represents the majority of Gerdau Group revenues. This chapter analyzes the specialty steel business strategy according to the Delta Model methodology[1] and correlates the project goals to the company's strategy in its competitive environment.

The Delta Model defines three distinct strategic positionings to be adopted by a firm or business to compete in its marketplace. The possible positionings are graphically represented by a triangle, with each corner linked to a specific strategic option and a different approach to target the customer.

The three distinct strategic options are described below:

Best Product

Normally this option is called "classic" competition form and considers two ways of achieving customer bonding:

- Low Cost, where the goal is to provide price advantage to the customer

- Differentiation, where specific and attractive features of the product create customer willingness to pay a higher price.

To achieve competitive advantage from the Best Product positioning, the firm must focus on the efficiency of its internal supply chain and product economics to beat its competitors. The Best Product option provides weak bonding with the customer.

Total Customer Solutions

The focus of this strategy is to develop an integrated supply chain with customers and suppliers to leverage the customer economics. The outcome of the successful

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[1] Hax, A. C and Wilde II, D. L., *The Delta Project,* Palgrave 2001

adoption of this outwardly driven strategy is a stronger bonding with the customer. There are three ways to achieve this positioning:

- Redefining Customer Experience, which provides the customer with a unique experience through the complete life cycle or ownership of the product.

- Horizontal Breadth, where the goal is to create a set of product options which fulfill all customer needs.

- Customer Integration, where the involvement of the firm in the customer value chain leverages the joint capabilities and increases the switching cost for the client.

System Lock-In

This strategy presents the highest potential bonding, because its focus is on the extended enterprise economics. The extended enterprise includes, besides the firm, suppliers and customers, the so called "complementors". The complementors are external or internal firms which are able to deliver services or products that enhance the value of the company's product. There are three possible approaches to achieving System Lock-In:

- Restricted Access, where the goal is to limit the access channel to the customer by competitors.

- Dominant Exchange, where the company establishes an interface between buyers and sellers, creating reinforcing loops that further increase the firm's dominance. In this case, the customers are also complementors.

- Proprietary Standard, where the company develops a proprietary product or service design and/or the network of product and services provided by complementors. This adds so much value that it is virtually impossible for the customer to choose other options.

The analysis of the specialty steel business strategic positioning, according to the Delta

Model, is described below. Additionally, the contribution of the melt shop for every strategic positioning is explained.

Best Product

- Low Cost:

Like other steel mini mill plants, the main cost drivers in the Aços Especiais Piratini by far are raw materials (scrap and alloys) and energy inputs (electrical energy and chemicals). The melt shop area has the strongest contribution to the entire plant cost composition, due to its intensive energy use and raw materials consumption. Although Aços Especiais Piratini plant enjoys strong synergies in procurement with all of the Gerdau Group units, the cost is not perceived as a critical competitive advantage in the specialty steel business, because the product requirements are extremely diverse and difficult to commoditize.

Of course, operational efficiency is a mandatory requirement for this size of industrial units and the company has implemented varied and comprehensive programs towards it, such as 5S, Six Sigma, TPM (Total Productive Maintenance), RCM (Reliability Centered Maintenance), among others.

- Differentiation:

To illustrate the importance of differentiation in the specialty steel business, the Aços Especiais Piratini plant regularly produces in its melt shop more than 300 different grades of steel to meet the specific customer applications requirements. As most of products are used in automobile industry applications, quality assurance and production order tracking are considered basic requirements. The processes and/or product of the plant are certified by international norms such as ISO (International Standards Organization) and specific norms as QS (Quality Standards for GM, Ford and Chrysler). In addition to processes controls, the plant performs quality inspection in 100% of the product and the features inspected range from chemical composition and dimensional compliance to surface and subsurface defects. The inspection is mostly automated and employs diverse equipment, such as spectrometers, lasers, ultrasonic devices, electromagnetic equipment and eddy current analyzers. Quality is definitely a strategic advantage and its absence could be responsible for brand damage and immense financial losses in the case of a "recall", for example.

Besides simply quality assurance, the compliance to environmental standards is increasingly becoming a competitive advantage and the company is also certified in the ISO 14000 norms.

The melt shop is responsible for the steel chemical composition and the melt shop processes are the most energy consuming and environmentally demanding in the entire plant.

Total Customer Solutions

- Customer Integration:

Due to the plant's make to order production strategy, customer integration is a critical competitive requirement. The joint forecasting and planning with customers and suppliers collaborates towards product availability and lower inventory costs. Internally, the company must have flexible processes in order to meet the volume and product specifications.

The customer integration positioning is also enhanced through a strong customer support structure to leverage the capabilities of the whole supply chain. Besides the integrated forecast and production planning, the company provides the online tracking of production orders and their production schedules, allowing the customers to choose the most favorable period to place their orders, to make changes in specifications or volumes and even negotiate to change production priorities.

Although the melt shop area output presents many features of a continuous process and the production planning aims to keep the melt shop operating continuously, the electric arc furnace is by definition a non-continuous process. The possibility of producing different steel grades in each heat provides flexibility, which properly fits the "make-to-order" production strategy and thus enhances the value of joint forecast and planning agreements. Chapter 4 provides an overview of the electric arc furnace process steps in order to facilitate their understanding.

- Redefining Customer Experience:

The company performs the collaborative development of new products, working closely with its actual and potential customers, towards the increase of the whole supply chain competitiveness. The company's technical expertise helps the customers to define the best product fit to the end users and to translate its specifications to the internal production processes, providing a competitive advantage due to the integrated product development approach.

Although the composition of the steel grades is well defined by international standards, the process technologies which support their production are the drivers of competitiveness. If the product development is conducted in a way to optimize internal process capabilities while matching customers' needs, the result will be an enhancement of product competitiveness.

- Horizontal Breadth:

Although for the plant as whole the diversity of products is a critical skill, the melt shop works to meet extremely restrictive requirements related to different steel grades, which per se assures a broad variety of product options. Again, the flexibility provided by the non-continuous process of the electric arc furnace heavily supports the horizontal breath strategic positioning.

System Lock-In

Restricted Access and Dominant Exchange

The two positioning options in this corner, Restricted Access and Dominant Exchange, are attended by the company's highly developed skills in the specialty steel business as a whole, but the influence of the melt shop processes is limited.

The footprint of the commercialization structure of Gerdau Group provides an availability of products in a broad range of locations, including remote places. In addition to the established distribution network, the customers can purchase products through an innovative business-to-business system and also can choose financing options through the company's own bank.

- Proprietary Standard:

This strategic positioning is achieved through the quality of internal processes, which allows the plant to produce grades of steel that the competitors are not able to produce. The Aços Especiais Piratini plant provides products with features not reachable by the competitors, such as defect free assurance, customized sizes and properties and even packing options. As mentioned before, the melt shop processes define the intrinsic product features, with the electric arc furnace process responsible for some primary metallurgical characteristics which could not be changed in the subsequent processes. Thus, the electric arc furnace process is strongly tied to the company's Proprietary Standard positioning due to its unique process development characteristics.

Tables 3.1 – Customer Segmentation and 3.2 – Value Proposition illustrate a practical example of the strategic approach to target one customer tier, the Auto Parts Manufacturers.

Table 3.1 – Customer Segmentation shows the qualitative analysis for the five major tiers of Aços Especiais Piratini customers. The quantitative data were omitted for

confidentiality reasons.

Table 3.2 – Value Proposition illustrates the value proposition to the Tier 1 customers, the auto parts manufacturers, giving an overview about how the company develops its strategies. Again, the qualitative data were omitted to preserve confidentiality.

The strategic option chosen by Aços Especiais Piratini is the Lock-In positioning, but the company did not present the whole set of skills to successfully achieve this positioning. Therefore, the company developed a Strategic Agenda to support the changes needed to the strategic repositioning. As described in the company's strategic positioning assessment, the melt shop played an important role in facilitating this repositioning as well as the project of furnace capacity increase.

Table 3.1 – Customer Segmentation

Customer Tier	Description
(1) Auto parts Manufacturers (including trucks and agricultural systems)	• High volume buyers, but quality is an implicit feature (eventual recalls can lead to bankruptcy) • Seeking for commoditized steel suppliers • Commoditized suppliers of automobile industry • "Squeezed" by the automobile industry (GM, Volkswagen, Ford, FIAT, Renault, John Deere, Caterpillar, etc) • Threatened by imports from Asia • Inventories management is critical, due to the just-in-time policies of the automobile industry • Seasonality in demand • Also "squeezed" by the by the few players of the steel industry • High infrastructure costs = High exit costs • Outstanding manufacturing capabilities
(2) Resellers	• High combined volumes, but also high diversity of products • Focus on prices • High inventories due to the products variety • Seek for selling commodities • Infidelity: buy from anybody • Occupy a niche not captured by the steel companies, due to low volume clients
(3) Electric Motors Manufacturers	• High volumes • Developed manufacturing capabilities • Steel is not important in the final price of products
(4) Screw and Spring Manufacturers	• Medium volumes • Reasonable manufacturing capabilities • Threatened by imports from East Asia • Intense rivalry within industry • Low entry/exit costs • Diverse clients, but biggest buyers are automobile manufacturers, which also "squeeze" them • Other buyers are medium size resellers
(5) Forgers	• Low volume (5~10% of AEP production) • Seasonal Demand • Good Manufacturing Capabilities • Low scale jeopardizes competitiveness

Table 3.2 – Value Proposition

Business Dimension	Tier 1: Auto Parts Manufacturers
Products	Products which allow to improve the efficiency of the processes, with certified quality
Services	Consultancy to select the grade of steel in order to match the client needs and production processes efficientization. On line appraisal information and volume availability. Unique service of ultrasonic inspection and certification
Channels	Direct - Sales consultant and sales manager relationship - Project leaders (Product manager & engineer, top management) Indirect - Quality Department, Management Systems Department and Engineering/Maintenance Department
Complementors	Screw and spring manufacturers Logistics providers (transportation) Manufacturing Management and Optimization Staff and Consultancies Technical Schools (to provide specialized labor) Engineering and Maintenance (staff or subcontractors)
Unique Competencies	Lean Manufacturing Processes (6 Sigma, TQM, etc) Research and Development capabilities Highly trained consultants
Set of experiences to the tier	Solutions for optimization of the production processes and products with assured quality.
Set of value delivery systems needed to provide the experiences	Sales force (experienced & highly qualified) Customized Products to optimize production processes (pre-cut, inspection, quality certification) Research and Development Quality Department Management, Engineering and Maintenance staff
Value appropriation	**Value gained by the customers:** - Simplification of processes by means of customized products - Quality assurance for its customers - Lean production processes (less steps) **Value gained by us:** - Lock in and sales volume - Knowledge about the end users` needs - Product brand enhancement **Value shared by both:** - Supply chain competitiveness

CHAPTER 4 - UNDERSTAND THE TECHNOLOGY TRENDS IN THE INDUSTRY

The process technology trends are mainly obtained from the sources listed below:

- Systematic benchmarking process in the Gerdau Group industrial units, where the search was focused on the compatibilities among equipment and processes. Although the metallurgical processes in specialty steel plants are by far more complex than common steel ones, in the case of the electric arc furnace the main equipment is fairly similar, differing normally by auxiliary systems added in the case of specialty steel plants.

- State-of-the-art technologies, presented in the steel industry seminars and congresses. The process engineers constantly participate in these events to search for potential improvements to implement in our processes. Frequently these events trigger the development of viability studies jointly with the engineering departments, many of them end up in new engineering projects.

- New technologies developed by the suppliers, presented and discussed in seminars or specific meetings with the engineering departments.

- Suppliers' technical proposals for engineering projects in course, not only limited to a specific unit of the Gerdau Group. Commonly the evaluation of proposals includes visits to steel plants where the technology is already been utilized or visits to the suppliers' development laboratories. Due to the physical constraints in laboratories and the limitations of visits to the industrial units among competitors, major suppliers arrange for visit to steel companies making other types of products with similar equipment, in order to provide the opportunity to assess the technologies' performance in real production conditions.

ELECTRIC ARC FURNACE PROCESS BACKGROUND

Figure 4.1 – EAF General View, Figure 4.2 – EAF Tilting Platform and Figure 4.3 – EAF Shell Overview provide a general overview of the electric arc furnace equipments and parts, in order to facilitate the understanding of the electric arc furnace processes.

Figure 4.1 – EAF General View

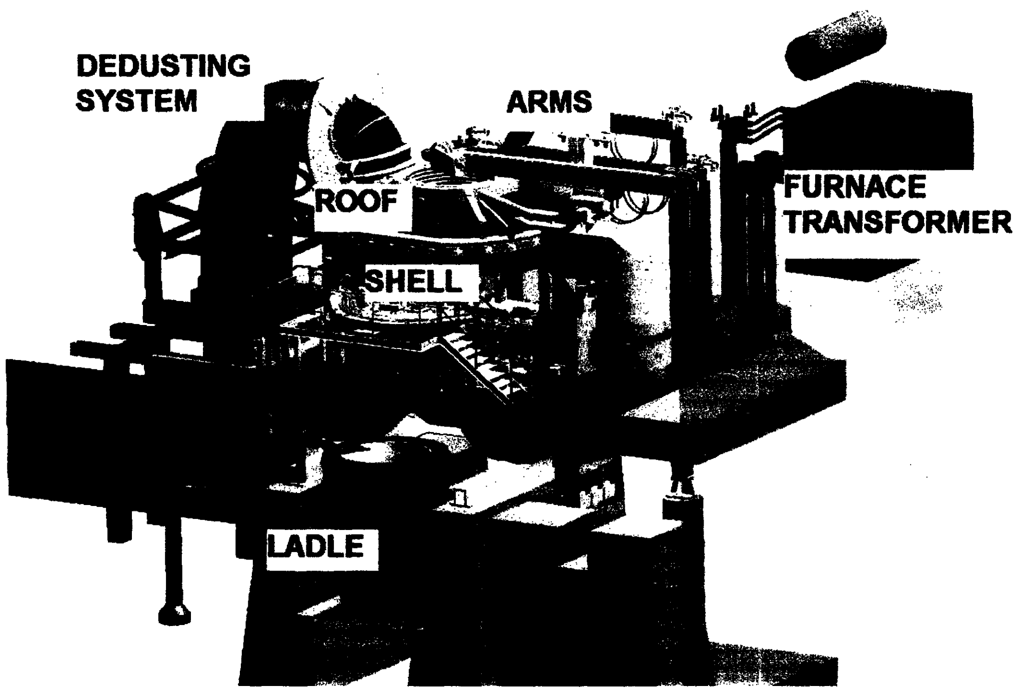
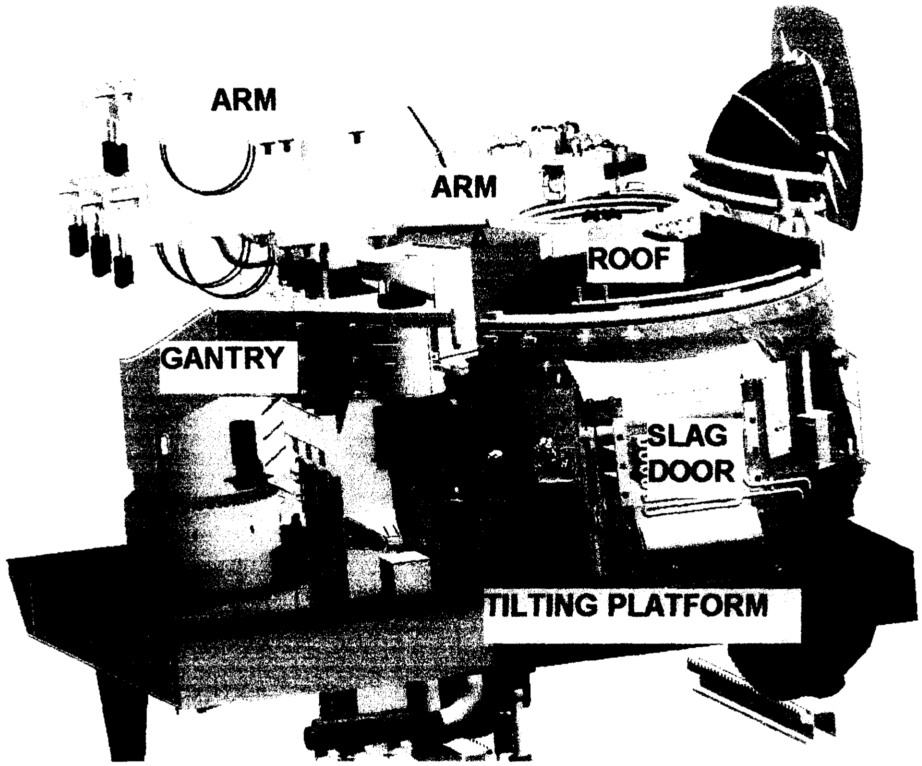


Figure 4.2 – EAF Tilting Platform



The basic sequence of operation consists of the following steps:

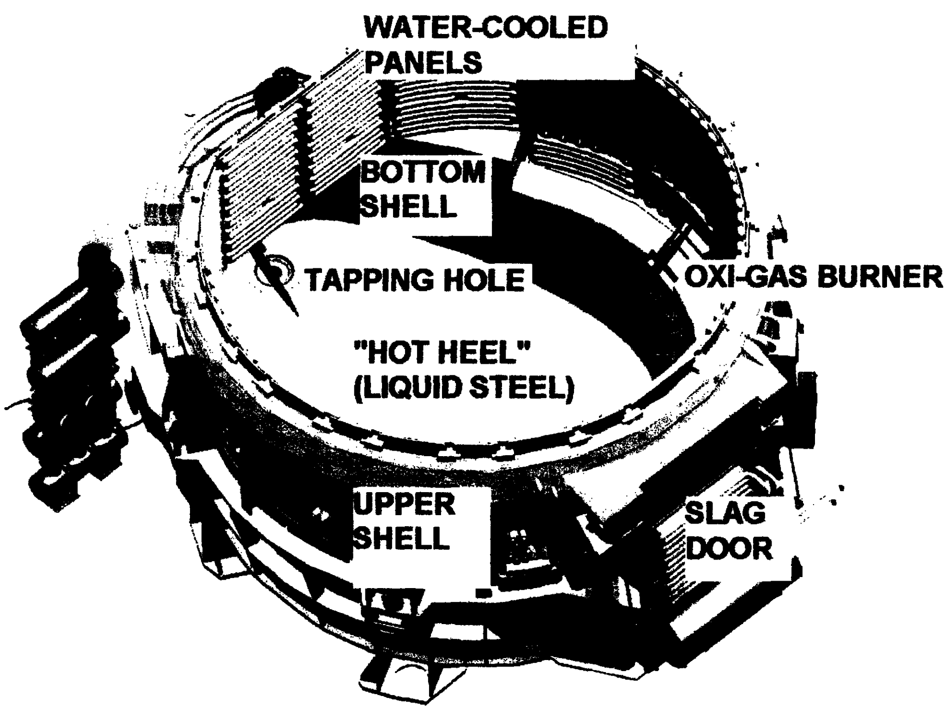
- Charging:

The objective of this step is to fill the shell with scrap and alloys in an adequate layers' disposition and density. The scrap buckets are mounted in the scrap yard, following a predetermined sequence of different layers. They are then transferred to the charging line, where overhead charging cranes transport them to the furnace shell. In order to be charged, the furnace must have its gyratory roof opened and its electrode arms must be rotated to provide clearance for the buckets' positioning over the shell by the cranes.

The charging operation must be performed in such a way that the furnace is filled with enough scrap to reach its tapping capacity with the minimum number of chargings and without excessively high level of scrap. Excessive scrap could cause, among other things, problems closing the roof and to position the electrode arms.

The major variables which influence the charging productivity are the available volume inside the furnace shell (see figure 4.3 – EAF Shell Overview), the "hot heel" (melted steel inside the shell) and the speed of the roof and arms movements. It is worth mentioning that the charging process is a batch process, repeating until the furnace reaches its tapping capacity, defined as 65 tons for this project.

Figure 4.3 – EAF Shell

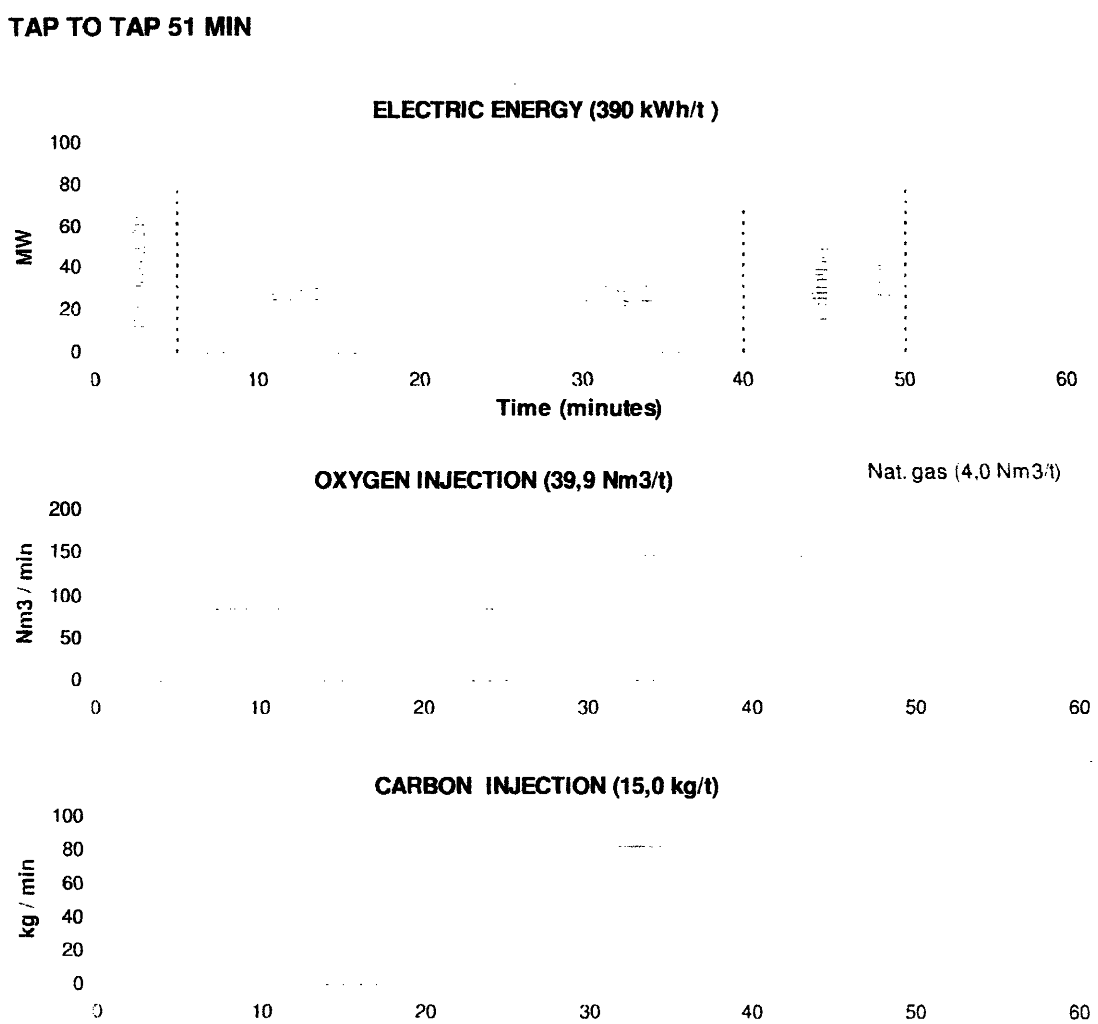


- Melting

The aim of the melting process is to melt the scrap and alloys inside the furnace shell in a homogeneous manner with minimum energy consumption (see Figure 4.1).

After being filled with scrap, the furnace roof rotates back to close the top of the shell, as well as the whole set of three single-phase electrode columns (gantry). Then the electrodes' columns are lowered to guide the electrodes through the three-holed roof centerpiece towards the scrap to initiate the melting process. Basically, the electric arc furnace process employs both electrical and chemical energy, with the electrical energy provided by the furnace transformer and the chemical energy by a dedicated utility system with oxygen and natural gas pipes. We considered here only external energy inputs, disregarding any energy generated by the exothermic internal reactions during the melting process. Figure 4.4 - EAF Energy Profile exemplifies a typical power profile for an entire heat in an electric arc furnace, showing the different amounts of each energy input per process step.

Figure 4.4 - EAF Energy Profile



During the melting phase, the efficiency of energy transfer to the scrap will determine the equipment's performance, dictating the melting times and energy consumption. The electrode regulation system controls the electrical energy transfer through the adequate electrode positioning and the burners' control system handles the chemical energy transfer through the oxygen and natural gas valves modulation.

The main influencing variables in this process step are the efficiency of the energy transfer to the scrap, which will result in melting homogeneity, and available volume inside the shell for the subsequent chargings. The system of electrode regulation plays a fundamental role in this step, adjusting the electric arc length to the different conditions of the scrap inside the furnace shell. As the electrode regulation system, the transfer of the burners' power should be maximized by modulation in a way that prevents dangerous ricochets and splashes generated by scrap with different densities.

- Refining

The aim of the refining step is to adjust the chemical composition and the liquid steel temperature to match the tapping requirements.

Although the energy transfer continues at this process phase, now most of the scrap inside the furnace is already melted and the chemical energy external input is highly reduced due to the loss of transfer efficiency and to avoid "splashing".

The exothermic reactions inside the furnace become more important, mainly for the metallurgical point-of-view. The carbon and alloys injection and the measurement of the steel quality parameters are the major control variables. Close to the end of the refining steep, the furnace tilting platform (see Figure 4.2) tilts towards to the opened slag door in order to remove the contaminants trapped in the steel slag through metallurgical processes.

- Tapping

Once chemical composition and temperature are reached, the last step of the process, called tapping, can initiate. Although this appears to be the simple act of pouring liquid steel into a refractory coated ladle, the tapping step is critical to the whole electric arc furnace process. In order to tap the liquid steel, the furnace platform tilts towards the ladle (or tapping) side and the tapping hole is opened (see Figures 4.3 and 4.1). The rate of steel tapping is controlled by the inclination of the tilting platform and the quality of the steel is strongly affected by this control loop. The feed back loop in this case is the measure of the weight of steel inside the ladle. The variable ladle temperature, controlled by external pre-heaters, is also important, but the preheating step was not included in the scope of this project.

The technology trends analysis will cover the major design groups affected by the project:

- Construction and Layout
- Equipment
- Mechanics
- Power and Automation
- Maintenance
- Operation

The project followed some general guidelines, generated by previous strategic decisions of the company. By the time of the project, the company was developing a strategic plan for the whole specialty steel business and was still performing the analysis of the medium term scenario due to the recent market dynamics. Besides investing in a complete revamp of Gerdau Aços Especiais Piratini plants, there were the options of building another specialty steel plant in the center of Brazil or of buying specialty steel plants in Europe or North America.

The strategic guideline for the project was that the increase of the melt shop capacity at that time should be provided by electric arc furnace investment, because other major possibilities of production increase in the Gerdau Aços Especiais Piratini plant implied in a significant revamp of the melt shop.

The most critical change for capacity improvement that would trigger the complete change in the entire melt shop equipment is the ladle capacity augment. Looking at Figure 2.3 – AEP Production Flow, we can observe that the ladle receives liquid steel from the electric arc furnace, being then transported to the ladle furnace, vacuum degasser and continuous casting turret or ingot area. During the last years, the ladle capacity was being increased until the limit where the next step should be its radius increase. Any significant increase in ladle radius would cause a change in the upstream equipment, including the overhead cranes which transport the ladles, the ladle pre heaters, the refractory repair and mounting station and the design of refractory pieces.

The technology trends analysis covers the usual design groups in which the engineering projects are divided and also considers the impact of the respective constraints.

CONSTRUCTION AND LAYOUT

The detailed layout decisions are discussed in Chapter 6, but the set of alternatives were heavily constrained by the existing installations. Figure 4.1 – EAF General View shows an overview of the whole equipment, developed jointly with one potential supplier, to ease the comprehension. The main constraints to the construction work and layout decisions are described below:

- **Foundations**

The reuse of the actual foundations was one of the major constraints to the civil works. It meant that the weight of the new set of equipment should not be increased significantly.

- **Existing electric power installations**

In addition to the foundations, the electrical feeding system (transformer, high current bars and flexible cables) would be kept the same in the new project.

- **Auxiliary Systems**

Similarly, the existing auxiliary systems such as dedusting, carbon injection and measurement systems had their locations kept basically the same in the new project.

The construction of a totally new control room, as described in the scope of the project, targeted two major goals:

- Provide a safer environment for the operators, as well as improving cleanliness, acoustic insulation, space availability and furnace visualization.

- Create an alternative to reduce the downtime in the start up phase, since all construction services related to the control room could be initiated in advance.

The new control room presented an opportunity to apply new technologies to the electric arc furnace process related to the control room insulation. Although originally the construction of the new control room focused on sound insulation, we realized that the vibration was also significant. Specialized companies were hired to define the best alternatives for the new control room in order to meet the project objectives. As the control room insulation knowledge is not directly related to the process technology, the subject will not be discussed in this chapter.

Additionally, as there were no significant new technologies in civil works related to the electric arc furnace processes, the only improvements adopted were the use of concrete cure accelerators or pre-molded reinforced concrete profiles in the new installations.

EQUIPMENT

As described before, the electric arc furnace is result of an aggregation of equipment and the major ones are described below:

- **Shell**

The most successful constructive design of shells for electric arc furnaces consists of an upper shell with water cooled panels and a lower shell internally coated with refractory material. In the case of our project, to allow the complete replacement of the upper shell for maintenance reasons, it was designed in two separate parts (split type).

The technology challenges related to equipment encountered were:

- Using the same shell for the production of stainless steel and other steel grades:

The conventional strategy for stainless steel production at that time was the use of a dedicated spout tapping type shell, This kind of shell allows higher tapping inclinations, reaching up to 45 º, and the consequent better slag and hot heel control. The Gerdau Aços Especiais Piratini plant was already using this technology for the stainless steel production and could verify its effectiveness in the quality of the stainless steel and high alloy grades produced. The spout-type is not normally used to produce non-stainless grades of steel because it is not as efficient as the EBT (eccentric bottom tapping) - types and because of the refractory contamination caused by the alloys used in the stainless steel production and its quality risk for other steel grades. Before the project, the plant was utilizing three different shells: one spout-type for stainless and high alloy steel grades and two EBT-type shells for the other steel grades production. The EBT-type shell operates with reduced tapping inclinations, up to 15 ^{o}, due to the bottom tapping hole and valve design. The use of only one type of shell could bring the benefits of productivity and maintenance simplicity, but could significantly risk the compliance to product chemical composition and also lead to operational complexities.

- Use of partial steel / partial copper water cooled panels in the upper shell:

The use of copper instead of steel in the upper shell panels is becoming more and more popular. The reliable steel panels have reduced heat exchange gradient when compared to copper, limiting the specific power and specific production per shell volume. The competitive UHP (Ultra High Power) furnaces, with their high power densities, are migrating to the use of copper panels and thus avoiding the risks of high temperature operation points in the water cooled panels. The downside of the copper panels' utilization is their cost and maintenance requirements. As water cooled panels may be damaged during the normal operation of the furnace, there is a need for a higher level of maintenance for the copper panels (skilled welders and higher spare parts inventory). Above all production issues, safety is the main concern: leakage from water cooled panels is already a major cause of serious accidents in melt shops around the world. Undoubtedly there was a need for the higher power density possible in the new furnace due to the layout constraints, but the extremely variable range of scrap used was another major concern because the associated potential panel damage. The partial steel (top), partial copper (bottom) panels would provide a solution that minimizes the safety risks and improves the heath removal.

- Choice between "panel-cooled" or "spray-cooled" furnace roofs:

The spray-cooled roof is being utilized in the former electric arc furnace, due to its reliability and low safety risks. This type of roof does not employ pressurized pipes to cool it down, but instead uses internal water sprinklers, and the heat removal process is performed by changing water's physical state (from liquid to steam). The spray-roof design is more recent and complex than the traditional water-cooled panels design. The major advantage of the first one is the possibility of operation even with leakages, because the low water pressure prevents the leakage of large amounts of water and allows the postponement of maintenance interventions to more favorable periods. In this case, the water that leaks is far less dangerous, because the water evaporates before being trapped into the hot steel. The disadvantages are high frequency of maintenance interventions and system complexity. In the case of water cooled panel roof, although presenting simpler design and comparatively reduced maintenance interventions, even small leakages could stop the furnace due to the risk of panel explosion. Besides the simplicity of construction, this kind of roof design allows the operation with higher power densities, an extremely desirable feature in the project.

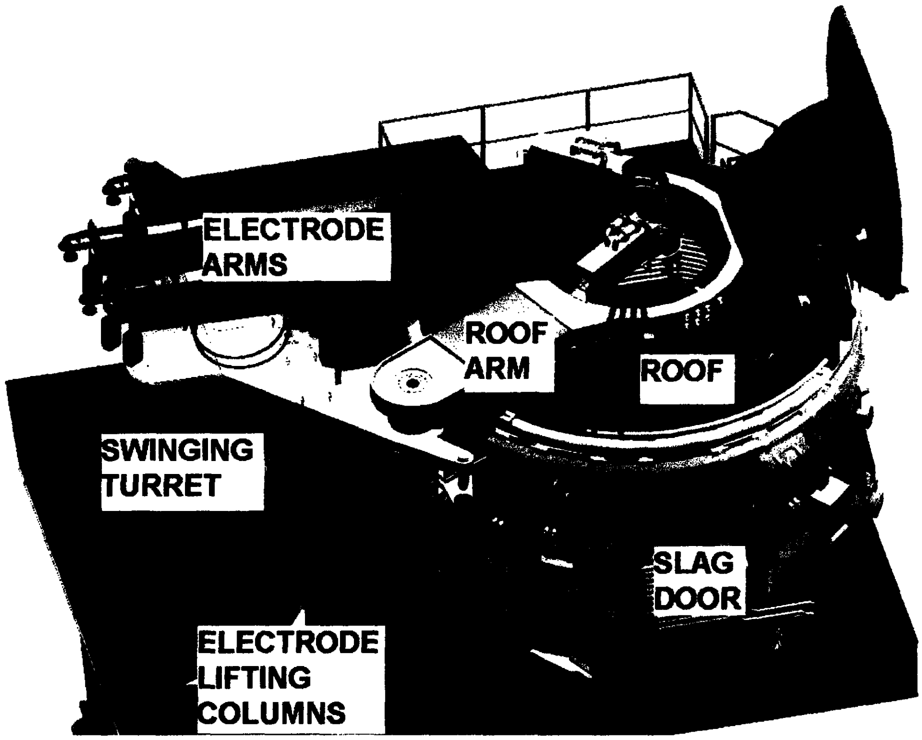
MECHANICS

In order to increase operational flexibility and consequently reduce operational delays, some of the most competitive electric arc furnaces were adopting design which allowed independent mechanical operation among the electrode columns and roof arm. Figure 4.5 – EAF Opening Movements shows a furnace view where we can see the main parts involved in these operations: the swinging turret, the roof and roof arm, and the electrode columns. Basically the proposed design permits the choice of coupling the roof to the turret rotating and lifting movement, enabling the furnace to remain covered by the roof when the electrodes are rotated. The major operational advantage is the possibility of electrode length adjustment or replacement with the roof closed, enabling the cleaning routines in the furnace roof to happen simultaneously. Also, the roof provides the furnace with thermal insulation from the external environment, allowing energy savings, pollution reduction and diminishes the molten steel oxidation.

The new design has clear advantages over the traditional joint movement design, but increases the mechanical complexity of the system, as well as the safety risks related to incorrect operations. The simultaneous operations involve auxiliary equipments to perform the activities, such as cranes, which are intrinsically dangerous for people in the furnace platform and increase the need of coordination.

Additionally, as the evolution of the electrode regulators is pointing to higher hydraulic operation pressures to allow higher response speeds, and the best performing systems are operating at pressures around 150 kgf/cm2, then this level of pressure was considered a natural choice for the new system. Although it is not uncommon to find industrial equipment operating at this pressure, the choice required unusual design requirements for the installation projects and assembling due to the aggressive environmental conditions in the furnace surroundings.

Figure 4.5 – EAF Opening Movements

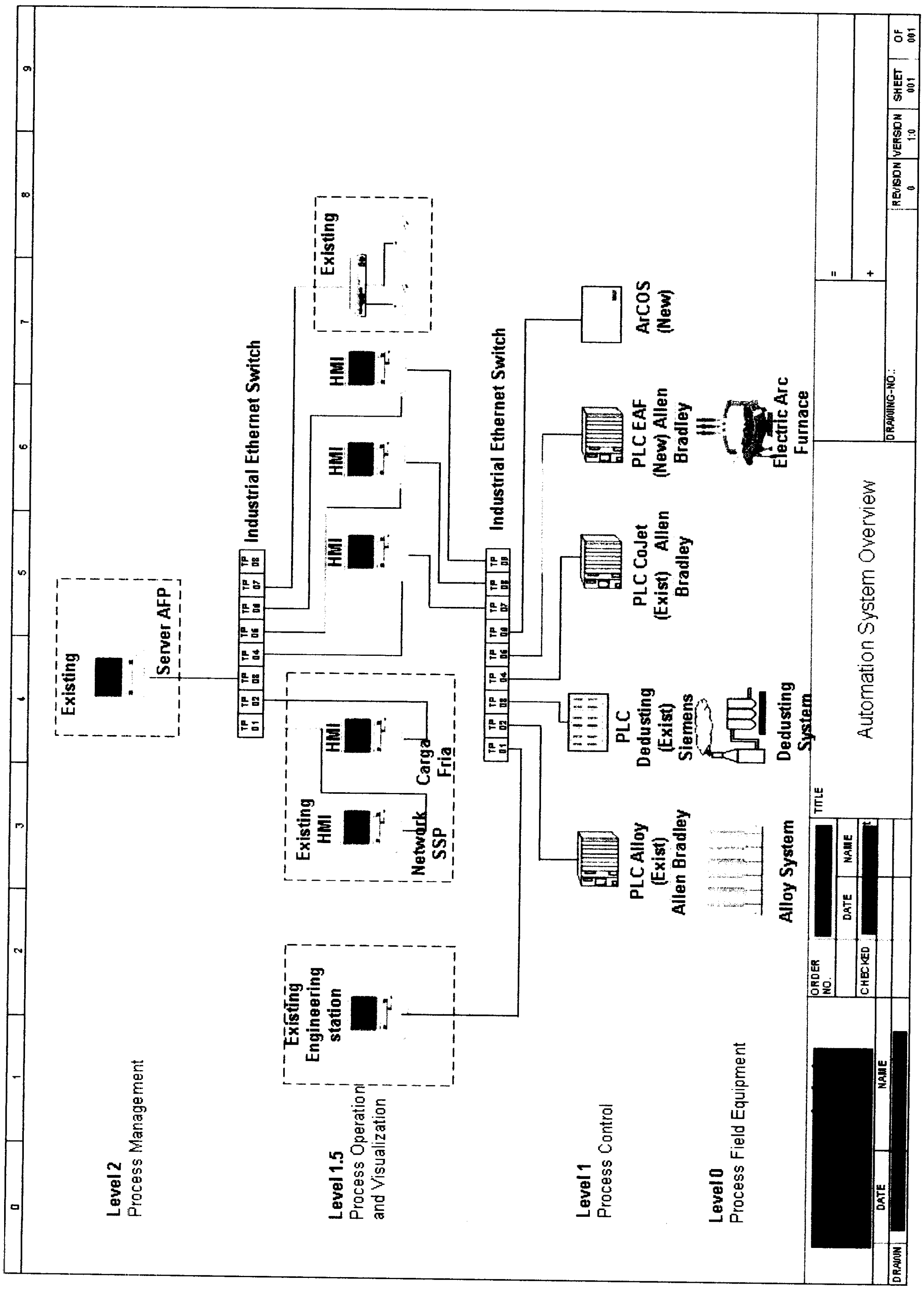


POWER & AUTOMATION

As described in the project scope, there was a need for integration among various different automation systems at various different levels, due to the existence of systems and equipment from different suppliers using different proprietary protocols.

The project presented challenges which required the joint development of an integrative solution among suppliers not accustomed to doing it. Figure 4.6 – Process Automation Layout illustrates the proposed configuration of the whole electric arc furnace automation system.

Figure 4.6 – Process Automation Layout



In order to achieve high productivity levels at extremely variable operational conditions, integration between the electrode regulation system and the electric arc furnace production planning system was necessary. Normally, advanced electrode regulators could operate with limited integration to supervisory systems, basically exchanging standardized recipes' information. But the dynamic of the Aços Especiais Piratini melt shop production processes provoked the need for a fully integrated automation configuration, allowing the alternatives of dynamic heat rescheduling and optimization and even manual operation on some occasions.

Besides the dynamic heat rescheduling and optimization, the fully integrated automation system could allow the implementation of a state-of-the-art control algorithm, called "foaming slag control". This control algorithm was under development by one of the suppliers at the time of the project implementation and aimed at energy and electrode consumption savings through the control of the level of foaming slag in the refining, modulating the carbon injection rate during this process step. Although a strong theoretical basis supported the development of this control system, there was no record of successful implementation. Also, as the system affects the liquid steel carbon content, it could risk product quality and would demand new operational routines from the operators or higher levels of automation control loops.

Although challenging, the automation could play a fundamental role in the expected return of the investment, through the simplification and flexibility of the future furnace operation.

MAINTENANCE

The project demanded a complete revision of the maintenance strategy in the melt shop. Due to the changes described in the items Equipment, Mechanics and Power & Automation, there was a strong need for skills development in the maintenance teams. For example, some of the new skills which would be necessary were:

- Specialized copper welders;

- Automation maintainers with an understanding of the new automation systems and tools;

- Mechanics able to work with stricter requirements related to hydraulic installations, etc;

Besides working towards the team qualification, other aspects of the maintenance strategies should be considered:

- Thorough spare parts inventory evaluation, including compatibility with existing spare parts or suppliers' products;

- Redefinition of the maintenance schedules and resources, due to the change in the melt shop scheduling;

Due to the electric arc furnace dynamics, the maintenance teams need to have a close interaction with the operational routines. They are critical players as trainers of the operational teams and contribute to the successful ramp up of the system.

OPERATION

Although the furnace operators were experienced in electric arc furnace processes, the dynamic of the new equipment required new understanding. The whole man-machine automation interface would be changed in order to make the learning curve steeper, but its fundamental concepts would be new for the operators and could surely affect the ramp up of the system and steady state performance.

SUMMARY

The search for new technologies resulted in many different options and choices, each of them implying a specific trade-off to be evaluated by the company. The technologies applied in electric arc furnaces are far from being standardized among the steel plants and there are innumerous cases of big failures in accomplishment of goals due to the applicability deficiencies. Although the technologic concepts are theoretically clear, the replication of results obtained in laboratories, simulations and even in some practical applications in steel plants, is not guaranteed. Additionally, delays in reaching the targeted performance could jeopardize the whole investment implementation and expected returns.

CHAPTER 5 - UNDERSTAND THE INTERNAL CAPABILITIES OF THE COMPANY

Specialty steel manufacturing has unique requirements related to its production, which the company has to consider when implementing new processes through engineering investments.

The assessment of Aços Especiais Piratini plant capabilities applies the Porter Five Forces model[2] as guidance and only the major aspects involved are considered. The evaluation was performed at company level and at melt shop level, where the capabilities include the electric arc furnace process.

INDUSTRY LEVEL (Specialty Steel Plants)

Projects implementation management:

The Aços Especiais Piratini engineering department has a solid record of successful project implementations, and is involved in a series of major investments in the plant's modernization.

The plant was initially owned by the state government and was acquired by the Gerdau Group in 1992. Since then, there has been a massive flow of investments to transform the plant into a competitive industrial unit through the most advanced technologies implementation. To illustrate, the amount of investment managed by the engineering department between 1992 and 2003, when the electric arc furnace project was implemented, reached more than 200 million dollars. The teams of project coordinators, designers and supporting staff were composed of experienced people which had being working for decades in the plant (some of them participated in the plant's startup), mixed with new employees brought by Gerdau Group after the plant's acquisition in 1992. The Gerdau Group, through its engineering committee, had been utilizing a comprehensive investment management system as shown in the Figure 2.2 – Investment

[2] Porter, M. E., *Competitive Strategy,* New York Free Press 1980

Implementation Flow, assuring method and consistency in the best practices application. As described in Figure 2.2, the quality of each investment is assessed through the evaluation of the benefits generation in comparison to the investment goals and through a detailed evaluation of the process of the implementation. In both cases, the Aços Especiais Piratini plant has been demonstrating outstanding results in comparison to its benchmarks in the steel industry for new process technologies development. Focusing on the melt shop production area, the Aços Especiais Piratini plant was the first steel plant in Latin America to employ the continuous casting process to produce specialty steel grades, playing frequently the role of the innovator in new process technologies implementation.

Technical Expertise

The most critical core capabilities in steel plants are related to the melt shop processes, where their development plays a fundamental role in the company competitiveness. In the case of electric arc furnaces, the main equipment utilized in steel production are very similar to those employed to produce common steel grades, but the technical expertise and process controls in a specialty steel arc furnace are by far more important.

As specialty steel grades present a great deal of diversity and strict targets of chemical composition, the metallurgic processes, as well as the process controls, must be extremely well developed and clearly defined to meet the product tolerance ranges. The R & D department and the team of process engineers are renowned for their accomplishments in specialty steel products development, with these capabilities considered some of the most important assets of the company.

New Process Technologies Implementation

Although considered a strategic capability by the company, excellence in the production process still remains a desired skill. Mainly in the melt shop area, deviations penalize heavily the yield of the production processes and consequently the production costs. The electric arc furnace has a considerable impact on whether the chemical composition requirements can be met.

The plant already implemented strict quality control programs such as TQC (Total Quality Control) and Six Sigma, but the overload of controls and process samples frequently overwhelms the operators, causing rework or generating process waste (scrap).

SUPPLIERS LEVEL

Suppliers of equipments

Due to the scope of the project, only established world class suppliers could be considered in the proposals evaluation. At that time, the Gerdau Group as a whole had considerable leverage even with these major suppliers of steel manufacturing equipment, because it was investing heavily in the upgrade of existing plants as well as the construction of a completely new steel plant. The leverage in this case considerably affected the dimensions of cost, quality and availability of equipment/systems.

Each major supplier developed some equipment and process specificities which normally are considered proprietary technology. In the case of process technologies, usually the suppliers provide the clients with basic process operation technology and develop jointly with the customers an optimized variation tailored to the client specific needs and constraints. During this phase of development, there is a constant flow of information which must be tightly controlled, because important process knowledge could end up being used by competitors who acquire equipment from the same suppliers.

Suppliers of Process Technologies

Process technology development was supported by partnerships with the local university. The plant has a long term relationship with this well regarded institution, which provides the company with qualified metallurgical engineers and important research programs.

SUBSTITUTES, NEW ENTRANTS AND CLIENTS LEVEL

As the project involved an internal change in the plant's melt shop, these three forces were analyzed adopting an integrated approach:

Substitutes and New Entrants:

The product from an electric arc furnace to the subsequent processes is liquid steel with specific temperature, homogeneity and chemical composition and has no viable substitution options in the case of the Aços Especiais Piratini plant

Clients:

The sole client of the electric arc furnace, as shown in Figure 2.3 – AEP Production Flow, is the ladle furnace. The process phase in the ladle furnace is called secondary metallurgy and it has well defined requirements related to the electric arc furnace.

CHAPTER 6 - IDENTIFICATION AND ASSESSMENT OF PROCESS TECHNOLOGY INVESTMENT ALTERNATIVES

PRODUCT PROCESS MATRIX

This chapter begins the assessment of process technology alternatives through the Product-Process Matrix tool, in order to evaluate the matching between the process technology choices made in the project and the product needs. The different process features are analyzed below to provide a framework to facilitate the process technology decisions' analysis.

Equipment

The entire electric arc furnace process cycle is called a "heat" and, to exemplify, 5674 heats were produced by the existing equipment during one year prior to the project implementation. Roughly 5% of that amount was employed in the production of high alloy and stainless steel grades utilizing the spout-type shell and the remaining production was obtained from the EBT-type shell.

The set of main equipment employed in the electric arc furnace process could be considered as general purpose equipment for steel industry, with auxiliary equipment added to the main equipment to provide process flexibility to match the product needs. Due to the main equipment's size, cost and complexity, normally few of them are found in each industrial plant. As the amount of equipment is strongly related to production capacity, usually specialty steel plants have less main equipment than common steel plants, although having more auxiliary ones because of process requirements.

As mentioned before, the electric arc furnace process needs to be flexible enough to accommodate 300 different grades of steel and to meet their strict quality requirements. The production of this broad range of steel grades with mostly general purpose equipment presents efficiency disadvantages, described previously in Chapter 4.

The production planning usually follows a sequence related to steel grade families, which are grouped due to their raw materials' needs and refractory contamination constraints. The steel families' grouping dictates the use of auxiliary equipment in the process and ultimately dictates the production cycle of the whole melt shop.

Operation and Maintenance

The electric arc furnace process requires teams with broad skills to perform the tasks, but the all operators must have a solid background in the metallurgic field. Due to the dynamics of the process, the operators must be able to perform adjustments according to the result of each process step. Normally less experienced operators execute activities such as physical inspections, cleaning, small repairs and process sampling at the shop floor level (furnace platform and auxiliary equipments). As long as the operators acquire experience, they are moved from the shop floor to perform more complex tasks related to the process's overall operation, such materials and heats planning, quality control activities and operational routines. These activities are executed at the control room level and involve a high level of interaction with the automation systems and demand a higher level of equipment knowledge in order to facilitate the equipment's troubleshooting.

The maintenance teams follow the same pattern, with less experienced personnel in charge of the inspection and repairing of field instrumentation and less complex equipment. The personnel who are based at the control room must possess a deep knowledge about information and automation systems and additionally must understand the metallurgical processes involved in order to interact with the operators for preventive and corrective maintenance activities.

Finally, activities related to planned operational or maintenance stoppages also involve additional teams, less skilled in the case of operational tasks, and very specialized in the case of maintenance tasks. The plant has a supporting structure to provide the melt shop with these labor needs.

Information Requirements

The process management requires information on production planning, tracking and scheduling. This set of information includes the on line production tracking of the whole melt shop, as well as quality results from process samples, which are sent to the laboratory to define process adjustment needs. At the process operation level, the information requirements are related to cold charging (raw materials) specifications, calculated from the product specifications, and raw materials inventory.

Figure 4.6 – Automation Systems Layout illustrates the integration needed among diverse information technology systems to manage, operate and control the electric arc furnace process.

It is worth mentioning that, in case of specialty steel plants, there is a trade-off between flexibility and productivity of the electric arc furnace. The utilization of different alloys and cold charging standards (combination of steel scrap, pig iron, lime, etc) to produce a broad range of steel grades leads to contamination of the shell refractory coating. For example, the production of high alloy or stainless steel grades strongly limits the subsequent scheduling of low alloy steel grades, due to the quality problems generated by the refractory contamination. There are two different approaches to dealing with these constraints:

- Changing of the upper and lower shells. The result is production stoppages due to the need for disassembling and assembling heavy equipment and consequent "cold" restarts.

- Scheduling the production of steel grades according to their tolerance to refractory contamination and the refractory decontamination rate. It is a complex planning task which avoids "cold" restarts, but could introduce serious production constraints.

Inventory

The basic inputs for the electric arc furnace process are energy, raw materials, sampling and refractory materials. All of them could be considered work-in-process inventories along with furnace output (liquid steel)..

Costs

As opposed to common steel plants, where fixed costs account for a significant part of total costs, the costs of the electric arc process in a specialty steel plant are largely variable. In the case of Aços Especiais Piratini plant the fixed costs accounted for less than one third of the variable costs at the time of the project implementation (23% and 77% of the total costs, respectively), a consequence of the products' high aggregate value.

Job or Part Costing

The costing of products was determined for each steel family. The steel grades with similar chemical composition (families) are produced in campaigns, employing approximately the same raw materials and energy inputs, and their costs are calculated by batch (campaign). Because of the demand seasonality in the specialty steel business and/or big melt shop planned stoppages, costing can be strongly affected by capacity utilization. When implementing engineering projects, the company also considered the impact of the related equipment stoppages on financial performance.

Manufacturing Process Summary

The electric arc furnace process presents characteristics which are a mix of job shop and batch models.

Trends for the specialty business at the time of the project suggested that the requirement would be more appropriate for job shop manufacturing process. As long as the Gerdau Group units continued to consolidate operation, the Aços Especiais Piratini plant would focus on a broader variety of products. Although it was considered a natural shift supported by the plant capabilities and could generate opportunities related to product decommoditization, the pace of this change would not significantly affect the production mix, at least in a medium term scenario.

The considerations about product maturity revealed that the Aços Especiais Piratini plant held an established brand reputation and the future growth in market share would mostly be limited by plant capacity constraints.

ROLE OF AUTOMATION

Process automation plays a critical role in the electric arc furnace and its evaluation considers four major issues: business, operation, social/politic and regulatory issues[3].

Business Issues

The company's strategic positioning pushed the process automation to a state-of-the-art level. The capability of providing the customers with a broad range of differentiated products, with quality assurance and rastreability, needed to be supported by a comprehensive automation system. The plant had achieved a brand reputation related to quality, which provided it with a competitive advantage over the competitors, and the enhancement of this skill was considered indispensable. As discussed previously in this chapter, the information requirements and process flexibility demanded an individualized treatment for each heat processed in the furnace, which is difficult to achieve without a high level of automation.

Although the labor costs in the furnace process accounted for less than 2% of the total costs, the company prioritizes safety as the first goal, and this policy is an important guideline for processes automation. The general definition was to reduce to the minimum the level of manual interference in the furnace process. At the time of the project, the most

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[3] Goldberg, Jeffrey M., *"Process automation in the biopharmaceutical industry: a critical discussion of decision making and implementation"*, MIT Thesis, 2001

advanced automation technologies could eliminate a broad range of manual operations, limiting them to indispensable sampling and inspection tasks, under safe and controlled environment.

Additionally, as the plant melt shop was operating at maximum capacity, the furnace process implementation and ramp up was critical to product availability and market share.

Operational Issues

On the operational level, the automation should provide product flexibility with repeatability, reducing the dependence of product quality on human decisions. Also, the automation system should provide the operators and process engineers with process data to improve their knowledge about the furnace process and the impact of their decisions in the whole melt shop operation. The process data should support the increase in processes yield and allow new product development with reliability and accuracy. Finally, as production increase was the major goal of the project, the automation system should improve the capacity of the operational and maintenance teams to troubleshoot the equipment through a broad and detailed monitoring system.

Social and Political Issues

As the melt shop is the main area of a steel plant and it is treated as such, the "cool tech" factor presented some attractiveness for the team involved in the project implementation. Also, the company's "engineering" culture always provided the melt shop with investments in new technologies to keep it among the most modern in the world. So the furnace operators and maintainers became used to new technologies implementations and the learning processes associated, and the engineering department was knowledgeable about the automation newest trends.

Unlike the case of many other projects, the main goal of this one was not related to cost savings, and the operation and maintenance teams did not perceive job security as major concern. The previous equipment was already heavily automated, but the lack of integration among the different automation systems caused an unnecessary degree of operational complexity. So, the teams were expecting operational simplifications, although they were aware of the fact that new skills would have to be developed in order to perform their jobs accordingly.

Additionally, the company used the project as an opportunity to develop the team skills, providing them with a comprehensive training program, including visits to suppliers' installations and steel plants inside and outside Brazil. The result was that all the teams could contribute to the decision making process.

Regulatory Issues

The major regulatory issue in this project was related to environmental aspects of the electric arc furnace process. The Aços Especiais Piratini plant decided to be certified in the ISO 14000 Norms and the electric arc furnace would be a critical process in the compliance to these international standards. Although the melt shop had its dedusting system for atmospheric emissions control already installed in the previous furnace, the challenge for the project would be how to operate the new furnace under stricter atmospheric emission constraints without loosing process efficiency. Formerly, the dedusting system operated with limited integration to the electric arc furnace, but in the new equipment the automation should optimize process efficiency and atmospheric emissions control.

EXPERIENCE CURVE

Although the Experience Curve tool was not utilized to help in process technology decisions in this project, its application would have been helpful due to the strong correlation with the project results. The Experience Curve was demonstrated to be a useful tool for understanding and estimating the behavior of this and future project implementations.

In order to perform Experience Curve simulations, certain premises were adopted:

- The marginal costs used to calculate the production cost for the first unit produced, measured in US$/t of steel, was assumed equal to the marginal averaged costs in the first month after the project startup in order to make the comparison of the learning patterns between the theoretical and the real cost curves.

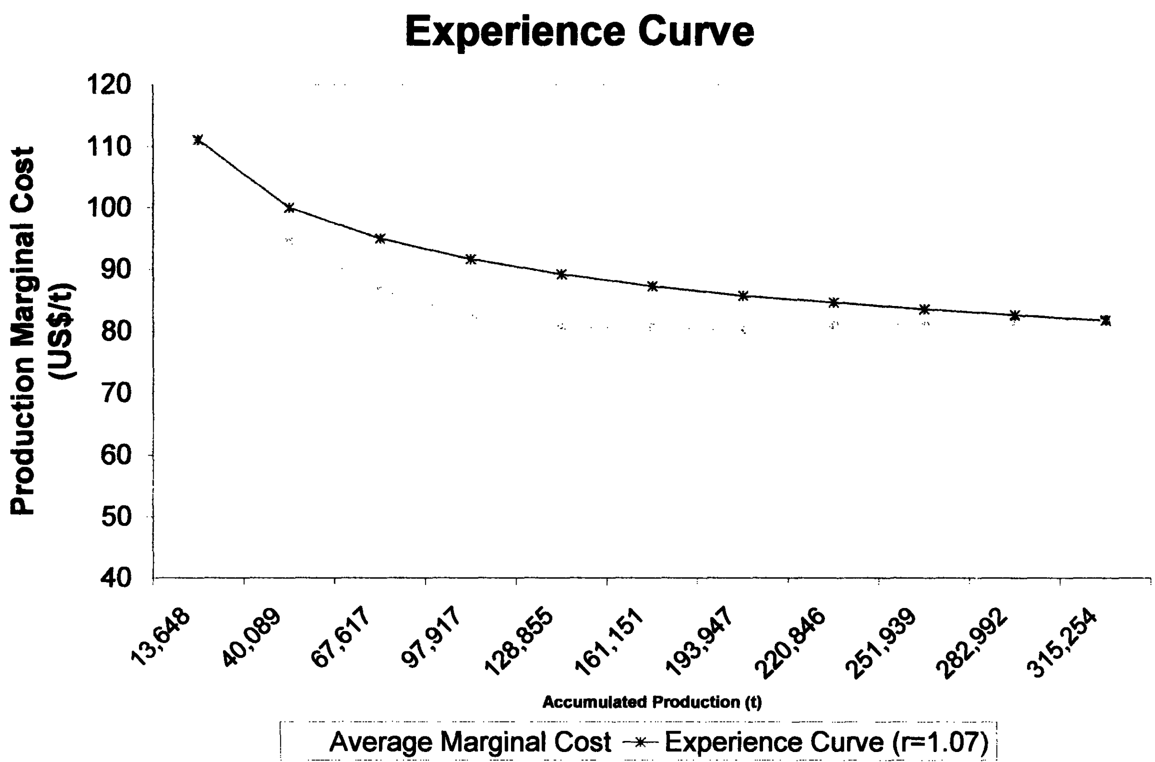
- According to the Boston Consulting Group[4], cost reduction between 20% to 30% at each doubling of produced volume represents actual learning in typical manufacturing environments.

Observations and Conclusions

Figure 6.1 – Experience Curve shows the results of one simulation, employing a rate of learning of 1.07, and the real behavior of the unit production cost after the project implementation.

[4] Henderson, B. D., *"The Experience Curve"*, Boston Consulting Group Inc., 1973, www.bcg.com/this_is_bcg/mission/experience_curve.html

Figure 6.1 – Experience Curve



This simulation was close to the real process behavior and utilized the rate of learning equal to 1.07, which means that the process would achieve 7% of cost reduction with each doubling of volume. This rate of learning is sensibly lower than the usual values experienced by the Boston Consulting Group and this result could be attributed to some causes such as:

- The electric arc furnace process already presented high level of maturity at the start up of this project and the assumption of no accumulated production at the start up could not be valid. The project features reinforce this hypothesis, because the electric arc furnace process did not change profoundly with the change of the furnace, which remained basically the same. Most of the auxiliary equipment and the operation and maintenance teams remained unaltered and the process management, operation and equipment operation routines did not change significantly.

- The utilization rate heavily affects the production costs, determining the degree of the furnace "hot" operation. As long as the furnace is kept running, the furnace shell's thermal inertia helps the step of melting the next cold chargings. Additionally, for a limited amount of time, some amount of liquid steel can be maintained inside the furnace shell after the tapping steps. This operational practice is called "hot heel" and considerably assists the melting steps of the next heats. Once the furnace is stopped for some amount of time, the furnace must be emptied to avoid the solidification of the former "hot heel" inside the furnace shell, reducing the energetic efficiency and process yield and increasing the time of processing the new heats.

When the production costs were analyzed for the simulation, some potential explanations were observed:

- The Brazilian currency suffered a considerable appreciation (7.5 %) compared to the U.S. currency. As steel is considered a commodity and it is traded in international markets, the U.S. dollar is the standard currency to measure costs in steel industry.

- Depending on the market where the furnace process inputs are traded, their costs could present high variability and could affect heavily the product costs. For example, the electric energy is the most expensive energy input in the furnace process (representing more than 40% of the total cost) and it price increased by 20%, measured in the Brazilian currency, in the year of 2004 (after the project start up).

- Finally, the main project goal was to increase the furnace production and the resources were focused on the reduction of processing time, reduction of delays and increases in the process yield through quality control improvements, with cost reduction considered a marginal benefit.

PROCESS TECHNOLOGY DECISIONS

The major process technology decisions made in this project were evaluated through the framework developed and shown in the Table 6.1 - Assessment of Process Technology Choices (next page).

The framework was developed in order to explicate the relationship between the process technology chosen and the dimensions of competitiveness affected by the company's strategic positioning, in order to align project definitions with the company's strategy.

As detailed in the Chapter 3, the Delta Model methodology describes eight possible strategic positions to be targeted by the company. Once the targeted strategic positioning is defined, the plans of future actions must be focused on the reinforcement of the strategic positioning, including the development of skills towards it.

Each strategic position should have its evaluation metrics, with these metrics grouped in the framework under five major dimensions:

- Cost
- Quality
- Availability
- Social/Politic
- Regulatory

Table 6.1 – Assessment of Process Technology Choices

GROUP	TECHNOLOGY	RISKS / TRADEOFFS	DIMENSIONS: COST	QUALITY	AVAILABILITY	SOCIAL/POLITIC	REGULATORY	DEFINITIONS AND ACTIONS
EQUIPMENT	Unique shell for sainless steel/high alloy grades and low alloy grades	Quality problems due to refractory contamination, operational complexity for stainless and high alloy grades in EBT shell, difficulties to fit to Job Shop production strategy			■	▨	▨	Development of process knowledge about refractory contamination, implementation of production planning system which considers contamination aspects, intensification of joint planning and forecast with main customers, development of specific process technology for the operation of EBT shells with stainless and high alloy steel grades
	Steel/copper water cooled panels in the furnace shell	High costs related to spare parts and complexity of repairing		▨	▨	▨	▨	Development of internal repairing capabilities and operational practices to avoid panel damage
	Panel cooled type furnace roof	Safety risks due to design concep		▨		▨	▨	Development of operational process practices to avoid damage
MEC	Furnace movements higher speed and redesign	Complexity of operations on the furnace platform and maintainers skills	▨	▨		▨	▨	Redefinition of activities flow on the furnace platform and training for the mechanics
AUTOMATION	Total integration among automation and IT systems supporting the furnace process operation	Integration according to the former process practices, incompatibility among systems, political issues involving operational and maintenance responsibilities, difficulties to fit to the Job Shop operation strategy		■	■		■	Strategic definitions about the integration needs, considering the involvement of customers, suppliers and internal teams. Tactical definitions about process routines, operational and maintenance responsibilities and possible contingencies in case of emergencies. Careful detaying of the development, implementation and rampup activities.
	Foaming Slag Control	Quality problems, high "tech cool factor" without measurable return, operational issues due to profound foaming slag concept changes and "not invented here" syndrom.	▨		■		▨	Jointly development of the new foaming slag process with the supplier, including contingency alternatives in case of bad results.
	Dedusting System Control	The compliance to the environmental regulatory aspects demands a different process operation strategy and increase operational costs.		▨	▨	▨	■	Clarification of the environmental standards with regulatory agency and definition of the compliance level. Definition of the process strategy and operational parameters to comply to the environmental standards.

LEGEND:

ACTIONS TO ENJOY THE TECHNOLOGY BENEFITS, TO ELIMINATE OR TO MITIGATE RISKS AND TRADE OFFS

- ■ NEED OF STRATEGIC-LEVEL DEFINITIONS/ACTIONS
- (blank) NEED OF TACTICAL-LEVEL DEFINITIONS/ACTIONS
- ■ NEED OF OPERATIONAL-LEVEL DEFINITIONS/ACTIONS
- ▨ NO INFLUENCE

The framework also identifies the relationship between each technological decision and potential risks and/or associated tradeoffs, in order to force the definition of countermeasures aligned to the elimination or mitigation of these risks and/or tradeoffs.

The last column is dedicated to the countermeasures definition, to be included in the project, according to the risks and/or tradeoffs uncovered and according to the hierarchical level of the decisions and actions.

The framework includes the following steps:

1) List in first (column "Group") and second (column "Technology") columns the engineering design group and the technology trends considered available for the project.

2) According to the technologies assessment performed in Chapter 4, define the potential risks or tradeoffs related to each process technology evaluated. Additionally, assess the fit of each technology to the process needs utilizing the Product Process Matrix and the Learning Curve.

3) Consider the impact of each process technology on the company's strategic positioning and the hierarchy of decisions and actions needed to: enjoy all potential benefits of the new technology, eliminate or at least mitigate its risks and tradeoffs. It is worth mentioning that the implementation of process technologies which have no positive impact on the company's strategic positioning, or conducts risks impossible to eliminate or to mitigate, should be discouraged.

4) Assign the respective definitions and actions to the aspects considered in item 3), according to their hierarchical level. These definitions and actions should appear as project tasks during its implementation.

SUMMARY OF THE CHAPTER

The framework developed to assess the process technology decisions unify the results of the technology trends assessment performed in Chapter 4 and 6, the company's strategic positioning defined in Chapter 3 and the company's capabilities assessment performed in Chapter 5 to define a set of actions which promote the achievement of all potential benefits from the process technologies adopted, and eliminate, or at least mitigate, the risks involved.

The results of the framework should be included in the project implementation plan and will be used to evaluate to what degree the company's project implementation practices comply with these results.

CHAPTER 7 - DEVELOP AN IMPLEMENTATION PLAN AND IMPLEMENT

The Project Management Institute (PMI) methodology, adopted by the Aços Especiais Piratini plant engineering department for project implementations, is a comprehensive project management system. The PMI methodology was conceived to assure reliability on goals achievement not only in engineering projects, but considers the term project in a broader sense.

The methodology considers eight major steps in the management of a project and each managerial step was detailed in such a way to provide a check list for the project managers. The major aspects of the methodology's eight steps are detailed below and all of them must be agreed upon by the teams participating in the project (engineering, operations, maintenance, safety and environmental).

The system does not limit the execution of tasks from different steps at the same time if there are no other limits (physical interference, for example), with the exceptions of the Step 0 – Conception and Step 7 – Conclusion.

Step 0 – Conception

This step basically validates the viability study which generated the project and formalizes the official start of the project to the involved teams. The conception step also includes in its scope a broader range of potential interferences with its performance, such as:

- Changes in actual equipment or systems, or even backlogs left by previous projects;

- Interferences in actual equipment and installations or in other engineering projects' scope in the same area;

- Interference in operational or maintenance tasks or opportunities of improvement in these tasks' performance;

- Definition of the implementation schedule according to the client area needs, start-up and ramp-up curves and metrics for performance evaluation;

- Safety: emergency plan definition, risks assessment and insurance needs, licensing needs and compliance to safety regulatory aspects;

- Environment: licensing requirements, generation, recycling and disposition of sub-products in compliance to environmental laws, easy inspection access for internal or external audits, environmental risk assessment and emergency plans.

Once the scope, budget and start-up date are defined and recorded, the projects' management software "freezes" the information, asking for approval from superior instances in case of any deviation. Overrun in the budget items, startup date, or increase in scope are considered deviations.

Step 1 – Detailing

This step works with the project documentation. Its final deliverable for certification includes the detailed design and the definition of the operational, maintenance, safety and environmental standards.

The main items considered in the check list are:

- Update of the design documentation, according to international and internal standards;

- Appropriateness of information from the automation systems;

- Adequacy of the equipment design for maintenance, considering accessibility and availability of national parts suppliers;

- Definition of spare parts, their compatibility to the actual spare parts inventory and storage requirements;

- Training plan to the achievement of desired skills for operation and maintenance teams;

- Needs of specific operational and maintenance techniques or tools;

- Acceptance of the subcontractors' qualifications (for design, assembling and start up);

- Safety: specification of fire detection and automated firefighting systems, ergonomic design of the for operation, lock in safety systems for operation and maintenance interventions in the equipments and emergency plan;

- Environment: definition of the residue management plan and the start of the licensing process with the environmental agencies.

Step 2 – Procurement System

The general scope of this step is to assure that all project needs were included in the contracts with the suppliers and that the responsibilities were clarified. The deliverable for certification in this step is the signature of all contracts with third parts.

The major items considered in the check list are:

- Training for operation and maintenance teams contracted;

- Assembling and start up supervision contracted, as well as the spare parts;

- Update of documentation "as built";

- Insurance contracts signed;

- Safety and Environment: equipments and trainings contracted.

Step 3 – Fabrication/Construction

This step deals with equipment and systems which will be installed during the project implementation. Its ultimate deliverable is the equipment or systems received and approved at the company's installations.

The check list in this step addresses:

- Fabrication according to updated and approved specifications;

- Execution of follow up inspections during the fabrication;

- Highest possible degree of integrated testing and pre-assembling in the manufacturers' installations;

- Observation of handling and transporting requirements, including applicable insurance warranties.

Step 4 – Installation works

This step covers the execution of infrastructure works required and the installation of the equipment and systems. Its deliverable for certification is the conclusion of the equipment's installation and testing.

The major aspects considered in the check lists now are:

- Availability of utilities for installation, such electric energy, grounding, illumination, cooling water, etc;

- Activities of leveling, alignment, pipes fluxing, check of electric connections, etc;

- "As built" documentation generated;

- Lubrication activities performed;

- Integrated cold and hot tests when possible;

- Definition of the detailed startup procedures and pre use check lists and procedures;

- Safety: identification and warning signs in dangerous areas and for dangerous equipment, including underground installations;

- Environment: management of residues generated during the installation works.

Step 5 – Start-up

The start-up phase focuses on the system performance and the solution of the problems uncovered during the start-up activities. Its deliverable is the equipment operation and an action plan to solve the backlog list generated.

The check list looks for these main aspects:

- Detection of performance deviations against the plan and their analysis;

- Record of improvement opportunities;

- Establishment of a failure treatment system, gradually transferring responsibilities for the operation and maintenance teams;

- Action plan definition for the solvency of the backlog generated;

- Operational and maintenance procedures revised, in “as built” versions.

Step 6 – Supervised Operation

The supervised operation step covers the aspects of the process ramp-up. Its deliverable is system acceptance by the client area (operation and maintenance teams).

The major items observed in the check are:

- Solution of the backlog list;

- Contracts with suppliers concluded;

- Start of warranties coverage period;

- Storage of all documentation at the company’s archives and appropriate electronic servers;

- Execution of internal maintenance audit;

- Safety and environment: register of all procedures in the company’s quality management system.

Step 7 – Conclusion

The conclusion of the project occurs when the planned performance was achieved and the project has no backlog list for the engineering department. After the conclusion of the project, all expenses generated by the new system accrues to the production area cost center the amount invested during the project implementation begins the depreciation process.

SUMMARY OF THE PMI METHODOLOGY

The PMI provides a very comprehensive methodology for managing project implementation, assuring integration with other managerial systems adopted by the company.

In addition to the PMI methodology, the Aços Especiais Piratini plant engineering department employs specific software to handle the implementation tasks and their linkages, as well as the resources involved in their execution. The software utilized is the MS Project (from Microsoft Corporation) and the teams of engineers and designers are familiar with its utilization, considering it an indispensable tool to prioritize the execution of planned tasks.

Although the technical quality of the solutions developed during the project implementation could vary according to the teams' and suppliers' technical expertise, the customization of the PMI methodology for engineering projects strongly supports the technical aspects of the implementation through the adequate responsibilities and milestones identification.

After the adoption of the PMI methodology in engineering projects, the performance of implementations measurably increased, attesting to the robustness of the methodology.

ADDITIONAL CONSIDERATIONS

The scope of the furnace capacity increase project, as described in Chapter 2, presented certain constraints, which prevented the consideration of major changes in melt shop production processes.

The metallurgical process in the electric arc furnace did not change with the installation of the new equipments and systems, but features which strongly increased process flexibility were added to match the strategic needs described in Chapter 6.

If we consider the electric arc furnace process, the degree of scalability was heavily constrained with project implementation, because the physical limits of the installations were reached. To illustrate a major constraint, the foundations of the furnace platform will not allow other increases in shell size and weight without a complete reconstruction. Without a radically new technological development, the alternatives of production increase will be limited to fairly incremental steps with the installation of new and more productive auxiliary equipments, such as oxi-fuel burners, higher powered furnace transformer, etc.

Considering the three critical issues in new process technologies, according to Maffei and Meredith[5], the implementation plan could be evaluated as following:

- Role of the operators:

Operator methods were designed to be consistent with the old ones in this new implementation. For example, the failure treatment system adopted plant-wide was integrated with operational level automation in order to automatically generate requests of action when failures in the equipment occurred. Also, all new equipment was registered in the plant maintenance systems, automatically establishing the routines of inspection and maintenance for the operational and maintenance teams. Finally, during the supervised operation period, the operators and maintainers were trained to improve their problem solving skills in the new equipment and, together with the suppliers' personnel, perfected the operational and maintenance plans and routines.

- Structure of supporting planning systems:

Again the automation played a fundamental role in the integration of the supporting systems with the new technology. Many in house developed planning systems were rewritten in order to be integrated to the new planning system.

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[5] Maffei, M. J. and Meredith, J., *"Infrastructure, and flexible manufacturing technology: theory development"*, Journal of Operations Management, 13, 1995

Special dedication was given to the production sequencing due to the quality risks that could be generated by refractory contamination. During the startup period, the operation teams rapidly developed a comprehensive knowledge about contamination risks as a function of the presence and quantity of each chemical element contained in the heats produced. This knowledge allowed the development of a "decontamination" cycle through the production of specific grades of steel less subject to contamination after the stainless and high alloy steel grades' campaigns. The rules of the "decontamination" production cycle were included in the production planning and scheduling system and there was no occurrence of quality problems due to cross contamination since that cycle development. This achievement supported the operation with only one type of shell for any steel grade and generated benefits such as flexibility of production, reduction of the stoppage times due to shell changes, standardization of equipment and reduction of spare parts inventory.

- Integration of the technology with the organization:

The project did not influence product characteristics and it was treated as an equipment substitution by other plant areas, such as Sales and Marketing. The implementation plan did not consider opportunities of leveraging the increased production flexibility and tracking.

CHAPTER 8 - ASSESSMENT AND RESULTS MEASUREMENT

The management system previews an evaluation step for each project after its conclusion.

Table 8.1 – Investments Conclusion and Implementation Quality Assessment shows the formal evaluation method, which requires the participation and agreement with all teams affected by the project, as well as the recording of any pending tasks and related responsibilities.

The overall benefits evaluation is performed below:

Item	Measure	Plan	Real
Melt shop production increase	t/month	3,000	3,149
Tap-to-tap	min/heat	70.8	69.66
Electrode consumption	kg/t	2.4	2.74
Electric energy consumption	kWh/t	395	407.3
Refractory consumption	kg/t	3.4	3.23
Maintenance costs	US$/t	9.0	10.9

Although not achieving the totality of planned goals, the project exceeded the forecasted production volume and proved to be a successful example of project implementation. The results for performance evaluation were taken from a three-month measure performed after the conclusion of the implementation (end of the supervised operation), which continued to improve after a longer operation period. This fact could be indicative of ramp up improvement opportunities.

Table 8.1 – Investments Conclusion and Implementation Quality Evaluation

IA	TITLE:

COORDINATOR:	DATE	PARTICIPANTS
CLIENT:		

1) Please include any comments in "Weak/Strong Points" fields

2) Grades <= REGULAR need justification included in the "Weak Points" field

ITEMS	PLAN	REAL
Startup (mothe)		
Conclusion (months)		
Budget (US$ 1000)		

	BAD	UNSATISF.	REGULAR	GOOD	EXCELLENT	NA
I. VIABILITY STUDY						
01. Quality of proposed solution						
02. Proposed budget viability						
03. Proposed delivery viability						
II. IMPLEMENTATION						
COORDINATION						
04. Knowledge about processes/equipments						
05. Efficacy of meetings						
06. Quality/Flow of information						
07. Attendance of client area requests						
08. Problem solving efficacy						
09. Operation and Maintenance involvement						
QUALITY OF DOCUMENTATION						
10. Mechanic design						
11. Civil design						
12. Piping design						
13. Power/Automation design						
14. Operation/Maintenance manuals						
CONSTRUCTION WORKS AND ASSEMBLING						
15. Mechanics						
16. Piping						
17. Construction works						
18. Power/Automation						
19. Safety/Environment compliance						

	BAD	UNSATISF.	REGULAR	GOOD	EXCELLENT	NA
STARTUP/SUPERVISED OPERATION						
20. Training						
21. Suppliers' technical expertise						
22. Engineering department supporting						
23. Level of interference in production						
EQUIPMENTS/INSTALLATIONS						
24. Performance/Reliability						
25. Quality/Finishing						
26. Maintenability						
27. Compliance to safety/environmental standards						
ACCOMPLISHMENT PLAN X REAL						
28. Delivery real x authorized						
29. Budget real x authorized						
30. Scope execution						

a) Unit points	2	4	6	8	10	-
b) Number of checks						
c) Total points (a x b)						-

Final Assessment

	Points	Concept
Sum of points: / Number of items		

Bad: 2.0 a 3.0 Unsatisf.: 3.1 a 5.0 Regular: 5.1 a 7.0
Good: 7.1 a 9.0 Excellent : 9.1 a 10

STRONG POINTS	

WEAK POINTS	

The major results of the implementation process formal assessment, according to the adopted methodology, are presented below. The discussions at the operational level and technical details were omitted to keep the focus on the relationship between the results of the implementation process and the process's strategic needs. The ultimate objective of this assessment is to verify the degree of alignment that the project implementation methodology presents towards the company's strategy, in order to highlight the opportunities of improvement and ease the recommendations definition.

1) VIABILITY STUDY

01. Quality of proposed solution

The solution proposed presented a high degree of consistency with the process needs, including aspects of innovation and process flexibility which fitted the company's positioning. But the viability study did not consider the strategic decisions that should be performed in the process of integration of Automation and Information Technology systems which supported the production scheduling and planning. The integration process plan replicated the tactics which were being practiced before the project implementation, without leveraging the new possibilities or considering new process needs. Additionally, the complexity of integration between the new and old equipment was not understood. Neither was the desired level of environmental regulatory compliance related to atmospheric emissions analyzed in detail.

02. Proposed budget viability

The proposed budget was adequate to meet the proposed scope of solution, if the appreciation of the Brazilian currency in comparison with the U.S. currency was not considered. The overrun of the project budget stayed within the acceptable limits defined by the company (less than 10%).

03. Proposed delivery viability

The proposed time to implement the project would have been adequate for its scope, if the issues involving the integration between the automation and IT systems were included in the initial viability study.

Normally, the melt shop would have stopped in December and provision for new equipment was taken place then. Because of market changes this had to be postponed.

2) PROJECT IMPLEMENTATION

2.1) COORDINATION TEAM

04. Knowledge about processes/equipment

Considering the different expertise needs for the project implementation, the coordination team successfully involved the plant experts in each field (metallurgic, automation, energy, etc) to leverage the overall knowledge about the equipment and process. The clear definition of responsibilities among the coordination and supporting team members helped to orient them towards the project goals.

The people who could help in strategic decisions were not involved sufficiently.

05. Efficacy of meetings

The meetings used a formula which has being working well to save everyone's time: people who were asked to attend the meetings were those who would deal with its problems. The meetings were used for working purposes and did not have fixed audience. General information was communicated through specific meetings.

06. Quality/Flow of information

The process implementation methodology employs a tool called "Matrix of Document Circulation", which defines the responsibilities for each document generated in the project implementation, considering areas of expertise and the level of responsibility (information, revision, approval, etc.). This tool assures the continuous flow of information to the right people involved in each activity of the project implementation.

07. Fulfillment of client requests

The project scope confirmed the set of tasks in the implementation. Additional requests outside of the project scope were also accepted, but the client was charged for those. This general guideline acted as a filter to the client requests and as a prioritization tool to help in the reduction of the amount of work to be done.

08. Problem solving efficacy

The coordination team managed the available resources to solve the problems which appeared during the implementation, showing good prioritization capabilities. Thanks to well specified contracts with suppliers, their productive participation in problem solution tasks was assured.

09. Operation and Maintenance involvement

The involvement of the operation and maintenance teams through the division of responsibilities provided an effective integration, eliminating relationship barriers and misunderstandings about the project priorities. Although integrated in the project implementation activities, the maintenance teams lagged behind in building their skills related to the automation systems, due to the late definitions about the integration processes. This deficiency was addressed after the system startup.

2.2) QUALITY OF DOCUMENTATION

10. Mechanical design

As the mechanical design was performed basically by one big supplier with its proprietary technology, the quality of documentation was satisfactory.

11. Construction design

The construction work for engineering projects is usually outsourced to local and well known suppliers, and is supervised by an internal coordinator with expertise in the field. As the construction work presented no major complexities and the delivery of documentation is a formal milestone before payment of contracts, the quality of documents was satisfactory enough.

12. Piping design

As piping design presents a high level of complexity and interface with existing installations, the integration between the suppliers and internal teams is critical. As the main supplier outsourced non-core equipment delivery and the plant engineering department also outsourced the piping interface design, the goal of a high level of integration was not achieved. The result was an unsatisfactory quality of design solutions and poor documentation detailing.

13. Power/Automation design

As mentioned before, the lack of strategic definitions related to integration issues caused high levels of rework and on-field design definitions during the startup. As was the case for the piping design, the integration software development was outsourced by the supplier and the electric project was outsourced by the plant engineering department. The high degree of integration needed required the use of several different suppliers and created points of friction and problems related to the division of responsibilities, diminishing the quality of the documentation generated.

14. Operation/Maintenance manuals

Due to the supplier's experience with the system, the quality of operation and maintenance manual was adequate. In the case of process control and operation, the manuals were developed on-site during the startup and were a fair representation of the real operation tasks in the process.

2.3) CONSTRUCTION WORK AND ASSEMBLING

15. Mechanics

Due to the supplier's experience and assembling supervision, the mechanical installations presented an adequate quality.

16. Piping

The quality of the piping installations was strongly affected by the quality of design. Although following all pertinent standards for piping assembling, the design choices adopted during the design phase and the level of rework jeopardized the overall quality of the installations.

17. Construction work

Influenced by the lower degree of complexity required in the project, the construction work presented a very good quality. It is worth mentioning that, to avoid the long periods required to cure cement parts, the engineering department adopted an "external setup approach", employing pre-molded concrete reinforced pieces as often as possible to be assembled on site.

18. Power/Automation

The many design deficiencies mentioned before caused rework and delays. The many on-site changes during the startup also affected the quality of operational and maintenance troubleshooting. The system presented atypical levels of operational and maintenance delays, which limited the achievement of better process performance and lower operation and maintenance costs.

19. Safety/Environment compliance

All assembling tasks and construction work followed the standards defined by the company's safety and environmental policies.

2.4) STARTUP / SUPERVISED OPERATION

20. Training

The training process should begin earlier. Not all the teams presented the same level of understanding of the new system production management, operation and maintenance. Mainly the quality of automation projects and the late availability of manuals affected this item.

21. Suppliers' technical expertise

Even though the supplier was very capable, its suppliers were not as capable, which negatively influenced the project.

22. Engineering department supporting

The engineering department was very supportive, demonstrating experience and skill in project implementation through a consistent methodology.

23. Level of interference in production

The high level of planning during the execution of the implementation tasks contributed to the low interference in production activities. The implementation tasks employed simulation tools to reduce stoppage time and unexpected situations.

2.5) EQUIPMENT / INSTALLATIONS

24. Performance/Reliability

In general, all new equipment presented satisfactory performance and reliability. The reliability of the planning system was jeopardized by the integration problems, generating quality problems due to the wrong cold charging specifications. This problem was directly related to the lack of definitions mentioned in the item 01. Similarly, the existing dedusting system did not operate well with the new furnace process, sometimes limiting the production capacity due to environmental restrictions.

25. Quality/Finishing

Although the equipment and installations followed all pertinent standards for fabrication and assembling, there was still room for improvement in installations.

26. Maintainability

The equipment was projected to provide a good degree of maintainability, but the installations lacked this feature. The technical decisions adopted during the design phase did not favor accessibility for performing maintenance tasks.

27. Compliance to safety/environmental standards

The equipment and installations presented adequate compliance to safety and environmental standards. The compliance to environmental atmospheric emissions' standards sometimes limited the system performance.

2.6) ACTUAL VERSUS AUTHORIZED RESULTS

28. Delivery project time: actual versus authorized

The planned plant stoppage period to perform the final assembling tasks and startup had to be postponed due to plant market strategies negatively, impacting the pay back time of the project.

29. Budget: actual versus authorized

The approved budget was adequate for the proposed scope.

30. Scope execution

The proposed scope was executed in totality. It is worth mentioning that the plant had to invest in improvements of the melt shop dedusting system to facilitate the compliance to atmospheric emissions standards, with negative Net Present Value (NPV).

CHAPTER SUMMARY

Although successfully achieving the major goals, the project implementation process presented some deficiencies that could have risked this success or at least prevented a better performance.

As in the beginning of the project the company did not define strategically the needs of integration between the new and old Automation and IT systems and many related problems occurred during the implementation steps. These problems generated at the strategic level were mitigated or solved in the tactical or operational level, due to the capabilities of the coordination and implementation teams, supported by the implementation methodology.

The methodology of project implementation effectively helped the success of this project, but it demonstrated some important constraints. The proactive approach presented was limited to the operational and tactic levels, where the methodology is effective to anticipate problems, avoiding their occurrence or minimizing their effects. At the strategic level, a reactive approach was observed, and this was the focus of actions in the correction of existing problems. At this level, the methodology only allows the most efficient solution to problems.

CHAPTER 9 - CONCLUSIONS AND RECOMMENDATIONS

Table 6.1 – Assessment of Process Technology Choices developed in Chapter 6 and the project implementation evaluation were the main tools employed to draw conclusions about the effectiveness of the project implementation methodology, which has been applied by the engineering department of the Aços Especiais Piratini plant.

The analysis tried to keep its focus on systemic and strategic aspects of the methodology in order to make them replicable and to ease the applicability to other plants in the Gerdau Group. As the methodology is being standardized across the plants' engineering departments, the systemic approach will be supported by a formal process of communication and will contribute to the group organizational learning process as a whole.

The major conclusions drawn from the application of the analytical framework developed and the project evaluation are described below.

CONCLUSIONS

- The project management methodology applied to engineering projects provides a robust tool to their implementation, demonstrating a comprehensive coverage of all tactical aspects involved.

- The performance of the implementations is assessed according to the strategic goals of the projects, with all teams contributing to this assessment process.

- The methodology of project implementation includes the assessment of results obtained in the process of implementation, establishing a formal learning tool for the next projects.

- The methodology is formalized through a set of documented standards, unified under an official management system, which assures repeatability and uniformity.

- Additionally, the teams' technical capabilities are leveraged to a company-wide effort through the formal learning process delivered by the methodology.

- Although the methodology conception phase provides a re-evaluation of the project alignment to the company's strategic positioning, it often presented an inward looking bias. Frequently, the effectiveness of the feed back process is limited to the tactical level of analysis as the process does not address strategic issues.

- Management participated actively in the definition and approval of the company's strategic plan, including the approval of the projects' viability studies. Nevertheless, financial thresholds restrict strategic discussion by limiting the projects provided by the viability studies to the company's strategic plan. Hence, projects with important strategic implications (positive or negative), but lower investment levels, could be approved at lower levels of the organization.

- The application of the framework developed for the assessment of process technology choices provided a comprehensive vision of the link between the company's strategy and its implementation through engineering projects. Additionally, the assessment defines the actions which should be performed when the project is implemented, establishing a proactive approach at the strategic level of decision-making and avoiding unnecessary rework or decisions at the tactical and operational levels.

RECOMMENDATIONS

As mentioned above, the recommendations provided will be kept at the process and strategic levels in order to be standardized throughout the organization; technical or operational recommendations are out of the scope of this work.

The assessment of technology choices and the evaluation of the implementation process of the investment aimed at increasing the capacity of the electric arc furnace uncovered a deficiency in the linkage between the strategic and tactical level.

According to the potential flaws detected in the actual investments implementation flow, it is recommended that the whole company adopts the improvement opportunities as shown in Figure 9.1 – Investments Implementation Flow Revised in order to formalize the changes.

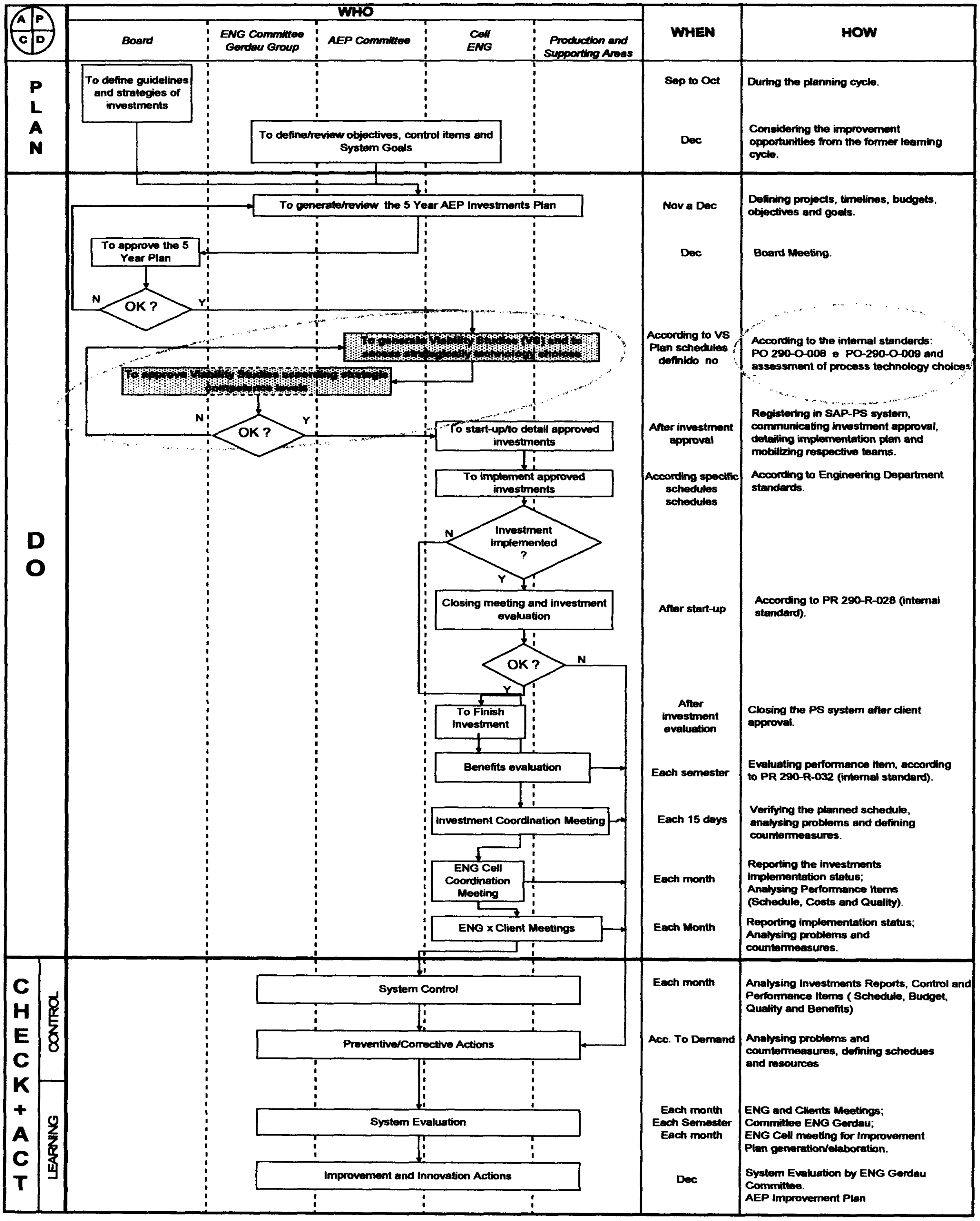
The improvements are highlighted in red and are described below:

- The generation of viability studies includes the technology choices assessment and it is formalized with the plant's committee, in order to check the strategic alignment before the board's approval. The responsibility for this task lies not only on the engineering department, but now it is shared between the engineering department and the plant level committee.

- The assessment of process technology choices should employ Table 6.1 – Assessment of Process Technology choices, which should be included in the company's documentation system.

- The approval or rejection of viability studies is now performed according to the strategic relevance of the projects. The plant's level committee should approve projects with strategic implications limited to the plant and the company's board should be in charge of the approval of projects with company or business unit-wide implications. The role of the group level engineering committee should be the technical evaluation and benchmarking for plant-wide projects and technical support for the board in technical issues for projects with company-wide implications.

Figure 9.1 – Investments Implementation Flow Revised



Remarks Preventive/Corrective actions, generated by the Control and Learning System Processes, are identified and implemented in the "ACT" step of the PDCA cycle.
Preventive/Corrective actions are related to the "DO" step (System Execution).
Improvement actions covers the whole PDCA cycle

- The recommendation at the system level is to include in the project implementation methodology, in the Procurement Process (step 2), the need of strategic alignment between the process technology's alternatives for the project and the plant strategies. The alignment could be accomplished through the discussion of the framework developed for assessment of process technology choices. Now, besides the technical specification, the procurement department will have a priority definition to guide its negotiation strategies.

- Analogous to the competence levels for viability studies approval, the procurement department adopts financial criteria to define which hierarchical level will participate in the negotiation processes. The task is to redefine these criteria by adding the strategic relevance criterion, as recommended for the viability studies approval process.

Figure 9 – Investments Implementation Flow Revised and the recommendations above do not show explicitly two benefits obtained by the company due to the recommendations adoption:

- In addition to the project goals approval, now the project strategic implications are discussed before the project is formally begun, alleviating pressures over the investment coordinators to keep the delivery time and budget even if important strategic issues are not being addressed. It is important to mention that the incentive system is closely attached to the budget and delivery time of the investments' implementation.

- During the negotiation process with suppliers, frequently strategic bargains are not included as negotiation alternatives because the procurement teams do not have enough information. If the engineering departments were able to provide the procurement department with a strategic access to the technologies involved, the results of the negotiation should be improved. For example, the deal with the main supplier of equipment and technologies included the delivery of the Foaming Slag Control system and it never operated in a satisfactory way. If the procurement department had access to the technology assessment results, the strategic choices would be the inclusion of a redesign and the optimization of the planning and scheduling system, or improvements in the dedusting system to facilitate the operation at lower levels of atmospheric emissions.

ADDITIONAL RECOMMENDATIONS

The recommendations above were elaborated according to a strategic perspective of the organizational design. If the three perspectives on organizations[6] are considered, there is a need for the addition of the political and cultural perspectives to the analysis. The Gerdau Group is a multinational company with presence in the Americas and Europe and the replication of the recommendations outside the headquarters in Brazil would be more effective if they were not limited to the strategic perspective lens.

There are two different ways to approach the implementation of the recommendations above:

- To follow the implementation of the PMI methodology for engineering projects: as the methodology is unevenly spread across the different units at the Gerdau Group and if the adoption of the recommendations is considered a tool to perfect the project management system, they can be inserted into the methodology and implemented jointly with it.
- To redefine the responsibilities and procedures as described in the Figure 9.1 – Investments Implementation Flow Revised and enjoy the benefits generated by the strategic alignment of the projects' implementation to the company's positioning.

Although the first approach would bring additional benefits, the PMI methodology implementation would take longer. The second approach is the recommended one.

It may be perceived that the recommendations could affect the division of

[6] Ancona, D. et al., *Three Perspectives on Organizations*, South-western College Publishing, 2005

responsibilities among many levels and departments and, in order to ease the recommendations implementation according to the political perspective of the organization, some additional suggestions could be included:

- Top-down: as the company's board interacts with the units around the world, it could establish the new standards practice as a condition for projects approval. The board has institutional power to implement the measures.

- To align the practices to the units' interests, the company could show the benefits obtained by other units in the recommendations practice at the leading units.

- The rewards or recognition systems could be attached to specific results of the new standards implementation.

- One unit which achieved compromise with the implementation and with credibility among the others could be used as a pilot.

- A charismatic or "high flyer" manager, with successful track records, could be chosen to implement the recommendations.

- If potential "blockers" can not be turned to supporters, they should be moved to other positions, and supporters should be chosen to help the implementation.

Looking at the organization through the cultural perspective, some recommendations could be added to the implementation process:

- The identity with organizational subcultures could be leveraged by, for example, establishing an implementation team of engineers, mixing experienced users of the method with inexperienced ones. The engineering subculture could establish an identity and eliminate barriers against the implementation.

- The company has a strong identity in Brazil which identifies the employees with its culture, but it does not occur abroad. The implementation could be attached to some cultural values recognized in each country, such as the benefits for the country, the competitiveness that could be achieved, etc.

SUMMARY

The six-step plan for developing a technology strategy[7] revealed to be an extremely useful method to assess the Aços Especiais Piratini plant technology strategic plan, implemented through the PMI methodology customized to engineering projects implementation. The six-step plan supported insightful conclusions at all organizational levels during its application, leading to important improvement opportunities.

The recommendations developed during the application of the six-step method were mainly related to the strategic and tactical levels of the organization and their adoption would generate a profound impact on the whole technology strategy across the company. The ultimate benefit of the recommendations' successful adoption should be an increase in overall project performance, assessed through objective criteria already applied by the company, such as achievement of planned goals and benefits at strategic level and conformity to the planned budget, quality and delivery time at the tactical level.

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[7] Beckman, S.L. and Rosenfield, D.B., *Operations Leadership Competing in the New Economy*, Irwin McGraw Hill, 2007l

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