Detailed Project Report for Expansion of existing Waste to Energy(WtE) Plant from 19.8 MW to 48 MW at Jawaharnagar.

BY

Hyderabad MSW Energy Solutions Limited

Survey No.173, Jawaharnagar, CRPF Road, Kapra Mandal, Medchal Malkajgiri District, Hyderabad, Telangana. 500087

PROJECT AT A GLANCE

1.0 Power plant Detail

1.1	Power Plant capacity	:	24000 kW
1.2	Power output at Guarantee LCV	:	24000 kW
1.3	Auxiliary power consumption	:	15%
1.4	Saleable Power to Grid	:	85%
1.5	Main Fuel used in the power plant	:	RDF
1.6	Lower Caloric Value of Fuel	:	1650 kcal/kg
1.7	Export grid voltage	:	66 kV
1.8	Grid Interconnection substation	:	Malkaram
1.9	Total water consumption	:	300 m^3/day

2.0 Capacity and detail of major power plant Equipments

2.1	Boiler & Auxiliaries		
	Design Capacity of Boiler	:	56000 kg/h
	No. of Boilers	:	Two (2)
	Boiler Outlet Steam Parameters	:	47.5 Bar(a) 415 ± 5 °C
	Feed water temperature at boiler inlet	:	130ºC
	Type of firing grate	:	Reciprocating grate
	Quantity of RDF used	:	2 x 600 TPD
	Particulate emission at chimney outlet	:	≤ 50 mg/Nm^3
	Dioxins and Furans emission	:	≤ 0.1ng/Nm^3

2.2 Turbo-generator & Auxiliaries

Turbogenerator capacity	:	24000 kW
No. of turbogenerators to be installed	:	One (1)
Turbogenerator type	:	Single bleed cum condensing
Turbine inlet Steam Parameters	:	46 Bar(a) 410± 5 °C
Turbine exhaust steam pressure	:	0.16 Bar(a)
Type of condensing equipment	:	ACC
De-aerator operating temperature (ºC)	:	130 ºC
Generation voltage	:	11 kV

2.3 Other BOP equipments

Aux. Cooling tower capacity	:	600 m^3/h
Cooling tower type	:	FRP
Air compressor capacity	:	2 x 450 Nm^3/h
Type of chimney	:	RCC
Chimney height	:	60 m
TG hall Crane for maintenance	:	EOT
Crane capacity	:	25/5 ton
Auxiliary transformer capacity	:	2 x 4 MVA
Generator transformer capacity	:	30 MVA
Start up DG set capacity	:	2 x 1010 kVA

3.0 Project cost

3.1 Total works cost for the plant (Rs. Lakhs)	:	55200

4.0 Project Schedule

Plant commissioning	:	24 months

1.0 INTRODUCTION

1.1 Modern metropolitan cities and urban areas have grown large and wide with population in millions. Rapid urbanization, increasing population and Industrial diversification has led to the generation of enormous volumes of municipal and Industrial waste. This necessitates management of solid waste at generation, storage, collection, transfer and transport, processing, and disposal stages in accordance with the best principles of public health, economics, engineering, conservation, aesthetics and environmental considerations.

1.2 Large population calls for the proper maintenance of the city in terms of infrastructure, traffic management, cleanliness, sanitation and waste management. Under such circumstances, the twin problems to be addressed are efficient and effective management as well as a scientific approach to it.

1.3 Cities are considered as the growth engines, but growth bereft of environmental concern is self-defeating. Despite the fact that the urban local bodies utilize major part of its staff and resource for collection and disposal of solid waste, most of the waste generated from households and commercial establishments is not collected and only a fraction of what is collected receives proper treatment / disposal. It is due to the fact that these local bodies lack financial and administrative resources apart from inadequate institutional mechanisms. Furthermore, in all metropolitan cities and most large cities in India, about 50 to 60% of the municipal waste collected is dumped in open dumpsites. The rest keeps lying around in municipal bins and roadsides for several weeks to months, becoming an environmental/health hazard.

1.4 It is reported that, bigger urban local bodies spent around Rs. 1000 to Rs. 1600 / ton on garbage for its collection, transportation and disposal. About 65% to 70% of the above amount is spent on collection, 25% to 30% on transportation and mere 5% to 10% on disposal.

1.5 Waste management in any region includes the following four aspects. They include:

- Proper mechanisms for collection of waste regularly from residential as well as industrial areas.

- A scientific and eco-friendly system of segregation of waste into organic, inorganic, plastic and metal etc.

- Transportation of waste from the place of collection to the destination of disposal.

- A method of disposal of waste in appropriate places following a clean procedure.

1.6 Nowadays municipalities are forced to find new methods for waste disposal due to critical environmental problems from old landfills and a lack of land availability caused by a fast growing population and a higher rate of waste production.

1.7 Most of the developed countries have been successful in addressing this problem by evolving efficient MSW management system and also by providing technological solutions to garbage disposal/treatment. With the ever increasing generation of garbage, it is time for immediate and concerted action. The proper disposal of urban waste is not only absolutely necessary for the preservation and improvement of public health but it has an immense potential for resource recovery.

1.8 Government of India (GoI) has taken several initiatives in the recent years to improve Solid Waste Management (SWM) practices. As per the constitution in India, SWM is a state subject and it is the primary responsibility of state government to ensure that, appropriate SWM practices are introduced in all the cities and towns in the state. The role of GoI is broadly to formulate policy guidelines and provide technical assistance to the states / cities wherever needed.

1.9 In the recent years, SWM system in India has received considerable initiatives from several Government Organizations.Some of the key initiatives are discussed below,

a. The first initiative was taken by Supreme Court of India in 1998, to form a committee to study and provide report on the current status of SWM in Indian cities. The report is highlighted with status of collection, storage, transportation, processing and disposal of MSW.
b. As a 2nd initiative, the Ministry of Environment and Forests (MoEF), Government of India, published "Municipal Solid Waste Rules 2000 (MSW rules 2000). The rules dictate the duties and responsibilities of various government organizations, starting from Village Panchayats to all the ministry's comes under Government of India.

c. Swachh Bharat Mission (SBM) was launched in the year of 2014, with a vision to achieve a clean India as a tribute to the father of the nation, Mahatma Gandhi, on his 150th birth anniversary, in 2019. Municipal Solid Waste Management is the main component of SBM.

d. The latest initiative is the concept of partnership between Solid Waste Management (SWM) and Swachh Bharat Mission (SBM). A draft SWM rules were published in the year of 2015, inviting public objections and suggestions. The suggestions / objections received were examined by the Working Group in the Ministry. Based on the recommendations of the Working Group, the Environment Ministry has revised the SWM rules in the year of 2016 i.e.,
SWM 2016 rules, which dictates a broad guidelines for MSW handling and disposal.

e. This DPR is prepared based on latest Municipal Solid Waste rules i.e., SWM rules 2016.

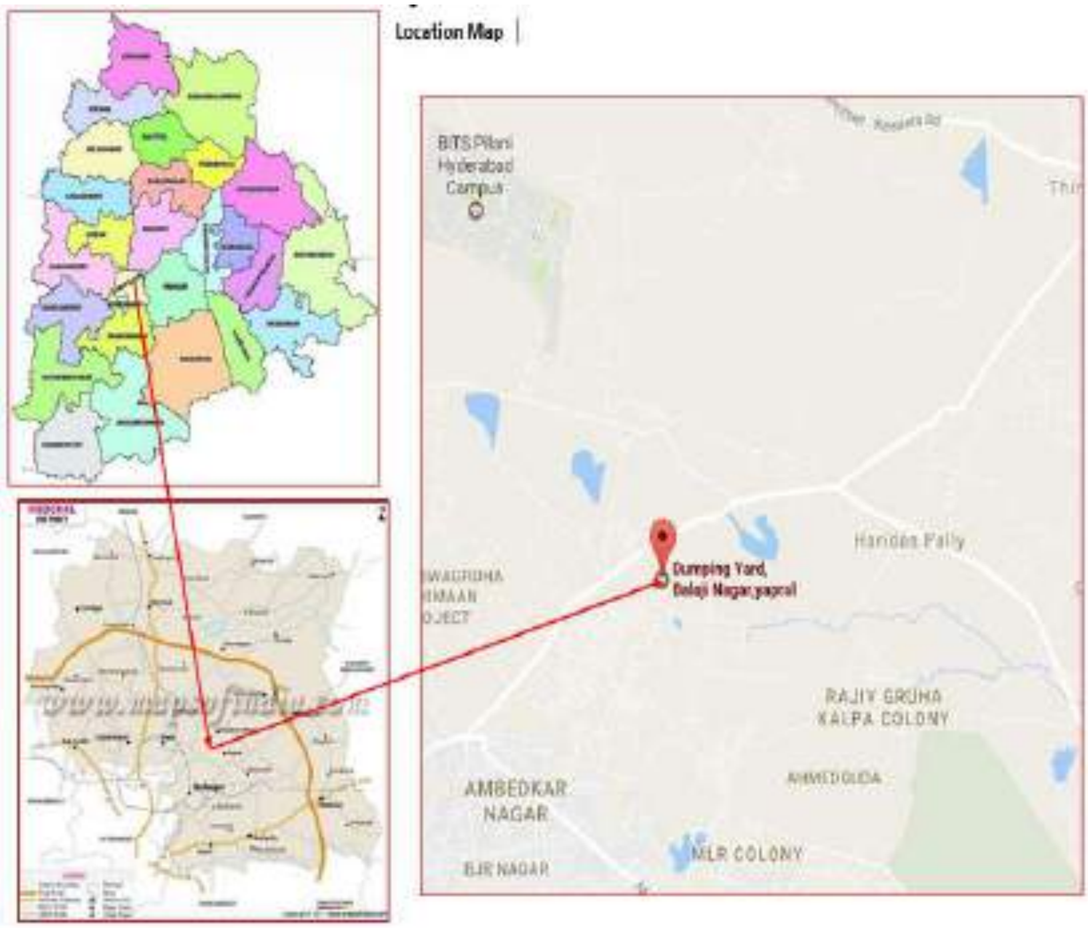
1.10 Waste To Energy (WTE) is the sum of processes that produce electric energy from waste. Nowadays it has also become a safe and favorable form of energy recovery from the environmental point of view. As such, it is currently regarded as an essential element in the mechanism of integrated waste management, in all industrialized countries. Waste-to-energy provides the fourth “R” in a comprehensive solid waste management program: Reduction, Reuse, Recycling, and energy Recovery.

1.11 Hyderabad MSW Energy Solutions Priavate Limited (HMESPL) is subsidiary of Ramky Enviro Engineers Ltd and belongs to the “Ramky Group” based at Hyderabad.

The group which has emerged as India's largest in the environmental sector and has pioneered the art and engineering of Solid Waste Management (SWM) in India. It has established itself in the Leadership position in the country in the field of environment and infrastructure.

1.12 HMESPL is currently operating a RDF Based Waste to Energy project (2x600 TPD) 19.8 MW WTE Plant for Greater Hyderabad Municipal Corporation(GHMC) at village Jawaharnagar, Hyderabad in compliance with SWM rules 2016.

1.13 The proposed Expansion of 2x600 TPD WTE power plant is also planned to establish at Jawharnagar Site. The site is a notified Solid waste disposal are of Greater Hyderabad. The site is accessible through Outer ring road of Hyderabad. This site is located at an aerial distance of 16 km from Charlapally railway station and 44 km from nearest airport. The following figure illustrates the site location of the proposed plant.


Location Map
BITS Pilani Hyderabad Campus
Dumping Yard, Balaji Nagar,yapral
Haridas Pally
RAJIV GRUHA KALPA COLONY
AMBEDKAR NAGAR
AHMEDGUDA
MLR COLONY
BJR NAGAR

2.0 FUEL, ITS PROPERTIES AND TECHNOLOGY SELECTION

2.1 MSW is highly heterogeneous and percentage of its constituents varies widely depending on the source. Further seasonal changes also contribute to the higher level of heterogeneity in MSW. To assess the suitability of any technology for processing MSW, it is very important to broadly analyse the composition and the weight fraction of each of the constituents with reference to different sources of its generation. The change in composition is also a function of the economic vibrancy of the society and the economic progress of the region as well.

2.2 Some of the municipal corporations make separate arrangement to collect, transport and dispose off the building construction / demolition waste mainly as land filling / levelling purpose. The waste generated in hospitals, nursing homes and clinics/diagnostic centers are generally disposed separately (biomedical waste) and is not part of MSW. Industrial waste also does not become part of MSW as it is separately collected, treated and disposed off. It is, therefore understood (for the purpose of finding technological solutions) that MSW consists generally of the waste generated from residential, commercial and some market/institutional places.

2.3 The MSW includes, garbage-organic material discarded or waste generated as a result of the storage, preparation and consumption of food, rubbish, paper, wood, glass, metal, leaves mainly generated from vegetable markets, hotels, community halls, street sweepings and residential areas. Composition of MSW differs widely from place to place and from season to season.

2.4 The difference in organic content in MSW which is much higher in the low income areas than the high income, while the paper and plastic content is much higher in high income areas than low income areas. This reflects the difference in consumption pattern, cultural and educational differences.

Relative compositions of House hold waste in Low, Middle and High income countries.

Parameters	Unit	Low income countries	Medium income countries	High income countries
Organics	%	40-85	20-65	20-30
Paper	%	01-10	15-30	15-40
Plastics	%	01-05	02-06	02-10
Metal	%	01-05	01-05	03-13
Glass	%	01-10	01-10	04-10
Rubber, leather	%	01-05	01-05	02-10
Others	%	15-60	15-50	02-10
Moisture content	%	40-80	40-60	5-20
Density	kg/m^3	250-500	170-330	100-170
Calorific value	kcal/kg	800-1100	1000-1300	1500-2700

2.5 Physical Characteristics of MSW in Indian cities

Population Range (million)	Paper %	Rubber, Leather & Synthetic %	Glass and Metals %	Combustibles %	Inerts %
0.1 – 0.5	2.91	0.78	0.89	44.57	43.59
0.5 – 1.0	2.95	0.73	0.67	40.04	48.38
1.0 – 2.0	4.71	0.71	0.95	38.95	44.73
2.0 – 5.0	3.18	0.48	1.08	56.67	49.07
> 5.0	6.43	0.28	1.74	30.84	53.90

2.6 Chemical characteristics of MSW in Indian cities

Population Range (million)	Moisture %	Organic matter %	Total N_2 %	P_2O_5 %	K_2O %	C/N Ratio %	CV (kcal / kg) %
0.1 – 0.5	25.8	37.1	0.7	0.6	0.8	30.9	1010
0.5 – 1.0	19.5	25.1	0.7	0.6	0.7	21.1	901
1.0 – 2.0	27.0	26.9	0.6	0.8	0.7	23.7	980
2.0 – 5.0	21.0	25.6	0.6	0.7	0.8	22.4	907
> 5.0	38.7	39.1	0.6	0.5	0.5	30.1	801

2.7 During the last 10 years, life and consumption styles have remarkably modified the composition of MSW. The quantity of organic waste has decreased, while packaging-related waste has increased (as of now it is about 40% of the total). Such a massive presence of packaging material, like plastic, paper, cardboard – all of which have high energy contents – has progressively raised the overall Heating Value of MSW.

2.8 Quantity of MSW in Indian Urban Centres

Population range (million)	Number of urban centres	Total population (million)	Average generation (per capita / day)	Quantity (tonnes / day)
< 0.1	328	68.300	0.21	14343
0.1 – 0.5	255	56.914	0.21	11952
0.5 – 1.0	31	21.729	0.25	5432
1.0 – 2.0	14	17.184	0.27	4640
2.0 – 5.0	6	20.597	0.35	7209
> 5.0	3	26.306	0.50	13153

2.9 RDF Properties considered for Design

2.9.1 Physical Properties of RDF

Shape - Irregular

Size - Irregular (as collected /received)

Bulk density - 400-450 kg/m^3

2.9.2 MSW widely varies in composition, heat value within a city depending on the area from which it is collected. High Income colonies generate richer waste and slum areas generate lower heat value waste. Commercial institutions have more recyclables, paper, packaging material and mixed plastics. The waste is presorted and the presorted-MSW/ RDF is homogenized to the extent feasible in the storage pit using a grab crane. The purpose of mixing is to mix, homogenize and make the heat value of the waste uniform to the extent feasible so that the boiler/combustor operates on a relatively regular load without shocks and power generation is sustained. However, seasonal fluctuations will set in.

2.9.3 Proximate analysis of RDF

Moisture	-	15 - 45 %
Ash content	-	20 - 30 %
Volatile matter	-	25 - 35 %
Fixed carbon	-	10 - 25 %
Sulphur	-	0.1 - 0.4 %

2.9.4 Ultimate analysis of RDF (% by Weight)

Carbon	-	15.0 - 25.0 %
Hydrogen	-	02.0 - 04.0 %
Oxygen	-	08.0 - 20.0 %
Moisture	-	15.0 - 45.0 %
Sulphur	-	00.1 - 00.4 %
Ash	-	20.0 - 30.0 %
Nitrogen	-	00.3 - 01.5 %

2.9.5 Calorific Value of RDF

GCV	-	1400 to 2250 kcal/kg
LCV	-	1100 to 1800 kcal/kg

2.9.6 Fuel analysis considered for design:

Table No. 2.1. Fuel Analysis

S.N	Constituents	Unit	Design CV	Min CV	Avg. CV	Max. CV
1	Carbon	%	19.00	13.85	16.55	20.91
2	Hydrogen	%	02.71	01.98	02.35	02.98
3	Oxygen	%	13.13	09.57	10.78	13.94
4	Moisture	%	36.09	44.08	41.42	36.03
5	Sulphur	%	00.16	00.12	00.15	00.18
6	Ash	%	28.29	29.94	28.20	25.27
7	Nitrogen	%	00.62	00.46	00.55	00.69
8	Total	%	100	100	100	100
9	LCV	kcal/kg	1650	1100	1393	1850
10	GCV	kcal/kg	2002	1460	1757	2215

2.9.7 RDF ash analysis:

SiO_2	-	45.0 – 60.0 %
Fe_2O_3	-	03.0 – 15.0 %

Al_2O_3	-	06.0 – 12.0 %
TiO_2	-	Traces
CaO	-	07.0 – 16.0 %
MgO	-	01.0 – 03.0 %
Na_2O	-	02.0 – 12.0 %
K_2O	-	10.0 – 20.0 %
MnO	-	Traces
SO_3	-	00.0 – 05.0 %
P_2O_5	-	02.0 – 10.0 %
Chlorides	-	00.0 – 02.0 %

2.9.8 Ash softening temperatures

Initial deformation temperature	-	750 – 900 °C
Softening temperature	-	800 – 1100 °C
Hemispherical temperature	-	960 – 1150 °C
Fluid temperature	-	1050 –1200 °C

2.10 Technology selection for Energy recovery from solid waste:

There are few alternatives, to recover Energy from Waste. All waste disposal alternatives eventually decompose organic materials into simple carbon molecules such as CO_2 and CH_4.The balance between these two gases and time frame for the reaction varies with alternatives. The various alternatives available for energy recovery from RDF are:

a. Bio Chemical conversion:

This process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas.

The bio-chemical conversion processes, are preferred for wastes having high percentage of organic bio-degradable matter and high level of moisture/ water content, which aids microbial activity.

The main technological options under this category are Anaerobic Digestion, also referred to as Biomethanation.

b. Thermo-chemical conversion:

This process envisages thermal de-composition of RDF to produce heat energy. The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content.

The main technological options under this category include Incineration and Pyrolysis/ Gasification

Pyrolysis:

Pyrolysis is the thermal degradation of a substance in the absence of oxygen. This process requires an external heat source to maintain the pyrolysis process. Typically, temperatures around $300^{0}C$ to $850^{0}C$ are used during pyrolysis of RDF.

The products from the pyrolysis process, are a Solid Residue and Syngas. The solid residue (sometimes described as a char) is a combination of non-combustible materials and carbon. The syngas is a mixture of gases (combustible constituents include carbon monoxide, hydrogen and methane) and condensable oils, waxes and tars. The syngas typically has a Net Calorific Value (NCV) of between 2500 and 5000kcal/Nm3.

Gasification:

Gasification is due to partial oxidation of the combustibles as the sub-stoichiometric air is supplied which prevents the complete combustion. The temperatures employed are typically above 650^{0}C. The main product is Syngas with a calorific value of 960 to 2400kcal/Nm3.

Pyrolysis and gasification processes require external energy to sustain the process. The pyrolysis and gasification also requires extensive segregation process.

The performance of the following WTE plant available in India with the Gasification / Pyrolysis technology is yet to be proved on a commercial scale.

- M/s. Rochem Separation Systems (India) Pvt. Ltd., Pune 4 x 2.6MW WTE Plant based on Pyrolysis technology, which is presently not in operation due to technical reasons

Incineration:

Incineration technology is the controlled combustion of waste, with the recovery of heat, to produce steam, that in turn produces power through steam turbines. Incineration process needs sufficient quantity of air for complete combustion of the incoming RDF to generate heat energy. Incineration of RDF allows huge savings at the landfill as the volume of RDF is reduced almost to 10 to 15% in the form of ashes and slag as compared to the original waste volume.

In WTE plants based on incineration, the entire energy contents of waste is recovered, except the unavoidable fraction that is lost through the flue gas, cooling devices, boiler walls and ashes.

The combustion of RDF releases more available energy compared to pyrolysis / gasification. In view of world wide experience of WTE plants, European Union (EU) has more than 400 units, Japan has more than 100units, USA has more than 80units and china has more than 60units in operation. From the above it is evident that the energy recovery from RDF through incineration is a proven technology.

In India, around Five (5) numbers of WTE plants with RDF incineration technology are in continuous operation

Indian Scenario for WTE plants

Various WTE plants available in India on Bio-Methanization, Pyrolysis / Gasification technology, are not under operation due to the technical limitations and are yet to be proved on a commercial scale.

The following plants under the technology of "Combustion of RDF, Heat Recovery and Power Generation" are under commercial operation.

- M/s. Timarpur Okhla Waste Management Private Ltd, 3 x 450TPD WTE Plant at Okhla, is in operation. The power generation capacity of the plant is 23.0MW. This plant is in operation for more than Six years.
- M/s. East Delhi Waste Processing Company (P) Ltd, 1 x 550TPD WTE plant at Gaziphur, is in operation. The power generation capacity of the plant is 12.0MW. This plant is designed for incinerating the RDF produced from the extensive RDF processing plant installed within the project site and in operation approx for last couple of Years.

- M/s. Essel Infra, 1 x 600TPD WTE plant at Jabalpur, is in operation. The power generation capacity of the plant is 11.5MW. This plant is in operation for more than Four years.

- M/s. Delhi MSW Solutions (P) Ltd, 2 x 600 TPD plant at Narela – Bawana. The power generation capacity of the plant is 24.0MW. This plant is in operation for more than Four years.

- M/s. JBM Environment Management Private Limited, 1 x 600 TPD plant at Sonipat. The power generation capacity of the plant is 19.8MW. This plant is in operation for more than Seven months.

Based on the above Indian operating experience of WTE plants, and worldwide reference / operating experience, "Combustion of MSW/ RDF, with Heat recovery and Power generation Technology" is considered for this WTE project.

2.10.1 Land fill Recovery:

Landfill gas recovery system is being implemented in large landfill sites to recover the methane gas that evolve during the land fill process. The landfill gas recovery system shall not be advocated as an efficient method to recover the energy content available in the MSW; however the CH_4 emission causing the greenhouse effect shall be avoided.

A typical LFG (landfill gas) has CH_4 concentration of 50%.Landfill gas has a calorific value of around 4500 kcal/Nm^3. It can be used either for direct thermal applications or for power generation.

However, Land fill is considered as inefficient gas recovery process which yields only 30-40 % of total gas generation. Large land area requirement and requirement of separation of waste from source are the other demerits of the system.

2.10.2 Anaerobic digestion

Anaerobic digestion is the process of treating the bio-degradable waste with micro-organisms in an anaerobic condition, where the waste is converted to gaseous mixture of Methane, carbon-di-oxide and traces of Hydrogen sulphide. The gaseous mixture is a low calorific value gas (GCV - 5000 kcal/Nm3) popularly known as biogas. Energy can be produced from the combustion of biogas either in boiler or Internal combustion Engines.

The anaerobic digestion is limited to bio-degradable wastes and requires separation of waste from source.

2.11 Boiler Technology selection for RDF combustion

2.11.1 There are various type of technologies adopted for RDF combustion. Few of them are listed below.

Movable Grate

- Reciprocating / Pusher Grate type
- Travelling grate type

Rotary Kiln

- Non cooled rotary kiln type
- Water cooled rotary kiln type

Fluidized bed type

- Bubbling fluidized bed type
- Circulating fluidized bed type

2.11.2 Of these three basic technologies, fluidised bed has been very little used for RDF combustion. This is due to the fact that fluidised bed technology requires the waste to be pre-treated in a homogenisation process, which is both costly and technically difficult.

2.11.3 Rotary kilns have been applied for low-value waste to achieve full burn-out of hazardous waste/clinical waste to safely contain the process and all residues.

2.11.4 The following table gives the suitability of various technologies

Sl. No	Technology	Untreated MSW	Pre-sorted MSW or RDF	Hazardous waste
1	Reciprocating / Pusher Grate	Widely Applied	Widely Applied	Not applied
2	Travelling Grate	Less Applied	Applied with little success	Rarely applied
3	Non cooled rotary kiln	Not applied	Applied	Widely applied
4	Water cooled rotary kiln	Not applied	Applied	Applied
5	Bubbling fluidized bed	Not applied	Rarely Applied	Not applied
6	Circulating fluidized bed	Rarely applied	Rarely Applied	Not applied

2.11.5 Reciprocating step grate (Refer fig-2.1) is widely used in various countries and is a proven technology for burning pre-sorted MSW.

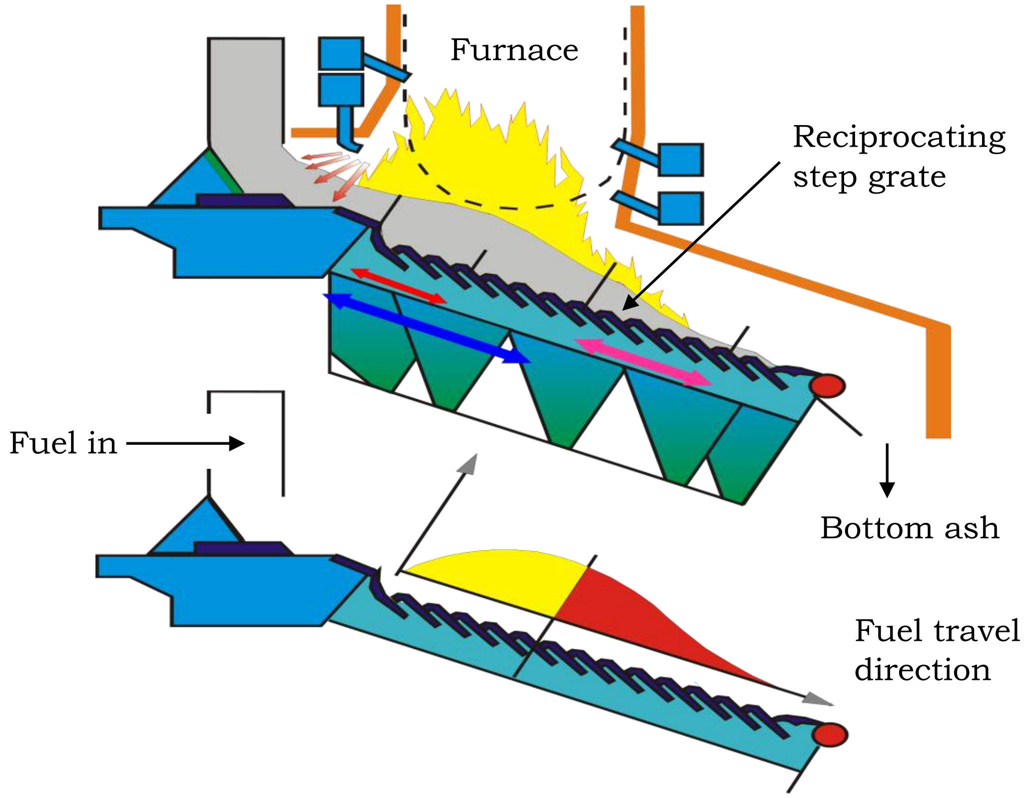


Fig-2.1 – Reciprocating Step Grate assembly

The proposed RDF based power plant shall be designed to burn the pre-sorted MSW/RDF in the boiler. Bulky objects present in the MSW are removed during the pre-sorting process. Presorting is often resorted to remove recyclables, bulky objects, boulders and pvc.

The Proposed Expansion power plant will be established adjacent to the Existing 2x600 TPD Waste to Energy Plant

Refer Figure 2.2 for the typical construction of a reciprocating step grate boiler for RDF based power plant.

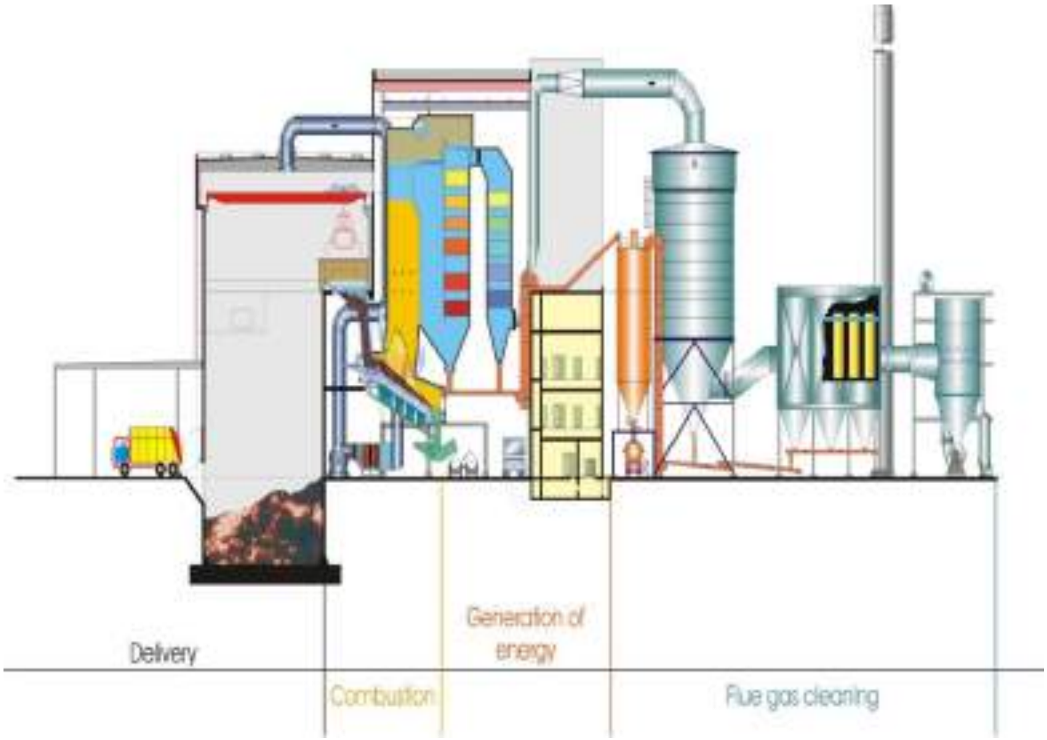


Fig 2.2 Typical view of a RDF fired boiler & Auxiliaries

2.12 Effect of corrosive nature of RDF in boiler design

The combustion products from waste are very corrosive. The components that are present in coal, oil, biomass and other fuels that contribute to corrosion, as well as high slagging and fouling are all present in waste.

The core of the corrosive problem in waste fired boilers is the high level of chloride content in waste. High temperature corrosion is being observed in the waste firing boilers caused by chlorine in either one of the following are in combination

- Corrosion by Hydrochlorides (HCl) in the combustion gas.

- Corrosion by NaCl and KCl deposit on the tube surface.
- Corrosion by low melting point metal chlorides (mainly $ZnCl_2$ and $PbCl_2$.)
- Corrosion of wet salts on the tube surface.

The predominant cause of corrosion is due to gaseous HCl with and without a reducing atmosphere and molten chlorides within the deposits.

Sulphur compounds are corrosive in nature, which can reduce or enhance the corrosion caused by chlorine. The important factor governing the high temperature corrosion are metal temperature of the heat transfer tube and the temperature difference between gas and metal, flue gas composition, deposit formation and reducing conditions, and SO_2 / HCl ratio.

The corrosion mechanism is generally categorized as follows:

a. Corrosion by HCl/Cl_2 or SO_2/SO_3 containing gas under oxidising/ reducing condition
b. Corrosion by solid or molten deposits of metal chlorides and sulphates.

The following figure describes the chemical reactions explaining corrosion on RDF fired boilers.

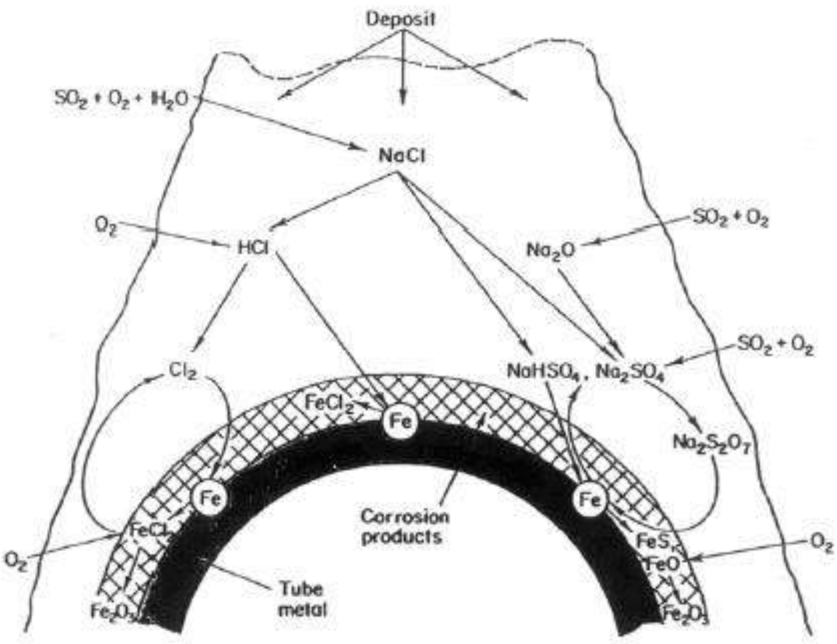


Figure No. 2.3. Corrosion mechanism

2.12.1 Chlorine corrosion

The corrosion mechanism for metal temperatures above 450°C is mentioned as ‘active oxidation’. The corrosion mechanism caused by chlorine is described below. Alkali chlorides in particular NaCl, $CaCl_2$ and KCl can be present already, or can be formed by the combustion and subsequent reaction of alkali oxides.

$$Na_2O + 2HCl \rightarrow 2NaCl + H_2O$$

The chlorine compounds will be converted to a sulphate form under certain conditions such as good mixing, sufficient availability of SO_2 & O_2 in the flue gas and sufficient residence time. This will provide an ideal condition for alkali chlorides to combine with SO_2 and O_2 to form sulphate salts.

$$2NaCl + SO_2 + \tfrac{1}{2} O_2 + H_2O \rightarrow Na_2SO_4 + 2HCl$$

This would result in formation of sulphates and volatile HCl. At the relatively low tube wall temperatures of most waste incinerators the sulphates are not very harmful and the HCl formed will be transported to the flue gas clean up system.

However if the gas reaches the cooler tube walls before the reaction is completed the alkali metals will tend to condense on the cooler metal surface. In this case, further sulphate formation can occur under the release of HCl which causes high chlorine partial pressures and enhanced corrosion.

Without SO_2 at 500°C NaCl and iron oxides can form Cl_2 according to following reactions.

$$2NaCl + Fe2O3 + \tfrac{1}{2} O_2 \rightarrow Na2Fe2O4 + Cl2$$

$$6NaCl + 2Fe_3O_4 + 2\ O2 \rightarrow 3Na2Fe2O4 + 3Cl2$$

At about 500°C, Cl_2 will penetrate the pores or cracks in oxide layer. The partial pressure of oxygen will be low near the metal oxide scale boundary. Thus the metal chlorides are observed with more stable phase due to the low partial pressure of oxygen.

The following reaction can result in Cl_2 partial pressure sufficiently high to react directly with the steel to form $FeCl_2$.

$$Fe + Cl2 \rightarrow FeCl2 \text{ (Solid deposit)}$$

2.12.2 Effect of Sulphur on corrosion:

The flue gas under good mixing condition and sufficient residence time, metal chlorides can be formed as metal sulphates in reaction with SO_2. The sulphur content can be beneficial for RDF fired boilers, thus higher Sulphur to Chlorine molar ratio will reduce the corrosion notably. As already discussed at relatively low tube wall temperatures of most waste incinerators, the sulphates are not very harmful.

At higher metal temperatures, sulphur compounds will induce corrosion. The deposit containing iron oxides will catalyse the reaction from SO_2 in SO_3 to produce pyrosulphate due to higher partial pressure of SO_3 at temperature between 320˚C and 480˚C.

$Na_2SO_4 + SO_3 \rightarrow Na_2S_2O_7$

$Na_2S_2O_7 + 3Fe \rightarrow \mathit{Fe_2O_3} + \mathit{FeS} + \mathit{Na2SO4}$

At 500°C sulphates and pyrosulphates become unstable and react with (protective) oxide. At the temperatures of 550°C and higher the tri-sulphates can attack the metal.

$Na_2S_2O_7 + Fe_2O_3 \rightarrow 2\ Na_3Fe\ (SO_4)_3$

$19Fe + 2Na_3Fe\ (SO_4)_3 \rightarrow 6\ Fe_3O_4 + 3FeS + 3Na_2S$

2.12.3 Sulphur to Chlorine molar ratio

The experience from the power plant suggests that Sulphur to Chlorine molar ratio shall be a good indicator of chlorine corrosion problem. Chlorine related corrosion is seldom seen in with S/Cl >4 in the fuel, whereas S/Cl <2 often led to problems. This ratio can be useful as a guideline, but more factors of the ash chemistry must be taken into account for making better predictions.

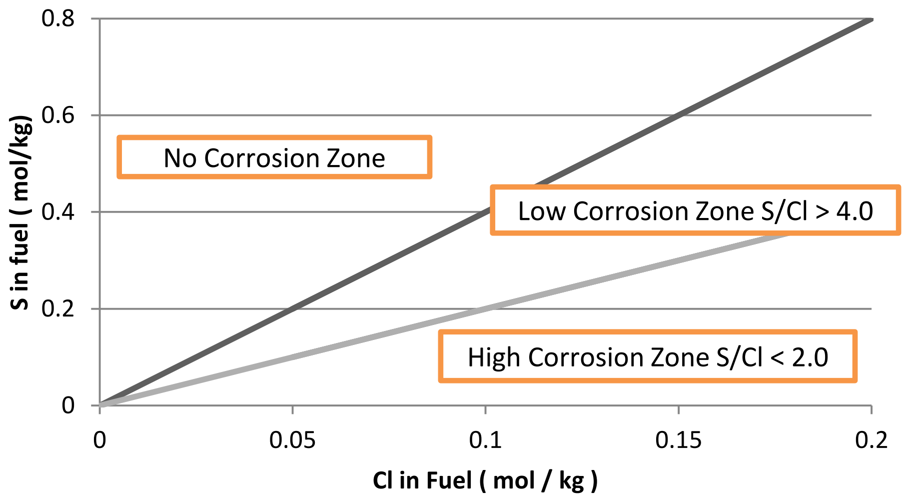


Figure No. 2.4. Corrosion zone with S/Cl ratio

2.12.4 Effect of fouling and slagging

Fouling is the deposition of layer of material, present in the gas stream onto a convective heat transfer surface. In many cases, though not always, the gas side fouling is accompanied by corrosion.

Slagging is the deposition of layer of semi-molten ash on the radiative heat transfer surface. Slag is formed when temperature exceeds a critical temperature where a fraction of the ash is molten and becomes sticky, gluing other particles together. If the semi molten ash remains in the fuel bed a sticky deposit slag is formed.

Generally, slagging occurs in the radiant zone whereas fouling occurs in the convective zone.

The deposition rate of the fouling / slagging is characterised by the flue gas properties such as dew point, melting point, stickiness and increased sintering reactions of the deposited material.

Slagging and Fouling of the boiler occur at temperature above 600 to 800°C, when the ashes are sticky due to the presence of alkali metals with low melting temperature such as Cl, Na, Mg, etc.,

The RDF combustors are prone to high slagging and fouling due to the higher alkali content which reduces the critical temperature of ash. The boiler shall be designed considering the above factors to minimise the problems arising due to the slagging and fouling, thus increases the availability of the power plant.

Boiler fouling has three effects on energy recovery.

- The first one is that it decreases the heat exchange coefficients and, therefore, leads to reduce the heat recovery.
- The second and major one is that it leads to blocking up the heat-exchange bundles and, therefore, to the shutdown of the plant.
- Another unwanted effect of boiler fouling is that it increases the risk of corrosion under the deposited layer. In general, the boiler requires manual

cleaning depending on the limit of boiler fouling.

The furnace of waste combustors is normally designed large enough to provide low gas velocities and long gas residence times. This allows combustion gases to be fully burned out, and prevents boiler tube fouling by:

- Reducing the fly ash content of the flue gases.

- Allowing the temperature of the flue-gases to be reduced before coming into contact with the heat-exchange bundles.

Heat transfer surfaces fouling may also be reduced by including empty passes water walls without obstructions in the gas path between the main furnace area and the heat-exchange bundles to allow gas temperature, and hence fly ash stickiness, to be reduced. Flue gas temperature is reduced 650°C before it enters the convective super heater. This reduces the adhesion property of ash to the boiler tubes and thus prevents fouling and corrosion.

A boiler must have a sufficient heat-exchange surface but also a well designed geometry in order to limit fouling. This can be achieved either in vertical, horizontal or combined vertical-horizontal boiler concepts.

Some good design practices are reported as follows:

- Gas velocities must be low to avoid erosion and homogeneous to avoid high velocity areas and to avoid stagnation, which can induce fouling over the whole diameter (space) of the boiler.

- Lower portion of the furnace is constantly changing from oxidizing to reducing environment which can rapidly accelerate corrosion. Lower furnace is covered with SiC (Silicon Carbide) refractory layer upto sufficient height, to protect tube from corrosion. The refractory applied in lower layer furnace reduces water wall slagging and is extremely erosion resistant.

- The first pass and the second pass of the boiler should not contain heat exchangers and have sufficient dimensions (especially height) in order to reduce flue-gas temperature below 600 – 650°C.

- The gaps between the tubes of the bundles must be wide enough to avoid "building" in between them by fouling.

- Water-steam circulation, in membrane wall and convective exchangers should be optimal in order to prevent hot spots, inefficient flue-gas cooling, etc.

- Boiler should be designed in order to avoid flue-gas preferential path, leading to temperature stratification and ineffective heat exchange.

- Suitable devices for cleaning the boiler from fouling in situ should be provided.

- Optimisation of convective exchanger arrangement (counter-flow, co-current flow, etc.) in order to optimise the surface according to the tube wall temperature and prevent corrosion.

The following diagram shows the safe operating metal temperature for steam circuits of RDF based power plants.

In order to avoid operational problems that may be caused by higher temperature sticky fly ashes, the boiler shall be designed such that, the gas temperatures are reduced sufficiently before entering the convective heat exchange bundles as described in below graph.

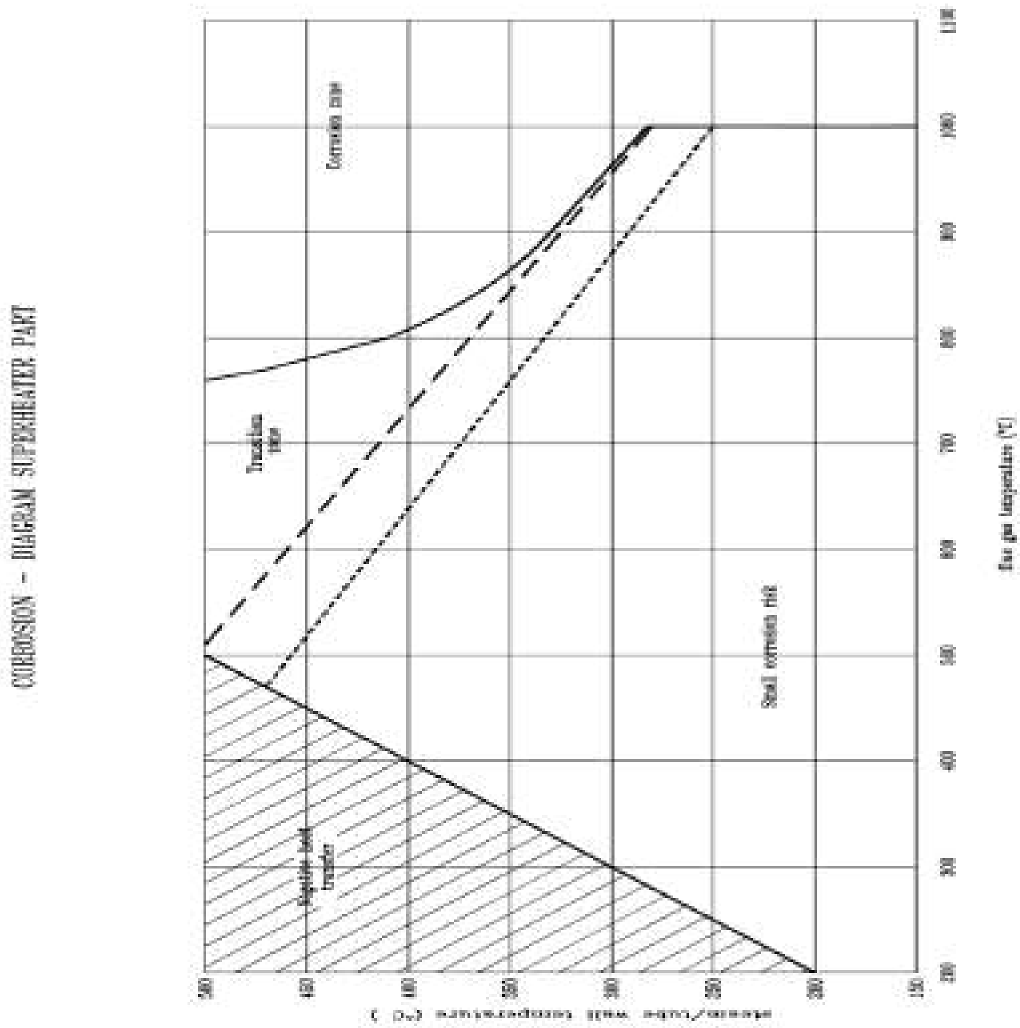


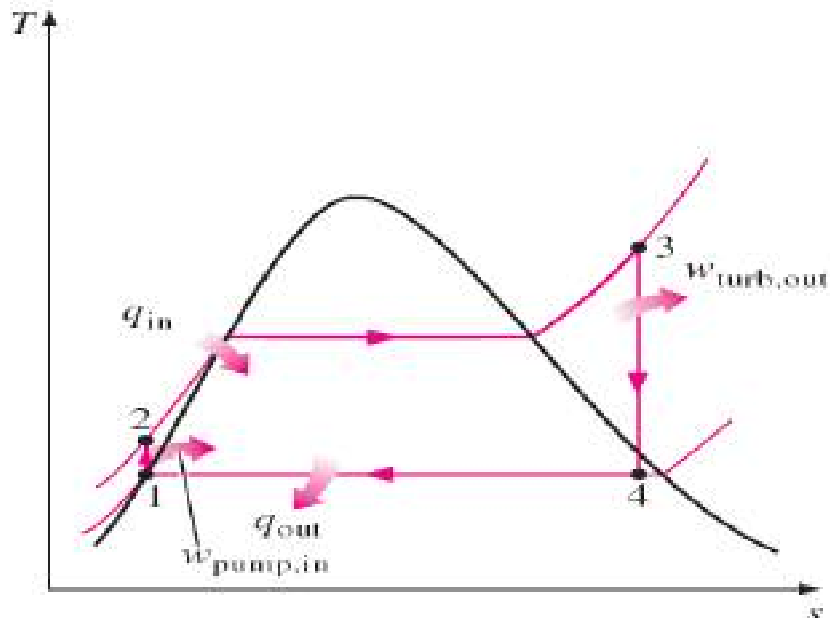
Figure No. 2.5 Corrosion zone with Flue gas and Metal temperature. – Super heater region.

3.0. THE POWER PLANT SCHEME

3.1. Steam Cycle for the Power Plant

3.1.1. The steam cycle defines the transformation of the heat energy to the mechanical energy at the turbine shaft, through the various thermodynamic processes that is capable of producing the net heat flow or work when placed between the energy source and energy sink. The heat energy is derived from burning of some fuels or using heat energy already available in the hot waste gases. The cycle needs a working fluid and steam is considered for the same. Steam is viewed as the most favoured working fluid mainly because of its unique combination of high thermal capacity, high critical temperature, high latent heat, excellent heat transfer characteristics, wide availability at cheaper cost, non toxic and non corrosive nature.

3.1.2. All the steam based power plants operate under the Rankine Cycle. In simple terms the Rankine Cycle is described as the combination of the various processes like the isentropic compression of water in the boiler feed water pumps (1 to 2), reversible heat addition to the working fluid (2 to 3) through the liquid, two phase and super heat states, isentropic expansion of the working medium in the turbine (3 to 4) and the constant pressure heat rejection to the atmosphere (4 to 1) through the condenser.



Simple Rankine Cycle

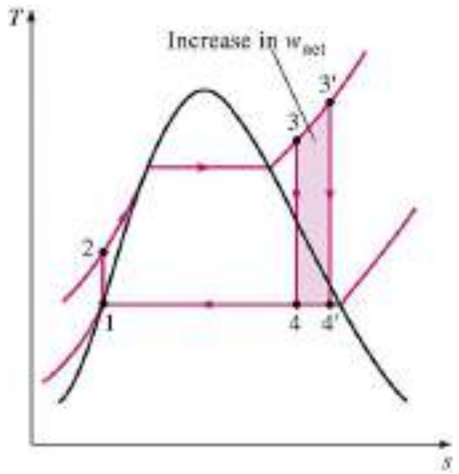
3.1.3. The cycle to be adopted for this project will be a modified Rankine Cycle with the addition of a Regenerative feed water heating.

3.1.4. High pressure and high temperature cycles are crucial for increasing the operating efficiency and the power output from the power Plants. The choice of the level of the pressure and temperature for the cycle depends on the level of confidence in the plant operators, quality of the feed water and the water treatment systems available, type and characteristics of fuel to be combusted, capacity of the power plant and the cost of the high pressure/temperature boiler and Turbogenerator systems and the financial benefits realizable from the power plant by way of the sale of the exportable power.

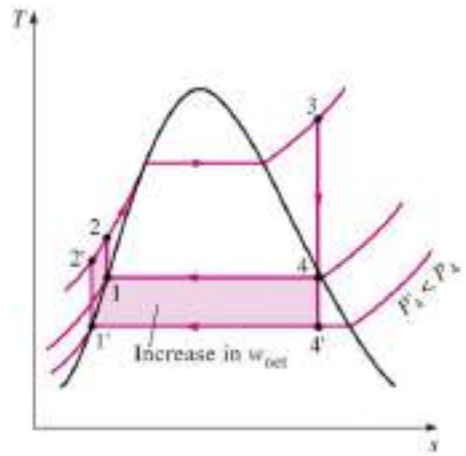
3.1.5. Thermodynamically, energy recovery from the Rankine Cycle is more dependent on the following factors

i) Steam inlet temperature to the steam turbine

ii) Steam outlet pressure from the steam turbine.



Increase in power output due to variation in the inlet steam temperature



Increase in power output due to variation in outlet pressure

3.1.6. Higher the inlet steam temperature (3 to 3’ in fig. 3.4), higher the cycle power output and in-turn higher cycle efficiency. However, because of the nature of the working medium, which is steam, the pressure also plays a major role in ensuring the optimum extraction of the useful energy from the working medium and hence, the increase in the steam temperature should be accompanied by the matching increase in the pressure. However, the practically attainable limits of temperatures are influenced by the metallurgy of the boiler tubing, piping and the turbine components and the complexity of the Creep fatigue interaction for the materials at higher temperatures.

Metal temperatures up to 400° C require the use of ordinary carbon steel and beyond 400° C, low grade alloy steels are employed. Above 500°C, the requirements become stringent and expensive. Above 550°C, the requirements are very stringent and prohibitively expensive.

It is also extremely important that the selection of the temperature is done keeping in mind the nature of the industry, type of fuel to be combusted and its characteristics capacity of the power plant under consideration, etc. Considerations such as cost, maintainability, provision of adequate safety margins, the experience of the industry so far and the level of the operating personnel available in the industry, enable us to select the practical limit on the steam temperature for the plants of the subject size and nature.

Considering the above, it is proposed to install steam generator with outlet steam parameters of 47.5 Bar (a) and 415±5°C. The steam inlet to the turbine will be 46 Bar (a) and 410±5°C, with the difference in the pressure and temperature accounting for the losses in the steam piping from the boiler to the turbine.

3.1.7. Lower the exhaust pressure higher the cycle power and in-turn higher cycle efficiency. The temperature at the vacuum will be at the saturation temperature corresponding to that pressure. Lowering the condenser pressure beyond a particular vacuum, will leads to higher moisture content in the final stages of the turbine. Higher moisture content is not advisable for the continuous operation of the turbine.

Selection of the condenser vacuum depends on various factors like, condensing medium selected for the plant, ambient conditions like dry bulb temperature, wet bulb temperature, relative humidity, etc.

Considering the present pollution norms, depletion of water quantity and quality year by year, it is envisaged to go for ACC. The performance of the ACC depends on the ambient dry bulb temperature.

Considering the maximum annual average temperature of 40°C, the practical possible vacuum that can be obtained is 0.16 Bar(a).

3.2. Selection of Turbo-generator for the Power plant

3.2.1. Steam turbines are broadly classified in to condensing steam turbines and noncondensing steam turbines. The non-condensing steam turbines are also called as back pressure turbines. In the power generation application, generally condensing steam turbines are widely used. The condensing steam turbine is designed to operate with the exhaust pressure below the atmospheric pressure (Vacuum pressure).

3.2.2. The high pressure condensing steam turbines for power generation application are broadly classified as Regenerative type steam turbine and Reheat type steam turbines. Regenerative turbines are widely used and well proven in the power and process industries for the capacity ranging from 10 MW to 100 MW. Reheat turbines are generally used for a capacity more than 100 MW range.

3.2.3. For the capacity under consideration, and the experience of the turbine vendors in the Indian market, Regenerative type steam turbine is selected for this project. The turbine selected will be a single bleed cum condensing machine. The steam required for the de-aerator and SCAP will be taken from the bleed of the turbine.

3.2.4. A typical cross section of a condensing steam turbine is shown in the below figure

Typical arrangement of steam turbine.

3.3. Selection of Pollution control equipment to control the emission. (Flue Gas cleaning system)

Combustion of waste in grate furnace results in the formation of exhaust gases that contain various pollutants. These pollutants include particulate fly ashes and gaseous flue gas constituents.

Substances found in the flue gas of WTE plants (before treatment) can be classified into three groups:

- Macro-pollutants:

Substances present in gaseous form, inorganic gases, such as CO, HCl, SO_2, HF, and nitrogen oxides (NOX).

- Micro-pollutants:

Substances present in very low concentrations, such as heavy metals (lead, cadmium, copper & zinc, etc.,), organic chlorinated compounds like chlorophenols, polychlorobiphenils, dioxins, furans and aromatic polycyclic hydrocarbons (PAH).

- Dust

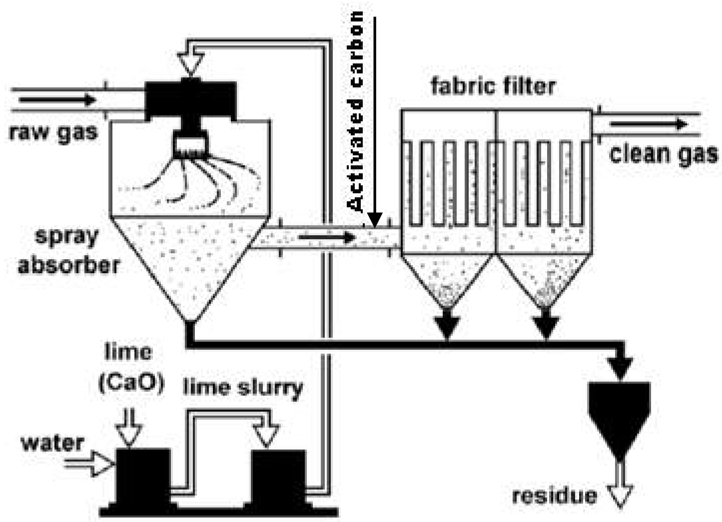
Solid-state particles upon which dioxins and other condensable micro-pollutants tend to fix.

Prior to the emission of flue gases into the atmosphere, concentrations of the pollutants mentioned must be reduced by technical measures.

3.3.1 Reduction of acid gases (HCl, HF & SOx)

Semi dry flue gas cleaning system is envisaged for reduction of acid gases.

In semi-dry processes, the adsorption agent added to the flue-gas flow is aqueous lime solution or lime slurry. An aqueous suspension of calcium hydrate is used to neutralize the acid potential in the flue gas. Calcium hydrate is effective on all gases but nitrogen oxides. The water solution evaporates and the reaction products are dry. The residue may be re-circulated to improve reagent utilisation.



Semi dry Flue gas cleaning system

3.3.2 Reduction of Nitrogen oxides

Nitrogen oxides in the flue gas of a waste incineration plant are formed largely from the nitrogen contained in the fuel.

NOx production can be reduced using furnace control measures such as Prevent over supply of air (i.e. prevention of the supply of additional nitrogen)

Although sufficient oxygen is required to ensure that organic materials are oxidised (giving low CO and VOC emissions), the oversupply of air can result in additional oxidation of atmospheric nitrogen, and the production of additional NOx.

Staged combustion in the furnace also envisaged by over fire air nozzles at various location along the height of the boiler. This involves reducing the oxygen supply in the primary reaction zones and then increasing the air (and hence oxygen) supply at later combustion zones to oxidise the gases formed.

NOx can be reduced by the prevention of unnecessarily high furnace temperatures (including local hot spots).

The use of a well distributed primary and secondary air supply to avoid the uneven temperature gradients that result in high temperature zones and, hence, increased NOX production is a widely adopted and important primary measure for the reduction of NOx production

Provisions shall be made in the furnace for Ammonia injection system which shall be installed later considering the pollution control requirements.

3.3.3 Reduction of Dioxins/Heavy metal

Dioxins are usually the principal contaminants due to the presence of plastics in the waste. Heavy metals may also be present as a secondary contaminant. The temperature at the point of injection has been reduced to 130°C to minimize the volatility of the contaminants, which consequently optimises the adsorption efficiency.

Activated carbon is injected into the gas flow. The carbon is filtered from the gas flow using bag filters. The activated carbon shows a high absorption efficiency for heavy metals as well as for PCDD/F. Different types of activated carbon have different adsorption efficiencies.

The adsorption of dioxins by activated carbon is controlled by the properties of both the carbon and the adsorbate, and by the conditions under which they are contacted. This phenomenon is generally believed to result from the diffusion of vapor-phase molecules into the pore structure of carbon particles. These molecules are retained at the surface in the liquid state because of intermolecular or Van der Waals forces.

As the temperature falls, or as the partial pressure of the vapour above the carbon rises, the average time that a molecule resides on the surface increases. So does the fraction of the available surface covered by the adsorbate. However, the carbon surface is not uniform and consists of sites whose activities vary. More active sites will become occupied first and, as the activity of the remaining available sites decreases, the adsorption energy will change.

The physical structure of activated carbon contain randomly distributed pores in the carbon, between which lies a complex network of irregular interconnected passages. Pores range in diameter down to a few angstroms and provide an internal surface area from

300 to 1,000 m^2/gram of carbon. The volume of pores at each diameter is an important variable that directly affects carbon performance.

Since adsorption takes place at the carbon-gas interface, the surface area of the carbon and pore radius is the important factors to consider.

The performance of activated carbon systems depends primarily on the carbon injection rate, carbon injection method, carbon properties, flue gas temperature, and PM control method.

3.3.4 Dust removal:

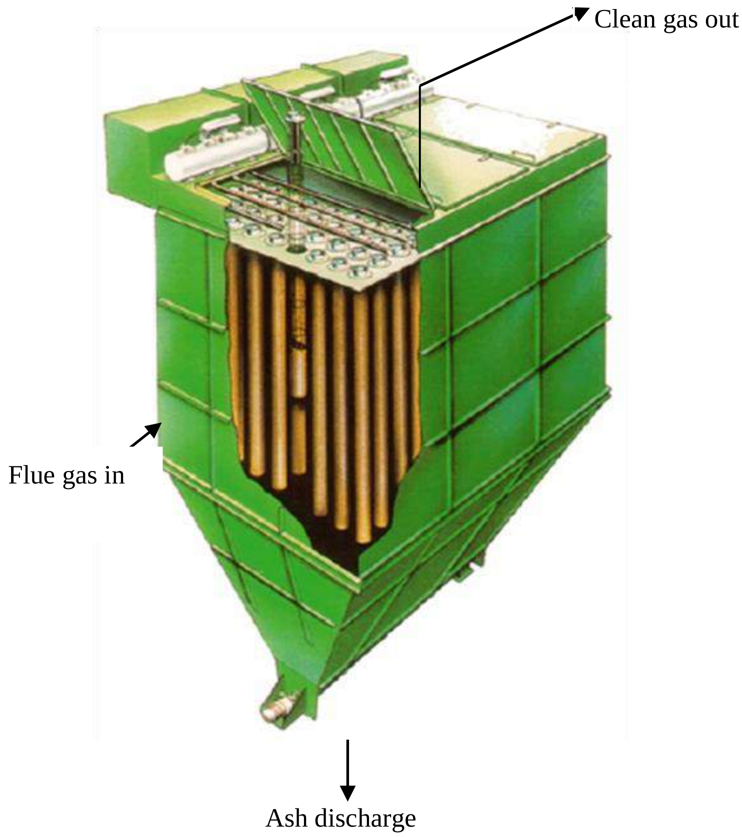
To separate dust particles from the flue gas, cyclones or electrostatic precipitators or bag filters are installed.

The selection of gas cleaning equipment for particulates from the flue-gas is mainly determined by:

- particle load in the gas stream
- the average particle size
- particle size distribution
- flow rate of gas
- flue-gas temperature
- compatibility with other components of the entire FGT system
- Required outlet concentrations.

Bag Filter:

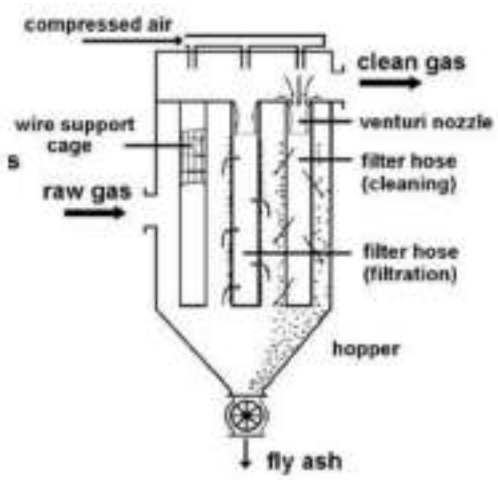
Filtration efficiencies of bag filters are very high across a wide range of particle sizes. Compatibility of the filter medium with the characteristics of the flue-gas and the dust, and the process temperature of the filter are important for effective performance. The filter medium should have suitable properties for thermal, physical and chemical resistance (e.g.hydrolysis, acid, alkali, oxidation). The gas flow rate determines the appropriate filtering surface i.e. filtering velocity.



Typical arrangement of a bag filter

Bag filters are filtering separators operating as surface filters. Separation of the particles takes place mainly on the surface of the filter medium, which is passed by the gas flow. On the surface of the filter medium, the particles retained form a layer, the dust cake, which causes an increasing pressure loss with increasing layer thickness. For this reason, the dust cake has to be removed regularly. By the construction of the filters and selection of filter media, these separators may be adapted optimally to the operation conditions and properties of the dusts, such that they can be used in various industrial sectors. Materials serving as filter media are fiber layers, membrane like materials, sintered metals or ceramics. For dedusting flue gas in waste incineration plants, for instance, PTFE membrane filter hoses are applied.

The filter areas can be cleaned by shaking or compressed air. In case of compressed-air cleaning, the filter elements are usually passed by an air flow from outside to inside and cleaned by a jet pulse (0.1 to 1 second) that is blown into the filter element. The setup and functioning of a fabric filter with jet-pulse cleaning are shown schematically in the following figure.



Bag filter with pulse jet cleaning

Operation temperature of a fabric filter is limited decisively by the filter materials used. In large-scale waste incineration plants, fabric filters are operated at temperatures ranging from 170 to 200 °C.

Fabric filters reach a very high separation efficiency of more than 99%. In particular for fine particles, Fabric filters represent a very efficient separation system.

The flue gas cleaning system envisaged for this project consists of Semi dry process with bag filters.

Semi dry flue gas cleaning system includes reaction tower, lime slurry making system & high speed atomiser. The acid gas is reacted with lime slurry and heavy metal and dioxins are absorbed by active carbon.

3.3.1. Selection of Condenser for the Power plant

3.5.1 The heat sink selection should be initiated in the early stages of the project development. The elements that significantly affect the selection of the heat sink option in a power plant includes the following:

- Availability and quality of water throughout the year.
- Change in water characteristics, due to change in ambient conditions and seasonal variations
- Disposal of water
- Site location (Near the sea)

3.5.2 Once the heat sink has been selected, its performance is optimized based on historical weather data for the wet bulb and dry bulb temperatures at site. Equipment design parameters such as approaches are then determined in order to achieve maximum cycle efficiency at the optimum cost.

3.5.3 If sufficient water is not available at the site, throughout the year, the only option is to go in for an Air Cooled Condenser system (ACC). Hence for this project ACC option is selected. The advantage of this system is, minimal or no issues associated with blowdown, disposal of water and plume formation. A typical arrangement of ACC is shown below

3.5.4 Air cooled Condenser must be placed close to the turbine building to minimise the pressure drop between the steam turbine and the Condenser, reducing the steam duct cost and improving the cycle efficiency.

3.5.5 The challenges on going for ACC are higher installed costs and larger foot prints.

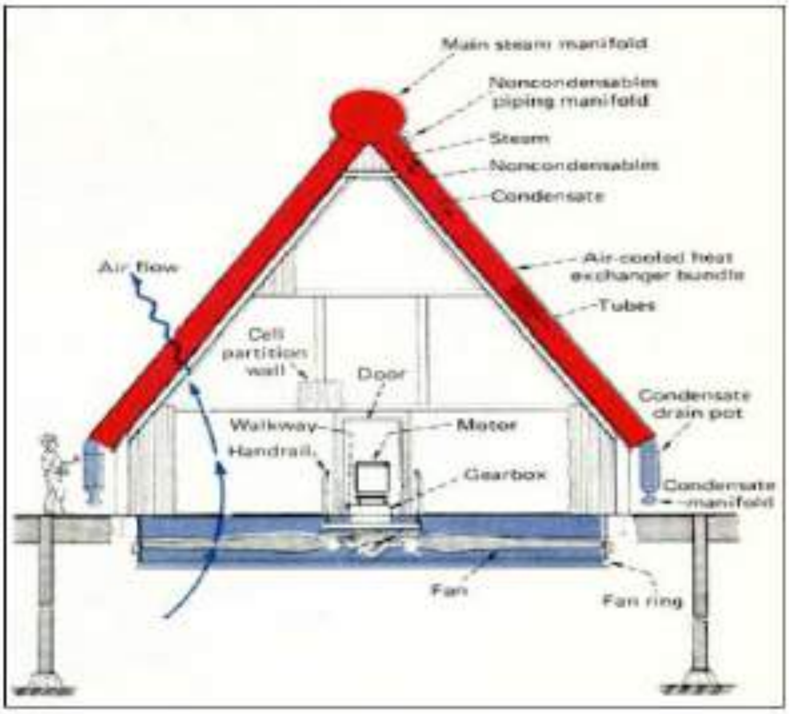


Fig: 3.8. Arrangement of ACC

3.6 Description of the Power Plant system

3.6.1 The proposed WTE plant scheme for the HMESPL, consist of two(2) number of steam generators capable to consume 600 TPD of pre-sorted waste in each boiler, with super heater steam outlet parameters of 47.5 Bar(a), 415±5°C and One (1) 24 MW extraction cum condensing turbogenerator.

3.6.2 The Turbo generator capacity is arrived based on the actual steam quantity available to generate power, with required margins to take care of the VWO conditions of the TG and to meet various operating and upset conditions of the power plant.

3.6.3 The steam generator is equipped with complete required system like air and flue gas system, fuel and ash system, feed water and steam system, Dust collection system, soot blower system, Steam and water analysis system, Boiler draft system, Instrument air system, Electrical system, instrumentation and control system, etc.

3.6.4 The turbine will be a single (1) bleed cum condensing machine. The steam required for the de-aerator is taken from the bleed of the turbine. ACC is identified as the condensing equipment. Steam required for the ejector and gland sealing is about 350 kg/h at 10.0 kg/cm^2 (a), is taken from live steam line through PRDS station.

3.6.5 The Power plant cycle will be provided with a de-aerator serving the dual purpose of de-aerating the feed water as well as heating the feed water with the bleed steam drawn through the turbine. The de-aerator considered is a floating pressure type.

3.6.6 The feed water management program shall ensure the supply of good quality make up water to the system. In the proposed power cycle, from the steam supplied to the turbine, about 98% will come back as the condensate from the ACC to the steam generator, through the feed water heating system (De-aerator). The complete make up required for the plant operation will be treated ground water.

3.6.7 Make up of required quality is considered from the water treatment plant. The make up for the cycle will be added in the condensate hot well and the quantity of makeup will be controlled by the hot well level control system.

3.6.8 Well engineered Fuel feeding and ash handling system is considered for this project.

3.6.9 The power generation will be at 11 kV level. After meeting the power plant internal consumption, the remaining power will be exported to Grid.

3.6.10 The complete plant instrumentation and control system for power plant shall be based on DCS philosophy, covering the total functioning requirements of measuring, monitoring, alarming and controlling, logging, sequence interlocks and equipment protection etc.

4.0 PLANT AND EQUIPMENT DESIGN CRITERIA

4.1 General

This section of the report gives the basic criteria for the design of the RDF based power plant. The design parameters like the size, layout, ratings, quantities, materials of construction, type of equipment etc., described in this report are approximate. Necessary changes could occur as the detailed engineering of the plant progresses and such changes are permitted as long as the detailed engineering of the plant achieves the intent of this report.

4.2 Ambient Conditions

4.2.1 Plant Elevation above MSL : 557 meter

4.2.2 Ambient Dry bulb Temperatures:

- Maximum : 47° C
- Minimum : 7.3° C
- Plant Design : 30° C
- Elec. equip.design : 50° C
- ACC design : 40° C

4.2.4 Relative Humidity:

- Average : 68%
- Plant Design RH : 60%

4.2.5 Precipitation:

- Total Annual Rainfall : 720.7 mm

4.2.6 Wind:

- Wind Direction : West - North West
- Design Wind Velocity : As per IS 875

4.2.7 Seismic Coefficient:

- Design : As per IS 1893
- Soil Bearing Capacity : 30 t/m^2 @ 2 m depth

4.3 Steam Generator & Auxiliaries

4.3.1 General

The grate considered for the burning of Fuel is reciprocating step grate, which is one of the critical equipment in the steam generator system. The steam generator is of Single drum, natural circulation, balanced draft, Two pass furnace design with water cooled membrane walls. Due to the nature of the fuel all the heat transfer coils are arranged in the third pass unlike a conventional boiler.

The furnace residence time is designed such that, the dioxin and furan emissions are within the specified limit of the pollution control board.

There are three (3) stages of superheater assembly with two (2) inter stage De-superheater, to control the superheater temperature.

4.3.2 Feed Water quality

The steam generator will be capable of operating with the following feed water quality requirements.

pH	:	8.8 - 9.2
Oxygen	:	0.007 ppm (max.)
Hardness	:	Nil
Total Iron	:	0.01 ppm (max.)
Total Copper	:	0.01 ppm (max.)
Total Silica	:	0.02 ppm (max.)
Hydrazine residual	:	0.01-0.02 ppm
Sp. elec. Conductivity	:	0.2 m.S./cm

(@ 25°C measured after cation exchanger in the H + form and fter CO_2 removal (max))

Total CO2	:	Nil
Oil	:	Not allowed

4.3.3 Steam Purity:

The steam generator will be capable of supplying uninterrupted steam at the MCR rating with the following steam purity levels.

Total Dissolved Solids	:	0.1 ppm (max)
Silica	:	0.02 ppm (max)

4.3.4 Boiler design parameters

Boiler type	-	Outdoor
Boiler circulation	-	Natural
Number of Boiler	-	Two (2)
Boiler Design Capacity	-	56 TPH
SH outlet pressure	-	47.5 Bar(a)
SH outlet temperature	-	415 ± 5°C

Feed water inlet temperature	-	130°C
De-aerated water temperature	-	130°C
Type of firing grate	-	Reciprocating step grate
Excess air percentage	-	40-60 %
Back end gas temperature	-	180°C
SH steam control range	-	60 to 100%
Main fuel	-	RDF
Start-up fuel	-	Light Diesel Oil

4.4 Turbogenerator & Auxiliaries

4.4.1 General description of steam turbine.

Steam turbine is a rotating device, which converts heat energy from the superheated steam to mechanical energy. When a generator is coupled with the turbine, this mechanical energy is converted into electrical power.

A condensing steam turbine is designed to operate with exhaust steam pressure below atmospheric pressure (vacuum pressure). The condensing equipment considered for this project is ACC. The vacuum that can be obtained in the ACC depends on the ambient dry bulb temperature. This vacuum pressure is maintained by a Steam Jet Air Ejector assembly, which takes motive steam from the main-steam line and ejects the non-condensable gases evolved during condensation process, there by maintain the vacuum.

4.4.2 Turbogenerator design data

Turbine inlet steam pressure	-	46 Bar(a)
Turbine inlet steam temperature	-	410 ± 5°C
Number of turbine bleeds	-	One (1)
Exhaust pressure	-	0. 16 Bar(a)
Condensing temperature	-	Wet, Saturated
Type of condenser	-	ACC
Design ambient temperature	-	40° C
Bleed pressure	-	5.85 ata
De-aerator outlet temperature	-	130°C
Power Factor (lagging)	-	0.80
Generation Voltage	-	11.0 kV
System Frequency	-	50 Hz + 5%
Turbine capacity	-	24 MW

4.5 Bag Filter & Auxiliaries

4.5.1 General description of Bag Filter.

Bag filter, used for this project as the dust emission control equipment, has collection efficiencies exceeding 99% for the fuel under consideration. The aspect ratio of the bag filter shall be optimally selected, so as to minimize re-entrainment and carry over of the collected dust, and for assured bag filter performance.

The material of the filter bags shall be of suitable material to withstand the corrosive effects of the gases. The material shall be a proven one for such applications and shall be easily available.

The filter bag shall be arranged in a manner to promote proper gas distribution to the bags and the bags will have an elongated cross section to promote better flexing, release and flushing of dust.

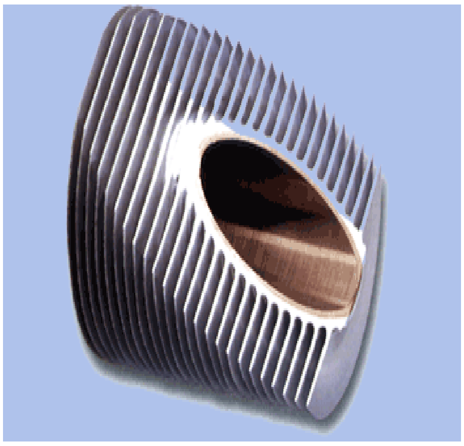
The bag to cage fixing method will be designed with a view of easy to install and maintenance. The bag will be held in tube sheet. Ease of extraction will be facilitated by the surface treatment of the filter bags, cage coating and bag to cage fit.

4.5 Air Cooled Condenser (ACC) & Auxiliaries

4.6.1 General description of Air Cooled Condenser:

The ACC will be of forced draft, direct air cooled and 'A' frame type, with the steam distribution manifold at the top and with drain manifolds at the bottom. The condenser elements are of finned tubes, arranged in parallel, on either side of the "A" frame, in two sections called the main condenser section and the vent or Dephlegmator sections.

There are several types of fins available, which can be used for ACC application. Considering the atmospheric condition and life of the equipment, generally two types of fin configurations are commonly used for the ACC application. They are Extruded Aluminium Fins (EA) and Carbon Steel Hot Dip Galvanised (CSHDG). Typical sketch of the fin configuration is given in figure . EA Fin assembly is considered for this project.



Extruded Aluminium Fins CSHDG Fins

The condensate from the ACC will be used to meet the feed water requirements of the steam generator. The makeup water (DM water) for the cycle will be from the water treatment plant, added in the Condenser Receiver Tank (CRT) of the ACC.

4.6.2 ACC design data

ACC operating pressure	-	0.16 Bar(a)
ACC steam temperature	-	59.6 °C
Design ambient temperature	-	40 °C
Variation in the operating pressure	-	0.2 to 0.1 ata
Variation in ambient conditions	-	7.5 to 45°C
Condensate flow quantity	-	82.2 TPH

Number of ACC cells	-	Eight (8)
Air temperature rise in ACC	-	15°C
Approach	-	5.0°C
Pressure drop across the system	-	12.0 mm WC
Air velocity across the bundles	-	< 2.0 m/s
Number of condensate ext. Pumps	-	2 x 100%
Number of hot well pumps	-	2 x 100%

4.6.3 General

The MSW from the various collection points will have different chemical and physical characteristics. The boiler has to be operated in a steady state condition which requires the fuel in a homogenous form. The pre-sorted MSW stored in the pit will be mixed by a grab crane provided on the pit head and it also feeds the homogenized Fuel to the Feed hopper.

Type of fuel storage in front of boiler	-	RDF pit
Capacity of refuse pit storage	-	5-7 days
Feeder arrangements from pit	-	Grab Cranes
No of grab cranes	-	2
Capacity of each grab	-	8 m3

4.7 Ash handling system

4.7.1 General

Mechanical ash handling system is envisaged to evacuate the ash generated from the boiler continuously. The ash handling system should be designed for evacuating the ash quantity at a suitable rate while firing the fuels under consideration.

The ash from Air Heater

The ash handling system basically consists of two schemes.

- Bed ash handling system consists of a submerged conveyer arrangement / Ash pit with suitable Crane for Feeding into truck.
- Fly ash handling system consists of fly ash removal from the Economiser, air heater and BF hoppers and transport to boiler fly ash silo.

4.8 Auxiliary Cooling water system

4.8.1 General

The steam from the Turbine exhaust is cooled in ACC. However, circulating cooling water is required for the following area in a power plant.

- Generator coolers
- Turbogenerator Oil coolers
- Boiler feed water pump
- Air compressors
- SWAS
- Bottom ash coolers

It is necessary to consider an auxiliary cooling tower of required capacity, to meet with the above cooling water requirements of the plant.

An FRP cooling tower with necessary auxiliaries could be considered for the auxiliary water requirements. Cooling water pumps of required capacity is considered for supplying cooling water to the auxiliaries. The detail on the cooling water pump is described under “Centrifugal Pumps”.

4.8.2 Auxiliary Cooling Tower Design data

Total cooling water quantity	-	600 m^3/h
Number of cooling tower cells	-	Two(2)
Capacity of single cell	-	300 m^3/h
Wet bulb temperature	-	30˚ C
Cooling water inlet temp	-	43˚ C
Cooling water range	-	8˚ C

4.8.3 Permissible circulating cooling water quality

Total dissolved solids	-	4000 ppm
Total hardness as $CaCO_3$	-	2200 ppm
Alkalinity as $CaCO_3$	-	250 ppm
Calcium as $CaCO_3$	-	1200 ppm
Sulphate as $CaCO_3$	-	1000 ppm
Total phosphate as PO4	-	14 ppm
Zinc as Zn	-	2.0 ppm
Reactive silica as SiO_2	-	200 ppm
Iron as Fe	-	3.0 ppm
$MgSiO_2$ as $CaCO_3$	-	35000 ppm
pH	-	7.0 to 9.0
Chloride as $CaCO_3$	-	500 ppm

4.9 Crane for the Turbogenerator Building

A Electrical operated overhead travelling (EOT) crane with a span of 12.0 meters, with the main hook lifting capacity of 25 Tonnes shall be provided to facilitate erection and maintenance of the Turbogenerators and their auxiliaries. The crane travel will cover the entire length of the Turbogenerator building.

4.10 Compressed Air System

4.10.1 General

The requirement of compressed air for instruments and the control systems of the power plant will be supplied the required number of air compressors. The air compressor shall be provided with accessories like Inter cooler, after cooler, Moisture separators, Air driers, Air receivers and control panel.

The design of the reciprocating compressor shall be in accordance with API-618. The rotating parts shall be dynamically balanced according to the standard.

The capacity (Nm^3/h) and free air delivery will be arrived at based on the air requirement for various equipment, control valve etc. The duty of the compressor shall be continuous and the control shall be dual type. The FAD will be calculated considering atmospheric temperature of 25°C.

4.11 Air Conditioning and ventilation System

The main plant control room housing the controls for the boiler and the turbogenerator shall be air conditioned with window mounted or split type air conditioners.

A dry bulb temperature of 24°C ± 1.0°C and a relative humidity of 55 ± 5% will be maintained in the control rooms, DCS terminal, laboratory, etc. A dry bulb temperature of 27° C ± 1.0°C and a relative humidity of 55 ± 5% will be maintained inside the battery room.

Wet pressurised ventilation system is to be provided for cable cellar room, TG building, MCC, VFD & PCC panel room, etc. Most of the areas like water treatment building, chemical storage area, toilets, will be ventilated with exhaust fans mounted on the walls or on the roof.

4.12 Fire Protection System

The fire protection system for the proposed power plant shall be consisting of:

- Fire hydrant system for entire power plant including boiler area, RDF Storage pit , STG building area and ACC area

- The high velocity water spray system for distribution transformers and lube oil tank

- Medium velocity water spray system for cable cellar
- Automatic fire detection and alarm system for the electrical panel rooms in the TG building.
- Portable fire extinguishers for the entire TG building.
- Portable fire extinguishers at strategic locations.

4.13 Centrifugal Pumps

4.13.1 General

The head / flow characteristics of pumps will be such that the head continuously rises with decreasing capacity until a maximum head is reached at zero flow. Maximum run-out flow should at-least 130% of duty point flow.

The shut off head should be at-least 1.1 times the duty point head and should not be more than 1.2 times the duty point head.

The power curve should be of non-overloading type with the maximum power occurring at or near duty point or towards maximum run out flow.

NPSHR curve should be a continuously rising one in the range of operation, from the minimum flow in the range to the maximum flow in the range. Required NPSH values shall not exceed available values over the entire range from minimum to rated flow.

There shall be 2 x 100% DM water transfer pump (1W +

1S), to transfer the DM water from the DM water storage tank to the surge tank, which is located in the top of the TG hall near the de-aerator, 2 x 100% cooling tower make up water transfer pump (1W + 1S) to transfer clear water from the Clear Water Storage Tank (CWST) to the cooling tower basin, and 2 x 100% Auxiliary Cooling Water (ACW) pumps (1W + 1S), to transfer cooling water from the cooling tower basin to the alternator cooler, oil coolers, Boiler feed pup cooling, SWAS, etc.

4.14 Raw water system

4.14.1 The water requirement for the power plant is met from the Hyderabad Metro Water and Sewerage Board(HMSSB). The Existing Plant have connection 600 KLD.

4.14.2 The design of the water treatment system for the power plant was carried out based on the actual chemical analysis of the secondary treated water supplied to the plant site.

4.15 Codes & Standards

Systems and equipment will be designed in accordance with the applicable sections of the following codes, standards and regulations in effect at the date of the Contract. Applicable sections of codes, standards and regulations will be defined in specifications.

Indian Standards (IS)

IS: 6	:	Moderate heat duty fire clay refractory Group-A
IS: 8	:	High heat duty fire clay refractory

IS: 325 : Three-phase induction motors

IS: 456 : RCC Structures

IS: 800 : Code of practice for Constructions in steel

IS: 807 : Code of Practice for Design,

Manufacture, Erection and Testing
(Structural Portion of Cranes & Hoists)

IS: 875 : Code of practice for Design loads for buildings structures.

IS: 1554 : PVC insulated (heavy duty) electric cables

IS: 1651 : Stationary cells and batteries, lead acid type (with tubular positive plates)

IS: 1893 : Criteria for Earthquake Resistant

Design of Structures

IS: 2026 : Power Transformers

IS: 2042 : Insulating bricks

IS: 2309 : Practice for the protection of the buildings and allied structures against lightning - code of practice

IS: 2429 : Round Steel Short link chain electric butt welded Gr.30

IS: 2544 : Porcelain post-insulators for systems with nominal voltage greater than 1000 V.

IS: 2705 : Current Transformers

IS: 2825 : Code for unfired pressure vessels

IS: 3043 : Code of practice for earthing

IS: 3144 : "Methods of test for Mineral Wool

Thermal Insulation Material"

IS: 3156 : Voltage Transformers

IS: 3177 : Code of Practice for design of

		Electric Overhead Traveling Crane and Gantry Cranes
IS: 3427	:	Metal-enclosed switchgear and Control gear for rated voltages above 1 kV and up to and including 52kV
IS: 3646	:	Code of practice for interior illumination
IS: 3832	:	Hand Operated Chain pulley blocks
IS: 3938	:	Specification for Electric Wire Rope Hoists
IS: 4503	:	Shell and Tube Heat Exchangers
IS: 4776	:	Troughed Belt Conveyors
IS: 5422	:	Turbine type generators
IS: 6547	:	Specification for Electrical Chain Hoists
IS: 7098	:	Cross linked polyethylene insulated
		PVC Sheathed cables
IS: 7155	:	Code of recommended practice for Conveyor Safety
IS: 8183	:	"Specification for Bonded Mineral Wool"
IS: 8531	:	Pulleys for Belt Conveyors
IS: 8598	:	Idlers and Idler Sets for Belt Conveyors
IS: 8623	:	Low voltage switchgear and control gear assemblies
IS: 9069	:	Inter-Carrier Chains
IS: 9921	:	Alternating current disconnectors (isolators) & earthing switches for voltage above1000V
IS: 10556	:	Code of practice for storage and handling of insulating materials.
IS: 11592	:	Code of Practice for Selection and Design of Belt Conveyors
IS: 13118	:	High voltage alternating current Circuit breakers
IS: 13947	:	LV switchgears and control gear

IS: 13779	:	Static watt-hour meters, class-1&2
IS: 14164	:	Industrial application and finishing of Thermal insulating materials at temp. above 80°C and up to 700ºC

American Society of Mechanical Engineers (ASME)

ASME Section I	:	Rules for construction of power boiler
ASME Section IX	:	Welding & Brazing Qualifications
ASME Section VIII	:	Un-fired Pressure Vessels Code
ASME Section IX	:	Welding Qualification

ASME Performance Test Code

ASME PTC 4	:	Steam Generating Units
ASME PTC 4.3	:	Air Heaters
ASME PTC 3.0	:	Guide for evaluation ofMeasurement Uncertainty in Performance test of Steam Turbine
ASME PTC 19.11	:	Water and Steam in the Power Cycle (Purity and Quality, Leak detection & Measurement)
ASME PTC 25.3	:	Safety and Relief Valves

American National Standards Institute

ASME B13.5	:	Pipe flanges and flanged fittings
ASME B 13.9	:	Butt welding fittings
ASME B 13.11	:	Socket Welding and Threaded fittings
ASME B 31.1	:	Code for Power piping

IEEE STANDARDS

IEEE: 80	:	Guide for safety in AC substation Grounding

IEEE: 141	:	Recommended Practice for Electric Power Distribution for Industrial Plants
IEEE: 142	:	Recommended Practice for Grounding of Industrial and Commercial Power Systems
IEEE: 241	:	Recommended Practice for Electric Power Systems in Commercial Buildings
IEEE: 242	:	Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
IEEE: 399	:	Recommended Practice for Industrial and Commercial Power System Analysis
IEEE: 446	:	Recommended Practice for Emergency and Standby Power for Industrial and Commercial Applications.
IEEE: 493	:	Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems.

IEC Standards

IEC:34	:	Rotating Electric machines
IEC:44	:	Instrument Transformers
IEC:56	:	HVAC circuit breakers
IEC:71	:	Coordination of Insulation
IEC:76	:	Power Transformers
IEC:85	:	Thermal evaluation and classification of Electrical insulations
IEC:99	:	Lightning Arrestors
IEC:129	:	Alternating current disconnectors (isolators) and earthing switches

IEC:144	:	Degrees of protection of enclosures for low Voltage switchgear & control gear
IEC:137	:	Bushings for Alternating Voltages Above 1000 V
IEC:183	:	Guide for selection of HV cables
IEC:185	:	Current Transformers
IEC:186	:	Potential Transformers
IEC:214	:	On load tap changers
IEC:227	:	PVC insulated electric cables
IEC:255	:	Electrical relays
IEC:269	:	LV Fuses
IEC:270	:	Partial discharge requirements
IEC:296	:	Insulating oils
IEC:298	:	AC metal enclosed switch gear and Control gear for rated voltages above 1 kV and upto and including 52 kV
IEC:354	:	Loading guide for oil immersed Power transformers
IEC:376	:	Specification and acceptance of new sulphur hexafluoride
IEC:439	:	LV switchgears and control gear assembly
IEC:502	:	Extruded solid dielectric insulated power for Rated voltages from 1 kV upto 30 kV
IEC:529	:	Classification of degree of protection
IEC:542	:	Application guide for on load tap changers
IEC:606	:	Application guide for power transformers
IEC:694	:	Degrees of protection provided by enclosure (IP code)

IEC:885	:	Electric test methods for electric cables
IEC:909	:	Short-circuit current calculation in three phase AC systems
IEC:947	:	LV switchgears and control gear
IEC:1036	:	Static meters

Industry Standards (As determined to be applicable by Contractor)

Indian Boiler Regulations (IBR)

American Gear Manufacturers Association (AGMA)

American Petroleum Institute (API)

American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Handbook

American Society for Testing and Materials (ASTM)

American Water Works Association (AWWA)

American Welding Society (AWS) Structural Welding Code (AWS D1.1)

Conveyor Equipment Manufacturers Association (CEMA)

Cooling Tower Institute (CTI)

Heat Exchange Institute (HEI)

Hydraulic Institute (HI)

Institute of Electrical and Electronics Engineers (IEEE)

Instrument Society of America (ISA)

Manufacturers Standardization Society (MSS) of the Valve and Fitting Industry

National Electrical Manufacturers Association (NEMA)

National Fire Protection Association (NFPA)

Pipe Fabrication Institute (PFI)

Tubular Exchanger Manufacturers Association (TEMA)

Turbine:

IEC Recommendation Publication No: 45

CSN 080030, DIN 1943

British Standards

BS 4592	:	Industrial type metal floors, Walk ways and Stair treads
BS 5395	:	Stairs, ladders and walkways
BS:2573	:	Permissible Stresses in Cranes
BS:5316	:	Performance Testing of Pumps Part-I Class C

5. PROJECT IMPLEMENTATION AND SCHEDULE

The most essential aspect regarding the implementation of the Power Project is to ensure the project completion within the schedule, spanning for Twenty Four (24) months from the date of placement of order for the main plant equipments like boiler and the turbo-generator.

A good planning, scheduling and monitoring program shall be imperative to complete the power project on time and without cost overruns.

6. PROJECT COST ESTIMATE

This section of this DPR, gives the estimate of the proposed power project only. The cost of the RDF based power plant is estimated on the basis of prevailing prices and based on in-house cost data of similar projects for Civil, Mechanical, Electrical and Instrumentation**.** The Estimated Total Cost of the Plant is Rs. 55200 Lakhs.

7. ABBREVIATIONS

ACC - Air Cooled Condenser
ACW - Auxiliary Cooling Water
ADB - Air Dried Basis
AGMA - American Gear Manufacturers Association
AOP - Auxiliary Oil Pump
API - American Petroleum Institute
ARC - Automatic Re-Circulation
ASME - American Society of Mechanical Engineers

BIS - Bureau of Indian Standards
BOP - Balance Of Plant
BFP - Boiler Feed Pump

CBD - Continuous Blow down Tank
CEP - Condensate Extraction Pump
CI - Cast Iron
CPCB - Central Pollution Control Board
CACW - Closed Air Closed Water
CRT - Condensate Receiver Tank
CSHDG - Carbon Steel Hot Dipped Galvanised
CT - Cooling Tower

DC - Direct Current
DCS - Distributed Control System
DG - Diesel Generator
DM - De Mineralized
DSCR - Debt Service Coverage Ratio

EA	-	Extruded Aluminum
EOP	-	Emergency Oil Pump
EOT	-	Electrically operated Overhead Travelling
ETP	-	Effluent Treatment Plant
ESP	-	Electro Static Precipitator
FAD	-	Free Air Discharge
FD	-	Forced Draft
FFL	-	Finished Floor Level
FOT	-	Furnace Outlet Temperature
FY	-	Financial Year
GCV	-	Gross Calorific Value
GOT	-	Government of Telangana
GSC	-	Gland Steam Condenser
HDG	-	Hot Dipped Galvanised
HMBD	-	Heat and Mass Balance Diagram
HP	-	High Pressure
HT	-	High Tension
IACO	-	International Civil Aviation Organization
IBD	-	Intermittent Blow-down Tank
IBR	-	Indian Boiler Regulation
ID	-	Induced Draft
IDC	-	Interest During Construction
IRC	-	Indian Road Congress
IRR	-	Internal Rate of Return
IS	-	Indian Standards

kW	-	Kilo Watt
LCV	-	Lower Calorific Value
LP	-	Low Pressure
LT	-	Low Tension
MAT	-	Minimum Alternate Tax
MCC	-	Motor Control Centre
MCR	-	Maximum Continuous Rating
MOP	-	Main Oil Pump
MS	-	Mild Steel
MSW	-	Municipal Solid Waste
MSL	-	Mean Sea Level
WTE	-	Waste To Energy
MW	-	Mega Watt
NPV	-	Net Present Value
O&M	-	Operation & Maintenence
OSHA	-	Occupational Safety and Health Administration
PA	-	Primary Air
PCDD	-	Poly Chloro Di-Benzo Dioxin
PCDF	-	Poly Chloro Di-Benzo Furan
PRDS	-	Pressure Reduction and De-superheater Station
PTC	-	Performance Test Code
QCNRV	-	Quick Closing Non Return Valve
RCC	-	Reinforced Cement Concrete
RDF	-	Refuse Derived Fuel

REEL	-	Ramky Energy and Environment Limited
RH	-	Relative Humidity
RO	-	Reverse Osmosis
SA	-	Secondary Air
SCAP	-	Steam Coil Air Pre-heater
SNA	-	State Nodal Agency
SPM	-	Suspended Particulate Matter
SS	-	Stainless Steel
STG	-	Steam Turbo Generator
SWAS	-	Steam Water Sampling Analysis
SWM	-	Solid Waste Management
TAC	-	Tariff Advisory Committee
TEMA	-	Tubular Exchanger Manufacturers Association
TDS	-	Total Dissolved Soilds
TG	-	Turbo Generator
TMCR	-	Turbine Maximum Continuous Rating
TPD	-	Tons Per Day
TPH	-	Tons Per Hour
VFD	-	Variable Frequency Drive
VOC	-	Volatile Organic Compounds
VWO	-	Valve Wide Open
WBD	-	Water Balance Diagram
WCM	-	Working Capital Margin
WDV	-	Written Down Value
WTE	-	Waste To Energy