CELSA MANUFACTURING UK

One 140 t/h Stein Digit@l Furnace®

→ Technical Specification

718243-A

INDEX	DATE	MODIFICATION
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FIVES STEEL SPAIN reserves the right to make any technical modifications or improvements found necessary during detail engineering without compromising the performance and guarantees given.

ISSUED by:	REVISED and APPROVED by:
Amaia Lizarralde  Signed: Date: 14th of June, 2024	Santiago Gil  Signed: Date: 17th of June, 2024

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1 GENERALITIES

In 2008 Celsa Steel UK placed an order to Fives Steel Spain for the supply of a new 140 t/h top and bottom fired walking beam furnace for their section mill in Cardiff.

During the project execution, many parts of the furnace were supplied to site, however, the project was put on hold and completion could not take place.

It is the aim of Celsa Steel UK to complete the supply of the missing parts of the furnace and have it operation in 2025.

The present specification describes the furnace design as it was designed in 2008/2009 with some modifications to the original designs based on modern developments in reheat furnace technology developed by Fives.

2 CONCEPTION OF PROPOSED FURNACE

Due to the heating quality required, the space available and its lay-out, a reheating furnace, top and bottom side MWFv2 central wide flame burners will be the best solution.

3 QUALITY

FIVES STEEL SPAIN at its head office in Bilbao was certified to **ISO 9001** in April 2005. This certificate has been issued by **BVQI** (Bureau Veritas Quality International) whose reputation is recognized all over the world.

This certificate demonstrate the maturity of the quality systems set up and illustrate our determination to continue our policy of progress and our willingness to better meet our customers' requirements. FIVES STEEL SPAIN's commitment to quality enables our customers to focus on production.

For this project, FIVES STEEL SPAIN's quality approach would consist of drawing up a **Project Quality control plan** defining the special features of this project and taking into account your particular requirements as well as the statutory requirements applicable to the site.

This **Project Quality control plan** would complete our **Quality control manual** and describe particularly :

- The organisation set up by FIVES STEEL SPAIN for this project (structure, persons in charge of the project…)
- The specific features of the project (statutory and standards requirements, …)
- Means implemented to perform services according to your specification and in compliance with the corporate quality procedures,
- Communication methods between the customer and the suppliers.

During the design work period, design would be subject to reviews to check conformity with your requirements defined according to the contract.

During the engineering stage, our subcontractors are selected and followed to check quality of products and services at all stages, from detailed design to installation and commissioning of equipment on site.

Inspections will be performed at all engineering and manufacturing stages. They will apply to products subcontracted as well as to our working methods by means of internal audits. They will obviously include inspections prior to commissioning to perform contractual performance tests.

Finally, since your satisfaction is a major concern, as we did for our previous contract we will certainly ask for your opinion and remarks at contract completion in order to improve our products and our working methods, in accordance with the recommendations of the new version of ISO 9000.

4 SAFETY COMMITMENT

Safety of the personnel working on installations designed and installed by Fives Steel Spain is a prime concern of our Design office and of our Construction and Commissioning department. We have not waited for the statutory regulations to come into force before training our specialists in the integration of safety requirements.

A safety approach already begins when designing the installation in the Design office and continues at site when setting up and complying with applicable regulations to guarantee the safety of persons and goods.

Safety on site

The work performed by Fives Steel Spain on the industrial sites of its customers is subject to the European regulation and Fives Steel Spain is therefore responsible for the implementation of preventive measures necessary to protect its personnel.

Even if the “user” (owner of the site) is responsible for the overall coordination of preventive measures, Fives Steel Spain takes part in the preparation of safety planning and ensures that its personnel working on site have been trained in safety procedures.

The site managers are regularly trained in the regulations and practical measures as well as the measures required in the contractual documents, Fives Steel Spain undertakes to:

- Comply with the applicable legislation and the rules applicable inside the plant and to use on site, state-of-the-art equipment in perfect working order and complying with the applicable rules and to use it only for the intended purpose.

- Make sure that the work is performed to safety and quality requirements in line with the safety plan,

- Train its personnel in the work to be performed and inform the personnel of corresponding hazards, and to check their ability at training completion,

- Check prior to performing the work that conditions have not changed since the inquiry and if necessary, carry out a new risks analysis in connection with the customer,

- Require of their subcontractors, if any, compliance with the above commitments.

5 STANDARS

All materials, equipment, design and installation will be in accordance with the relevant international standards or the standards of the country where they are manufactured.

Approval of the plant, when necessary, will be the responsibility of the Purchaser, however, the Contractor will make available all documentation and assistance necessary to obtain approval.

Combustion and fuel handling systems (natural gas and hydrogen blends) will be designed following ISO 13577-2 and 13577-4, which specify the safety requirements of these systems and the requirements of a protective system of industrial furnaces and associated processing equipment.

Seller ensures that the equipment will meet the environmental conditions of UE and those of UK.

Bureau Veritas Certification

Certification

Awarded to

FIVES STEEL SPAIN, S.A.

PLAZA DEL SAGRADO CORAZÓN DE JESÚS 4 SUBSUELO 2 – 48011 – BILBAO – VIZCAYA

Bureau Veritas Certification certifies that the Management System has been audited and found to be in accordance with the requirements of standard:

STANDARD

ISO 9001:2015

Scope of certification:

DESIGN, MANUFACTURING, ERECTION SUPERVISION AND INSTALLATION START UP OF INDUSTRIAL FURNACES AND EQUIPMENT FOR THE METALS INDUSTRY.

Certificate Number:	ES134886-1
Original approval date:	01-04-2005
Certification/Renovation Audit:	11-01-2023
Expiry date of previous cycle:	08-02-2023
Effective date:	09-02-2023
Certificate expiration date:	08-02-2026

This certificate is valid, subject to the general and specific terms and conditions of certification services

Bureau Veritas Iberia S.L.
C/ Valportillo Primera 22-24, Edificio Caoba, 28108 Alcobendas - Madrid, España
1/1

6 DEFINITION OF THE EQUIPMENT

The furnace proposed has been conceived for the reheating of billets destined for a section mill and will be a top and bottom fired walking beam type with an effective heating length of 19,000 mm. The products will be supported on a system of skid pipes which are themselves supported by a series of posts. This skid system consists of a series of alternate fixed and moving beams positioned across the furnace width which will be water cooled to maintain their mechanical strength.

The products will sit on the fixed beams and will be lifted and walked forward by the moving beams which walk in a rectangular cycle. In this manner the products are walked through the furnace, which is split into a number of heating zones, therefore as the products pass through each zone from the charge to the discharge end they are progressively heated up to the desired discharge temperature.

The furnace is provided with top and bottom fired zones.

7 THE BENEFIT OF OUR EQUIPMENT

7.1 AN OPTIMIZED ENERGY CONSUMPTION

It is always important to limit to a minimum the energy consumption. Therefore we will review all the parameters which affect the consumption of the furnace and explain our choice, case by case.

- Furnace length

  Furnace length is dictated by the residence time required to attain the heating requirements for a reference product. The shorter the furnace, the greater the compromise with heating quality and the higher the fuel consumption. The furnace length will comprise a long unfired recuperative zone to recuperate the maximum amount of energy contained in the waste gases.

- Division of heating zones

  - A short soaking zone to heat the products as late as possible while respecting a good temperature uniformity of the product.

  - A division sufficiently fine of the other zones to be able to permanently adapt to the changes in production (burner cascading).

  - A symmetrical heating of the products to avoid bending, especially in the heating zone where the differential temperatures in the product will be greatest.

- Preheating of combustion air

  The level of preheating of the combustion air is a compromise between the performance - and so the price of the recuperator - the quality of the air ductwork and the acceptable level of pollution (NOx).

The very high combustion air temperature at the exit of our recuperators result in energy savings that reduce the furnace specific consumption and therefore, the greenhouse gasses emissions.

- Excess air

  All the equipment for combustion control should be conceived to allow operation with an excess air as low as possible without the risk of incomplete combustion.

- Fuel

  The fuel used in this installation will be natural gas and full hydrogen (in the future).

  However, it will be capable of working with different blends of natural gas and hydrogen based on its availability.

- Thermal losses

  The number and size of furnace openings should be kept to a minimum to limit thermal losses.

  To this end, the side charge and discharge openings are as small as possible in relation to the products to be processed and the door opening periods are kept to a minimum.

  Viewing ports with pyrex glass covers have been foreseen in the furnace side casing for burner observation.

  The distance between moving beam support posts has been increased to its maximum to reduce the number of posts and so reduce the number of slots in the hearth to a minimum.

- Heating strategy

  In order to reduce consumption, we recommend heating as late as possible, reducing to a minimum possible the power of the lower zones while bearing in mind the need for symmetrical heating to avoid problems of bending of the products, especially as they enter the heating section of the furnace. Product bending could cause tracking problems in the furnace.

  Our objective is to attain the required thermal quality of the products at discharge with furnace wall temperatures lower than the acceptable limits.

7.2 MINIMIZED NOX EMISSIONS

The principal parameters which lead to the development of NOx are well known today. Our burners are therefore conceived to take advantage of those parameters.

Our solutions :

- burners having the maximum recirculation of waste gases to reduce NOx production at its source ;

- a compromise for the combustion air temperature to give low NOx while keeping fuel consumption to a minimum ;

- ☞ temperatures in the furnace as low as possible, taking account of the thermal objectives ;
- ☞ optimized control of excess air levels ;
- ☞ burners have been tested in our research station at Bar-le-Duc.

7.3 THE THERMAL QUALITY OF REHEATED PRODUCTS

To deliver, at discharge, products of uniform temperature, we propose:

- Lateral burners, so as to have good control of the thermal exchange within the furnace.
- The newly developed wide flame burners in the heating zones ensure optimum heat transfer.
- Support beams of double tube design to reduce skid marks.
- The beams spaced in the furnace as regularly as possible, within the constraints of the product lengths to be processed. This is also to reduce the skid marks.
- The position of the stagger of the beams, taking into account the product travelling speeds, will be optimized so that the skid marks developed in the heating zones are counterbalanced by the new skid marks created in the soaking zone.

  An incorrect position stagger can lead to higher skid marks.

  The form of the stagger in the beams is also very important as explained in paragraph 10.

  - A division of the fired zones which allows a strategy of heating adapted to the needs of the furnace.
  - An evacuation of waste gases as evenly as possible from the charging area roof which ensures that the full length of the furnace is used for heating.

8 FURNACE DESIGN AND GEOMETRY

8.1 THE DIGIT@L FURNACE CONCEPT AND TECHNOLOGY

The main features incorporated in the new concept are:

a. **Digital combustion control** with sequential impulse firing.
b. Heating by means of **central wide flame burners** (patented).

¿How does it work?

a. Digital combustion control

Heat demand is controlled by the firing duration of the burners (ON/OFF) rather than by the modulation of the air and fuel flows. The burners are sequentially impulse fired and each burner is controlled individually.

This allows the de-coupling of the flame profile and atmosphere control from the furnace production rate and results in :

− Greater fuel efficiency and reduced greenhouse gas emissions,
− Perfect control of the flame shape and heat distribution for unbeatable end product quality,
− Reduced scale formation,
− Reduced complexity, meaning less maintenance.

The graphical representation in fig. 1 shows a burner (ON/OFF) operating cycle, with a typical cycle time of 60 seconds.

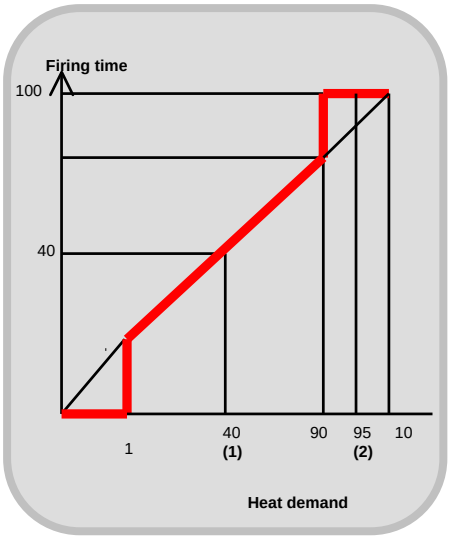
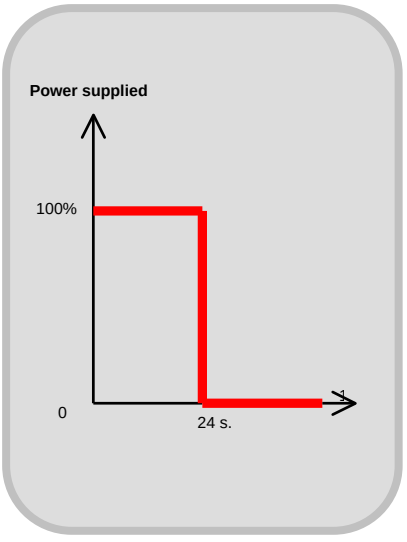


Fig (1)



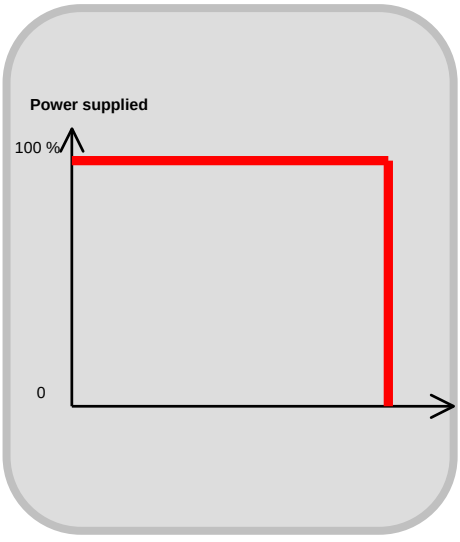


Fig (2)

Figure (1) shows an ON/OFF burner cycle equivalent to a heat demand of 40 % so the burner will fire for 40 % of the 60 seconds cycle, or 24 seconds.

Figure (2) shows the burner firing continuously since we consider that above 90 % heat demand the burners should be continuously ON.

The benefits from this type of control are most evident during delays and production rates away from the nominal. In contrast with a conventional furnace digit@l control gives a more consistent furnace performance over the whole operating range of the furnace.

Combustion efficiency is always optimal since the burners always fire at their maximum rate and therefore they maintain a constant air/combustible ratio.

The individual control of each burner gives the ultimate flexibility to adapt the heating in line with the optimum heating curve, for each product, and enables the operator to adjust the length of each phase of the heating process, preheating, heating and soaking to optimize the heating quality and consumption.

This flexibility , to adjust the heating lengths in each section of the furnace, which we call virtual zoning, enables the end user to adapt the furnace to the changing needs of his customers and he is no longer limited by the static multi-burner zoning of the old proportional firing system.

8.2 FURNACE PROFILE

The proposed furnace has an effective heating length of 18600 mm with side charging and side discharging on water cooled cantilever rolls.

Preheating zone

Both the upper and lower heating zones will be equipped with FIVES STEIN newly developed central wide flame burners which will ensure optimum heat transfer within the heating chamber.

This burner arrangement was chosen to be as symmetrical as possible and has the advantage that the upper and lower heating of the products can be controlled more easily to ensure minimum bending as the products enter the fired heating zone, since excessive bending can cause tracking problems which would inevitably lead to problems when transferring the products onto the discharge rolls with the consequence being loss of production.

This arrangement also has the added advantage that as production falls then the rows of side burners can be cascaded, switched off, to ensure optimum combustion efficiency.

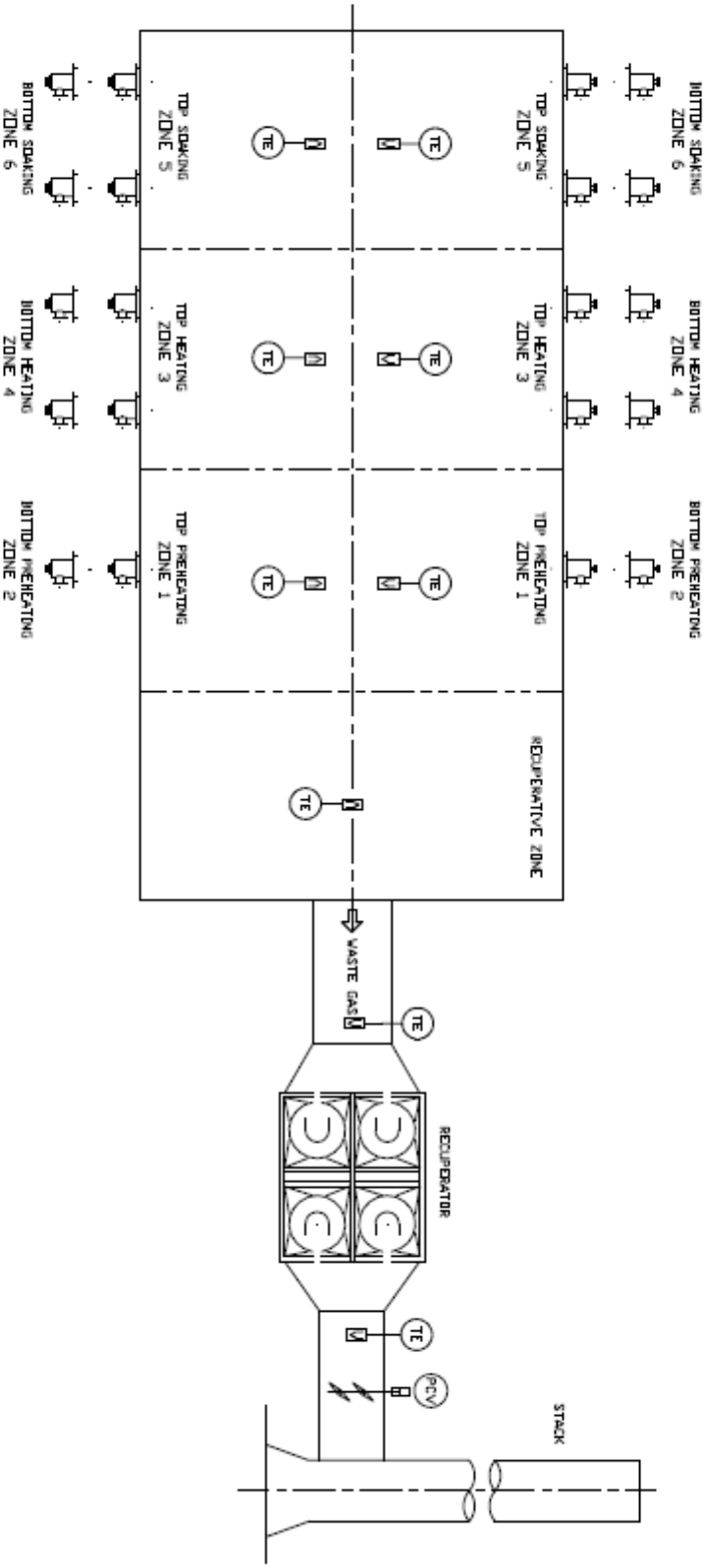
This means that the length of the recuperation zone “increase”, impossible to attain before with the typical proportional control system.

Heating zone

We also propose as in the preheating zone, central wide flame burners. Side firing in heating zones was chosen to allow the possibility of progressively switching off rows of burners in line with production changes, this allows for maximum economy of energy.

Soaking zone

The upper and lower soaking zones are equipped with side central wide flame burners of optimum efficiency as in the preheating and heating zones.


TOP SOAKING ZONE 5
BOTTOM SOAKING ZONE 6
TOP HEATING ZONE 3
BOTTOM HEATING ZONE 4
TOP PREHEATING ZONE 1
BOTTOM PREHEATING ZONE 2
RECUPERATIVE ZONE
TE
WASTE GAS
RECUPERATOR
PCV
STACK

Recuperative zone

This zone is fundamental for the consumption of the furnace. It should, in effect, permit maximum recuperation of energy from the waste gases before exhaust to the recuperator for preheating the combustion air.

Too long and it will impose wall temperatures which are too high in the heating zone.
Too short and it will lead to waste gas temperatures too hot in the flues.

Screen between recuperative and bottom heating zones

Installation of this screen is not recommendable with upper flue outtake as bottom gases will tend to be directed upwards, thus, leaving a cold area in the bottom recuperative zone.

Zonal division

The division per zones is more flexible with the digital heating and it could be considered that exist as many potential zones as pairs of burners. This disposition is more flexible in order to amend or create temperature profiles desired in the furnace.

At this moment, we consider that in the sense of the products travel through the furnace, the zones will be split as follows :

- Preheating (top & bottom)
- Heating (top & bottom)
- Soaking (top & bottom)

Division of capacity per zone

In the following table can be found the provisional installed capacities per zone for natural gas and air. Also the values for the different blends for hydrogen and same gas are shown.
Those values are calculated using natural gas with a net calorific value (LCV) of 36.760 MJ/Nm³ and a gross heating value (GHV) of 40.850 MJ/Nm³.

INSTALLED CAPACITY								
ZONE	Natural Gas (Nm³/h)	Air (Nm³/h)	Heat input (kW)	20% H2 Blended fuel flow (Nm³/h)	40% H2 Blended fuel flow (Nm³/h)	60% H2 Blended fuel flow (Nm³/h)	80% H2 Blended fuel flow (Nm³/h)	100% H2 H2 flow (Nm³/h)
1								
Upper	491	5100	4417	597	726	928	1284	1895
Lower	491	5100	4417	597	726	928	1284	1895
2								
Upper	491	5100	4417	597	726	928	1284	1895
Lower	621	6450	5586	755	918	1173	1624	2397
3								
Upper	491	5100	4417	597	726	928	1284	1895
Lower	491	5100	4417	597	726	928	1284	1895
4								
Upper	491	5100	4417	597	726	928	1284	1895
Lower	491	5100	4417	597	726	928	1284	1895
5								
Upper	308	3200	2771	374	456	582	806	1189
Lower	491	5100	4417	597	726	928	1284	1895
TOTAL	4855	50450	43692	5903	7184	9178	12701	18748

Note: These data can be modified during the detailed engineering period without affecting the performance guarantees.

9 HEATING QUALITY

9.1 DISCHARGING TEMPERATURE

Heating the reference product 120 x 280 x 12000 mm from 20 to 1150 C at 140 t/h.

The objective discharge temperature corresponds to the surface temperature of the billet.

From the heating curves it can be seen that for the required discharge temperature and for a good temperature uniformity we have chosen a heating length and a disposition of burners which allows us to keep the temperature differential between the top and bottom surfaces to a minimum to avoid bending. For a badly designed furnace with high differential temperature (top to bottom) this will lead to bending which can cause tracking problems and finally problems at discharge.

The following heating curves will be included.

PRODUCTION 140 tph

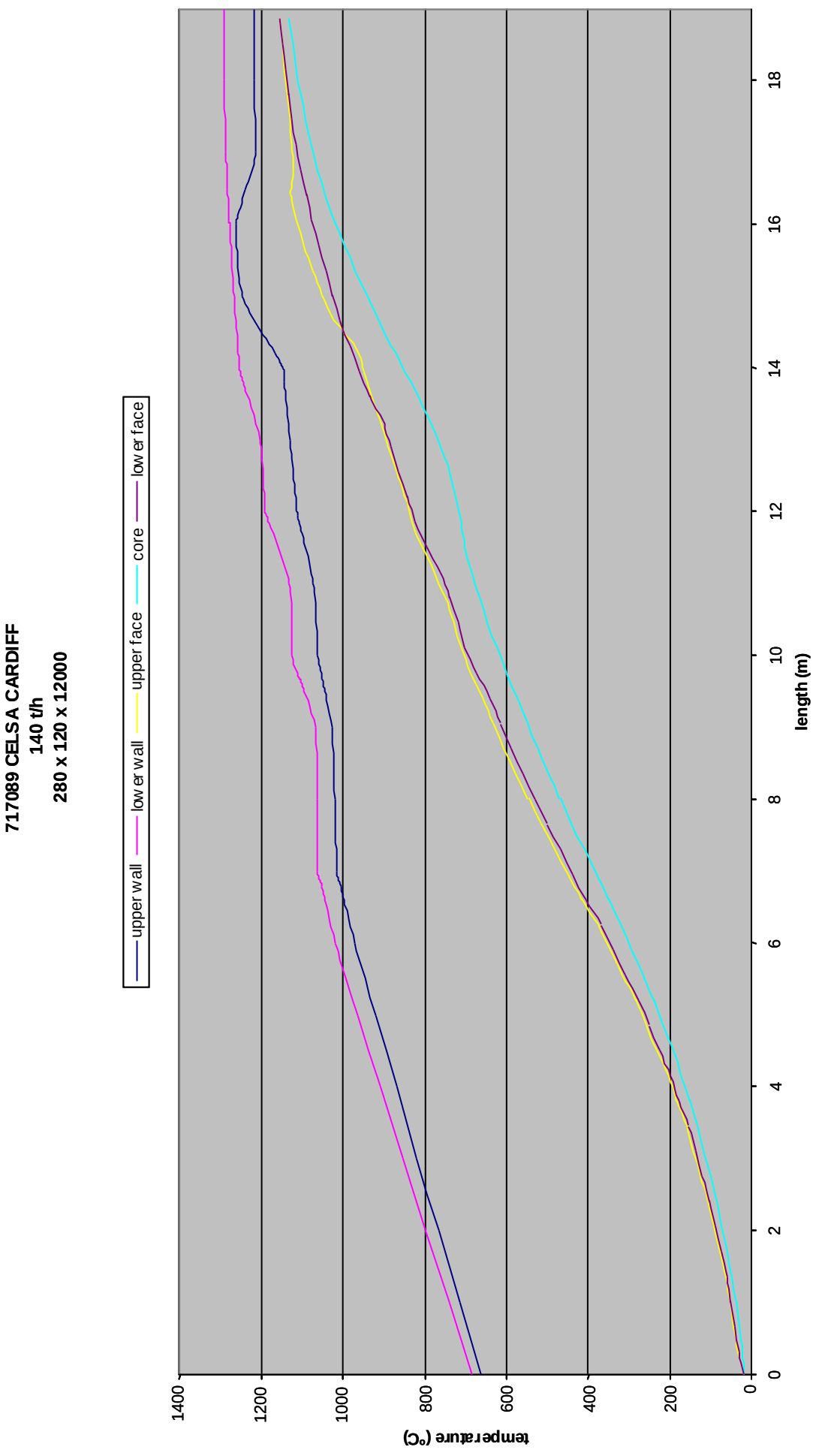
120 x 280 x 12000 charging at 20°C, discharging at 1150°C

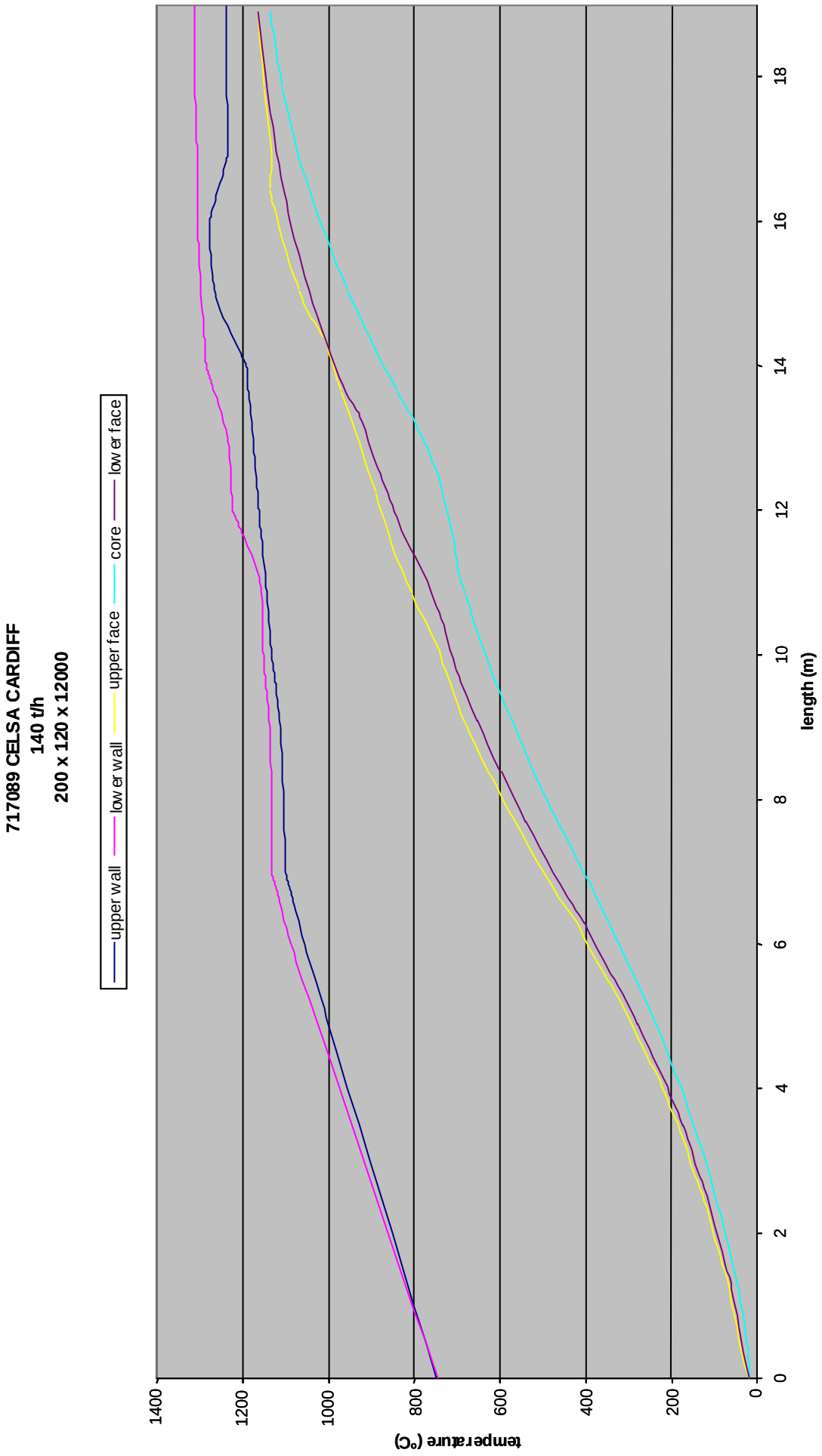
PRODUCTION: 140 tph

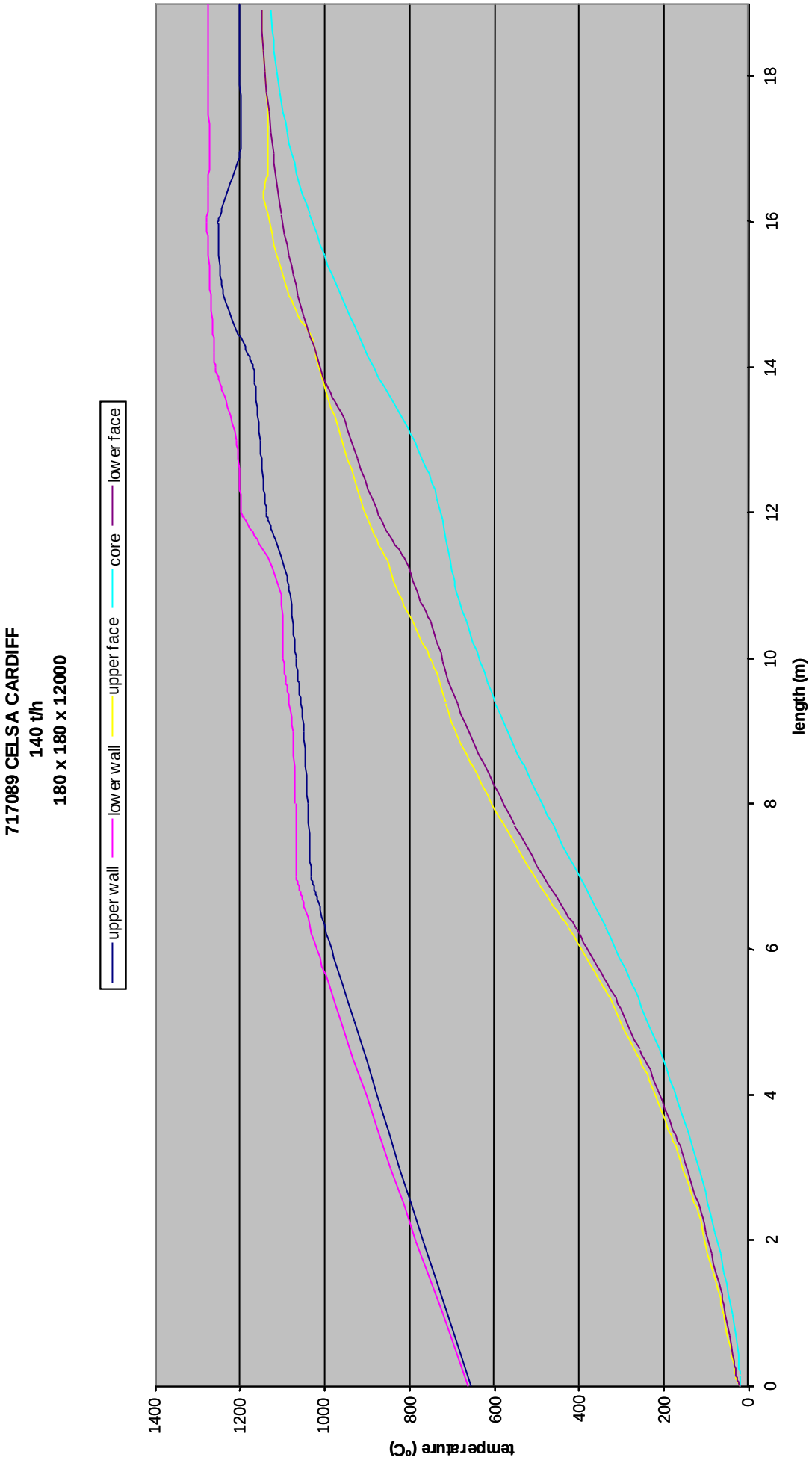
120 x 200 x 12000 charging at 20°C, discharging at 1150°C

PRODUCTION: 140 tph

180 x 180 x 12000 charging at 20°C, discharging at 1150°C


717089 CELSA CARDIFF
140 t/h
280 x 120 x 12000
upper wall
lower wall
upper face
core
lower face
temperature (°C)
1400
1200
1000
800
600
400
200
0
length (m)
0
2
4
6
8
10
12
14
16
18


717089 CELSA CARDIFF
140 t/h
200 x 120 x 12000
upper wall
lower wall
upper face
core
lower face
temperature (°C)
length (m)
0
200
400
600
800
1000
1200
1400
0
2
4
6
8
10
12
14
16
18


717089 CELSA CARDIFF
140 t/h
180 x 180 x 12000
upper wall
lower wall
upper face
core
lower face
temperature (°C)
1400
1200
1000
800
600
400
200
0
length (m)
0
2
4
6
8
10
12
14
16
18

9.2 TEMPERATURE HOMOGENEITY – SURFACE / CORE

The temperature uniformity surface-core, only has meaning if it is dissociated from the other reheating consequences, such as skid marks and longitudinal uniformity.

Uniformity between surface and core will only be considered in the part of the product between the beams and ignoring the product end effects.

In conclusion, the points of our conception which allow us to attain a small differential temperature between the surface and core are :

- sufficient power in the heating zone ;
- adequate residence time ;
- soak zone correctly dimensioned for good soaking.

9.3 SKID MARKS

This phenomenon is purely due to the beams which form a screen between the lower face of the product and the furnace.

Please refer to chapter 10 which gives a detailed explanation of our technique for minimizing this reheating fault.

9.4 TEMPERATURE UNIFORMITY OVER THE LENGTH OF THE PRODUCTS

The key to a good temperature uniformity over the length of the product is:

- the choice of burners,
- the positioning of burners in the combustion chamber,
- the control of the burners,
- the capacity which the combustion equipment has to adapt to the loading plan of the products,
- the control of furnace pressure and evacuation of waste gases from the furnace.

As a consequence, we consider that the strong points of our conception are:

- symmetrical heating,
- the specially designed wide flame side burners in the upper soak and heating zones allow us to control the heat transfer over the width of the furnace and the possibility of burner cascading in the heating zone enable operation at best efficiency.
- a good control of the evacuation of waste gases due to the provision of upper and lower barrage walls and the positioning of the waste gas exists in the lower charge wall.

9.5 SCALE MAKE

If the mechanisms of the fabrication of scale remain difficult to differentiate on a chemical level, the basic rules of conception and controlling a furnace which produce the minimum scale make are known :

- **Limit the residence time of the surface of the product over 900 ºC**

This imposes a furnace operation adapted to the discharge rate from the furnace and the objective discharge temperature.

- **Control of the furnace atmosphere**

In effect, high quantities of excess air favour the oxidizing reaction. Care should be taken, however, since operation too close to stoichiometric can cause the production of "sticky" scale.

In conclusion, to satisfy the requirements the following is proposed:

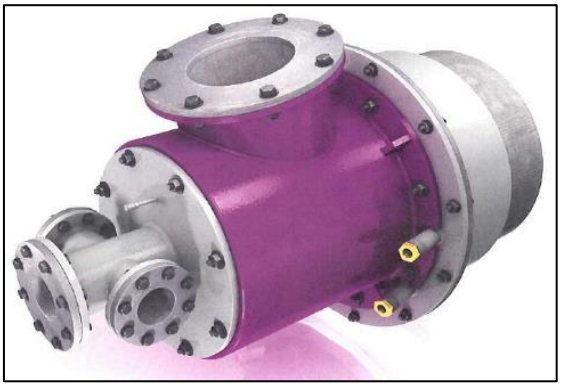
- the control of the furnace using an optimizing system,
- a good control of furnace pressure,
- air and gas flow ratio optimum for any furnace output thanks to the digital philosophy ON/OFF.

10 CHOICE AND LAYOUT OF BURNERS

SOAKING AND HEATING ZONES

The furnace will be fired in the top and bottom zones with Fives Stein patented Advantek® Ultra Low NOx MWF burners.

All burners are side mounted.



AdvanTek® burner

Each burner is connected to an air and gas header and has its own air and gas on/off valve. The so-called Digital Control Mode is the pulsing on/off of the burners at 100% power.

Nowadays, reheat furnaces have to comply with even more stringent performances, such as optimized heat transfer pattern in the product, very low NOx emissions, and more recently the ability to operate with very low calorific value fuel, dual-fuel firing or hydrogen. To comply with these new requirements, Fives Stein has developed a new generation of burners, called AdvanTek® Modulating Central Wide Flame (MWF).

The AdvanTek® MWF program was conducted over a period of several years, through an R&D project and Computational Fluid Dynamics (CFD), supported by a series of tests in the Fives Stein Manufacturing combustion test center, and finally industrial tests in an existing high capacity slab reheat furnace recently put into operation in Europe.

The burner development had several objectives, mainly to:

- Obtain uniform heat pattern in the product in any furnace size and with any type of fuel,
- Cut emissions such as NOx to levels far below the most stringent applicable standards,
- Optimize the burner design in order to facilitate installation of the burners in news furnaces or for revamping furnaces (for upgrading performances).

To reach these objectives, several industrialization steps were conducted in order to establish a new range of standard burners for new furnaces and revamping of existing furnaces. In addition, this burner is designed to be easily fitted in sidewalls of the furnace.

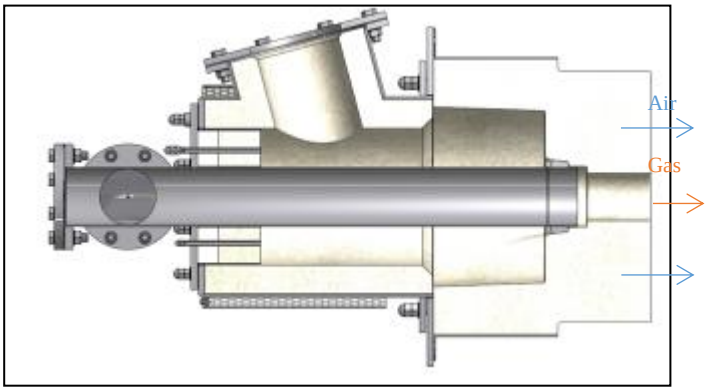
Heat demand control is operating either on/off firing (control of the duration of the firing during on cycle at burner design capacity) for installation on Digit@l Furnace® or proportional mode (flow control of the burner) in conventional existing furnaces.

Furthermore the MWF burners are able to operate within a wide range of capacities and with almost all kind of fuels available in steel plants.

Burner development

In order to achieve a wide flame shape the development was done in several steps by improvements of the AdvanTek® WFB.

The burner geometry was developed by step from the wide flame concept already known with the older Wide Flame Burners. The development path follows the way of gaseous fuel injection, combustion air port layout, fuel and air momentum and internal flue gas recirculation.

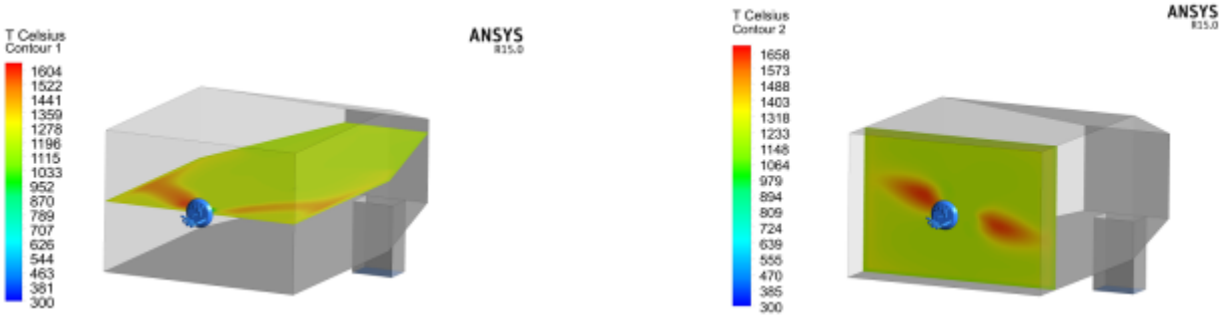


Schematic view of the AdvanTek® Modulating Central Wide Flame (MWF) burner.

Computational fluid dynamics

In order to anticipate the targeted results and optimize the design of the burners from the beginning, CFD simulations and analysis were performed. The main parameters considered are the diffuser geometry and the velocity.

Results were focused on the heat distribution in order to have a wide flame pattern, power distribution, flow and jets path and reactive mixing in order to avoid high pick of flame temperature.



Example of CFD calculation results: temperature (left) and velocity vectors (right) in the pilot furnace.

Experimental set up

Experimental tests of CWF burners were performed in Fives Stein Manufacturing Continuous emissions monitoring panel.

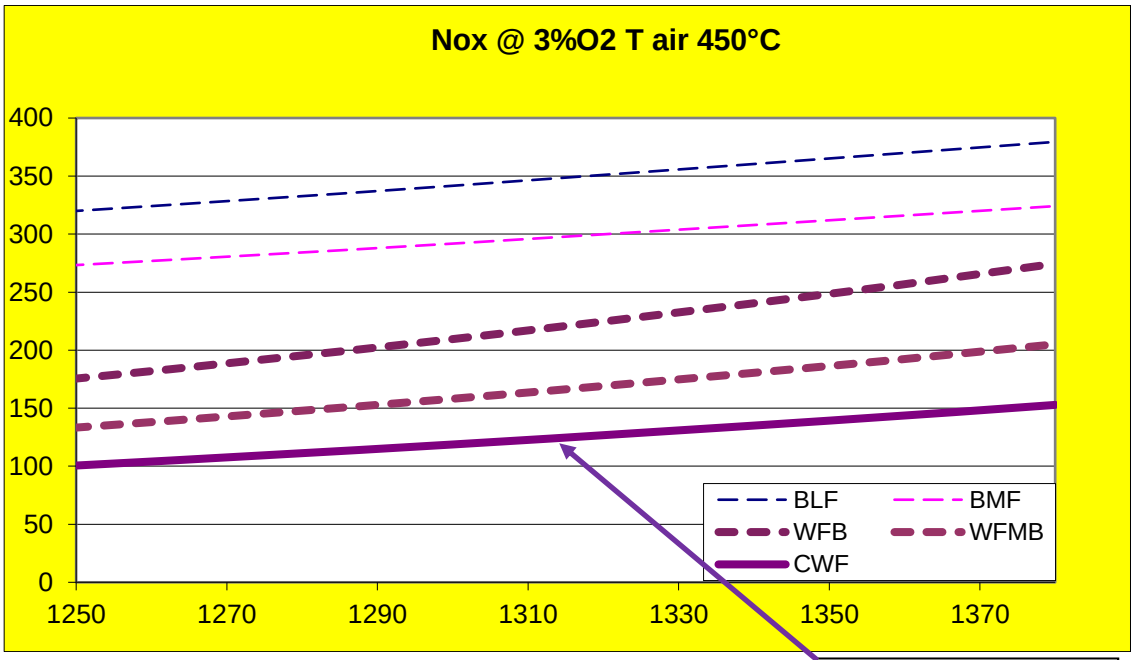
Lab tests

Every burner development includes general operating condition, e.g. ignition in cold condition, with several combustion air temperature, roof temperature and excess of air, duration modulating time control or proportional mode control. Flames are checked by visual observation. When the furnace is cold the flame is separated in two parts with butterfly wing shape. When the furnace is hot with gaseous fuel the flame is not visible on test furnace.

Results

Significant results were achieved with the new CWF burner on heat transfer optimization with a heat distribution very flat on a plane parallel to the burner horizontal axis.

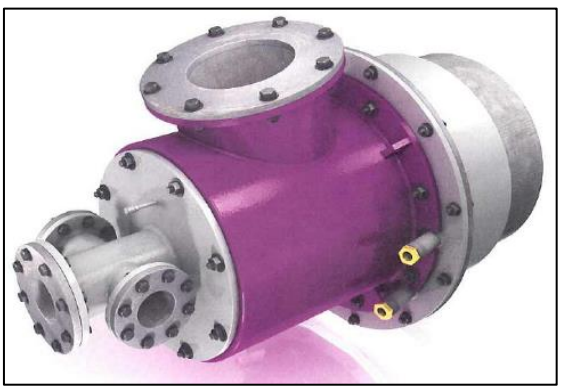
In spite of quite hot combustion air and hot furnace conditions usually required for slabs reheating, NOx emissions measured with AdvanTek® CWF burners are about 40% lower than with previous burners.



Emissions of different burner types in test centre (natural gas)

The furnace will be fired in the top and bottom zones with Fives Stein patented Advantek® Ultra Low NOx MWF burners.

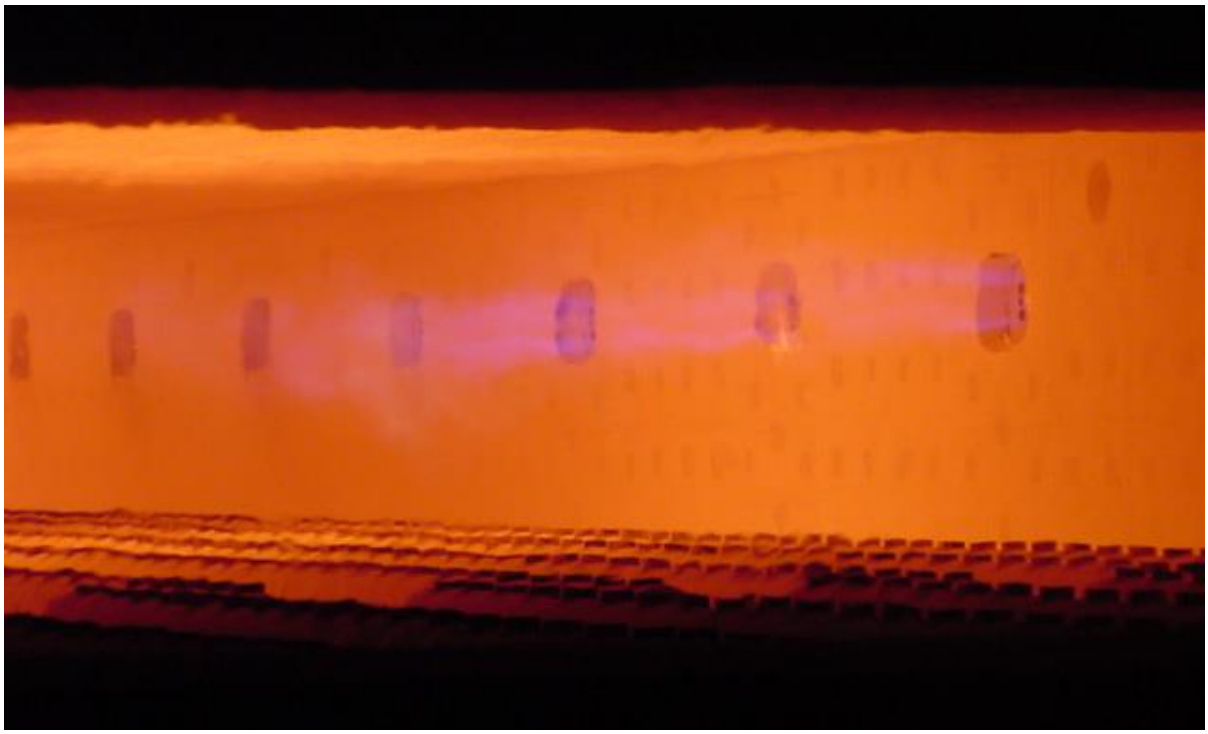
All burners are side mounted.



AdvanTek® burner

Each burner is connected to an air and gas header and has its own air and gas on/off valve. The so-called Digital Control Mode is the pulsing on/off of the burners at 100% power.

EXTERNAL VIEW OF A DIGIT@L FURNACE



INSIDE VIEW OF A DIGIT@L FURNACE

11 LOADING DIAGRAM AND SKIDS SYSTEM

From the available information FIVES STEEL SPAINproposes the moving skids morphology:

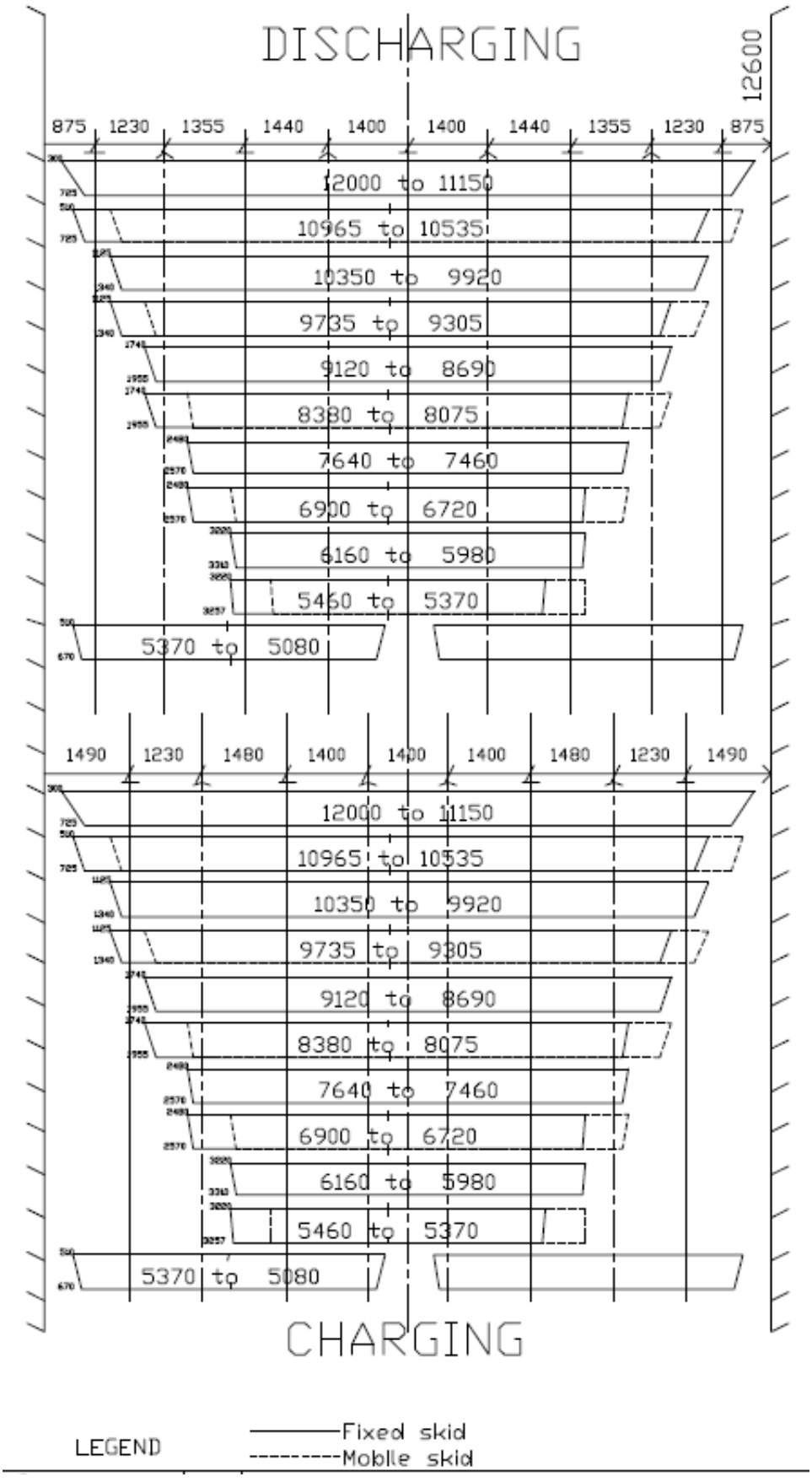
- 4 fixed skids
- 4 moving skids (5 at soaking)

The positioning of these skids takes account of:

- the maximum allowable overhang of the products as a function of the section and temperature,
- the bending between two supports in position of rest and during transfer,
- the precision of positioning at the charge end,
- protection of the skids,
- the wandering of the products in the furnace,
- the expansion of the products,
- the arms of the discharge machine.

This is a critical area in the design of the furnace and it is for this reason that FIVES STEIN has spent considerable time and effort in perfecting this aspect of our design capability, carrying out tests at our research station which were rechecked against actual results from furnaces we have built. With this information FIVES STEIN developed a computer program which is systematically used to prepare loading diagrams for each project. This in-depth experience and knowledge based on research and feedback from reference furnaces is particularly significant here because errors in the loading diagram, due to for example an inaccurate product positioning system or an inadequate designed walking frame guide system, can severely restrict the production capabilities of the new furnace.

Apart from the consequence of limitations on product lengths which can be processed and thus on possible output from the furnace, a badly designed skid system can also have great impact on the quality of the final product due to the skid marks produced in the products as they are heated.


DISCHARGING
12600
875 1230 1355 1440 1400 1400 1440 1355 1230 875
12000 to 11150
10965 to 10535
10350 to 9920
9735 to 9305
9120 to 8690
8380 to 8075
7640 to 7460
6900 to 6720
6160 to 5980
5460 to 5370
5370 to 5080
1490 1230 1480 1400 1400 1400 1480 1230 1490
12000 to 11150
10965 to 10535
10350 to 9920
9735 to 9305
9120 to 8690
8380 to 8075
7640 to 7460
6900 to 6720
6160 to 5980
5460 to 5370
5370 to 5080
CHARGING
LEGEND
Fixed skid
Mobile skid

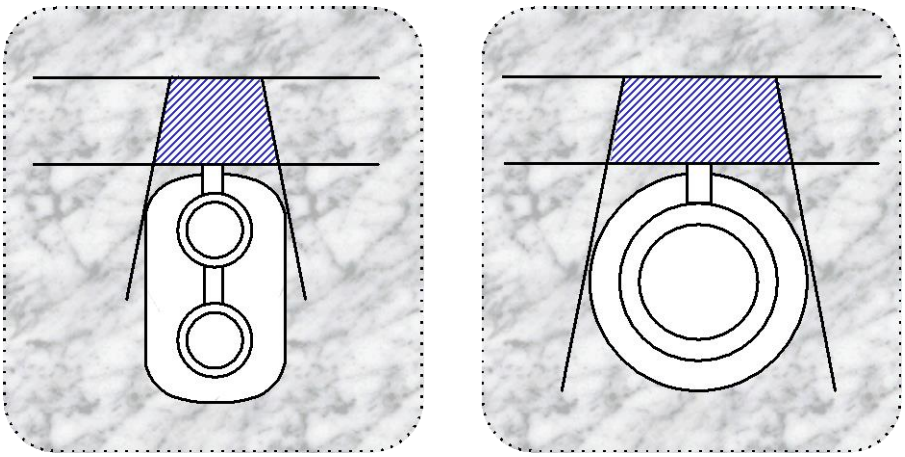
It is the product charging diagram which allows us to calculate the load on the beams and posts and therefore dimension the tube diameters.

Apart from the mechanical aspect, the beams have an influence on the thermal quality of the product.

In effect, if we analyze the cause of the skid marks, we find that the reheating defect is 85 % due to the shadow effect of the beams and 15 % due to the contact between the product and the rider bar.

Our objective is therefore to reduce to a minimum the diameter of the beams while respecting the mechanical resistance of the system. To that end we propose our double tube design. In this design, two tubes are joined by a plate, with one tube above the other.

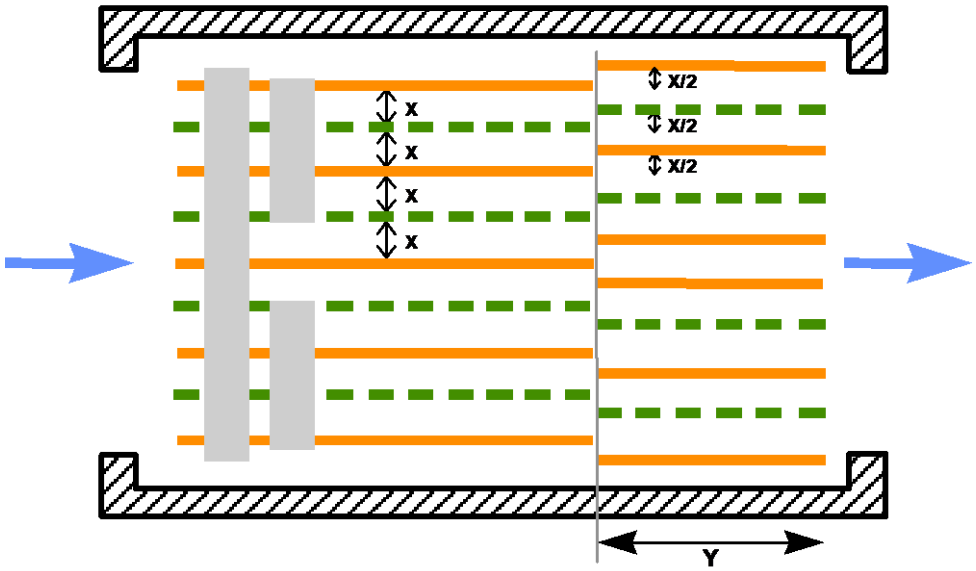
For the same moment of inertia, when compared with a single tube design, the tube diameter can be much smaller in the double tube solution. Small tube diameter leads to a smaller shadowing on the lower surface.



However, this is not sufficient to arrive at a charging diagram which is mechanically and thermally optimized.

In fact, the best solution for minimizing skid marks, as first implemented by FIVES STEIN, is to have a solution with the fixed and moving beams spaced at regular intervals in the heating zones, whereas the beams of the soaking zone are offset from those in the heating zones by half an interval.

Optimized staggering to minimize skids marks

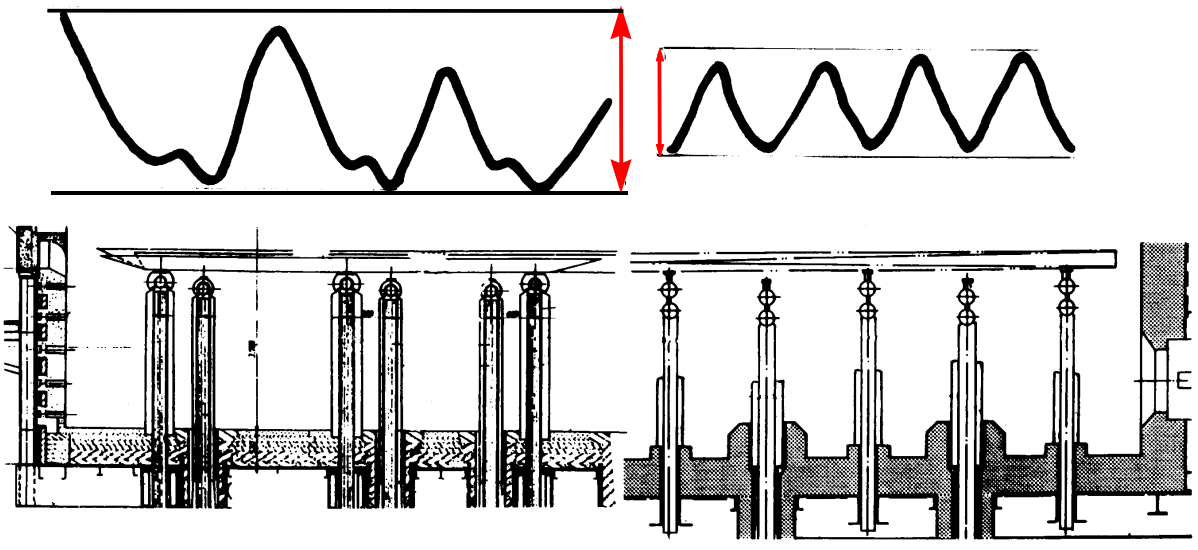


As can be seen from our proposed beam arrangement, this is not always physically possible due to the need to charge specific ranges of product lengths, however, we have tried to respect the requirements as much as possible.

The staggered beam arrangement means that the cold areas of the product on which shadows are cast by the beams in the heating zones will not be shielded from radiation in the soaking zone. Conversely, the hottest product areas leaving the heating zones will be subjected to "shadowing" when travelling through the soaking zone.

The equal spacing of the beams has great influence on the magnitude of the skid marks.

Influence of skid spacing on skid marks



To optimize the position of the stagger when considering the product travelling speeds, it is necessary to calculate the length of the soaking zone so that the skid marks developed in the heating zones are counterbalanced by the new skid marks created in the soaking zones.

For the installation and analysis of results from the SOLLAC Seremange furnace (the first walking beam furnace in the world equipped with staggered skids), FIVES STEIN developed a mathematical model to calculate the heat flux exchange between the furnace and the products as well as the temperature evolution within the products.

This model has been used to optimize the stagger position.

It should be noted that the influence of staggering, the beams for reducing the skid marks has a result many times greater than other methods such as so call hot riders or increasing the rider height or staggering the riders on the tubes.

The influence of a reduced skid mark on the final quality of the product and the operating cost can be shown by :

- the possibility of reducing the discharge temperature,
- reduced energy consumption,
- reduced scale loss,
- improvement in dimensional tolerances of the final product.

12 DESIGN OF PRODUCT SUPPORTS

FIVES STEIN has developed a program for calculating the temperature of the product support rider bars or buttons from their base in contact with the water cooled skid tube, to their face in contact with the product. We are therefore in a much better position to understand the conditions/temperatures in which the riders or buttons are operating.

This allows us to define, following the furnace zone, the quality and the characteristics of the metal which are best adapted to the conditions of operation.

We have also been able to increase the height of the riders and buttons, permitting a hotter surface of contact and especially increasing the product to skid distance thus reducing its shadow effect which is the principal cause of skid marks.

Two techniques exist today for the rider bar design :

- THE TECHNIQUE CALLED HOT RIDERS :

The riders are clipped on a bar which is welded directly to the beam. This conception facilitates, in theory, the replacement of the riders, but has the consequence of having parts operating at high temperatures.

We have seen on certain furnaces rapid crushing of the riders under the mechanical loads at too high temperatures. This design also has the drawback of uncontrollable cooling due to inconsistent contact between the rider and the support bar. As a consequence, there is a risk of premature wear without explanation for certain riders with respect to others.

♦ THE TECHNIQUE CALLED COLD RIDERS :

Before the introduction of staggered beams, all furnace constructors tried to find solutions for reducing skid marks developing rider which could function at higher and higher temperatures.

Feedback measurements have since shown that 85 % of skid marks are caused by the shadow effect of the beam and only 15 % due to cooling from the riders.

As a consequence, FIVES STEIN considers that with correctly designed staggered beams it is no longer necessary to have the riders operating at high temperatures.

We therefore recommend direct welding of the riders to the beams which allows us to assure a good surface contact, and therefore exchange, which is constant between the rider and the beam.

Our experience shows that the reliability and robustness of this design is very good over time.

Pads of special steel will be installed at the furnaces working with billets and in the same way as plots.

13 CONTROL AND AUTOMATION

13.1 CONTROL SYSTEM

The proposed microprocessor based system was introduced due to its improved performance, and includes :

- Pulse controlled heating,
- master-slave control for the adjacent zones,
- feed-forward control of the furnace pressure,

this permits an important improvement in the furnace process control.

14 PERFORMANCES FOR PRODUCTION VARIABILITY

A hot rolling mill does not work most of its time at its nominal capacity because different final products have different rolling speeds.

One of the advantage of the digit@I furnace is the variability in the heating geometry, allowing heating “as late as possible” in order to obtain advantages in consumption.

CHAPTER II

"TECHNICAL DATA"

1. MAIN CHARACTERISTICS

The furnace and equipment can be shown in the lay-out drawings attached (see chapter VII)

718243-A-0000-0-P-0001-R02	Lay-out
718243-A-0000-0-P-0010-R00	Longitudinal section
718243-A-0000-0-P-0011-R00	Section B-B
718243-A-0000-0-P-0012-R00	Combustion air ducts

1.1 GENERAL

Reference data:

. Billets of 120 x 280 x 12000 mm carbon steel (BISRA 3) .....140 MT/h
. Reheating capacity.....20 to 1150°C

1.1.1 Other products

120 x 200 x 12000 mm (BISRA 3)
180 x 180 x 12000 mm (BISRA 3)
160 x 160 x 12000 mm (BISRA 3)140 x 140 x 12000 mm (BISRA 3)

1.2 MAIN DIMENSIONS

⇒ Distance between charging/discharging axes.....19000 mm
⇒ Inside furnace width .....12600 mm
⇒ Roller table level.....+725 mm
⇒ Maximum level .....+9000 mm
⇒ Basement level .....- 6350 mm

1.3 DESIGN TEMPERATURE

Maximum temperature for refractory design: 1300°C.

2. TECHNICAL INFORMATION

All external equipment are foreseen to obtain a maximum production of 140 t/h with billets of 120 x 280 x 12000 mm.

3. HANDLING EQUIPMENT

3.1 LIST OF HANDLING UNITS

The products will be processed by the following handling units:

- Charge roller table inside the furnace,
- Fixed stopper,
- Aligning pusher,
- Walking beam mechanism (lift frame/transfer frame),
- Kick-off
- Discharge roller table inside the furnace,

3.1.1 Furnace charge rolls

The charging rollers inside the furnace shall consist of a set of individually driven cantilever rollers with variable speed A.C. motor drives. Each motor will be attached to the roll shaft mounted bevel gearbox by a separate coupling.

The roller shafts shall be supported on antifriction bearings housed in steel Plummer blocks located outside the furnace.

A special rotating water joint will be provided for water cooling. The shaft and roll body will be fully water cooled.

Each roll unit will be able to be dismounted and retracted for ease of maintenance.

Braking of the rolls will be ensured electrically via the inverter.

3.1.2 Inside roller table

- number 10
- roll profile .....conical
- Quality .....same as discharging rollers

- moving system..... hollow shaft individual gear motor

- Speed.....1 m/s
  - * number.....10
  - * power .....5,5 kW to 1500 rpm VVVF

- Pitch between rollers ..... from 1000 to 1400 mm.

Cooling system (only shaft cooling):
- * rotating joint: DEUBLIN type
- * unitary flow.....1 m^3/h

Furnace stopper

A fixed stopper will be provided and mounted at the side of the furnace in line with the furnace charge rolls. This stopper will be used for refractory protection. The stopper head will be water cooled.

Aligning pusher

A hydraulically actuated aligning pusher will be provided at the furnace charge end with the 4 pusher fingers passing through the charge end wall. The device will ensure that the products are aligned before they start their walking cycle through the furnace and that all products start their convey from the same position.

3.2 WALKING BEAM SYSTEM

3.2.1 Driving system

a) mechanical under furnace includes:

8 inclined ramps

1 lifting frame with:
- * 8 lifting wheels
- * 8 transfer wheels

1 transfer frame
- * 2 central guides

b) Cycle

Rectangular

Lifting : 200 mm

Transfer: two strokes 350 and 280 mm

350 mm for products 120 x 200 and 120 x 280
280 mm for 160 x 160, 140 x 140 and 180 x 180

3.2.2 Water troughs

Tightness at the slots, between the movable and fixed beams will be ensured by a series of seal water troughs, blades and covers. Water troughs will be made in stainless steel (AISI 304)

3.2.3 Scale removal systems

General

The oxidation and consequent scale build-up in the furnaces built by our Group is substantially reduced thanks to the special design features, however, when scale is required to be removed from the furnace hearth this will be done at each maintenance stop (once a year or less).

3.2.4 Under hearth mechanical equipment

Description

The walking beam mechanism consists of an upper transfer frame which carries the walking beams, and a lower frame which supports the upper frame and runs on inclined ramps.

The interconnections between the transfer cylinder and the movable upper frame, and the lift cylinders and lower frame, are achieved by a system of swivel joints and connecting rods.

To ensure easy removal of the lift cylinders, they are designed with an over-stroke, which allows the lower frame to be lowered onto back stops on the ramps. The cylinders are then off-loaded and may be removed and taken away.

Design of the mechanism allows the bearings to be positioned well below the furnace, where they will not be subjected to heat, and are easily accessible for maintenance.

3.2.5 Walking beam cycle

The walking beam cycle is rectangular, with movements carried out at variable speeds, in order to ensure:

- a gradual start-up and stoppage of the transfer and lifting / lowering movements, which prevents excessive stresses on the mechanical system, on the one hand, guarantees a linear conveyance of the stock through the furnace on the other hand, and avoids damage to the refractory insulation through vibrations. Slow-down upon lifting and/or lowering of the stock prevents the stock from being marked by the support pads on the longitudinal beams,

- an adequate speed to obtain a cycle of a total period which is consistent with the required charging and discharging rates.

- Vertical movement:
  The lifting and lowering movements of the walking beams are achieved through a set of hydraulic cylinders, causing the lower frame, which is equipped with a series of rollers, to run up and down the inclined bases. During these movements, the transfer cylinder is locked.

- Horizontal movement:
  The transfer movement of the walking beams is achieved by means of a hydraulic cylinder, which actuates directly on the upper frame, sliding over the top wheels of the lower frame. During the transfer movement, the lift cylinders are locked.

- Idling movement of the walking beams
  In the event of an extended stoppage of the mill, the walking beams switch to a holding mode where the moving beams position themselves at the same level as the fixed beams. In this way the stock is supported by all the beams.

3.3 DISCHARGING EQUIPMENT

3.3.1 Furnace discharge rolls (inside the furnace)

The discharge rollers inside the furnace shall consist of a set of individually driven cantilever rollers with variable speed A.C. motor drives. Each motor will be attached to the roll shaft mounted bevel gearbox, by a separate coupling. Braking of the rolls will be ensured electrically via the inverter.

The roller shaft shall be supported on antifriction bearings housed in steel plumer blocks located outside the furnace. Between the roller shaft and the furnace shell, suitable heat shield will be provided to minimize the heat losses and for protection of bearings from heat.

A special rotating water joint will be provided for water cooling. Only the shaft will be water cooling and the roll body will be made from high alloy heat resisting steel.

3.3.2 Inside discharging roller table

Characteristics of the roller:

- Number inside the furnace 10
- Roll profile ..... conical
- driving system ..... hollow shaft individual gear motor

  speed ..... 1 m/s
  * number 11
  * power ..... 5,5 kW at 1500 rpm VVVF
- pitch between rollers ..... from 1000 to 1400 mm

  Cooling system (only shaft cooling):
  * rotating joint: DEUBLIN type
  * unitary flow ..... 2 m^3/h

The discharging gear motors power are selected in the same way as the charging to reduce the number of the different spare elements.

3.3.3 Kick-off

It is a discharging machine (lift/advance) “kick-off” type. Each system is provided with a lifting and transfer movement.

Hydraulic lifting

Number of arms ..... 2 per machine
Number of cylinders ..... 1 per machine
Cylinders stroke (approx) ..... 50 mm
Lifting stroke (approx) ..... 225 mm
Lifting speed ..... 20 mm/s

Hydraulic transfer

Number of cylinders ..... 1 per machine
Cylinder stroke ..... 1700 mm
Transfer speed ..... 275/185 mm/s

3.4 HYDRAULIC EQUIPMENT AND GREASING SYSTEM

The hydraulic equipment described below will be supplied as complete sub-assemblies. Each main component (pump, tank, etc.) will be mounted on its support frame with all necessary fittings ready to be installed in the hydraulic room.

Variable displacement pumps shall be used to achieve the transfer and lift cycles with variable speeds.
Mineral oil based hydraulic oil will be used as working fluid.
The hydraulic power pack for the furnace and the external mechanical equipment will include:

- the main flow pumps, plus one in stand-by for the lifting/lowering and transfer movements,
- the pumps for filtering and cooling the hydraulic oil including one in stand by,
- the mild steel oil tank with fittings and level indicators,
- the hydraulic oil cooler,
- the necessary solenoid valves and valve stands,
- the safeguards for protection of the cylinders and pumps in case of failure of the pumps, pipe breakage, excess pressure rise, etc.,
- the cylinders for the transfer and lifting movements, together with their associated valves and flexible hoses,
- the cylinders for movements of the kick-off machine.

The power pack and its control devices will be housed in the furnace hydraulic room, supplied by others.
Alarms and monitoring signals in the hydraulic room will be repeated in the furnace control room on the HMI.

- *Hydraulic equipment*

  Number of lifting cylinders: 2

  Number of transfer cylinders: 1

  Hydraulic pressure: 110 bar (in the cylinder approx.)

- *Hydraulic station*

  structure
  * capacity of the hydraulic tank: 3500 litres
  * lifting and transfer pumps: 3 + 1
  * Main pumps

Qty	: 3 + 1 stand-by
Type	: variable flow
Maximum pressure	: 120 bar

Unitary flow : 360 l/min
Motor power : 90kW to 1500 rpm

* Filtered and cooling pumps

Qty : 1 + 1 stand-by
Type : fixed flow
Unitary capacity : 200 l/min
Motor power : 3 kW to 1500 rpm

3.4.1 Centralized grease system

An automatic centralized dual line grease lubrication system shall be provided for lubrication of the mechanical moving parts of the furnace.

The system includes:

* pumping station (1 pump at 250 kg/cm²)
* control panel
* all hoses fittings, grease manifolds and valves
* the number of points to be greased will be approx. of 150 (100 fixed + 50 movables)

3.5 SKIDS AND POSTS SYSTEM

→ Fixed skids: 4 in heating, recuperation and soaking zones

→ Movable skids: 4 in heating and recuperation zones and 5 in soaking zone

→ With the purpose of reducing the skid marks, their design is done with:

* double tube system
* Staggered skids in the soaking zone

Cooling water system

→ total cooling water: 400 m³/h

3.5.1 Product supporting pads

→ First section (around 50% of furnace length)

= Gx40 Cr NiSi 25-20

→ Second section (around 50% of furnace length)

= GNiCr28W

3.6 HEATING CHARACTERISTICS

⇒ Gas distribution
⇒ Combustion air

3.6.1 Heating equipment

a) The furnace profile is provided with:

→ One recuperative zone

→ One upper preheating zone

→ One bottom preheating zone

→ one bottom heating zone

→ one upper heating zone

→ one bottom soaking zone

→ one upper soaking zone

b) The combustion air is reheated up to max. 580 ºC at the recuperator outlet.

c) Fuel

- Natural gas

→ Low heating value ..... 8783 Kcal/Nm³ / 36.760 MJ/Nm^3
→ Gross heating value……9752 Kcal/Nm^3/40.818 MJ/Nm^3

→ Supply pressureFrom 2 to 7 bar (one final value to be agreed during detail

design engineering)

c) Fuel (alternative)

- Hydrogen

→ Lower calorific power..... 2572 Kcal/Nm^3/10.765 MJ/Nm^3
→ Gross heating value…….3062 Kcal/Nm^3/12.744MJ/Nm^3

→ Supply pressure ..... To be defined

The heating capacity of the furnace is oversized from 140 t/h in order to allow a quick response after a mill stoppage and an eventual heating consumption increase due to leak of refractories in the skids and posts.

3.6.2 Combustion air fan

Flow ..... 60400 Nm³/h
Static pressure ..... 1350 mm.c.a.
motor.....400 kW - 1500 rpm

2 fans, 1 working and 1 in stand-by

3.6.3 Recuperator – Figures for the reference product (calculation done for 140 t/h)

The recuperator here under has been selected to reduce the overall furnace consumption. This is obtained by significantly increasing the combustion air temperature.

Waste gases temperature at furnace outlet 740ºC

Waste gases temperature at recuperator inlet 720ºC

Waste gases temperature at recuperator outlet .....259°C

Waste gases volume at recuperator inlet (included dilution) ..... 47608 Nm³/h

Air temperature at recuperator inlet .....20°C

Air temperature at recuperator outlet .....580°C

Volume of the air to be heated (nominal) ..... 43346 Nm³/h

Air pressure drop .....237 daPa

Waste gases pressure drop ..... 15.5 daPa

Max air temperature (alarm) for recuperator material selection ..... 625 ºC

Max waste gases temperature (alarm) for material selection ..... 850 ºC

The recuperator will be protected against too high combustion air temperature by hot air bleed and against too high flue gases temperature with dilution air.

Data indicated are preliminary and they could be modified without affecting the performance guarantees.

3.7 COOLING WATER SYSTEM

3.7.1 Direct water (industrial cooling water)

use ..... water troughs
installed flow (filled) ..... 30 m³/h
flow (consumption) ..... 6 m³/h
pressure ..... 3 bar
temperature ..... 36°C
Δt ..... 15°C

3.7.2 Indirect water (close circuit) (filtered cooling water)

See also chapter 8. Conditioning and cooling water equipment

Skids and posts ..... 284,8 m³/h
Furnace charging rolls ..... 20 m³/h
Furnace discharging rolls ..... 30 m³/h
End bumper ..... 1,3 m³/h
cameras, etc. ..... 2 m³/h
Kick-off arms ..... 16 m³/h
Billet detectors ..... 3 m³/h
Discharging door frame ..... 2,50 m³/h
TV cameras ..... 2 m³/h
Hydraulic cooling ..... 12 m³/h
TOTAL REQUIRED ..... 371,6 m³/h

TOTAL INSTALLED ..... 400 m³/h

pressure ..... 4 to 5 bar

supply temperature .....36°C
Δt .....15°C

3.7.3 Emergency water

Circulated water flow.....300 m³/h
pressure.....4 bar

3.7.4 Filtered water quality

Items	Unit	Cooling water (CW)
PH	-	7 - 9
Suspended matter	mg/l	< 10
Total solids or residual after evaporating (solvable)	mg/l	< 225
Full hardness	Equivalent mg/l CaCO3 et Mg	<220
Carbonate hardness	Equivalent mg/l CaCO3	<180
M-Alkality (solvable)	Equivalent mg/l $HCO3^{-}$	< 50 à 150
Ca ion	mg/l (Based on Ca2+) average	< 200
Cl ion	mg/l (Based on Cl^{-})	< 100 at 40°C
Sulphate ion	mg/l (Based on SO_4)	< 250 at 40°C < 50 at 80°C
Full iron	mg/l (Based on Fe)	< 0,5 mg/l
Solvable SiO_2	mg/l (SiO_2)	< 20
Conductivity	µs/cm	< 1000
Organic matters		NONE

- Total hardness: This parameter is important because, if high, consequences will be problems of precipitation in the pipes, therefore reducing the heat exchange and destroying the skid pipes, roll shafts, etc. This means that the furnace will have to be shut down for a long period of time for repairs, therefore, meaning a big loss of production in the plant.

- Chlorides: This parameter is important because, if it is high, there will be corrosion problems in the pipes, therefore water leaks, and a reduced lifetime of the pipes.

- Sulphates: This parameter is important because incrustations will occur in the pipes, thus reducing the heat exchange and reducing the lifetime of the skid pipes, roller shafts, etc. (similar consequences as with hardness).

4. UTILITIES REQUIREMENTS

The following utilities will be supplied by client to Take Over Point (T.O.P.) with close valve (10 meter from furnace).

4.1 COMBUSTIBLE

4.1.1 Natural gas

- Net calorific value ..... See 3.6.1
- Connected flow..... 5300 Nm³/h
- Pressure TOP..... See 3.6.1

4.1.2 Hydrogen

- Net calorific value ..... See 3.6.1
- Connected flow..... 18000 Nm³/h
- Pressure TOP.....See 3.6.1

4.2 FILTERED COOLING WATER

- Pressure at T.O.P .....4 bar
- Inlet temperature (approx.) .....36°C
- Maximum temperature rise .....15°C
- connected flow (close circuit).....400 m³/h

4.3 INDUSTRIAL COOLING WATER

- Pressure at T.O.P. .....1.5 bar
- Inlet temperature (approx.) .....36°C
- Connected flow.....37 m³/h

4.4 COMPRESSED AIR

4.4.1 Compressed air

- quality..... Class 4.3.2 according to ISO 8573-1:2010
- pressure .....6 bar
- flow..... 155 Nm³/h
- use .....cylinders

4.4.2 Compressed air – instrumentation

- quality ..... Class 3.2.1 according to ISO 8573-1:2010
- pressure ..... 6 bar
- flow ..... 155 Nm³/h
- use ..... positioners and pneumatic actuators for valves

4.5 ELECTRICITY

- Voltage ..... 400 V ± 10%
- frequency ..... 50 Hz
- supply power ..... see motor list

4.6 NITROGEN

Natural gas pipe purging when necessary

- connected flow ..... 60 Nm³/h (15 min)
- pressure ..... 3 bar

5. DESCRIPTION

5.1 CHARGING SYSTEM

5.1.1 Normal operation

The billets are charged in the furnace by a set of individually driven rollers with AC motor and frequency converter. The cooling system includes one rotating joint “DEUBLIN” type on each roller.

In order to avoid a considerable collision between the billet and the stopper, the speed of the roller inside the furnace is reduced, hiding the photocell.

When a photocell detects the billet, the counter starts to count down and will eventually stop the roller rotation, even if the bumper proximity switch has not detected the billet.

Once the billet is positioned on the roller table, the aligning machine aligns the product to the correct position and the movable skids take it out from the roller table.

5.1.2 Occasional operations

Furnace emptying

In case of emergency the billets that are inside the furnace can be transferred to the charging side. This operation is done manually.

All the billets are conveyed to the charging table by means of an outside charging roller table.

5.1.3 Aligning machine

The aligning machine will have an enough stroke for exceptional cases.

5.2 MOVABLE SKIDS SYSTEM

The transfer and lifting movements are controlled by means of hydraulic cylinders wheel and ramp type.

, Billet conveyance through the furnace

After the billets have been correctly and automatically positioned in the roller table inside the furnace, according to the attached loading diagram, the stock will be taken over by the walking beams and stepped forward.

At the end of the forward travel, the beams will lower, gently positioning the stock onto the fixed beams. In this manner, the stock is moved through the furnace to the discharge position avoiding any friction or rubbing between the stock and beams.

A slow-down period during lifting and lowering allows the stock to be gently lifted and lowered onto the beams, minimizing shock loads.

Once conveyed through the furnace the stock will be walked onto the discharge rolls by the kick off machine.

5.2.1 Movable beams cycle

The walking beam cycle is rectangular, i.e., the vertical and horizontal movements are never performed simultaneously. The lifting/lowering and transfer movements are carried out at variable speeds, to ensure:

- ✓ a gradual start-up and stoppage of the transfer and lifting/ lowering movements, which prevents excessive stresses on the mechanical system, on the one hand, guarantees a linear conveyance of the stock through the furnace on the other hand, and avoids damage to the refractory insulation through vibrations.

- ✓ Slow-down upon lifting and/or lowering of the stock prevents the stock from being marked by the support pads on the longitudinal beams,

- ✓ a relatively high max. speed to obtain a cycle of a total period which is consistent with the required charging and discharging rates.

Vertical movement

Lifting and lowering of the walking beams are achieved through a set of hydraulic cylinders, causing the lower frame, which is equipped with a series of rollers, to run up and down the inclined bases. During these movements, the transfer cylinder is locked.

Horizontal movement

The transfer movement of the walking beams is achieved by means of a hydraulic cylinder, which acts directly on the upper moving frame, sliding over the upper rollers of the lower frame. During the transfer movement, the lift cylinder is blocked.

5.2.2 Beams mechanism

The walking beam mechanism comprises an upper frame that carries the walking beams, and a lower frame that supports the upper frame and runs on inclined ramps.

The upper and lower frames are guided by means of guiding rollers.

Our guiding system ensures uniformity of the walking beam movement during the cycles; this is necessary to prevent any drift of the stock while progressing through the furnace.

To ensure easy removal of the lift cylinder, it is designed with an over-travel, which allows the lower frame to be lowered onto back stops on the ramps. The cylinder is then off-loaded and may be removed and taken away.

Design of the mechanism allows the bearings to be positioned well below the furnace, where they will not be subjected to heat, and are easily accessible for maintenance.

5.2.3 Skids and posts

The skid tubes are water cooled and insulated externally by a double-layer insulation. Posts consist on two concentric pipes and fabricated in such a way that allow the water to cool the post heads first.

The skids and posts are secured to each other by welding and made from seamless, heavy carbon steel tubes of high mechanical resistance.

Special steel pads are welded onto the skids to support the stock clear of the beams.

To largely reduce the formation of skid marks, our design features the following characteristics:

→ double tube design for skid pipes,

→ maximum possible distance between the movable and stationary skids,

→ maximum possible distance between the posts, to reduce the heat losses,

→ specially designed pads of an optimum height. These pads are made of:

* GNiCr28W steel in the central part of the furnace and discharging,
* G40 CrNiSi 25-20 (or similar) steel in the charging section of the furnace.

The vertical supports of the walking beams will project through slots in the hearth brickwork and furnace under-structure, and will be carried on the moving top frame of the walking beam mechanism.

The fixed beams will be supported from and secured to the hearth under-structure.

Steel grades

Movable and fixed skids ..... St 52.0 or similar
Movable and fixed posts..... St 52.0 or similar

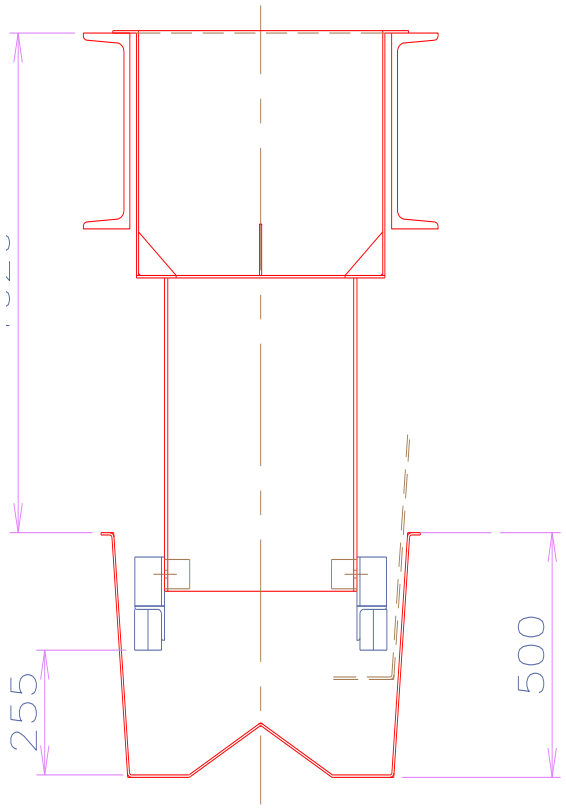
5.2.4 Water troughs

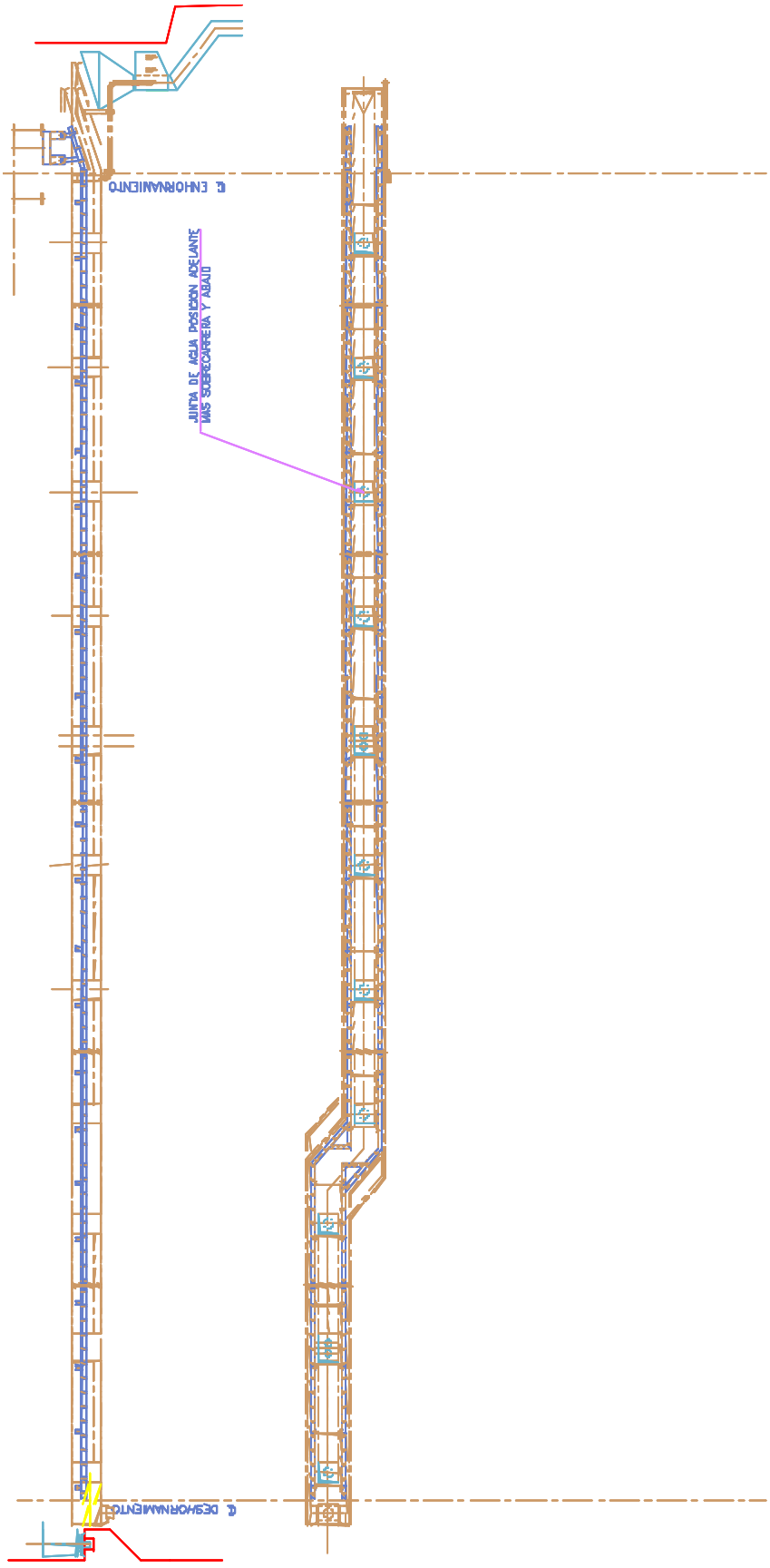
Tightness at the slots, where the movable support tubes extend through the furnace bottom will be ensured by a series of seal water troughs, blades and covers.

The water troughs and scrappers are fabricated from stainless steel plates.

Scale falls through the slots (opened in the furnace Herat for movable skids pass) to the four longitudinal troughs and is removed automatically step by step at the discharging side by the scrappers which are welded to the movable blades. The transfer occurs during the forward movement of the movable beams when the water troughs are in the highest position and the fixed scrappers are located about 10 mm above the lower trough which contains the solid deposits.

In the following pages you will find the sketches of the water trough.




E ENHORNAMIENTO
JUNTA DE AGUA POSICION ADELANTE
MAS SOBRECARRERA Y ABAJO
E DESAHORNAMIENTO

5.3 DISCHARGING MACHINES – KICK-OFF

After the crossing of the billets along the furnace, they will be extracted from the furnace by means of a kick-off.

This arm mechanism will be ready to extract the billets one by one automatically and independently of the way they are located.

This mechanism allows a quick transfer of the products

The lifting of the arms shall be carried out by hydraulic cylinders It is finger type which introduces into the furnace through openings.

Advantages of this mechanism:

- ✓ Limit the products
- ✓ Not to leave the product at beams edges.
- ✓ Decoupling beam cycle from discharging cycle.
- ✓ To manipulate misaligned products manually.
- ✓ To charge an already discharged product.
- ✓ Detection of product are made by sensors.

5.4 SCALE TREATMENT

5.4.1 Inside the furnace

→ It is recommended to be cleaned once a year through the lateral doors located at hearth level.

→ Scale ducts are located under the discharging rollers. These ducts are closed by cleanout doors.

5.4.2 In the water troughs

Scale will be automatically separated from the water troughs by a patented system by FIVES STEIN.

5.5 CENTRALIZED GREASING SYSTEM

An automatic centralized grease lubrication system permits the lubrication of the mechanical parts of the furnace and machines. The system will include reservoir, pumping unit, control panels, hoses, trays to collect drippings, valves and all the accessories necessary for a operation complete system.

5.6 STEEL STRUCTURE AND CASING

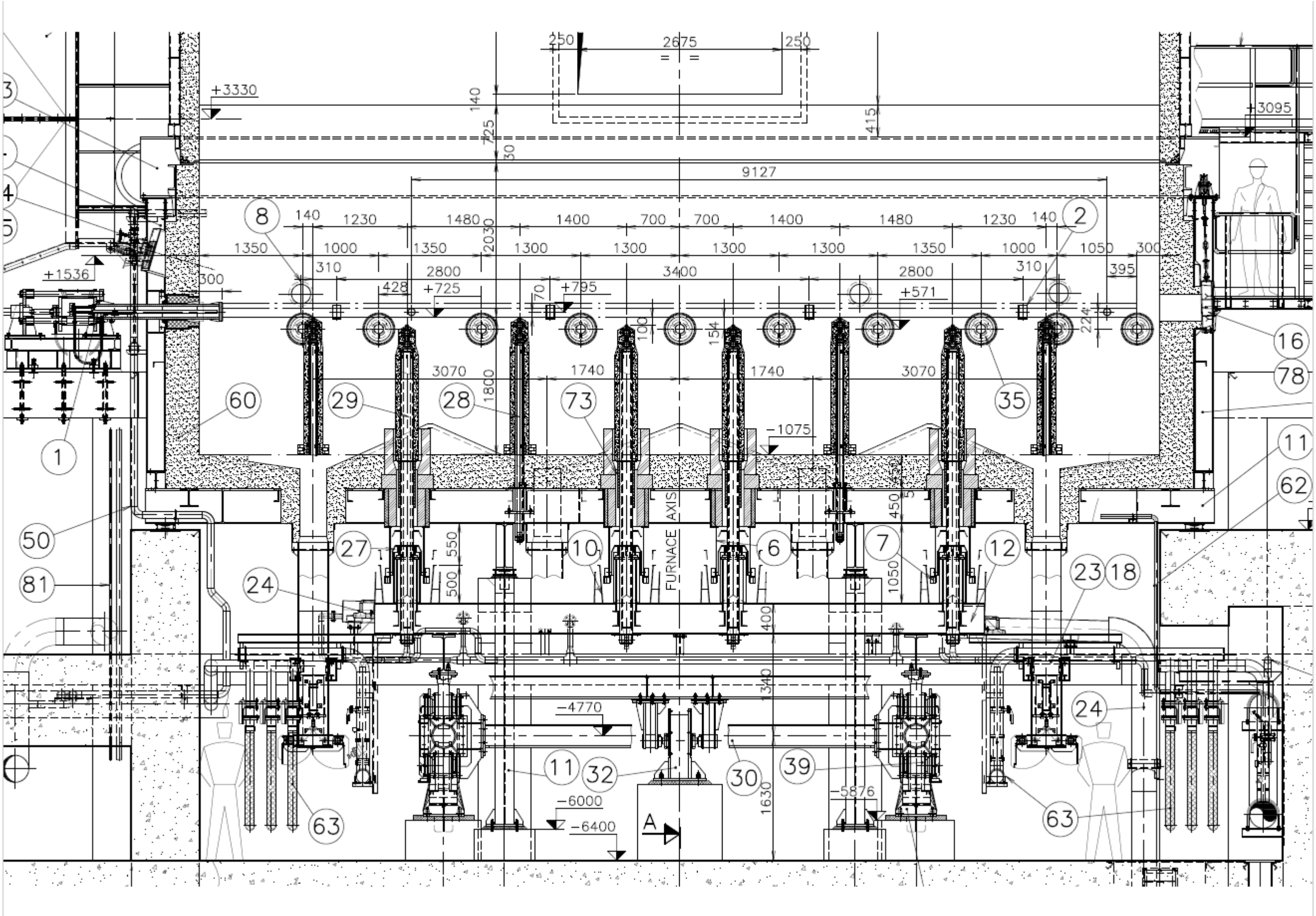
The furnace casing will be a mild steel fabricated construction, consisting of rolled steel sections and plating, designed to retain and support the furnace refractories, burners and doors.

Sidewalls

Sidewalls will be designed as a panel in 5 mm plates construction, reinforced with wide-flange rolled steel sections. The vertical binders will be spaced at approximately 1800 mm centres, and will be bolted to the hearth grillage and roof members. The side plating will be used to attach the heat resistant anchors for the wall refractories.

Hearth

The structure under furnace rests on the concrete foundations through the columns. The grillage will be braced and designed to support the hearth refractories, fixed beams and furnace charge. Beneath the hearth steelwork around the holes for the moving beams, dipper plates will be installed to ensure the furnace tightness. Plates thickness will be 5 mm.


+3330
2675
250
250
140
725
30
415
+3095
9127
140
1230
1480
2030
1400
700
700
1400
1480
1230
140
1350
1000
1350
1300
1300
1300
1300
1350
1000
1050
300
310
2800
3400
2800
310
395
+1536
300
428
+725
70
+795
+571
224
3070
1740
1740
3070
1800
100
154
−1075
FURNACE AXIS
550
500
450
1050
400
1340
−4770
−6000
−6400
−5876
1630
A
1
2
8
16
78
60
29
28
73
35
11
62
50
81
27
10
6
7
12
23
18
24
63
11
32
30
39

Roof

The furnace roof will consist of large section rolled steel beams spanning the furnace width. The main roof beams and girders will be tied to and supported from the side wall buckstays. The roof members will be used to retain and support the refractory support joists.

Doors

The furnace is equipped with:

- three visit doors (bolted) (1800 x 800 mm)
- six cleaning doors (manual)
- one charging door (pneumatic)
- one discharging door (pneumatic)
- six inspection doors
- two frontal inspection doors in each side, over the kick-off.

Platforms, stairs and walkways

For burner and thermocouples access.

5.7 REFRACTORIES AND LINING

The refractories and insulation which are described hereafter have been selected according to our wide experience and with the aim of ensuring optimum life and minimize heat losses.

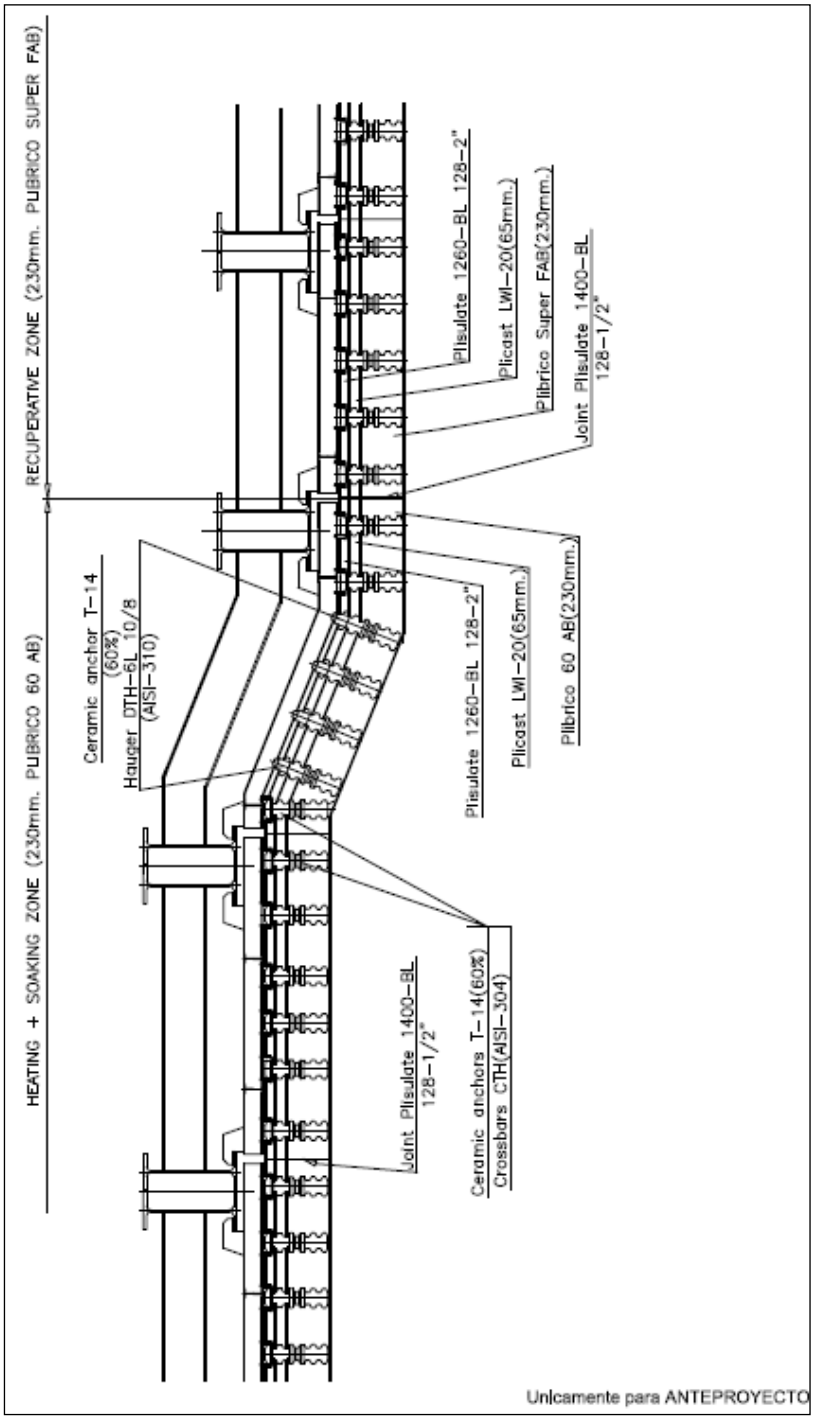
Note : to assure the best thermal shock of the different furnace refractory linings, it is recommended that, during the first operation year, the temperature rise or decrease speeds are limited to around 25-50ºC/h.

ZONE	QUALITY	THICKNESS
	ROOF	
Recuperative	Plastic 60 AB of refractory concrete d= 2,40	200
	Light castable Plicast LWI-20 d=1,14	60
	Isolating panel 1260-BL 128 d=0,128	50
	Total	310
Others	Plastic 60 AB or efractory concrete d= 2,24	230
	Light castable Plicast LWI-20 d=1,14	50
	Isolating panel 1260-BL 128 d=0,128	65
	Total	345
Various	Ceramic anchors T-14 (60%)	
	Crossbars CTH (AISI 310)	
	SIDEWALLS	
Recuperative	Plastic Superal FAB or efractory concrete d= 2,1	230
	Isolating bricks G-23 d= 0,65	115
	Cerablock 1100	50
	Plitherm	50
	Total	445
Others	Plástico 60 AB or refractory concrete d= 2,24	230
	Isolating bricks G-23 d= 0,65	115
	Cerablock 1100	50
	Plitherm	50
	Total	445
Various	Ceramic anchors T-14 (60%)	
	Anchor holders DTH-2L (AISI 310)	
	Metallic extensions “L” L = 75 mm	

ZONE	QUALITY		THICKNESS
FRONT WALLS			
Discharging	Plastic 60 AB or refractory concrete	d=2,40	230
	Brick G-23	d=0,63	115
	Cerablock 1100		60
	Plitherm		50
		Total	445
	Ceramic anchors T-14 (60%)		
	Anchor holders DTH-2L (AISI 310)		
	Metallic extensions L= 75 (AISI 304)		
Charging	Plastic Superal FAB and refractory concrete	d=21	220
	Brick G-23	d=0,65	115
	Cerablock 1100		60
	Plitherm		50
		Total	445
	Ceramic anchors T-14 (60%)		
	Anchor holders DTH-2L (AISI 304)		
	Metallic extensions L= 75 (AISI 304)		
HEARTH			
Recuperative	Plicast 28	d=2,087	120
	Plicast LWI-MIX724	d=0,54	130
	ISOLMOS brick	d=0,425	115
	Isolating panel		65
		Total	430
Others	Plicast Strongmix 150	d=2,26	120
	Plicast Stronglite	d=1,40	80
	Plicast LWI-12	d=1,2	100
	ISOLMOS brick		65
		Total	430
Separation wall	Refractories bricks 44/46 Al_2O_3		max. 460
Skids and posts lining	Plicast strongmix 160	d=2,50	50
	Plisulate 1260-BL 128 1”		20
		Total	70
	Metallic anchors KSST 10 x 50 AISI 310		
DOORS			
Charging door	Ceramic fiber modules	d=217 kg/m³	130

ZONE	QUALITY		THICKNESS
		Total	130
Discharging doors	Light isolating castable	d=1,30	130
	Isolating panels	d=0,24	50
		Total	180
	DUCTS		
Hot air ducts and pipes	with Ø < 1000 mineral wool		100
		Total	100
	DUCTS BEFORE RECUPERATOR		
Ducts before recuperator	Isolating concrete Plicast LWI-22		150
	Isolating panel	d= 0,3	40
	Isolating panel d=0,4 t/m³ Plitherm		30
		Total	220
	RECUPERATOR CASING		
Sidewalls	Isolating concrete Plicast LWI 22		150
	Isolating panel	d= 0,3	40
	Isolating panel	d= 0,14 t/m³	30
		Total	200
	DUCTS AFTER RECUPERATOR		
	Isolating concrete Plicast LW MIX 124	d=0,98	125
	Plitherm	d=0,2 t/m³	25
		TOTAL	150
	STACK		
	Plicast LW Mix 124	d=0,9	80
		TOTAL	80

All these refractory materials are given for information only, the final lining compositions and brands being determined during the detailed design period without affecting the furnace performances


RECUPERATIVE ZONE (230mm. PUBRICO SUPER FAB)
HEATING + SOAKING ZONE (230mm. PUBRICO 60 AB)
Ceramic anchor T-14 (60%)
Hauger DTH-6L 10/8 (AISI-310)
Plisulate 1260-BL 128-2"
Plicast LWI-20(65mm.)
Plibrico Super FAB(230mm.)
Joint Plisulate 1400-BL 128-1/2"
Plisulate 1260-BL 128-2"
Plicast LWI-20(65mm.)
Plibrico 60 AB(230mm.)
Joint Plisulate 1400-BL 128-1/2"
Ceramic anchors T-14(60%) Crossbars CTH(AISI-304)
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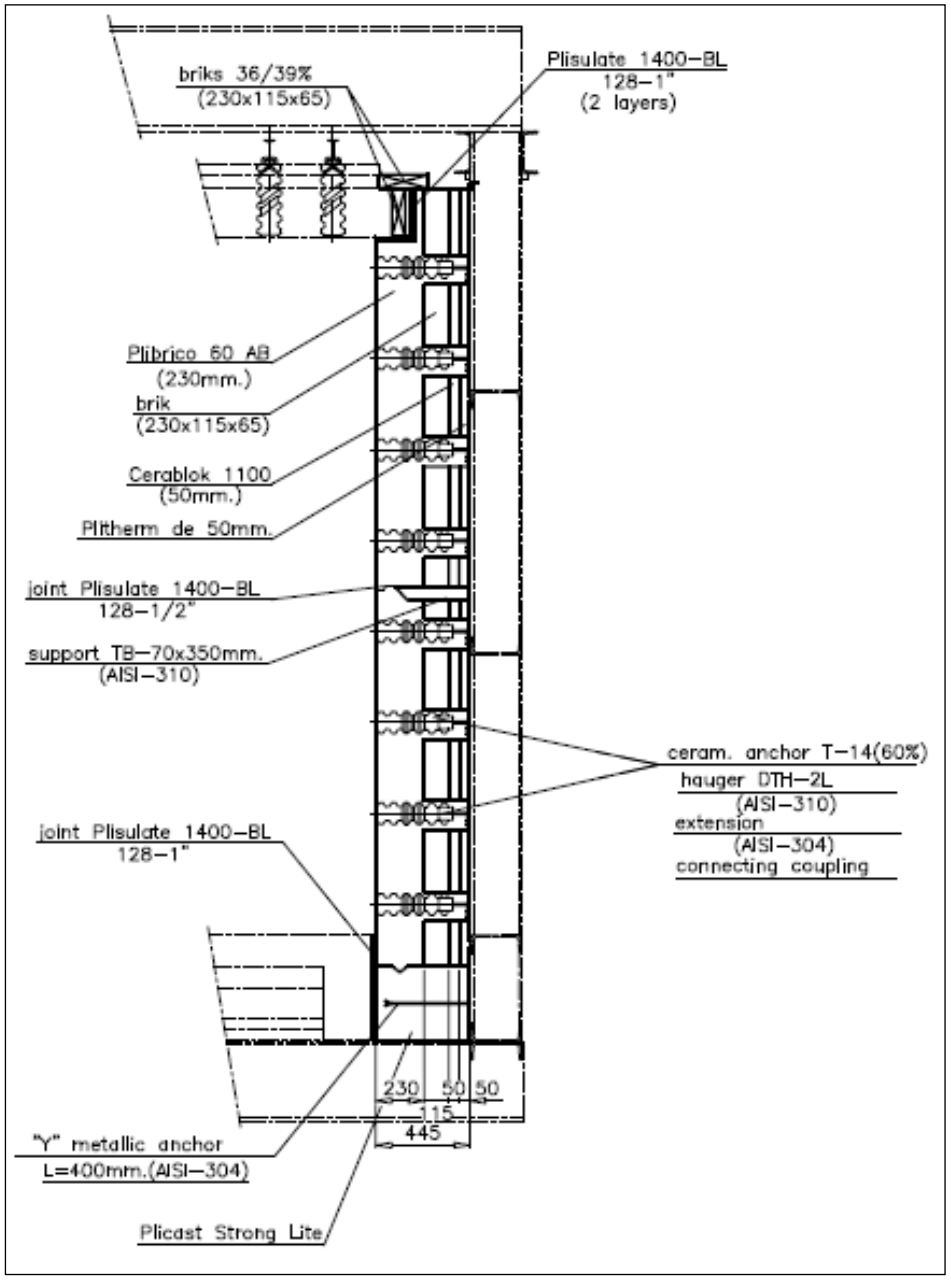
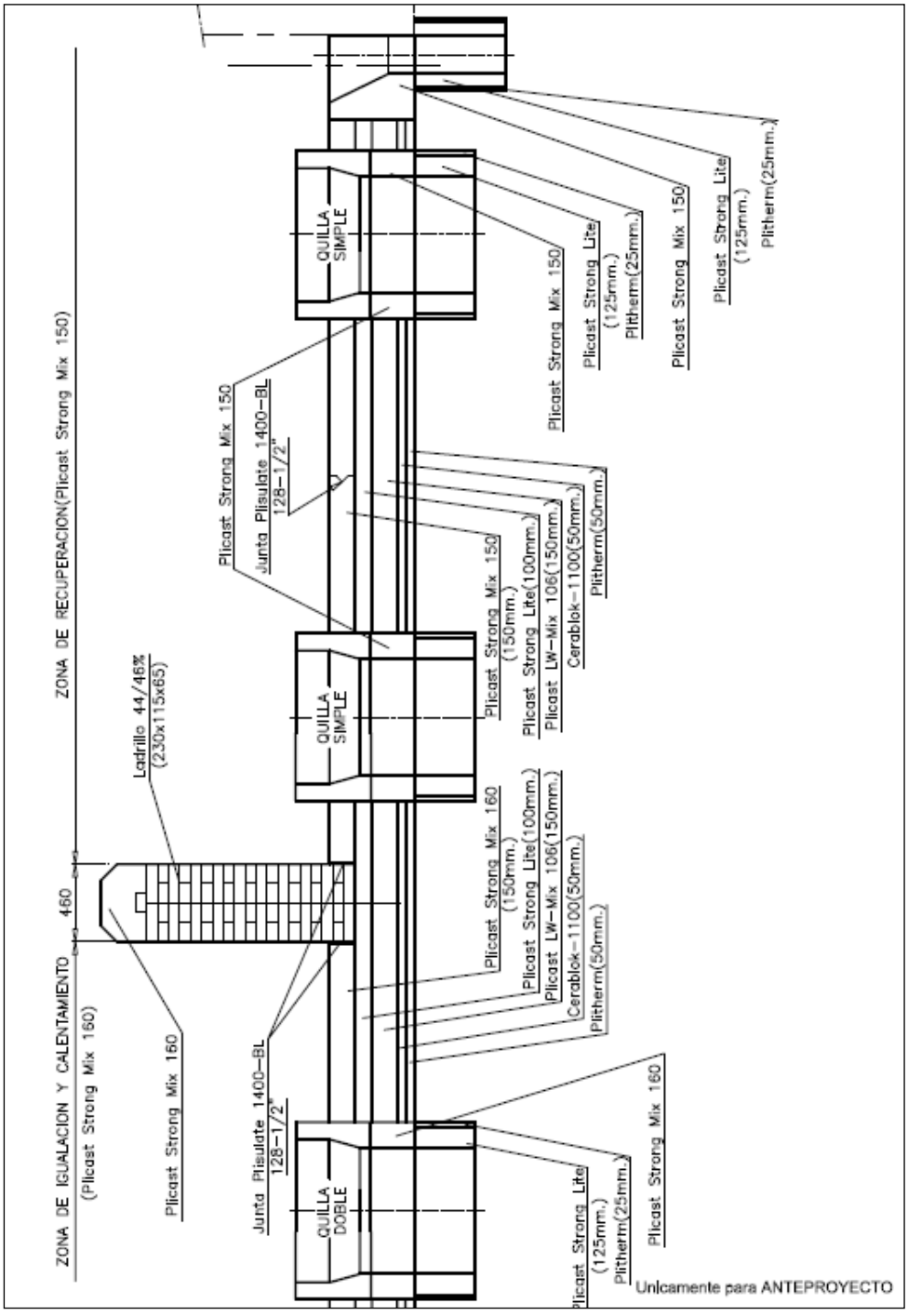
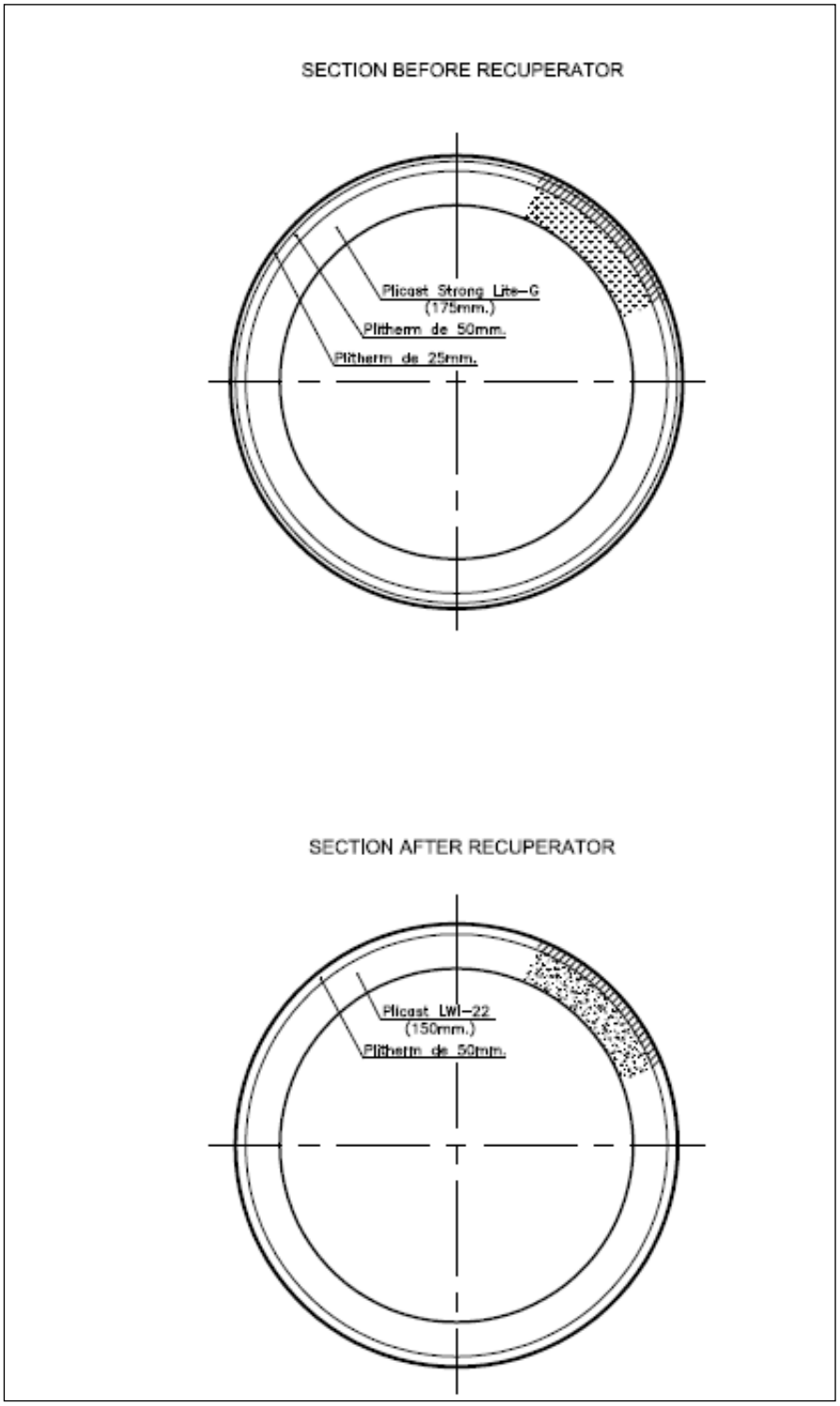
Roof


briks 36/39%
(230x115x65)
Plisulate 1400-BL
128-1"
(2 layers)
Plibrico 60 AB
(230mm.)
brik
(230x115x65)
Cerablok 1100
(50mm.)
Plitherm de 50mm.
joint Plisulate 1400-BL
128-1/2"
support TB-70x350mm.
(AISI-310)
ceram. anchor T-14(60%)
hauger DTH-2L
(AISI-310)
extension
(AISI-304)
connecting coupling
joint Plisulate 1400-BL
128-1"
230
50
50
115
445
"Y" metallic anchor
L=400mm.(AISI-304)
Plicast Strong Lite

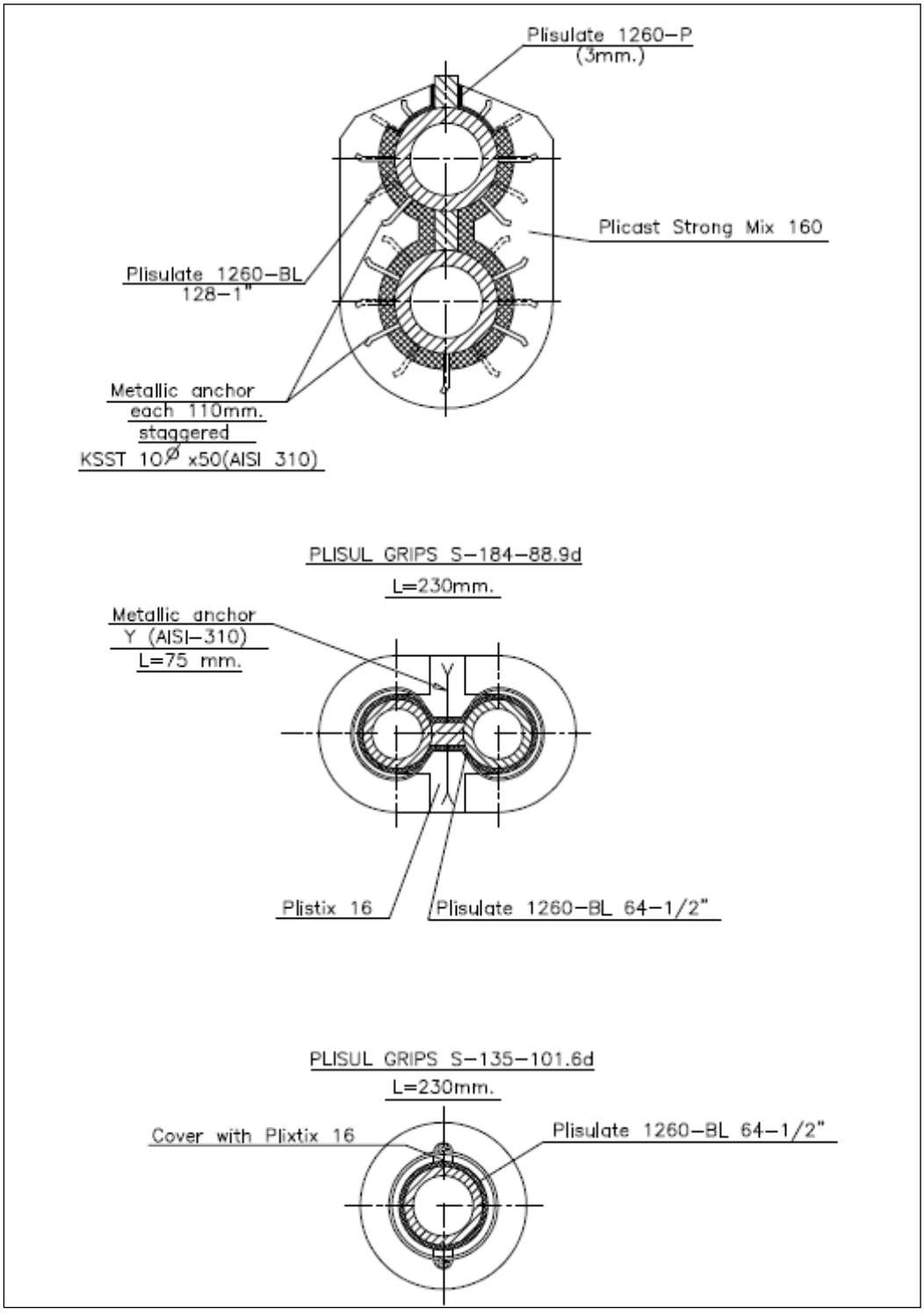
Side walls


ZONA DE RECUPERACION(Plicast Strong Mix 150)
ZONA DE IGUALACION Y CALENTAMIENTO
(Plicast Strong Mix 160)
460
Ladrillo 44/46%
(230x115x65)
Plicast Strong Mix 160
Junta Plisulate 1400-BL
128-1/2"
QUILLA
DOBLE
QUILLA
SIMPLE
QUILLA
SIMPLE
Plicast Strong Mix 160
(150mm.)
Plicast Strong Lite(100mm.)
Plicast LW-Mix 106(150mm.)
Cerablok-1100(50mm.)
Plitherm(50mm.)
Plicast Strong Mix 150
(150mm.)
Plicast Strong Lite(100mm.)
Plicast LW-Mix 106(150mm.)
Cerablok-1100(50mm.)
Plitherm(50mm.)
Junta Plisulate 1400-BL
128-1/2"
Plicast Strong Mix 150
Plicast Strong Lite
(125mm.)
Plitherm(25mm.)
Plicast Strong Mix 150
Plicast Strong Lite
(125mm.)
Plitherm(25mm.)
Plicast Strong Mix 160
Plicast Strong Lite
(125mm.)
Plitherm(25mm.)
Plicast Strong Mix 160
Unicamente para ANTEPROYECTO

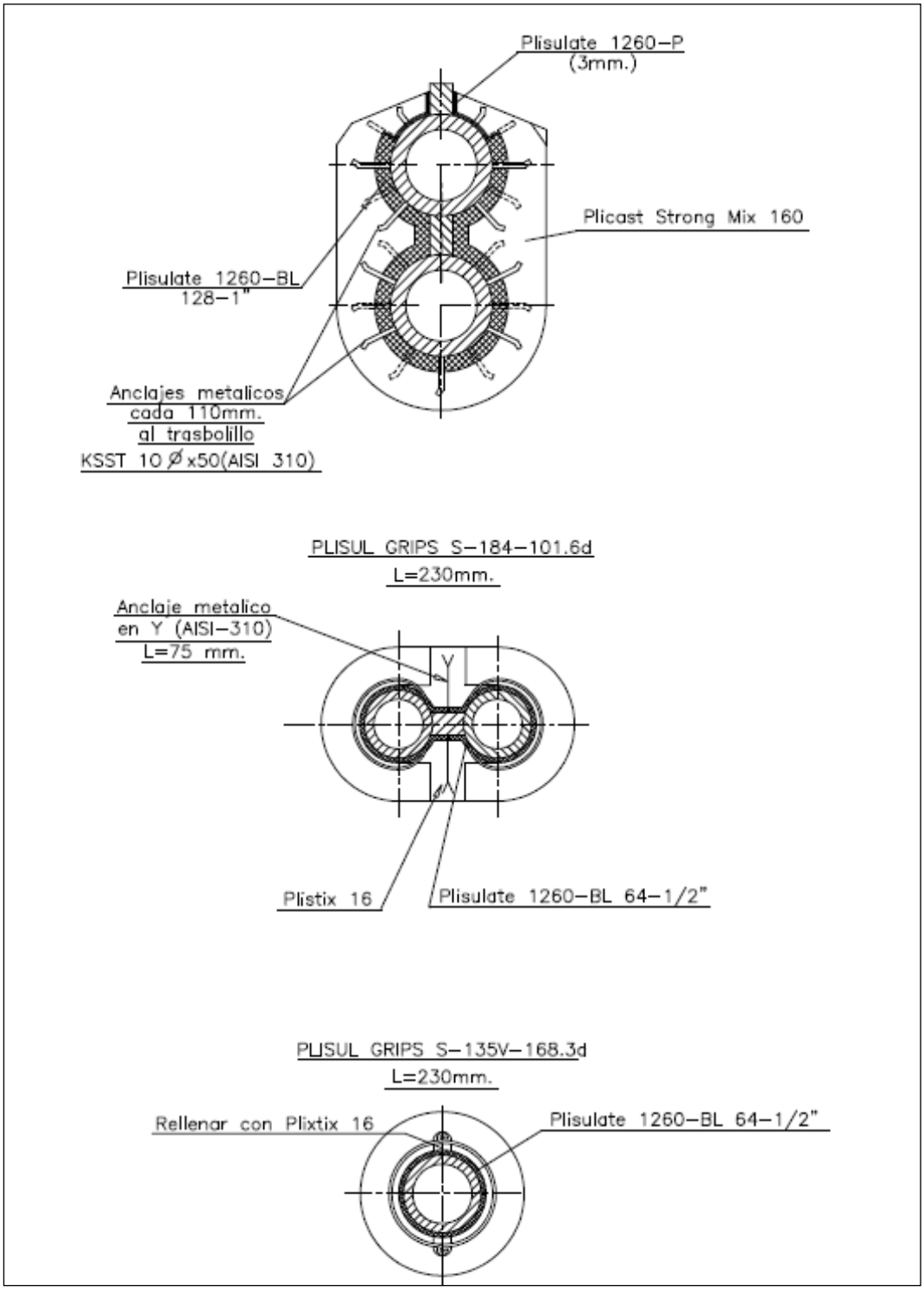
Hearth



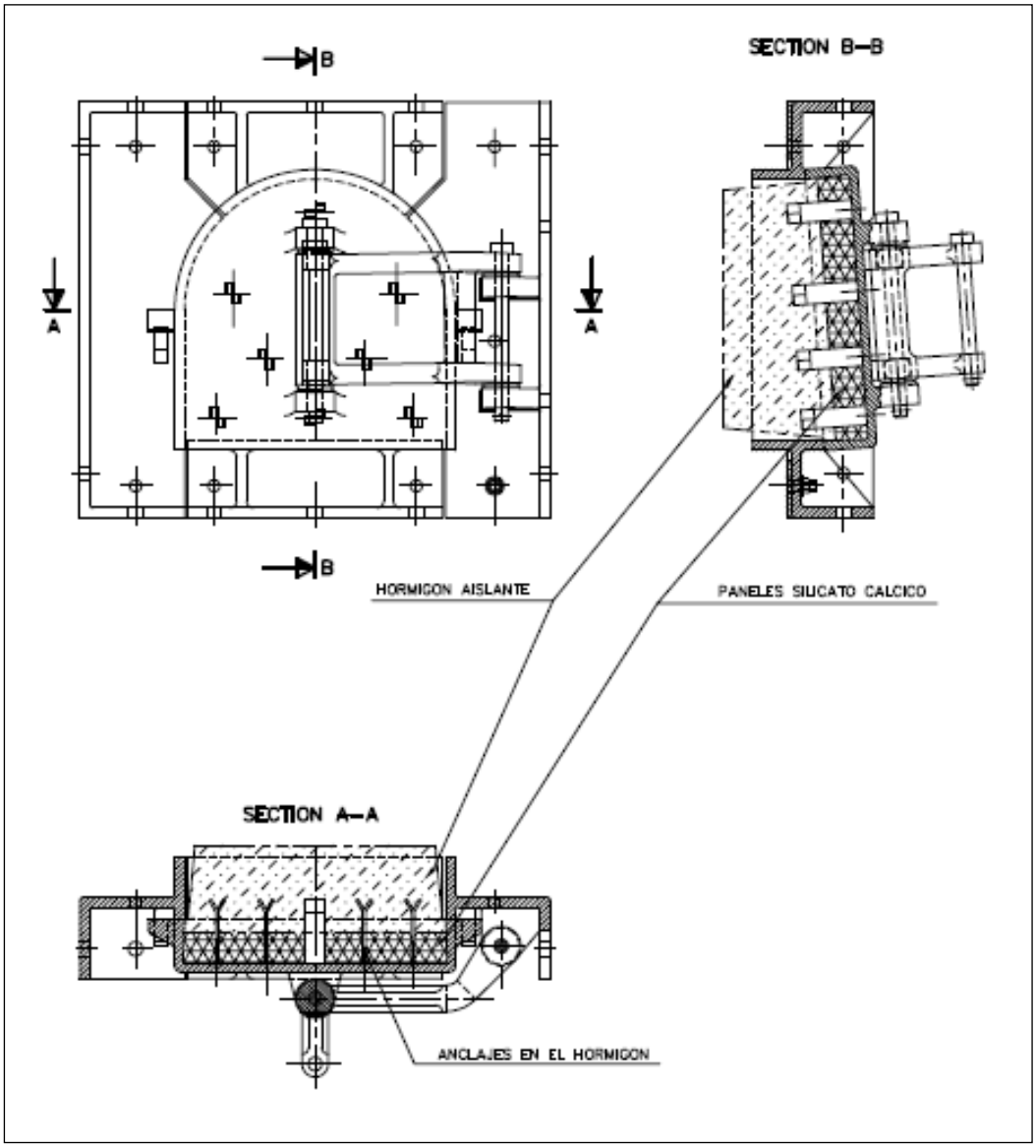
Waste gas ducts



Fixed skids and posts



Movable skids and posts



Inspection doors

Product Name: **SUPER F AB**
ISO 1927 (Classification): **Class I**
Ved Code: 3 4 0 5 10 45 23 45
ASTM (Clasification) : ----

Type : **plastic mortar**
Linking component : **ceramic**
Installation mean: **ramming**
Basic raw material : **chamotte**

GENERAL PROPERTIES				
Maximum recommended temperature *(°C)*				1.600
Material required *(tm/m³)*				2,37
Grano maximum dimension *(mm)*				7
Plasticity *(%)*				15-35
Apparent density *(g/cm³)*	2,1	after being heated at		1000°C
Apparent porosity *(%)*	25	after being heated at		1000°C
Reversible thermal expansion *(%)*		0,65	at	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
48	45	1,8	1,3	4,3

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			500	1,00
110	1,2 (contraction)	9	800	1,07
1.000	1,2 (contraction)	18	1.200	1,25

Product Name: **BRICK G-23** Type : **Isolating refractory brick**
Group ASTM C-155: **23**

PHYSICAL CHARACTERISTICS	
Maximum recommended temperature *(°C)*	1.250
Pyrometrical equivalent cone *(CS)*	31/32
Apparent density *(g/cm³)*	0,65 (máx. 0,77)
Resistance to the cold compression *(N/mm²)*	2,0 (mín.1)
Permanent variation of the dimension– ASTM C.210- *(%)*	máx.2

PHYSICAL PROPERTIES			
Linear permanent contraction		**Thermal conductivity -ASTM C –182- *(W/mK)***	
(%)			
	After 12 h. at	200°C	0,17
		400°C	0,20
1250°C	-0,5	600°C	0,23
		800°C	0,26
		1000°C	0,30

CHEMICAL ANALYSE *(%)*	
Al_2O_3	Fe_2O_3
33	1,5 (max. 1,75)

Product name: **60 AB**
ISO 1927 (Clasification):
Ved code:
ASTM (Clasification) : ----

Type : **plastic mortar**
Linking component: **ceramic**
Installation mean: **ramming**
Basic raw material: **High alumina**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.650
Material required *(tm/m³)*			2,52
Grano maximum dimension *(mm)*			
Plasticity *(%)*			15-35
Apparent density *(g/cm³)*	2,24	after being heated at	1000°C
Apparent porosity *(%)*	25	after being heated at	1000°C
Reversible thermal expansion *(%)*	0,65	at	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
60	30	1,5	0,8	

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compresión *(N/mm²)***	**Temperature *(°C)***	**Termal conductivity *(W/mK)***
			500	1,36
			800	1,44
1.000	1,2 (contraction)	17,5	1.200	1,57

Product Name: **Plicast Strong Mix 160**
ISO 1927 (Clasification): **class I**
VDEh Code: ----
ASTM (Clasification) : **class E**

Type: **dense castable (LCC)**
Linking component: **hydraulic**
Installation mean: **vibration**
Basic raw material: **raw material of high alumina**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.600
Material required *(tm/m³)*			2,48
Grano maximum dimension *(mm)*			7
Water adition *(1/100 kg)*			6-7,8
Apparent density *(g/cm³)*	2,45	after being heated at	1000°C
Apparent porosity *(%)*	19	after being heated at	1000°C
Reversible thermal expansion *(%)*	0,65	a	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
64	28	1,5	0,8	0,7

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			500	1,58
110	0,03 (contraction)	70	800	1,52
1.000	0,35 (contraction)	78	1.200	1,47

Product Name: **Plicast Strong Lite**
ISO 1927 (Classification): **class II**
VDEh Code: ----
ASTM (Classification) : ----

Type : **isolating castable**
Linking component: **hydraulic**
Installation mean: **poured**
Basic raw material: **light chamotte**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.300
Material required *(tm/m³)*			1,43
Grano maximum dimension *(mm)*			5
Water addition *(1/100 kg)*			25-35
Apparent density *(g/cm³)*	1,42	after being heated at	800°C
Apparent porosity *(%)*	51	after being heated at	800°C
Reversible thermal expansion *(%)*	0,55	at	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
38	40	4,2	1,1	1,7

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			200	0,39
110	0,10 (contraction)	15	500	0,42
800	0,20 (contraction)	12	800	0,44

Product Name: **Plicast LWI 22**
ISO 1927 (Classification): **class II**
VDEh Code: ----
ASTM (Classification) : **class Q**

Type : **isolating castable**
Linking component: **hydraulic**
Installation mean: **poured**
Basic raw material: **light chamotte**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.250
Material required *(tm/m³)*			1,25
Grano maximum dimension *(mm)*			5
Water addition *(1/100 kg)*			35-50
Apparent density *(g/cm³)*	1,23	after being heated at	800°C
Apparent porosity *(%)*	50	after being heated at	800°C
Reversible thermal expansion *(%)*	0,50	at	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
38	42	4	1,1	1,4

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			200	0,32
110	0,10 (contraction)	6	500	0,34
800	0,25 (contraction)	4,5	800	0,36

Product Name: **Pligun LW Mix 124**
ISO 1927 (Clasificación): **class II**
VDEh Code: ----
ASTM (Classification) : ----

Type : **isolating castable**
Linking component: **hydraulic**
Installation mean: **gunited**
Basic raw material: **light aggregate**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.100
Material required *(tm/m³)*			1,32
Grano maximum dimension *(mm)*			5
Water addition *(1/100 kg)*			
Apparent density *(g/cm³)*	1,18	after being heated at	800°C
Apparent porosity *(%)*	55	after being heated at	800°C
Reversible thermal expansion *(%)*	---	at	--- °C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
27	34	7	1,5	2,1

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			200	0,28
110	0,15 (contraction)	4	500	0,3
800	0,5 (contraction)	3	800	0,33

Product Name: **Anchorage T-14/60** Type : **ceramic anchorage**

PHYSICAL PROPERTIES	
Refractoriness with load *(Ta, °C)*	min. 1470
Seger Cone	35
Apparent density *(g/cm³)*	min. 2,35
Porosity open *(%)*	max. 22
Resistance to the cold compression *(N/mm²)*	min. 35

CHEMICAL ANALYSE (% weight)		
$Al_2O_3 + TiO_2$	Fe_2O_3	Álcalis
mín. 60	máx. 2,0	máx. 1,2

Product Name:: **Plicast Strong Mix 150**
ISO 1927 (Classification): **class I**
VDEh Code: ----
ASTM (Classification) : **class E**

Type : **dense castable (LCC)**
Linking component: **hydraulic**
Installation mean: **vibration**
Basic raw material: **high alumina raw materials**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.550
Material required *(tm/m³)*			2,37
Grano maximum dimension *(mm)*			7
Water addition *(1/100 kg)*			5-7
Apparent density *(g/cm³)*	2,26	after being heated at	1000°C
Apparent porosity *(%)*	19	after being heated at	1000°C
Reversible thermal expansion *(%)*	0,65	at	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
56	35	1	1	0,7

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			500	1,35
			800	1,4
1.000	0,35 (contraction)	60	1.200	1,45

Product Name: **Plicast LWI 20**
ISO 1927 (Classification): **class II**
VDEh Code: ----
ASTM (Classification) : **class Q**

Type : **isolating castable**
Linking component: **hydraulic**
Installation mean: **poured**
Basic raw material: **light chamotte**

GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.250
Material required *(tm/m³)*			1,25
Grano maximum dimension *(mm)*			5
Water addition *(1/100 kg)*			35-50
Apparent density *(g/cm³)*	1,23	after being heated at	800°C
Apparent porosity *(%)*	50	after being heated at	800°C
Reversible thermal expansion *(%)*	0,50	at	1000°C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
38	42	4	1,1	1,4

PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			200	0,32
110	0,10 (contraction)	6	500	0,34
800	0,25 (contraction)	4,5	800	0,36

Product Name: **Plicast LW-Mix 106**
ISO 1927 (Classification): **class II**
VDEh Code: ----
ASTM (Classification) : ----

Type : **isolating castable**
Linking component: **hydraulic**
Installation mean: **poured / gunited**
Basic raw material: **light chamotte**

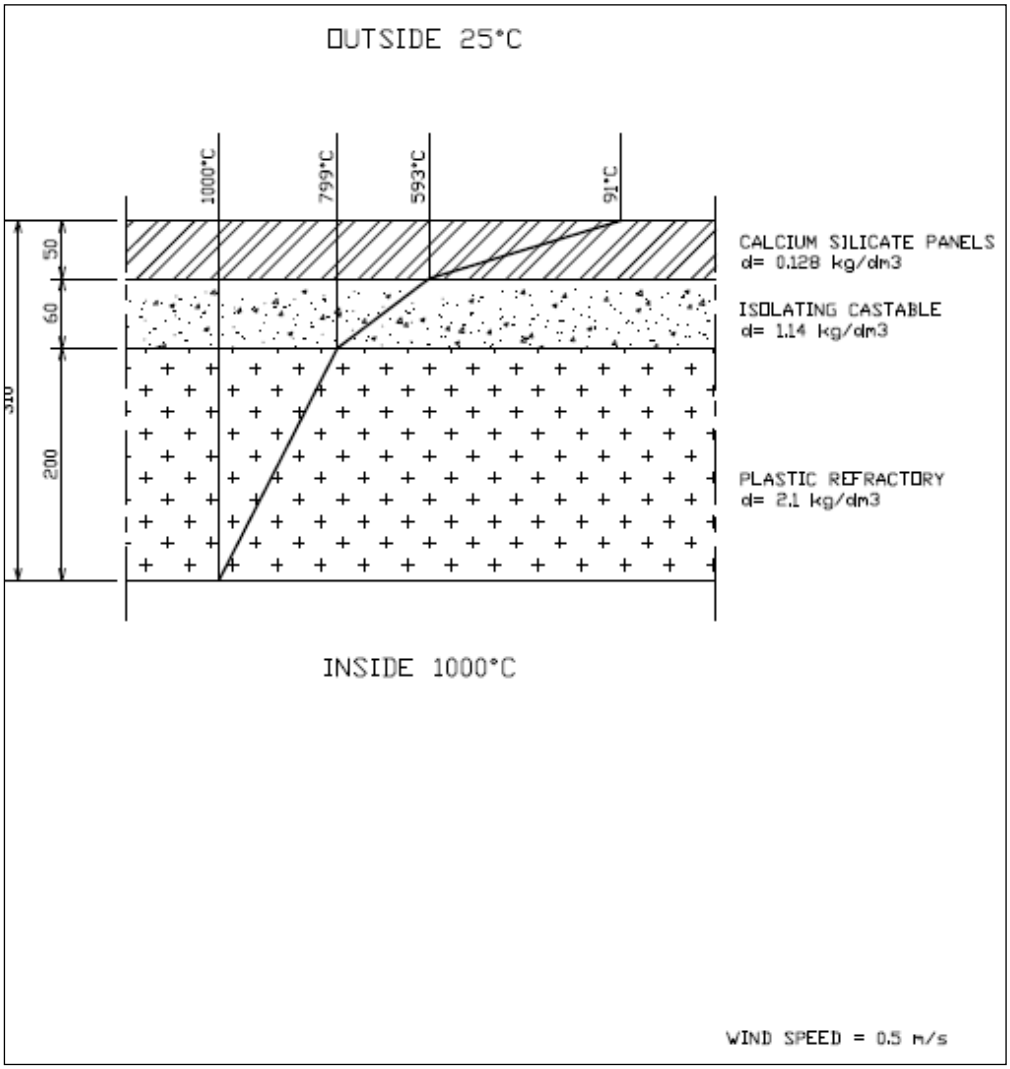
GENERAL PROPERTIES			
Maximum recommended temperature *(°C)*			1.100
Material required *(tm/m³)*			0,53
Grano maximum dimension *(mm)*			5
Water addition *(1/100 kg)*			95-115
Apparent density *(g/cm³)*	0,5	after being heated at	800°C
Apparent porosity *(%)*	51	after being heated at	800°C
Reversible thermal expansion *(%)*	0,55	at	1000 °C

CHEMICAL ANALYSE (% weight on calcinated sample at 1100°C)				
Al_2O_3	SiO_2	Fe_2O_3	Álcalis	Losses by calcination *
31	25	9	2,1	1,7

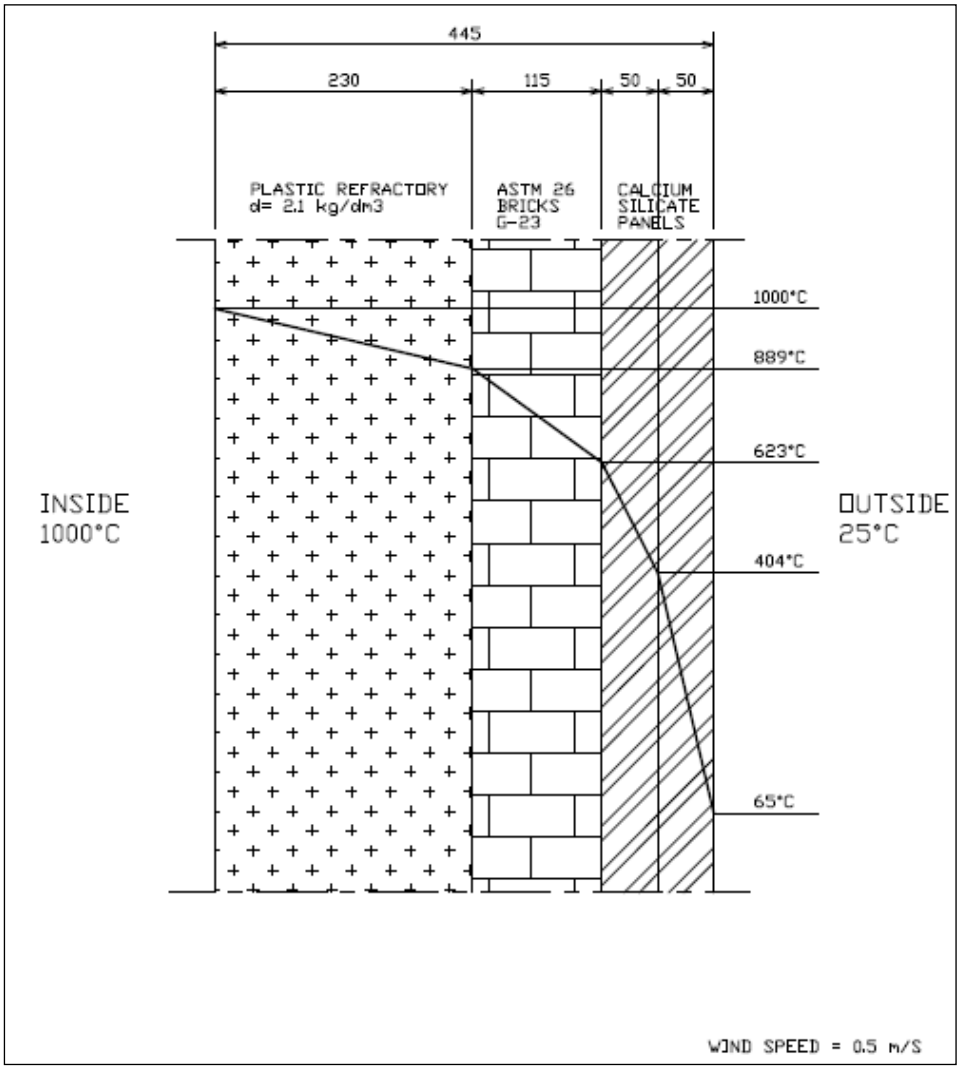
PHYSICAL PROPERTIES				
After being heated at *(°C)*	**Permanent linear changing *(%)***	**Resistance to the compression *(N/mm²)***	**Temperature *(°C)***	**Thermal conductivity *(W/mK)***
			200	0,12
			500	0,15
800	0,20 (contraction)	9	800	

5.7.1 Temperatures distribution

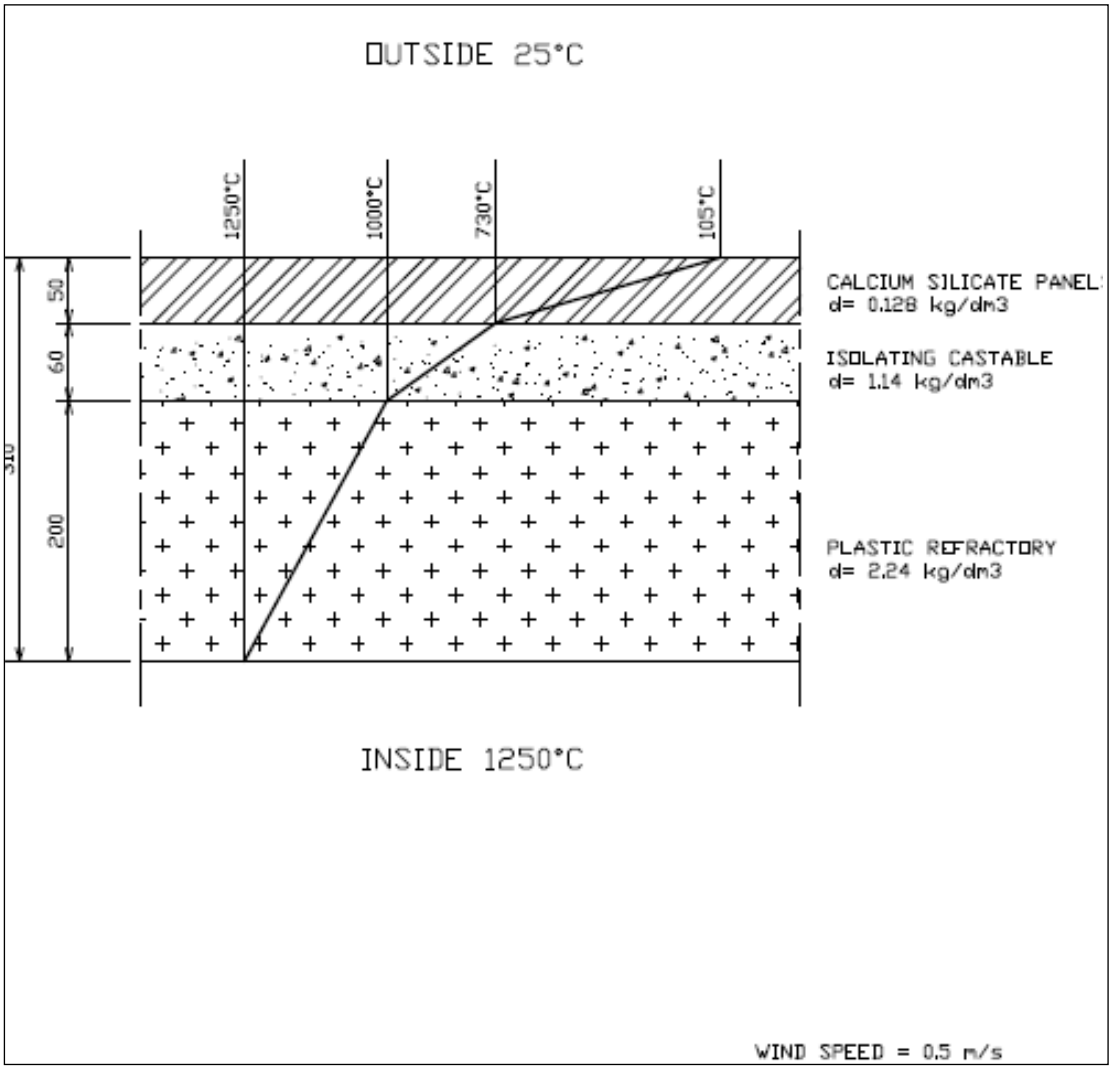
Temperatures distribution shown in the following pages is the result of the calculation using the physical characteristics of the materials. These temperatures are ideal and do not consider the anchorages thermal points or discontinuity due to edges bidimensional.



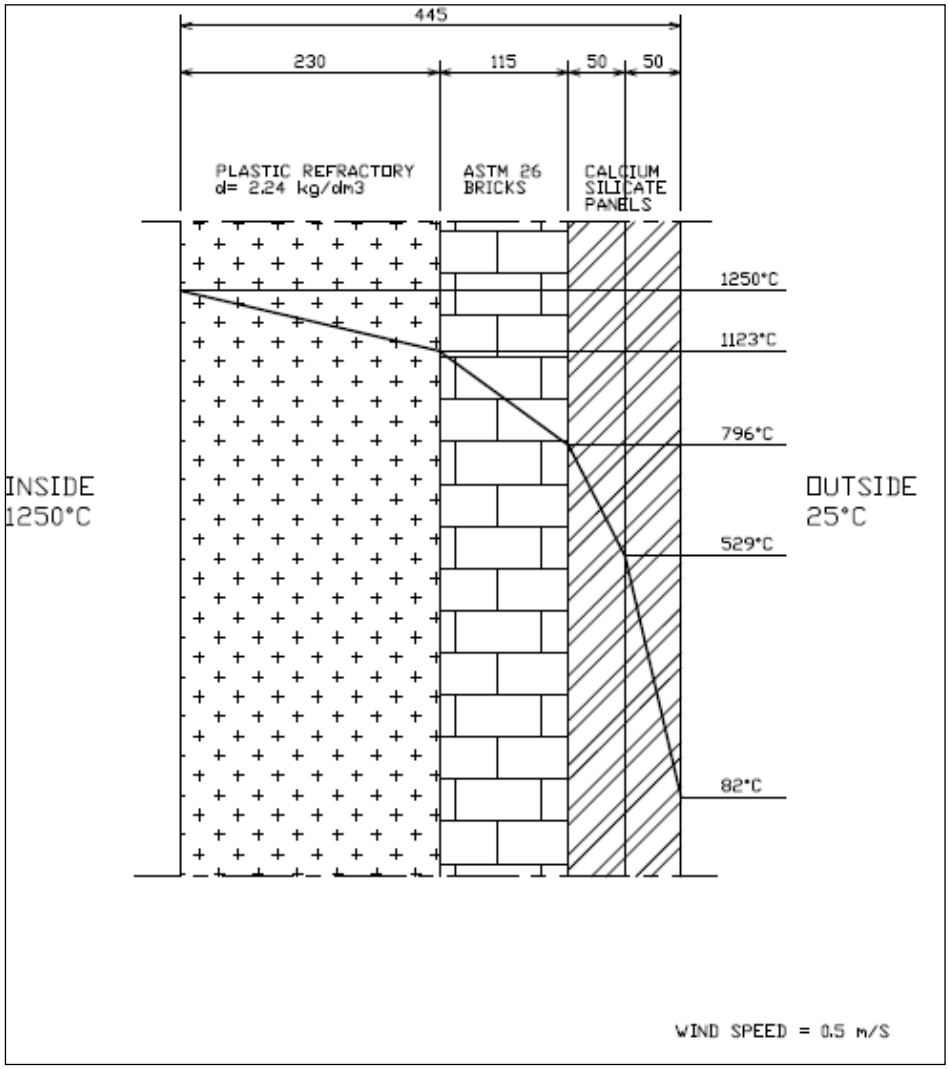
ROOF RECUPERATIVE ZONE



RECUPERATIVE SIDE WALLS



ROOF HEATING ZONES



SIDE WALLS HEATING ZONES

5.8 COMBUSTION EQUIPMENT

The combustion system will designed to ensure the maximum safety conditions during the production following international standards for thermoprocessing equipments ISO 13577-2:2023 and ISO 13577-4:2022.

5.8.1 Furnace profile and heating method

(1) **General**

The combustion system proposed is designed to ensure a production of 140 t/h when reheating billets 120 x 280 x 12000 mm from 20 °C to 1150 ºC.

⇒ Furnace profile is composed of:

- ✓ Side firing in the top preheating zone
- ✓ Side firing in the bottom preheating zone
- ✓ Side firing in the top heating zone
- ✓ Side firing in the bottom heating zone
- ✓ Side firing in the bottom soaking zone
- ✓ Side firing in the top soaking zone

⇒ Eight temperature control zones:

- ✓ 1 top preheating zone
- ✓ 1 bottom preheating zone
- ✓ 1 top heating zone
- ✓ 1 bottom heating zone
- ✓ 1 top soaking zone
- ✓ 1 bottom soaking zone

⇒ Combustion provided with air preheated to 580 ºC at nominal conditions.

⇒ Fuel used:

- ✓ Natural gas
- ✓ Hydrogen
- ✓ Blend of natural gas and hydrogen

5.8.2 Combustion air system

We will provide one combustion air fan which will be direct driven at 1500 rpm AC motor and will be equipped with:

(another fan will be supplied in stand-by)

- ✓ inlet louvers which allow the regulation of the combustion air pressure and to limit the electrical power consumption at reduced production rates.
- ✓ inlet silencer designed to limit the noise level to 85 dBA, at a distance of 1,5 m from the silencer inlet.

The characteristics of the fans are as follows :

- ➢ Flow ..... 60400 Nm^3/h
- ➢ Static pressure ..... 1350 daPa.
- ➢ Motor rating .....400 kW at 1500 rpm

Air distribution

Fans and combustion air piping are shown in the schematics enclosed.

At the recuperator outlet, the hot air will be first collected in a manifold and then distributed between the different heating zones and burners. The pipes will be externally lagged with mineral wool protected with galvanized iron sheet. Expansion bellows will be installed to absorb the thermal expansion of the system.

5.8.3 Natural gas circuit

As per ISO 13557-2

The gas supply system will include all required components from the Take Over Point (T.O.P.), to the burners as follows:

- ❑ on the main gas header:
  - ✓ manual valve
  - ✓ filter
  - ✓ pressure control and safety valve
  - ✓ safety key composed of two automatic shut-off valves “A” type and a tightness detector.
  - ✓ For the mixing station:
    - ▪ Two flow control valves
    - ▪ Two orifice plates and flow transmitters

Natural gas supply includes on each burner down-take:

- on each burner down-take:
  - ✓ 1 manual shut-off valve with 1 limit switch
  - ✓ 1 ON/OFF shut-off valve with 2 limit switches
  - ✓ 1 orifice plate
  - ✓ 1 adjusting valve

Preassembled gas train (analogy)

5.8.4 Hydrogen circuit

As per ISO 13577-2

The H2 supply system will include all required components from the Take Over Point (T.O.P.), to the burners as follows:

- on the main header:

  - ✓ manual valve
  - ✓ filter
  - ✓ pressure control and safety valve
  - ✓ safety key composed of two automatic shut-off valves “A” type and a tightness detector.
  - ✓ For the mixing station:
    - Two flow control valves
    - Two orifice plates and flow transmitters

5.8.5 Combustion circuit after mixing station

As per ISO 13577-2

The circuit will, in general, include the following elements:

- ✓ Mixer
- ✓ Two pressure control valves
- ✓ Pressure switches
- ✓ Safety valves

5.8.6 Nitrogen purging

During furnace shut down it is required to purge the gas piping with nitrogen to eliminate any risk of combustion.

We have, therefore, foreseen the engineering and supply of all required piping, valving and elements for purging of the furnace.

Nitrogen purging will be manual.

5.8.7 Waste gas system

Most of the heat losses from the furnace are due to the waste gas enthalpy out of the furnace.

To limit at maximum those losses, we use two solutions:

1) Counter flow waste gases from the product flow inside the furnace to allow radiation and convection heat transfer.

2) Waste gases go through the recuperator before being extracted through the stack to heat up the combustion air and thus reduce the fuel consumption.

5.8.7.1 Heat recuperator

Waste gases are exhausted through an exit located on the furnace roof.

The recuperator is bundle convection tubular type.

The waste gases transmit their heat by convection to the bundles pipes placed vertically and the combustion air which is preheated goes through these bundle pipes.

The bundles pipes are welded on their top and on their bottom to the heavy base plates of the boxes and the bundles hang from their top allowing a free expansion.

The recuperator is protected:

⇒ by hot air exhaust in case of excessive combustion air temperature. The corresponding safeguards are described in chapter “Instrumentation and Control”

⇒ by cold dilution air in case of excessive waste gases temperature. The corresponding safeguards are described in chapter “Instrumentation and Control”

5.8.7.2 Waste gases ducts – Furnace pressure control damper - Stack

Pressure damper (damper)

The furnace pressure damper is located in the waste gases duct after the recuperator together with the control loop of the furnace pressure maintains the furnace under a positive pressure.

The damper is louver type and it is controlled by a pneumatic cylinder with an electropneumatic positioner.

Waste gas duct

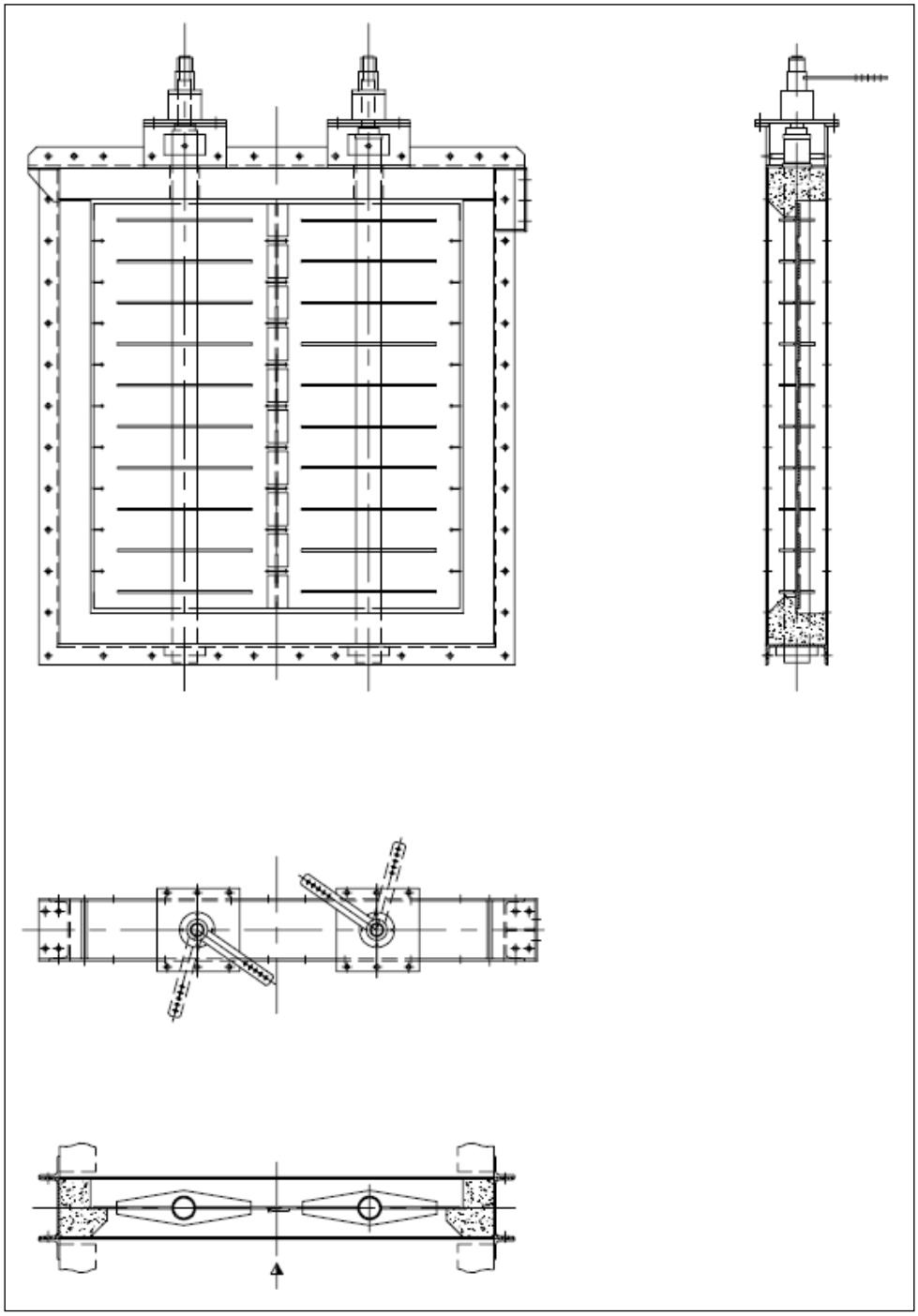
Waste gas duct lined with a refractory lay and isolating material, supplies waste gases to the stack via recuperators. We will supply an access to the waste gases duct on the pressure regulation level.

Stack

One metallic stack lined with isolating castable will be supply. It will have aprox 60 m. height and an internal diameter of 2,5m.

5.8.8 Oxygen enrichment

The furnace casing and piping design (space reservation) will foreseen the future installation of an oxygen enrichment with lances or premixing in the burners.



DAMPER

5.9 WATER SYSTEM

Furnace includes two separate water cooling systems.

The difference between the indirect cooling water and the closed recirculated cooling water is that the first is lost due to its contact with scale and the second is recuperated in the cooling tower.

The quality of the last one is the quality usually used in factories for exchangers cooling and closed circuits

See cooling water diagram enclosed:

717089-A-0520-5-P-1000-R00 Sheet 1	Circuit data
717089-A-0520-5-P-1000-R00 Sheet 2	Main circuit Charging rollers circuit
717089-A-0520-5-P-1000-R00 Sheet 3	treated cooling water – skids and posts Water troughs circuit
717089-A-0520-5-P-1000-R00 Sheet 4	treated cooling water – Fixed skids and posts
717089-A-0520-5-P-1000-R00 Sheet 5	treated cooling water –Discharging rolls
717089-A-0520-5-P-1000-R00 Sheet 6	treated cooling water - kick-off
717089-A-0520-5-P-1000-R00 Sheet 7	direct cooling water – water troughs
717089-A-0520-5-P-1000-R00 Sheet 8	cooling water system

You will see in the movable skids diagram of the recuperative zone that it has been located at the entry and exit zone, 5 flexible hoses with their isolating valves and check valves to ensure in case of breakdown of one of them the lack of water in the pipes and avoid a big leakage.

5.9.1 Direct cooling water circuit

This water is used for the water trough between the movable skids and the hearth.

See diagram 718243-A-0520-5-P-1000-R00

The water seal troughs are filled with cold water for furnace atmosphere tightness and their level is maintained constant through a permanent overflow.

For the water through to tight the movable furnace parts, industrial water will be needed in each and every of the boxes.

5.9.2 Undirect cooling water circuits

This circuit will be closed type, water cooling will be done with a set of air coolers as described at the end of this specification.

Cooled parts are:

- skids and posts
- photocells, TV cameras, hydraulic coolers
- furnace internal rollers
- the kick-off machines, openings, etc..

6. CONTROL SYSTEM AND ELECTRICAL EQUIPMENT

Generalities

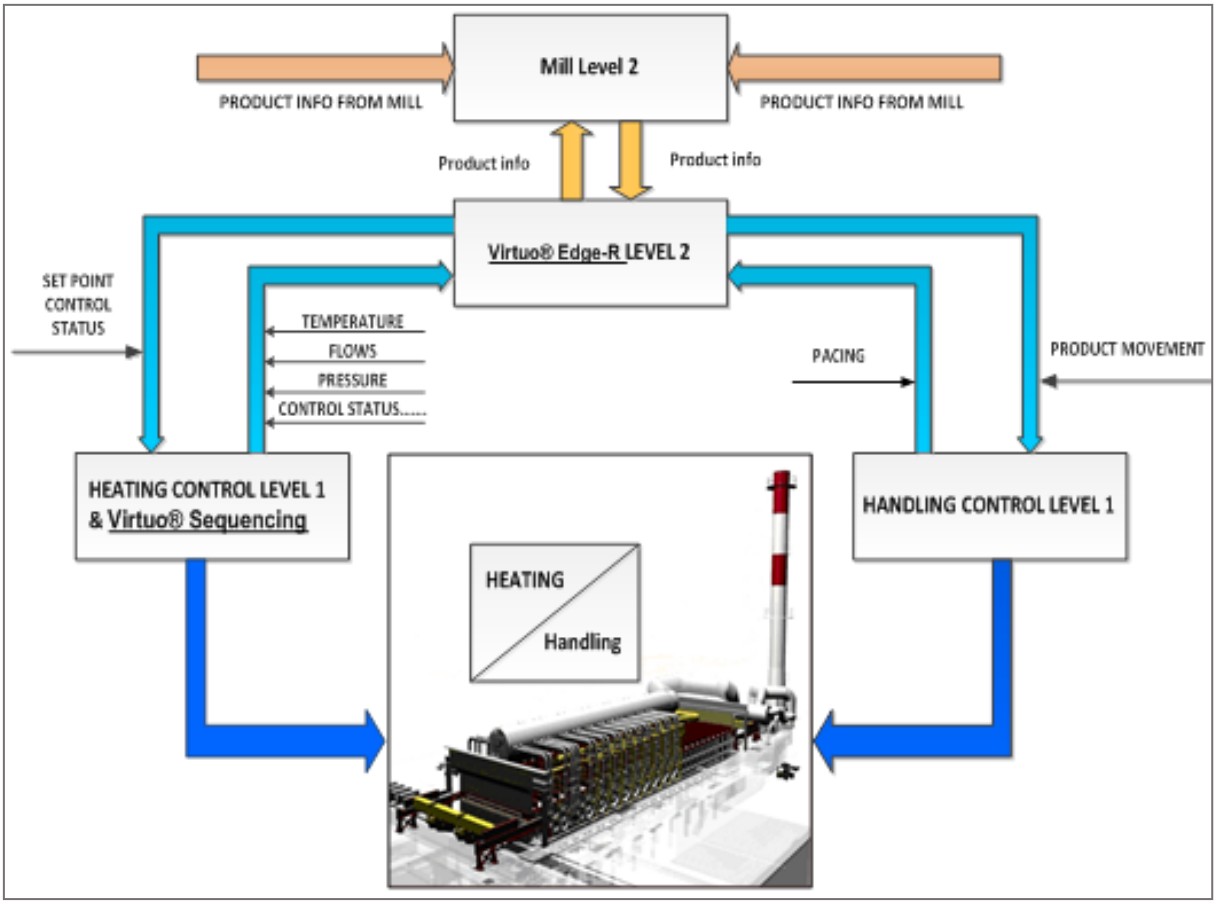
The heating and handling control systems are designed with 3 different functional levels :

Level 0 : field devices, instrumentation, etc. (supply by Fives Stein)

Level 1 : heating and handling control systems (supply by others)

Level 2 : optimization control system for heating (Option)

Level 3 : product information from and to mill computer (not in Fives scope of supply).



6.1 LEVEL 1 – HEATING CONTROL

Introduction

The heating control equipment will include:

- the heating control system.

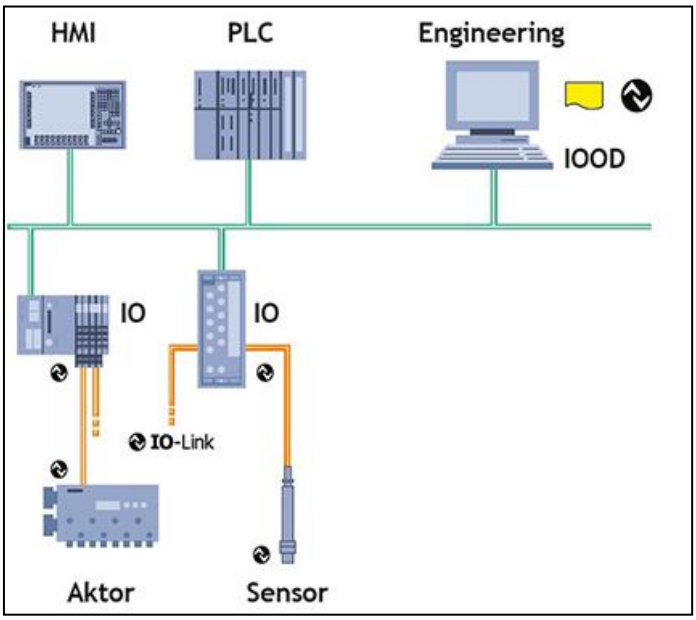
- The following instrumentation:
  . Shut-off and control valves,
  . Thermocouples,
  . Pressure transmitters,
  . Temperature, pressure, flow detector,
  . Etc.

The proposed microprocessor control system is a PLC SIEMENS designed with special care regarding the control reliability and long term data storage possibility and based on FIVES STEIN experience is a microprocessor control system.

FIVES has developed unique solutions in the field of INDUSTRY 4.0 for reheat furnace which responds to the most recent requirements by steel producers. Increased connectivity results in more information, better diagnosis and better control of preventive maintenance.

With IO-Link, multiple process values or parameters of a device are transmitted at the same time via a standard unshielded cable.

IO-Link is the first standardized IO technology worldwide (IEC 61131-9) for the communication with sensors and also actuators. The powerful point-to-point communication is based on the long established 3-wire sensor and actuator connection without additional requirements regarding the cable material. So, IO-Link is no fieldbus but the further development of the existing, tried-and-tested connection technology for sensors and actuators.



Example of system architecture

Safety standards

The electrical and automation system will follow the following safety standards and SIL ratings:

- ISO 12100
- For combustion system: International standard ISO 13577-2:2023and EN 13577-4:2022…
- For material handling .....ISO 14120 / EN 60204
- The hydrogen gas train and hydrogen downtakes will be considered areas with an explosive atmosphere with a category of zone 2 (ATEX Zone 2)
- SIL rating (to be confirmed during project after dedicated risk analysis):
  - Emergency stop .....SIL 2 /PLd
  - Pre-purge .....SIL 2 /PLd
  - Tightness control .....SIL 2 /PLd
  - Automatic control unit BCU..... EN 298
  - Flue gas venting (Furnace pressure control PT) .....SIL 2 /PLd
  - Air-fuel ratio ..... EN 12067-2
  - Pressure switches .....EN 1854 (PSL1921, PSL1916, PSH1902, PSL1902, PSH1901, PSL1901A, PSL1926, PSL1904)
  - Pressure transmitters .....SIL 2 /PLd (PT1904B,PT1901B)
  - Temperature transmitters .....SIL 2 /PLd (TE10x0B/C)
  - Automatic shut off valves..... EN 161 (FSV1083A-1/FSV1083A-2 & FSV1083B-1/ FSV1083B-2)
  - Valve proving system .....SIL 2 /PLd

6.1.1 Functions carried out by the Level 1 control system

A. Automatic temperature control of each zone

B. Automatic furnace pressure control

C. Automatic control of hot air pressure with the feed forward function

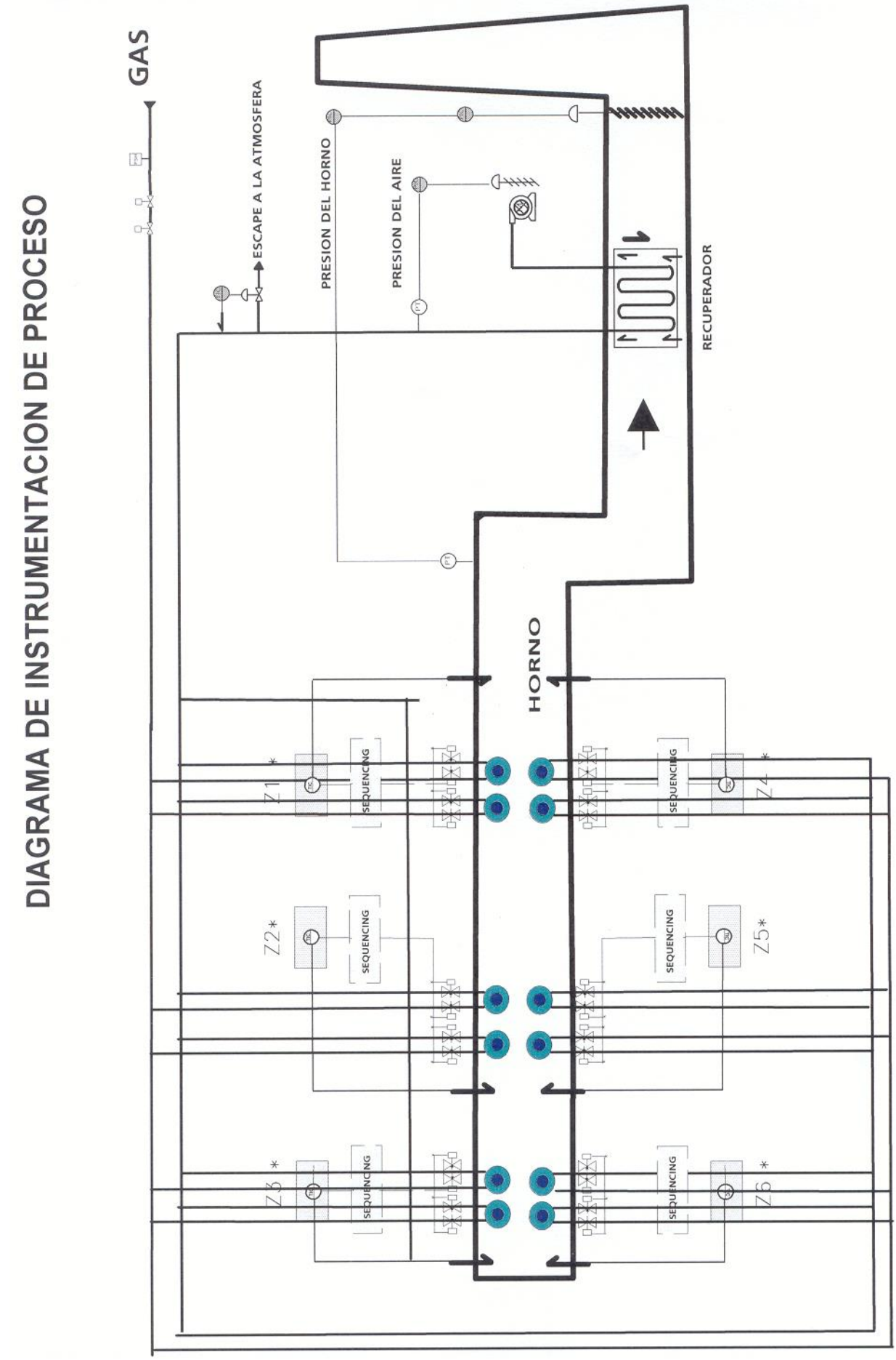
D. Protection of the recuperator by :

- hot air exhaust.
- dilution.

E. safety control by means of pressure switches mounted in the main utility systems

F. Flame control

DIAGRAMA DE INSTRUMENTACION DE PROCESO



6.1.2 Main control process functions descriptions

A. Automatic temperature control

There are 8 temperature control zones in the furnace.

The temperature of the zone is measured by 2 thermocouples type S (one for normal operation & one on stand-by).

Three positions of the thermocouple selection are available :

- Thermocouple 1
- Thermocouple 2
- The highest temperature from these two thermocouples. In this case, when the selected thermocouple is burn-out, the system switches automatically to the second thermocouple.

The temperature controller (TIC1) has three modes :

- Manual mode: the temperature set point can be manually adjusted.
- Automatic mode level 1 : the temperature set point can be adjusted by the operator.
- Automatic mode level 2 : the temperature set point is automatically adjusted by the level 2 computer.

The calory limiter (FY1) controls the maximum heating rate in accordance with the furnace load and heating up limitation.

B. Burner management system

To achieve the flexibility of the heating equipment, we will provide a sequencing of the burner firing using air and gas shut-off valves. An automatic burner control unit will sequentially control the lighting and shut-off of the burners in each zone. The switch on/switch off of the burners in this manner allows us to obtain a uniform heating in the furnace with a constant flame length and high efficiency of the selected burners.

The temperature signal, via a temperature transmitter, is the measurement point for the temperature controller.

The set-point is given by a process programmer and the output signal through a calorific limiter is sent to an automatic burner control unit.

This system starts and stops the burners according to the heat demand in a cyclic manner.

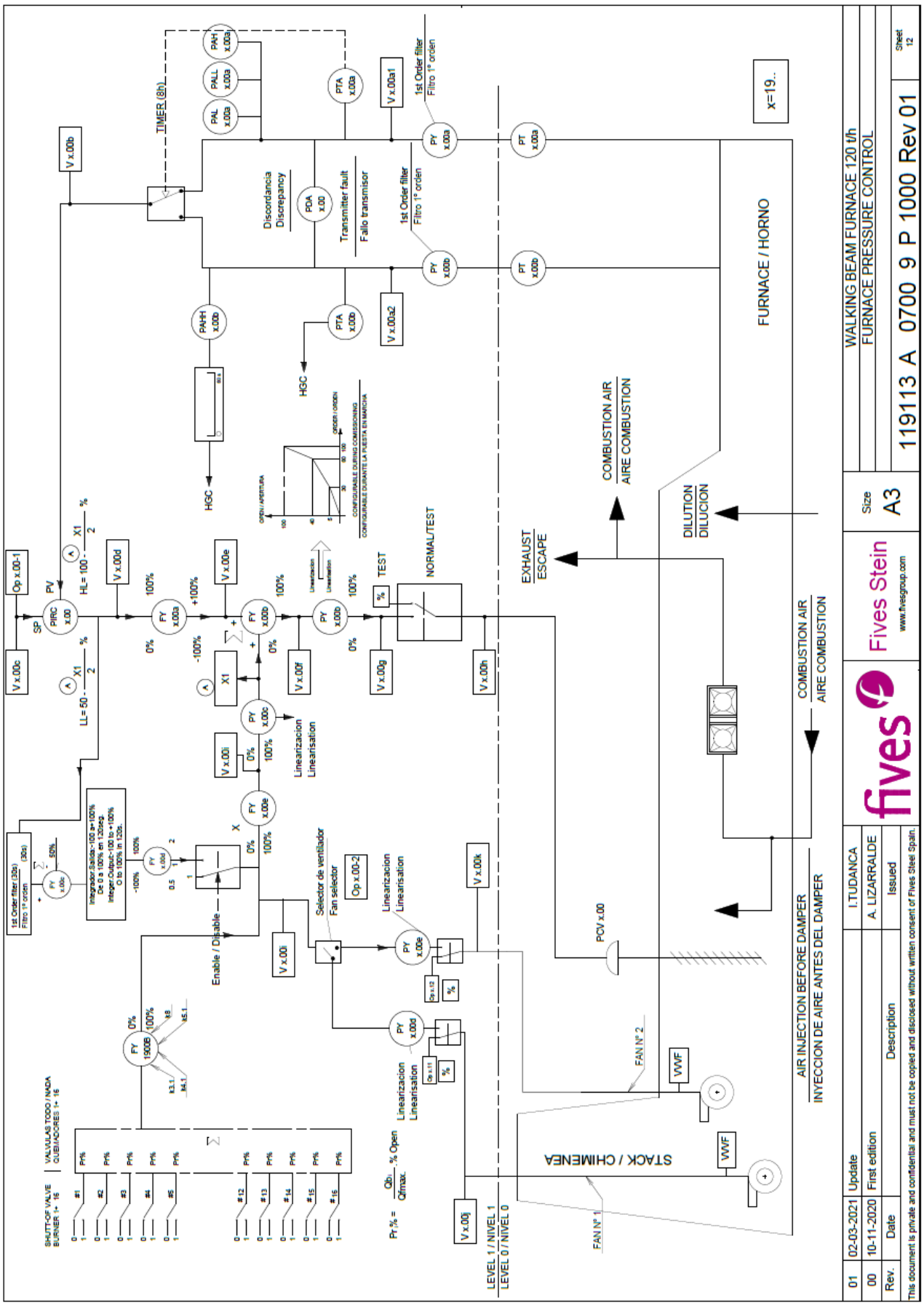
C. Automatic furnace pressure control

The furnace pressure control loop incorporates a special feed forward function:

To avoid the typical furnace pressure variations due to the distance between the pressure transmitter and the damper, the total combustion air flow of the furnace is considered as a reference to calculate the feeding forward correction coefficient of the furnace pressure controller output.

One low differential pressure sensors detect the pressure difference between the furnace and the atmosphere. The differential pressure signal from the differential pressure sensor is sent to the controller where the set-point has been adapted.

The output from the pressure controller is connected to the existing control valve.


WALKING BEAM FURNACE 120 t/h
FURNACE PRESSURE CONTROL
119113 A 0700 9 P 1000 Rev 01
Size A3
Sheet 12
Fives Stein
www.fivesgroup.com
fives
I.TUDANCA
A. LIZARRALDE
Issued
Description
Date
Rev.
01 02-03-2021 Update
00 10-11-2020 First edition
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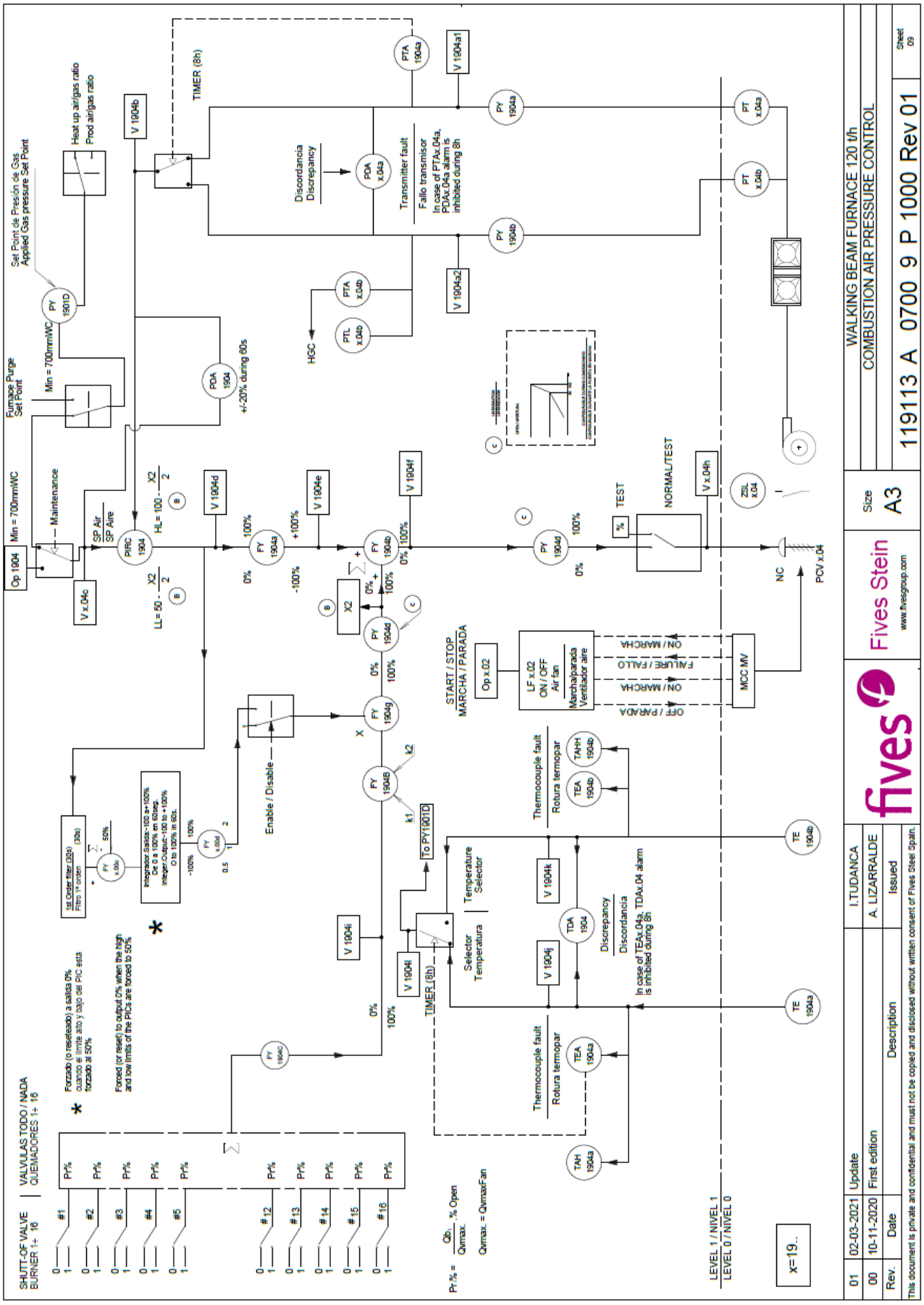
FURNACE / HORNO
EXHAUST
ESCAPE
COMBUSTION AIR
AIRE COMBUSTION
DILUTION
DILUCION
AIR INJECTION BEFORE DAMPER
INYECCION DE AIRE ANTES DEL DAMPER
STACK / CHIMENEA
FAN N° 1
FAN N° 2
PCV x.00
VWF
NORMAL/TEST
TEST
HSC
TIMER (8h)
Discordancia
Discrepancy
Transmitter fault
Fallo transmisor
1st Order filter
Filtro 1º orden
Linearizacion
Linearisation
Selector de ventilador
Fan selector
Enable / Disable
LEVEL 1 / NIVEL 1
LEVEL 0 / NIVEL 0
SHUT-OF VALVE
BURNER 1º 16
VALVULAS TODO / NADA
QUEMADORES 1º 16
x=19..

D. Automatic combustion air pressure control

The sensor (PT) measures the hot air pressure in the furnace common header and delivers this measured signal to the pressure controller (PIC) which controls the position of the control valve via an electropneumatic positionner installed upstream the recuperator.

To avoid the typical air pressure variations due to the distance between the pressure transmitter and the control valve, the total combustion air flow of the furnace is considered as a reference to calculate the feed forward correction coefficient of the combustion air pressure controller output.


WALKING BEAM FURNACE 120 t/h
COMBUSTION AIR PRESSURE CONTROL
119113 A 0700 9 P 1000 Rev 01
Sheet 09
Size A3
Fives Stein
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I.TUDANCA
A. LIZARRALDE
01 02-03-2021 Update
00 10-11-2020 First edition
Rev. Date Description Issued
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Furnace Purge Set Point
Min = 700mmWC
Maintenance
Op 1904
V x.04c
SP Air
SP Aire
PIRC 1904
HL = 100 - X2/2
LL = 50 - X2/2
V 1904d
V 1904e
V 1904f
FY 1904a
FY 1904b
FY 1904d
FY 1904g
FY 1904f
X2
PY 1904d
TEST
NORMAL/TEST
V x.04h
ZSL x04
NC
PCV x.04
PT x.04a
PT x.04b
PY 1904b
PY 1904a
PY 1901D
Set Point de Presión de Gas
Applied Gas pressure Set Point
Heat up airgas ratio
Prod airgas ratio
V 1904b
TIMER (8h)
PTA 1904a
V 1904a1
V 1904a2
PDA 1904
+/-20% during 60s
PDA x.04a
Discordancia
Discrepancy
Transmitter fault
Fallo transmisor
In case of PTAx.04a, PDAx.04a alarm is inhibited during 8h
PTA x.04b
PTL x.04b
HGC
START / STOP
MARCHA / PARADA
Op x.02
LF x.02
ON / OFF
Air fan
Marcha/parada
Ventilador aire
ON / MARCHA
FAILURE / FALLO
OFF / PARADA
MCC MV
Enable / Disable
1st Order Filter (30s)
Filtro 1º orden
Integrador Salida:-100 a+100%
De 0 a 100% en 60seg.
Integer Output:-100 to +100%
0 to 100% in 60s.
Forzado (o reseteado) a salida 0% cuando el límite alto y bajo del PIC está forzado al 50%
Forced (or reset) to output 0% when the high and low limits of the PICs are forced to 50%
To PY1901D
Temperature Selector
Selector Temperatura
TIMER (8h)
V 1904i
V 1904j
V 1904k
TDA 1904
Discrepancy
Discordancia
In case of TEAx.04a, TDAx.04 alarm is inhibited during 8h
Thermocouple fault
Rotura termopar
TAH 1904b
TEA 1904b
TAH 1904a
TEA 1904a
TE 1904b
TE 1904a
SHUTT-OF VALVE
BURNER 1÷ 16
VALVULAS TODO / NADA
QUEMADORES 1÷ 16
#1
#2
#3
#4
#5
#12
#13
#14
#15
#16
Pr%
Pr% = Qb... / Qvmax. % Open
Qvmax. = QvmaxFan
LEVEL 1 / NIVEL 1
LEVEL 0 / NIVEL 0
x=19...

E. Recuperator protection

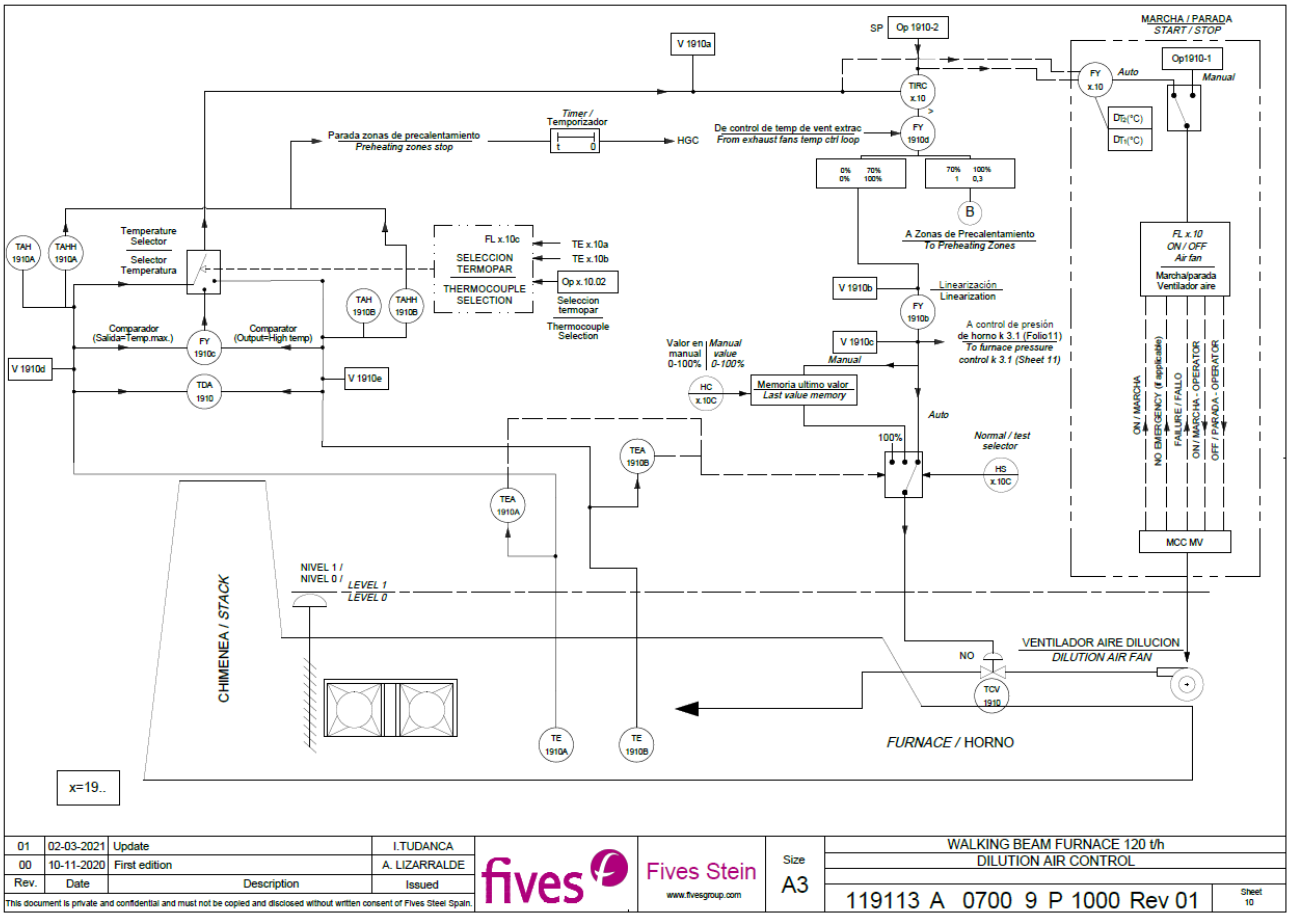
The control system protects the recuperator from over heating by

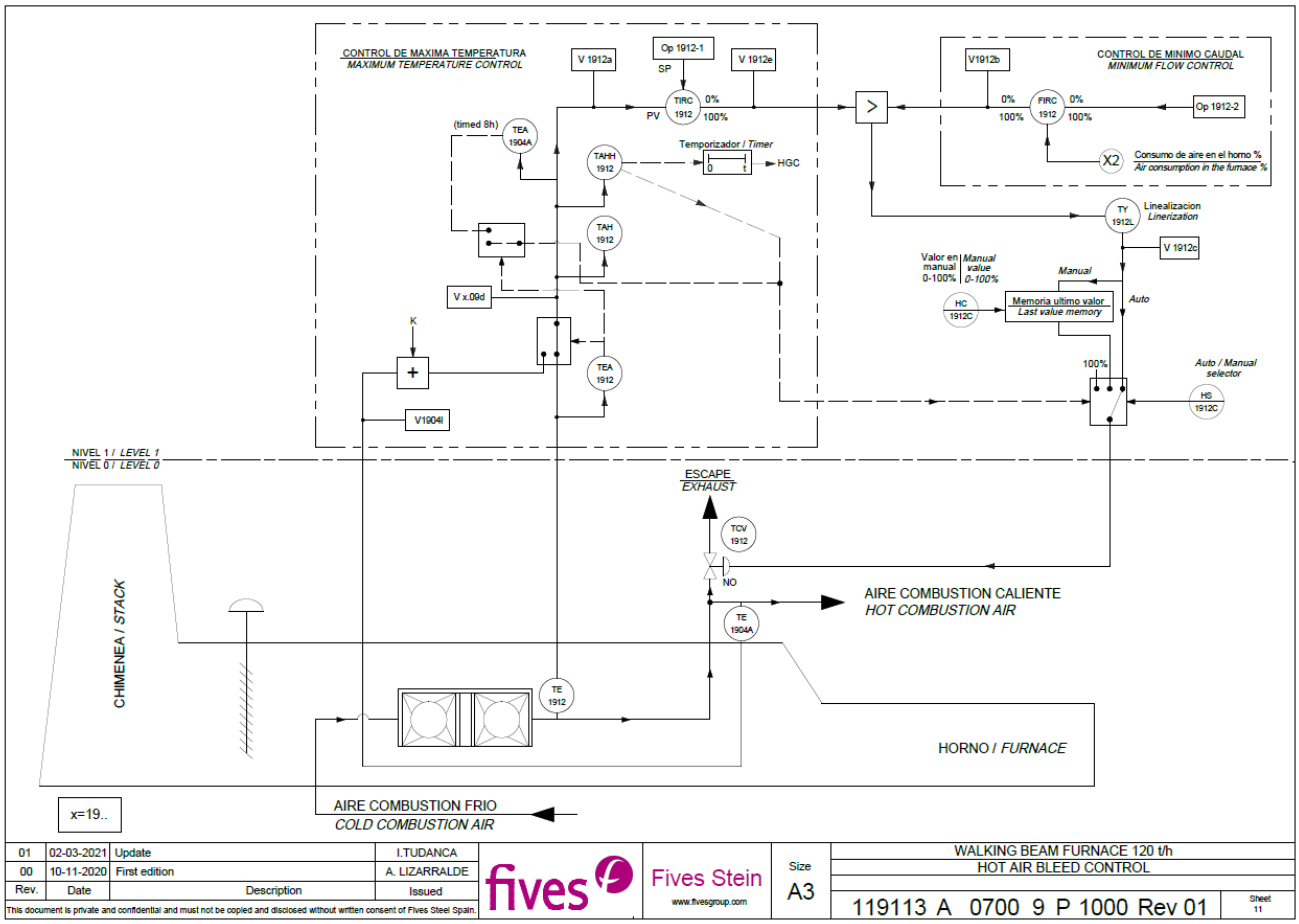
a) introducing dilution air before the recuperator
b) exhaust by hot air exhaust

* Hot air exhaust

When the combustion air temperature of the recuperator exceeds its high limit, a control valve will open to cause hot air exhaust and increase the cold air volume flowing through the recuperator.

Hot air temperature is measured by a thermocouple. This temperature is transmitted through a transmitter (TT) to the controller (TIC) which controls the position of the adjusting valve, via an electropneumatic positioner.





F. Safety control

All the safety control is done by a safety PLC

G. Flame control

Full flame supervision will only be supplied and fitted to the lower soak zone burners. The consequence of which is that these burners can be extinguished and re-ignited on command.

When the lower soak has been ignited interlocks on the other zones will ensure that gas cannot be fed to these zones until the required zone temperature to ensure auto-ignition is satisfied.

6.1.3 Description of Level 1 control system

The system based on PLC is the best technical solution for the control of the furnace.

The prosed system is a SIEMENS S1500 safety CPU, composed of:

- 1 card with CPU processor with system program
- 1 Communication card ProfiBus for I/O's remotes
- 2 Communication cards for ETHERNET
- 1 PROFIBUS DP communication card for frequency converters
- Voltage distribution
- Feeders
- Main board with:
- the necessary remotes I/O units including the power unit, assembled in boxes foreseen for:

  620 digital inputs 24 VDC
  315 digital outputs, transistor or relay
  120 analogic inputs 4-20 mA o 0-10 V, TC, Pt100 24 VDC
  8 analogic outputs, 4-20 mA

- One (1) PC based Programming tool is included

The C P U capacity of the PLC have increased greatly and are capable of handling many PID loops with appropriate cycle times and high reliability.

They are particularly suitable for high speed processing (arithmetic operations and closed loop control) and high speed binary signal processing (logic control).

The solution based on the same PLC for heating and handling control reduces the hardware cost, the spare parts, the training, and facilitates the communication between Level O, Level 1 and Level 2.

The following 4 functions are realized by the proposed system :

- Process supervision
- Communication
- Control
- Safety

The process control system supervises and monitors the combustion process of the furnace (automatic). The temperature control, as well as the hot air bleed, combustion air pressure control and furnace pressure control will be done on PLC bases, as well as the automation control

The system will be supplied for control and monitoring of various parameters of the furnace.

6.2 HMI –SUPERVISION EQUIPMENT

6.2.1 Supervision functions

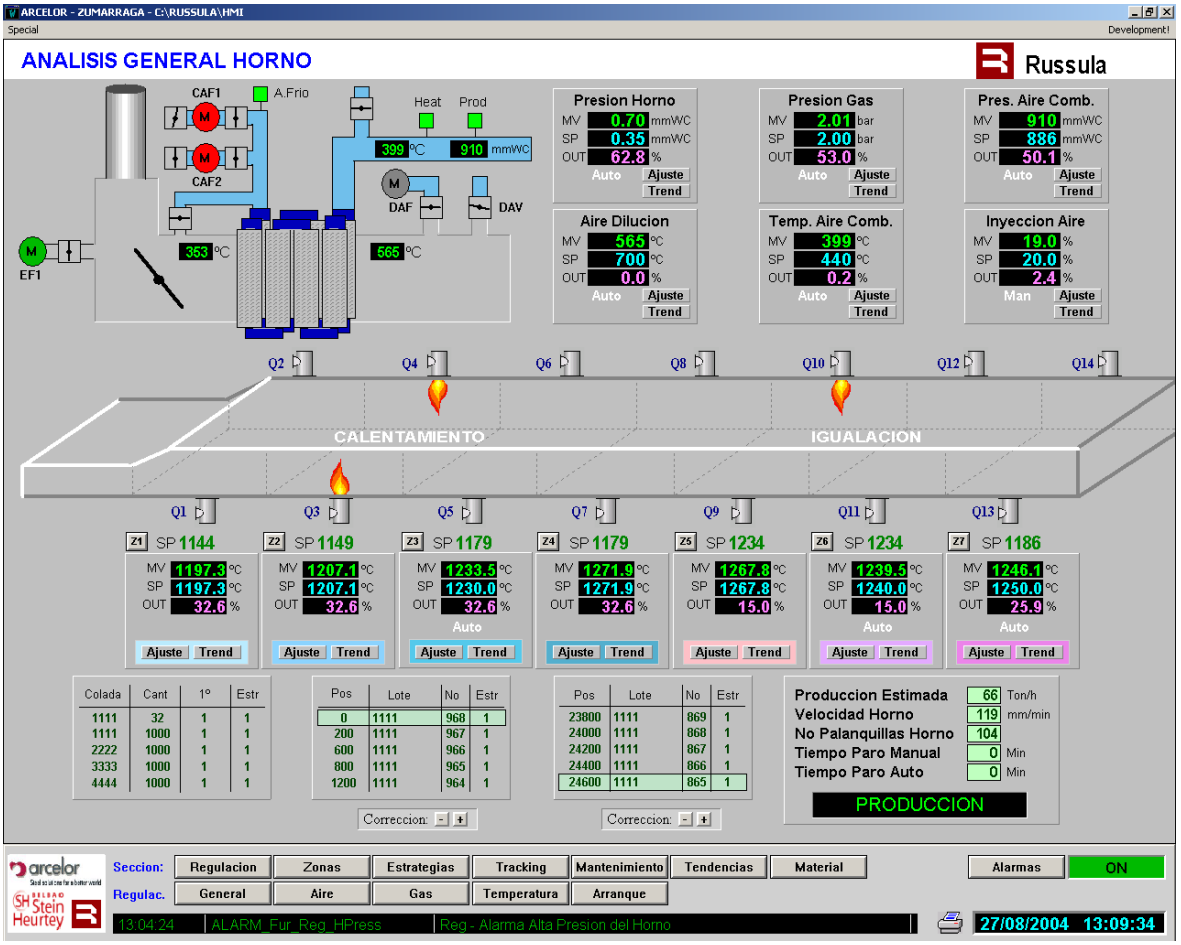
In case of control station failure, the process can continue under normal conditions.

The operator can operate and monitor all variables process by means of the screen and keyboard

The keyboard equipped with function keys enables the changing of displays and the modification of set points.

The following displays are available for the furnace operator.

General view showing the installation configuration with all necessary data for supervision.



- 9 displays showing the configuration of each zone, common areas and image of the control loops with indication of the following data :

  . zone temperature
  . combustion air pressure
  . totalisation of fuel
  . control status
  . alarm and events
  . set points.
  . furnace pressure
  . waste gas temperature
  . cooling water

  – 1 loop display by controller showing detailed status of each controller and a short time trend of the process values.

- 1 table with intelocking and alarms.

Alarms

All alarms are displayed on the screen, stored in the hard disk, and printed out at the time of occurrence.

- nitrogen failure
- natural gas failure
- combustion air failure
- instrument air failure
- water failure
- breakage of thermocouple
- all process variables.

Process data recording (historics)

Approximately 50 process values will be recorded in the measured value archive and stored in time files. The storage on hard disk will be one month.

All stored process values can be shown on screen.

The following values will be recorded :

- zone temperature
- combustion air pressure
- furnace pressure
- waste gas temperature
- recuperator element temperature
- hot air temperature
- alarm and events.

Note: This data will be updated during the basic engineering.

I/O modules

Standardized for whole furnace: I / O & RIO.

. analog input ..... AI (mV) for thermocouples S, K
. analog input ..... AI (mA) for resistors Pt100 (3 wires)
. analog input ..... AI (mA) with power 4-20 mA
. analog input ..... AI (mA) without power 4-20 mA
. analog output ..... AO (mA) 4-20 mA
. digital input ..... DI (24 V DC)
. digital output ..... DO (24 V DC)

The final quantity and type of modules will be defined during the basic design.

Safety

Safety procedures will be done following ISO 13577-2:2023 and ISO 13577-4:2022

A safety table will be elaborated during basic design, with explanation for each alarm case.

According to the level of safety required, either each zone or the complete furnace will be shut down.

6.3 ELECTRICAL EQUIPMENTS OF THE FURNACE

6.3.1 Motors list

COMBUSTION AIR FAN									TAC									
0500MCA001	2	ACM						400		VVVF				Pt 100 bearings	Soft starter	00		
a / to 002	FSE		400	1450				50						Stator windings PTC	1 IN STANDBY			
DILUTION AIR FAN									TAC									
0500MCA003	1	ACM						400		NR					Direct on line starter	00		
	FSE		11	3000				50							Emergency power supply			
INSIDE FURNACE CHARGING ROLLERS									TAC									
0250MCA001	10	ACM/G						400		VVVF					Emergency power supply	00		
a / to 010	FSE		5,5	1420				50						Stator windings PTC				
INSIDE FURNACE DISCHARGING ROLLERS									TAC									
0251MCA001	10	ACM/G						400		VVVF					Emergency power supply	00		
a / to 010	FSE		5,5	1420				50						Stator windings PTC				
HYDRAULIC MAIN PUMPS									TAC						1 with emergency power supply			
0570MCA001	3	ACM						400		NR					Soft starter	00		
a / to 003	FSE		90	1450				50						Stator windings PTC	1 IN STANDBY			
HYDRAULIC CONDITIONING PUMPS									TAC									
0570MCA004	2	ACM						400		NR					Direct on line starter	00		
a / to 005	FSE		3	1450				50							1 IN STANDBY			
HYDRAULIC HEATERS									TAC									
0570RCE001	2	HE						400								00		
a / to 002	FSE		3					50										
GREASING PUMP									TAC									
0560MCA001	2	ACM						400		NR					Direct on line starter	00		
a / to 002	FSE		0,37	1450				50										
COMPRESSED AIR DRYER									SAC									
0530SA001	1	EC						220								00		
	FSE		1					50										
INSTRUMENTATION									TAC									
	1	EC						400								00		
	E		10					50							Power to be confirmed by E			

AIR COOLER #1								TAC							
	18	ACM						400		NR					00
	FSE		57,6					50						Emergency power supply	
AIR COOLER #2								TAC							
	18	ACM						400		NR					00
	FSE		57,6					50						Emergency power supply	
AIR COOLER #3								TAC							
	18	ACM						400		NR					00
	FSE		57,6					50						Emergency power supply	
AIR COOLER #4								TAC							
	18	ACM						400		NR					00
	FSE		57,6					50						Emergency power supply	
COOLING PUMPS								TAC							
	2	ACM						400		NR				VFD	00
	FSE		90	1500				50						Emergency power supply	

6.3.2 Programmable logical controller for the control of process sequence

The programmable logical controller is based on the microprocessor technology.

The functions carried out by the PLC will be as follows:

a) Control of furnace movements

b) Control of doors movements

c) Interlocking between charging, discharging devices and walking beam movements

d) Alarm management.

6.3.3 Motor Control Center (C.C.M.)

A MCC is foreseen for the control of all motors and exit lines and will comprise:

- Voltmeters and ammeters.
- Feeders and MCC, including for each individual motor: automatic switch, disjunctor, thermal relay.
- Outputs for motor list:

The MCC will be ready for triphasic alternating voltage of 50 Hz y 400 V, as well as ready to incorporate the outputs with switches for emergency group.

The voltage control will be monophasic at 110Vac or 220Vac.

6.3.4 Desks and cabinets

The following desks and panels will be supplied:

- One manual control console for the furnace mechanism (main desk)
- One local panel for the charging movements
- One local panel for discharging movements
- One separate cubicle in the hydraulic room.

6.3.5 CCTV system

One television system will allow the operator to visually charging and discharging zones inside the furnace for the billet feeding labours.

Three camera will be foreseen, endoscope type, location to be agreed during detail engineering

TV camera case is cooled by means of a water circuit.

Inside the camera, and near the front lens, i.e., in the support, is cooled by compressed air.

The cameras are automatically retractables

6.3.6 Thermographic camera

One thermographic camera will be installed in from of discharging door to allow checking of the discharging surface temperature of the billets.

This camera will be also automatically retractable.

6.3.7 Handling control equipment

Introduction

The handling control equipment necessary for furnace control is described hereunder:

- main and local control desks for furnace operation
- the control system equipment (PLC) for furnace operation
- industrial TV equipment
- all local sensors required for the furnace control

Functions carried out by the Level 1 controls system

Automatic control of the process in the furnace area.

All the sequencing, interlocking and signaling functions are realized by the PLC.

The proposed system is completed by the closed circuit TV system allowing the operator's to visually monitor the process.

Product handling control

The process control begins when the product has been laterally introduced into the furnace by the out-furnace roller table.

After positioning with the positioning stoppers the product is directly transferred to the fixed skids by the movable skid system.

Transfer through the furnace

Once the charging operation of the products is completed and the interlocks with the discharging operation allow it, the order to perform one cycle (one step) is issued by the PLC system and the walking beam movements are then executed.

The walking hearth will lift the product from the fixed hearth, move it forward one step and lay it down again.

All the furnace movements lifting up and down, transfer forward and reverse are controlled by the PLC, which actuates the corresponding solenoid valves for the hydraulic system.

All the movements of the walking beams are controlled automatically or manually, from the general pulpit, located in the control room.

When the product arrives at the discharge end, it will be placed directly onto the discharge rolls by means of the twin discharging machines.

Discharging operation

Billets are discharged by means of a kick-off, which transfers the billet from the beams to the discharging roller table inside the furnace.

Thanks to the program performing, the product tracking inside the furnace and with the aim of billet detection finger, we will know if there are billets at the last position ready for being discharged. Hence, the walking beams movement is authorized, or the discharging sequence is carried out. Every time the walking beam gives a step, the Billet Detection Fingers will give a cycle to check if there is billet on last position.

In case of presence of billet on the last position and request from the rolling mill, the kick-off cycle will start, as long as conditions are fulfilled. Once collected the billet with the kick-off, before starting the descent movement on the rollers, the roller table stops and the door opens. Provided the confirmation of open door and kick-off in down position, the roller table starts turning forward, and the kick-off goes backwards. A signal from the outside roller table (sent from the PLC of the mill) of -discharged billet will issue the order of closing the door.

Control modes

Manual, semi automatic and automatic one cycle modes are usually used for maintenance or for exceptional operating movement.

- Manual mode

  All movements are performed from the keyboard at the furnace operator station.

  The safety interlocks are active to prevent damage of the equipment.

- Semi automatic mode

  In this mode, each elementary movement of the automatic cycle can be performed separately.

  This mode can be selected and controlled from the local desk or from the control cabin.

- Automatic one cycle mode

  In this mode, the operator can initiate each cycle (one cycle of walking beams, one cycle of pusher).

  This mode can be selected and controlled from the control cabin.

- Automatic mode

  Automatic mode is used in normal running conditions. In this mode, all cycle are performed automatically without operator intervention. This mode can be selected and controlled from the control cabin.

  Handling control functions carried out by the PLC

  - Control of all handling motors shown on motor list.
  - Control of kick off
  - Control of hydraulic systems
  - Control of furnace movements
  - Control of door movements
  - Interlocking between charging, discharging devices and walking beam movements
  - Alarm management.

  Main exchange signals between furnace PLC and Mill PLC :

  - authorization for product discharging.

  Control desks

The handling control will be carried out from the following desks :

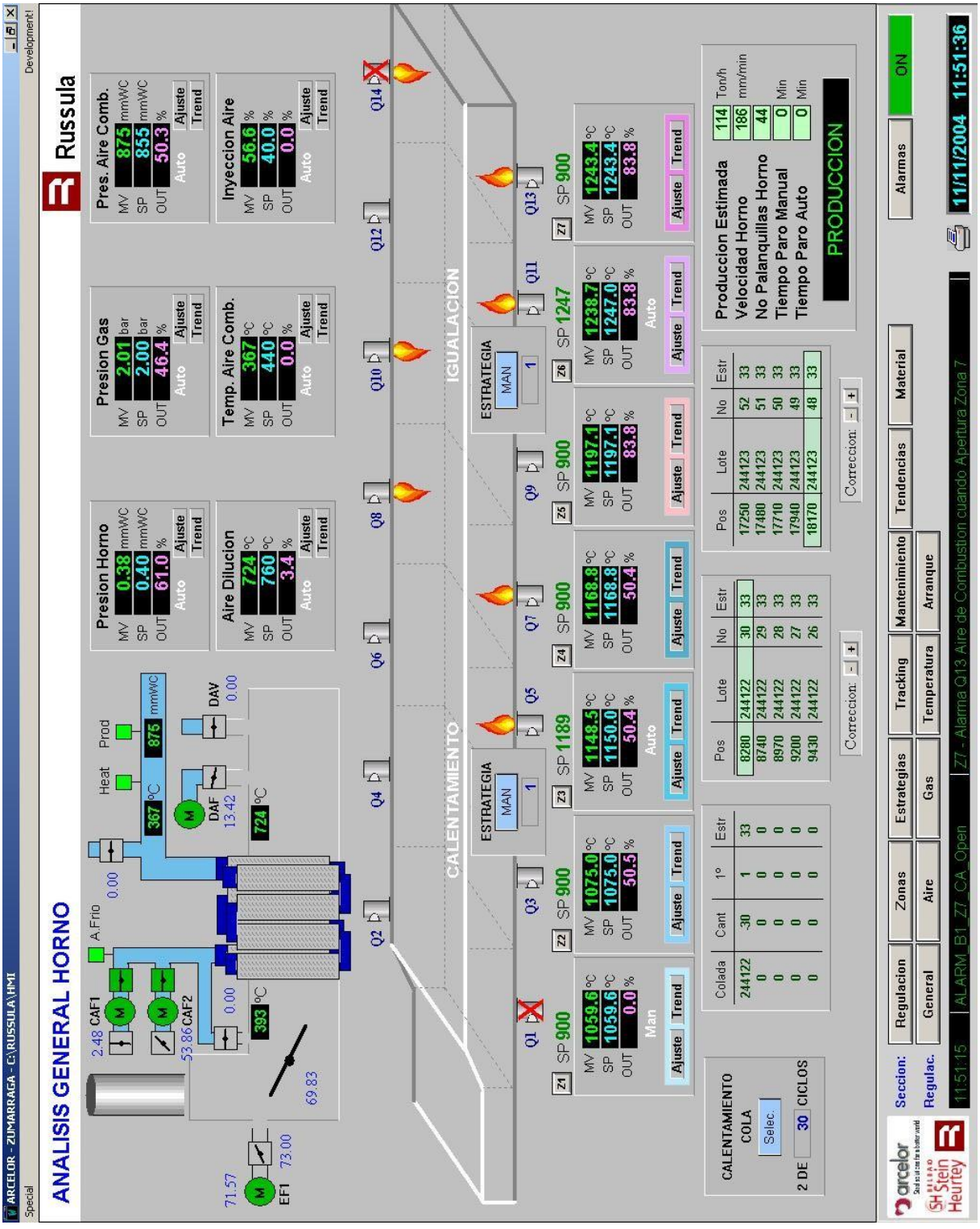
- one main control station for general furnace control (in control room)
- one hydraulic control desk for hydraulic pumps control (in hydraulic room).
- one local control desk on discharging side
- one local control desk on charging side (for maintenance)

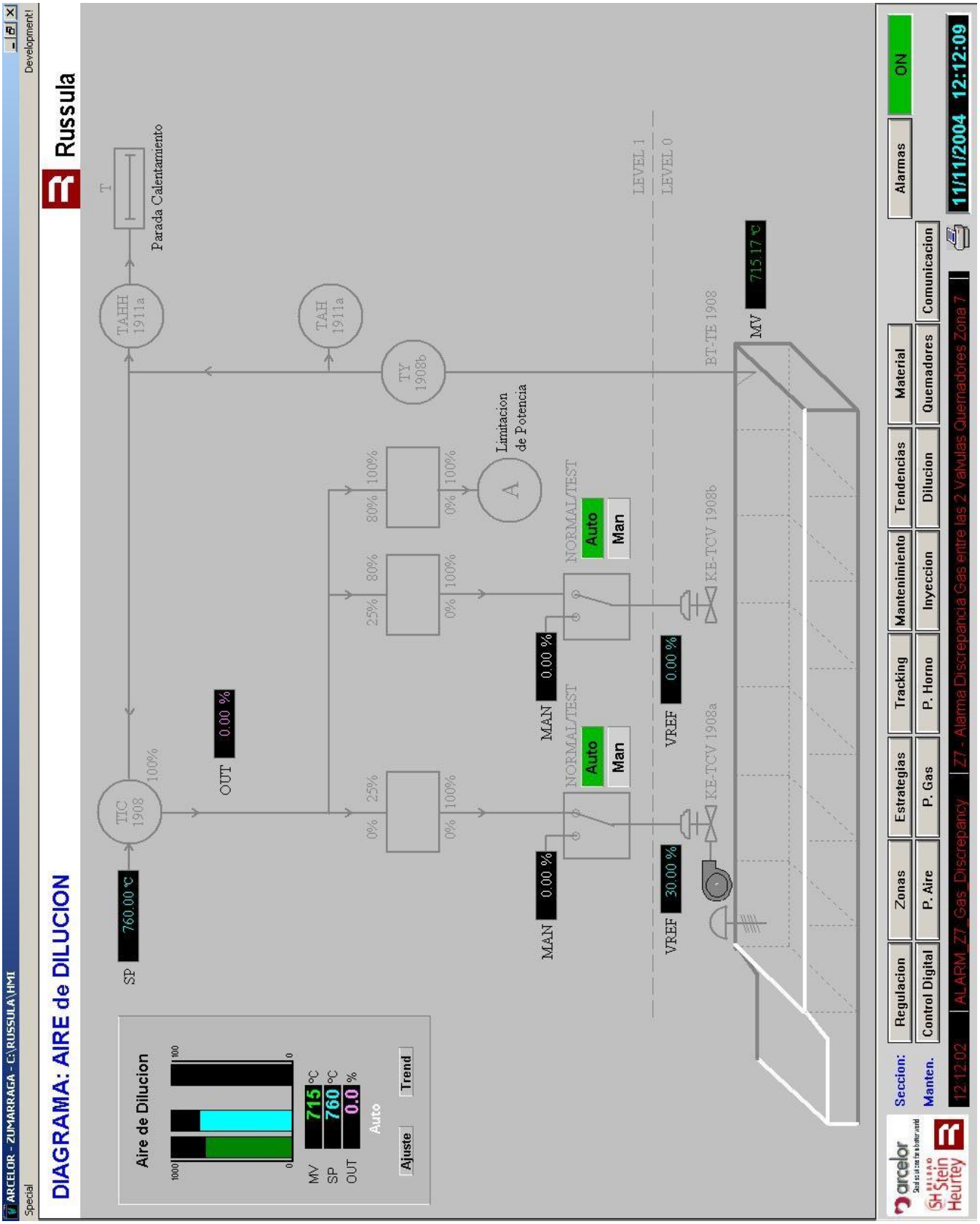
Local sensors

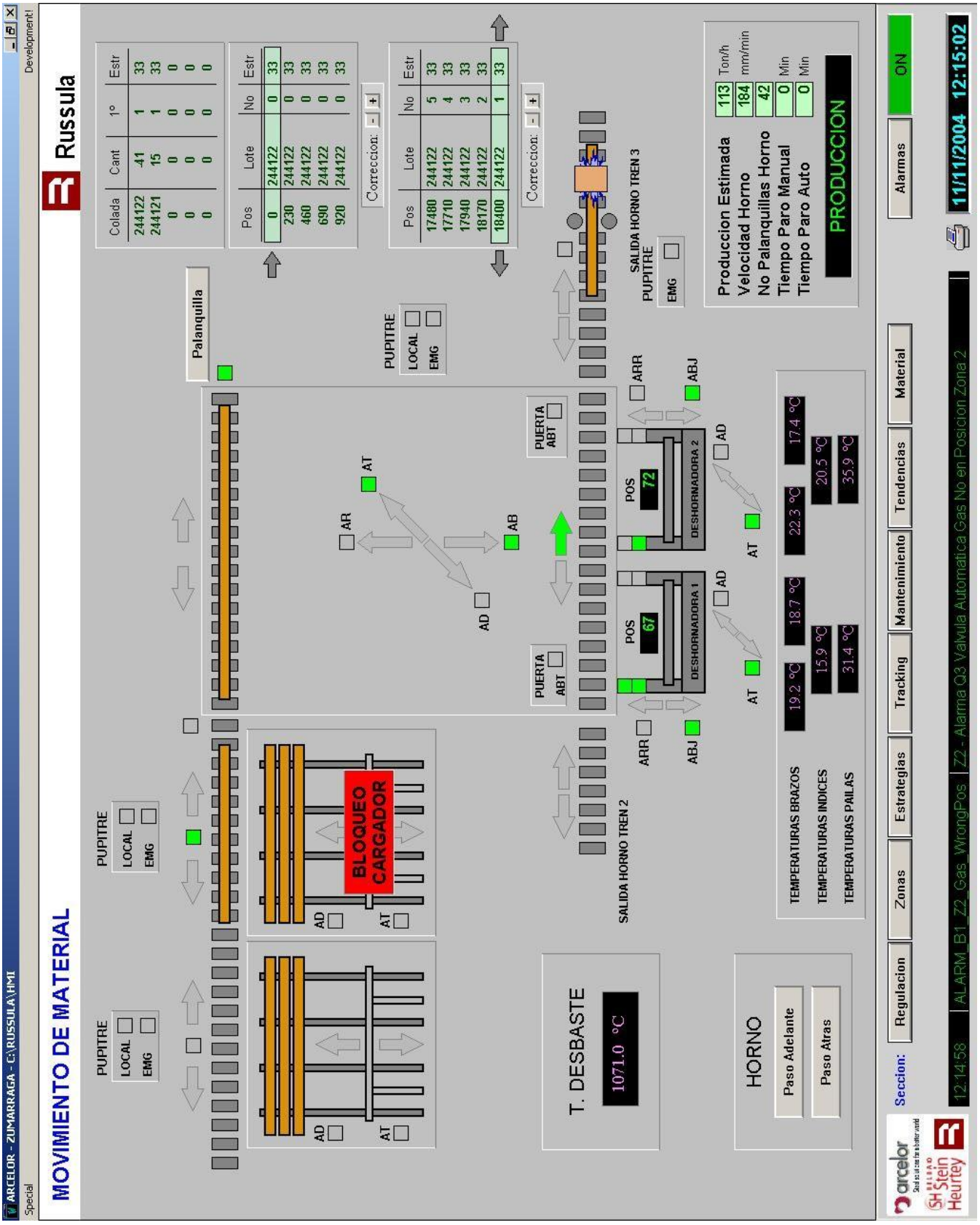
All electrical field devices are specially selected and adapted to ensure the maximum reliability and the highest process control performance. The electrical field devices are limit switches, detection cells, encoders, etc. The final quantity and the type of this devices will be defined during the basic design.

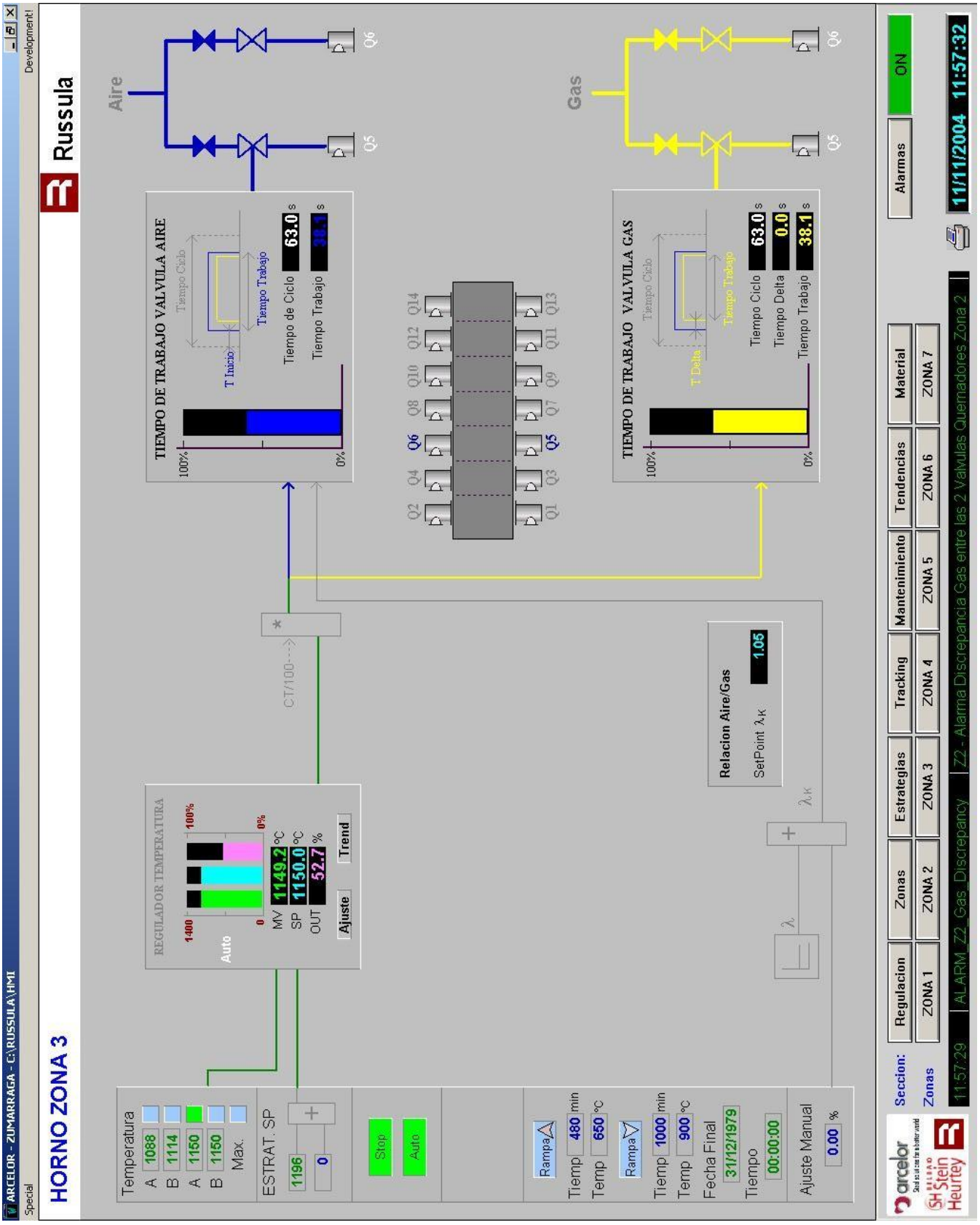
7. ANALOGY DISPLAYS

Hereinafter you will find the analogy displays of the control supervision for a walking beam furnace.




ARCELOR - ZUMARRAGA - C:\RUSSULA\HMI
Special
Development!
Russula
DIAGRAMA: AIRE de DILUCION
SP
760.00 ºC
TIC
1908
100%
OUT
0.00 %
TAHH
1911a
T
Parada Calentamiento
TAH
1911a
TY
1908b
Limitacion
de Potencia
LEVEL 1
LEVEL 0
BT-TE 1908
MV
715.17 ºC
NORMAL/TEST
Auto
Man
MAN
0.00 %
VREF
30.00 %
KE-TCV 1908a
KE-TCV 1908b
Aire de Dilucion
MV
SP
OUT
715 ºC
760 ºC
0.0 %
Auto
Ajuste
Trend
Regulacion
Zonas
Estrategias
Tracking
Mantenimiento
Tendencias
Material
Alarmas
ON
Control Digital
P. Aire
P. Gas
P. Horno
Inyeccion
Dilucion
Quemadores
Comunicacion
Seccion:
Manten.
11/11/2004 12:12:09
ALARM_Z7_Gas_Discrepancy
Z7 - Alarma Discrepancia Gas entre las 2 Valvulas Quemadores Zona 7


ARCELOR - ZUMARRAGA - C:\RUSSULA\HMI
Special
Development
Russula
MOVIMIENTO DE MATERIAL
Colada Cant 1º Estr
244122 41 1 33
244121 15 1 33
0 0 0 0
0 0 0 0
0 0 0 0
Pos Lote No Estr
0 244122 0 33
230 244122 0 33
460 244122 0 33
690 244122 0 33
920 244122 0 33
Correccion: - +
Pos Lote No Estr
17480 244122 5 33
17710 244122 4 33
17940 244122 3 33
18170 244122 2 33
18400 244122 1 33
Correccion: - +
Palanquilla
PUPITRE LOCAL EMG
PUPITRE LOCAL EMG
PUPITRE LOCAL EMG
SALIDA HORNO TREN 3
PUPITRE EMG
Produccion Estimada 113 Ton/h
Velocidad Horno 184 mm/min
No Palanquillas Horno 42
Tiempo Paro Manual 0 Min
Tiempo Paro Auto 0 Min
PRODUCCION
BLOQUEO CARGADOR
AD AT
AR AT AB AD
PUERTA ABT
PUERTA ABT
ARR ABJ
POS 72
POS 67
DESHORNADORA 2
DESHORNADORA 1
AD AT
SALIDA HORNO TREN 2
TEMPERATURAS BRAZOS 19.2 °C 18.7 °C 22.3 °C 17.4 °C
TEMPERATURAS INDICES 15.9 °C 20.5 °C
TEMPERATURAS PAILAS 31.4 °C 35.9 °C
T. DESBASTE
1071.0 °C
HORNO
Paso Adelante
Paso Atras
ON
Alarmas
Seccion:
Regulacion
Zonas
Estrategias
Tracking
Mantenimiento
Tendencias
Material
12:14:58
ALARM_B1_Z2_Gas_WrongPos
Z2 - Alarma Q3 Valvula Automatica Gas No en Posicion Zona 2
11/11/2004 12:15:02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Special
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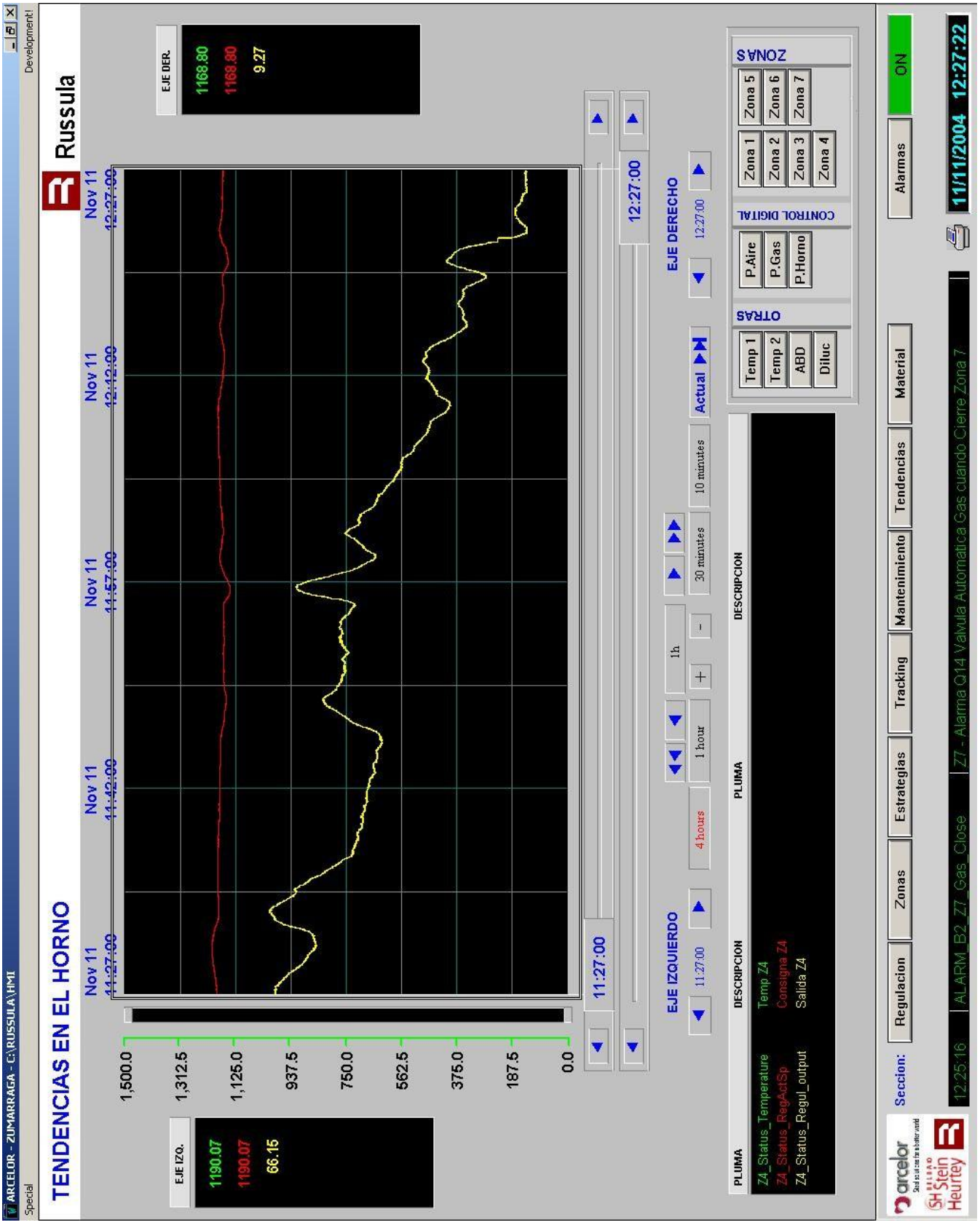
Russula
HORNO ZONA 3
Aire
Gas
TIEMPO DE TRABAJO VALVULA AIRE
TIEMPO DE TRABAJO VALVULA GAS
Tiempo Ciclo
Tiempo Trabajo
T Inicio
T Delta
Tiempo de Ciclo
Tiempo Delta
REGULADOR TEMPERATURA
Auto
MV 1149.2 °C
SP 1150.0 °C
OUT 52.7 %
Ajuste
Trend
CT/100-->
Relacion Aire/Gas
SetPoint λK 1.05
Temperatura
A 1088
B 1114
A 1150
B 1150
Max.
ESTRAT. SP
1196
0
Stop
Auto
Rampa
Tiemp 480 min
Temp 650 °C
Tiemp 1000 min
Temp 900 °C
Fecha Final 31/12/1979
Tiempo 00:00:00
Ajuste Manual 0.00 %
Regulacion
Zonas
Estrategias
Tracking
Mantenimiento
Tendencias
Material
ZONA 1
ZONA 2
ZONA 3
ZONA 4
ZONA 5
ZONA 6
ZONA 7
Alarmas
ON
Seccion:
Zonas
11:57:29
ALARM_Z2_Gas_Discrepancy
Z2 - Alarma Discrepancia Gas entre las 2 Valvulas Quemadores Zona 2
11/11/2004 11:57:32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TENDENCIAS EN EL HORNO
EJE DER.
1168.80
1168.80
9.27
EJE IZQ.
1190.07
1190.07
66.15
1,500.0
1,312.5
1,125.0
937.5
750.0
562.5
375.0
187.5
0.0
Nov 11
11:27:00
Nov 11
11:42:00
Nov 11
11:57:00
Nov 11
12:12:00
Nov 11
12:27:00
11:27:00
12:27:00
EJE IZQUIERDO
11:27:00
4 hours
1 hour
1h
30 minutes
10 minutes
Actual
EJE DERECHO
12:27:00
PLUMA
DESCRIPCION
Z4_Status_Temperature
Z4_Status_RegActSp
Z4_Status_Regul_output
Temp Z4
Consigna Z4
Salida Z4
PLUMA
DESCRIPCION
OTRAS
Temp 1
Temp 2
ABD
Diluc
CONTROL DIGITAL
P.Aire
P.Gas
P.Horno
ZONAS
Zona 1
Zona 2
Zona 3
Zona 4
Zona 5
Zona 6
Zona 7
Seccion:
Regulacion
Zonas
Estrategias
Tracking
Mantenimiento
Tendencias
Material
Alarmas
ON
12:25:16
ALARM_B2_Z7_Gas_Close
Z7 - Alarma Q14 Valvula Automatica Gas cuando Cierre Zona 7
11/11/2004 12:27:22

PLC of furnace control

All sequential control functions of the furnace are carried out by a multiprocessor system based on PLC.

Automation cards and connection elements are located in cabinets mainly designed for this application. This cabinet is composed of two individual compartments. The system cards frames are assembled in one compartment and the connecting boxes for I/O modules, auxiliary relays for solenoid control are located in the other compartment.

Our supply will be:

1x PLC cabinet with an approximative dimension of 2300 x 1600 800 mm, completely wired with the following components and their interfaces:

1 x Processor
1 x Interbus communication board (handlings bus of frequency variable)
1 x Profibus communication board
n x digital input
n x digital output
n x analog input
n x analog output

I/O remote modules will be used when necessary.

Connection elements, miniature automatics for I/O modules and all auxiliary elements will be installed in cubicles
Junction boxes will be provided where necessary and the connection to cubicles will be performed with multi-core cables

Communication network

1x Bus system for the transmission and coordination of data

Note.- It is out of our scope of supply the link

8. CONDITIONING AND COOLING WATER EQUIPMENT

8.1 COOLING CLOSED CIRCUIT OF THE FURNACE

The furnace cooling water will be circulating in a closed loop circuit. The main advantages of this system are:

- Minimized water loss due to evaporation,
- Water parameters easily controlled and regulated,
- Water consumption reduction in the main Plant water treatment system,
- Elimination of cooling towers and associated environmental and health problems.

Hot water coming from the different furnace cooling circuits will be collected in headers and will deliver water to the main return line.

This water will be cooled down in a set of forced draft air coolers. Four (4) units will be supplied. During normal operation it is recommended to work with all of them at a lower cooling fan motor speed.

In case of mainteinance of one of the units, the system can continue working, however at maximum ambient temperature, the cooling water exit temperature will increase.

The control of the air cooler units will be done in continuous mode by changing the speed of the motors instead of switching units on or off depending on the temperature conditions.

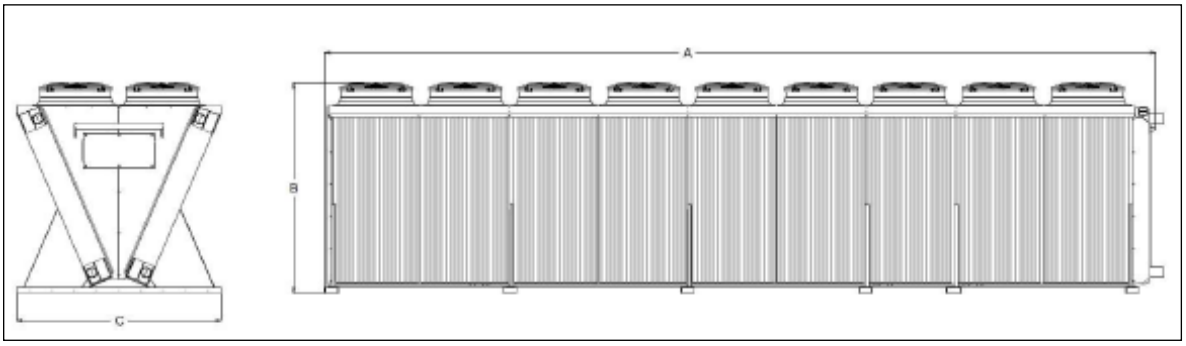
Once the water is cooled in the air coolers, it will be pumped to the furnace main entry pipe and distributed to the different headers and cooling circuits as described before.

AIR COOLERS CHARACTERISTICS:

THERMAL BALANCE		
Nominal ambient temperature (design)	°C	27
Minimum ambient temperature (winter)	°C	8
Maximum ambient temperature (unusual)	°C	35
Average maximum	°C	15
Average annual	°C	11
Minimum average	°C	8
		DESIGN
Power	KW	6400
Water flow rate (max)	m^3/h	400
Percentage of glycol	%	0
Water inlet temperature (design)	°C	50
Water inlet temperature (unusual)	°C	54

THERMAL BALANCE		
Water outlet temperature (design)	°C	35
Water outlet temperature (unusual)	°C	39
Air inlet temperature	°C	35
Air outlet temperature	°C	41,7
Air flow rate	m^3/h	504.000
Height above sea level	m	7
Pressure drop – water side	bar	0,32
Number of units		3 (+1 in standby)
CONSTRUCTION SPECIFICATIONS (UNIT)		
Type of tube		Copper
Type of fin		Al – Mg (corrosive ambient)
Fin pitch	mm	2,1
Number of circuits		330
Surface	m^2	5.428,2
Internal volume	dm^3	714,8
Dimensions (Length / Width / Height)	mm	11.300 / 2.350 / 2.490
Net weight	kg	6.470
Fan characteristics		
Type		Helical
Fan location		Forced draft (fan on the top part)
Number of fans		18
Fan diameter	mm	910
Motor speed	Rpm	1105
Motor unit power	W	3.200
Mode of operation		EC – variable speed

- Manual valves before and after the air coolers and purges/vents will be installed to isolate them during maintenance operations.



Typical air cooler design

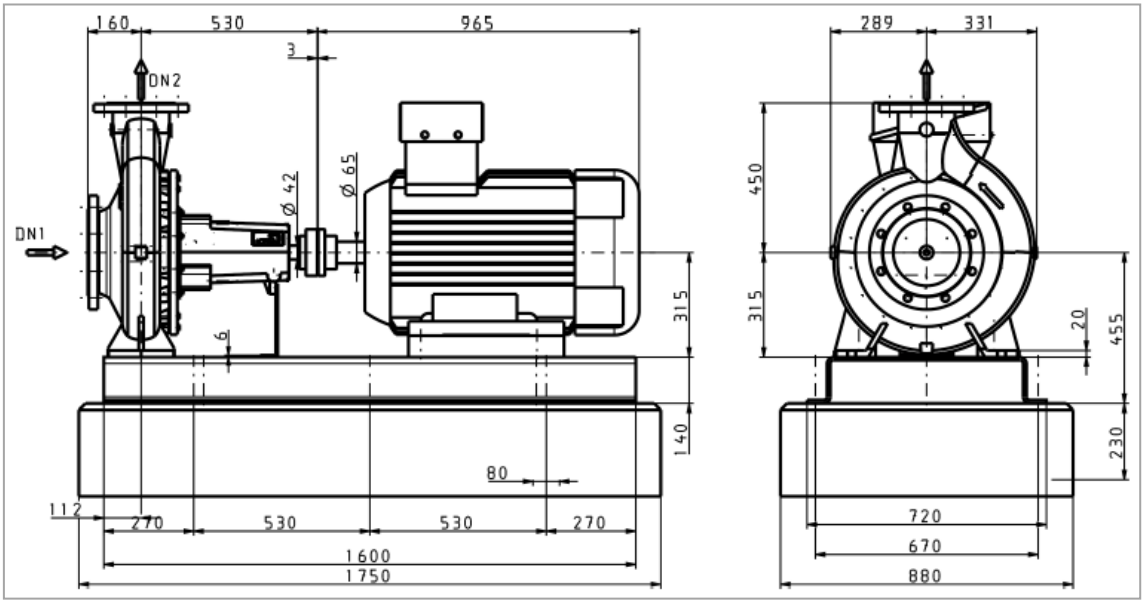
REMARKS

- Space between coolers is recommended to allow fresh air circulation
- No need to be installed above ground except if layout requires it
- Final dimensions, characteristics, etc. to be defined during engineering phase

PUMPS

The pumping system is composed of one main electric motor driven centrifugal pump (plus one in standby).

Typical dimensions of the pumps are shown hereafter:



Typical pump dimensions (analogy, to be defined during detail engineering)

- Flexible bellows will be installed at the suction and impulse sides of the pumps to minimize vibrations in the circuit.

- Manual valves upstream and downstream the pumps will be installed to isolate them during maintenance operations.
- Check valves will be installed at the impulse side of the pumps to avoid backflow through the standby and emergency pumps.
- Air eliminators will be installed in the high points of the circuit to eliminate air contained in the pipes typically during filling up of the circuit.
- Flow, pressure and temperature will be measured in the main lines before and after the cooling units.

The system is completed with a pressurized expansion tank with a capacity of 30 m^3 that will supply water to the circuit in case of emergency situations before the emergency power generator is started. This tank will include:

- Inlet supply of compressed air (or nitrogen) to keep the membrane pressurized.
- Visual level indicator to check water level

Installation of this tank can be vertical or horizontal depending on its final dimensions and location (to be agreed during basic engineering).

The control, monitoring and treatment of the water quality to reduce corrosion and deposits in the furnace circuits will be supplied by others.

Characteristics:

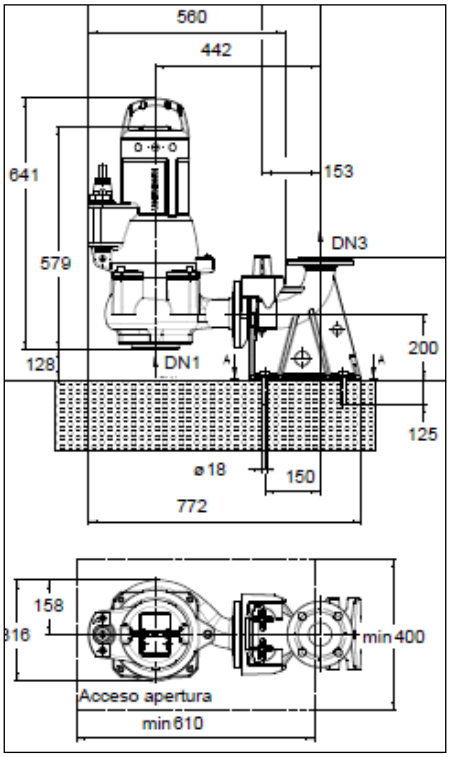
- Flow ..... 400 m^3/h
- Pressure ..... 5 bar
- Motor rating..... 90 kW at 1500 rpm

SUMP PUMP (BY CUSTOMER)

One sump pump plus one in standby will be installed at the furnace basement in order to pump the direct cooling water with scale and particles to the main scale pit.

Characteristics (preliminary):

- Flow ..... 10 m^3/h
- Pressure ..... 5 bar (to be defined)
- Motor rating..... 5,5 kW at 3000 rpm



Typical sketch of sump pump

9. SAFETY FENCES

See drawing: 718243-A-0000-0-P-0013-R00

There will be 3 (three) safety fences provided to enclose the equipment

* Entry area – enclosing the charge area
* Basement – enclosing the walking beam mechanism
* Exit area – enclosing the discharge area

There will be 4 (four) security locks on the safety fences. The security locks will be connected to the Safety PLC.

* Entry area – 1 (one) lock
* Basement – 2 (two) locks
* Exit area – 1 (one) lock)

The access and actions related to the safety locks will be defined and agreed during the engineering phase. The locks considered in the offer stop the mechanism if the doors are opened without permission

10. HAZARDOUS AND OPERABILITY STUDY (HAZOP)

A Hazard and Operability Study (HAZOP) is a structured and systematic examination of a planned or

existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation

Fives Stein conducts systematically the HAZOP study for each equipment during the engineering phase. This study is conducted in close cooperation with the customer and takes into account the customers requirements.

CHAPTER III
"Virtuo® System Mathematical Model"

Furnace Level 2: Virtuo® Access-R – Furnace Optimization System

TABLE OF CONTENTS

1. Salient Features

1.1. Purpose of the Virtuo™ Model

The Fives Furnace Level 2 for Reheating Furnaces (Virtuo™ -R) proposed is a modern technology, a state-of-the-art of Level 2; Since 1980, Fives Stein, the world's major reheating furnace designer and supplier, has improved its Furnace Level 2 solution thanks to its know-how and experience.

Virtuo™ -R has been designed for today's steel makers needs to provide high production efficiency and energy saving, as well as Labour saving and insurance of Product quality.

→In this sense, Virtuo™ -R performs the optimization of the process, based on the requirements of the grades, mill process and furnace capacity.

Virtuo™ -R carries out automated operations, optimizing and monitoring the product reheating process through the furnace. The main functions of the optimizing system are the calculation and assignment of temperature set-point values for the various furnace zones in accordance with the actual operating conditions.

Moreover, Virtuo™ modular design allows an easy integration and customizing into global plant wide optimizing systems.

Virtuo™ -R provides a high-level monitoring interface in order to keep the operator aware of furnace heating conditions, and whether local (operator) or remote (computer) control is to be applied

Five key points permit to characterize what Virtuo™ -R offers:

- **Expertise** through proven physical based models with optimization in real time,
- **Versatility** with complete range of functionalities,
- **Reliability** thanks to repeatability & flexibility,
- **Efficiency** measured with product quality,
- **Payback** by reducing operating cost & quality loss.

Virtuo™ -R solution is built as a solid set of functions and features to answer steel makers' expectations.

In consequence, Fives Stein Level 2 Virtuo™ -R reaches new level of excellence; offering much more than any other Math Models. It helps steel makers to meet today's challenges of quality requirements and get ready for tomorrow's even more demanding steel applications.

1.2. Key features

Virtuo™ -R is a trustworthy level 2 offering many advantages compared to manual control or any other Level 2 systems.

- Virtuo™ -R uses proven physical based thermal models.

- Virtuo™ -R computes individual product optimal heating curves online; no offline model or predefined curve tables are used.
- Virtuo™ -R computes optimal zones temperature set-points that ensure all products to reach the discharging targets with uniformity
- Virtuo™ -R permits to reduce delays side effects on products and consumption.
- Virtuo™ -R permits high discharging temperature accuracy even with Cold and Hot charged products.
- Virtuo™ -R has enhanced heating strategy thanks to its optimal heating curves and zone control management can decrease scale formation.
- Virtuo™ -R permits to reduce manpower requirements in automatic control mode during production of the furnace.
- Virtuo™ -R permits to decrease the fuel/gas consumption rate.
- Virtuo™ -R is very flexible and can control and optimize any furnace design with any fuel type.
- Virtuo™ -R is open to new steel grades to be added without further programming and commissioning.

2. Virtuo™ -R System description and scope

2.1. Hardware architecture

Computers will be supplied according to calculation capabilities recommended in the table below (for reference).

Item	Designation	Quantity	Recommended Location
Virtuo™ -R Server *			
H1	▪ One (1) Xeon® CPU type with 7.2GTps ▪ 16 GB RAM ▪ Two (2) Hot Plug HDD 500 GB with 6Gbps ▪ One (1) Hot Plug HDD 500 GB with 6Gbps as spare ▪ Two (2) Ethernet Gigabit network ports ▪ RAID 1 with Controller ▪ Dual Hot Plug Power Supplies ▪ One (1) flat screen of 22 inches or wider ▪ One (1) mouse ▪ One (1) US keyboard	1	Computer Room
Virtuo™ -R HMI Station (thin client)			
H2	▪ Thin client (characteristics to be defined during basic engineering) ▪ One (1) Ethernet Gigabit network port ▪ One (1) flat screen of 22 inches (or wider) ▪ One (1) mouse ▪ One (1) US keyboard	1	Furnace Control Room

* = Well-known Server brand such as HP or Dell.
** = if required

Note: Virtuo™ -R can be installed on virtualized server if required.

2.2. Software

2.2.1. Virtuo™ -R software

Virtuo™ -R runs automatically as a Windows service, ensuring high availability.
Virtuo™ -R does not require any Windows user logged in to run automatically.

Item	Designation	Quantity	Equipment
Virtuo™ -R Software			
FS1	Virtuo™ -R Application (Model) Software	1	Virtuo™ -R Server
FS2	Virtuo™ -R HMI Application Software	1	Virtuo™ -R HMI Station

Usage of Virtuo™ -R is in accordance with fives Stein's End User License Agreement (EULA).

The source codes of Virtuo™ -R application software, namely Fives Stein know-how, are not supplied.

Fives Stein will remain the owner of any source code, explicit and well-documented, and any Fives Stein's know-how.

2.2.2. 3rd parties' software

Third parties' software to run and use Virtuo™ -R software solutions are supplied according to calculation capabilities recommended in the table below (for reference).

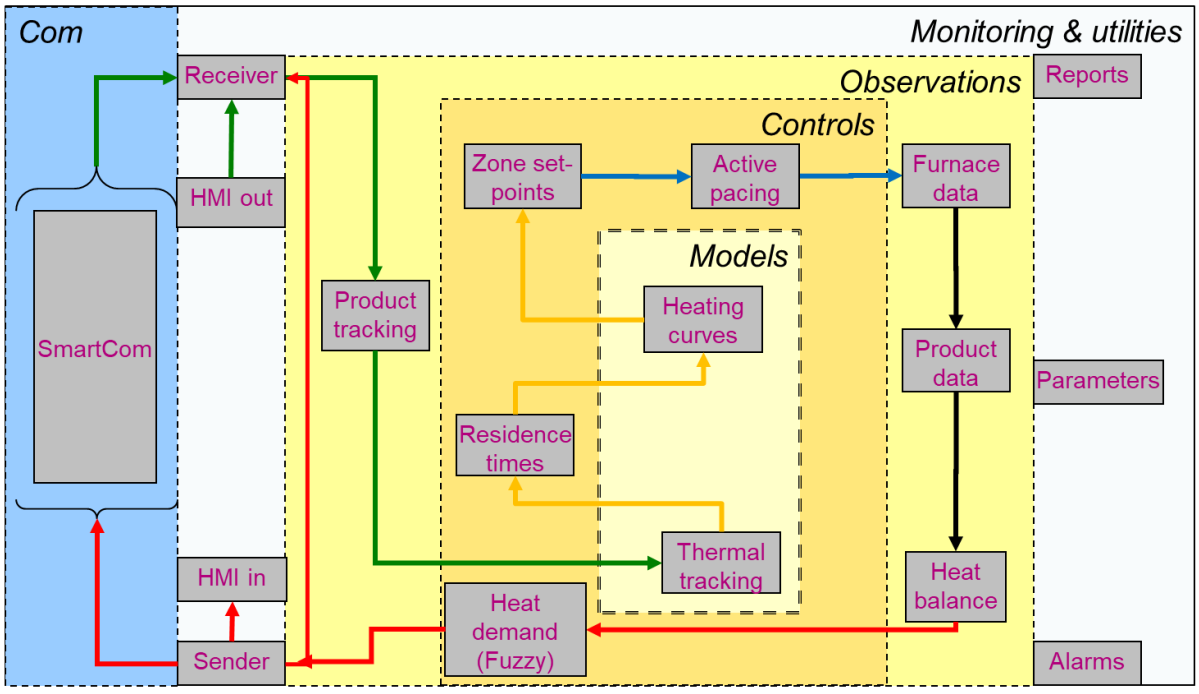
They are supplied under their latest release/version compatible with Virtuo™ -R.

All licenses of 3rd parties' software will belong to the Steel producer without any restrictions from Fives.

Item	Designation	Quantity	Equipment
Third party's software			
S1	Microsoft Windows Server 2022 (OEM English version)	1	Virtuo™ -R Server
S2	Microsoft Windows 10 (OEM English version)	1	Virtuo™ -R HMI Station

2.3. Virtuo™ -R software architecture

Virtuo™ -R working principle is described as follows with this flow diagram through the different Models/Functions:

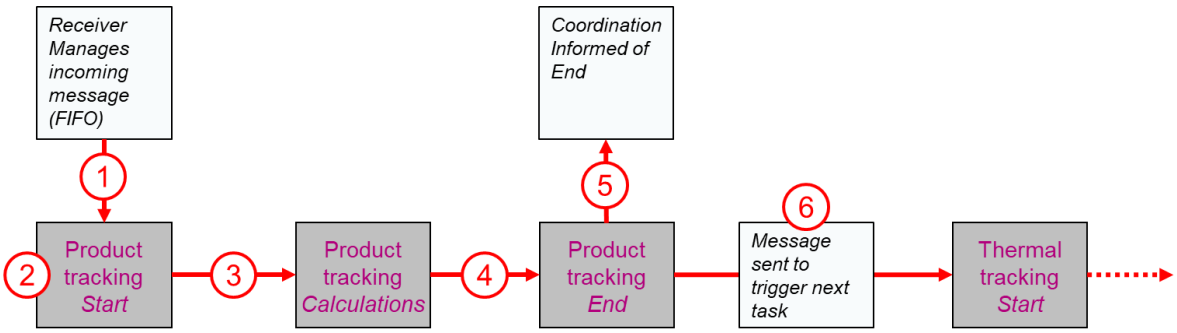


As shown on the sketch above, the system is organized in 5 functional layers regrouping tasks (EXE) in gray:

- The SmartCom function to communicate with external systems via Steel producer's communication interface,
- The Process Observation functions to manage tracking and furnaces,
- The Model Driven functions to calculate the thermal and heating equations,
- The Control functions to calculate and apply the furnace set-points,
- The Monitoring and Utilities functions to control and process information.

There is a chaining between all the tasks from *Receiver* to *Sender*, two 'interface' functions that belongs to the monitoring and utilities layer.

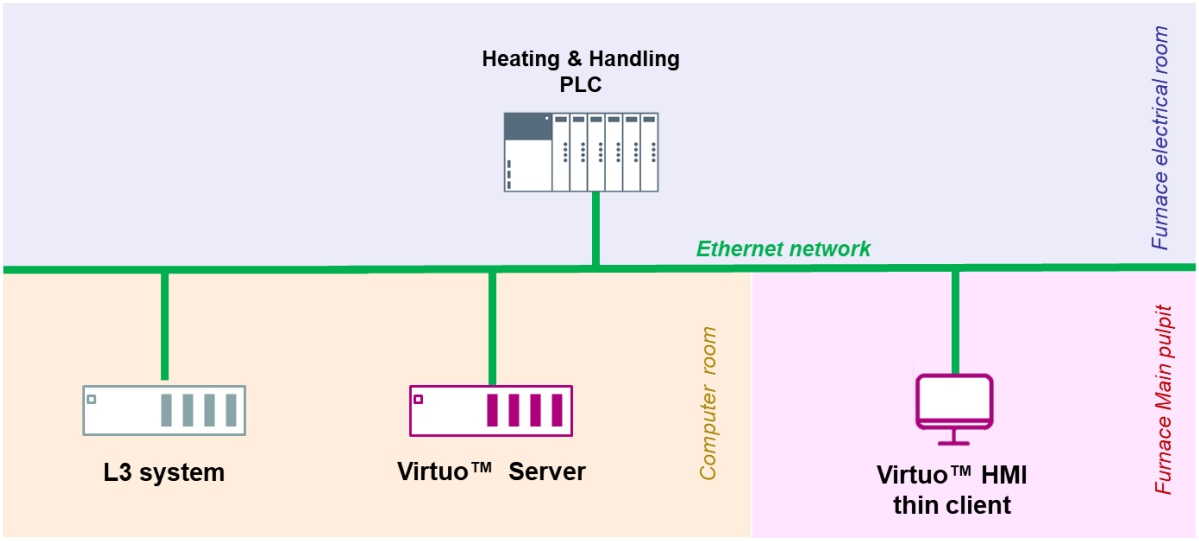
Each function (task) performs its dedicated job according to the chaining above. The functions are working according to the reception of the incoming messages*, until *Sender* function informs back *Receiver* function the message treatment is done. An example for the tracking task is described in the drawing below:



* = an incoming message is an event related to any kind of changes of handling & heating conditions or HMI changes (product move, product charging, product discharging, offset, delay start…).

2.4. Network architecture

The Fives Stein Furnace Level 2 is connected to external systems through ETHERNET / 8802.3 network; the basic network architecture principle is shown here below:



2.4.1. Communication specification

Data transmission (communication) is established between external systems and Virtuo™ -R with periodical telegrams exchanges with the following specification:

- Protocol : TCP/IP
- Port No : 2 ports (one for sending, one for receiving)
- Application : Socket interface
- Data transfer : Periodically and on events
- Design : Though configuration files

The communication interface that permits messages exchanges between Virtuo™ -R and other external control systems is done with the SmartCom using dedicated configuration files.

2.4.2. Message format

The messages exchanged between Virtuo™ -R and the other control systems consist of a header and a data part. Standard structure of message is as following:

	Item	Type	Bytes	Remark
Header (4 bytes)	Message ID	short	2	Message identification No.
	Message length	short	2	The whole length from Header to User part.
Data Part				The data content depends on message.

Data transfer takes place periodically (10 to 60 seconds period) and on events (products & furnace status change, …).

2.4.3. Message list

Here below is a basic list of messages between Virtuo™ -R and other external control systems, organized in 2 categories. All data and messages content to be sent and/or received from/to will be defined and reviewed in detail during detail design phase.

Sender (→)	Receiver (←)	Type	Occurrence	Messages	Category
Incoming communications					
Furnace PLC	Virtuo™ -R	TCP	Events	Tracking events (charging, Discharging, movements)	Handling management
Furnace PLC	Virtuo™ -R	TCP	Periodical	Furnaces measurements (temperatures and flows…)	Heating management
L3	Virtuo™ -R	TCP	Events	PDI, delays, rolled products	Handling management
Outgoing communications					
Virtuo™ -R	Furnace PLC	TCP	Events	Movement waiting timer for Active pacing, time before next product to be discharged	Handling management
Virtuo™ -R	Furnace PLC	TCP	Periodical & events	Temperature set points	Heating management
Virtuo™ -R	L3	TCP	Events	Process data results	Heating management

Note:

- Each zone individually controlled,
- Control switch in Furnace Level 1,
- Whatever the control mode, Virtuo™ -R is calculating.

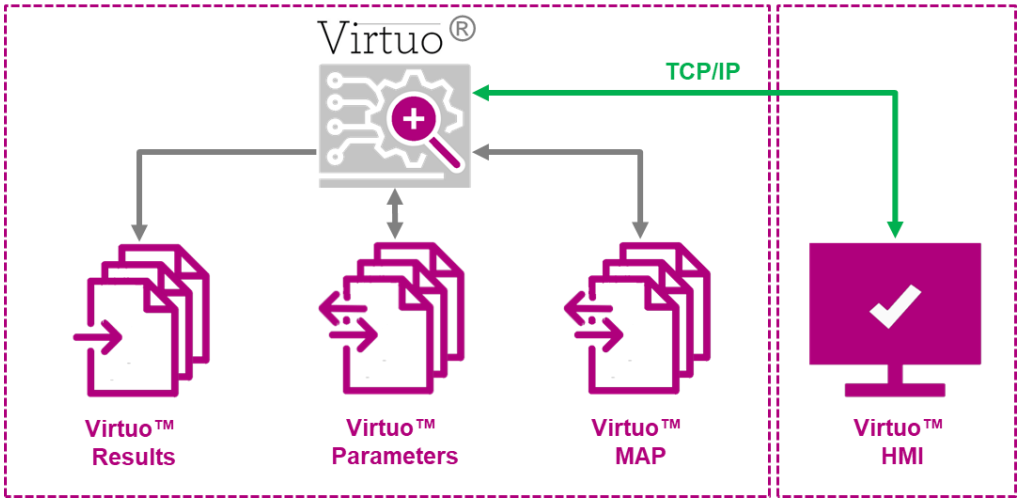
2.5. Virtuo™ -R data architecture

Data storage and management is of 3 kinds within Virtuo™ -R application, HMI and tools, on dedicated binary files.

Item	Designation	Description
Data storage		
DS1	Parameters files	• All software settings and useful parameters for Virtuo™ -R design and tuning, • Can be changed on-the-fly for tuning without stopping the application, • Ease of use for backup and restore thanks to dedicated parameters management function.
DS2	Results files	• Logs, alarms, reports & history covering for long-term storage duration.

Item	Designation	Description
DS3	MAP files	• Known as 'global sections', • Non-permanent data used in real-time for calculation, • Automatically renewal as per usage basis, • Reliable way for fast data usage and update calculations by the thermal model, • Simplified maintenance and data manipulation.

Note: Virtuo™ -R does not require any database to store information, data, parameters or logs.

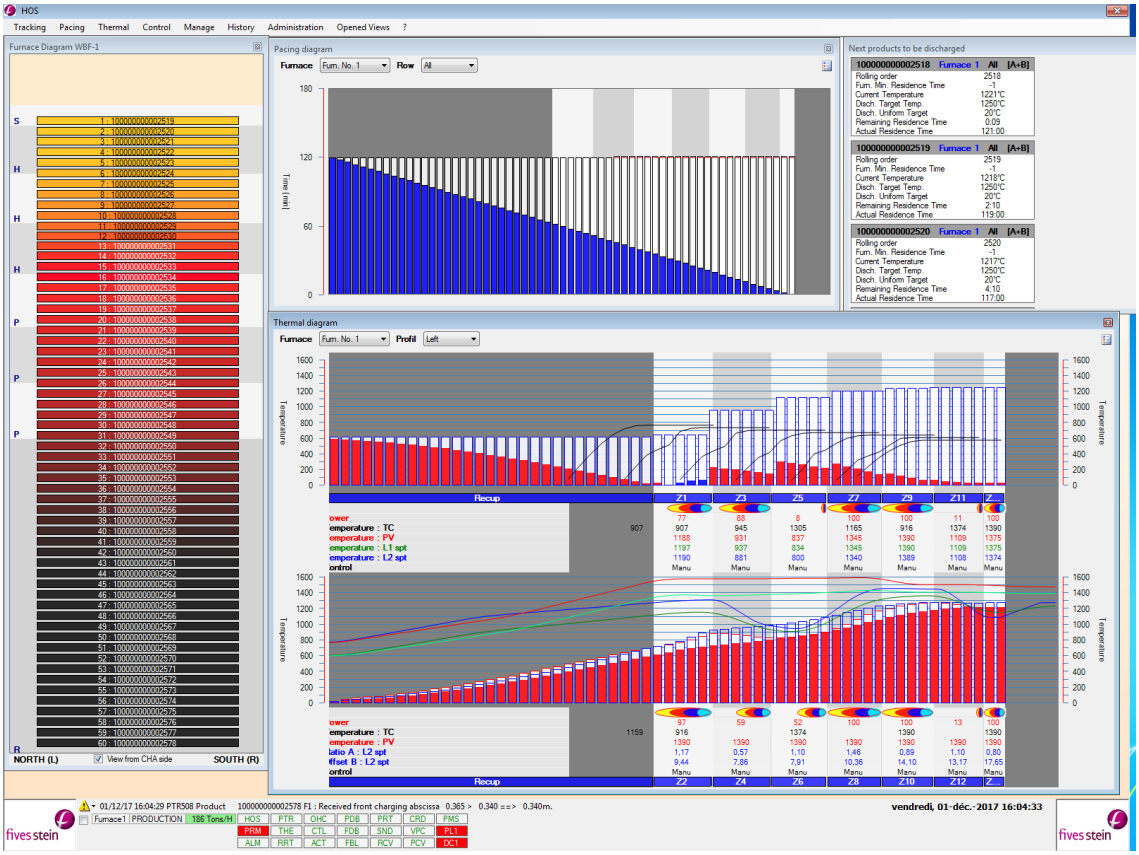


2.6. Virtuo™ -R HMI

The main views for Furnace Level 2 (Virtuo™ -R) are:

- Product location tracking,
- Product thermal tracking,
- Production pacing,
- Delay management,
- Set-points behavior,
- Furnace operation management,
- Furnace heating parameters tuning…

Virtuo™ -R display is customizable; each view is a movable & resizable pop-up window.



Note about reports and displays

All reports and displays will be within the Fives Stein standard application in English language, and in SI units and Imperial units. HMI views supports Steel producer native language (one click in HMI's menu to switch from one language to another).

All displays showed in this technical document are not contractual, there are not referring to any design and or calculation made for this project but are given as example and are for information only.

2.7. VPN connection

To facilitate technical assistance and commissioning, a VPN access to site is mandatory and shall be put in place by the Steel producer to facilitate work.

IT requirements of the VPN setup will be mutually agreed between the Steel producer and the Supplier.

2.8. Documentation

The following documents related to Furnace Level 2 are to be supplied:

Item	Description	Quantity	Format	Delivery
D1	Virtuo™ -R functional analysis (English version) which includes: • Hardware & software description • Function description • Communication & messages	1	PDF	Preliminary at functional analysis review Final 15 days after end of performances
D2	Virtuo™ -R operating user guide (English version) which includes: • HMI views description • HMI usage to operate the Furnace in optimization control mode.	1	PDF	Final 15 days after end of performances
D3	Virtuo™ -R software maintenance manual (English version) which includes: • Installation instructions • Instructions for configuring and running Virtuo™ -R software	1	PDF	Final 15 days after end of performances

2.9. Services

2.9.1. Training

Training is intended for Steel producer trainees having a good knowledge of data processing and furnace thermal processes, as well as knowledge of hardware and standard software supplied technology:

Item	Designation
Virtuo™ -R Training	
TC1	Design: • Design type of furnace Level 2 system • Fundamentals of software modules • Hardware & software layout • Computer design for Level 2 • Functions of furnace Level 2 • Furnace Level 2 application parameters definition • Data storage • HMI • Evaluation of heating results • Alarms & errors management
TC2	Communication: • TCP/IP Interfaces • Telegrams basis
TC3	Thermal: • Product thermal model temperature calculation • Determination of optimal heating curves
TC4	Control: • Furnace zone set points calculation • Delays management

General information about the theoretical training courses is:

- Language → English language,
- Location → Steel producer's site,
- When → During commissioning phase,
- Duration → 5 days,
- Attendees (recommended) → Process engineer + Production engineer + Level 2 engineer,
- Performed by → Fives Stein Level 2 engineer(s).

In addition, during commissioning, the Supplier will provide continuous 'operative' training focused on practical usage, control basic principles, HMI usage and specific maintenance. This training course is provided as well as trainees involved to the previous session and the operators.

2.9.2. Interface testing

During the engineering phase and before the commissioning of Virtuo™ -R an integration test will be performed between Virtuo™ -R and the new furnace automation system to check the communication interface & messages exchanges.

2.9.3. Commissioning

The commissioning of Virtuo™ -R is performed by the Supplier personnel. The commissioning is divided in the following main steps.

Item	Designation
Virtuo™ -R commissioning	
CS1	Communication tests
CS2	Tracking & pacing
CS3	Furnace Control & Model tuning
CS4	Takeover period – Coaching Part 1
CS5	Fine tuning – Coaching Part 2

Note: During Virtuo™ -R commissioning, furnace is at least running at 50% of the maximum production capacity to tune the application during working hours of Fives Stein Level 2 engineer(s). The operators must follow the instructions given to them by Fives Stein Level 2 engineer(s).

Coaching:
Coaching is performed by the Supplier to support the Steel producer in achieving a specific goal by providing training and guidance & fine tuning. This coaching particularly focusses on specific tasks or objectives, in addition to the more general skills learning goals provided during the training session.

3. Virtuo™ -R tracking and heating control

Virtuo™ -R tracking and heating control functions refer to different tasks of Furnace Level 2 application that have an active role in the furnace process optimization, monitoring and controlling furnace operations continually. These tasks are described below and belong to 3 functional layers of Virtuo™ -R:

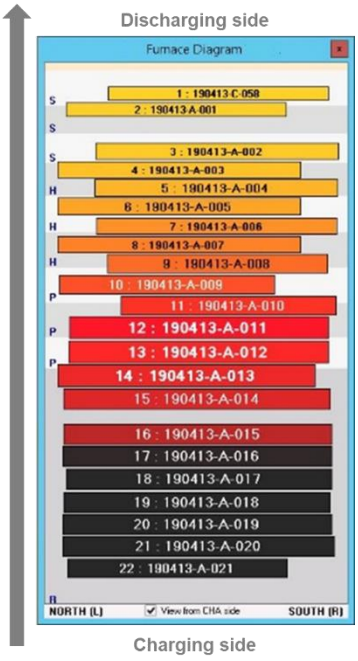
- The Process Observation functions to manage tracking and furnaces,
- The Model Driven functions to calculate the thermal and heating equations,
- The Control functions to calculate and apply the furnace set-points.

3.1. Products tracking location

Purpose:

In building Virtuo™ -R own product tracking inside the furnace (from charging to discharging) and updating the products status, the product tracking function maintains real time knowledge of the furnace content in terms of:

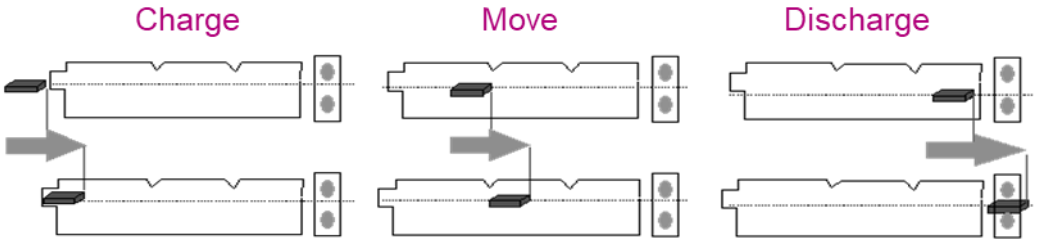
- Product characteristics,
- Exact location of products inside the furnace.



Products' location can be determined independently from the Furnace heating control by Virtuo™ -R, considering the following information:

- Actual product location inside the furnace, tracking diagram (furnace map),
- Product characteristics from primary PDI (dimensions, steel grade, targets, charged temperatures ...),
- Pacing diagram, residence times (elapsed, remaining ...),
- Next products to be charged,
- Next products to be discharged, products just discharged and discharge intervals,
- Uses the available measuring devices, such as lasers, for tracking update and automatic correction of positions to the discharging line, if any.

Virtuo™ -R is informed of the following events to update its own furnace tracking:



3.2. Online heating product model

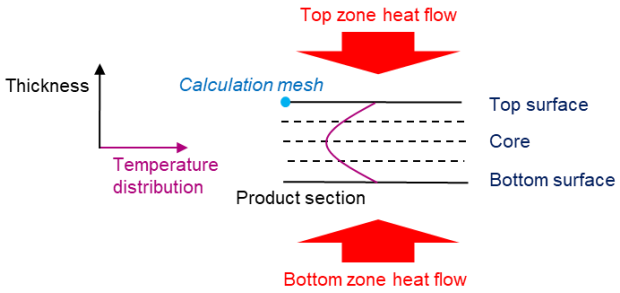
3.2.1. Principle

Purpose:
Virtuo™ -R online thermal model determines the temperature of each products inside the furnace by means of physical laws of heat transfers occurring between the products and the furnace as well as inside the product itself.

This model calculates the temperature uniformity through the product thickness. Calculation Mesh is determined according to product dimensions.

The online thermal model considers the product dimensional data, steel grade, residence time of each product in the furnace zones and variations of the furnace temperature from charge to discharge end.

Note: The thermal model precision doesn't require pre-calculated table, offline/online simulator or need of maintenance plan to adjust its tuning parameters.



Calculation steps:

- Flue gas calculation per zone

$$a_{Roof}T_{Roof}^4 + a_{Product}T_{Product}^4 = a_{Flue\ gas}T_{Flue\ gas}^4$$

- Radiative transfer to determine Flue gas and roof temperature all along the furnace
- Net heat flow received by the product

$$\Phi_i = S \cdot K \cdot \varepsilon \cdot F \cdot \sigma \cdot \left(T_{Roof}^4 - T_{Product}^4\right)$$

- Temperature change of the product

$$\rho C_p \frac{dT_{Product}}{dt} = \lambda \frac{d^2T_{Product}}{dx^2}$$

These calculations consider the following model inputs:

- The roof temperature of each top zone, measured by thermocouple,
- The hearth temperature of each bottom zone, measured by thermocouple,
- The flue-gas temperature at furnace outlet, measured by thermocouple in the flue-gas duct,
- The product temperature at charging, measured by optical pyrometer.

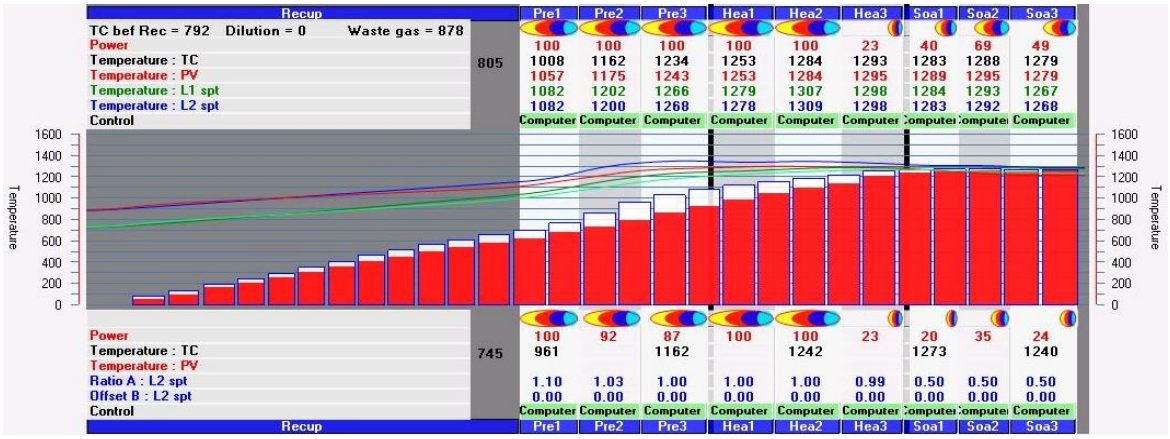
These calculations provide the following model outputs:

- Average temperature of the product,
- Top-face surface temperature of the product,
- Core temperature of the product,
- Bottom-face surface temperature of the product.

3.2.2. Online thermal tracking

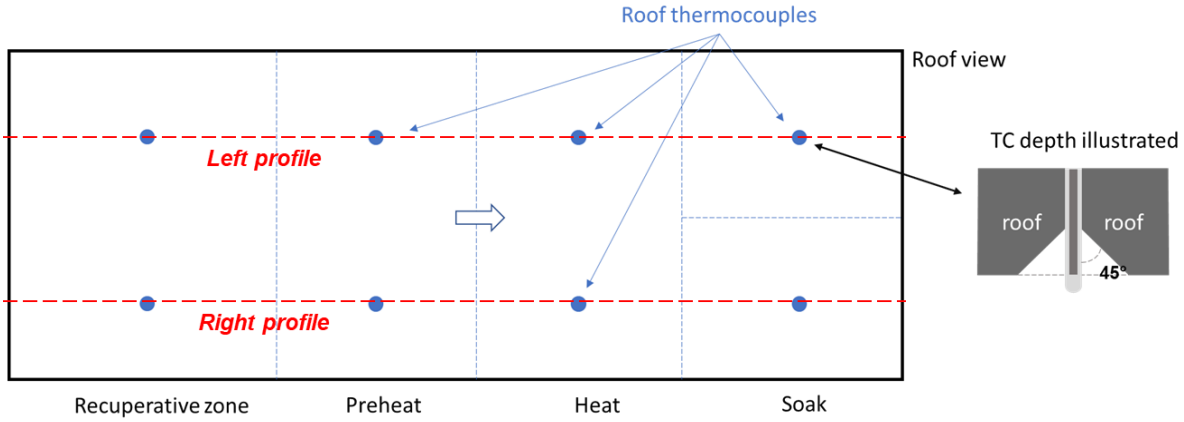
Virtuo™ -R calculates online thermal tracking and its HMI provides a dedicated view for thermal diagram of the furnace where the following data are available for each zone (Left & Right or Center Profiles, depending on thermocouples locations):

- Product average (bulk) temperature → Red full bar-graph,
- Product top-face temperature → Red empty bar-graph,
- Product bottom-face temperature → Blue empty bar-graph
- Bottom zone flue-gas temperature → Red full-line,
- Top zone flue-gas temperature → Blue full-line,
- Bottom hearth temperature → Bright Green full-line,
- Top roof temperature → Dark Green full-line,
- Thermocouples position & measurement →Black values.



Thermal profile:

A thermal profile is defined by a 'line' of roof thermocouples with at least 1 thermocouple per zone and can be represented as follows:



Virtuo™ -R HMI provides a dedicated view for Furnace Content where the following data are available for each product calculated by the thermal model:

- Product position in the furnace,
- Product dimensions and weight,
- Product residence times,
- Product temperatures calculated by the thermal model,
- Product temperature target.

Product Id	Furnace	Charge Date/Time	Zone	BISRA	Width	Thick.	Length	Weight	Abscissa	Elapsed time	Recup Time	Preheat Time	Heating Time	Soaking Time	Discharge Temp. Target	Average Temp.	Top Temp.	Bottom Temp.	Core Temp.	Charging Temp.
190412-A-032	Furnace1	12-04-2019 10:47	Soaking 3	1	1599	220	7674	21246	40481	311:21	191:03	38:29	55:25	26:24	1260	1256.8	1258.9	1258.9	1254	35
190412-A-033	Furnace1	12-04-2019 11:02	Soaking 2	1	1470	220	8314	21160	38354	296:33	183:23	48:46	48:54	15:30	1260	1247.8	1259.8	1259.8	1239.5	35
190412-A-034	Furnace1	12-04-2019 11:18	Soaking 1	1	1471	220	8308	21160	36805	280:53	177:28	46:52	53:51	2:42	1260	1234.8	1254	1254	1222.1	35
190412-A-035	Furnace1	12-04-2019 12:40	Soaking 1	1	1457	220	10079	25426	35204	198:09	102:21	48:04	47:44	0:00	1260	1210.2	1242.7	1242.7	1189.1	35
190412-A-036	Furnace1	12-04-2019 12:56	Heating 3	1	1352	200	8385	17844	33646	182:42	95:43	50:27	36:32	0:00	1260	1213.5	1243.7	1243.7	1194.2	35
190412-A-037	Furnace1	12-04-2019 13:03	Heating 2	1	1341	200	8347	17618	32169	175:12	94:04	54:44	26:24	0:00	1260	1190.3	1231.6	1231.6	1164.3	35
190412-A-038	Furnace1	12-04-2019 13:11	Heating 2	1	1342	200	8783	18552	30698	167:33	102:29	48:51	16:13	0:00	1260	1155.9	1210.2	1210.2	1121.7	35
190412-A-039	Furnace1	12-04-2019 13:27	Heating 1	1	1350	200	8598	18270	29229	151:38	95:05	47:31	9:02	0:00	1260	1103.3	1175	1175	1057.7	35
190412-A-040	Furnace1	12-04-2019 13:36	Heating 1	1	1335	220	10207	23593	27750	142:47	94:13	47:18	1:16	0:00	1260	989.3	1112.5	1112.5	907.4	35
190412-A-041	Furnace1	12-04-2019 13:42	Preheat 3	1	1324	220	9184	21053	26288	136:33	98:08	38:25	0:00	0:00	1260	913.3	1063.6	1063.6	832.5	35
190412-A-042	Furnace1	12-04-2019 13:48	Preheat 3	1	1334	220	10200	23559	24837	130:12	102:35	27:37	0:00	0:00	1260	849.7	1007.7	1007.7	763.1	35
190412-A-043	Furnace1	12-04-2019 13:56	Preheat 2	1	1334	220	10101	23330	23389	122:47	100:14	22:33	0:00	0:00	1260	779.2	927.3	927.3	711.9	35
190412-B-001	Furnace1	12-04-2019 14:02	Preheat 2	1	1305	220	9186	20756	21911	116:09	100:39	15:30	0:00	0:00	1260	724.5	834.2	834.2	671.9	35
190412-B-002	Furnace1	12-04-2019 14:09	Preheat 1	1	1320	220	10166	23234	20475	108:55	106:13	2:42	0:00	0:00	1260	681.4	755.9	755.9	631.2	35
190412-B-003	Furnace1	12-04-2019 14:19	Preheat 1	1	1338	220	10214	23662	19023	99:07	99:07	0:00	0:00	0:00	1260	631.8	705.2	705.2	587.4	35
190412-B-004	Furnace1	12-04-2019 14:28	Recuperat	1	1305	220	9128	20625	17557	90:43	90:43	0:00	0:00	0:00	1260	584.3	653.4	653.4	542.7	35
190412-B-005	Furnace1	12-04-2019 14:34	Recuperat	1	1312	225	9057	21041	16114	84:52	84:52	0:00	0:00	0:00	1260	530.3	595.5	595.5	491	35
190412-B-006	Furnace1	12-04-2019 14:50	Recuperat	1	1352	225	9106	21800	14663	68:08	68:08	0:00	0:00	0:00	1260	456.8	517	517	421.2	35
190412-B-007	Furnace1	12-04-2019 14:56	Recuperat	1	1325	225	9154	21478	13171	62:34	62:34	0:00	0:00	0:00	1260	414.1	468.2	468.2	382	35
190412-B-008	Furnace1	12-04-2019 15:02	Recuperat	1	1105	225	8322	16283	11705	56:37	56:37	0:00	0:00	0:00	1260	374.5	424	424	345	35

3.3. Residence time

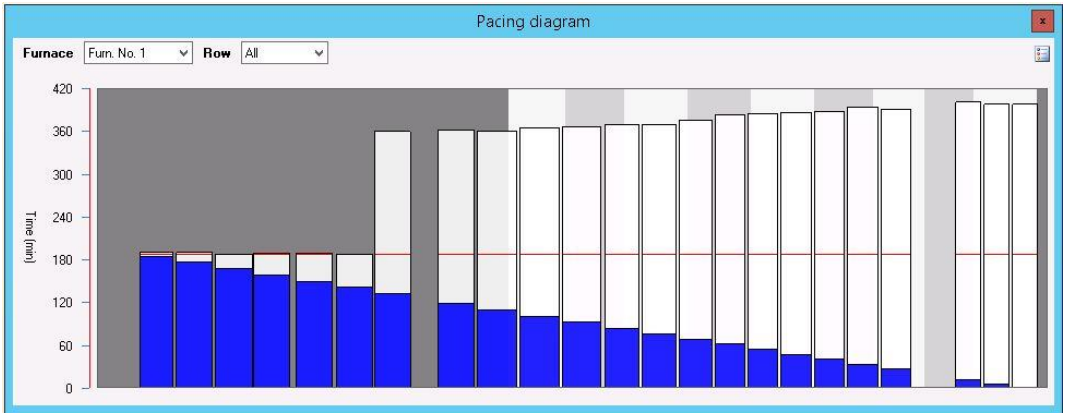
3.3.1. Principle

Purpose:

The Residence time function computes the required remaining and expected residence time of each known product inside each furnace. Such residence times are calculated by considering the production capacity of the furnace and of the rolling mill, as well as the current pace and the production delays, if any.

3.3.2. Reheat In-Furnace pacing model

To achieve the minimized of the heat input into the furnace, it is necessary to determine the average pace of the products crossing the furnace.



This function calculates products' remaining product residence time inside the furnace periodically and displays pacing diagram. Its calculation depends on:

- The furnace characteristics,
- The product characteristics,
- The product temperature targets.

The furnace Pacing function will use the Mill interval and the Furnace residence time to estimate, *i.e.* predict, the nominal pace of the production.

Mill interval:
It is defined as the time separating the moment when the product "i" enters the mill and the moment when the product "i+1" enters the mill, where this time is supposed to be computed based on the mill different equipment (descaling boxes, roughing mill, finishing mill, down coilers…) working at its optimal capacity without collision with another product.

This mill interval is a key parameter for the in-furnace pacing management and doesn't include the Furnace residence time, and thus must be known by Virtuo™ -R before or during the charging of each product to ensure pacing consistency between the furnace and the Mill.

3.4. Online optimal heating curves

3.4.1. Principle

Purpose:
These curves provide products End of Zone (T_{TGTi}) temperature targets to be reached at each zone exit. Each product optimal heating curve ensures the lowest gas consumption.

Optimal heating curves are fully calculated by Virtuo™ -R and do not require any operator intervention. Virtuo™ -R heating curves determination philosophy is as follows:

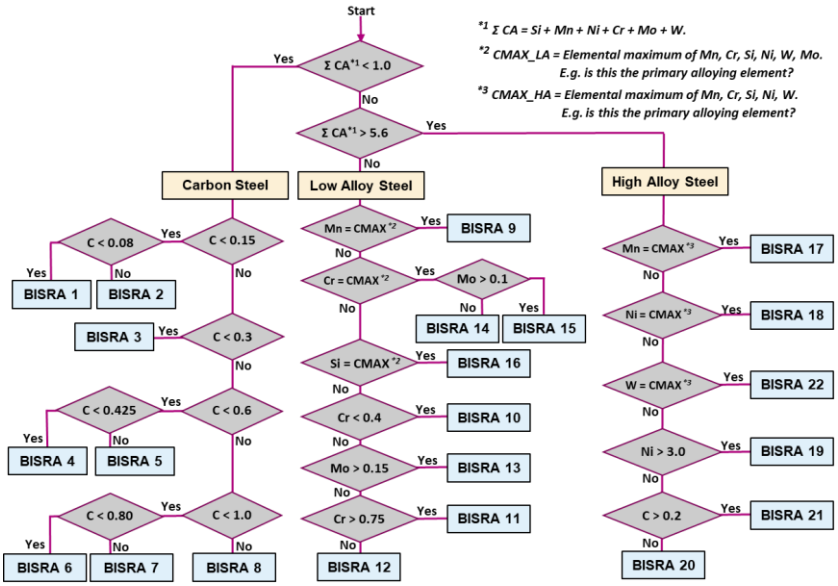
- No pre-computed or read from tables,
- As soon as a product is known (primary PDI) by Virtuo™ -R, a unique “Optimal Heating Curve” are individually calculated online using thermal models,
- This product-related “Optimal Heating Curve” is computed according to:
    - The furnace characteristics (zones dimensions, zones power, maximum temperature of zones…),
    - The given product characteristics from primary PDI (dimensions, steel grade, charged temperature (cold or hot), discharging temperature targets, maximal allowed discharging temperature uniformity, maximal allowed surface temperature…),
    - The predicted residence time in the furnace, in link with furnace pace (number of minutes from charging to discharging),
    - Furnace conditions change (events based).

Calculation steps:
The End of Zone (T_{TGTi}) calculation is done from soaking zone to recuperative zone, where:

- The soaking zone is calculated to impose the discharging uniformity target,
- The heating zone is calculated in order to use its maximum connected input power,
- The preheating zone is the only adjustment parameter to obtain the average temperature target,
- The recuperative zone is used to recover waste gas energy to increase the thermal efficiency of the furnace and is calculated simultaneously with the preheating zone,

3.4.2. Standard steel grades

Virtuo™ -R thermal calculation is based on products thermal properties, linked to the grades’ characteristics. Fives’ thermal model can either use chemical composition (as seen in diagram below) or Standard steel grades defined as BISRA code to determine proper thermal properties to be used to perform heating curves calculation.



3.4.3. Steel producer specific steel grades

In case steel grades to be processed do not have standard chemistry and don't belong to BISRA international classification, the Steel producer shall provide the thermal properties to be used within Virtuo™ -R for its thermal calculations.

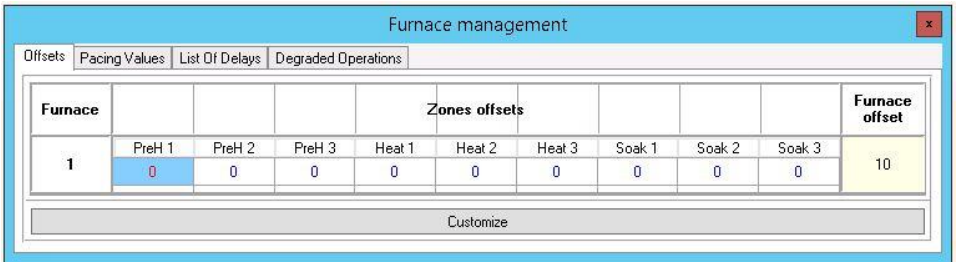
The following thermal properties values are given as a function of temperature (usually, every 50°C, from 0°C to 1350°C) related to Steel producer specific compositions:

- Enthalpy H (J/kg)
- Conductivity λ (W/(m.K))
- Density ρ (kg/m³)
- Specific heat C_p (J/(kg.K)),
- Diffusivity α (m²/s)
- Emissivity (0<Ɛ<1)
- Usage flag (yes or no) of defined steel grade thermal data for heating curves.

3.4.4. Steel producer specific heating curves

In some rare production cases, operators can change the optimal heating curve from the HMI by:

- Setting End of Zone temperature offsets,
- Setting discharge temperature offsets.



Once a change is applied, Virtuo™ -R will automatically re-generate new optimum heating curves for charged products in accordance with this Steel producer specific heating curve.

3.5. Set-point regulation of the furnace zones

3.5.1. Principle

Purpose:
The regulation of the furnace consists in controlling the operation of the furnace heating process by calculating the zone set-points to achieve each products' heating curve. In addition, this function optimizes the heat input to be applied to the furnace to ensures the lowest gas consumption.

The Zone set-points function acts as a dynamic control system, with real-time and automatic adaptation to achieve current operating conditions that are adjusted to the varying furnace production rate.

The Zone set-points function will be involved in the Zone set-points determination & control, based on the knowledge of the following data:

- Product location inside the furnace given by the product tracking function,
- Product current temperature given by the thermal model function,
- Production rate (pace) given by the residence times function,
- Product End of Zone temperature target (T_{TGTi}) given by the optimal heating curve function.

Bottom zones:
Virtuo™ -R can control the bottom zones in 2 modes:

- 'Temperature set-point mode' (Virtuo™ -R temperature set-point per zone is used by the heating automation system to apply the corresponding power),
- 'Ratio mode' (Virtuo™ -R power set-point per zone is calculated as a fraction (A) of the power in the top zone and a power offset (B)). This mode helps to improve heat demand control since temperature measurement in the bottom is not as precise as top zone measurement.

3.5.2. Optimal zones temperature set-points

The calculated set-point of each zone is the one that minimizes the deviation from the target temperature of all the products that will be influenced by this new set point.

Calculation steps:
Virtuo™ -R will determine the optimal zone temperature set-point for all products considered in a zone as follows:

- Estimation of the end of zone temperature for the current product (i) starting with its actual thermal state (temperatures, enthalpy…)
- Comparison of the estimated bulk temperature (T_{PREi}) to the End of Zone target (T_{TGTi})
- Computation of the disparities (differences) between the estimated bulk temperature (T_{PREi}) and the target/tolerance/constraints/…
- Determination of the zone global disparities (differences),
- Determination of the next possible temperature set-point until the optimum temperature set-point (T_z) is found.

The optimum zone temperature set-point is obtained when the weighed quadratic discrepancy function C is minimized.

$$C = \frac{\sum_{i=1}^{n} \alpha_i \cdot g_i \cdot [T_{TGTi} - T_{PREi}(T_Z)]^2}{\sum_{i=1}^{n} \alpha_i \cdot g_i}$$

Note: To deal with different products, Virtuo™ -R aims the best compromise between different requirements, considering tolerances (Min & Max).

To do so, it is mandatory for Steel producer to provide within PDI such tolerances.

No manual intervention by the operator is required.

3.5.3. The importance of weighing factors and the influence zone

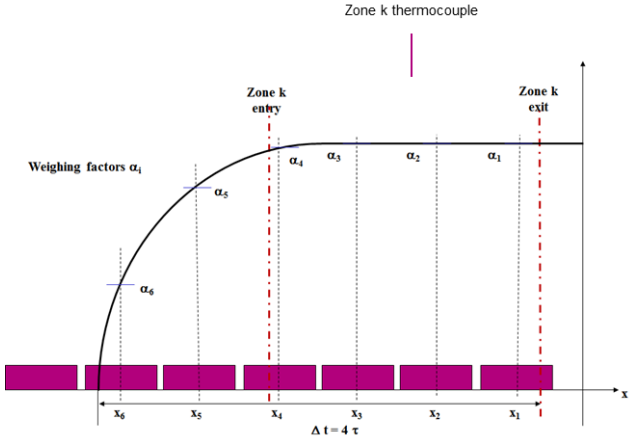
The influence zone, as no change in zone temperature is instantaneous, the set-point calculation takes into consideration the zone response time τ, (tuning parameter). The products in the influence zone ($\Delta T=4\tau$) affect each other and are thus considered in the calculation of the optimal zone set-points.

This strategy allows both a good anticipation of the set-point adjustment regarding the production conditions and the ability to deal with all the different products influencing each other.

As for the weighting factor feature is introduced to set priority to the zone temperature set-point calculation when different types of products are in the same zone. There are 2 weighing factors:

- The first weighting factor given as a coefficient (g_i) related to the product characteristics reflect the level of importance, for the Steel producer & given by the Steel producer, of the products. The bigger g_i is, the more difficult is the product to be heated (cold charged, big thickness, special steel grade…).

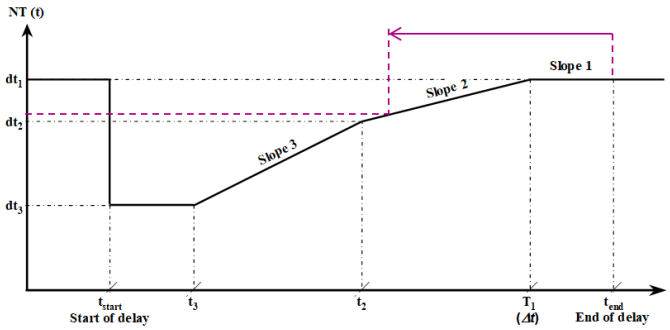
- The second weighting factor in Virtuo™ -R is (α_i) related to the position of the product in the zone knowing that a product leaving the zone will be much more important than a product just arriving at it as illustrated below:



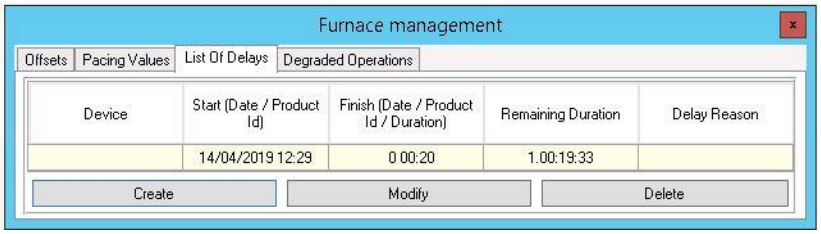
3.5.4. Delay strategy

The zone control function is designed to manage automatically productions delays, due to the Mill or the furnace. The delay management strategy, whatever the delay duration is short long or long, scheduled, or immediate, permits to minimize the fuel consumption as well as to improve the product quality as product overheating is minimized.

The products end of zone set-points are automatically recomputed at delay start according to the delay duration and the products temperature inside the furnace. Once computed, they are ramped following slopes (tuning parameter) in real-time to reach the products End of Zone temperatures at delay's end (on production resuming, movement or discharging event).



Delays can be received from the Level 3 or entered by the furnace operator in Virtuo™ -R HMI as shown below in the furnace management screen:



Moreover, Virtuo™ -R can automatically goes in delay mode (noticed delay) when neither a discharge nor a product movement has occurred within a pre-determined duration (tuning parameter).

Virtuo™ -R automatically returns in production mode after the first product is discharged. No manual intervention by the operator is required.

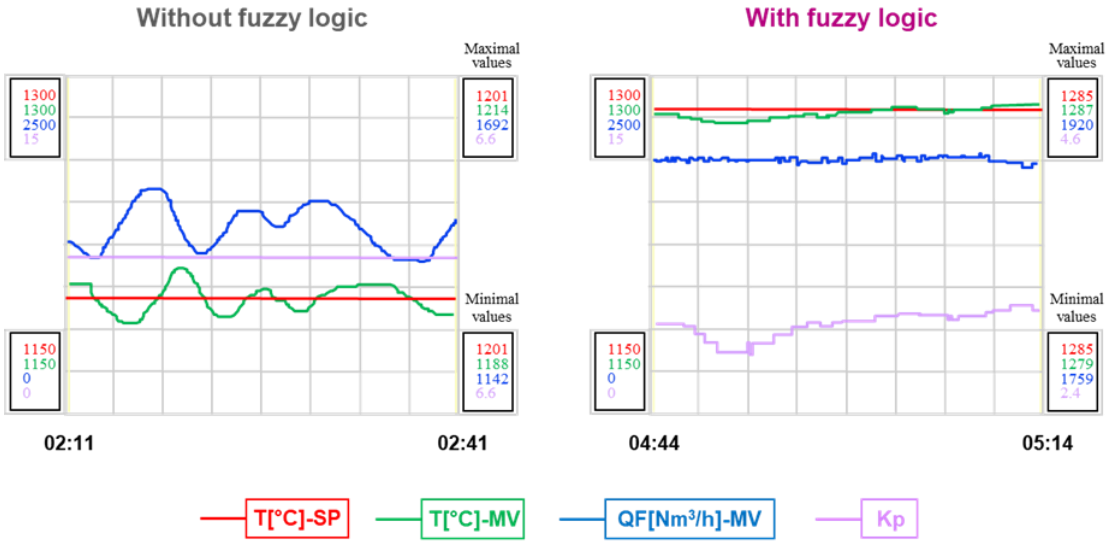
3.5.5. Heat demand control (fuzzy logic based)

Purpose:

Virtuo™ -R heat demand control adapts dynamically the Heating PLC zone temperature PID parameters using a fuzzy logic feature to overcome the limitation of standard PID controllers to better fit the measurements to the temperature set-points faster and more accurately, improving the control of the furnace.

The following diagrams clearly show the improvements while comparing heat demand control without (left) and with (right) Virtuo™ -R fuzzy logic feature on. The main achievements thanks to the Fuzzy Logic control are:

- Oscillations of temperature measurements and fuel flows reduced up to 4-fold,
- The Heating control is greatly improved in terms of temperature accuracy and response time.



4. Virtuo™ -R data monitoring

Virtuo™ -R data monitoring functions refers to different tasks of Furnace Level 2 application that provide and deal with useful information. They have passive role in the furnace process optimization. These tasks are described below and belong to the following 2 functional layers of Virtuo™ -R:

- The Process Observation functions to manage tracking and furnaces,
- The Monitoring and Utilities functions to control and process information.

Production data collection starts when each product is identified in Virtuo™ -R at charging and stops when the products are discharged.

4.1. Furnace process data

Purpose:
The main purpose of this function is to store periodically from the thermal model the following furnace process data:

- Furnace measured process values,
- Furnace production conditions (delays, production rate & set-points).

The furnace process data function provides to Virtuo™ -R HM individual product heating curves and relevant values like roof temperature profile or zone crossing time.

4.2. Processed product data

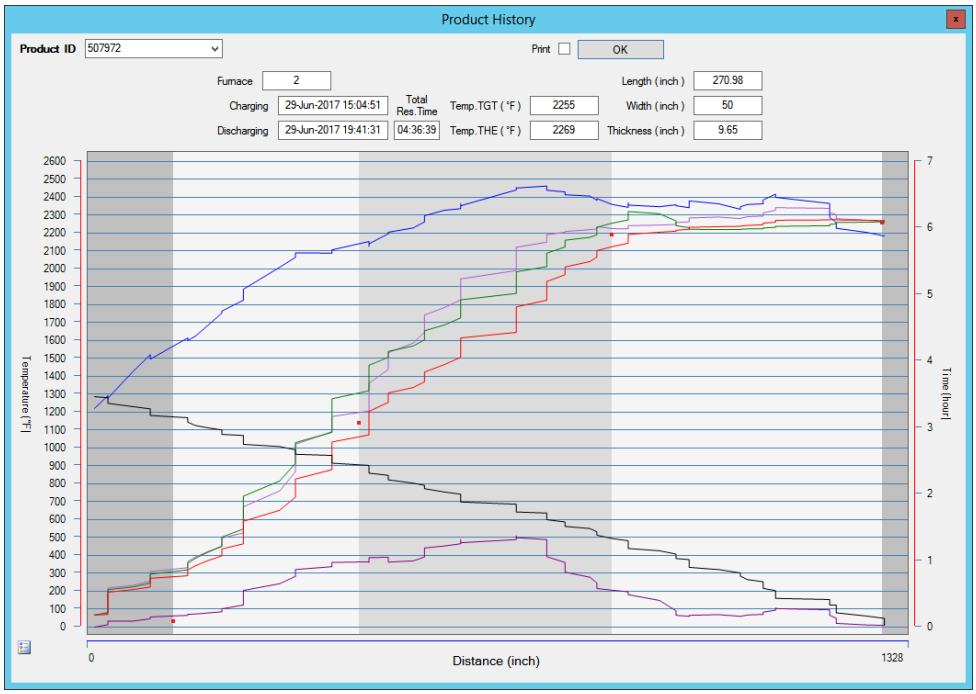
Purpose:
The main purpose of this function is to store periodically data about the product heat-up and progress through the furnace.

The product data function stores the product's history trend of processed products by Virtuo™ -R.

From Virtuo™ -R HMI, the following information is available for the selected product:

- Furnace number (of the furnace from which the product was discharged),
- Product dimensions (length, width and thickness),
- Charging & discharging dates and times,
- Discharging date and time,
- Total observed residence time inside the furnace,
- Discharging target bulk temperature (aimed at furnace exit time),

- Discharging bulk temperature (calculated by the thermal model at furnace exit time),
- Roof temperature curve → Blue full-line,
- Top surface temperature curve of product → Violet full-line,
- Average (bulk) temperature curve of product → Red full-line,
- Bottom surface temperature curve of product → Green full-line,
- Uniformity curve across the furnace → Dark violet full-line,
- Remaining residence time curve → Black full-line,
- End-of-zone intermediate target temperatures → as small Red dots.



4.3. Heat balance

Purpose:
Based on the knowledge from production tracking and the integration of furnace measurements, this function builds up a heat balance over various periods of time for the furnace and recuperator.

There are 2 levels of information available:

- Basic information concerns the fuel consumption of the furnace referred to the total tonnage discharged in a given period (hour, shift, day, week and month),
- Detailed information concerns the distribution of energy inputs and outputs. This information is required to track and analyze furnace performance.

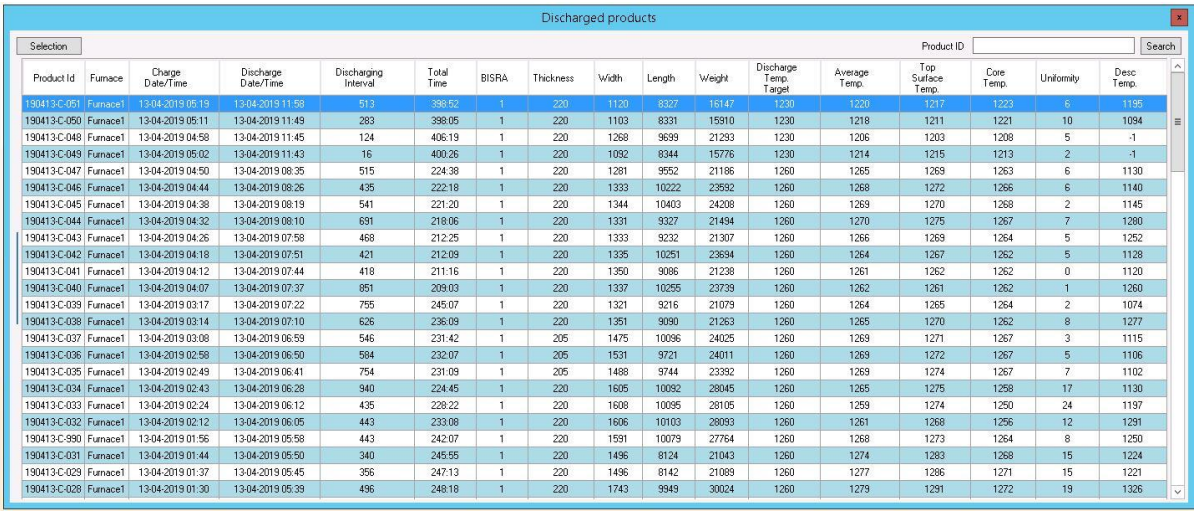
4.4. Reports

Purpose:
The reports function of Virtuo™ -R permits to create production and heat balance reports that are made available in Virtuo™ -R HMI as well as dedicated results files.

4.4.1. Production reports

The production reports provide a detailed list of products that have been discharged for a given period. The information gathered concerns:

- Product characteristics,
- Production pacing (residence times, discharge dates, delays...),
- Product temperatures (results, targets...).



Product Id	Furnace	Charge Date/Time	Discharge Date/Time	Discharging Interval	Total Time	BISRA	Thickness	Width	Length	Weight	Discharge Temp. Target	Average Temp.	Top Surface Temp.	Core Temp.	Uniformity	Desc Temp.
190413-C-051	Furnace1	13-04-2019 05:19	13-04-2019 11:58	513	398:52	1	220	1120	8327	16147	1230	1220	1217	1223	6	1195
190413-C-050	Furnace1	13-04-2019 05:11	13-04-2019 11:49	283	398:05	1	220	1103	8331	15910	1230	1218	1211	1221	10	1094
190413-C-048	Furnace1	13-04-2019 04:58	13-04-2019 11:45	124	406:19	1	220	1268	9699	21293	1230	1206	1203	1208	5	-1
190413-C-049	Furnace1	13-04-2019 05:02	13-04-2019 11:43	16	400:26	1	220	1092	8344	15776	1230	1214	1215	1213	2	-1
190413-C-047	Furnace1	13-04-2019 04:50	13-04-2019 08:35	515	224:38	1	220	1281	9552	21186	1260	1265	1269	1263	6	1130
190413-C-046	Furnace1	13-04-2019 04:44	13-04-2019 08:26	435	222:18	1	220	1333	10222	23592	1260	1268	1272	1266	6	1140
190413-C-045	Furnace1	13-04-2019 04:38	13-04-2019 08:19	541	221:20	1	220	1344	10403	24208	1260	1269	1270	1268	2	1145
190413-C-044	Furnace1	13-04-2019 04:32	13-04-2019 08:10	691	218:06	1	220	1331	9327	21494	1260	1270	1275	1267	7	1280
190413-C-043	Furnace1	13-04-2019 04:26	13-04-2019 07:58	468	212:25	1	220	1333	9232	21307	1260	1266	1269	1264	5	1252
190413-C-042	Furnace1	13-04-2019 04:18	13-04-2019 07:51	421	212:09	1	220	1335	10251	23694	1260	1264	1267	1262	5	1128
190413-C-041	Furnace1	13-04-2019 04:12	13-04-2019 07:44	418	211:16	1	220	1350	9086	21238	1260	1261	1262	1262	0	1120
190413-C-040	Furnace1	13-04-2019 04:07	13-04-2019 07:37	851	209:03	1	220	1337	10255	23739	1260	1262	1261	1262	1	1260
190413-C-039	Furnace1	13-04-2019 03:17	13-04-2019 07:22	755	245:07	1	220	1321	9216	21079	1260	1264	1265	1264	2	1074
190413-C-038	Furnace1	13-04-2019 03:14	13-04-2019 07:10	626	236:09	1	220	1351	9090	21263	1260	1265	1270	1262	8	1277
190413-C-037	Furnace1	13-04-2019 03:08	13-04-2019 06:59	546	231:42	1	205	1475	10096	24025	1260	1269	1271	1267	3	1115
190413-C-036	Furnace1	13-04-2019 02:58	13-04-2019 06:50	584	232:07	1	205	1531	9721	24011	1260	1269	1272	1267	5	1106
190413-C-035	Furnace1	13-04-2019 02:49	13-04-2019 06:41	754	231:09	1	205	1488	9744	23392	1260	1269	1274	1267	7	1102
190413-C-034	Furnace1	13-04-2019 02:43	13-04-2019 06:28	940	224:45	1	220	1605	10092	28045	1260	1265	1275	1258	17	1130
190413-C-033	Furnace1	13-04-2019 02:24	13-04-2019 06:12	435	228:22	1	220	1608	10095	28105	1260	1259	1274	1250	24	1197
190413-C-032	Furnace1	13-04-2019 02:12	13-04-2019 06:05	443	233:08	1	220	1606	10103	28093	1260	1261	1268	1256	12	1291
190413-C-990	Furnace1	13-04-2019 01:56	13-04-2019 05:58	443	242:07	1	220	1591	10079	27764	1260	1268	1273	1264	8	1250
190413-C-031	Furnace1	13-04-2019 01:44	13-04-2019 05:50	340	245:55	1	220	1496	8124	21043	1260	1274	1283	1268	15	1224
190413-C-029	Furnace1	13-04-2019 01:37	13-04-2019 05:45	356	247:13	1	220	1496	8142	21089	1260	1277	1286	1271	15	1221
190413-C-028	Furnace1	13-04-2019 01:30	13-04-2019 05:39	496	248:18	1	220	1743	9949	30024	1260	1279	1291	1272	19	1326

4.4.2. Heat balance reports

The heat balance reports gather information detailing the fuel consumption and the energy efficiency of the furnace and recuperator, automatically stored at the end of a given period (hour, shift, day, week and month).

information available regroups Enthalpy and energy data related to:

- Charged steel,
- Discharged steel,
- Fuel flow,
- Combustion air,
- Waste gas and cooling water enthalpy.

4.5. Parameters management

Purpose:
The parameters files – available to the Steel producer – store the settings and useful parameters for Virtuo™ -R design and tuning. The parameters management function permits to:

- Set all Virtuo™ -R functions settings,
- Load the configuration of Virtuo™ -R Application without stopping it,
- Spread useful parameters among the functions of Virtuo™ -R.

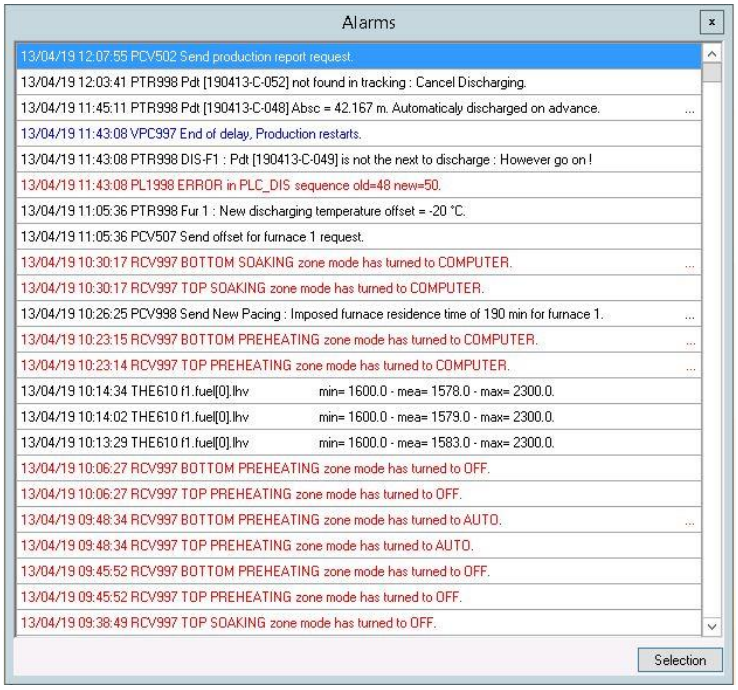
4.6. Alarms and Logs

Purpose:
The alarm function manages alarms and log files for every function of Virtuo™ -R. These files gather information describing useful process information.

Alarms are automatically generated and stored as Results files by the primary and secondary functions of Virtuo™ -R application with two main goals:

- Reporting any abnormal condition occurring at computer and process level,
- Guiding the operator for changed process events (change of pace, delay…).

Logging is as per Fives Stein's standards and it includes ID with time, module, function & description of the event and severity flag. The Alarms function has a dedicated Virtuo™ -R HMI view that offers quick and easy access to the last 1,000 alarms, helped with their displayed color that depends on alarm severity.



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CHAPTER IV

"Guarantees"

INDEX

1. FURNACE INSPECTION AND TEST PROCEDURES

1.1 PRELIMINARY INSPECTION AND TEST

Upon completion of erection of the reheating furnace equipment, the Contractor, in conjunction with Buyer's representative, will establish a procedure and perform preliminary inspection and tests for this furnace equipment.

The following will be checked:

Protocol - I

- Completeness of work,
- Proper assembly of work,
- Compliance with contractual specification,
- Walking beam tests,
- Mechanical and electrical operation and synchronization,
- Instrumentation & controls adjustments and tests,
- Readiness of each functional unit to be commissioned.

Any defects that are reported will be corrected by the responsible party (Contractor or Buyer) before further tests are started.

Cold Test Protocol (CTP) will be established, confirming that this facility is ready for dry-out. It will be signed by both Buyer's and Contractor's representatives, signifying that the equipment has been inspected and tested as outlined here above, and that defects have been corrected.

Signing of the CTP shall not be held up for rectification of minor faults which do not impede the move to the next stage. A list of faults requiring rectification shall form an annex to the certificate.

1.2 DRYOUT AND READINESS OF FURNACE TO DELIVER FIRST HOT PRODUCTS

The heating curve for dry out of the furnace will be provided by Contractor before dry out proceeds.

Dryout of the furnace will be opened by Purchaser's personnel under the supervision and direction of Contractor's engineer (only during the day shift).

During dryout, the instrumentation and combustion control system will be rechecked and finally adjusted.

Condition of furnace, heating rate and other necessary data will be recorded during dryout.

After dryout, a thorough inspection of the refractories in the furnace, flue duct and stack, and other equipment will be conducted by both Contractor's and Purchaser's representatives.

If serious cracking of the refractories or other major defects are found, they shall be corrected before proceeding further.

Protocole II

Certificate of completeness will be established upon completion of the dryout, inspection of the furnace and finally discharge of the first hot product. This protocol will be signed by both Purchaser's and Contractor's representatives, signifying that the furnace equipment has been dried out and satisfactorily inspected, and is ready for operation and finally moving to performance testing.

With the discharge of the first hot product, this protocol also marks the beginning of the 12 month warrantee period for the new furnace equipment.

1.3 PERFORMANCE TESTING PROCEDURE AND ACCEPTANCE

Purchaser commits himself to perform the tests to check the performance guarantees given hereafter by the Contractor within three (3) months of discharge of first hot product.

The performance tests will be conducted by Purchaser's personnel under the supervision and direction of Contractor's start-up engineer. All data recorded during the tests shall be in duplicate with one copy to Purchaser and one copy to Contractor.

All preset temperatures and discharge rates will be defined by the Contractor.

The performance guarantees will be tested according to procedure and tolerance given by the furnace VDeH standard “GUIDELINES ON ORDERING AND ACCEPTANCE OF FUEL FIRED HEATING AND HEAT TREATMENT FURNACES “. Test results shall be interpreted taking account performance tolerance and the measuring instrument accuracy.

The tests will be performed after:

- Heating all the furnace zones up to the set temperatures chosen by the Contractor,
- Establishing a thermal equilibrium condition of the furnace.

The following operation values must be measured:

- Dimensions and weights of the products,
- Instantaneous charging and discharging rates,
- Air flow rates,
- Fuel flow rates,
- Total duration of mill or furnace delays, each identified as to cause,
- Slab temperature measurement using a Data logger,
- Any other data that may be agreed to in order to provide a complete record of all events during test periods,
- Performance test procedure shall be prepared and submitted by Fives prior to the test.

The performance test will be divided in 3 phases and the total duration of the test must be equal to 3 times the heating time of the billet.

The three different phases are:

1. Preheating phase: the target is to take the furnace to the state of thermal equilibrium at the nominal production, so the first billet of the test phase and the remaining load enters the furnace in nominal, thermal and load conditions.

2. Test phase: data taking

3. Post-heating phase: the target is to make the last billet to find the nominal, thermal and load conditions during its heating process.

During the three phases the furnace must be completely loaded and in continuous production state, therefore taking into consideration the production guaranteed, the reference billet weight and the residence time in the furnace.

The valid data for analysing the results will be the ones taken during the second test phase, which will mainly be:

- number and weight of the charged billets
- fuel consumption during the second phase
- billet exit temperature

In case of mill stoppages, two possibilities could occur:

- Mill stoppages are less than 15 minutes, the tests could proceed and the stop time will be deducted as well as the volume of gas consumed.

- If mill stops are longer than 15 minutes, the tests will be carried out until 3 consecutive hours are attained; in this case the billets could be discharged, and sent to billets storage area.

Mill and furnace stoppages or delays: the corresponding time must be measured by chronograph, each time there is an anomaly (Fives Stein will write down the starting and end time of the stop as well as the fuel volume consumed).

The purchaser must supply the necessary quantity of products, in accordance with the technical specification (dimensions and correct steel grade) and also in accordance with the chosen methods.

The tests must be done with all contractual parameters, as new reference products, and all utilities available in necessary quantities and qualities.

If the customer does not provide the reference products (different steel grade, different product dimensions), new calculations must be done and new guaranteed values will be established.

- different steel grade: new thermal characteristics (new heating curve to define, new calculations to be done)
- different product dimensions:
    - the main parameter is the thickness because it changes the residence time and the heating conditions
    - the length: it changes the production rate

1.3.1 TEST CONDITIONS

REFERENCE TEST CONDITONS

- Product dimensions.....280x 120 x 12000 mm
- Steel grade .....BISRA 3
- Charging temperature .....20°C

REHEATING FURNACE CONDITIONS

- Refractory lining ..... new

FUEL (As per chemical compositions given in Chapter I)

- Type Natural gas
- Net Calorific Value (kcal/Nm^3) 8783

AIR EXCESS

- Percentage (%) 5

Protocolo – III – FINAL ACCEPTANCE CERTIFICATE (FAC)

Final Acceptance Certificate (FAC) will be established after the performance tests have been successfully accomplished on the furnace equipment and will be signed by both Purchaser's and Contractor's representatives. Protocol III confirms that the production guarantees have been successfully accomplished and confirms acceptance of the facility by the Buyer.

2. PERFORMANCE GUARANTEES

2.1 PERFORMANCES

Guarantee item	Guarantee value	Definition & condition	Testing Method & condition	Remarks
		Reference conditions Billet dimensions: 120x280x12000 mm 3165 kg Steel grade: Carbon steel (Bisra 3) Natural gas LHV: 8783 kcal/Nm^3 Charging temperature: 20 ºC Discharging surface temp.: 1150 ºC ± 15 ºC Excess air of 5% New refractory lining	(refer to § 2.2.2)	
Furnace output	140 t/h	"	(refer to § 2.2.1)	
Temperature uniformity (Temperature difference between top and core)	28 ºC ± 3 ºC	"	(refer to § 2.2.3)	
Fuel consumption Based on LHV of fuel	257 kcal/kg ±5% Based on LHV of fuel 286 kcal/kg ±5% Based on HHV of fuel 332 kWh/t ±5% Based on HHV of fuel		In accordance with VDEH standard (refer to § 2.2.4)	
NOx emissions	< 100 mg/Nm^3	at 3% O_2 in dry waste gases		
Scale loss	0,53% ± 0,1	"	(refer to § 2.2.5)	

Guarantee item	Guarantee value	Definition & condition	Testing Method & condition	Remarks
		Reference conditions Billet dimensions: 120x280x12000 mm 3165 kg Steel grade: Carbon steel (Bisra 3) Natural gas LHV: 8783 kcal/Nm^3 Charging temperature: 20 ºC Discharging surface temp.: 1100 ºC ± 15 ºC Excess air of 5% New refractory lining	(refer to § 2.2.2)	
Furnace output	140 t/h	"	(refer to § 2.2.1)	
Temperature uniformity (Temperature difference between top and core)	20 ºC ± 3 ºC	"	(refer to § 2.2.3)	
Fuel consumption Based on LHV of fuel	245 kcal/kg ±5% Based on LHV of fuel 273 kcal/kg ±5% Based on HHV of fuel 317 kWh/t ±5% Based on HHV of fuel		In accordance with VDEH standard (refer to § 2.2.4)	
NOx emissions	< 100 mg/Nm^3	at 3% O_2 in dry waste gases		
Scale loss	0,40% ± 0,1	"	(refer to § 2.2.5)	

2.2 MEASUREMENT METHODS

Performance tests will be carried out according to detailed procedure and mutually agreed at least 1 month before Performance Guarantee Test.

Tolerances of equipment will be considered in all the measurements carried out and analysed.

2.2.1 Furnace output

Exact dimensions of billets will be taken during the test period.

The number of billets charged and discharged and the duration of the test period will be recorded.

On the basis of the above recorded data the exact production rate shall be recalculated.

$$\text{Furnace output} = \frac{\text{(billet weight during the second tested load)}}{\text{(Duration of the second tested load)}}$$

2.2.2 Discharge temperature

The reference discharge temperature given for performance guarantee is the surface temperature of the reference product. Measurement of the discharge temperature will be by a handheld optical pyrometer once the product is discharged.

The point of measurement will be far from the billet edges (minimum 500 mm) and between skids position to avoid distortions due to shadow effect of the skids.

The duration between discharging and temperature measurement is taken in order to apply a correction because the product cooling rate at the surface after the exit of the furnace is approximately 1°C per second.

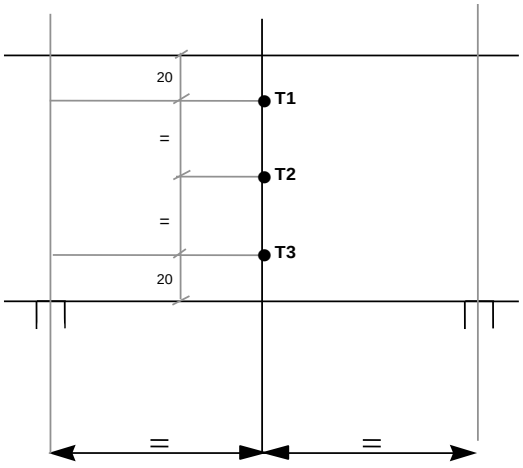
2.2.3 Difference between core and surface temperature (ΔT1)

A reference product will be equipped with thermocouples in order to ensure the temperatures through the thickness of the product at the following points:

T1 : Temperature at 20 mm from the upper surface as indicated on the sketch here above,

T2 : Temperature at the core as indicated on the sketch here above

T3 : Temperature at 20 mm from the lower surface as indicated on the sketch here above.



$$\Delta T1 = ((T1 - T2) + (T3 - T2))/ 2$$

Note: The instrumented product supplying is at the charge of the buyer.

The position of the thermocouples will be far from the billet edges (minimum 500 mm) to avoid the 3rd face effect and in between skids to avoid distortions due to shadow effect of the skids.

Depth of measurements of the products surface temperature in the billet will be 20 mm.

The final quantity and position will be defined and agreed before the performance tests.

2.2.4 Specific consumption

Specific consumption will be determined by measuring the fuel consumption during a period equal to the heating time of one billet in steady production and measuring the output of the furnace during the same period.

Specific consumption during the test period will be calculated with the following formula:

$$E = \frac{(\text{Fuel energy during the test period})}{(\text{Billet weight heated during the test period})}$$

Consumption: the furnace consumption calculation is based on the here above production, and the total heat input, calculated with the Natural Gas volume corresponding to the period of test (composition of the gas has to be provided by the customer before the test to have the correct LHV in kcal/Nm^3).

If dimensions of products provided by the customer are different than the dimension of reference products, then new calculation of guaranteed consumption will be provided by Fives Stein.

If fuel is not the reference fuel, a new calculation of guaranteed consumption will be provided by Fives Stein.

2.2.5 Scale loss

The procedure for the guarantee test will be defined in detail at the time of the test but will be based on applying the following methods:

2.2.5.1 Sample testing methodf

Test samples will be cut from reference products and will have a clean surface quality. The initial thickness of the samples will be measured.

Before being charged into the furnace, they will be put on a product, daubing the lower samples faces with oil (specific oil with copper).

By averaging the found values (difference between initial and final measurement), the oxidation scale thickness will be calculated.

Samples thickness will be measured and averaged.

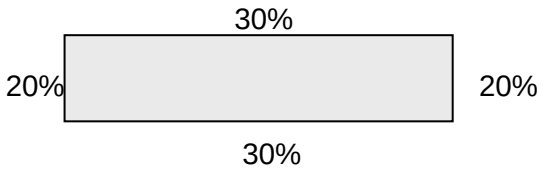
Sample should not be bended and should stay in contact with the product top face during the whole test.

Sample oxidation thickness = sample average thickness before test minus sample average thickness after test

l = product length
w = width for reference product
e = product thickness

Oxydizing layer isn't the same on each face. Our calculation is based on a German reference: Handbuch des Industrieofenbaus – Hans A. Behrens – Stahl & Eisen 2001, which takes account of a different oxidizing according to the face:

- Upper face : 30%
- Lower face : 30%
- Side face : 20%



The corrections on each face are given in table beside.

	Scale loss
Upper face (Uf_Loss)	ATdiff
Lower face (Lf_Loss)	ATdiff x 20/30
Side face (Sf_Loss)	ATdiff x 20/30

From these calculations, we will be able to calculate the loss on the product, with a difference on the volume.

Product	**Before heating**	**After heating**
Length	Lbt	Lsa = Lbt – 2 x Sf_Loss
Width	Wbt	Wsa = wbt – 2 x Sf_Loss
Thickness	Tbt	Tsa = Tbt – Uf_Loss – Lf_loss
Volume	Vbt = Lbt x Wbt x Tbt	Vsa = Lsa x Wsa x Tsa

Loss on product	1 – (Vsa / Vbt)

Lbt = product length
Wbt = product width } for reference product

Tbt =produc thickness

If required, the following correction factors will apply:

- Discharging temperature T in case of any difference between theoretical and actual temperature

- Theoretical and actual oxidation time using the formula:

$$e = K1 \sqrt{t} \quad \exp\frac{-K2}{T}$$

Where : e = metal thickness lost in mm
T = temperature in Kelvin
t = time in seconds

2.2.5.2 Weighing method (alternative)

Three reference billets will be measured, weighed and brushed clean prior to being charged in the furnace.

At the end of their heating period, they will be discharged from the furnace and cooled down in a water tank with sufficient volume. Once the billets are cold, they will be weighed again.

The weight difference will be used to calculate the percentage loss due to scale.

If required, the following correction factors will apply:

- Discharging temperature T in case of any difference between theoretical and actual temperature

- Theoretical and actual oxidation time using the formula:

$$e = K1 \sqrt{t} \quad \exp\frac{-K2}{T}$$

Where : e = metal thickness lost in mm
T = temperature in Kelvin
t = time in seconds

2.2.6 NOx emissions

The procedure for the NO_X emissions guarantee test will be defined in detail at the time of the test but will be calculated using the following formula:

NO_X (mg/Nm^3) = Average NO_X emissions during the test period

The NO_X emission is based on dry waste gases and for a given fuel chemical composition, with 3% O_2, the guaranteed NO_X figure does not include any NO_X which may be produced due to NH_3 or CNH in the fuel.

3. CLIENT'S OBLIGATIONS

All personnel and materials for cold test, commissioning and performance guarantee test shall be provided by the Purchaser under the supervision of the Seller.

CHAPTER V

"SCOPE OF SUPPLY"

A. DIVISION LIST FOR SUPPLIES / ERECTION

Division list of furnace equipment applicable for one 140 t/h walking beam furnace for billets. The equipment shall be delivered DDU, main international ports Incoterms 2010.

CO : Commissioning	**CELSA** : CELSA UK
E/SUP : Erection & commission supervision	**EX** : Delivered equipment (existing)
SITE: CELSA UK facilities	**FSS** : FIVES Steel Spain
REF: Refurbished parts	**NEW** : Already supplied parts not refurbished and supplied new and new parts

- All information, drawing, etc., communicated by Fives for this project shall be treated confidentially and shall not be disclosed to any third party without Fives prior consent.

- All communications and documentation to be given to customer will be in English language (drawings, specs, schematics).

- The final documentation will be in English language.

- As built drawings and documents will be submitted at the end of commisioning:

    - Assembly drawings in .dwg and .pdf format
    - Bills of materials (BOMs) in .pdf format
    - Updated 3D model in NavisWorks .nwd format
    - Specificacions and manuals in .pdf format

- 3D model:

  Complete 3D model of the furnace will be provided in NavisWorks . nwd format.

  This 3D model will be built as follows:

  . Detailed 3D models of the equipment supplied in 2008 will be done from the original 2D drawings. New drawings will not be issued from this 3D model.

  . Detailed 3D models and detailed drawings from native 3D files will be created for the equipments redesigned. For natural gas, hydrogen, and compressed air piping, isometric drawings in.pdf format will be provided.

- Furnace drawings will be submitted at the end of erection:
    - Assembly drawings in .dwg and .pdf format
    - Bills of materials (BOMs) in .pdf format
    - 3D model in Navisworks (.nwd) .format

DESCRIPTION	Basic Eng	Detail Eng.	Supply	Erection	CO	E & SU Superv	Refurbished or new	Refurbished by:	Where:	REMARKS
CASING AND STEEL to be revised										
Furnace casing										
Side walls	FSE	FSE	EX	CEL	FSE	FSE	REF/NEW	CELSA/FSS	SITE	As per inspection report 108032-A-0000-0-T-0001 R02 1.Burner plates with flanges need to be changed for the accomodation of new burners. FSS will supply new plates with flanges CELSA to accommodate them in existing walls 2. Minor changes to be done during erection for installation of new type of cameras in charging and discharging side
Charging wall	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Discharging wall	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Roof beams and girders	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting

										local supplier for sandblasting and complete painting
Water troughs (in AISI 304)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Scrappers (in AISI 304)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Platforms, walkways and stairs	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Charging and discharging scale spouts	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Scale evacuation	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Side skimming traps	EX	EX	EX	CEL	FSE	FSE				Will be cancelled in furnace
Charging / Discharging doors										
Structure	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting

Mechanisms	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Visit doors	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Steel structure under furnace										
Fixed hearth beams and posts	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Neoprene pads	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Transfer frame	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Mechanical under furnace										
Lifting frame	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02. Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Wheels (group 2000)	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02. NOTE: New bearings not considered, in case of need of change

										they will be quoted at time of refurbishment
Ramps	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02 Rust in rails can be cleaned at site
Guiding (group 5000)	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02
Lifting and transfer mechanism(group 6000)	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02
Skids and posts										
Fixed and movable skids and posts	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02 Internal cleaning of each skid and post recirculating water. After pipes cleaned do pressure test
Riders	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	Are part of skids.
Movable posts protection boxes	EX	EX	EX	CEL	FSE	FSE	NEW			New protection boxes due to material change in water troughs (top part in carbon steel / bottom in stainless)
Moulds for skids and posts refractory	EX	EX	EX	CEL	FSE	FSE				No action required
CHARGING INSIDE ROLLERS										
Metallic frame	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02 Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Shafts and supports	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02 NOTE: New bearings not considered, in case of need of change they will be quoted at time of refurbishment

Rollers	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
Gear motors and accessories	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
END STOPPER										
Metallic frame	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
ALIGMENT PUSHER										
Metallic frame	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02
Shafts and supports	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02
Hydraulic cylinders	EX	EX	FSE	CEL	FSE	FSE	NEW			
DISCHARGING INSIDE ROLLERS										
Metallic frame	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02 Possibility of rust. Small areas to be repaired at site. In case of big rusted surfaces to be sent to painting local supplier for sandblasting and complete painting
Shafts and supports	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02 NOTE: New bearings not considered, in case of need of change they will be quoted at time of refurbishment
Rollers	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
Gear motors and accessories	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
KICK-OFF MACHINES										

Fixed Metallic frame	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	As per inspection report 108032-A-0000-0-T-0001 R02
Movable Metallic frame	EX	EX	FSE	CEL	FSE	FSE	NEW			As per inspection report 108032-A-0000-0-T-0001 R02
Arms	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
Mechanisms and accessories	EX	EX	FSE	CEL	FSE	FSE	REF	FSE	WORKSHOP	As per inspection report 108032-A-0000-0-T-0001 R02
Hydraulic cylinders	EX	EX	FSE	CEL	FSE	FSE	NEW			As per inspection report 108032-A-0000-0-T-0001 R02
DETECTION FINGERS										
Metallic frame	FSE	FSE	FSE	CEL	FSE	FSE	NEW			New design
Arms	FSE	FSE	FSE	CEL	FSE	FSE	NEW			New design
Pneumatic cylinders	EX	EX	FSE	CEL	FSE	FSE	NEW			
PIPING SYSTEM										
Combustion air equipment										
Cold and hot air manual valves	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Cold and hot air expansion bellows	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Combustion air piping (AISI 304)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports (for new ducts)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping isolating material and protection plates (lagging)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Natural gas equipment										
Valves	FSE	FSE	FSE	CEL	FSE	FSE	NEW			

Preparation group elements	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping and accessories	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Hydrogen equipment										
Valves	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Preparation group elements	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping and accessories	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Oxygen enrichment equipment										
Injection points	FSE									
Piping	FSE									
Pilot burners circuit										
Manual and automatic valves	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Filters, regulators, etc.	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Ignition devices (burner control units)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
UV cells	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Flexible hoses	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping and accessories	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Dilution air										
Valves	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping (reused)	EX	EX	EX	CEL	FSE	FSE	NEW			
Piping (new)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			

Supports	EX	EX	FSE	CEL	FSE	FSE	NEW			
Hot air bleed										
Valves	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping in AISI 304	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Purging nitrogen circuit										
Valves and elements	EX	EX	FSE	CEL	FSE	FSE	NEW			
Piping	EX	EX	FSE	CEL	FSE	FSE	NEW			
Supports	EX	EX	FSE	CEL	FSE	FSE	NEW			
Compressed air system										
Valves	EX	EX	FSE	CEL	FSE	FSE	NEW			
Pneumatic cylinders	EX	EX	FSE	CEL	FSE	FSE	NEW			
Piping and accessories	EX	EX	FSE	CEL	FSE	FSE	NEW			
Supports	EX	EX	FSE	CEL	FSE	FSE	NEW			
Air dryer for instrumentation	EX	EX	FSE	CEL	FSE	FSE	NEW			
REFRACTORY MATERIAL										
Roof material	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Side walls material	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Frontal walls material	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Hearth material	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Inside roller tiles	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Burner tiles	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Waste gas flue outlet material	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Waste gas duct and recuperator material	EX	FSE	FSE	CEL	FSE	FSE	NEW			

Stack material	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Skids and posts refractory	EX	FSE	FSE	CEL	FSE	FSE	NEW			
COOLING SYSTEM										
Manual valves	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Check valves	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Flow adjusting valves	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Shut off valves	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Air coolers	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Filters	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Recirculation pumps	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Expansion tank (30 m^3)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Expansion bellows	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Sump pumps	CEL	CEL	CEL	CEL	CEL	CEL				
Sump pumps installation structure	CEL	CEL	CEL	CEL	CEL	CEL				
Piping and accessories	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Flexible hoses	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
HYDRAULIC SYSTEM to be refurbished										
Hydraulic equipment	EX	FSE	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	
Cylinders	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Piping and accessories	EX	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	EX	FSE	FSE	CEL	FSE	FSE	NEW			

FANS To be refurbished										
Combustion air fans	EX	FSE	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	
Dilution air fan	EX	FSE	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	
RECUPERATOR										
Air recuperator	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
BURNERS										
Main burners (MWFv2 type)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Pilot burners	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
WASTE GAS DUCTS Partially redesigned										
Furnace pressure damper	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	
Waste gas duct metallic structure (reused)	EX	EX	EX	CEL	FSE	FSE	REF	CELSA	SITE	
Waste gas duct metallic structure (new)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Recuperator casing	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Walkways and stairs	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
STACK										
Metallic structure	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Walkways and stairs	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
CENTRALISED GREASING SYSTEM										

Elements	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Piping and supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
ELECTRICAL EQUIPMENT to be revised										
LV motors (existing: fans, hydraulics, rollers)	EX	EX	EX	CEL	FSE	FSE	REF	FSE	WORKSHOP	
LV motors (new: pumps, coolers)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Motor Control Centre (MCC)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Local control desks	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Main control desks	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Special cables	CEL	CEL	CEL	CEL	FSE	CEL				
Piping and ducts	CEL	CEL	CEL	CEL	FSE	CEL				
Power and control cables	CEL	CEL	CEL	CEL	FSE	CEL				
FIRE PROTECTION SYSTEM										
Fire protection system	CEL	CEL	CEL	CEL	CEL	CEL				
CONTROL ROOM										
Structure	CEL	CEL	CEL	CEL	CEL	CEL				
Ventilation	CEL	CEL	CEL	CEL	CEL	CEL				
ROOM FOR ELECTRICAL EQUIPMENT										
Structure	CEL	CEL	CEL	CEL	CEL	CEL				
Ventilation	CEL	CEL	CEL	CEL	CEL	CEL				

ROOM FOR HYDRAULIC EQUIPMENT										
Structure	CEL	CEL	CEL	CEL	CEL	CEL				
Ventilation	CEL	CEL	CEL	CEL	CEL	CEL				
INSTRUMENTATION AND AUTOMATION										
Transmitters, orifice plates, valves, etc.	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Thermocouples	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Flow and temperature switches	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Oxygen analyser (1)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Photocells, lasers, pulse generators	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Position transducers	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Cell supports	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Limit switches, proximity switches	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
PLC	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
System hardware	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Drawings, manuals and documents	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
CCTV SYSTEM										
Endoscopes (3)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Monitors for supplied cameras (3)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Emergency retractable system for endoscopes (3)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			

Control cabinet for supplied endoscopic system (3)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Supports and flexible hoses for supplied endoscopic system (3)	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
Thermographic (1) camera	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
ANCHORS BOLTS	FSE	CEL	CEL	CEL	CEL	CEL				
FURNACE LIGHTING	CEL	CEL	CEL	CEL	CEL	CEL				
LIGHTING ARRESTER	CEL	CEL	CEL	CEL	CEL	CEL				
WARNING LIGHT	CEL	CEL	CEL	CEL	CEL	CEL				
SAFETY FENCES	FSE	FSE	FSE	CEL	FSE	FSE	NEW			
CIVIL WORKS (Furnace zone)	FSE	CEL	CEL	CEL	CEL	CEL				
FIRST FILL GREASES & LUBRICANTS FOR OPERATION	FSE	CEL	FSE	CEL	CEL	CEL	NEW			Hydraulic oil not included
EMERGENCY POWER SUPPLY EQUIPMENT	FSE	CEL	CEL	CEL	CEL	CEL				

B. EXCLUSIONS

The following services and supplies are excluded from FSS scope of supply:

- The civil works and buildings including the civil construction drawings,
- The Hydraulic room, the motor rooms, compressor rooms, and control rooms complete, including the furniture in these rooms and air conditioning if required,
- The main power feeds to the furnace power distribution panels,
- HT switchgear and cables up to CA Fan motors
- All fire detection and firefighting equipment,
- Any re-routing of existing cables and junction boxes,
- Measuring instruments and analysers for gas, except O_2,
- Roller tables outside furnace at the charging side and discharging side,
- Necessary permits to carry out work at site,
- Any costs incurred due to the Purchaser choosing outside organization for checking/acceptance, tests,
- Operators and maintenance personnel during the commissioning,
- Provision of existing GA drawings soil data, necessary plant parameter required for design and engineering,
- The emergency water and power supply systems,
- All the lighting and ventilation systems for the furnace area,
- The earthing network,
- The drainage system,
- The intercommunication systems,
- Adaptation work on existing equipment or automation systems in view of their connection to the new automation, unless otherwise mentioned in the present specification,
- Spare parts and consumables,
- First fill of fluids,
- Flushing, cleaning of the hydraulic, gas, water, compressed air and nitrogen circuits,
- Offices, communication facilities for Fives supervisors (broadband internet connection), changing rooms, lockers, etc.

- Adaptation work on existing equipment or automation systems in view of their connection to the new automation (if required),
- Any cost arisen from the obligation of the local authorities to issue certificates/autorizations/assesments whatever due to local legislation. However, Fives Stein will assist customer with necessary documentation
- Any other service, equipment or materials not expressly indicated as included in FSS scope of supply in each of the options considered.

C. SUPERVISION SERVICES

Erection is in the scope of the customer. We propose the following man-months based on standard furnace erection times.

Erection

- General erection supervisor ..... 6 man-months
- Mechanical erection ..... 2 man-months
- Refractory installation..... 2 man-months
- Electrical installation..... 2 man-months

Commissioning

- General commissioning supervisor..... 4 man-months
- Burner specialist.....1 man-month
- Process supervisor..... 2 man-months
- Electrical supervisor ..... 2 man-months
- HMI supervisor ..... 2 man-months
- L2 supervisor..... 2 man-months

- Total Fives supervisors ..... 25 man-months

Training

- Technician..... 1 man/months

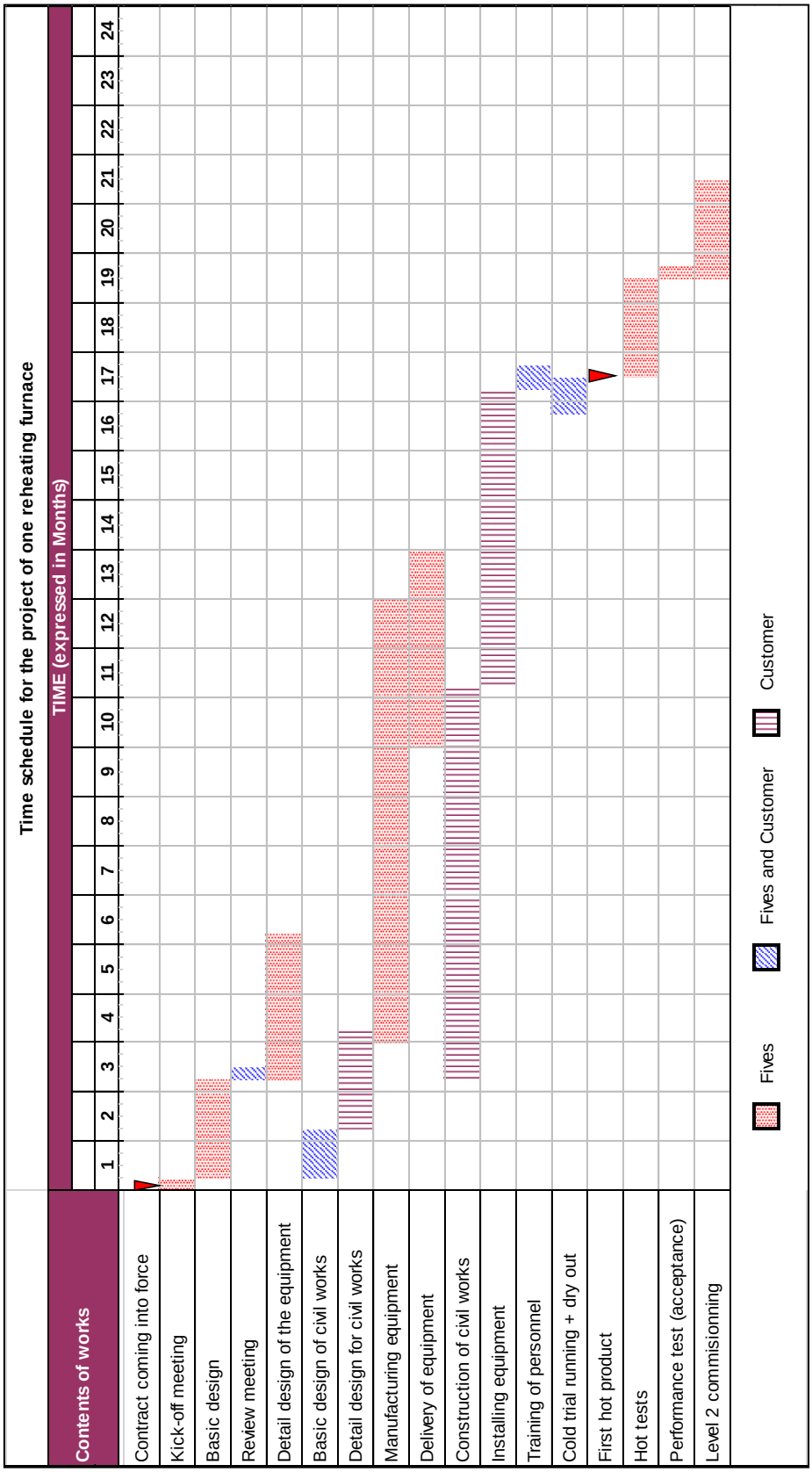
Training will be done during the commissioning stage. It will consist in classroom training and training at site.

Only the total number of man/months is binding. The final quantities may vary but not the total included in our proposal.

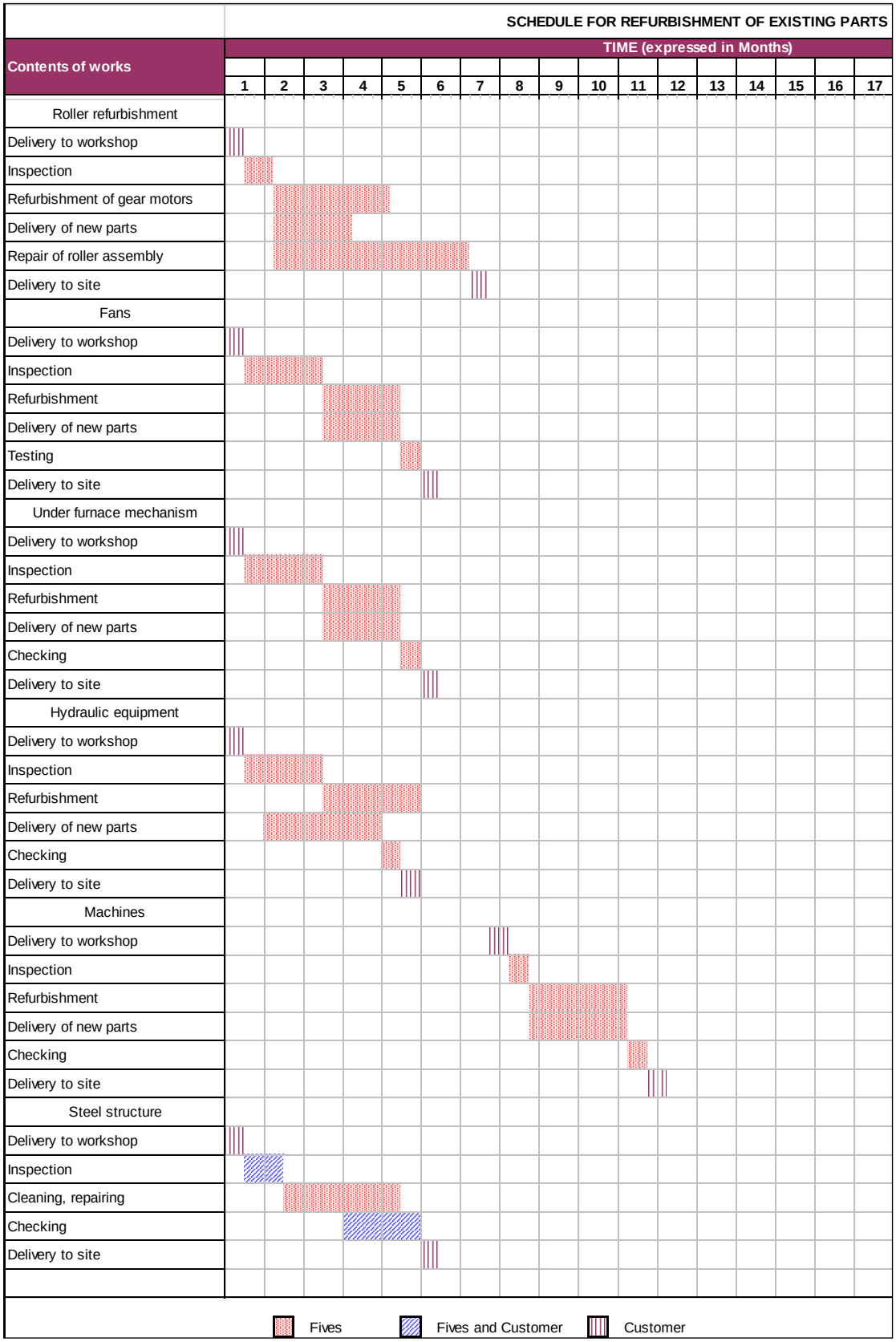
CHAPTER VI

"TIME SCHEDULE"

TIME SCHEDULE – GENERAL



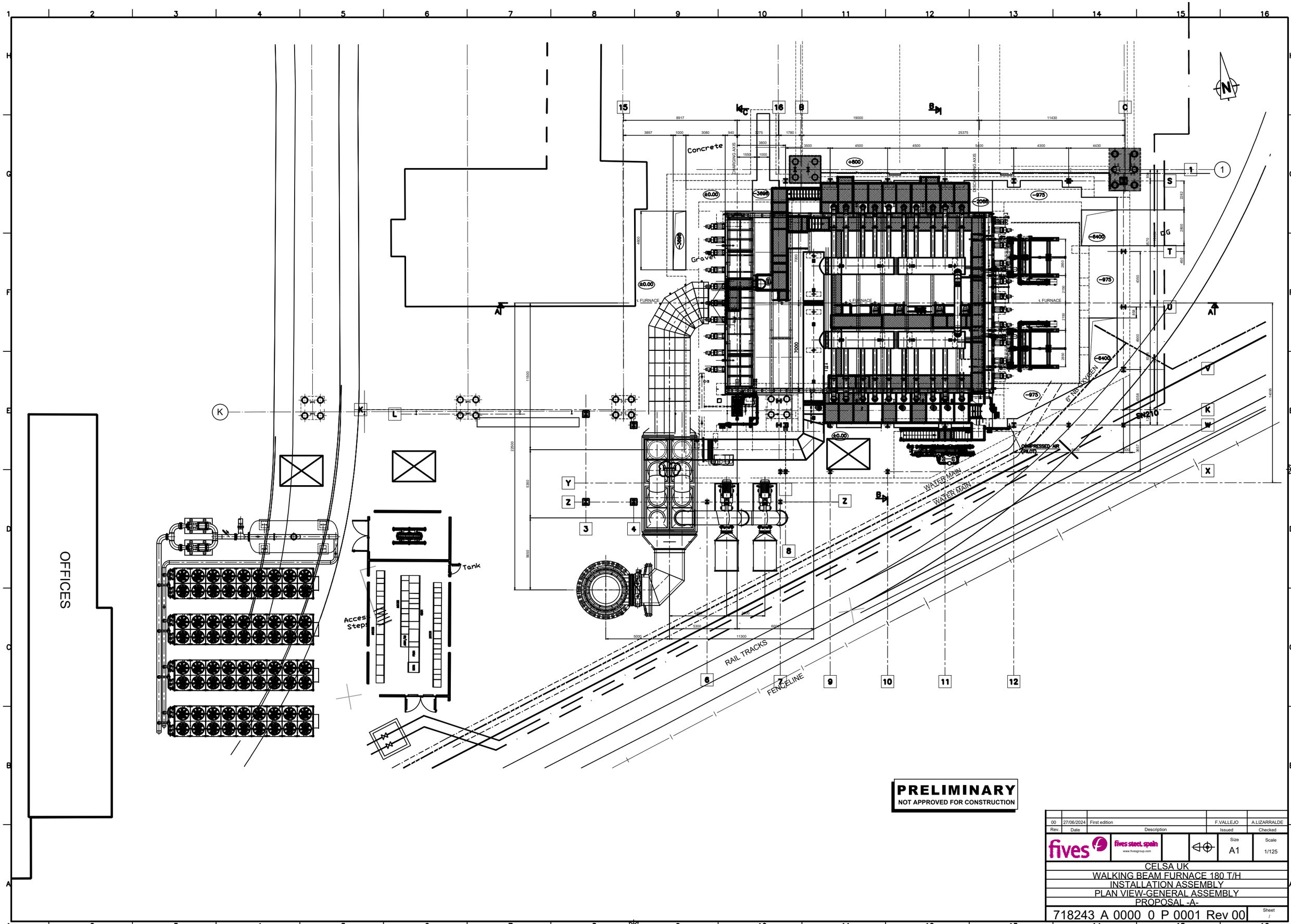
1. TIME SCHEDULE – REFURBISHMENT OF DELIVERED PARTS



CHAPTER VII

"DRAWINGS & DIAGRAMS"

DRAWINGS AND DIAGRAMS



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CELSA UK
WALKING BEAM FURNACE 180 T/H
INSTALLATION ASSEMBLY
PLAN VIEW-GENERAL ASSEMBLY
PROPOSAL -A-

718243 A 0000 0 P 0001 Rev 00 | Sheet /

15 | 16 | B | C

B

C

61

+7620 HOOK CLEARANCE HEIGHT

+5182 CABIN CLEARANCE

+6600

+6495

+4857.5

+3330

±0.00

WASTE GAS EXIT

+1845

+725

−295

−975

−3400

−4770

−6400

±0.00

SH

TC

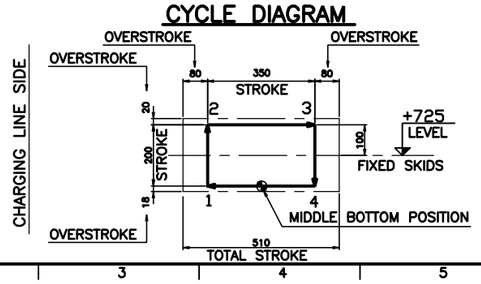
DISCHARGING AXIS

CHARGING AXIS

TRANSFER FRAME
MIDDLE BOTTOM POSITION

WHEELS	1440 · 5100 · 5100 · 5100 · 2260
TRANSFER GUIDING	4500 · 10000 · 4500
HEARTH STRUCTURAL	3885 · 4830 · 4445 · 2110 · 3730
TRANSFER DRIVE	9375 · 9625
	19000

CYCLE DIAGRAM



1_ REAR DOWN POSITION
2_ REAR UPPER POSITION
3_ FORWARD UPPER POSITION
4_ FORWARD DOWN POSITION

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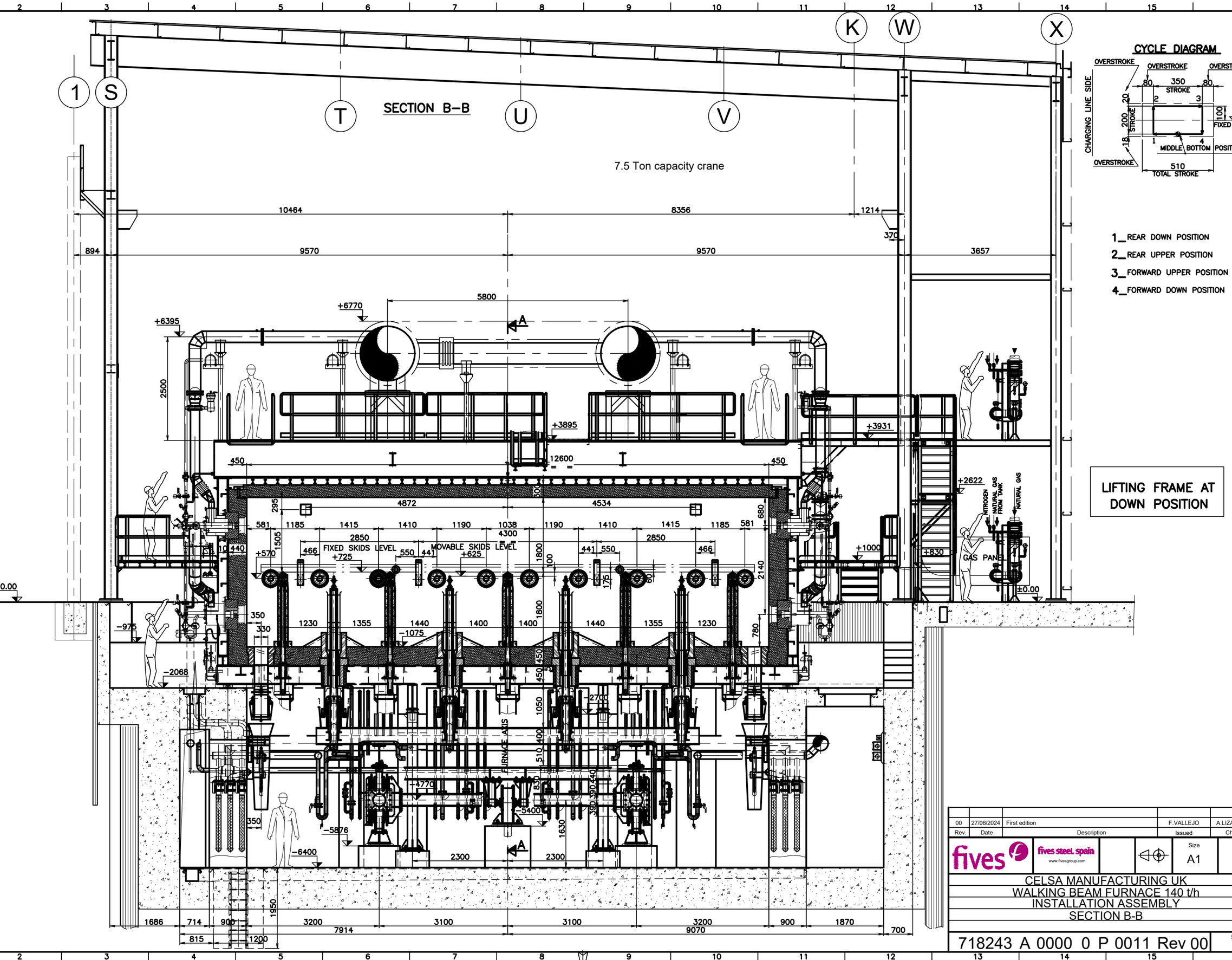
WALKING BEAM FURNACE 140 t/h
INSTALLATION ASSEMBLY
LONGITUDINAL SECTION

718243 A 0000 0 P 0010 Rev 00

Sheet /

SECTION B–B

7.5 Ton capacity crane



CYCLE DIAGRAM

1_ REAR DOWN POSITION
2_ REAR UPPER POSITION
3_ FORWARD UPPER POSITION
4_ FORWARD DOWN POSITION

LIFTING FRAME AT DOWN POSITION

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WALKING BEAM FURNACE 140 t/h
INSTALLATION ASSEMBLY
SECTION B-B

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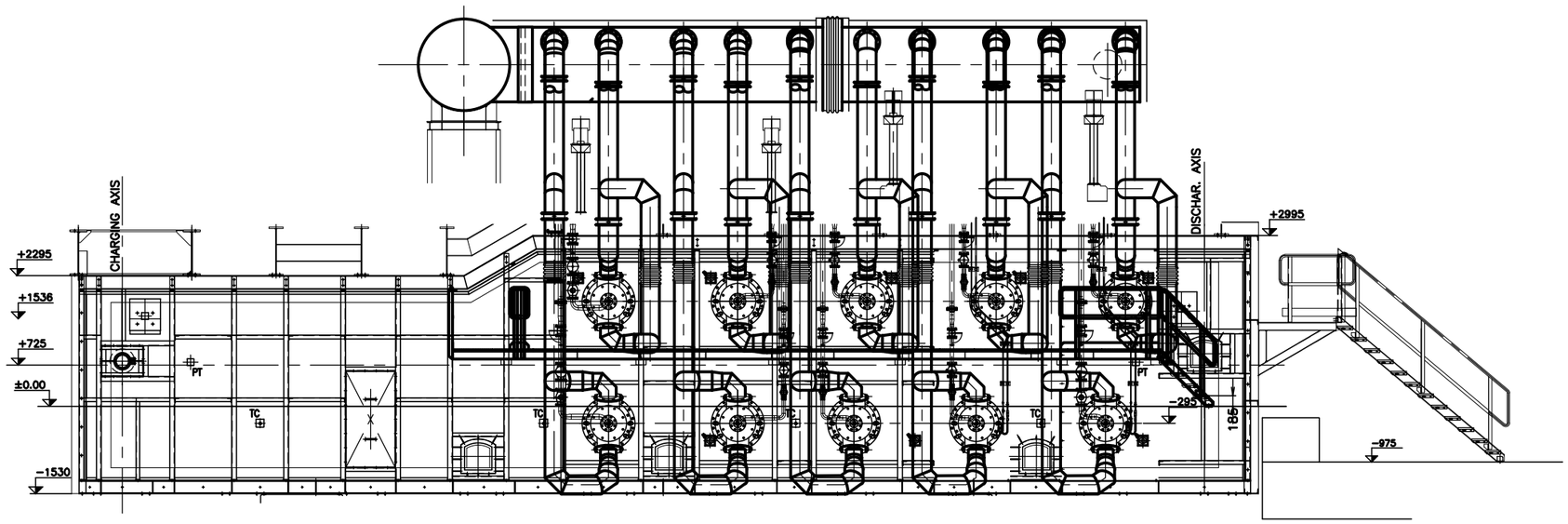

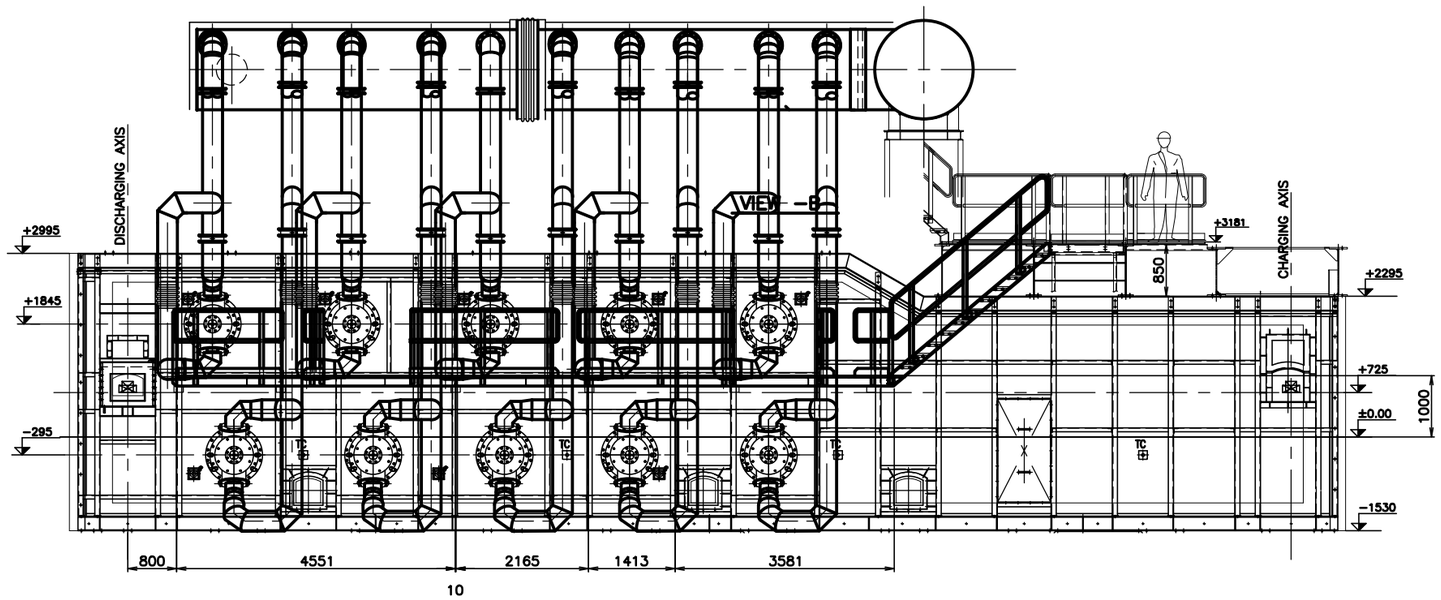

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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
COMBUSTION AIR DUCTS

108032 A 0000 0 P 0012 Rev 00

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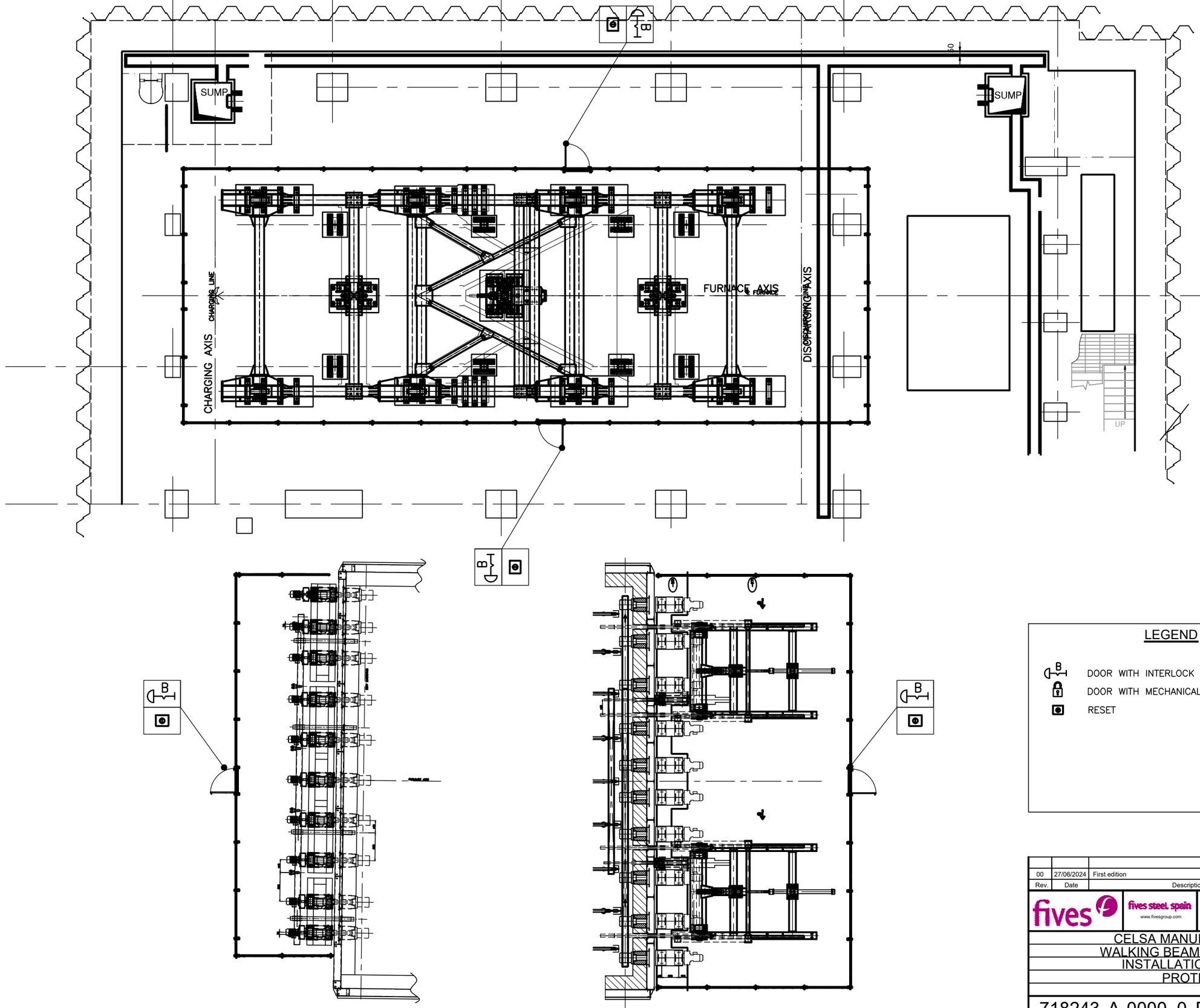

LEGEND

- B — DOOR WITH INTERLOCK AND ELECTRICAL LOCK
- DOOR WITH MECHANICAL LOCK
- RESET

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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
INSTALLATION ASSEMBLY
PROTECTION

718243 A 0000 0 P 0013 Rev 00

Sheet /

Customer | F.S

NITROGEN
Flow : 340 Nm3/h
Pressure : 4 bars
Temp. : AMBIENT

NATURAL GAS
Flow : 5400 Nm3/h
Pressure : 3 bars
Temp. : AMBIENT

HYDROGEN – H2
Flow : 18000 Nm3/h
Pressure : x bars
Temp. : AMBIENT

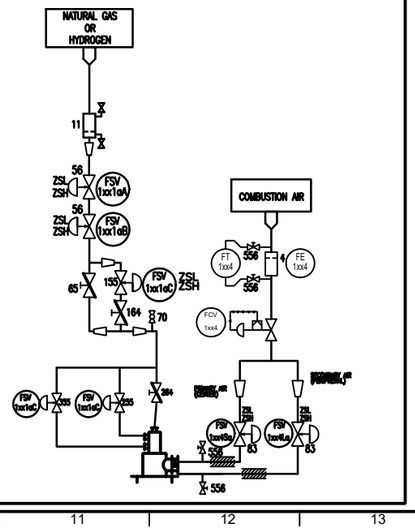
0.2 bar

TO PILOT DIAGRAM 0500-5-P-1003

TO PILOT DIAGRAM 0500-5-P-1003

MIXER

MWF TYPE BURNER



PRELIMINARY DRAWING

Rev.	Date	Description	Issued	Checked
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CELSA UK

WALKING BEAM FURNACE
HEATING EQUIPMENT
NATURAL GAS & HYDROGEN CIRCUIT

718243 A 0500 5 P 1002 Rev 00 | FSet /

AGUA REFRIGERACION INDIRECTA
INDIRECT COOLING WATER

EQUIPOS REFRIGERADOS HORNO *COOLED EQUIPMENTS FURNACE*	PERDIDAS TERMICAS KW *HEAR LOSSES KW*	DT (°C) *DT (°C)*	CAUDAL DE AGUA CALCULADO Nm3/h *WATER FLOW CALCULED Nm3/h*	CAUDAL DE AGUA INSTALADO Nm3/h *WATER FLOW INSTALLED Nm3/h*	ø TUBERIA ALIMENTACION ND *FEEDING ø PIPE ND*	VELOCIDAD EN LA TUBERIA m/s *SPEED IN PIPE m/s*	NUMERO DE LINEAS *NUMBER OF LINES*	CAUDAL TOTAL INSTALADO Nm3/h *TOTAL FLOW INSTALLED Nm3/h*
MORILLO FIJO ENHORNAMIENTO *FIXED SKID CHARGING SIDE (MF)*	220	15	12,82	12,90	65	0,94	4	51,60
MORILLO FIJO DESHORNAMIENTO *FIXED SKID DISCHARGING SIDE (MF)*	110	15	6,39	6,40	40	1,30	4	25,60
MORILLO FIJO CENTRAL DESHORNAMIENTO *CENTRAL FIXED SKID DISCHARGING SIDE (MF)*	110	15	6,39	6,40	40	1,30	1	6,40
QUILLAS FIJAS *FIXED POSTS (QF)*	61	15	3,53	4,00	40	0,81	4	16
QUILLAS FIJAS *FIXED POSTS (QF)*	47	15	2,76	4,00	40	0,81	4	16
QUILLAS FIJAS *FIXED POSTS (QF)*	36	15	2,09	4,00	40	0,81	1	4
MORILLOS MOVIL ENHORNAMIENTO *MOBILE SKID CHARGING SIDE (MM)*	220	15	12,82	12,90	65	0,93	4	51,60
MORILLOS MOVIL DESHORNAMIENTO *MOBILE SKID DISCHARGING SIDE (MM)*	110	15	6,39	6,40	50	0,81	4	25,60
QUILLAS MOVILES *MOBILE POSTS (QM)*	61	15	3,53	11,00	65	0,79	4	44
QUILLAS MOVILES *MOBILE POSTS (QM)*	47	15	2,76	11,00	65	0,79	4	44
RODILLOS DE ENHORNAMIENTO *CHARGING ROLLERS*	34	15	1,96	2,00	25	0,87	10	20
RODILLOS DE DESHORNAMIENTO *DISCHARGING ROLLERS*	51	15	2,93	3,00	25	1,31	10	30
TOPE EXTREMO *STOPPER*	23	15	1,30	1,30	20	0,75	1	1,30
BRAZOS KICK OFF *KICK OFF ARMS*	70	15	4,00	4,00	25	1,74	4	16
INDICES DE DESHORNAMIENTO *DETECTION FINGERS*	26	15	1,50	1,50	25	0,65	2	3
MARCO PUERTA DESHORNAMIENTO *DUSCHARGING DOOR FRAME*	44	15	2,50	2,50	20	2,95	1	2,50
CAMARAS DE TV *TV CAMERA*	17	15	1,00	1,00	20	1,18	2	2
								FLOW= 359,60
GRUPO HIDRAULICO *HIDRAULIC STATION*	209	15	12	12	65	0,88	1	12
								FLOW= 12
								TOTAL FURNACE CONNECTED (Nm3/h)= 371,6
								TOTAL FURNACE INSTALLED (Nm3/h)= 400

AGUA INDUSTRIAL – AGUA DIRECTA
INDUSTRIAL WATER – DIRECT WATER

	UTILIZACION *OPERATING*			LLENADO *FILLING*		
	CAUDAL DE AGUA UNIT Nm3/h *WATER FLOW UNIT Nm3/h*	NUMERO DE LINEAS *NUMBER OF LINES*	CAUDAL TOTAL INSTALADO Nm3/h *TOTAL FLOW INSTALLED Nm3/h*	TIEMPO min. *TIME min.*	VOLUMEN AGUA POR JUNTA m3 *WATER VOLUME PER THROUGH m3*	CAUDAL TOTAL INSTALADA Nm3/h *TOTAL FLOW INSTALLED Nm3/h*
JUNTAS DE AGUA *WATER THROUGHS*	3	4	12	40	5,1	30.60

CHARACTERISTICS MENTIONED IN THESE TABLES ARE THEORETICAL.
THEY WILL BE REVISED AND ADJUSTED DURING COMMISIONING.

01		05	
02		06	
03		07	
04		08	

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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
DATE TABLE

Folio / Sheet 01

Dibujado: Por:
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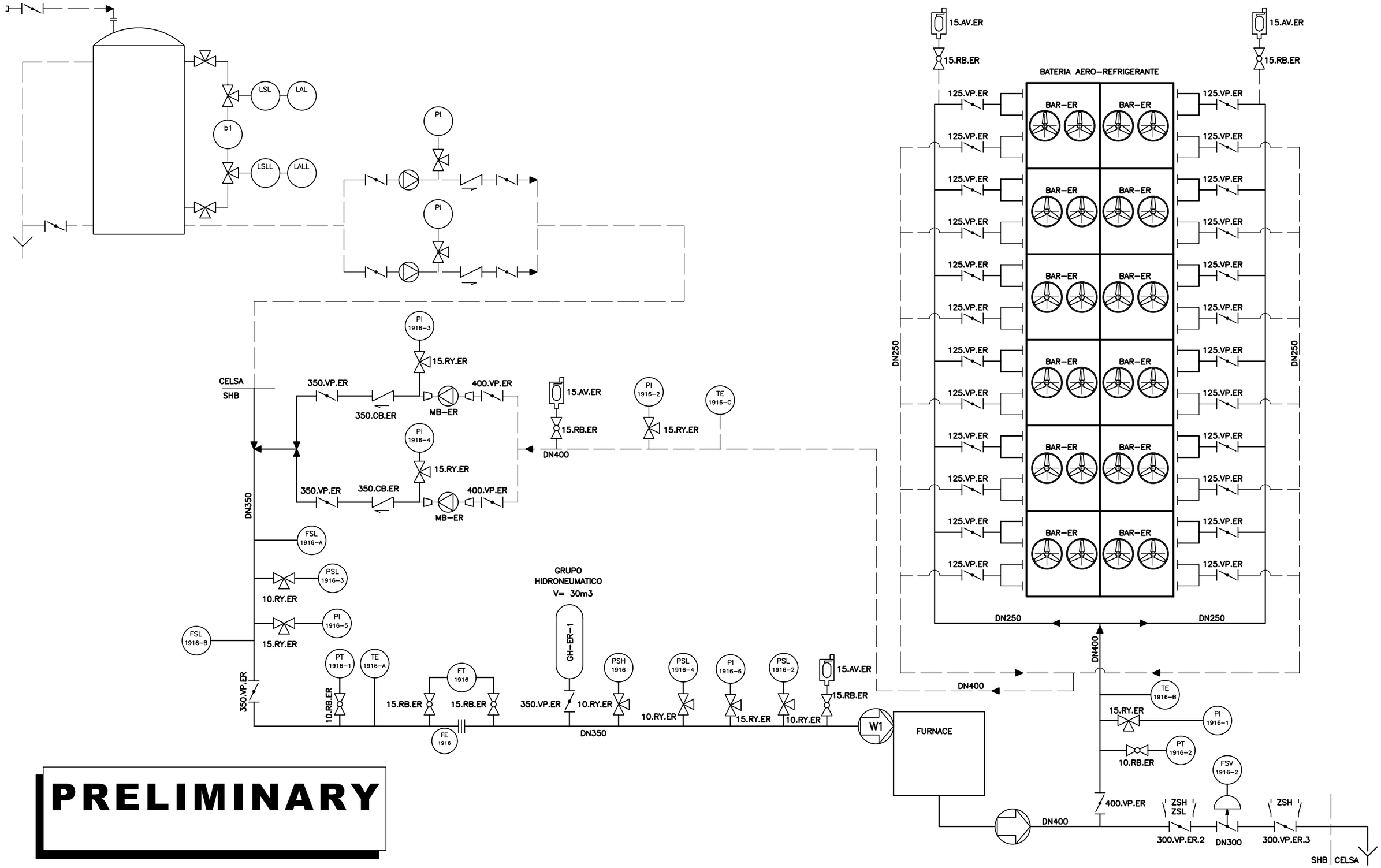

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WALKING BEAM FURNACE 140 t/h
INDUSTRIAL WATER DIAGRAM

Folio / Sheet 10

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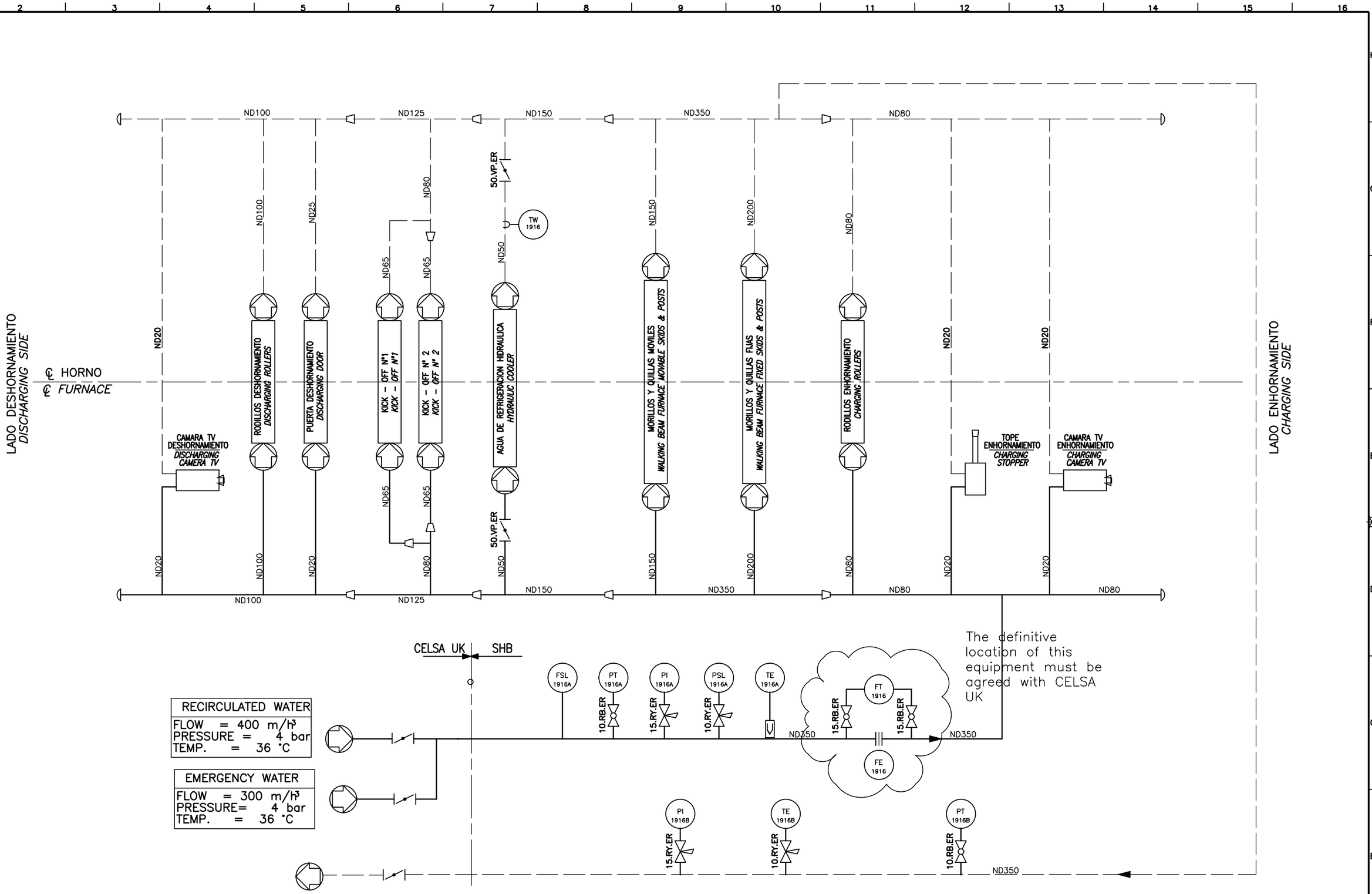

01		05	
02		06	
03		07	
04		08	

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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
INDIRECT COOLING WATER DIAGRAM

Folio / Sheet 02

Dibujado: Por:
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718243 | A 0520 5 P 1000 | R 00

DISCHARGING SIDE

PRODUCT

CHARGING SIDE

ND350

DISCHARGING FIXED SKID

CHARGING FIXED SKID

PURGING VALVES 15.RB.ER

QF01 40.RB.ER
MF01 40.RB.ER
MF02 65.VP.ER
QF02 40.RB.ER

ND40 QF02
ND65 MF02
ND40 QF01
ND40 MF01

DISCHARGING FIXED SKID

CHARGING FIXED SKID

PURGING VALVES 15.RB.ER

QF03 40.RB.ER
MF03 40.RB.ER
MF04 65.VP.ER
QF04 40.RB.ER

ND40 QF04
ND65 MF04
ND40 QF03
ND40 MF03

DISCHARGING FIXED SKID

PURGING VALVES 15.RB.ER

QF05 40.RB.ER
MF05 40.RB.ER

ND40 QF05
ND40 MF05

DISCHARGING FIXED SKID

CHARGING FIXED SKID

PURGING VALVES 15.RB.ER

QF06 40.RB.ER
MF06 40.RB.ER
MF07 65.VP.ER
QF07 40.RB.ER

ND40 QF07
ND65 MF07
ND40 QF06
ND40 MF06

DISCHARGING FIXED SKID

CHARGING FIXED SKID

PURGING VALVES 15.RB.ER

QF08 40.RB.ER
MF08 40.RB.ER
MF09 65.VP.ER
QF09 40.RB.ER

ND40 QF09
ND65 MF09
ND40 QF08
ND40 MF08

01		05	
02		06	
03		07	
04		08	

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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
FIXED SKIDS AND POSTS FEEDING

Folio / Sheet 03

Dibujado: Por:
Drawn on: 15-12-08 By: O. PRIETO

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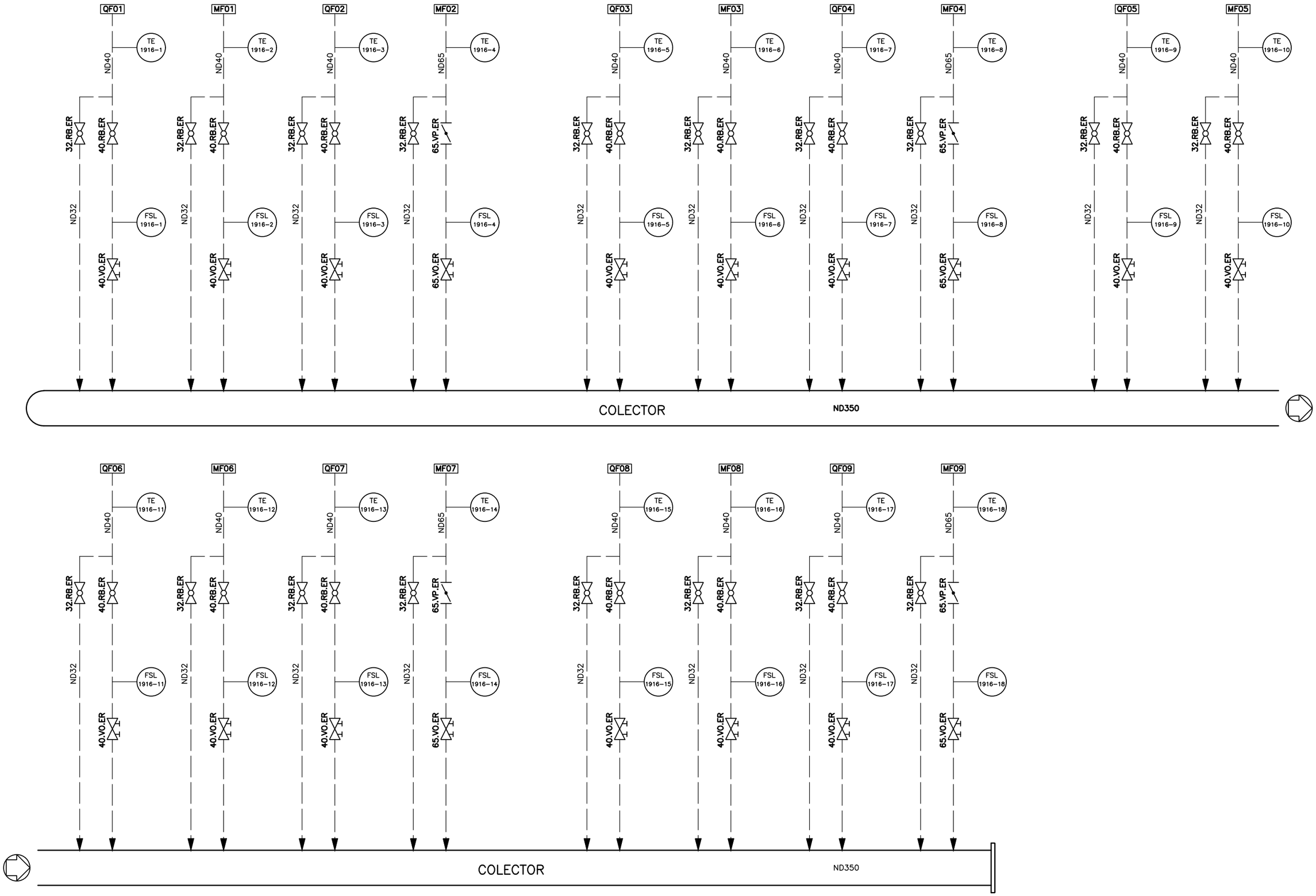

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Pl. Sgdo. C. Jesús: 4-sub.2
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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
FIXED SKIDS AND POSTS RETURN

Folio / Sheet 04

Dibujado: Por:
Drawn on: 15-12-08 By: O. PRIETO

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DISCHARGING SIDE

PRODUCT

CHARGING SIDE

DISCHARGING MOVABLE SKID

CHARGING MOVABLE SKID

PURGING VALVES 15.RB.ER

QM01 65.VP.ER
MM01 40.RB.ER
MM02 65.VP.ER
QM02 65.VP.ER

ND65 ND65 ND65 ND40

TE 1916-19 FSL 1916-19 65.VP.ER 65.VO.ER QM02 32.RB.ER ND32
TE 1916-20 FSL 1916-20 65.VP.ER 65.VO.ER MM02 32.RB.ER ND32
TE 1916-21 FSL 1916-21 65.VP.ER 65.VO.ER QM01 32.RB.ER ND32
TE 1916-22 FSL 1916-22 40.RB.ER 40.VO.ER MM01 32.RB.ER ND32

ND150

15.RB.ER

100.VP.ER 100.CS.ER 100.VP.ER
100.VP.ER 100.CS.ER 100.VP.ER
100.VP.ER 100.CS.ER 100.VP.ER

ND150

ND150

DISCHARGING MOVABLE SKID

CHARGING MOVABLE SKID

PURGING VALVES 15.RB.ER

QM03 65.VP.ER
MM03 40.RB.ER
MM04 65.VP.ER
QM04 65.VP.ER

ND65 ND65 ND65 ND40

TE 1916-23 FSL 1916-23 65.VP.ER 65.VO.ER QM04 32.RB.ER ND32
TE 1916-24 FSL 1916-24 65.VP.ER 65.VO.ER MM04 32.RB.ER ND32
TE 1916-25 FSL 1916-25 65.VP.ER 65.VO.ER QM03 32.RB.ER ND32
TE 1916-26 FSL 1916-26 40.RB.ER 40.VO.ER MM03 32.RB.ER ND32

15.RB.ER

℄ FURNACE

ND150

100.VP.ER 100.CS.ER 100.VP.ER
100.VP.ER 100.CS.ER 100.VP.ER
100.VP.ER 100.CS.ER 100.VP.ER

ND150

DISCHARGING MOVABLE SKID

CHARGING MOVABLE SKID

PURGING VALVES 15.RB.ER

QM05 65.VP.ER
MM05 40.RB.ER
MM06 65.VP.ER
QM06 65.VP.ER

ND65 ND65 ND65 ND40

TE 1916-27 FSL 1916-27 65.VP.ER 65.VO.ER QM06 32.RB.ER ND32
TE 1916-28 FSL 1916-28 65.VP.ER 65.VO.ER MM06 32.RB.ER ND32
TE 1916-29 FSL 1916-29 65.VP.ER 65.VO.ER QM05 32.RB.ER ND32
TE 1916-30 FSL 1916-30 40.RB.ER 40.VO.ER MM05 32.RB.ER ND32

ND150

15.RB.ER

100.VP.ER 100.CS.ER 100.VP.ER
100.VP.ER 100.CS.ER 100.VP.ER
100.VP.ER 100.CS.ER 100.VP.ER

ND150

ND150

DISCHARGING MOVABLE SKID

CHARGING MOVABLE SKID

PURGING VALVES 15.RB.ER

QM07 65.VP.ER
MM07 40.RB.ER
MM08 65.VP.ER
QM08 65.VP.ER

ND65 ND65 ND65 ND40

TE 1916-31 FSL 1916-31 65.VP.ER 65.VO.ER QM08 32.RB.ER ND32
TE 1916-32 FSL 1916-32 65.VP.ER 65.VO.ER QM08 32.RB.ER ND32
TE 1916-33 FSL 1916-33 65.VP.ER 65.VO.ER QM07 32.RB.ER ND32
TE 1916-34 FSL 1916-34 40.RB.ER 40.VO.ER MM07 32.RB.ER ND32

15.RB.ER

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CELSA MANUFACTURING UK

WALKING BEAM FURNACE 140 t/h

RETURN AND FEEDING OF MOVABLE SKIDS AND POSTS

Folio / Sheet 05

Dibujado: Por:
Drawn on: 15-12-08 By: O. PRIETO

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CHARGING AREA

T.V.

ROLLERS

STOPPER

℄ FURNACE

ND80

ND20

ND25

20.RB.ER

25.RB.ER

20.RS.ER

25.RS.ER

M

FSL 1916-35

FSL 1916-36

FSL 1916-37

FSL 1916-38

FSL 1916-39

FSL 1916-40

FSL 1916-41

FSL 1916-42

FSL 1916-43

FSL 1916-44

FSL 1916-45

FSL 1916-46

TE 1916-35

TE 1916-36

TE 1916-37

TE 1916-38

TE 1916-39

TE 1916-40

TE 1916-41

TE 1916-42

TE 1916-43

TE 1916-44

TE 1916-45

TE 1916-46

01		05	
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CELSA MANUFACTURING UK

WALKING BEAM FURNACE 140 t/h

COOLING WATER - CHARGING ROLLERS - STOPPER - T.V.

Folio / Sheet 06

Dibujado: Por:

Drawn on: 15-12-08 By: O. PRIETO

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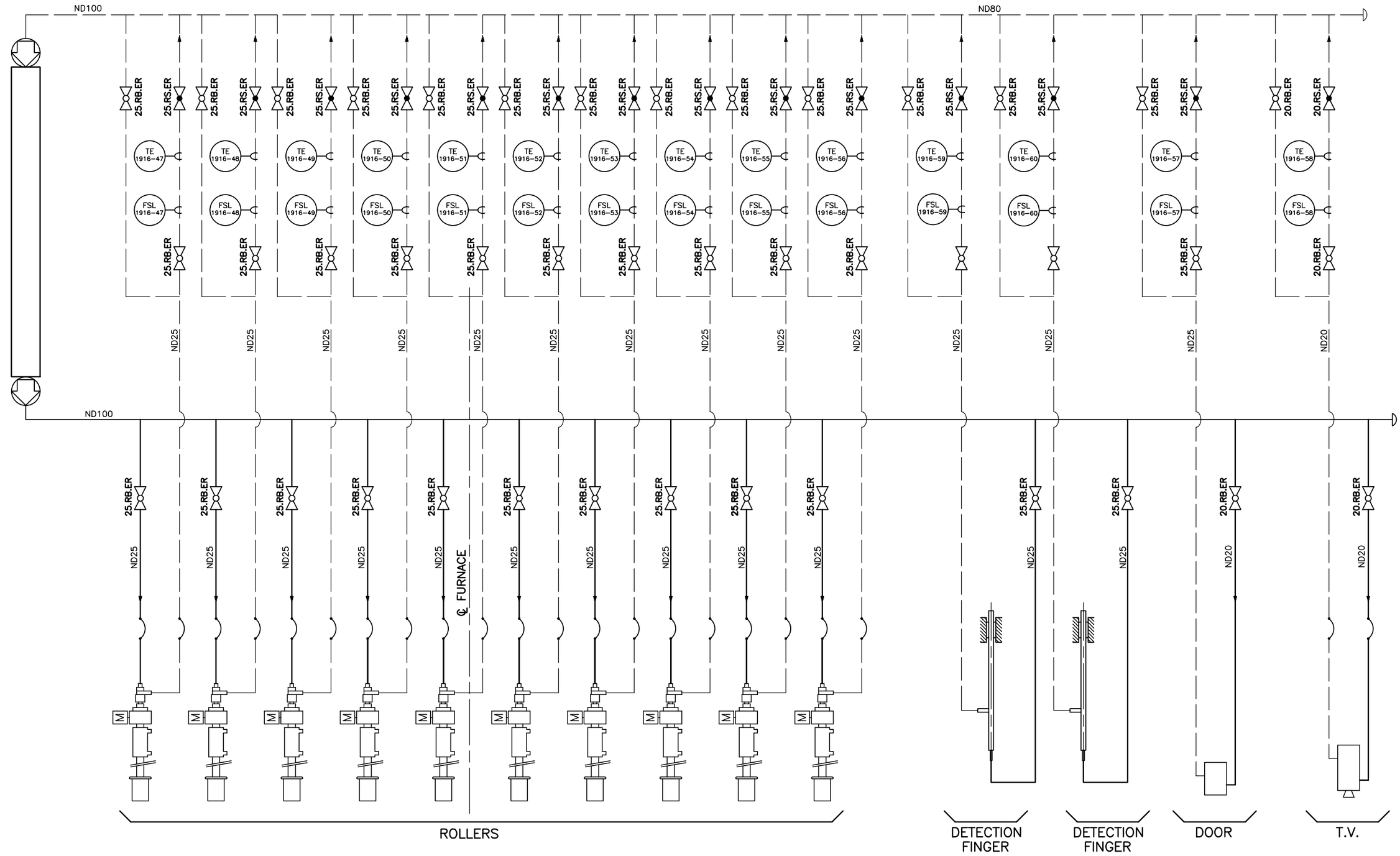

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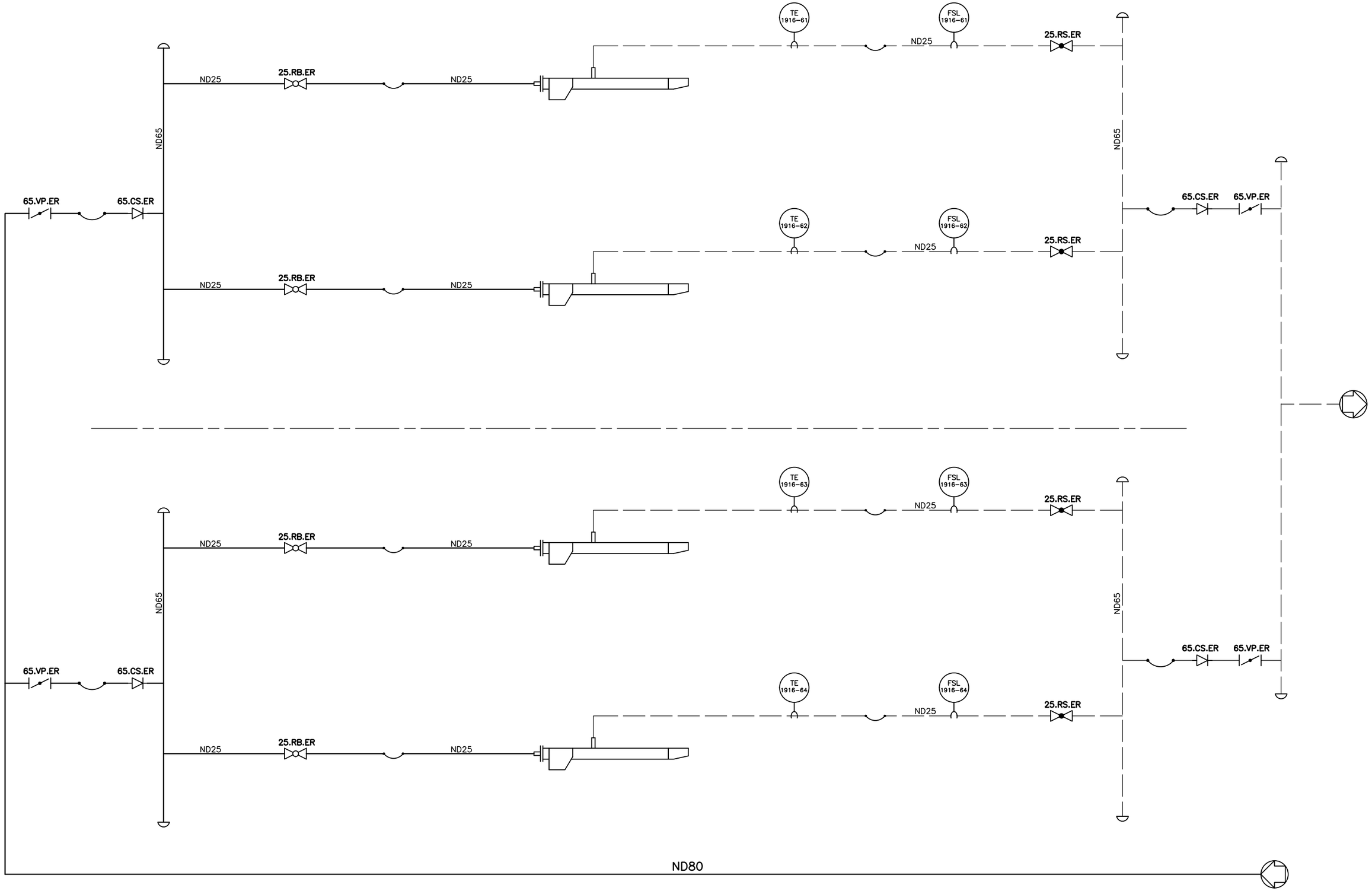
CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
COOLING WATER - DISCHARGING ROLLERS - T.V.

Folio / Sheet 07

Dibujado: Por:
Drawn on: 15-12-08 By: O. PRIETO

718243 | A 0520 5 P 1000 | R 00



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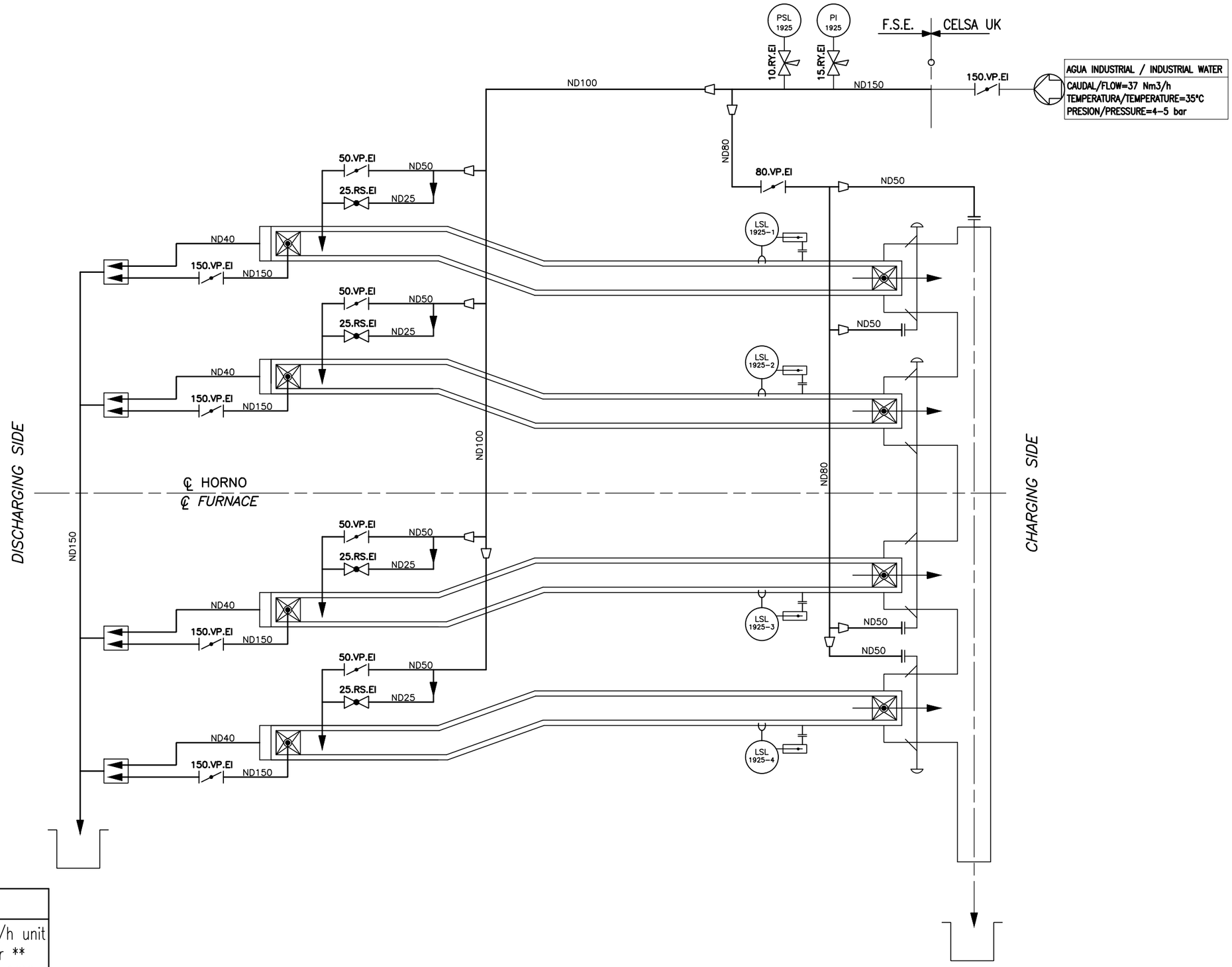
CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
RETURN AND FEDING - KICK-OFF Nº1 & Nº2

Folio / Sheet 08

Dibujado: Por:
Drawn on: 15-12-08 By: O. PRIETO

718243 | A 0520 5 P 1000 | R 00



SUMP PUMP	
Flow :	10 m3/h unit
Pressure :	bar **
Temp. :	35 TO 90°C

** TO BE AGREED WITH CUSTOMER DEPENDING ON THE POSITION OF THE SCALE FLUME

01		05	
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CELSA MANUFACTURING UK
WALKING BEAM FURNACE 140 t/h
INDUSTRIAL WATER DIAGRAM

Folio / Sheet 09

Dibujado: Por:
Drawn on: 15-12-08 By: O. PRIETO

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