T.A.C.T. 3

Terminal for the Accurate Control of Temperature

Technical presentation

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SUMMARY

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1. PURPOSE OF THE DOCUMENT

This document presents and describes T.A.C.T. 3: the improvement system for heating continuous furnaces, developed by R.A. System.

2. INTRODUCTION

T.A.C.T. 3 is typically employed on heating furnaces for the production of billets, slabs, blooms and steel profiles, and that's the reason why all examples indicated in this document refer to those production processes.

Obviously, in case of need, R.A. System, as developer of T.A.C.T. 3 is able to fit the device also to other heating processes.

2.1. AUTOMATION LEVELS

The theory of automation, distinguishes different adjustment and control levels:

- level 0: the field, that is the measurement devices and the actuators installed on the plant (thermo-couples, transmitter, diaphragm, limit-switches, valves, servo-motors, etc.)
- level 1: adjustment and control. The adjustment is the system that corrects the values of the dimensions measured on field by adequate actuators (valves, servomotors, etc), normally using an adjustment loop. The control is usually the set of the safety systems of the plant and of the interface devices that allow the operators to intervene and modify the operation of the system. Normally in R.A. System's products the real adjustment is managed by a PLC and/or by process adjustment devices, while the control functions are distributed among PLC, board/pulpits and supervision PC.
- level 2: optimisation, i.e. the system managing the adjustment objectives according to the production need and/or contingencies (e.g. stop of the plant). Generally speaking optimisation aims at obtaining the best possible results thus minimizing any collateral cost and effect.
- level 3: production management. Coordinates the different working processes aiming at reducing bottlenecks and idle times due to slowing downs of one or more processes.
- Level 4: orders management. Manages the ingoing and outgoing warehouse, orders to suppliers and delivery to face the orders received by the customers in the required times.

Obviously this structure is just one of the methods to organize automation (or, generally speaking, the management) in a production company.

Nevertheless, there's always the possibility to find cases with less levels than those indicated, and similarly, often, different names are used (particularly for "higher" levels).

Following this example, the production process of steel can be represented by the following outline.

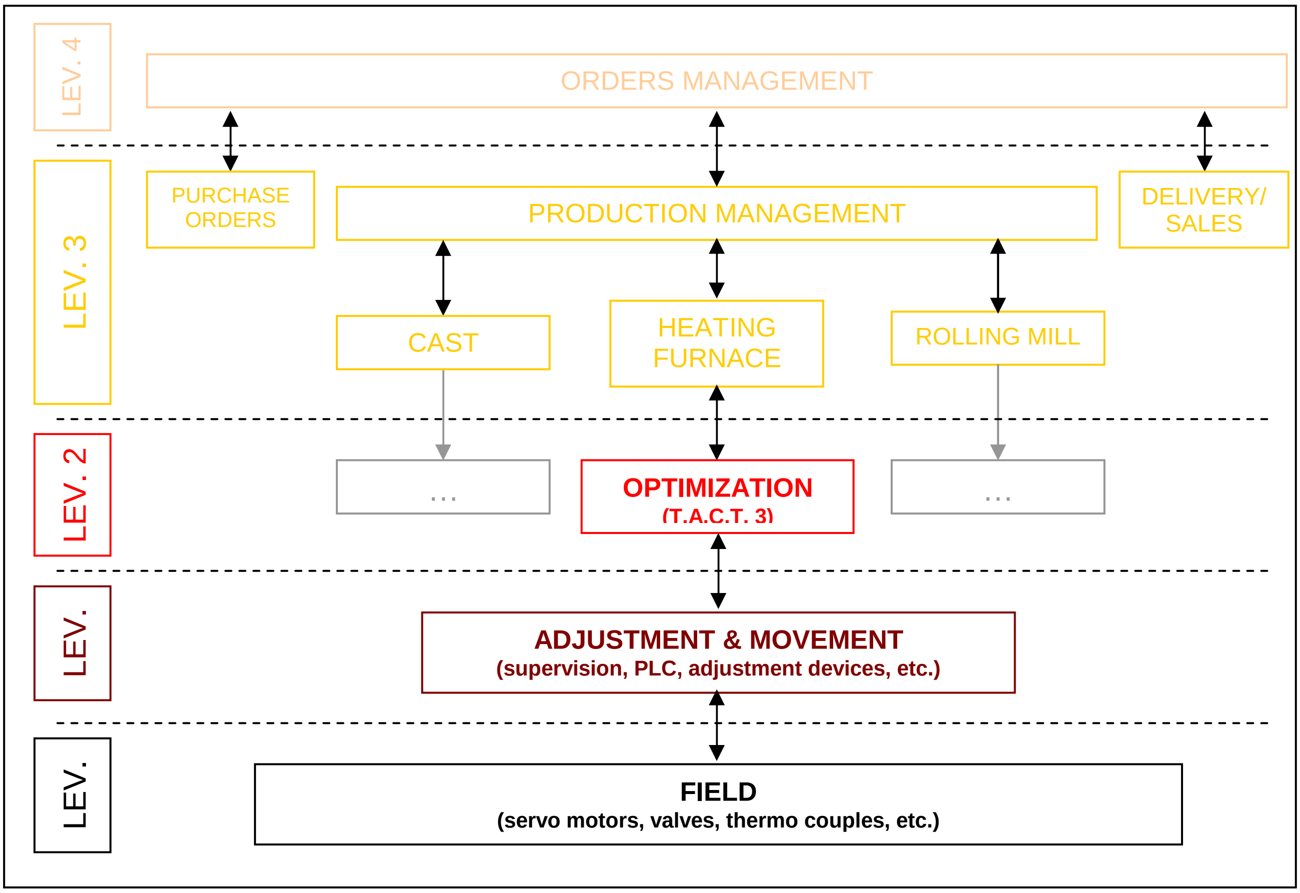

Fig. 1. Example of automation structure in steel production.

3. T.A.C.T. 3

As already mentioned, T.A.C.T. 3 deals with the optimisation of heating furnaces, and therefore is located at level 2 of the previous outline.

That means that it has to receive some data concerning the production on the run from the upper level (that can be either the company information system or the operator managing optimisation): namely the type of product introduced in the furnace and the required productivity rate.

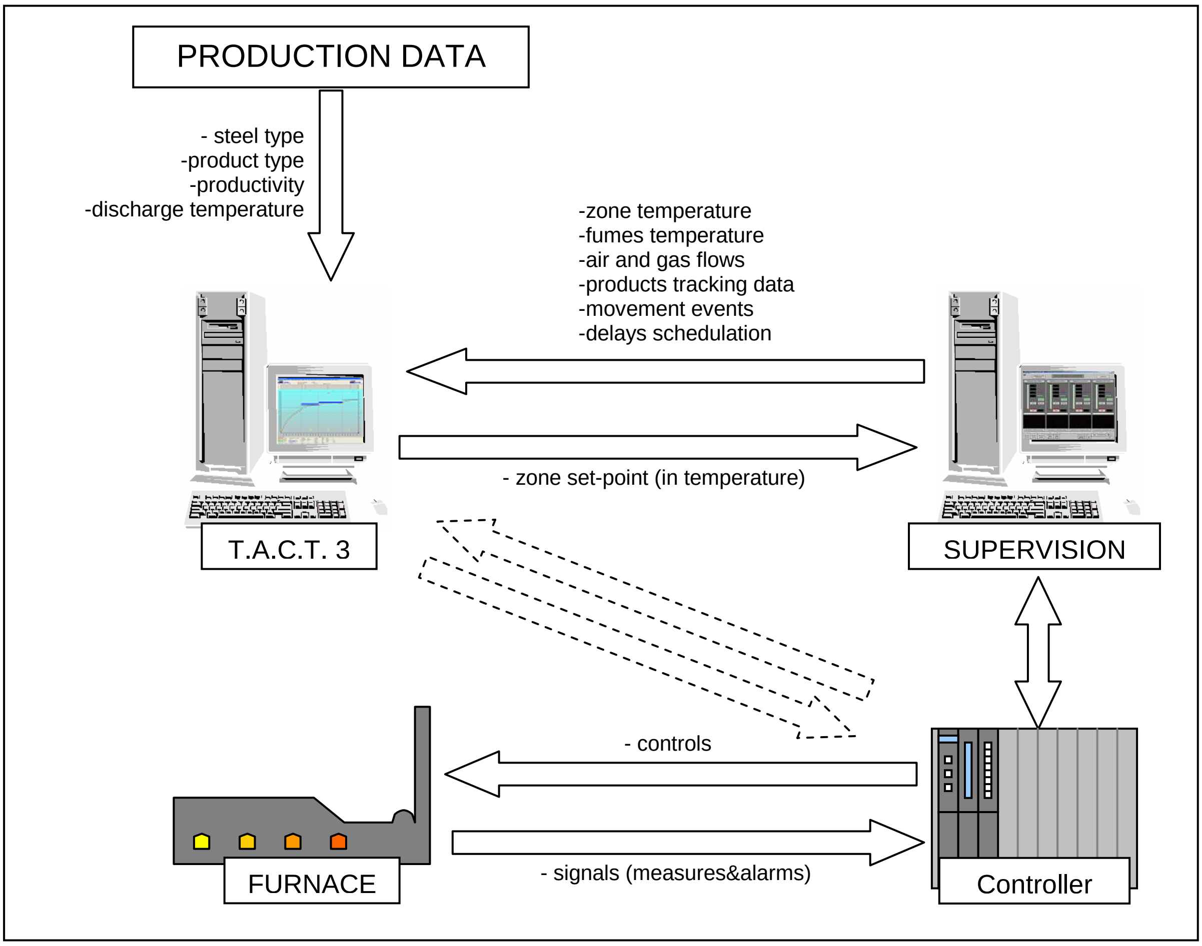

Fig. 2. Example of automation in steel production.

T.A.C.T. 3 sets a bi-directional communication with the lower level (furnace supervision system): it receives the temperatures measured in the different areas, air and gas capacities, movement events (chargements, steps, dischargements), tracking data and delays schedulation and it indicates the optimal set-point for each zone.

These set-points can be automatically set as adjustment set-point or can be simply displayed on the supervision as suggestion for the operator controlling the furnace.

Considering a typical situation, the lower levels at supervision (adjustment and field) are not directly in touch with optimisation. That allows to install T.A.C.T. 3 also on already operating plants, simply setting few modifications on the supervision system.

In other cases it is also possible to install T.A.C.T. 3 immediately above the adjustment level and make it directly communicate with PLC. This, on one hand, requires a different communication management, but, on the other hand, allows to use T.A.C.T. 3 also on plants that do not have any supervision, or where this one cannot be modified.

Generally speaking T.A.C.T. 3 can communicate with all main supervision systems and PLC available in the industrial automation environment.

3.1. THE AIMS OF T.A.C.T. 3

T.A.C.T. 3 is based on a well tested physical-mathematic model of heat exchange, that simulates the steel heating process inside the furnace.

The system can calculate the conduction and the thermal radiation due to the temperature differences (among products, and furnace vault and atmosphere), the profile of the furnace, the physical-chemical features of the pieces set in the furnace and their positioning (distance among pieces in the furnace and forwarding speed).

T.A.C.T. 3 calculates in real time the temperature set point of each zone in the furnace so, that:

- the furnace guarantees the required productivity;
- the products are output at the required temperature:
- the products reach the required temperature in each zone, as late as possible (considering the a.m. points).

These aims, together with the functions of T.A.C.T. 3 described later on guarantee the following advantages:

- reduction of lamination troubles;
- consumes reduction;
- emissions reduction;
- oxidation control;
- decarburation control;
- capacity of heating curves repetition;
- Production Efficiency increase;
- Quality Improvement

Reduction of lamination troubles

Namely, the main lamination troubles can be referred to the temperature of the product (too cold, too hot) and to the poor temperature uniformity on the product section.

Both these questions are eliminated by T.A.C.T. 3 thanks to its capacity of discharging the product at the exact temperature required by the rolling mill, that can be repeated, reducing at a minimum the differences due to operating conditions.

All this leads to a higher reliability and productivity rate of the whole rolling mill.

Consumes reduction

T.A.C.T. 3 is able to dramatically reduce the fuel consumption thanks to three main guidelines:

- as already mentioned, the zones of the furnace are adjusted so, that the product reaches the required temperature as late as possible (considering the set pace, the temperature homogeneity and the technological limits of the plant);
- the adaptation capacity as the milling pace varies (and, generally speaking, when the working conditions vary), allows T.A.C.T. 3 to always use the most regular heating curve;
- the discharging temperature of the products can be chosen according to the milling energy required for programmed deformation (calibration). As a result different heating curves are generated, variable not only according to the characteristics of the charged product (dimensions and steel quality), but also according to the final profile of the rolled product, of the rolling program and of the working conditions.

Emissions reduction

The emissions in the atmosphere are directly proportional to consumptions: therefore it is obvious that consumption reduction also guarantee a reduction of pollutant emissions (e.g. CO) in the atmosphere.

Oxidation control

The quantity (weight) of the product lost by oxidation, depends on:

- temperature and time-in-temperature of the product surface;
- composition of the atmosphere around the product.

When the combustion occurs around the stechiometric ratio (normal conditions), the oxidation due to the atmosphere composition is insignificant in comparison to that due to high temperature.

That means that in normal working conditions, an increase of losses due to oxidation exclusively depends on a longer permanence of the products in a high temperature furnace (which is normally due to stops or pace reductions not balanced by a ready and correct reduction of the zone-temperatures).

T.A.C.T. 3, evaluates the permanence time of the product in the different areas of the furnace and can intervene immediately to correct the zone temperatures to maintain two main guidelines:

- the products are discharged at correct temperature (and are not overheated);
- the products reach the high temperature as late as possible (thus reducing the time-in-temperature).

Decarburation control;

Also the depth of steel decarburation is directly proportional to the surface temperature and to time-in-temperature: that’s why the same principles that allow T.A.C.T. 3 to reduce oxidation, also guarantee the decarburation reduction.

Capacity of heating curves repetition

T.A.C.T. 3 is set up thanks to the collaboration of a process engineer and/or with expert operators.

This fact, together with a lower need of human intervention on the furnace control, guarantees the optimal performance of the plant, also with respect to changing working conditions.

This dramatically reduces the risk that the furnace supervision performed by less skilled operators increases the consumptions and reduces the productivity and/or quality of the products.

Furthermore these operators can find in T.A.C.T. 3 a tool adequate to supply information and data concerning the furnace that will be useful for a quick professional growth.

Production Efficiency increase

The guarantee that the products are discharged at the required temperature, eliminates rolling troubles and the risk to reduce the furnace pace, particularly as consequence of a top: T.A.C.T. 3 therefore reduces at minimum the production drops.

On the other hand, knowing the temperature of each charged product, it is possible to detect possible increase margins of production rate.

Quality Improvement

All benefits listed and the regular production guaranteed by T.A.C.T. 3 can result in a generally increase of the average quality of the discharged products.

3.2. T.A.C.T. 3 STRUCTURE

T.A.C.T. 3 is composed by different programs (all developed in C++) and works on Oracle database (v. 10G Express Edition). T.A.C.T. 3 fundamental programs are:

- Core: is the simulator containing the mathematic model that calculates the products', vault's, and waste gas' temperatures and consequently modifies zone's set-point;
- Communication: is the tool that manages the communication between T.A.C.T. 3 and external environment, i.e. automation level 1 and the factory information system;
- Interface: is the set of windows and controls available for the operator.

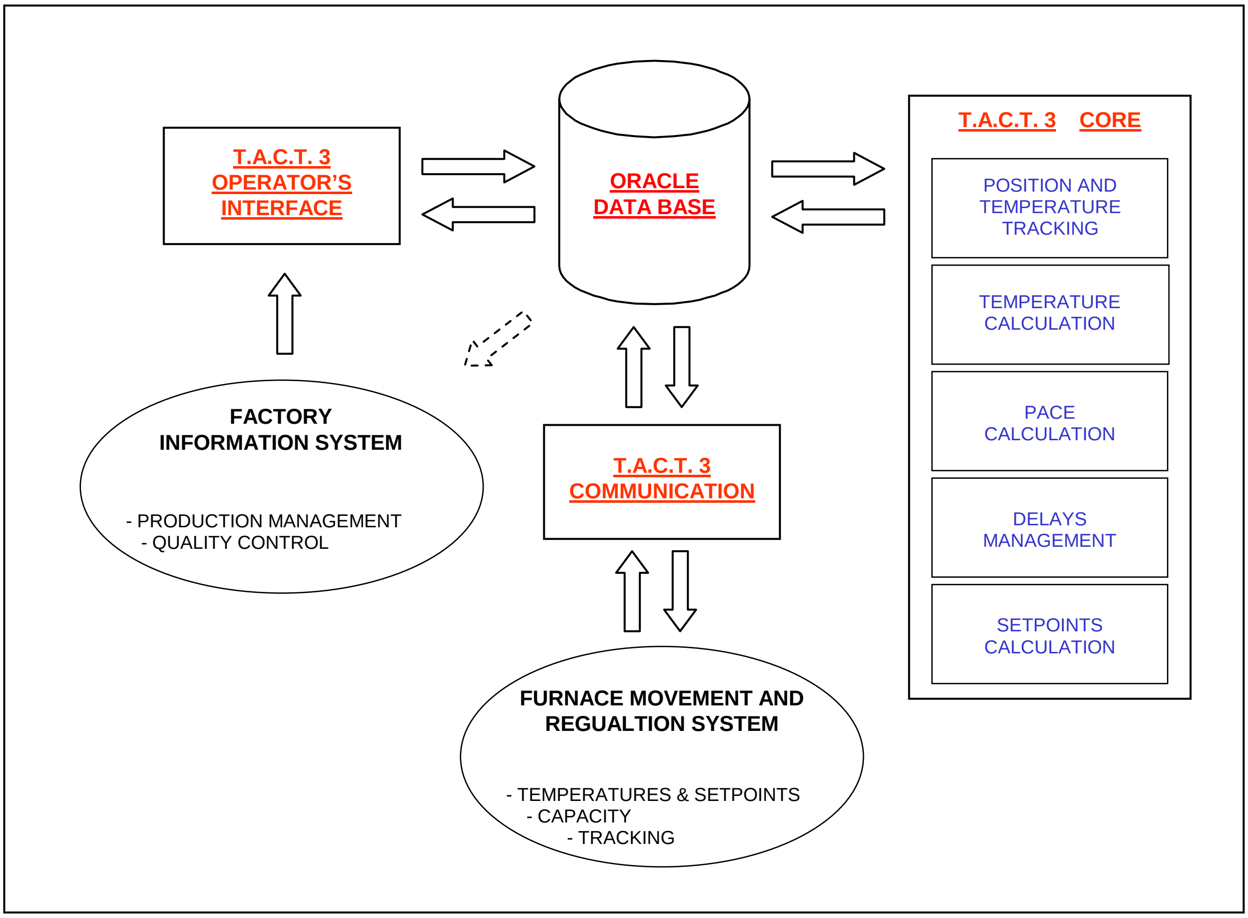

Fig. 3. T.A.C.T. 3 structure.

Client / server architecture

In the typical situation, all T.A.C.T. 3 programs run on the same PC (which could also be the same on which the furnace supervision is installed).

It is also possible to get different copies of the interface application of T.A.C.T. 3 running on other PCs net-linked.

In this case there is a ‘server’ optimisation PC where it is possible to use all T.A.C.T. 3 functions and other “n” ‘client’ PC working as displays of the optimisation system.

Database

As already pointed out, T.A.C.T. 3 has been developed over Oracle Express Edition version 10G (free version).

This database grants the required performances in data access even on a normal PC.

Besides, the Oracle database can be easily queried through an ODBC driver that allows to export data right within programs such as MS Excel® for possible off-line analysis.

Core

T.A.C.T. 3 Core it is the calculation system based on mathematical model that simulates the steel heating process within furnace.

This program reads, processes and updates all data contained in the database and it always must be working to grant T.A.C.T. 3 correct functioning.

The specific functions of this equipment are analysed at paragraph 3.3. (T.A.C.T. 3 Functions).

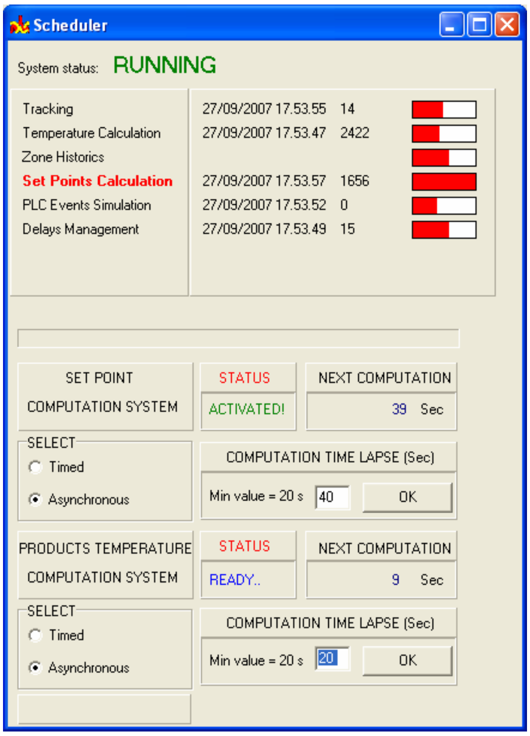

Fig. 4. T.A.C.T. 3 core program.

Communication

The communication program transfers the data between level 1 and T.A.C.T. 3 database: this implies that this program too has to always be running to grant T.A.C.T. 3 correct functioning.

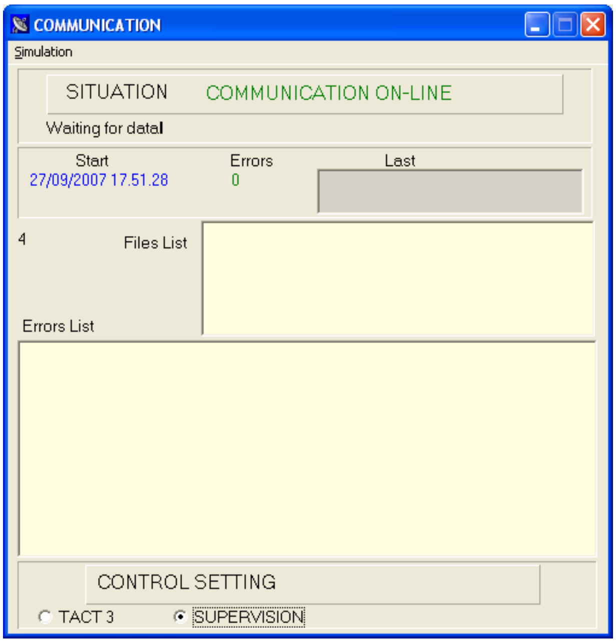

Fig. 5. T.A.C.T. 3 communication program.

Data exchange is based on text files (CSV) and foresees that:

- level 1 generates a file for each movement event or when a timer expires;
- T.A.C.T. 3 reads the file (or the files) coming from level 1and generates an answer file.

The easiness of this method is a grant about its strength and its capability of being used in the most different hardware and software configurations.

In particular cases, such as when T.A.C.T. 3 directly communicates with PLC instead of supervisor, it is used another communication program that reads and writes in PLC DB through O.P.C.

Interface

This part of the system contains all displays and controls available.

As previously mentioned, this program has not to be necessarily installed on the same PC hosting the other two components of T.A.C.T. 3 and it is also possible to have different interface systems connected to the same Core.

The graphical interface follows the style commonly used by MS Windows® applications.

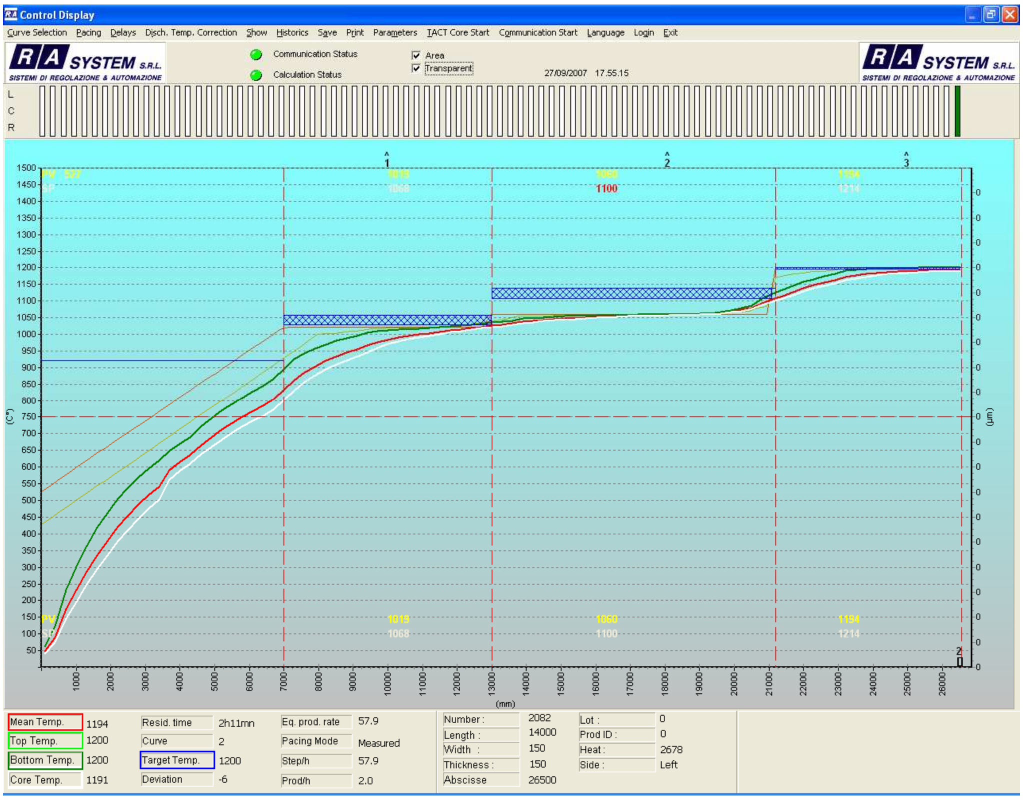

Fig. 6. T.A.C.T. 3 interface program main window.

In the main screen of T.A.C.T. 3 are shown the curves concerning the heating of the products currently in the furnace.

The horizontal axis represents the longitudinal section of the furnace (in mm), while on the vertical axis are indicated the temperature scales (in ℃) a nd decarburation and oxidation depth (in µm).

The curves that can be displayed by the operator are:

- temperature of furnace combustion chamber (for upper and lower zones);
- temperature of waste gas within the furnace (for upper and lower zones);
- medium temperature of the product;
- temperature of the upper surface of the product;
- temperature of the lower surface of the product;
- temperature of the product's core;
- decarburation depth of the product;
- oxidation depth of the product.

Furthermore a green horizontal line is displayed to indicate the temperature target that should be reached by the output product.

If the product exiting from the zone is too cold or too hot, T.A.C.T. 3 respectively displays a blue or red area.

In the area over the graph it is represented the current furnace's charge (seen from high).

Clicking on any product, its data are shown in lower panels.

3.3. T.A.C.T. 3 FUNCTIONS

As already mentioned, all main simulation and calculation functions of T.A.C.T. 3 are managed by Core program: here's a short description.

Temperature and position tracking

Through the analysis of the information received from the movement system, T.A.C.T. 3 is able to define the position of any single product inside the furnace.

Each product is associated to a table containing the management data and the heating data: abscissa (position along the furnace), charging row, lot, id, cast number, quality of the steel, size, medium temperature, temperature of upper surface, temperature of lower surface, core temperature, difference between medium temperature and objective, oxidation thickness, decarburation depth, time of permanence in the furnace.

These data are analysed by the Core's mathematic model to calculate temperatures and set points, but are also available for the operator, to be displayed in any moment on the interface program.

Temperature calculation

The mathematic model used by T.A.C.T. 3 Core can calculate, along all the furnace profile, the most relevant temperature values for each product in the furnace.

This extremely detailed knowledge of the charge in the furnace is the main issue that allows T.A.C.T. 3 to define the optimal set points for each zone. Other optimisation systems based on empirical tables, supply similar functions, but cannot reach the accuracy (even considering external events) ensured by the mathematic model.

Pace calculation

The pace calculation verifies what is the real production of the furnace on the basis of the signals deriving from the movement.

This is how T.A.C.T. 3 succeeds in calculating exactly the permanence times of each product in the different zones of the furnace, and, as a consequence, is able to match the set point values to maintain the products on the correct heating curve (also in correspondence of stops, not declared by the operator).

Management of stops

Stops are the interruptions in rolling and movement of the products and can be managed differently by T.A.C.T. 3 in case of:

- Programmed stops: normally due to programmed maintenance interventions. These are notified in T.A.C.T. 3 (or in supervision in advance, therefore the system "knows" when the stop will start and how long will it last.
- Unforeseen but declared stops: normally due to troubles downstream the furnace or in the furnace itself. In the moment in which the operator detects the problem, he confirms the stop in

T.A.C.T. 3 indicating the possible running time: that means that even in this case the system recognize beginning and running time of the stop but just when it occurs.

- Unforeseen and not declared stops: differently from the previous ones, no statement is performed in T.A.C.T. 3 therefore the system does not know the starting time nor the running time of the stop: it is simply detected by the missing movement.

In any case the immediate effect of these stops is a longer permanence time of the products in the furnace, which causes an overheating of the products leading to rolling, oxidation and decarburation troubles, and waste of fuel.

T.A.C.T. 3 is able to eliminate or at least reduce at a minimum level, these problems, thus progressively reducing the zone set points.

Best optimization is obtained on programmed stops, where T.A.C.T. 3 is able to grant that:

- last product that will reach the discharge position before the stop begin will be at desired temperature;
- following products will be left cooling down even before stop begin, because system already knows that they will be discharged only after the end of the stop;
- all furnace’s zones will be then reheated so that, at the end of the stop, last product will be ready to be immediately discharged at the desired temperature.

The same logic is applied to the stops declared at their starting time.

However, in these cases the temperature lowering cannot be anticipated when furnace is still producing: it has to wait the stop begin.

In case of not declared stops, T.A.C.T. 3 gradually lowers zones set-point so to keep all products on their optimal heating curves: last product is always ready to be discharged at any time.

It’s obvious, in this last case T.A.C.T. 3 optimization is sensitively inferior compared to the two previous cases.

Set-points calculation

The calculation of zone set points, is based on three main parameters: products temperature, foreseen permanence time (depending on furnace pace) and optimal heating curve.

The optimal heating curve is expressed by “zone targets” setting the average temperature that the product should have at the exit of each area.

The operator can define different curves according to:

- size of the charged products;
- belonging group (i.e. the chemical composition of steel);
- type of finished product (i.e. the energy of foreseen rolling);
- discharging pace.

When the real pace differs from the one theoretically set, T.A.C.T. 3 performs an interpolation of the set values to obtain optimal zone targets.

The products' temperature and the related permanence times are calculated by the corresponding functions, described above.

Simulation system

If required, T.A.C.T. 3 can be supplied with a simulation environment where it is possible to re-execute a list of events recorded by primary system (the one that physically controls the plant).

This grants:

- a separate environment from production process, where it is possible to test the optimization system tuning the thermal calculation parameters without interfering with plant's productivity;
- an extremely precise evaluation of the effects of the changes tried during the tests, that can be infinitely repeated on the same series of real events;
- having reheated a sample product equipped with a temperature recorder, it is possible to set-up T.A.C.T. 3 calculation parameters so that experimental data and calculated ones will practically be identical.

4. SYSTEM REQUIREMENTS

As already mentioned, T.A.C.T. 3 needs a PC connected by Ethernet at level 1 and to the information system of the plant.

In the typical case (one only PC that manages all the T.A.C.T. 3 programs, and the db engine), the requirements of this PC are the following:

HARDWARE

	Minimum	**Recommended**
CPU:	Pentium 4 @ 1Ghz	Core 2 @ 2Ghz or superior
Memory RAM:	512 MB	1 GB or superior
Hard Disk:	20 GB	100 GB or superior
Video Board	SVGA color	SVGA color
Ethernet Board	10Mbps	100Mbps or superior
Monitor:	17” (1280x1024)	19” or superior (1280x1024)

SOFTWARE

T.A.C.T. 3 PC must have a MS Windows operating system (minimum required Windows 2000, recommended XP) and Oracle database engine version 10.

It is finally recommended to use a color printer to improve any possible graph printout.

5. DOCUMENT’S UPDATES

Version 2.0 - 20/09/2007

Starting version.

Version 3.1 - 01/10/2009

Added details regarding direct communication T.A.C.T. – PLC.

Added the description of simulator functions.