PEX PROCESS EXCELLENCE AWARDS

North America 2013 Awards

Best Project Over 90 Days

2013 Winning Entry:
Braskem UNIB 2 RS

PEX PROCESS EXCELLENCE NETWORK

PEX
PROCESS EXCELLENCE
AWARDS

The Process Excellence Awards, a global awards series run by the Process Excellence Network, recognize companies and individuals that have achieved exceptional results through the use of process improvement methodologies. Entries are judged by a panel of process professionals.
To find out more about the awards go to:
www.processexcellencenetwork.com/awards/

PEX
PROCESS EXCELLENCE
NETWORK

PEX PROCESS EXCELLENCE AWARDS

The 2013 winner of the Best Project Over 90 Days was Braskem UNIB 2 RS for their Lean Six Sigma Green Belt project “Reduction on Fuel Gas Consumption at 11F08”. Here is their entry.

Reduction on Fuel Gas Consumption at 11F08

Maintenance Unit – UNIB 2 RS

Lean Six Sigma – Green Belt Project

Leader: Vanessa Eidelwein
Team: Fernanda Ribaski
Vitor Hugo Kirst
Susam Arend

BRAZILIAN PETROCHEMICAL INDUSTRY

<u>1st Generation</u> → 4 Naphta Crackers

Ethene: 3.7 MM t/year and Propene: 1.8 MM t/year

2nd Generation → 18 Polimer Units (PP, PE, PVC and CS)

Resins Capacity : 6.46 MM t/year and Soda: 0.5 MM t/year

COMPETITITVE INTEGRATION

EXTRACTION
Raw Materials

1st GENERATION
Basic Petrochemicals

2nd Generation
Thermoplastic Resins

3rd GENERATION
Plastic Converters

Braskem

World's eighth-largest petrochemical company

Thermoplastic resins leader for Latin America

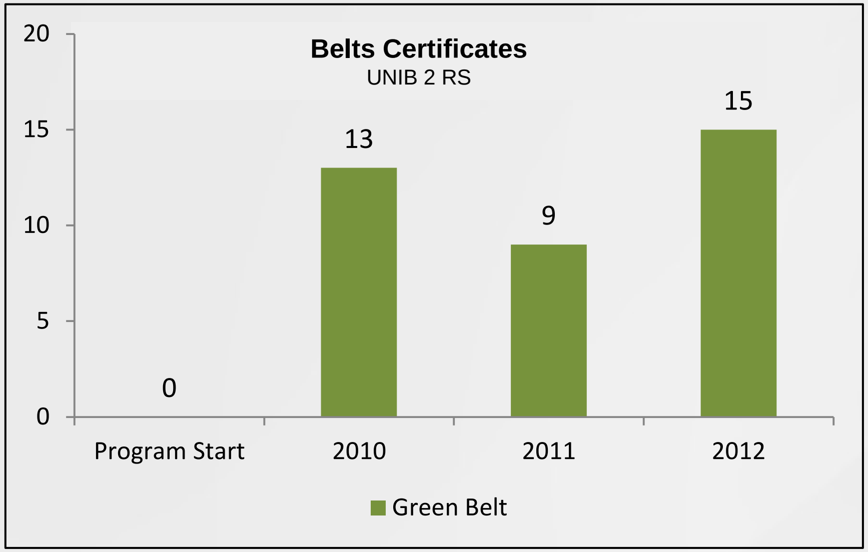
Created in 2002, it employs 7.2 thousand workers

<u>Major Global Challenges</u>

- Globally competitive, with access to raw materials at competitive costs (Gas Base and Shale x Oil)

6 Sigma

Olefins Basic Inputs Unit – South: UNIB 2 RS

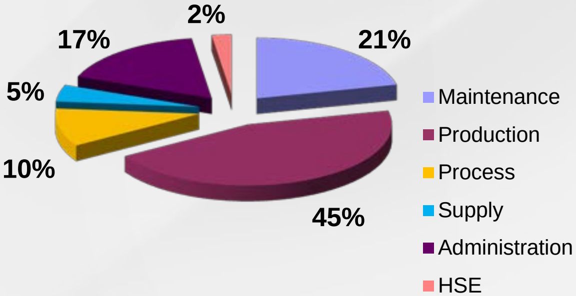


- The 6 Sigma projects have started in the UNIB 2 RS in 2009 focused on Industrial Processes, Material Losses and Productivity.

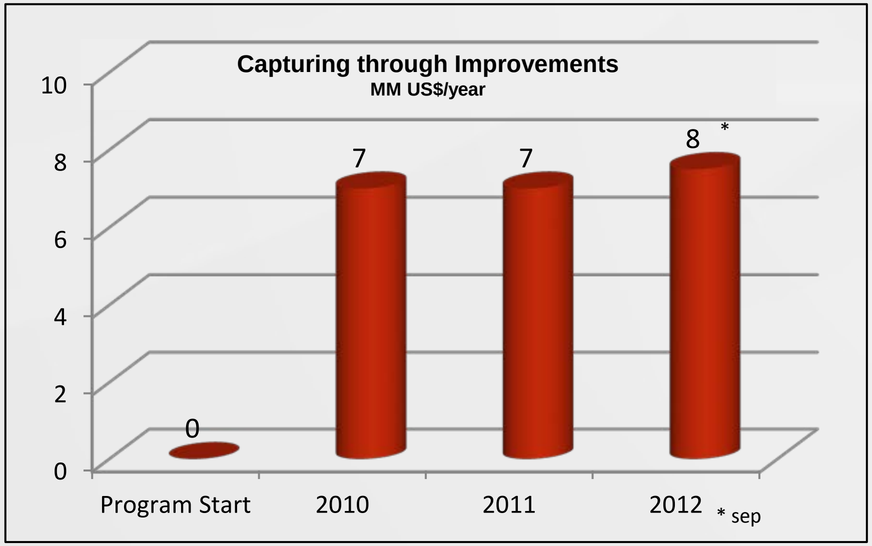
- Production: Ethene: 1,2 MM t/year and Propene: 0,6 MM t/year

- Employees: 950

PROJECTS DISTRIBUTION



PARTICIPATION IN NATIONAL AND INTERNATIONAL EVENTS



REGIONAL ANNUAL CERTIFICATION EVENTS

ACKNOWLEDGEMENT OF THE BEST PROJECTS

Introduction and Context

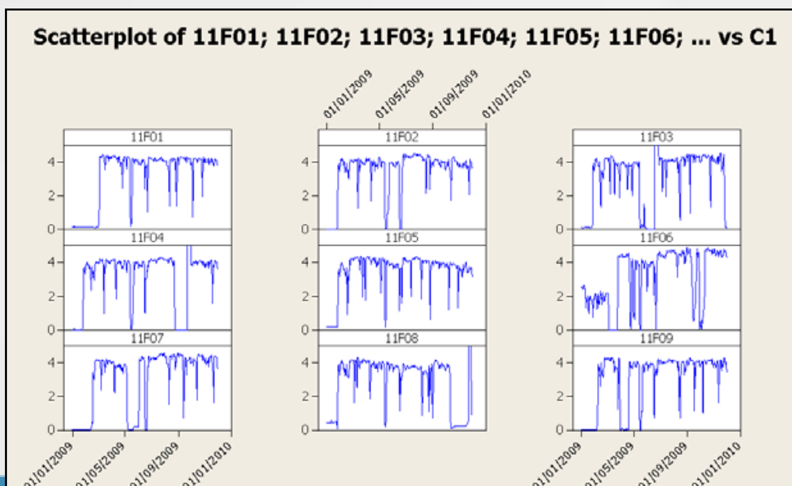
D M A I C

The project was designed in accordance with **Cost Reduction** goals and initiatives for the capture of **Strategic Industrial Planning Gaps 2011-2016** for the Basic Inputs Unit RS (UNIB 2 RS).

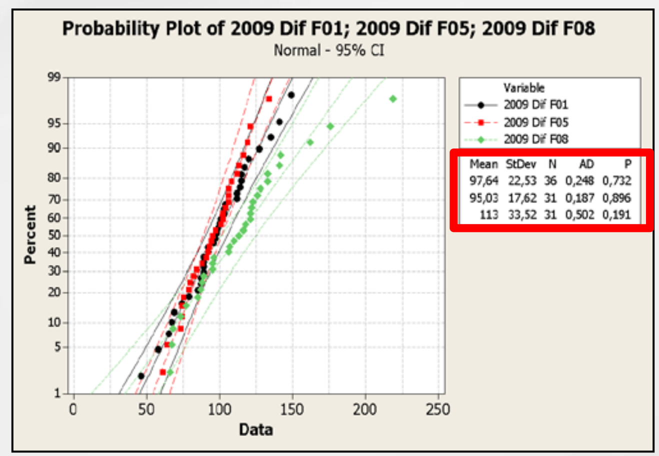
Commitment - to optimize performance indicators:
Energy Indicators (reduction of process energy consumption per ton of final product)
Fuel Gas Consumption (reduction of fuel gas consumption for power generation)

Restrictions - not to impact negatively on the following environmental indicators:
Emission of Gases to the Atmosphere (CO, NO_x and SO_2)
Emission of Greenhouse Gases (CO2)

Choosing the pilot: One pilot equipment was chosen for each of the ethene production areas. This project refers to the pilot developed at the Olefinas 1 plant.
Method: statistical evaluation of the average consumption of fuel gas (FG) and changes in internal temperature for the 9 furnaces which comprise Olefinas 1. Verified: highest FG consumers and highest mean and standard temperature deviations for each furnace (indicating process instability) . The equipment chosen was: **11F08.**



1. Analysis of FG consumption over time



2. Analysis of temperature differences (Δ) in furnaces with higher FG consumption

Definition

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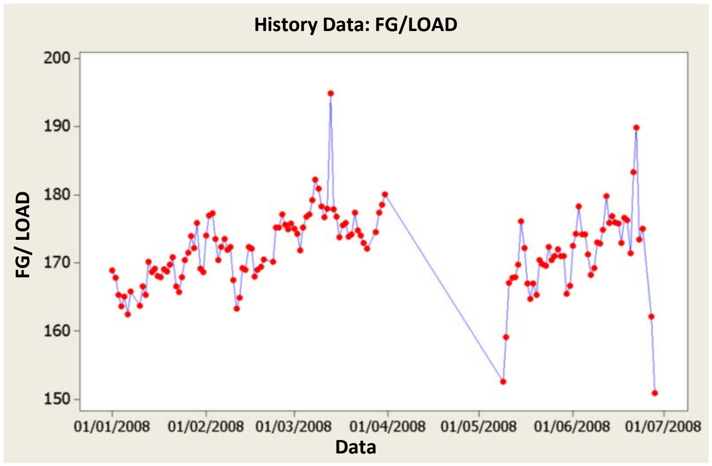
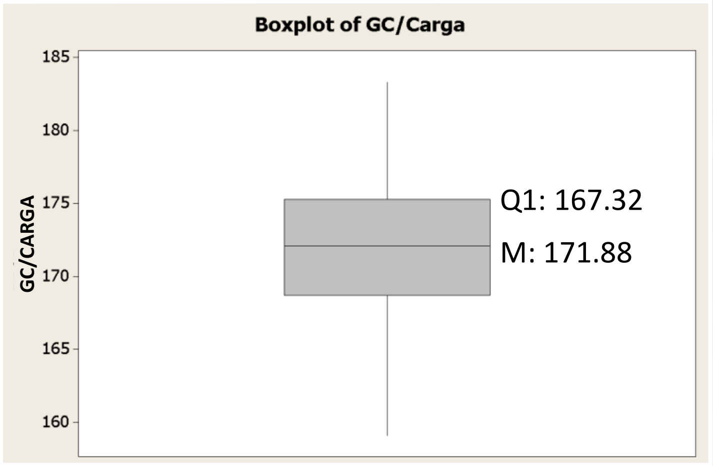
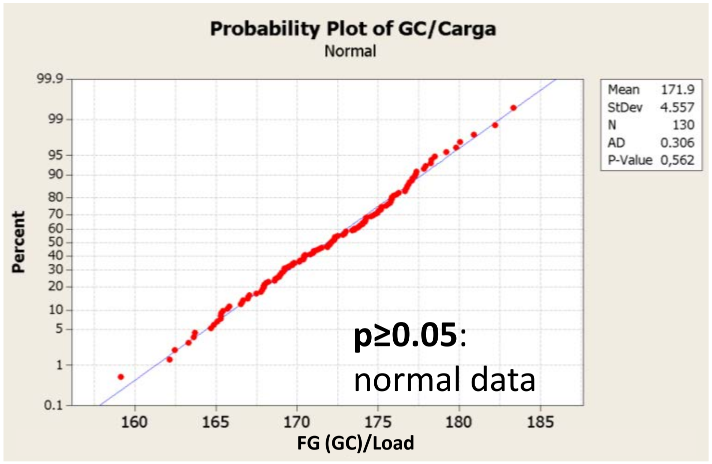
Definition of KPI: kg FG/ton Processed Load



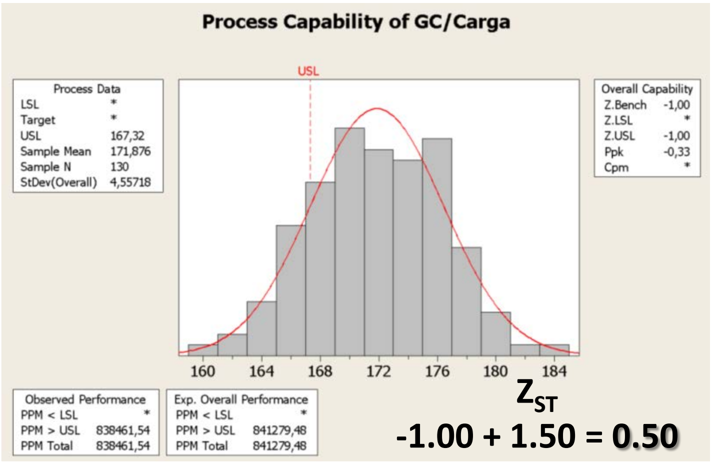
1. Analysis of KPI historical data



2. Verification of position measurements, dispersion, outliers



3. Evidence for type of distribution



4. Capability calculation for calculated goal

GOAL: Reduce from **171.88** to **167.32** kg of consumed FG per ton of processed load (shifting of the mean to the 1st quartile Q25% - statistical goal chosen by lack of *benchmarks* for pyrolysis furnace indicators)

FINANCIAL GAIN: **R$ 1.1 million** (only for the pilot)

Measurement

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WORKFLOW

1. Preparation of the **PROCESS MAP,** for understanding the GF route throughout the entire furnace and verification of the first potentiale Xs comparing with a single output : FG consumption

2. BRAINSTORMING with a multidisciplinary team to survey other Xs

3. Making of **ISHIKAWA** to organize the first Xs collected and visualization of other Xs

Results: mapping of 45 POTENTIAL Xs for prioritization

4. Building of the **CAUSE x EFFECT MATRIX** for prioritizing process inputs according to the outputs. All Xs collected were used and compared with a single output: FG Consumption

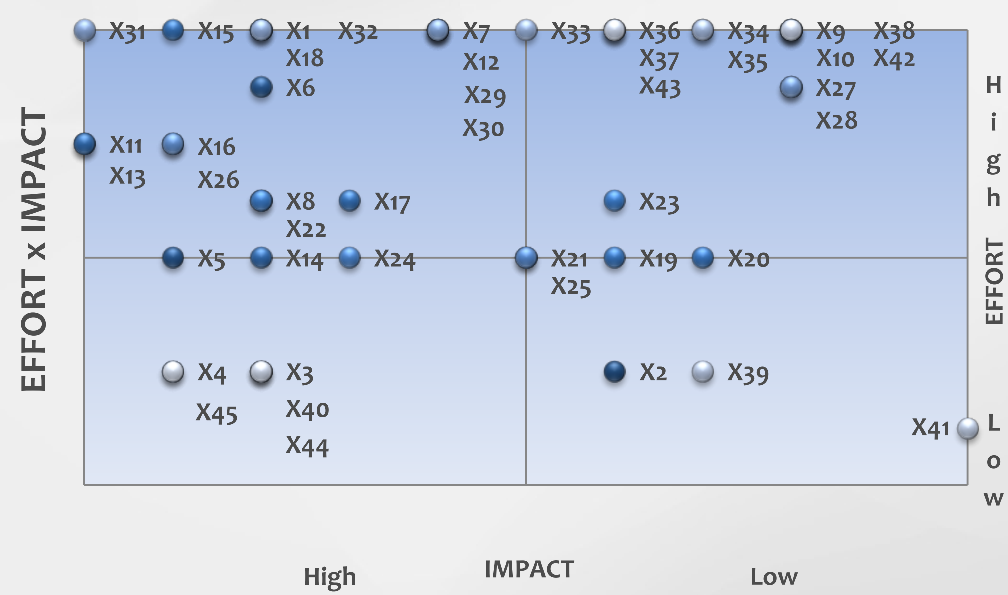
5. Building of the **EFFORT x IMPACT MATRIX** to prioritize which Xs will be analyzed. High Impact quadrants were chosen.

Results: mapping of 18 POTENTIAL Xs for the Analysis Stage

PROCESS MAP

Y = FG Consumption

Header GC + 11FR2008	11PC0508 + 11PC0608	Burners	Radiation	Convection	Stack
• **X1** Pressure • **X2** PCI FG • **X3** Density FG • **X4** Position of furnace • **X5** Valve model • **X6** Valve opening	• **X7** Pressure • **X8** Opening of the valves • **X9** Model of the valves	• **X10 Bore diameter** • **X11** Cleaning • **X12** Primary air opening • **X13** Secondary air opening • **X14** Model of burner	• **X15** Heat for coils • **X16** Heat for refractories • **X17** Heat for false air • **X18** Heat for air burning • **X19** Heat to external environment	• **X20** Heat for convection • **X21** Heat for refractory • **X22** Heat for false air • **X23** Heat to external environment • **X24** Fouling • **X25** VD flow • **X26** Co-crack flow	• **X27** Temperature



Analysis

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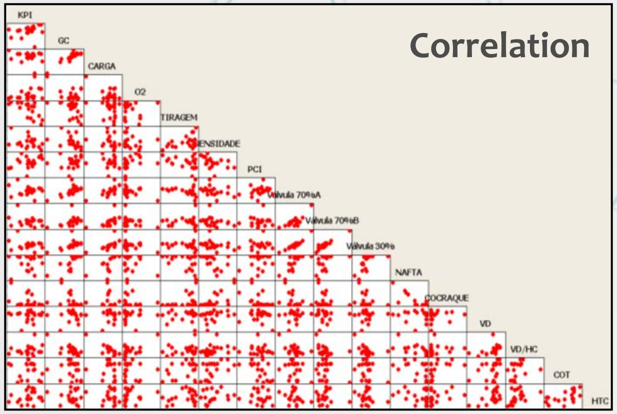
STEP 1 – Large amount of continuous variables (operational parameters of the furnace). Verification of the relevant parameters and their actual impact through the development of multiple regression models for each operation mode.



1. Correlation analysis for the choice of variables used in the regression models

Maximization of ethene:

GC = - 0.4 + 0.124 C + 0.0017COT – 0.0479 O2 – 0.0771 T

Maximization of propane:

GC = 10.2 + 0.161 C – 0.0122COT + 0.0248 O2 – 0.0532 T

Generalist Model:

$$GC = \sqrt[3]{17.5 + 0.00394\ C - 0.152\ O_2 - 0.0444\ T}$$

Regression Analysis: GC versus CARGA; COT; O2; TIRAGEM

The regression equation is
GC = - 0,4 + 0,124 CARGA + 0,0017 COT - 0,0479 O2 - 0,0771 TIRAGEM

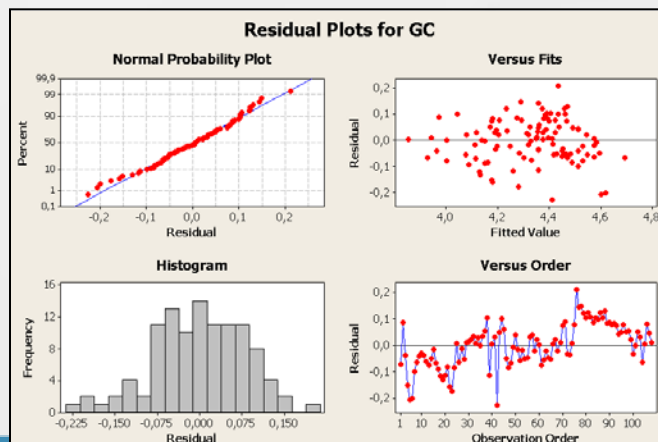
Predictor	Coef	SE Coef	T	P
Constant	-0,42	10,81	-0,04	0,969
CARGA	0,124271	0,008169	15,21	0,000
COT	0,00171	0,01290	0,13	0,895
O2	-0,04789	0,02530	-1,89	0,061
TIRAGEM	-0,077089	0,009097	-8,47	0,000

S = 0,0837960   R-Sq = 81,4%   R-Sq(adj) = 80,7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	3,16928	0,79232	112,84	0,000
Residual Error	103	0,72324	0,00702		
Total	107	3,89252			

2. Development of the three models



3. Residue analysis: normality, distribution, stability and randomness

Best Subsets Regression: GC versus CARGA; COT; O2; TIRAGEM

Response is GC

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	CARGA	COT	O2	TIRAGEM
1	67,6	67,3	75,5	0,10903	X			
2	80,8	80,4	4,7	0,084476	X			X
3	81,4	80,9	3,0	0,083399	X		X	X
4	81,4	80,7	5,0	0,083796	X	X	X	X

4. Multicollinearity analysis: assessment of the highest R^2adj, Mallow's Cp closest to the number of variables used and lowest S

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Analysis – Complete Methodology

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STEP 2 – Statistical analysis of the 18 variables mapped. Of these, **10 were confirmed as variables that impact the process significantly (VITAL Xs)** – Action Plan developed

X3	Calibration 11FR2008 (measuring instrument)	Calibration plan and history verification	✗
X4	Calibration of 11AR0608 (measuring instrument)	Hypotheses testing (1ST)	✗
X5	Location 11AR0608 (measuring instrument)	Hypotheses testing (1ST), Multiple regression, Histogram	✓
X6	Heat loss by insulation	Hypotheses testing (2ST), Box plot	✓
X8	Adjustment of primary and secondary air	Hypotheses testing (2ST), Multiple regression, Correlation, Dispersion	✓
X11	Excess O2 Set	Hypotheses testing (2ST), Multiple regression, Control chart, Correlation, Dispersion, Trend	✓
X13	Draught Set	Hypotheses testing (2ST), Multiple regression, Control chart, Correlation, Dispersion, Trend	✓
X14	On-line DMC factor	Logistics Regression	✗
X16	Size of nozzle holes	Hypotheses testing (2ST)	✓
X17	Assessment of burning efficiency	FTA	✓
X21	Green oil drainage at FG header	Hypotheses testing (2ST), Column Graph	✗
X22	Burner cleaning	FTA	✓
X24	Initial furnace setup	FTA	✓
X25	Drainage of 10V04 (pressure vessel)	Canceled	✗
X26	Presence of false air	Hypotheses testing (2ST), Box plot	✓
X40	Calibration 11FC0108 (measuring instrument)	Calibration plan and history verification	✗
X44	Calibration 11FT1908 (measuring instrument)	Calibration plan and history verification	✗
X45	Calibration 11PT0308 (measuring instrument)	Calibration plan and history verification	✗

Analysis – 10 vital Xs

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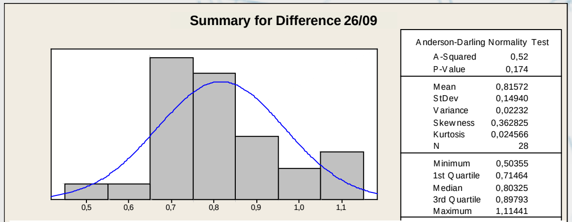
EQUIPMENT



Variable	N	Mean	StDev	SE Mean	95% Lower Bound	T	P
Difference 26/09	28	0,8157	0,1494	0,0282	0,7676	28,89	0,000

X5 – Localization of 11AR0608

(comparing the difference of values measured between 2 installation locations for the oxygen analyzer)

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20/06/2011 14:58:47

Welcome to Minitab, press F1 for help.

Two-Sample T-Test and CI: 2,4; 2,8

Two-sample T for 2,4 vs 2,8

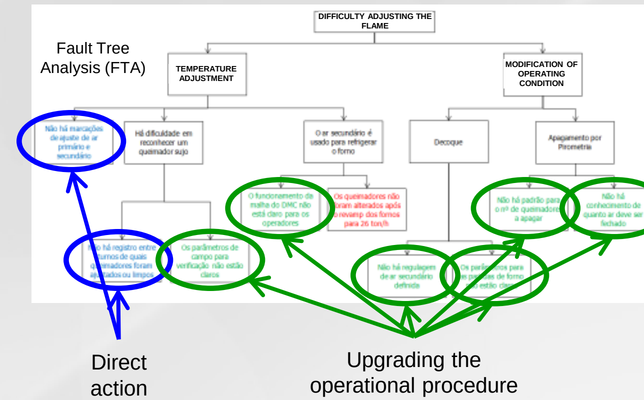
      N    Mean   StDev  SE Mean
2,4  170  4,4369  0,0845   0,0065
2,8  170  4,3614  0,0987   0,0076

Difference = mu (2,4) - mu (2,8)
Estimate for difference:  0,07551
95% CI for difference:  (0,05591; 0,09511)
T-Test of difference = 0 (vs not =): T-Value = 7,58  P-Value = 0,000  DF = 330
```

X16 – Dimension of burner holes

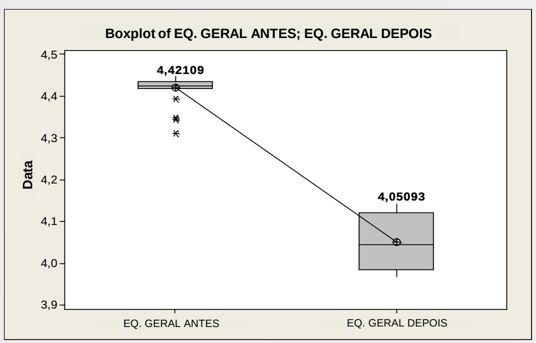
(comparison of gas consumption using 2 different models of burner)

PROCEDURE



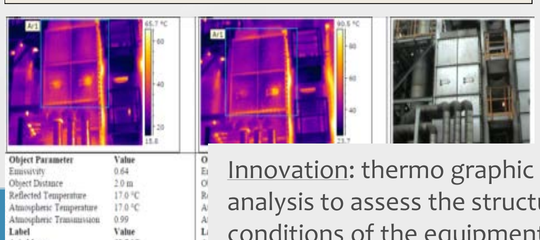
X17 – Assessment of burning efficiency
X22 – Burner cleaning
X24 – Initial furnace setup

(analysis of the causes and update of work instructions)



X6 – Heat loss by insulation failure
X26 – Presence of false air

(comparison of gas consumption before and after furnace maintenance and thermo graphic analysis – assessment of heat loss)

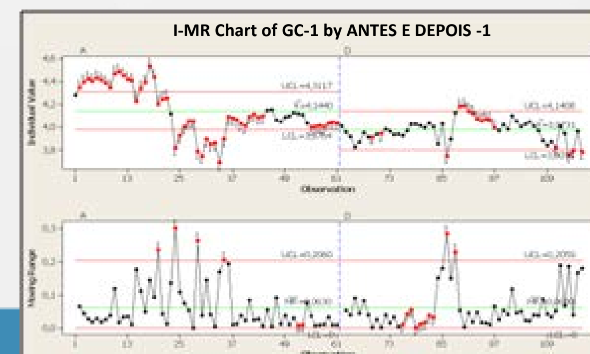


Innovation: thermo graphic analysis to assess the structural conditions of the equipment **without** removing it from operation

OPERATIONAL PARAMETERS

X8 – Air adjustment
X11 – Excess O2 set
X13 – Draught set

(change in the operating parameters – statistical analysis of the field test in relation to gas consumption BEFORE and AFTER)



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Improvements

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ACTION PLAN MANAGEMENT
Summary of the situation in: 30/09/2011

TODAY 20/11/2011

ID	WHAT?	HOW?	WHY?	WHO?	HOW	WHEN?	STATUS	WHEN?	STATUS	ACTION
X3 – Calibration 11FR2008 (FG)	Verify the efficiency of the FR calibration plan	Verify through hypotheses testing 1 Sample-T if the calibration plans for this instrument meets/does not meet/exceeds the needs Requires data colleciton	The reading results of this instrument directly impacts the calculation of KPI since it belongs to the numerator in the equation	Vanessa	R$ 0	15/05/2011	**Ongoing**	**20/06/2011**	**Completed**	The instrument is classified in the X category by MGMC. It does not have a calibration plan, and its frequency for failure is between 2 and 5 years. There was no statistical analysis and the variable was excluded from the project.
X4 – Calibration 11AR0608 (O2)	Verifiy the efficiency of the AR calibration plan.	Verify through hypotheses testing 1 Sample-T if the calibration plans for this instrument meets/does not meet/exceeds the needs Requires data collection	The reading results of this instrument sends data to the DMC which influences directly on the amount of air that will be inserted in the radiation chamber by actuating 11PC0308 (Draught), which in turns acts on 11PC05/06/07.08 de GC.	Vanessa	R$ 0	18/04/2011	**Ongoing**	**10/06/2011**	**Completed**	Verification by analysis 1 –Sample T proved that the calibration interval is appropriate, and can be extended.
X5 – Location of 11AR0608 (O2)	Verify the influence of the analyzer's location for the result of analysis of %O2 in the radiation chamber.	Perform DOE: place a new probe at a new point inside the furnace and perform O2 and CO analyses with reliable samples. The new point shall be on an inlet above the seventh burner platform but below the shadow box, where it is believed there is a large intake of false air. Afterwards, compare the data with those measured by 11AR0608. Requires preparation	The current point of the probe is located above the shadow box, where there are known false air intakes, to cool down this area's plating and other unmapped areas. The test aims to verify whether inside the chamber, where the excess O2 which really counts for combustion is, the O2 measurements are different (probably smaller) than the current ones. The Co content will also be analyzed, verifying the quality of combustion in the chamber	Vitor Hugo	R$ 448	09/05/2011	**Ongoing**	**01/10/2011**	**Completed**	Analyses were performed with the Horiba probe and with a portable gas analyzer. It was verified from it a measurement for O2, and the point tested measures an amount of O2 lower than the current point. However this analysis must be detailed in another project, since more detailed tests should be conducted to quantify this hypotheses in a more precise way.
X6 – Heat loss due to insulation	Verify the points in the furnace where there is heat loss	Perform visual inspection in the entire furnace using a thermal imager. All the hot spots must be photographed and their temperature recorded. Places marking over 100ºC will enter the work map for insulation improvements.	Hot spots in the furnace indicate points where there is heat loss. Every joule of heat lost will be produced again by burning of more FG, increasing input consumption.	Otávio	R$ 0	04/07/2011	**Ongoing**	**19/08/2011**	**Completed**	Maintenance performed in the furnace as of October 2010, where insulation flaws were mitigated. Perform new thermographic inspection before next shutdown to see new points generated.
X8 – Calibration of primary and secondary air	Improve regulation system for primary and secondary air in the furnace	Currently the primary air system is maintained at 100% open. Therefore during this adjustment there will be no improvements done. The secondary air system works under varying conditions. In this case, a sticker tag will be placed with the positions CLOSED, 25%, 50%, 75%. OPEN.	The air regulation mechanisms for the Olefinas 1 furnaces are the same since the plant was installed in 1979, they have become obsolete and precise control is difficult. The exchange of systems is not feasible, due to costs involved. The action aims at improving operator visualization when activating the system.	Vanessa	R$ 40	09/05/2011	**Ongoing**	**19/08/2011**	**Completed**	Sticker tags were placed on each burner indicating the percentages of secondary air openings. Parameters for air openings were also clarified during review of the operational process.
X11 – Excess O2 Set	Test new sets for excess of O2 in the furnace.	Perform DOE (step test) in the furnace according to automation area procedures	The O2 set today is maintained at a level of 2,5~2,0%, with some variations. This setting is based on determinations done a few years ago, and it could no longer be applicable for the process. This X depends on the X5 test, because if the DOE confirms a new location for the O2 probe, this step test should be done with the new configuration.	Vanessa Conz	R$ 0	02/06/2011	**Ongoing**	**01/10/2011**	**Completed**	Test performed to reduce excess O2 from 2.5% to 2.0%. Jointly, the pressure in the radiation chamber was also changed, reaching -3mm H2O. Analyses of gases CO, CO2, NO, Nox at the top of convection and at the top of radiation were done, to make sure the furnace was not "drowning". The new operational levels were approved.

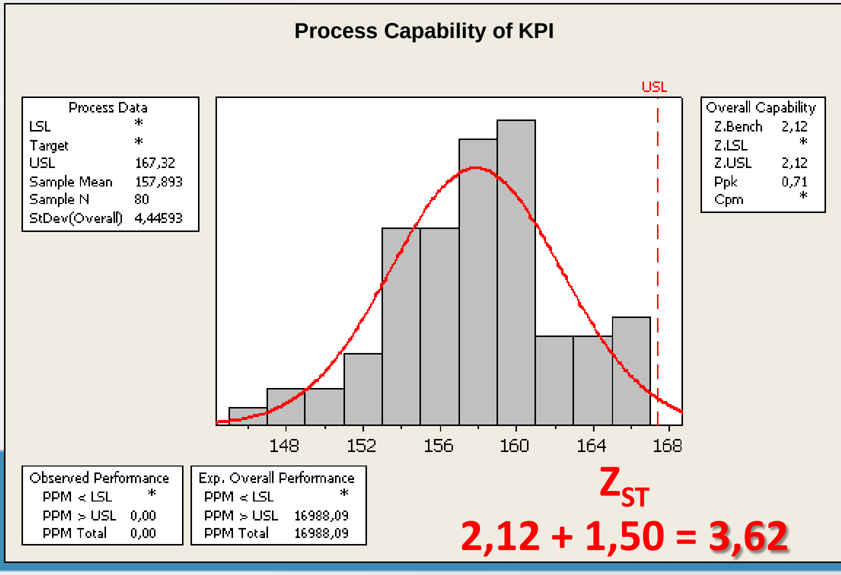
Action Plan: 5W2H

- Description of each variable
- Description of the analytical methods
- Detailed justification on why each analysis was performed
- Definition of 1 responsible per action
- Monitoring of costs
- Detailed description of each action
- Monitoring of deadlines

Responsible for analysis: project leader
No. Involved in the actions: 5 persons
Execution costs: **R$ 488.00**

After Improvements:

- Increased capability: 7-fold (**0.50** to **3.62**)
- Change in the linear regression model: new process equation with R^2adj = 97% and adjustment of the signals (equation with physical meaning, not just only mathematical)
- Financial goal achieved during improvement stage: 4 months in advance
- Value agreed for 1 year, achieved in 3 months



Control

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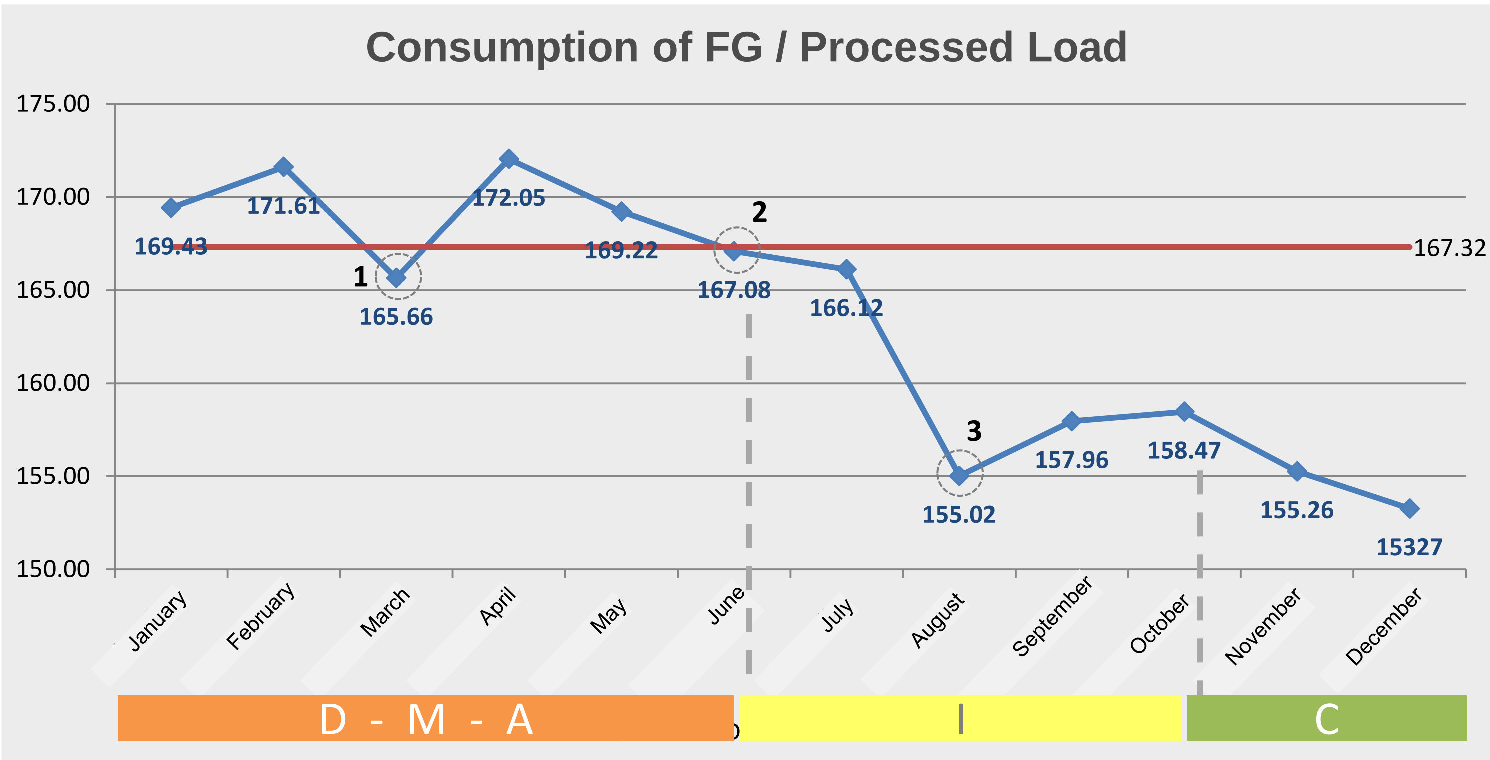
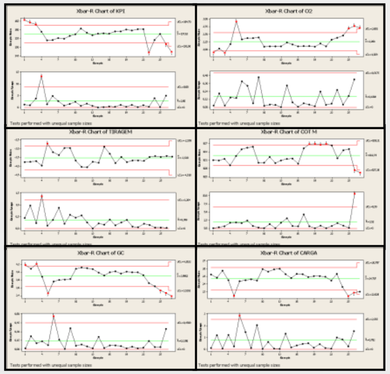


1. Acting on **X6** and **X26** (performed in the Analysis stage by chance of equipment shutdown derived from conditions outside the project);

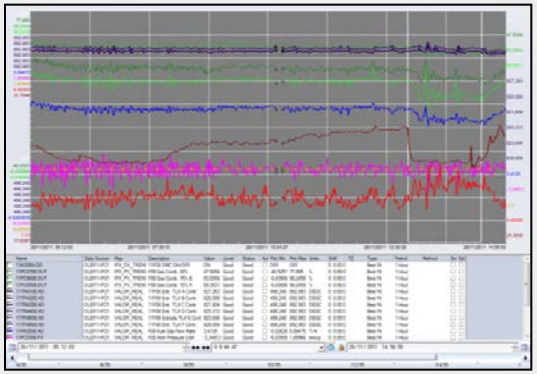
2. Acting in **X17** and **X22**;

3. Acting in **X8**, **X11**, **X13** and **X24.**

For **X5** and **X16** no actions were taken, since due to statistical analysis it had already been proven that they were in optimal conditions, and should be maintained as such.



CEP for consumption of FG and KPI (Control phase)



Monitoring of process indicators online (Xs)

Revision of 1 procedure, 1 work instruction and records creation in the Operations management software

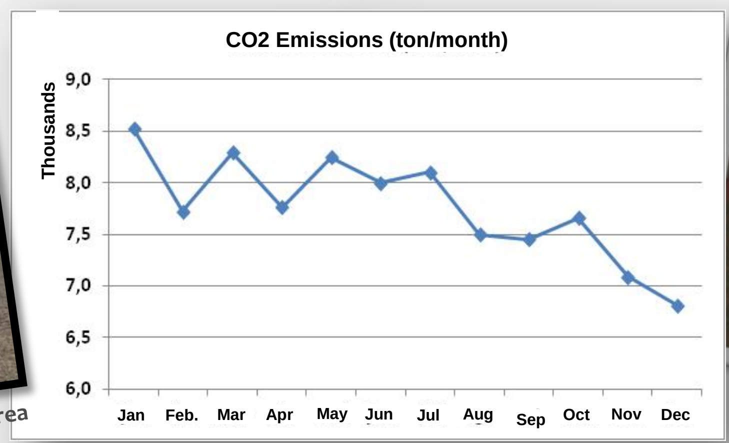
Permanent change of 3 operational parameters

Learning and Benefits

D M A I C

- **Breaking Paradigms**: the modification of the operational parameters represented a break with previous models – it was believed that is was not possible to operate the furnace with lower levels of oxygen without generating carbon monoxide emissions outside set limits;
- **Involvement of people**: the project was conducted by a maintenance area engineer, with direct support from the Operations, Processes, Quality and Safety areas. Staff members of varying seniority were involved;
- **Technical development**: throughout the analyses, many operators made questions and clarified doubts concerning their own work. The procedure reviews was essential to stimulate people's creativity and due to the technical complexity of the project, all the involved had a chance to acquire knowledge;
- **Use of resources for new purposes**: chemical analyses of the gases were performed to monitor the restrictions imposed (not to increase CO, CO_2, No_x and SO_2 emissions) with efficient and practical instruments which had been forgotten and were out of use. The thermo graphic camera was also employed, increasing its usefulness/usage rate;
- **Sustainability**: use of smaller amounts of fuel gas and improve of burning efficiency cut down CO, CO_2, NO_x and SO_2 emissions by **20%**. Commitment to the environment and surrounding communities;
- **Acknowledgement**: the project was awarded the Best Focused Improvement Project developed by RS UNIB in an event involving all the leaderships and the Quality area.

Teams: Maintenance and Operation in the furnaces area



Environmental indicators – reduction of emissions by 20%

Awards: Project Leader and Industrial Manager

Financial Benefits

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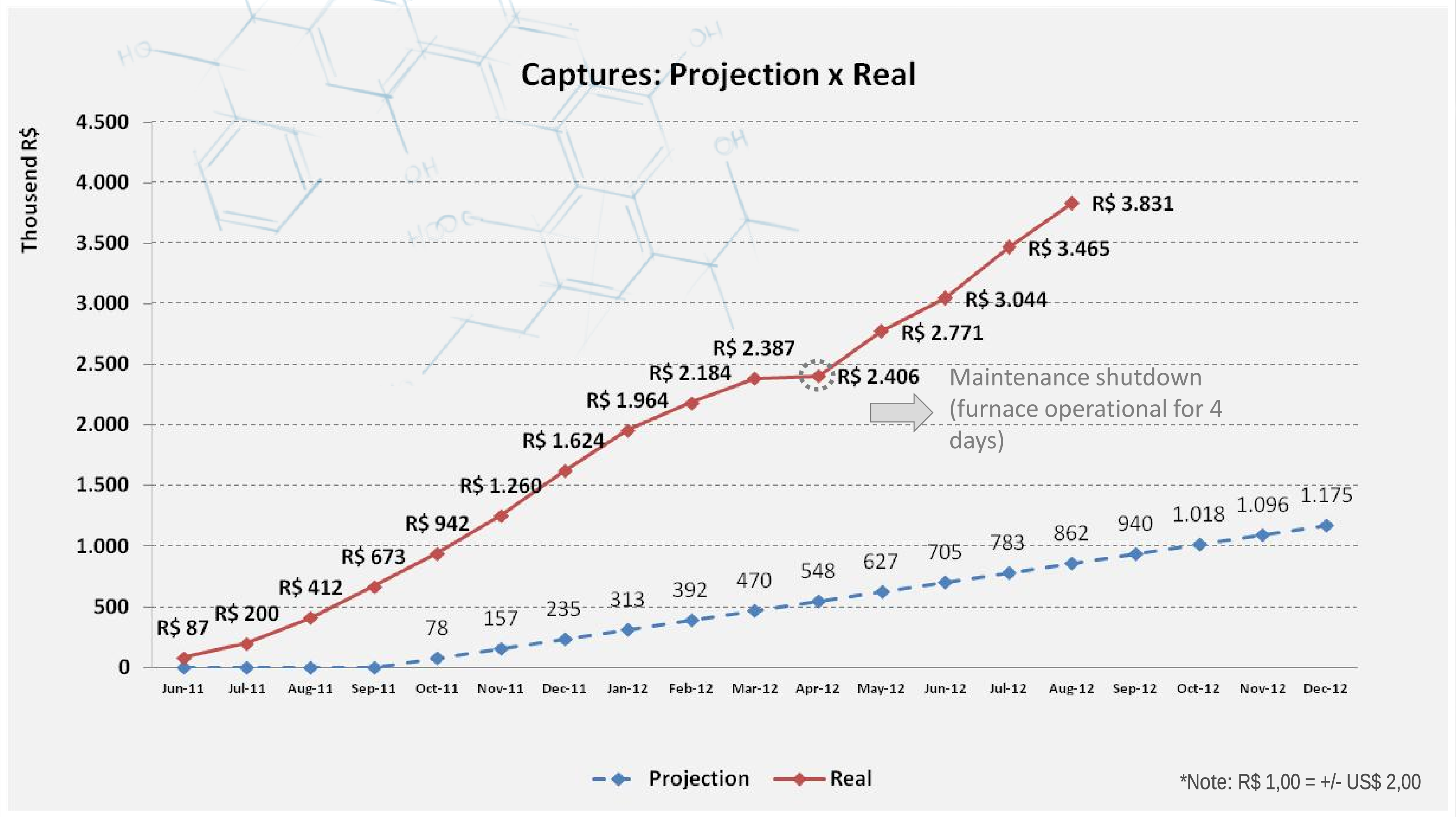

Goal:
R$ 1,174,818.43

Project Development

New Forecast:
R$ 3,831,166.24

Replication

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FURNACE	MULTIPLE REGRESSION (BASE 2011)	CAPTURE MONTH
11F01	$GC = 8.84 + 0.244C + 0.286O_2 + 0.0346T - 0.0137COT$	Optimized furnace
11F02	Unable to establish – evolve analysis for replication	Not calculated
11F03	$GC = -10.8 + 0.196C + 1.76O_2 + 0.046T + 0.007COT$	R$ 20,000.00
11F04	$GC = -8.51 + 0.131C - 0.045O_2 - 0.0811T + 0.0106COT$	R$ 240,000.00
11F05	$GC = -6.46 + 0.0948C + 0.177O_2 - 0.102T + 0.00891COT$	R$ 125,000.00
11F06	$GC = 38.5 + 0.094C + 0.388O_2 - 0.0622T - 0.0454COT$	R$ 130,000.00
11F07	$GC = -191 + 0.0888C - 0.0568O_2 - 0.0575T - 0.232COT$	R$ 245,000.00
11F09	Unable to establish – evolve analysis for replication	Not calculated

Minimum monthly capture forecasted: **R$ 760,000.00**

Extrapolation of the model: using the same variable, it was possible to create new regression models. Stipulating operational parameter goals for each furnace, the potential $ gain potential was also calculated.

Beginning of replications: May 2012
New data collection for each furnace and change the project replication leader.

Multiplication of Benefits: replication of the project has the potential to reduce by 5% the overall energy consumption of the plant and 20% total of gas emissions in the furnaces. Per month, this means:

- Reduction of **5,76 giga Joules/ton product produced** consumed;
- Reduction of **15,400 tons in CO_2** emissions;

Featured: Furnace Area Olefinas 1

QUESTIONS ?

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