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Atomai Feasibility Study

Power Plant Technical Specification

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1 Introduction

MSMS (Mauritania Saudi Mining and Steel Company S.A) known as “Takamul” is a Joint Venture between the Saudi company SABIC and the Mauritanian government agency SNIM (Société Nationale Industrielle et Minière). Takamul plans on developing the ATOMAI iron ore mine located 35 km west of the city of Zouerate and 8 km north of the village of F’Derik in the Tiris Zemmour area of north-east Mauritania. The project aims at producing Direct Reduction Pellets (DRP) from magnetite ore containing 35-37% iron. The mine will be of the open-pit type using conventional mining methods. The project will produce 5 million tons per year of pellets during Phase 1 to be expanded to 10 million tons per year in Phase 2 of the project. It is expected that the project will come into production in year 2022.

The processing of the ore will be split between two plants: A dry beneficiation plant located at the Atomai site and a wet beneficiation and pelletizing plant located in the Nouadhibou peninsula. The two plants will be linked by an existing 700-km railway property of SNIM. Pellets will be exported from the SNIM Port at Nouadhibou to world markets.

The present document pertains to the equipment to be designed, manufactured and supplied for the Atomai project.

2 Scope

This specification details the technical requirements for the design, fabrication, supply, testing, delivery, erection, commissioning and guarantee of a reciprocating engine, heavy fuel oil (HFO) fuelled power station.

Detailed requirements for particular equipment are given in data sheets associated with this Technical Specification.

It is not intended that Manufacturers depart from their standard design. However, any deviations from these specifications shall be listed and explained in the Supplier's proposal. The lack of such a listing shall indicate that no such deviations exist.

3 Codes and Standards

3.1 General

The material and equipment supplied shall be new and comply in all respects with this specification. Except where otherwise specified herein, they shall comply with the latest revision, in force at the date of issue of the enquiry, of the relevant standards listed below.

However, in order to allow flexibility in design and sourcing of equipment, standards shall be applied with the option of Suppliers to offer alternatives to other standards providing approval is obtained from the Purchaser.

Where conflict exists between different Codes, Standards or Regulations, the more onerous requirements shall apply.

The mechanical and electrical systems shall be designed, manufactured, constructed and installed according to the appropriate extent of the following standards.

Table 1 Standards

Description	Code
Engine test run	ISO 15550
Vibrations	ISO 8528 part 9
Design	EN 12100
Pipe design calculations	EN 13480 and DIN 2413
Welding	EN 1011
Stair and platforms	ISO
Dimensional standards for installation materials (pipes, beams, etcetera)	DIN, ISO, SFS and EN
Vertical tanks	API 650 or EN 14015
Horizontal tanks	EN 12285, excluding nozzle location
Pressure equipment	PED 97/23/EC
Typical material standards	DIN, SFS and EN
Generator	IEC 60034
Transformer, oil type	IEC 60076
Transformer, dry type	IEC 60726
MV switchgear	IEC 62271-200 or IEC 62271
LV switchgear	IEC 60439-1
Enclosure protection	IEC 60529
WOIS workstation hardware	IEC 60950
WOIS workstation software	Applicable parts of VDE 3699
Earthing network	IEEE 80
Control panels	IEC 60439-1
PLC software	IEC 61131-3
Lighting installation	IEC 60598
Fire detection	EN 54
Protection of structures against lightning	IEC 1024

4 Operating Conditions

4.1 General Conditions

All equipment will be required to operate continuously at full load for 24 hours per day, 365 days per year, with a lifespan of 20 years (24 years?) or more under the climatic conditions detailed in the data sheets.

All equipment shall be designed to perform this duty safely and without being attended.

4.2 Site Conditions

For the purpose of design, the service conditions for site that are specified in the document Site Conditions Design Criteria – 101901-DC-0101 will apply.

4.3 Dust

Air filters design shall take into account the sand/dust winds and shall be calculated for high dust conditions. Power plant design shall take into account and comply with Dust Management Design Criteria (doc. No. 1201901-DC-0502).

4.4 Hazardous area classification

Wherever practical, electrical or control equipment shall not be located inside a hazardous location.

All electrical apparatus and material that must be installed inside a hazardous location shall be rated for the proper class and zone of the hazardous location with respect to IEC 60079 and IEC 61241. The only potentially hazardous locations for the project are related to fuel handling and explosives storage.

5 Power Generation Equipment

5.1 Engine

5.1.1 General

The engine and generator shall be mounted on a common base frame. The common base frame shall be flexibly mounted on a concrete foundation by means of steel springs.

The engine shall be of the four stroke, direct injected, trunk piston, turbocharged and intercooled design.

The engine shall be designed for continuous operation at any load between 30 - 100% and can be started and stopped on heavy fuel oil in emergency situations. It shall be noted however that normal procedure for starting and stopping the engines is to use light diesel No2 to start and prior to normal shut down.

5.1.2 Engine Platforms

Partly prefabricated maintenance platforms shall be provided for easy maintenance and access to the engine. To minimize vibrations, the platforms and stairs shall be freestanding on the floor and not connected to the engine.

5.1.3 Engine block

The engine block shall be made of nodular cast iron and shall be of stiff and durable design to absorb internal forces. The engine block carries the under slung crankshaft. The nodular cast iron main bearing caps shall be fixed from below by two hydraulically tensioned studs. The caps shall be fixed sideways by hydraulically tensioned horizontal side studs. Together they shall provide a rigid crankshaft bearing. The inlet air receiver and the cooling water and lubricating oil channels shall be integrated into the engine block. The engine shall be provided with an oil sump, mounted against the engine block and sealed by an o-ring gasket.

5.1.4 Crankshaft

The crankshaft shall be forged from one piece of high tensile steel. Counterweights shall be fitted on the crankshaft webs. A high degree of balancing shall result in an even and thick oil film for all bearings. The main bearings and the crankpin bearings shall have a steel backing and a soft running layer with excellent corrosion resistance.

5.1.5 Connecting rod

Connecting rods shall be of the drop forged, totally machined type. Connecting rods shall be of three-piece design with a horizontal split at the crankpin bearing and a flanged connection to the rod. The oil supply for the piston cooling, gudgeon pin bush and piston skirt lubrication shall take place through a single drilling in the connecting rod.

5.1.6 Cylinder liner

Cylinder liners shall be centrifugally cast iron with special alloy elements to create wear resistance and high strength. Liners shall be of stiff bore cooled collar design and supported symmetrically at the top of the engine block. They shall be equipped with an anti-polishing ring at the top, preventing bore polishing.

5.1.7 Piston

Each piston shall consist of an oil cooled steel crown bolted on to a nodular cast iron skirt. The piston crown shall have two compression rings and one oil scraper ring. The piston skirt and cylinder liner shall be lubricated by a patented pressurised lubricating system utilising lubricating nozzles in the piston skirt. This system shall ensure excellent running behaviour, and constant low lubrication oil consumption.

5.1.8 Cylinder head

Cylinder heads shall be made of nodular cast iron. Ample height and the stiff design shall allow only four hydraulically tightened studs to fix the cylinder head on to the cylinder block/liner. Each cylinder head shall have two inlet and two exhaust valves, all equipped with rotators. The exhaust valves shall be made of Nimonic and the exhaust valve seat rings shall be water cooled.

5.1.9 Camshaft and valve mechanism

The cams shall be integrated in the drop forged camshaft. The bearing journals shall be made of separate pieces that shall be fitted to the camshaft sections by means of flanged connections. The design shall allow lateral dismantling of the camshaft sections. The camshaft bearings shall be located in integrated bores in the engine block casting. The camshaft shall be driven from the crankshaft through a fully integrated gear train.

5.1.10 Fuel Oil System

All the high pressure fuel injection equipment shall be located in a closed compartment with a removable cover providing maximum reliability and safety for preheated heavy fuel.

The fuel system shall comprise the following equipment:

- Low pressure pipes made of steel
- High pressure pipes, double wall with common leak alarm
- Injection pumps, individual for each cylinder
- Pneumatic stop cylinder at each injection pump
- Fuel injector in each cylinder
- Fuel limiter to limit smoke at start up
- Solenoid valve for fuel limiter at start up

5.1.11 Lubricating Oil System

The lubricating oil system shall lubricate the main moving parts of the engine and also cool the piston tops. The engine shall have a wet lubricating oil sump.

The lubricating oil system shall comprise the following equipment:

- Pipes made of steel
- Oil sump of wet type
- Engine driven main lubricating oil pump with pressure regulating valve
- Pre-lubricating pump with electrical motor
- Lubricating oil cooler
- Lubricating oil thermostatic valve
- Lubricating oil automatic back-flushing fine filter, with integrated safety filter
- Centrifugal filter to clean the back-flushing oil from the automatic filter
- Start-up/running in filters
- Non-return valves in oil supply pipes
- Crankcase ventilation pipe

5.1.12 Starting Air System

The engine shall be started by means of compressed air with nominal pressure of 30 bar. The start shall be performed by direct injection of air into the cylinders through starting air valves in the cylinder heads.

The starting air system shall comprise the following equipment:

- Pipes made of steel
- Starting air master valve, electrically and manually operated
- Start blocking valve to prevent starting when turning gear is engaged

- Starting air distributor
- Starting air valves in A-bank cylinder heads
- Air container for emergency stop system
- Flame arrestors

5.1.13 Cooling Water System

The engine cooling system shall be divided into three circuits, the jacket cooling circuit, the 1st stage charge air cooler circuit and the 2nd stage charge air cooler circuit.

The cooling water system shall comprise the following equipment:

- Pipes made of steel
- Engine driven pump for jacket cooling circuit
- Engine driven pump for low temperature cooling circuit
- Non-return valves after circulating pumps

5.1.14 Combustion air system

The compressor side of the turbocharger shall feed air into the cylinders via the charge air cooler. The engine shall be equipped with one turbocharger per cylinder bank. The turbocharger shall be of the axial turbine type.

The combustion air system shall comprise the following equipment:

- Compressor on the turbocharger
- 1st stage charge air cooler
- 2nd stage charge air cooler
- Fresh water cleaning device for the compressor

5.1.15 Exhaust Gas System

The engine mounted exhaust gas pipes shall be made of cast iron, with separate sections for each cylinder. Stainless steel bellows shall be installed between the sections to absorb heat expansion. The pipes shall be fixed by brackets, but shall be free to move axially. The engine exhaust gas pipes shall be fully covered by an insulation box.

The exhaust gas system shall comprise the following equipment:

- Single Pipe Exhaust System (SPEX) exhaust manifold with bellows
- Flexibly mounted insulation box
- Turbine on the turbocharger
- Fresh water turbine washing system

5.1.16 Speed & Load Regulating System

Speed control of the engine shall be provided by using an electronic governor and a hydraulic actuator mounted on the engine. The electronic governor shall be provided with a starting fuel limiter and load ramp controller which shall assure that the air to fuel ratio shall be kept within acceptable limits at starting and when the load setting is changed, thus limiting smoke during start-up and loading. The engine shall have an overspeed protection system, working independently from the speed governing system.

The engine shall be provided with the following control and protection equipment.

- Pneumatic starting fuel limiter and load ramp controller
- Electro-pneumatic over speed trip device
- Speed measuring system, with magnetic pick-ups for engine an turbocharger speed

5.1.17 Temperature sensing

Temperature measurements shall be fitted on the engine to read the following temperatures:

- Fuel oil before the engine
- Lubricating oil before lubricating oil cooler
- Lubricating oil after lubricating oil cooler
- Cooling water before engine
- Cooling water after turbocharger
- Cooling water after engine
- Cooling water before the charge air cooler
- Cooling water after charge air cooler
- Cooling water after the lubricating oil cooler
- Charge air in the air receiver
- Exhaust gas after each cylinder

5.1.18 Other Included Items

The following shall also be included:

- Flywheel with fixing bolts
- Electrical motor driven turning device
- Counter flanges for pipe connection
- Indicator valves in the cylinder heads
- Safety valves in cylinder head
- Terminal box for electric cables
- The engine shall have one coat of priming paint and one coat of finishing paint

5.2 Generator

5.2.1 General

The generator shall be synchronous, three-phase, brushless, salient pole type.

The generator shall be designed to operate together with reciprocating engines. The stator frame shall be constructed with a rigid welded steel structure. The stator core shall be built of thin electric steel sheet laminations. The rotor shall consist of a shaft and salient pole type main revolving field. The generator should have a tight fit between the coils and the stator core to achieve exceptional thermal conductivity and hence very high efficiency.

5.2.2 Terminals

The six stator winding ends shall be brought to terminal boxes on the generator sides. Monitoring and auxiliary equipment terminal boxes shall be separate.

5.2.3 Damper winding

The generator shall include a damper winding for parallel operation with other generators and/or separate power grid.

5.2.4 Shaft and bearing

The generator shall be horizontally mounted and include two sleeve bearings. The generator rotor shall be designed to minimise the effect of torsion rotor oscillations due to system disturbances and rapid load changes.

5.2.5 Excitation

The exciter shall be a brushless type with a rotating armature/rectifier assembled on the same shaft as the main generator rotating armature. The exciter field shall be controlled by the automatic voltage regulator (AVR). The rectifiers shall be silicon diode type in a full wave bridge arrangement. The rotating armature and stationary field of the exciter shall be insulated with Class F materials.

5.2.6 Cooling

The generator shall be air cooled. A fan mounted on the generator shaft shall take cooling air from the engine hall, through washable filters, and pass it through the generator.

5.2.7 Automatic voltage regulator

The automatic voltage regulator (AVR) shall be of a completely solid state type for controlling generator voltage and reactive power by means of controlling the exciter field. The regulator shall control the generator exciter field as required to maintain a constant and stable generator output voltage. (The AVR shall be installed in the engine generator set control panel).

The AVR should adhere to the following:

- Voltage regulation accuracy ± 0.5%
- Within power range 0 – 100%
- Within speed range 95 – 105%
- Voltage setting range 90 – 110%

5.2.8 Flexible coupling

A flexible coupling between the engine flywheel and the generator shall transmit the torque from the engine to the generator. The use of a flexible coupling shall prevent the crankshaft from being loaded by external bending forces. The elements in the coupling shall be made of rubber.

5.3 Base Frame for Engine and Generator

5.3.1 Common base frame for engine and generator

The engine and generator shall be rigidly mounted on a common base frame. The base frame shall be of rigid welded steel box construction, and shall facilitate straightforward and fast installation and alignment of the engine and generator at site.

5.3.2 Steel springs

Steel spring type vibration isolation units shall be installed between the common base frame and the concrete foundation block. The number of steel spring units for each type of generator set shall be determined by the weight of the generating set and an analysis of the natural frequency of the rigid body. A fitting plate shall be installed between the common base frame and the steel spring packages to adjust to the level of the surface of the foundation block.

5.3.3 Fastening equipment

Equipment for fastening the engine and generator to the common base frame, including bolts nuts, washers and steel chocks shall be provided.

5.4 Connections and Auxiliary Systems

5.4.1 Flexible connections between engine and external piping

Flexible hoses and bellows shall be provided for installation between the generating set and external piping systems, to minimise the transmission of engine vibrations to the plant piping systems.

Flexible connections shall be supplied for the following auxiliary systems:

- Starting/control air
- Cooling water
- Lubricating oil
- Exhaust gas
- Fuel
- Crankcase ventilation

5.4.2 Mechanical Auxiliary Systems

The proper function of the stationary power plant shall depend on the mechanical auxiliary systems. The proposed systems should be optimised for this particular application. The function of these systems shall be to provide the engine with fuel, lubricating oil, starting air, cooling water, and charge air, of the required quantity and quality, as well as to dispose of exhaust gases in a proper manner.

Typical modules include:

- Engine module including:
  - Fuel oil filter
  - 1 Fuel booster pump

- 1 Return fuel pump
- 1 Fuel oil cooler
- 1 Return fuel tank
- 1 Pre heating unit
- 1 Thermostatic valve high temperature water system
- 1 Thermostatic valve low temperature water system
- 1 Pressure increasing pump
- 1 Steam heater
- 1 Piping and insulation
- 1 Valves and gauges
- 1 Module control panel

- Exhaust gas module including:
  - 1 Low temperature expansion tank
  - 2 Charge air silencers
  - 1 Exhaust gas branch pipe
  - 1 Piping and insulation
  - 1 Oil mist separator

Where practical, auxiliary systems shall be prefabricated modules to secure installation quality and reduce erection time.

5.5 Fuel System

5.5.1 General

The main function of the fuel system is to provide the engine with fuel at correct flow, pressure and degree of purity.

5.5.2 Light Fuel Oil System

Light Fuel Oil System shall be used in case of operation disturbances and flushing of the system before maintenance work, before longer stoppages and during start up when the HFO system has not been heated to operation temperature.

A LFO day tank shall be provided for approximately 8 hours of full operation of all engines.

In addition to the LFO day tank, the main LFO storage tank with a capacity as described in the data sheets shall be included in the power plant perimeter.

5.5.3 Heavy Fuel Oil System

Heavy Fuel Oil shall be the main fuel for the power plant. A preheated engine can be started directly on HFO provided that the fuel has been circulated through the fuel system and has achieved the correct temperature and pressure. The engine shall have the ability to be stopped on HFO provided that the fuel circulation can be restarted after the outage or the external system has to stay in operation i.e. fuel must be circulated through the stopped engine continuously for heating purposes.

A buffer tank shall be provided as an intermediate tank for heavy fuel oil before the fuel goes to a separator unit. The buffer tank shall ensure constant temperature and suction height for the fuel oil separators and thus it shall improve the fuel oil cleaning process.

Centrifugal separators shall be installed to remove water and solids from the fuel. The separator unit shall receive fuel from the buffer tank and send clean fuel to the day tank.

A HFO day tank shall be provided for approximately 8 hours of full operation of all engines.

In addition to the HFO day tank, the main HFO storage tank with a capacity as described in the data sheets shall be included in the power plant perimeter.

The HFO fuel specification which will be supplied for the operation of the power plant is described in Appendix 1.

5.5.4 Natural Gas System

Power plant shall have the possibility to convert to natural gas with minimum interventions and interruptions in its operation. Supplier shall make sure that all systems (engine, turbocharger, injectors, etc.) are suitable for dual operation.

5.6 Lubrication oil system

The lubricating oil system shall provide required lubrication for all moving parts on the engine. It shall consist of the engine related lubricating oil system which handles the cooling and filtration of the lubrication oil and the plant related lubricating oil system, with storage of new and old lubrication oil.

Each lubricating oil system shall consist of:

- Lubricating oil separator unit consisting of:
- Lubricating oil storage tank for fresh oil
- Separator cleaning unit
- Lubricating oil service tank
- Mobile Lubricating oil transfer pump
- Stationary Lubricating oil transfer pump
- Lubricating oil storage tank for used oil

5.6.1 Lubricating Oil Separator Unit

Centrifugal separators shall be installed to remove water and solids from the lubricating oil. The separator unit shall consist of:

- A separator delivery pump
- Single strainers on pump suction side
- Steam heater for the lubricating oil
- Sludge tank
- Sludge pump
- Steel frame

- Local control panel for manual and automatic operation
- Set of interconnection pipes, flanges, seals and valves

5.6.2 Separator cleaning unit

Separator cleaning unit is a device for cleaning separators without dismantling. As the cleaning time can take typically 2-4 hours, cleaning shall take place without stopping the engine(s).

The cleaning unit shall not prolong the service intervals. Normal service intervals shall apply, but the unit shall keep the separating efficiency high between the intervals.

5.6.3 Lubricating Oil Service Tank

The function of the lubricating oil service tank shall be to provide for intermediate storage of engine lubricating oil during maintenance of the engine.

5.6.4 Lubricating Oil Transfer pump unit (Mobile)

The function of the transfer pump unit shall be to pump lubricating oil to and from the engine when topping up or changing oil, or to transfer oil to and from drums as needed. The transfer pumps and auxiliary equipment shall be built on a wheeled dolly.

5.6.5 Lubricating Oil Transfer pump unit (Stationary)

The function of the transfer pump unit shall be to pump lubricating oil from the storage tank to the engines when topping up or changing oil. The transfer pumps and auxiliary equipment shall be built on a steel frame, to form a compact skid unit.

5.7 Compressed Air System

5.7.1 General

Compressed air shall be used for starting the engines and for control and instrument air.

5.7.2 Starting Air Bottle

Starting air shall be produced by the starting air compressor unit. Compressed air from the starting air unit shall be stored in starting air bottles until it is used for starting the engine. The pressure equipment shall be designed, manufactured and tested according to the European Union directive 97/23/EC “Pressure Equipment Directive”.

5.7.3 Starting Air Compressor Unit

The starting air compressor unit shall be dimensioned to fill the starting air bottle(s) with required air for 2-3 start attempts per engine in 60 minutes. The components shall be built on a steel frame, which forms a compact skid unit.

5.7.4 Instrument Air Compressor Unit

The instrument air compressor unit shall produce control, instrument and working air. The compressed air shall be stored in the built-on air bottle until it is distributed to the different consumers.

The instrument air compressor and related equipment shall be built on a common frame to form a compact unit.

5.8 Cooling System

The main task of the cooling system is to provide adequate cooling of critical engine components such as cylinder jackets, cylinder heads and turbochargers as well as to cool the lubrication oil and charge air entering the cylinders after it has been compressed by the turbocharger.

The engine cooling water cools the low temperature charge air cooler, lubricating oil cooler, high temperature charge air cooler and engine jackets in a common single-circuit radiator.

5.8.1 Cooling Radiator

The engines shall be cooled with remote mounted, horizontal type radiators with electrically driven induced draft fans. Radiators shall be supplied with railings and inspection ladder.

Recommended cooling radiator fins design is described in Appendix 2.

5.8.2 Maintenance water tank unit

During maintenance of the engine, cooling water from the engine shall be drained and stored in the maintenance water tank and shall be pumped back after maintenance. The maintenance water tank shall also be used for mixing chemicals which are needed for the engine cooling water.

5.8.3 Piping and valves maintenance water system (set)

Pipes, valves, flanges and gaskets for the plant maintenance water system up to the interconnection point shall be included.

5.8.4 Piping and valves cooling system inside engine hall

All necessary pipes, valves, flanges and gaskets for the engine cooling water system up to the interconnection point shall be included.

5.9 Charge Air System

5.9.1 General

The charge air filter shall protect the engine against impurities in the inlet air and the charge air silencer shall reduce the air intake noise from the engine.

The filtering system shall be of a robust industrial design equipped with self-cleaning air filters.

5.9.2 Ducting charge air system

This shall include all necessary ducts, flanges, gaskets, bolts and nuts for the engine charge air system.

5.10 Exhaust System

5.10.1 General

The exhaust gas of the engine shall be discharged at the required height through the exhaust gas silencer and stack pipe.

5.10.2 Exhaust gas silencer

The exhaust gas silencer shall reduce the noise emission from the engine exhaust outlet. Location of the silencers shall not impede maintenance of the generating unit.

5.10.3 Bellows for exhaust gas silencer

The expansion bellows shall isolate the exhaust ducting from vibrations and shall also allow for thermal expansion.

5.10.4 Ducting exhaust gas system

Ducting for the exhaust gas system between the engine and the exhaust gas stack shall be included.

5.10.5 Bellows for exhaust gas ducting

Expansion bellows shall isolate the exhaust ducting from vibrations and also allow for thermal expansion.

5.10.6 Insulation exhaust gas ducting

Insulation material and cladding shall be included for the exhaust gas ducts inside the building and in accessible places with a surface temperature over 60 °C up to the exhaust gas stack.

5.10.7 Exhaust gas stack pipe

The exhaust gas of each engine shall be discharged through an individual exhaust gas stack.

5.11 Oily Water System

5.11.1 General

The function of the oily water system shall be to collect the oily water produced in the power plant, and to separate it into treated water and sludge. The treated water can be mixed with other effluent flows before discharging from the power plant. The sludge shall be collected for further disposal.

5.11.2 Oily Water Transfer Pump

The purpose of the oily water transfer pump unit shall be to transfer the oily water from oily water collecting sumps to an oily water buffer tank. The pump shall be designed for pumping oily water which may contain some particulate matter.

5.11.3 Oily Water Buffer Tank

The oily water buffer tank shall be used for collection and storing of oily water prior to treatment.

5.11.4 Oily water feed pump unit

The oily water feed pump shall be installed between the oily water buffer tank and oily water treatment unit. The control of this pump shall be integrated in the control panel of the oily water treatment unit.

5.11.5 Oily water treatment unit

The plant shall be equipped with a skid-mounted oily water treatment unit designed for continuous operation. The system shall be based on two stage dissolved air flotation system. The purpose of the first stage shall be to separate most of the free oil and heavier solids from water. The second stage shall be used for removing residual oil and impurities from the water. The oily sludge and solids removed from the water shall be pumped to the plant sludge tank.

Chemicals shall be added to the stage two to achieve better treatment result. The chemical dosing system shall contain dosing pumps for coagulant, flocculants and NaOH. The Main Components of the system shall be:

- flotation basin for removal of free oil (pre – treatment)
- flotation basin after chemical addition
- Set of interconnecting piping, valves and necessary gauges and sensors
- Pump for transfer of oily sludge and separated bottom solids
- Pump for transfer of pre-treated water to the stage two
- Buffer tank or basin for separated oil with level controllers
- Intermediate tank or basin for pre-treated water with level controllers
- Discharge pump for treated water
- Activated Carbon filter for final polishing of the effluent
- Set of heating equipment
- Set of pumps for chemical dosing
- Local control panel

5.11.6 Sludge Tank

The sludge tank shall be used to store sludge consisting of oily and solid compounds with free and emulsified water.

5.11.7 Sludge Transfer Pump Unit

The purpose of the sludge transfer pump shall be to transfer the sludge from the sludge tank to a tank truck. The pump shall be specially designed for pumping sludge.

5.12 Heat Recovery System

5.12.1 Steam Generation System for Fuel Heating

The pressure equipment shall be designed, manufactured and tested according to the European Union directive 97/23/EC “Pressure Equipment Directive”.

The steam generation system shall generate steam to be used for fuel heating in the power plant. Steam shall be generated by recovered waste heat from the engine exhaust gas. A standby fuel fired boiler shall be supplied for backup use. The system shall be designed based on an “N+1 redundancy principle” including the fuel fired boiler.

Steam shall flow from the heat recovery boilers to a steam header for distribution to the steam consumers in the plant. A non-return valve on the steam outlet of the drum shall prevent backflow when the boiler is not in use. Condensate shall be collected in the feed water tank and returned to the boilers by the feed water pumps.

A fuel fired boiler shall be provided to generate steam when the engines are not running or when the exhaust gas boilers require maintenance.

The exhaust gas boiler shall be a horizontal/vertical smoke tube type. The expansion bellows shall isolate the exhaust ducting from vibrations and also allow for thermal expansion.

Steam from all the boilers shall be collected to the steam header and forwarded onwards to the steam consumers. Shut-off valves shall be installed on each incoming and outgoing line from the steam header. The steam header shall also function to separate possible water droplets in the steam and drain them to the condensate return system.

Dirty washing water from the boilers shall be collected in the boiler washing water tank.

The boiler washing water pump shall transfer dirty water from the boiler washing water tank to the plant's oily water system.

5.13 Waste Oil Disposal

A waste oil tank of capacity of not less than seven days storage at full load operation complete with transfer pump shall be installed in the tank farm,. The pump shall be arranged to take suction from each engine sump and each lube oil centrifuge sludge tank. Transfer pumps shall be provided to transfer the contents of the waste oil tank to the waste oil incinerator.

The waste oil tank shall be of welded steel construction, designed for outdoor installation, and shall be complete with all connections, level gauge glass, and hardware as required.

5.14 Waste Oil and Sludge Incinerator

The power plant shall be equipped with a waste oil incinerator capable of destroying the waste material produced by the fuel and lube oil centrifuges, and the periodic replacement of lube oil. The incinerator shall be a modular type with integrated control and safety system. The incinerator shall be capable of processing the full volume of the waste oil storage tank in not more than 48 hours.

The incinerator shall limit the emissions from waste processing to not more than the following limits:

- particulate concentration of100 mg/Nm2) corrected to 7% oxygen
- average opacity is 1% (not visible)

The incinerator shall operate with at least the following characteristics:

- minimum reduction efficiency of 99.5% by weight
- The furnace residence time shall be 2 seconds at 850°C

The incinerator shall be designed to use Light Diesel No2 or propane as the start-up and stabilizing fuel. The incinerator should operate without such fuel once stable combustion of the waste oil is established.

The incinerator shall be installed in a separate building adjacent to the power plant

6 Fire Protection System

6.1 General

Fire protection system requirements shall depend on the applicable local codes and requirements of the Owner's insurance company. Systems and devices listed in this technical specification have been specified in spirit of the standards mentioned below. If local codes or the insurance company requirements call for additional equipment or material, it shall be taken into account in the final design. The stand pipe system inside the power house shall follow "NFPA14 class II stand pipe system" requirements. Additionally, mobile foam units shall be provided. For immediate action against small local fires, the power house shall be equipped with a number of 6 kg and 12 kg dry powder extinguishers at strategic locations, and 5 kg CO_2 extinguishers for electrical fires (spacing as per NFPA10).The fire main shall be built using "NFPA24 Private Fire service main" as a design guideline.

The fire water requirements for the power plant will be supplied from the process plant main fire protection ring at the interconnect point.

Although the protection system philosophy shall be based on widely recognized NFPA standards, piping and equipment may still follow standards used by the fire protection equipment supplier.

The plant should be subdivided into separate fire areas for limiting the spread of fire, protecting personnel, and limiting the consequential damage to the plant. Fire areas should be separated from each other by fire barriers, spatial separation, or other approved means. The design philosophy described above aims for avoiding interruption of power generation due to false alarms and failures in automation system — and shall be based on the following assumptions:

- Skilled personnel attend the Power Plant 24 hours a day.
- The personnel operating the plant is trained in correct operation procedures on regular basis
- The plant, including installed fire protection equipment, is well maintained and kept in good order. The equipment is periodically tested.
- Maintenance work, including welding and cutting, shall be done with appropriate precautions and instructions

6.2 Fire detection system

The fire alarm system shall be designed considering the following basic principles:

- The fire alarm centre shall be placed in a continuously manned room (the control room).
- The supervised rooms should be divided into alarm zones to ease locating the fire.
- Every room must be provided with a suitable amount and type of detectors.

Alarm bells, sirens and flashing lights shall be situated so that they can easily be heard or seen.

6.2.1 Fire alarm zones

The purpose of fire alarm zones is to group the fire detectors in order to ease the fire location at an alarm.

At least the following areas should be defined as separate fire alarm zones:

- Separate buildings
- Separate floors (except stairways which may encompass several floors)
- Rooms separated by fire walls
- Areas of different fire classes
- Rooms or areas of essentially different heights
- Rooms that cannot be accessed without passing through other zones

6.2.2 Type of detectors

The basic principle is to install the type and amount of fire detectors that detects fires without causing false alarms during normal operation conditions.

Optical smoke detectors shall be used in engine room, auxiliary space, switchgear rooms, offices, stores and control rooms. In workshops and similar rooms, where smoke may appear as a result of normal use of the room, differential maximum heat detectors shall be used.

6.2.3 Manual call points

In a manual alarm device, the fire alarm shall be activated with a push button, protected with a cover that can be crushed.

Push buttons for activating fire alarms manually should be placed close to each exit route and close to the fire alarm panel or alarm centre. Each fire detection loop will have at least one push button. There will be at least one manual call point within 30 meters from any spot in the buildings.

6.2.4 Fire detection loops

The fire detectors and fire call buttons shall be located along one or more closed loops, starting and ending in the fire alarm centre. Each detection loop shall be partitioned by a number of disconnecting devices. At a possible line break or short circuit on the loop, the faulty section shall be isolated at the two closest disconnecting devices — while the other detectors on the loop will stay in contact with the fire centre.

6.2.5 Alarm signalling system

The following types of alarm signalling devices shall be used:

- Alarm bells
- Flashing lights (mandatory in engine hall and auxiliary space)
- Alarm sirens (where feasible)

Table 2 Principles for placing alarm signal devices.

Engine Room	Visual alarm devices (flashing light) are placed so that they can be seen in all locations where people stay more than temporarily
Control Room	One audible alarm device (alarm bell)

Other Rooms	Audible alarm devices are placed so that they can be heard in all rooms where people stay more than temporarily
Outdoors	One audible alarm device on each side of the power house is installed. Additional alarm devices shall be provided when there are other buildings or other obstructions which may limit the hearing of the alarm

6.2.6 Fire alarm signalling loops

All alarm devices in the plant should be activated at a fire alarm. (Exception: alarms clearly meant only for separated area or building not having immediate impact on plant operation).

The fire alarm loops shall be arranged so that a fault message is obtained at cable break or short circuit.

6.2.7 Fire alarm centre power supply

There will be at least two independent power supplies:

- 230 VAC taken from the LV switchgear
- One or more batteries (generally 24 VDC) with battery charger.

Each of them must be able to feed the power required when the system is in alarm state and the current for 0.5 hours in alarm state.

6.2.8 Connecting to other systems

Available potential free contacts should be arranged to open at a fire alarm or fault (normally closed). The contacts can be used for transferring alarm and fault signals to the plant control system.

6.3 Fire Protection - Common

6.3.1 Outdoor Hydrants

The plant shall be equipped with exterior hydrants which shall be located on the site area outside the powerhouse. The outlet connections are typically 2 x 21/2".

6.3.2 Outdoor Hose Cabinets

Hose cabinets shall be painted steel cabinet with two folded hoses in a hose rack. The hose length shall be 20 m, diameter 2.5" and designed for 16 bar pressure. The hoses shall be equipped with quick couplings. The adjustable water fog nozzle shall be included in the hose cabinet.

6.3.3 Portable Fire Extinguishers

The capacity of each portable dry powder fire extinguisher shall be 12.0 kg. They shall be ABC type.

6.3.4 Fire Water System Piping and Valves Inside Engine Hall

Pipes, valves, flanges and gaskets for the fire water system up to the interconnection point shall be included.

6.4 Fire Protection - Engine Hall

6.4.1 Hydrant valve pairs

The engine hall shall be equipped with a fire pipe network called standpipe system. From this network there shall be outlets for the pairs of 1½" hydrant valves with couplings for the fire hoses in vicinity of the hose cabinets inside the engine hall. Two of the valve pairs shall penetrate the outside wall for external use.

6.4.2 Standpipe hose cabinet

Hose cabinets shall be painted steel cabinet with folded hose in a hose rack. The hose length is 20 m, diameter 1½" and designed for 16 bar pressure. The hose shall be equipped with quick coupling and an adjustable water fog nozzle.

6.4.3 Mobile foam unit

Each mobile foam unit shall consist of a low expansion foam branch pipe, inductor, foam concentrate tank and two fire hoses with couplings suitable to be connected to the fire hydrants. Foam can be used to suppress an oil based fire. The foam unit shall have wheels and can be moved to the location of a fire. Capacity 200 l/min water flow, 100 l foam concentrate tank.

6.5 Fire Protection - Electrical Building

The plant shall be equipped with portable carbon dioxide type fire extinguishers which shall be located in electrical spaces and control room.

7 Automation System

The control and supervision system shall be designed for safe, reliable, efficient and easy operation of the generating sets, their associated auxiliaries and electrical systems. A modular design shall allow easy extension of the system.

The power plant shall be controlled from either the operator’s workstation, or from the central control panel.

The operator’s workstation and central control panels are located in the control room where all the main supervision of the plant takes place. The generating set control consists of two control panels, the central generating set control panel and the local generating set control panel, which is placed next to the generating set.

7.1 Operator's station

The power plant shall be controlled and supervised from the Operator’s workstation. All actions necessary for the normal operation, such as start and stop of the generating sets, load increase and load reduction shall be activated and supervised via the workstation, using a mouse, keyboard and display. The operator shall also be able to supervise key data from the plant such as various temperatures and pressures as well as measurements of electrical variables such as generator power, voltage and frequency. The workstation shall also include a hardcopy laser printer.

7.2 Control Panels

7.2.1 Central Common Control Panel

The central common control panel shall contain the operating switches, buttons and meters for synchronising and the mimic for the plant Medium Voltage system. It shall also contain the common Power Plant Control System.

7.2.2 Local Generating Set Control Panel

The local generating set control panel shall contain selectors for the generating set operating mode, control switches for manual control, the Power Monitoring Unit and the protection relays. In auto-mode the Power Plant Control System shall perform the starting sequence and stopping sequence automatically and shall set the active load and the power factor references to the primary controls according to the workstation set points. The Power Plant Control System shall monitor the status of the engine constantly regardless of the running mode. The local generating set control panel shall also contain the speed controller, the Automatic Voltage Regulator (AVR) and the hardwired engine shutdown and breaker trip circuits.

8 Electrical Systems

8.1 Main Switchgear (MV System)

The main switchgear shall be three-phase, metal enclosed and air insulated type and provided with withdrawable circuit breakers.

The switchgear shall be designed, manufactured and tested according to IEC 62271-200 and IEC 62271 standards.

The circuit breaker shall be mounted on a truck, incorporating all electrical and mechanical interlocks. Operating and indicating devices shall be visible on the front panel of the truck.

Circuit breakers shall be equipped with auxiliary contacts, charging motors, closing and shunt tripping coils.

Current and voltage transformers shall have a rated burden to suit the connected measuring and protection devices.

Circuit breakers shall be equipped with auxiliary contacts, charging motors, closing and shunt tripping coils.

Current and voltage transformers shall have a rated burden to suit the connected measuring and protection devices and have accuracy classes as follows.

Table 3 Current transformers

Description	Accuracy Class
Phase current protection transformers	5P10
Earth fault current transformers	10P10
Measuring transformers	Class 0.5

Table 4 Voltage transformers

Description	Accuracy Class
Earth fault voltage transformers	6P
Measuring transformers	Class 0.5

Generator cubicle

Main circuit shall generally include:

- Circuit Breaker
- Current Transformers for measuring and protection
- Voltage Transformers for measuring and protection
- Earthing Switch
- Cable transformer for earth fault

Secondary circuit shall generally include:

- Ammeter
- Miniature Circuit Breaker
- Breaker control switch
- Auxiliary relay

Neutral point cubicle

Neutral point cubicle shall have a neutral grounding resistor, single pole disconnector switch and a Current Transformer (single phase) for earth fault.

Outgoing feeder cubicle

The main circuit shall include:

- Circuit Breaker
- Current Transformers for measuring and protection
- Voltage Transformers for measuring and protection
- Earthing switch
- Cable transformer for earth fault

The secondary circuit shall include:

- Ammeters
- Voltmeter
- Two stage over current protection relay
- Two stage earth fault protection relay
- Breaker control switch

- Set of Miniature Circuit Breakers
- Set of auxiliary relays

Station auxiliary transformer feeder cubicle

The main circuit shall include:

- Circuit Breaker
- Current Transformers for measuring and protection
- Voltage Transformers for measuring and protection
- Earthing switch
- Cable transformer for earth fault

The secondary circuit shall include:

- Ammeters
- Two stage over current protection relay
- Two stage earth fault protection relay
- Breaker control switch
- Set of miniature circuit-breakers
- Set of auxiliary relays

Measuring cubicle

The main circuit shall include:

- Voltage Transformers
- Lightning arresters (one per phase)

The secondary circuit shall include:

- Voltmeter
- Under and over frequency protection relay
- Under and over voltage protection relay
- Neutral voltage relay
- Miniature circuit-breaker
- Set of auxiliary relays

8.2 Station Service System (LV System)

8.2.1 General

The station service system shall distribute low voltage electricity to electrical consumers.

8.2.2 Station Auxiliary Transformer

The station auxiliary transformer shall be a three-phase, two-winding, naturally cooled distribution transformer.

8.2.3 Black Start Unit

The function of the black start unit is to enable a black-start of the power plant when there is no power supply from the grid.

The black start unit shall provide power for the auxiliaries (such as the starting air compressor, pre-lubricating pump and battery charger) which are needed to be able to make a black-start of the power plant. The black start unit shall be connected directly to the low voltage switchgear of the plant. The components shall be built on a steel frame, which forms a compact skid unit.

8.2.4 Low voltage switchboard

The low voltage switchboard shall be a steel sheet enclosed, Form 3B minimum cubicle-type type-tested switchboard that feeds motor control centres, motors and other apparatus of the power plant.

8.2.5 Variable Speed Drives

Variable Speed Drives shall control the rotation speed of the district heating circulation water pump and the engine cooling radiator fans. The frequency converters shall minimize power consumption and noise level of the pumps and the cooling radiators.

8.3 DC System

The DC system shall be used in the power plant to supply DC power to devices and systems that need to have ensured power supply to maintain safe operation and shutdown of the plant, in case of failure in main power supply (AC).

8.3.1 Lighting, General Power and Earthing

The safety earthing system shall be based on an earthing ring line. The ring line shall be connected to the main equipment of the plant.

Power supply for indoor and outdoor lighting and small power outlets shall come from distribution boards connected to the station low voltage switchgear.

All lighting fixtures and small power outlet sockets shall be of the general type for industrial use.

8.3.2 Emergency Lighting

Emergency lighting fixtures shall be divided into signal and safety lights.

Signal lights shall be installed above exit doors and along escape routes to ensure safe exit.

Safety lights shall be installed in every room where reliable lighting is required during an emergency situation. Emergency lighting fixtures shall be provided with built-in battery and charger. Chargers shall be supplied from lighting distribution board.

8.3.3 Cable ladders

Cables shall be laid on cable ladders or in conduits. Cable ladders shall be made of hot dip galvanised steel or aluminium. External trays shall be covered.

Cable ladders shall be bonded to structural steel and directly connected to an earth conductor at maximum 20 metre intervals.

All wall sockets and cable channels on the walls shall be surface mounted.

Above-ground Conduits shall be made of galvanised rigid steel. Underground conduits and those in concrete shall be HDPE or PVC.

8.3.4 Lightning protection system

The lightning protection system shall be designed to decrease the risk of damage to the building and structures in case of lightning strikes. The lightning protection system shall provide a low impedance path to the ground for the lightning current.

The lightning protection system for buildings shall consist of a roof circuits made of steel wires, interception rods and clamps. The roof circuit shall be then connected to the earthing grid by copper wires.

The stack(s) shall be protected by an interception rod mounted on the top of the stack and then connected by down conductors to the earthing grid or earthing rods. The tanks shall be protected by grounding directly to the earthing grid.

9 Special Tools

The following tools shall be provided:

- Engine maintenance tools (set)
- Engine hand tools (set)
- Tools for turbocharger (set)
- Heavy fuel oil separator tools (set)
- Lubricating oil separator tools (set)

10 Testing and Training

10.1 Workshop Test

After the assembly is completed, the engine shall be tested in accordance with the following test program:

Item	Duration (min)	Load (%)	Notes
1	15	-	Start test and heating up

2	45	60	Site output, main fuel
3	45	85	Site output, main fuel
4	45	100	Site output, main fuel
5	45	100	Site output, alternative fuel (if applicable)
6	-	-	Test of overspeed devices

Comprehensive test documentation shall be provided.

10.2 Training

Relevant training shall be offered in order to give the operation personnel the necessary basic knowledge of how to operate and maintain the supplied equipment in order to reduce production loses and maintenance cost and increase the total economy of the installation.

Training shall be provided to the plant operation and maintenance staff of the daily operation routines and give them basic instructions regarding the preventive maintenance measures.

11 Spare Parts

The Supplier shall provide a list of recommended spare parts for all of the equipment ordered. The spare parts list shall be provided following award. The spare parts list shall be divided into three sections containing spare parts of the following types:

- commissioning spares
- consumable/operating spares
- Insurance/critical/emergency spares.

The list should include, but not be limited to the following:

- circuit breakers, trip blocks, fuses and contactors of each size used
- hinges, keyed latches, doors and other structural items
- CTs, ammeters, voltmeters, panel lights and switches
- lifting trolley for main incoming ACB.

The spare parts list shall include cost, availability and delivery at time of printing. The cost of spare parts shall be fixed and may be exercised up to three months from the delivery of equipment in this tender document to site. The Supplier shall nominate their closest spare parts and service centre to the Project site.

The Purchaser will, in conjunction with the successful Supplier select appropriate quantities of these items.

Spare parts from this list which are purchased by the Owner shall be delivered with the equipment ordered for the Project by the Purchaser.

12 Delivery and Shipping

If accessories are removed or the equipment is split, suitable blank shipping plates must be installed. Items which are free to move, vibrate or chafe during shipping shall be adequately secured or blocked. Provide warning notices to ensure removal on site prior to operation.

Equipment shall be export packed and protected for ocean sea freight. Equipment shall be packed in heavy duty, weatherproof wooden crates with substantial bases suitable for crane lifting and truck transport to site over rough roads. Sensitive items shall be removed and packed separately as required to prevent damage. Suppliers shall outline their methods of shipping and crating, and whether units can be shipped whole, or if not, how many shipping units are required. Suppliers shall include in their quote, all costs related to crating and equipment protection.

Each shipping unit shall be tagged on the outside of the shipping crate with its contents, number of packages, match marking, destination, designation, description, Client's name, address and purchase order number.

13 Appendix 1 HFO Fuel Specification

5. Produit : Fuel Oil

a) Spécification générales

<table>
<tr><td colspan="2">Caractéristiques</td><td>Unités</td><td>Limites</td><td>Méthodes</td></tr>
<tr><td colspan="2">Masse Volumique à 15° C</td><td>Kg/ l</td><td>≤ 0,991</td><td>ASTM D 1298</td></tr>
<tr><td colspan="2">Viscosité à 50 ° C</td><td>cSt</td><td>≤ 180</td><td>ASTM D 445</td></tr>
<tr><td colspan="2">CCAI</td><td></td><td>Maxi 860</td><td>(*B3)</td></tr>
<tr><td colspan="2">Point d'éclair</td><td>° C</td><td>≥ 60</td><td>ASTM D 93</td></tr>
<tr><td colspan="2">Teneur en eau</td><td>% vol</td><td>≤0.5</td><td>ASTM D 95</td></tr>
<tr><td colspan="2">Point d'écoulement</td><td>° C</td><td>< 10</td><td>ASTM D 97</td></tr>
<tr><td colspan="2">Teneur en soufre</td><td>% masse</td><td>< 1.7</td><td>ASTM D 129</td></tr>
<tr><td colspan="2">Indice de Conradson résidu</td><td>% masse</td><td>≤15</td><td>ASTM D 189</td></tr>
<tr><td colspan="2">Teneur en Sodium</td><td>Mg/Kg</td><td>≤ 50</td><td>IP 470</td></tr>
<tr><td colspan="2">Teneur en Vanadium</td><td>Mg/Kg</td><td>≤ 150</td><td>IP 470</td></tr>
<tr><td colspan="2">Teneur en Sédiments</td><td>% poids</td><td>≤ 0,1</td><td>ASTM D 473</td></tr>
<tr><td colspan="2">Teneur en aluminium + silice</td><td>Mg/Kg</td><td>≤ 50</td><td>IP 470</td></tr>
<tr><td colspan="2">Asphaltènes</td><td>% masse</td><td>≤ 5</td><td>ASTM D 6560</td></tr>
<tr><td colspan="2">Teneur en cendre</td><td>% masse</td><td>≤ 0,07</td><td>ASTM D 482</td></tr>
<tr><td colspan="2">Sulfure d'hydrogène</td><td>mg/kg</td><td>≤ 2</td><td>IP 570</td></tr>
<tr><td colspan="2">Indice acide</td><td>mg/KOH/g</td><td>≤ 2,5</td><td>ASTM D 664</td></tr>
<tr><td rowspan="2">Teneur en huile de vidange</td><td>Teneur en calcium+ Zinc</td><td>mg/kg</td><td>Calcium ≤ 30
Et Zinc ≤ 15</td><td>IP 470</td></tr>
<tr><td>Teneur en phosphore + Zinc</td><td>mg/kg</td><td>Phosphore ≤ 30
et Zinc ≤ 15</td><td>IP 470</td></tr>
</table>

b) Spécifications particulières :

1. Ratio Asphaltènes/ Conradson < 1/2

2. Ratio Sodium/ Vanadium < 1/3

3. CCAI = D-140,7 log log (V + 0 ,85) – 80,6

Avec **D** : densité à15 ; **V** : Viscosité en cSt à 50° C

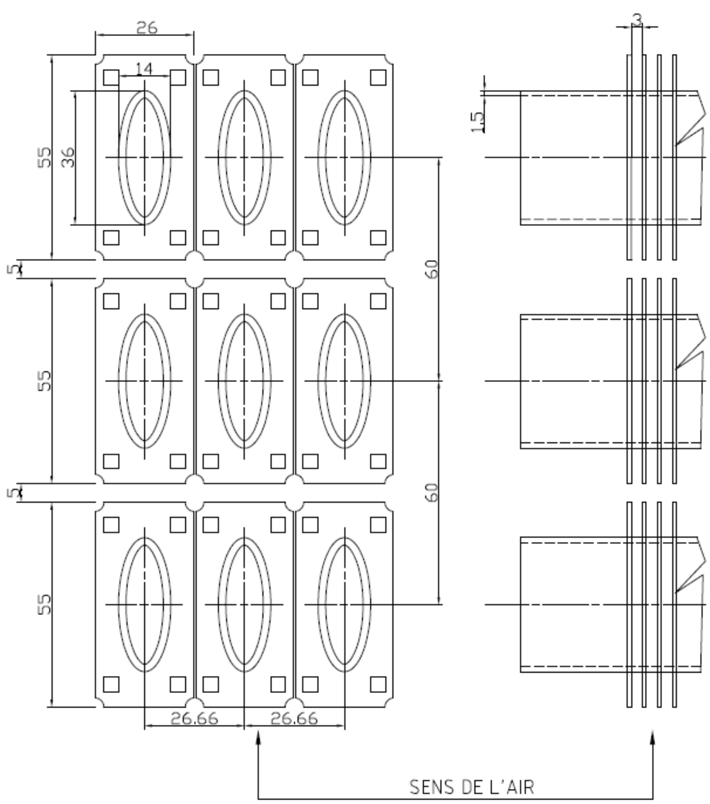
4. entre deux cessions en bacs successives, la viscosité à 50°c du produit livré ne devra pas varier de plus de 15%
5. Garantir la compatibilité et la miscibilité des produits à l'occasion des cessions en bacs successives.

14 Appendix 2 Recommended Radiator Design

The proposed design was developed for Mauritanian conditions and has been in use for several years at several SNIM mines in the Zouerate area. Its characteristics are described below:

- Exchanger tube shape allowing to reduce the risk of clogging by entrapped particles:
  - Elliptical tube supports, large axis in the direction of air flow, maximum number of rows of 3; perfectly aligned in the air flow direction
  - Rectangular parallel fins, spaced at 2.5 to 3.0 mm minimum and perpendicular to the tube

- Resistance to environmental wear:
  - Hot galvanization of the tubes and fin assemblies, 80 microns minimum



This technology allows:

- To maintain a heat exchange coefficient of the water / ait circuit and a reduction of losses on the air side, by means of the elliptical shape of the tubes and their arrangement

- An easy cleaning of the external tube surface (reduced loss on the air side and “aligned” elliptical tubes

- String tube-fin assemblies (external protection provided by the hot galvanization) allowing, if needed, high-pressure cleaning (200 bars in all directions) and excellent resistance to ambient air abrasion and corrosion

Moreover, it is imperative that the circuits (HT + LT for instance) are aligned in parallel, with a minimum of 3 rows per heat-exchange bundle

The overlaying of the bundles of the two circuits (HT – LT) one on top on the other (in series for air) will result in an accumulation of clogging particles between the bundles, rendering the cleaning inefficient and affecting ultimately the air flow and the exchange of heat.