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| KLM Technology Group<br>#03-12 Block Aronia,<br>Jalan Sri Perkasa 2<br>Taman Tampoi Utama<br>81200 Johor Bahru<br>Malaysia | <b>PROCESS DESIGN OF STEAM BOILERS</b><br><br><b>(PROJECT STANDARDS AND SPECIFICATIONS)</b>  |                |

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## SCOPE

This Project Standards and Specifications is intended to cover minimum requirements for process design of field erected water tube boilers.

## REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. ASME (American Society of Mechanical Engineers)
  - PTC-4.1 "Heat Loss Abbreviated Method"
  - ASME "Boiler and Pressure Vessel Code, Section I"
2. ASTM (American Society for Testing and Materials)
  - "Special Technical Publication No. 148"
  - ASTM D-1066 "Standard Practice for Sampling Steam"
  - ASTM D-1125-50T "Standard Test Method for Electrical Conductivity and Resistivity of Water"
3. NAFM (National Association of Fan Manufacturers)
  - "Standard Test Code"

## DEFINITIONS AND TERMINOLOGY

**Air Heater or Air Preheater** - An air heater or air preheater is a heat transfer apparatus through which combustion air is passed and heated by a medium of higher temperature, such as the products of combustion, steam or other fluid.

**Atomizer** - An atomizer is a device used to reduce a fluid to a fine spray, Atomization means are normally either steam, air or mechanical.

**Blowdown** - The drain connection including the pipe and the valve at the lowest practical part of a boiler, or at the normal water level in the case of a surface blowdown. The amount of water that is blown down.

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**Burner** - A burner is a device for the introduction of fuel and air into a boiler at the desired velocities, turbulence and concentration to establish and maintain proper ignition and combustion. Burners are classified by the types of fuel fired, such as: oil, gas or a combination of gas and oil. A secondary consideration in classifying burners is the means by which combustion air is mixed with the fuel.

**Burner Management System** - That portion of a boiler control system associated with the supply of fuel to the burners. This includes the complete fuel train, safety shut-off valves, fuel pressure and temperature limits, burner starting and sequencing logic and annunciation of trouble signals.

**Carryover** - The moisture and entrained solids forming the film of steam bubbles, a result of foaming in a boiler. Carryover is caused by a faulty boiler water condition.

**Combustion Control System** - The portion of a boiler control system associated with the control and maintenance of air/fuel mixtures throughout the operating range of the burner and during changes in firing rate.

**Contractor** - Refers to the persons, firm or company whose tender has been accepted by the Employer and includes the Contractor's personnel representative, successors and permitted assigns.

**Damper** - A damper is a device for introducing a variable resistance for regulating the volumetric flow of gas or air.

**Downcomer** - A tube or pipe in a boiler or waterwall circulating system through which fluid flows downward between headers.

**Draft** - Draft is the negative pressure (vacuum) of the flue gas measured at any point in the boiler, expressed in millimeters of water column (kilopascals).

**Economizer** - A series of tubes located in the path of the flue gases. Feedwater is pumped through these tubes on its way to the boiler in order to absorb waste heat from the flue gas.

**Efficiency, Fuel** - Efficiency, fuel refers to the heat absorbed divided by the net heat of combustion of the fuel as heat input, expressed as a percentage.

**Efficiency, Thermal** - Efficiency, thermal refers to the total heat absorbed divided by total heat input, expressed as a percentage.

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**Excess Air** - Excess air is the amount of air above the stoichiometric requirement for complete combustion expressed as percentage.

**Ignitor** - A term used in industry to denote the device that provides the proven ignition energy required immediately to light on the pilot flame.

**Low Heating Value (LHV)** - The high heating value minus the latent heat of vaporization of the water formed by burning the hydrogen in the fuel.

**Mud or Lower Drum** - A drum or header-tube pressure chamber located at the lower extremity of a water tube boiler convection bank which is normally provided with a blowoff valve for periodically blowing off sediment collecting in the bottom of the drum.

**Pressure Part** - A component that contains pressurized water or steam or a mixture of the two.

**Shop-Assembled Boilers** - Water tube boilers, wholly or partly assembled in the manufacturer's workshop, requiring no further fabrication work on the pressure parts and shipped as one unit. It should be noted that such boilers are sometimes referred to as Packaged Boilers by suppliers.

## **SYMBOLS AND ABBREVIATIONS**

### **SYMBOL/ABBREVIATION**

### **DESCRIPTION**

|      |   |
|------|---|
| ABMA | American Boiler Manufacturers Association.  |
| ANSI | American National Standard Institute.       |
| API  | American Petroleum Institute.               |
| ASME | American Society of Mechanical Engineers.   |
| ASTM | American Society for Testing and Materials. |
| BEDD | Basic Engineering Design Data.              |
| BSI  | British Standards Institution.              |
| BSP  | Burner Start-up Panel.                      |
| CCR  | Central Control Room.                       |
| DCS  | Distributed Control System.                 |
| DN   | Diameter Nominal, in (mm).                  |
| FDF  | Forced Draft Fan.                           |
| HPP  | High Point of Paving.                       |
| ID   | Internal Diameter.                          |
| LHV  | Low Heating Value.                          |
| LLL  | Low Liquid Level.                           |

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|      |  |
|------|--|
| LLLL | Low Low Liquid Level.                      |
| MCR  | Maximum Continuous Rating.                 |
| MFT  | Master Fuel Trip.                          |
| NAFM | National Association of Fan Manufacturers. |
| NPS  | Nominal Pipe Size, in (inch).              |
| ppm  | parts per million.                         |
| PTC  | Performance Test Code                      |
| TDS  | Total Dissolved Solids.                    |
| vol% | Volume Percent.                            |

## UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

## DESIGN DATA

1. Vendor's guarantee of boiler performance shall be based on specified ambient conditions at plant site.

The design shall be proven in practice, rugged and reliable, tenderer shall provide a list of similar installations which have already been built and which are in operation.

Ease of operation, safety, inspection, maintenance, repair and cleaning shall be of major concern in design and arrangement of boilers.

The boilers and auxiliary equipment shall be designed and erected in accordance with the latest edition of section I of the ASME boiler and pressure vessel code, including all published addenda and interpretations thereto. The boiler and all auxiliary equipment listed as being supplied by Vendor shall be suitable for outdoor installation.

2. Boiler and ancillaries shall be capable of continuous 24 hours a day operation between a 36 month statutory shut down period.
3. The boiler supplier shall inform Contractor/Company of the pressure of the feed water required at the inlet to that section of the feed pipework in his supply. He shall provide Contractor/Company with the breakdown of the total pressure requirement, indicating maximum operating pressure of the boiler and the various pressure losses in the feed system, including static head to be overcome.

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4. Boiler shall be designed for the following operating conditions:
- a. Guaranteed net steam capacity, for each boiler at superheater outlet excluding all blow down, heat losses and all steam used for boiler auxiliaries such as fans, soot blowers, burners, etc., as specified on data sheet
  - b. Over design capacity for four hours continuous operation with an interval of not less than 20 hours between periods, Vendor to specify (minimum acceptable 15%). The vendor shall also specify the time required for increasing the load of the boiler from ¼ MCR to full load of MCR.
  - c. Guaranteed turn down ratio, Vendor to specify.
  - d. Minimum thermal efficiency, as specified in the project specification, on fuel gas firing based on LHV.  
The above mentioned boiler efficiency shall be guaranteed under the following conditions:
    - Final superheater/desuperheater pressure.
    - Final superheater/desuperheater temperature.
    - Feed water temperature at economizer inlet.
    - Ambient air temperature at FDF inlet.
    - Ambient air relative humidity.
    - Barometric pressure.
    - Fuel gas temperature.
    - Based on ASME PTC 4.1 heat loss abbreviated method.
    - Continuous blow down rate.
  - e. Superheater (in case desuperheater is not considered) outlet temperature shall be uncontrolled and Vendor shall guarantee the maximum variation in superheater steam outlet temperature throughout the operating range from 40% to full load.
  - f. Guaranteed operation superheater/desuperheater outlet pressure specified on the data sheet (typical boiler data sheet is shown in Appendix A).
  - g. Feedwater inlet temperature specified on the data sheet.
  - h. Purity of produced steam as specified in the project specification in ppm mass (mg/kg) with consideration of ppm mass (mg/kg) of total solids in the boiler water. The boiler manufacturer shall state the maximum TDS in the boiler water at which the required steam purity can be obtained.

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- i. The steam as measured at drum outlet shall have an impurity not greater than 0.02 mg/kg (ppm mass) silica. The wetness of the steam leaving the drum shall not exceed 0.02%.
- j. Heat release (maximum and average) per cubic meters of furnace volume (volume enclosed by the effective heating surface) when firing specified fuels, Vendor to specify subject to Company's approval.

Maximum intensity of heat flow rate in kW/m<sup>2</sup> released in furnace based on effective heating surface (as defined below), Vendor to specify subject to Company's approval.

Effective heating surface is defined as the flat projected area of tubes and extended surface integral with tubes exposed to direct radiation (only first row of tubes in flue gas passes exposed to direct radiation should be counted for calculation of flat projected surface and refractory covered surface shall not be counted).

- k. Superheater, drums and boiler tube system maximum design pressure, Vendor to specify, but a minimum of 300 kPa (3 bar) above operating pressure is required.
- l. Steam drum and boiler tube system maximum design temperature specified on data sheet, superheater design temperature per code.
- m. Total continuous and intermittent blowdowns shall not be more than allowable figure specified in the boiler data sheet of steam generated, Vendor to specify capacity at 100% rating.
- n. Steam for fan drivers specified on the data sheet.
- o. Exhaust steam from fan drivers specified on the data sheet.
- p. Stack temperature, Vendor to specify.
- q. Boiler feedwater and chemical injection specified on the data sheet.

## **SPECIAL DESIGN FEATURES**

### **Drums and Steam Generators**

1. Necessary drum connections shall be provided for chemical cleaning and nitrogen sealing of boilers in addition to connections as required, i.e., steam outlet, safety valves, continuous blowdown, chemical feed, water column level controls, level alarm, feedwater, vent and bottom blowdown, etc. In case of



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necessity for winterization of the boiler, Vendor shall provide steam coils in each lower drum.

2. Suitable internals shall be provided for the distribution of the incoming feed water to ensure a proper distribution of the incoming water along the length of the drum, suitably placed to feed the down comer tubes but not to interfere with the correct function of the water level gages, and also for the chemical and for the collection of the continuous blowdown.
3. Provision for acid cleaning of boilers and nitrogen blanketing of (idle) boilers shall be provided.
4. Adequate provision should be considered for inspection and cleaning of waterwall headers (minimum two, one at each end of header).
5. Steam drums shall be equipped internally with steam separators and scrubbers to ensure that the carryover of total solids from the boiler water shall not exceed the following:
  - 1 ppm mass (mg/kg) up to 65 bar (ga).
  - 0.5 ppm mass (mg/kg) from 65 bar (ga), to 135 bar (ga).
6. In order that drum stability may be evaluated, the boiler designer shall indicate the steam drum water content (effective) at normal, low-level and MCR loading.
7. The boiler designer shall state the minimum and maximum water levels between which the boiler should be allowed to continue operating.
8. Furnace wall, floor and roof tubes shall not incorporate bends or sets sufficiently small in radius to interfere significantly with water circulation. In particular, roof tubes exposed to radiant heat shall be free from bends and sets as far as possible, so as not to upset the division of flow between tubes or bring to a doubtful value the head available to promote circulation in any part of the circuits.
9. Downcomers supplying the furnace wall, etc. with feed water shall preferably be outside the flue gas path. If the downcomers are in contact with the flue gases, the heat transfer shall not significantly affect the circulation head.
10. Tube banks shall be arranged, as far as practicable, to permit access for tube renewal with minimum cutting out of serviceable tubes.
11. The boiler designer shall state the holding time provided by the reserve of water in the steam drum, between "low liquid level" (LLL) and "low-low liquid level" (LLLL), and the Company will approve this time against that required to introduce effectively the standby boiler feed pump. The size of the steam drum may have to be increased to provide a longer period in which to recover water level without incurring the automatic shut down of the boiler.

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## Burners

1. Combination forced draft burners for firing all specified gas, all gasoline, all gas oil, all oil or any combination thereof shall be provided. Atomizing steam facilities for fuel and gas oil (if required) burners should be provided. The fuel on which boiler performance shall be guaranteed shall be specified. Provision shall be made for changing fuel or any one burner without affecting boiler operation in any way. One liquid fuel burner gun and one gas fuel burner shall be provided per each burner, separate tips for fuel oil and gasoline fuel shall be provided. Vendor shall specify the possibility of using single tip for both liquid fuels. Provision shall be made for preventing flue gas leakage when oil burner gun is removed for tip change or cleaning by use of air purge, etc.
2. A fixed gas fired pilot burner, removable for maintenance while the boiler is in operation shall be provided at each burner assembly. It must be suitable to ensure safe and efficient ignition of all fuels specified. Each pilot burner shall be permanently lit when its main burner is in use. the pilot flame shall be visible through the burner peep-hole, at least prior to the ignition of the main flame. The pilot burner shall be proven capable of igniting the main fuels efficiently and of remaining lit under all windbox and furnace conditions likely to be experienced.
3. Each burner shall be sized for 110% of its design load or such that the boiler MCR can be maintained with one burner out of use, whichever is greater. Burner flames shall be horizontal and not parallel with steam drum. Flame shall not impinge on wall or any metal parts.
4. The boiler supplier shall state the heat input of the proposed pilot burners.
5. Each furnace shall be supplied with burners with insulatable forced draft registers with steam atomizing oil units, center fired-type gas units, flexible metallic oil and steam hoses, flexible stainless steel gas hose, oil and steam shut-off valves and oil burner fittings. The oil units shall be equipped with swing check valves and air seals for use in a pressurized type steam generating Unit. The registers shall be equipped with necessary seals. Where gasoline fuel is specified, each burner shall be equipped with an interlocking device on the gasoline and atomizing steam supply complete with valves, interlock discs, piping and flexible joints on gasoline supply lines.

Each burner shall be provided with an electric gas ignitor with complete flame protection system with flame scanners, flame protection relays, interlocks, purge cycle timer, operating switch indicating lights, transformer, safety shut off valves, stainless steel gas hose, air hose, stainless steel gas strainer and air seal.

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One burner holder and wrench assembly shall be provided for each boiler. Steam atomizing oil units for gasoline and one spare gun complete with tip end assembly shall be provided for each boiler. Fuel oil return lines should be equipped with non-return valves. The liquid fuel oil lines should be large enough with low friction factor.

6. The boiler manufacturer shall furnish a burner windbox cut and drilled to accommodate the burners described herein. Windbox shall be complete with necessary supports, division plates and access door, if required.
7. Specification of fuels to be burnt will be indicated for each installation.
8. Number of burners and arrangement of burners shall be submitted to the Company for approval.
9. A complete flame monitoring and safety control system to perform the functions shall be furnished by the Vendor. The system shall be clearly described in the proposal and shall be guaranteed for safe and efficient operation of the boiler. Logic circuitry being proposed shall be included in Vendor's proposal. Burner management systems shall be installed local to the burners, the system shall jointly monitor the burner and boiler to ensure safe start-up and shut-down of burners and boiler. Unless otherwise required by the Company, the system shall, on the pressing of push-buttons, arrange for the whole sequence of burner light-up or shut-down to be automatically carried out with a high degree of safety and reliability. It shall also automatically shut down the burners on identification of a fault condition serious enough to warrant such action, or raise alarms to indicate faults of a less serious nature. Reset facilities shall be provided for both boiler and individual burner trips.

The system shall ensure that the agreed logic on which the sequence of operating functions is based shall not be capable of being interchanged or abridged. It shall be of proven reliability, operating on the stop-check principle where the system can only proceed if the preceding sequence has been completed. A failure to complete a sequence shall operate an alarm and a fault location system will identify the area of malfunction, and where practicable, the fault itself. Separate circuits shall be used so that only those required for actual operation are retained in service, the others maintaining a passive but energized role so that should component failure occur, it can be identified and repaired with the burner in service.

Two main flame detectors shall be fitted to each burner, with any one detector signal arranged to give an alarm and the two signals together to cause lockout of the fuels to the burner.

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The system shall be complete, without any areas of split responsibility, specially regarding furnace purging and boiler safety.

10. Separate buttons shall be provided to initiate purge and individual burner start-up, and also for individual burner and boiler shut-down.
11. Local and control room panels shall provide all the information necessary to enable the operators to ascertain the condition of each burner and all the associated functions of fans, purging, register positions, fuel valve positions and safety interlocks.
12. The boiler designer shall justify any atomizing steam consumption greater than 0.5% of boiler MCR
13. Burner minimum turndown ratio shall be 33% for liquid fuels and 10% for fuel gas, with the boiler supplier's guaranteed low O<sub>2</sub> in the flue gas maintained over the ranges mentioned below.
14. Boilers having four or more burner assemblies for use with fuel gas or commercial grade liquid fuel shall operate satisfactorily with combustion conditions as near stoichiometric as practicable. The excess air shall not exceed 3% for liquid fuels and 5% for gaseous fuels. Over the full operating range of the boiler the following O<sub>2</sub> vol. percentage in flue gases should be achieved with liquid fuels:
  - 0.5% O<sub>2</sub> between 70-100% MCR
  - 1.0% O<sub>2</sub> between 25-70% MCR
  - 5.0% O<sub>2</sub> between 0-25% MCR
15. Carbon monoxide in the flue gas shall not be greater than 0.01% by volume at specified O<sub>2</sub> content in flue gases.
16. Duplex type filters, or two filters in parallel, of 125 micrometers (.005 in) mesh in monel, shall be provided in the gas supply for each convenient group of pilot burners. The pipework from the strainers to the pilot burners shall be in stainless steel.
17. Horizontal distance between main burners and the vertical distance between rows of burners shall be such as to facilitate discrimination between individual flames by the proposed flame detectors.
18. Burner viewing ports shall be fitted to each burner assembly front plate in such a position as to afford an adequate visual examination of the pilot burner and the root of the flame.