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1 Subject of specification

This specification and other documents referenced herein establish the minimum requirements for the design, fabrication, erection, inspection and tests for Fired Heaters.

This specification shall be applied in conjunction with basic process requirements attached to the inquiry/purchase order, mainly consisting of:

- Type of heater to be used
- Heat design duty
- Fluid type, flow rate and state (liquid, vapor or two phases).
- Process inlet and outlet temperatures
- Allowable pressure drop
- Fuel type, composition and pressure
- Corrosive elements in fuel (sulfur, vanadium)
- Plot plan for heater area.
- Draft available if the heater is to connect to an existing or common stack.
- Maximum allowed process film temperatures for services susceptible to coke formation.
- Tube material
- Flash vaporization curve for 2-phase heater.
- Properties of process fluid
- Details of any long-term turndown conditions to be taken into account in design
- Site conditions
- Type of burners (forced or natural draft)
- Minimum allowable stack height
- Actual environmental pollution requirements

2 Application

This specification applies to the preparation of tender documents, inquiries and contracts for newly planned investment or modernization projects of Grupa LOTOS S.A.

It shall also be a basis for preparing both detailed specifications and inquiries for individual or package unit supplies.

2.1 Deviations

Any deviation from this specification and the relevant specifications, standards and related documents including proposals, which the bidder claims to be economically and / or technically superior solutions must be submitted in writing for review and approval by Grupa LOTOS S.A. Non-approved exceptions are not acceptable by Grupa LOTOS S.A.

The supplier must report in writing any ambiguity in this or any other specifications of Grupa LOTOS S.A. or non-compliance with the referred documents / standards and obtain a written explanation from Grupa LOTOS S.A.

2.2 Order of Precedence

In case of conflicts existing between this specification and other documents, the following order of precedence shall govern:

- The current Polish legislation
- Terms of purchase order / contract and other requirements agreed in writing Grupa LOTOS S.A.
- Data Sheets approved by Grupa LOTOS S.A.
- This specification
- Other Specifications
- Drawings and other documents
- Standards

3 Basic design requirements

3.1 Heater duty

The heater and all its equipment shall be designed for 120% over firing for one hour, and for continuous operation at the rated capacity.
Unless otherwise specified, operation at 60% of the design capacity shall be possible with satisfactory thermal efficiency and stability.

3.2 Heater efficiency

The minimum heater thermal efficiency shall be as follows:

- Natural draft heaters – min. 86%
- Forced draft heaters with air preheat – min 91.5%
- Forced draft heaters with waste heat boiler – min 89 %

Furnace fuel efficiency calculation shall be based on LHV of the fuels and heat loss of:

- 1.5% for natural draft heaters
- 2 % for forced draft heaters with air preheat

Furnace efficiency shall be measured in accordance with API 560.

3.3 Average radiant heat transfer rates

Below are listed recommended average radiant heat transfer rates based on 2:1 center to center spaced, one side fired and backed by refractory tubes.

Heater Service	Average Radiant Heat Transfer Rate (kW/m^2)
Atmospheric Crude Distillation	31.5 ÷ 45.0
Vacuum (Reduced) Crude Distillation	25.5 ÷ 31.5
Reboilers	31.5 ÷ 38.0
Circulating Oil Heaters	25.5 ÷ 35.0
Catalytic Reformer Charge & Reheat Service	23.0 ÷ 38.0
Delayed Cokers	31.5 ÷ 35.0
Visbreakers – heating section	28.5 ÷ 31.5
Visbreakers – soaking section	19.0 ÷ 22.0
Propane De-asphalting	25.5 ÷ 28.5
Reduced Crude Lubes	23.0 ÷ 27.0
Hydrotreaters, Hydrocrackers	31.5
Steam Superheaters	28.5 ÷ 41.5
Catalytic Cracker Feed heaters	31.5 ÷ 35.0
Gas Heaters	31.5 ÷ 38.0
Hydrocarbon Liquid Heaters/Preheaters	31.5 ÷ 38.0
Helical Coil Heaters (all radiant)	19.0 ÷ 25.5

For larger tube spacing average radiant heat transfer rate can be increased.

For both side firing above rates shall be increased by 1.5 times.

The final Average Radiant Heat Transfer Rate shall be determined and confirmed by fired heater Supplier taking into account his experience with specific process / heater service.

3.4 Mass velocity in the tubes

Below are listed recommended typical mass velocities in tubes.

Heater Service	Mass velocity (kg/sec m^2)
Atmospheric Crude Distillation	1200 ÷ 1700
Vacuum (Reduced) Crude Distillation	300 ÷ 500
Reboilers	750 ÷ 1200
Circulating Oil Heaters	1700 ÷ 2200
Catalytic Reformer Charge & Reheat Service	200 ÷ 350
Delayed Cokers	1700 ÷ 2200
Hydrotreaters, Hydrocrackers	750 ÷ 1000
Steam Superheaters	150 ÷ 370
Steam Generators (forced circulation)	750 ÷ 1200
Catalytic Crackers Feed Heaters	1500 ÷ 1950
Asphalt Heaters	1200 ÷ 1700
Gas Heaters	Dictated by Pressure Drop
Hydrocarbon Liquid Heaters/Preheaters	1700 ÷ 1950

The tube diameter and number of passes shall be determined according to the allowable pressure drop and the acceptable mass velocity for the type of fluid and the operating conditions.

Wherever possible, tube diameter should be selected from standard nominal pipe sizes in the range of 2-12".

Use of tubes of a diameter larger than to 8" is not recommended and should be avoided wherever possible.

The final mass velocity in tubes shall be determined and confirmed by fired heater Supplier taking into account his experience with specific process / heater service.

3.5 Radiant section dimensions

For vertical cylindrical heaters H/D ratio should be between 2 and 2.75, where H- height of firebox, D- tube circle diameter based on tube centerlines.

For box or cabin heaters, the height of the fire box, with tubes on the sidewalls only or with intermediate tube banks parallel to the sidewalls divided by the distance between tube row centerlines (i.e. H/D) should not exceed 2.75.

For box heaters with vertical tubes on all walls H/D ratio should be between 2 and 2.75 where D is a hydraulic diameter

$$D = 4\frac{(cross\ section\ area)}{perimeter}$$

The tube section circle diameter should be at least 2 (two) times the diameter of the burner muffle block for cylindrical heaters.
For box heaters, use equivalent of the hydraulic diameter and the same rules.

4 Basic mechanical design requirements

4.1 Steel structure

The steel structure shall meet the requirements of the Polish building regulations standards and Grupa LOTOS S.A. specification 5120. It is mandatory that fired heater steel structure calculations shall be reviewed, verified and approved by licensed structural engineer in accordance with Polish Building Law prior to installation and putting into operation.

Materials used for fired heater construction shall comply with the relevant PN-EN codes. The minimum quality of material used for casing plates, structural shapes, main supports shall be S235JRG2 in accordance with PN-EN 10025 or equivalent and S235JR for secondary structural elements..

The casing shall have a minimum thickness of 5 mm. The floor shall have a minimum thickness of 6 mm.

A minimum headroom clearance of 2 m shall be provided under the bottom of the heater above the final paving level.

The furnace design shall allow for easy disassembly and replacement of coil tubes.

4.1.1 Tolerances

Following tolerances are required as a minimum:

- For cabin type heaters, the plates shall have a flatness tolerance of 5 mm when assembled.
- Cylindrical heaters Diameter tolerances shall be within ±5 mm for a diameter less than 5 m and ± 0.001 D for a diameter of D over 5 m.
- Vertical tolerance should not exceed 20 mm for a height of 15 m.
- For other tolerances requirements of PN-EN-ISO13920 shall be followed.

4.1.2 Platforms, Walkways, stairs and ladders

The furnace shall be furnished with suitable platforms, stairs and ladders, allowing for access to the inspection doors/peepholes, valves, instruments and auxiliary equipment in accordance with requirements of Grupa LOTOS S.A. specification no. 5120.

Platforms shall be provided for safe operation and service of the heater and its accessories such as:

- Burners, air registers, burner valves, soot blowers (servicing, lubrication, maintenance)
- Dampers
- Guillotine dampers
- Sampling connections,
- Gas analyzers
- All instruments
- Vents, drains, valves etc.
- Decoking system

Walkways shall be provided at the level of the header boxes, if any, for opening and closing of the boxes and tube servicing, between the platforms giving access to the wall burners and between the platforms of adjacent heaters. In this case the platforms shall be at the same level, if possible.

Access by stairways shall be provided to platforms for normal servicing (burners, flame and tube inspection).

Emergency escape ladders shall be provided at stairways area.

Access by ladders shall be provided to the service platforms listed above at the opposite side to stairway, to platforms without stairways and to any location where checking or service may be required.

4.1.3 Access and observation doors

Following access doors shall be provided as minimum:

- One access door to the radiation section or two doors for large heaters (diameter over 10 m). Cabin heaters shall have two access doors per radiant chamber
- Sufficient number of access doors to the convection section shall be provided for inspection and cleaning purposes between each tube bank
- One access door to the breeching above the last convection tubes
- Tube removal doors

At least one explosion doors, suitably located so as not to endanger the personnel using the platforms and walkways shall be provided

A sufficient number of observation doors, made of cast gray iron according to ASTM A 48 cl. 25 or equal, with adequate dimensions shall be provided shall be provided to permit observation of entire burner flame and for general viewing of the entire radiant tubes length and tube skin thermocouples.

Observation doors should be equipped with easy removable temperature resistant glass for remote tube skin temperature control (IR Scaner). The observation door cover shall be self-closing and tight.

4.1.4 Breeching, flue gas ducts and stack

One flue gas exhaust is required for each 12 meters of convection section tube length.

Blinds and guillotine dampers should be provided to isolate heater connected to the common flue gas channel or stack.

For other requirements refer to Grupa LOTOS S.A. specification no 2120 - Flue gas stack, ducts measurement and monitoring nozzles.

4.2 Pressure bearing components

The pressure parts of fired heaters shall meet requirements of Directive of the European Parliament and of the Council on the approximation of the law of the Member States concerning pressure equipment 97/23/EC and ASME BPVC. The Manufacturer / Supplier shall obtain at his own expense all required by the regulations and codes approvals, acceptance, certificate, including these involving Notified Body.

All pressure parts of fired heaters shall carry CE marking.

Pressure equipment of fired heaters shall be hydrostatically tested in accordance with PED requirements and under Notified Body supervision.

Pressure equipment hall have nameplate in Polish or Polish and English language in accordance with PED 97/23/EC. Nameplates shall be of corrosion resistant material installed on a nameplate bracket by solid stainless steel rivets. Inscriptions on the nameplate shall be engraved. Pressure equipment name plates shall be accessible, located next to fired heater name plate.

4.2.1 Coils

The tubes lay out and sizing shall be selected in accordance with API Standard 560 and shall ensure a uniform heat distribution throughout the whole length of the tubes without risk of local overheating. In multiple parallel pass heaters (number of passes shall be minimized), the passes shall be arranged in relation to the burners or flue system in such a manner that each of them receives approximately the same amount of heat.

A proper heat distribution shall be provided to all passes by means of adequate arrangement of the inlet and outlet piping and if necessary installation of flow control valves or restriction orifices with sufficient pressure drop to ensure a uniform heat distribution in the passes between 60 and 120% of the rated capacity.

4.2.1.1 Tube design considerations

Tubes shall be selected considering required strength, corrosion and erosion resistance, oxidation/reduction characteristic and temperature level.

Tube life shall be minimum 100 000 hours.

4.2.1.1.1 Temperature

The maximum skin temperature shall be calculated according to API 530. If applicable a coke deposit of minimum 1 mm shall be used for calculation.

Selecting tube material, following temperatures shall not be exceeded:

- 450 °C for carbon steel tubes
- 540 °C for molybdenum steel tubes
- 565 °C for 0.5% Cr. - 0.5% Mo steel tubes
- 595 °C for 1 to 1.25% Cr. - 0.5% Mo steel tubes
- 625 °C for 2.25% Cr. - 1% Mo steel tubes
- 650 °C for 5% Cr. - 0.5% Mo steel tubes
- 700 °C for 9% Cr. - 1% Mo steel tubes
- 850 °C for 18/8 Cr. - Ni alloy steel tubes
- 950 °C for 25/20 Cr. - Ni alloy steel tubes

4.2.1.1.2 Corrosion allowance

- For non alloy or low alloy steel tubes up to 9 % Cr., the following corrosion allowance is recommended:
- 3 mm - for tube wall temperature up to 100 °C below the limit for selected material (refer to 4.2.1.1.1)
- 1.6 mm - for tube wall temperature more than 100 °C below the limit for selected material

4.2.1.1.3 Tube thickness

Tube wall thickness calculations shall be in accordance with API 530 for process fluids tube and ASME BPVC Section I for steam generation or superheating tubes. Moreover computer stress analysis is recommended. The said analysis shall be subject to agreement with Grupa LOTOS S.A.

Design temperature for tube wall thickness calculation shall be 28 °C above the maximum calculated tube wall temperature.

Tubes shall be design to withstand steam-air decoking.

Wall thickness shall be calculated for return bends made of austenitic stainless steel located inside firebox. Corrosion allowances used for calculation shall be the same as for tubes.

4.2.1.2 Radiant coils

Maximum tubes length for horizontal radiant sections shall be limited to about 25 m and to 18 m for vertical coils.

Radiation coil tubes shall be arranged in single rows with minimum spacing between tube axes equal to twice the nominal diameter and near the refractory walls.

The minimum distance between the axes of the tubes and the inner surface of the furnace wall can not be less than:

- for tubes Dz = 89 mm 2 x nominal diameter
- for tubes Dz = 114 mm 152 mm
- for tubes Dz = 141 mm 203 mm
- for tubes Dz = 168 mm 229 mm

Tubes shall be made of seamless pipes. Circumferential welding on straight section of coil tube is not allowed.

Forged return bends shall be used. Return bends and fittings shall be of the some material grade as the tube they connect. Return bends shall be located inside furnace and welded to the tubes.

Header boxes can be used only when return bends with plug headers or jump over fittings are used.

Expensive tube supports can be avoided by using header boxes (subject to agreement with Grupa LOTOS S.A.).

Material and test certificates in accordance with applicable codes shall be provided for radiant coils.

Welding joints between tubes and bend requiring PWHT shall be done in Manufacturer / Supplier shop to the most possible extent. Welding at the site shall be limited to.

Prior to fabrication, any welding procedure and welder's qualification records required shall be duly checked and approved by third party as required by PED 97/23/WE and purchase order.

All welded parts shall be inspected in the shop prior to shipment to the field in accordance with the requirements of the applicable standards and Grupa LOTOS S.A. specifications.

All welded joints shall be made by arc welding using electrodes of the same material composition as that of the tube and forging material. In case different grade materials are joined, the electrodes shall have the composition of this material, which has higher content of alloy components.

4.2.1.3 Convection tubes

Maximum tubes length for convection section shall be limited to about 25 m. The maximum unsupported length of the horizontal tubes shall be 35 times the outside diameter.

The bottom three rows of the convection section shall be bare and made of the same material as the radiant section tubes.

To reduce flue gas bypassing no bare section should left at tube support or in the flue gas flow path and no return bends should be located in the flue gas main flow. Only straight tube sections with full-extended surface (or bare on shock rows) shall be exposed to the flue gas stream.

Convection section return bends shall be located in header boxes. Header box plate thickness shall be at least 6 mm. Boxes shall be airtight and refractory lined (min. 50mm), made as bolted with gasket provided. Doors shall be hinged. Drain shall be provided at the lowest points of the boxes.

Standard short radius 180° U-bends shall be used (R=1D).

A minimum clearance of 20 mm shall be provided between fin or stud tip and the refractory wall.

Corbels shall be provided for each row to prevent bypassing of flue gas up the sides of the convection section.

For future addition of two rows of tubes, including the end tubesheets space provision in convection section shall be provided.

4.2.1.3.1 Extended surface

For heavy liquid fuels (API gravity 10 or lower) stud type extended surface shall be used only.

For gas and light liquid fuels (API gravity above 25) fin type extended surface is allowed.

For liquid fuels with API gravity between 10 and 25 heavy-duty fins can be used.

For liquid fuels with Vanadium content above 400 ppm bare tubes are allowed only.

The spacing of the tubes shall remain sufficient, to ensure that the flue gas pressure drop across the convection section does not become excessive at the end of the run. For pressure drop calculations, each tube shall be considered as a cylinder enveloping the fins/studs.

The minimum spacing between fins or studs on adjacent tubes is 30 mm.
Stud and fin type extended surface material shall be carbon steel for maximum tip temperature up to 480 ^{o}C, 11-13% chrome up to 650°C and stainless steel above 650 ^{o}C.

4.2.1.3.1.1 Studs

Maximum number of the studs per circumferential row depends of tube diameter and shall not be higher than listed in table below:

Tube OD (inches)	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	8.5
Studs No.	8	10	12	14	16	18	20	22	24	32

Minimum stud diameter shall be 12.7 mm (1/2”) and maximum height 25.4 mm (1”)

4.2.1.3.1.2 Fins

Fins material shall be selected for zero oxidation at the maximum temperature. It is recommended to provide 11-13% chromium fins for the 2 first finned rows even though the design conditions call for carbon steel only.

The fins shall be continuously welded to the tube by a fillet weld.

Recommended fins dimensions and density are listed in table below:

	Gas firing	Oil firing
Min. fin thickness [mm]	1.5	2.5
Max. fin height [mm]	25	19
Max. fins density [fins/meter]	165	118

4.2.1.4 Steam superheater coil

The steam superheat coil shall be arranged in a proper position to not fail when operated without steam even during decoking run. Risk of overheating and vibration shall be reduced to a minimum.

The steam superheat coil in the convection section shall be ASTM A-355 grade P5 or better.

Start-up steam silencer with relevant piping, valves and supports shall be provided.

4.2.2 Tubes supports

Supports and guides and shall be attached directly to the steel structure of the heater.

The maximum allowable stress shall not exceed the values given in the API 560 in all operating cases, including decoking.

The spacing between supports of the horizontal tubes shall not exceed 35 times the outside diameter of the tubes or 6 meters. Provisions shall be made to prevent tubes from leaving their supports. End tube sheets shall be lined with at least 75 mm refractory concrete.

Vertical tubes shall preferably be supported at their upper end. Guide shall be provided at the lower end and if necessary at intermediate positions.

The tubes shall be supported (suspended) in the way to avoid their damage resulting from vibration or expansion joints.

4.2.2.1 Material selection

Materials for supports, guides shall be selected based on API 560, based on the maximum design temperatures.

Refractory lining covering cannot be considered for supports design.

The minimum design temperature for radiant support selection shall be 871°C.

All radiant supports, tube hangers as well as shield section tube sheets and their supports shall be of cast steel minimum 25% Cr – 12% Ni.

If the fuel burnt in the furnace contains more than 50 ppm of vanadium and sodium, supports shall be made of 50-50 % CrNi alloy with an additional of Nb.

Tests shall be performed in accordance with applicable standards and specifications.

4.2.3 Manifolds and Transfer lines

Manifolds shall be designed for uniform flow distribution to all passes.

Dead space of the manifolds shall be minimized.

For liquid and vaporization services flow control shall be provided wherever coking can appear (coil outlet temperature above 315 ^{o}C).

For vapor (gas) heaters natural distribution can be achieved by proper inlet/outlet manifold sizing.

Fluid velocity in transfer line should not exceed 80% of sonic velocity.

Long radius elbows shall be used for transfer line design (R=1.5D).

4.2.4 External Piping

External piping shall be designed and made according to ASME B31.3 and Grupa LOTOS S.A. piping specifications no 2600 and 8800.

The piping system shall be designed to allow for complete draining and venting. Piping terminals at battery limit shall be designed to accept external loads (forces and moments) coming from outside external piping. Loads and moments provided by Grupa LOTOS S.A. shall to be checked and confirmed by fired heater Manufacturer / Supplier.

Piping handling hazardous fluids (eg. gas and oil burner piping) above 1” is subject of Notified Body approval in accordance with requirements of Pressure European Directive 97/23/EC (PED).

Impact test for piping elements is mandatory.

The Manufacturer / Supplier shall obtain at his own expense all required by the regulations and codes approvals, acceptance, certificate, including these involving Notified Body.

4.2.4.1 Burner piping

Burner piping shall be steam heat traced up to the connection at burner.

Piping shall be designed to allow easy disconnecting and burner maintenance/removal. Flexible hose connections shall be avoided.

Manual shut off valves shall be located close to the observation doors.

4.3 Combustion air system

4.3.1 Natural draft heaters

For natural draft heaters, the stack shall be sized to provide sufficient draft to permit the operation of the heater at a capacity controlled by the available capacity of the burners.

4.3.2 Forced draft heaters

4.3.2.1 Fans

Two fans for forced air draft to burners with electric drives (one working and one stand by) shall be provided.

Each fan shall ensure at least 120% of the normal capacity required for burners.

Normal capacity of the fan shall be calculated on design duty of the heater and following excess air:

- 15% for fuel oil firing
- 10% for fuel gas firing

The discharge pressure of the fan shall cover all flow resistance and ensure the overpressure demand for normal operating conditions.

The rated power output of the drive motor shall be at least 125% of the maximum power demand for normal operating conditions.

The fans shall meet API 673 requirements. Any deviation requires Grupa LOTOS S.A. approval in writting.

The fans drive motors shall meet the requirements of Grupa LOTOS S.A. specification No. 4200.

4.3.2.2 Combustion air ducts

Combustion air ducts shall be designed for equal air distribution to all burners. Short radius elbows, section changes, and any cause of disturbance of the airflow shall be avoided.

Duct location shall allow on stream burners removal and adequate clearance for maintenance of furnace equipment.

Multi cell heaters and multi wall fired heaters shall be provided with several air registers to adjust air to each set of burners.

Air ducts to the burners shall be made of steel plate thickness minimum 4 mm with heat insulation outside.

Air intake shall be located outside explosion hazard zone. The inlet of the duct shall be protected against precipitation, icing (traced) and birds.

All necessary expansion joints for to protect from the thermal expansion air preheater and fans shall be provided.

4.3.2.3 Combustion air preheater.

Air preheater shall be designed based on average ambient temperature.

Preferred solution is the use of a recuperative, plate type preheater.

The selection of the preheater shall ensure flue gas temperature at outlet at least 20 ^{o}C higher than the dew point. An additional steam or tempered water air preheater shall be provided for wintertime operation.

The preheater shall be provided with inspection doors and door for cleaning purposes.

The installation of the preheater shall be provided with a bypass on the air and flue gas side with shut-off gates to allow disassembly of the preheater during furnace operation.

Air preheater shall be equipped with washing installation which allows its surface washing from the flue gas side.

4.4 Refractory lining

Refractory and/or insulating lining shall be selected and designed according to API 560.

The lining thickness shall be calculated in such a manner that the external temperature of the combustion chamber does not exceed 82 ^{o}C at an ambient temperature of 27 ^{o}C without wind.

The refractory lining shall be designed to withstand the maximum conditions and a minimum service time of 50,000 hours without major repair.

The heater Manufacturer/Supplier shall submit data concerning lining type selection and thickness calculation for Grupa LOTOS S.A. approval.

All refractory linings shall be arranged, in the way to ensure free expand at the operating temperature, tightness of the expansion joints and replace ability for any part of the refractory setting.

Materials for refractory shall be according ASTM standards.

The refractory around the observation doors shall be beveled to allow the maximum visibility.

All observation doors shall be lined as a minimum with 65 mm of concrete or 25 mm of ceramic fiber panels.

Inspection and access doors shall be designed as a ceramic fiber back up lined for to reduce its weight.

The drying of the refractory lining procedure shall be submitted for Grupa LOTOS S.A. approval.

4.4.1 Castable refractory

Castable refractory lining is obligatory for areas of turbulence or high gas velocity such as convection section, stacks, ducts, breeching and for areas where gas temperatures are near or at the dew point or when the fuel gas contains over 100 ppm of combined metals.

The refractory material used in any layer shall be selected for a maximum service temperature at least 150 ^{o}C greater than predicted hot face temperature. In radiant and shield section refractory shall have a minimum service temperature of 980 ^{o}C.

The hot face layer shall be at least 75 mm thick.

Anchors material shall be selected based on hot face temperature according to below table:

Hot face temperature [^{o}C]	Anchor Material
< 400	Carbon Steel
400 - 820	TP304 Stainless Steel
820 - 1100	TP310 Stainless Steel
1100 - 1200	Alloy 601 or RA-330

Anchor type and spacing shall be determined based on refractory manufacturer standard.

It is recommended to use stainless steel fibers additive (up to 3% by weight) in higher density castables.

Stored castable mixes cannot be older, than 6 months when mixed and applied.

4.4.2 Ceramic fiber

Ceramic fiber refractory application is allowed for radiant sections only.

Hot face material shall be selected for temperature of at least 275 ^{o}C higher, than calculated and not lower, than 1150 ^{o}C.

If low temperature corrosion is expected, acid resistant coating and TP304 stainless steel foil shall be provided. Foil shall be installed at minimum distance of 50 mm from the casing.

Ceramic fiber anchors material shall be selected based on hot face temperature according to below table:

Hot face temperature [^{o}C]	Anchor Material
< 820	TP304 Stainless Steel
820-980	TP310 Stainless Steel
980-1100	Alloy 601
1100-1200	RA-330
> 1200	High alumina ceramic anchors

Metal anchors parts shall be covered for to avoid direct exposure.

4.4.3 Brick lining

Bricks lining may be considered for hot service in addition to concrete lining and are recommended for heater floor.

Radiant section gravity division walls made of fireclay bricks shall not be higher, than 7.5 meter. Light refractory bricks are not permitted for gravity walls.

For walls, where flame impingement is possible, brick construction shall be designed for a minimum temperature of 1420 ^{o}C.

The number of different sized bricks shall be limited to a minimum.

The brick grinding and cutting shall be avoided.

4.5 Burners

The burners shall comply with requirements of the Grupa LOTOS S.A. specifications no. 2110 and No. 8500.

The burners and their controls and protection system as well as the fuel feed system shall meet the requirements of the standard PN-EN 746-2 and Grupa LOTOS S.A. specifications No 3220 and 3230.

4.5.1 Burners selection

Forced draft low NOx burners shall be selected for heaters connected to refinery flue gas ducting system.

Natural draft burners are allowed for low duty heaters (<10MW) with own stack and for gas fired multi burner sidewall fired heaters.

In any case forced/natural draft selection shall be agreed with Grupa LOTOS S.A.

4.5.2 Number of burners

Minimum 2 burners shall be installed in box heaters and minimum 3 in cylindrical heaters.

Number of burners shall be agreed with Grupa LOTOS S.A.

4.6 Soot blowers

For the oil-fired furnaces retractable soot blowers shall be provided for the convection tubes. For the gas-fired furnaces or bare tubes convection, space for the future installation of the soot blowers shall be foreseen together with provision for the cleaning of the convection tubes during shutdown.

Dense castable refractory or stainless steel shroud plates shall be provided for to protect sidewalls against erosion.

The lance length should be limited to maximum 3 meters.

Soot blower shall be spaced to cover a radius of maximum 1.2 m to either side to obtain adequate cleaning.

The retractable soot blower shall adequately clean a maximum 4 rows, bare or extended surface, immediately above and below the lance position.

Adequate soot blowers lance depth (recommended 0.5 meter) must be provided in order the blowers to be effective. The space of 0.5 m between tube layers is a reasonable minimum.

The lance depth and frequency should be specified after consultation with a soot blower vendor.

Saturated steam of pressure of 1.9 MPa g is recommended for proper operation of the soot blowers.

For to protect tubes against unacceptable corrosion limited to 2.4 MPa g for rotary types and 2.1 MPa g for retractable soot blowers.

Sufficient platforms shall be provided for soot blowers maintenance and lubrication.

The soot blowers shall be controlled by PLC from local panel located at ground. Steam silencer shall be provided for steam line heating up.

4.7 Others

4.7.1 Snuffing steam

The combustion chamber, convection section and header boxes shall be equipped with snuffing steam injection nozzles. Minimum nozzles diameter for radiant section is 1 ½". Nozzles shall be so located that steam jets are not directed on the tubes or headers. The steam injection nozzles inside the heater shall be made of stainless steel 18/8 as a minimum. A permanent drain shall be provided at the low point of the inlet piping. Snuffing steam system shall be activated from the control room.

4.7.2 Decoking

Steam and air decoking, reverse flow type system shall be provided with all related lines, equipment and decoking drum.

Water injection shall be provided immediately downstream to sampling tap for to reduce downstream temperature and velocity.

Direct decoking effluent disposal to the stack or flue gas channel is not allowed. Decoking drum with water quench shall be provided in any case. The decoking line should enter the stack or duct at angle of 45° in direction of the flue gases flow. If necessary, erosion protection shall be foreseen on stack/duct refractory lining.

If decoking system will be designed by others, heater vendor shall provide decoking procedure and process requirements.

4.7.3 Natural draft heaters purge

Small purge air fans shall be provided for natural draft heaters for to ensure proper inside atmosphere exchange as required by PN-EN 746-2.

Steam purge is not acceptable.

5 Instrumentation

Heater shall be provided with complete local instrumentation (in accordance with the applicable Grupa LOTOS S.A. standards 3010 to 3910) for the control and command system including measurement, control, interlocking, alarm and safety equipment including complete interlock Burner Management System (BMS) necessary for proper operation of the unit and required by relevant codes.

It is in Manufacturer/Supplier responsibility to provide all necessary documents for heater firing control system, BMS and start-up/shut-down implementation in to the refinery DCS.

The Manufacturer/Supplier is responsible for SIL level calculation in accordance with PN-EN 61508 and 61511. Fired Heater instrumentation shall be selected based on calculated SIL level.

All instrumentations shall fabricated and installed in accordance with requirements of Grupa LOTOS S.A. specifications series (group) 3000. Requirements of Grupa LOTOS S.A. specification no. 1020 paragraph 4.2.3 shall be met in case instrumentations are installed in explosion hazard zones.

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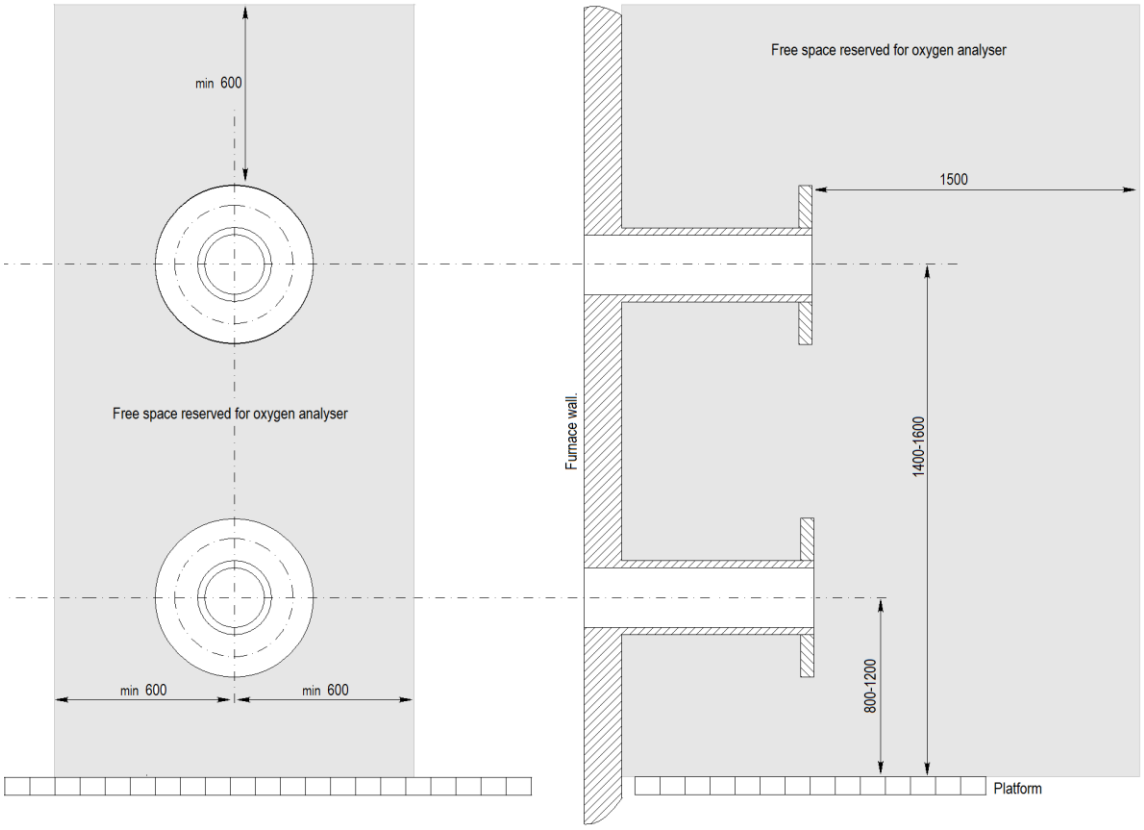
Instrument connections shall be sized according to instrument specification.

5.1 Heater instrumentation

Following instrumentation shall be provided as a minimum:

- Three skin thermocouples per pas - thermocouples shall be located facing the nearest burner at an elevation of 1/4 to 1/3 the radiant box height. One thermocouple shall be located on the outlet tube (refer to Grupa LOTOS S.A. specification no. 3430).
- One skin thermocouple on shield section.
- Temperature indicator with high temperature switch at each pass outlet.
- Temperature indicator with high temperature switch at heater arch.
- Temperature indicator with high temperature switch in the flue gas duct/stack.
- Oxygen analyzer (preferably below convection section) but at suitable distance from the burners and located to avoid possibility of fouling by soot blowers.
- Two separate flanges must be foreseen for oxygen analyser, located at 800-1200 mm and 1400-1600 mm from platform. One flange should be used for on-line oxygen analyser and second flange will be used to place portable zirconia oxygen analyser used for validation purposes. At minimum 600 mm on any direction, and 1500 m at front must be left free of obstacles to ensure working space for analyser and maintenance crew. Oxygen analyser is typically retraced from furnace so minimal free space of 1.5m at front is necessary for this operation (refer to below sketch).
- Draft gauge to indicate negative pressure in the furnace (at floor, arch and above convection).
- Furnace pressure indicator with high pressure switch at heater arch.
- Complete Burner Management System.
- Flame scanners.
- A mushroom head type buttons allowing quick and immediate emergency shutdown.
- Any additional nozzles for instruments connection (number of nozzles and nozzle sizes will be confirmed during detail design).
- Any flanges or nozzles for measuring equipment must be located at level that will assure easy maintenance.

Any other instruments not mentioned above and required by applicable codes shall be included in supply.



5.2 Air supply instrumentation

Following instrumentation shall be provided as a minimum for combustion air system:

- Differential pressure switch if any filter is provided
- Air flow measurement
- Low flow switch for purging purpose
- Minimum flow blow-off valve to prevent surge for large fans
- Fail-open air control valve/vanes with limit switches or position indicator
- Skin thermocouple on cold side of air preheater with low temperature alarm.
- Temperature indicators at the inlet and outlet of the air preheater
- Temperature indicators at the outlet of the air preheater downstream to the by-pass
- Pressure indicators at each side of the air preheater

6 Electrical Requirements

All electrical work, electrical parts, devices, panels and equipment furnished as a part of the heater system shall be in accordance with applicable Grupa LOTOS S.A. specifications and including the scope of supply.

Electric motors to be supplied as a part of the packaged system shall be delivered in accordance with the applicable Grupa LOTOS S.A. specifications.

7 Prefabrication and Erection

The heater shall be delivered to the site as a prefabricated elements assembled to a maximum degree allowed by transport conditions.

Heater shall be supplied complete including: stack, damper, all structural steel parts, refractory, burners, piping and other parts require to constitute a complete heater.

The convection section shall be delivered assembled as a whole together with lining at the fabrication place. Horizontal split for bigger modules is allowed.

All delivered elements shall have unequivocal marking allowing for their identification at site.

8 Inspection

The Inspection and Test Plan (ITP) shall be completed and submitted to Grupa LOTOS S.A. for fixing the notification, review, witness and hold points.

The Manufacturer/Supplier will grant for LOTOS Group S.A. representatives unrestricted access to all steps of fabrication and testing in his own or his sub-suppliers shops and laboratories.

The Manufacturer/Supplier and his sub-suppliers will provide free of charge the necessary assistance for Grupa LOTOS S.A. inspection as manpower, tools, instruments, cranage etc.

All parts of the heater presented for the inspection shall be subject of a previous dimensional check by the Manufacturer/Supplier. The Manufacturer/Supplier shall prepare a dimensional record indicating the actual dimensions of each part and submit it to Grupa LOTOS S.A. before inspection. Any deviations from the specified tolerances shall be clearly marked in this record for clarification.

The parts made available for the inspection shall be free from slag, dirt, oil, welding spatter and other foreign matter.

No protection paint or other filling shall be applied before the equipment has been inspected tested and approved

All loose components included in the scope of supply shall be kept ready for the inspection before dispatch.

Inspection by Grupa LOTOS S.A. shall in no way relieve the Manufacturer/Supplier from the responsibility to meet the requirements of the purchase documents.

The records listed below shall be available for review by Grupa LOTOS S.A. representative at the time of inspection:

- Mill test reports pressure parts. The test reports shall state the specification to which the material complies, the heat, lot or heat number, and the heat treatment (if any) and the results of chemical analysis and mechanical tests.
- Certificates for non-pressure part
- Certificates for bolting material
- Welding procedure specifications, procedure qualification records and welder qualification tests.

- Radiographic films of required radiographic test incl. the expert's assessment and records of the results of any required magnetic particle, fluid penetrant, or other method of examination.
- Charts or other records of required hydrostatic, pneumatic, and other tests.
- Detailed records of heat treatment (post-weld, normalising, heating for forming, etc.).
- Certificates for valves and instrumentation
- Certificates for electrical parts

8.1 Design Check

The design / technical documentation, including strength calculation, of pressure parts / equipment of fired heaters shall be verified and approved by authorized inspection party (Notified Body) to certify conformity to mandatory regulations.

It is the Manufacturer / Supplier responsibility that fired heater steel structure design, including calculations, shall be reviewed, verified and approved by licensed structural engineer in accordance with Polish Building Law.

The compliance of fired heater design with requirements of this specification and purchase order will be verified by Grupa LOTOS S.A.

8.2 Rejection

Equipment or parts thereof and materials entering therein, indicating irremediable or injurious defect, improper fabrication, excessive repairs, or they are not in accordance with the requirements of this specification shall be subject to rejection. They shall be subject to rejection at any time or place by the Grupa LOTOS S.A. authorised representative if such conditions are discovered after acceptance of the items at the Manufacturer/Supplier's shop.

9 Painting and Temporary Corrosion protection

All surfaces of structural steelwork including the exterior surface of air ducts and flue gas ducts shall be shop painted at Manufacturer/Supplier's shop in accordance with Grupa LOTOS S.A. specification No 1190. In duly justified cases structural steelwork may be painted at site. This shall be subject to prior Grupa LOTOS S.A. written approval.

The outside surface of heater and inside lined ducts shall be painted with paints having a maximum application temperature of at least 180 °C.

Plastic caps shall close all nozzles. Wooden plates shall protect flanges. Other parts such as piping components, rotating equipment etc. shall be corrosion-protected or shop painted in accordance with the relevant specifications.

Cabinets, electrical motors and burner casing shall be final coated according to manufacturer standards if not otherwise noted.

10 Documentation

The documentation shall be delivered in the quantity fixed in the Grupa LOTOS S.A. specifications No 6400, 6500 and purchase order documents.

Manufacturer/Supplier shall deliver technical documentation that will cover all drawings, data sheets, operating manuals, manuals and description of components, electrical and instrument documents and brochures necessary for the operating, maintenance, repair and spare parts ordering.

11 Basic Design information required from bidder

The API-560 data sheet shall be completed including description, diagrams and drawings showing the dimensions, materials, lay-out and main characteristics of:

- Tubes, return bends, tube supports and guides, crossovers, manifolds and connections to inlet and outlet lines
- Calculated tube wall thickness; number and location of skin thermocouples
- Combustion chamber(s) (number, arrangement, dimensions, position of observation and inspection doors, etc.)
- Steel structure and casing
- Breaching, stack, damper
- Burners (type, number, characteristics, lay out)
- Convection section cleaning facilities
- Operating conditions: heat absorbed, released at the burners
- Heat transfer rates both maximum and average
- Maximum tube skin temperature
- Maximum inside film temperature
- Temperature of the fluid at the outlet of the convection zones
- Flue gas temperature at the inlet and outlet of the convection section (or at the radiant section outlet if there is no convection)
- Pressure at the burners
- Guaranteed efficiency
- Efficiency expected at 60% of the design capacity
- Battery Limit definition
- Heater and BMS P&ID

12 Relevant documents

Any “Technical Specification” issued by Grupa LOTOS S.A. listed in Contract Files.

13 Norms and standards

Codes and standards listed below form part of this specification. Each publication shall be the latest revision and addendum in effect at the Contract award, unless otherwise specified:

- 97/23/WE (PED) Directive of the European Parliament and of the Council on the approximation of the law of the Member States concerning pressure equipment
- PN-EN 746-1 Industrial thermoprocessing equipment. Common safety requirements
- PN-EN 746-2 Industrial thermoprocessing equipment. Safety requirements for combustion and fuel handling systems
- PN-EN 746-3 Industrial thermoprocessing equipment. Safety requirements for the generation and use of atmosphere gases
- PN-EN-161 Automatic shut-off valves for gas burners and gas appliances
- PN-EN 125 Flame supervision devices for gas burning appliances. Thermoelectric flame supervision devices
- PN-EN-264 Specification for safety requirements and testing of safety shut-off devices for combustion plants using liquid fuels
- PN-EN 61508 Functional safety of electrical/electronic/ programmable electronic safety related system (all parts)
- PN-EN 50156 Electrical equipment for furnaces and ancillary equipment. Requirements for application design and installation
- PN-EN 61511 Safety instrumented systems for the process industry sector (all parts)
- PN-EN-10204 Metallic products - Types of inspection documents
- PN-EN-ISO 13920 Welding - General tolerances for welded constructions - Dimensions for lengths and angles; shape and position
- API 560 Fired heaters for general refinery service
- API RP 535 Burners for Fired Heaters in General Refinery Services
- API 530 Calculation of Heater Tube Thickness in Petroleum Refineries
- API 534 Heat Recovery Steam Generators
- API 536 Post-Combustion NOX Control for Fired Equipment in General Refinery Services
- API RP 556 Instrumentation, Control, and Protective Systems for Gas Fired Heaters
- API RP 573 Inspection of Fired Boilers and Heaters
- ASME B31.3 Process piping
- ASME BPVC ASME Boiler & Pressure Vessels Code – Sections I through X

14 Record of changes

No.	Date	Description	Introduced by
0		This specification entirely replaces the former LOTOS Group S.A. standard No. PR 07 210 with the same title.	B. Kowalewski
1	14.11.2006.	In the point 4.2.1.1. changed working time of the tubes 200 000 h to 100 000 h	B. Kowalewski
2	09-05-2010	Changed point 5.1	P. Skoneczny
3	30-11-2013 (rev.3)	Review, update, standardize and changes to the Standard within scope of order No. OK/990/2012	Editorial board coordinated by T.Wróbel
-	31-08-2015	Page layout corrections, no contents changes.	T. Wróbel