



Dongwha Timbers

Bombala Sawmill Modification to Consent Submissions Response

December 2014

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1. Introduction

1.1 Background

Dongwha Timbers (Dongwha) propose to modify the existing project approval to install a new wood-fired boiler within its existing saw milling facility located south-west of Bombala in the Monaro Region of NSW. The new wood-fired boiler involves the installation of a 18 megawatt (MW) boiler to replace the use of three gas fired boilers and an existing wood fired boiler currently approved at the site (hereafter referred to as “the proposal”).

Dongwha are progressively implementing a major expansion of the sawmill in accordance with the Project Approval (PA 07_0161) issued under Part 3A of the *Environmental Planning and Assessment Act, 1979* (EP&A Act). PA 07_-161 requires the development and ongoing operations to be undertaken in accordance with the conditions of approval together with the description of the proposed development provided within the environmental assessment supporting the original project application

The proposal represents an alteration to the development as described in the original project application and therefore requires approval from the NSW Minister for Planning in the form of a modification under Section 75W of the EP&A Act.

An Environmental Assessment (EA) was prepared to support the application to the Department of Planning and Environment (DP&E) to modify the existing approval under Section 75W of the EP&A Act. The application was placed upon public exhibition from the 24th of September to the 9th of October 2014 and submissions in regards to the proposal were received by the Environment Protection Authority (EPA) and two public submissions.

Key issues raised by the EPA were in regards to:

- Level of design detail and performance specification of the proposed boiler
- Adequacy of the air quality assessment in regards to the requirements of the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (Approved Methods).
- Details of noise generated by the proposed boiler
- Waste streams to be created as a result of the proposed boiler
- Requirement for a variation to the existing Environmental Protection Licence (EPL) including upgraded monitoring conditions.

Two public submissions were received in regards to the proposed modifications from local residents and raised the following issues.

- Noise generated at the sawmill and compliance with existing compliance with existing EPL limits
- Capacity of the proposed boiler
- Deterioration in air quality associated with the proposal.

A detailed response to each of these issues is provided in the following sections.

2. Submissions Response

2.1 Availability of design data

The EPA have provided comment that the EA is built on the premise that the actual model, size, final capacity and environmental performance of the proposed boiler will be finalised after receiving consent and that this makes it difficult for the environmental performance of the boiler to be determined.

The level of detail available at the time of EA preparation was limited by the availability of proprietary data from the proposed boiler supplier prior to the completion of contractual negotiations.

The approach taken within the environmental assessment process was to utilise the available conceptual design details to define the proposal with sufficient detail to allow consideration of the significance of environmental risks associated with the proposal and the extent of departure from the approved development.

The proposed 18 MW boiler represents an relatively small project component of the overall sawmill expansion project and the level of detail provided within the EA is commensurate with the level of detail for the boiler configuration initially proposed as part of the project approval. The project description allows for the definition of the extent of environmental impacts which may potentially arise from the proposal, whilst maintaining a degree of flexibility to allow the detailed boiler design to work within a set of defined environmental parameters and performance standards required for the project.

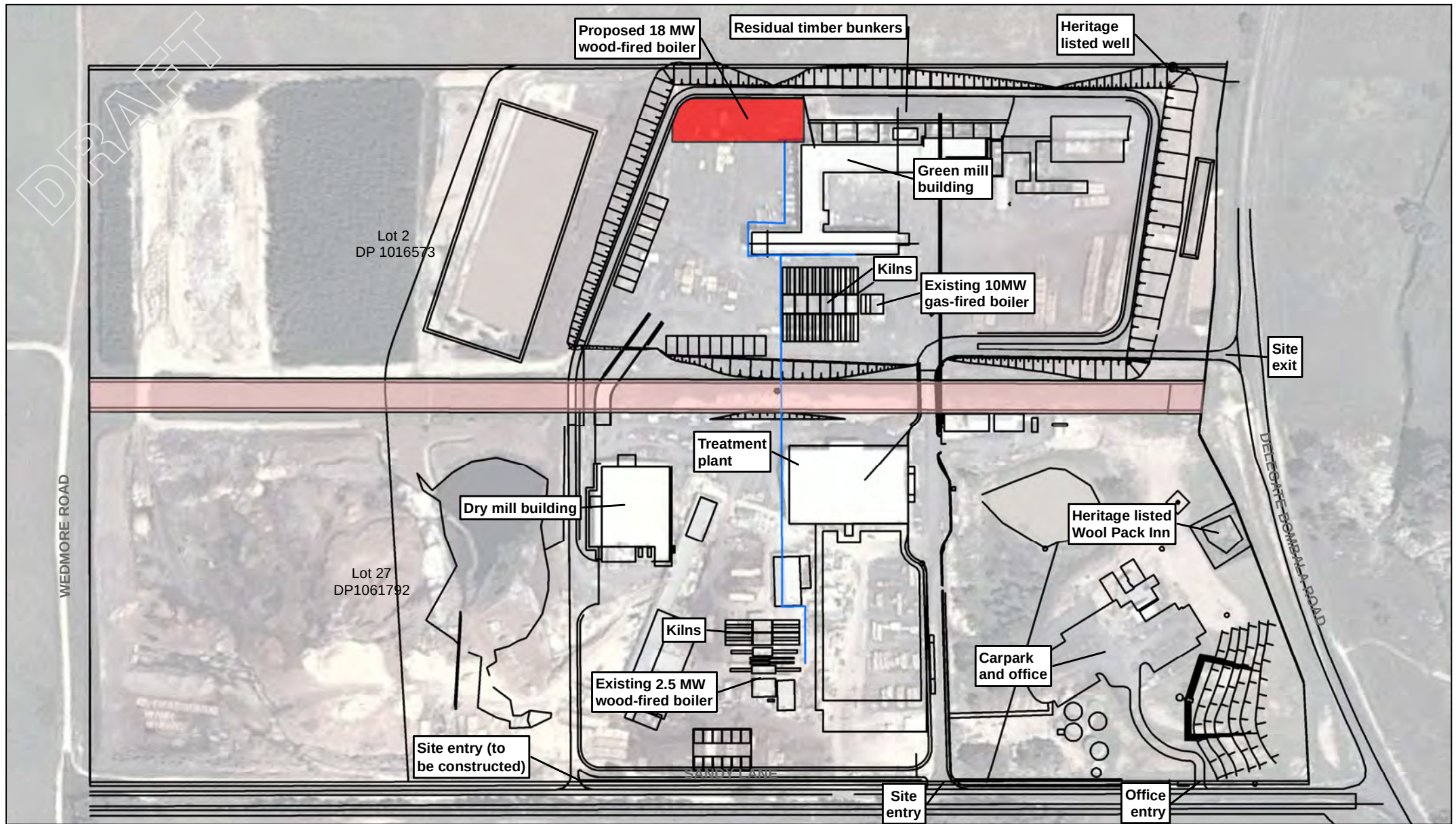
A central element to defining the environmental performance standards for the project was compliance with the EPAs Clean Air Group 6 standards of concentrations for a biomass boiler installed after 1st September 2005. The dispersion modelling undertaken as part of the Air Quality assessment for the EA indicated that adherence to the Group 6 emission standards would result in full compliance with the impact assessment criteria at all surrounding receivers. The predicted levels for most pollutants are one or more orders of magnitude below the respective impact assessment criterion at surrounding receivers.

Compliance with the Group 6 standards was highlighted as the key performance standard by the EPA during initial liaison between Dongwha and the EPA. Compliance is noted as mandatory and the proponent has committed to the design of a boiler which can readily meet the required level of emission controls. This is considered suitable for inclusion as part of the approval conditions for the modification and monitoring and testing during commissioning would be required to demonstrate compliance prior to full operation.

The design process has progressed following the submission of the EA and additional data has been sought from the preferred boiler supplier with the proposed design details and performance calculations included in Appendix A.

It should be noted that the preferred supplier for the boiler a Korean based company with numerous similar sized boiler installations. The performance specifications have been translated into English to allow for a detailed review as part of this submission to provide confidence that the proposed standards can actually be achieved by a boiler of this capacity.

The EA indicated that the footprint of the boiler would be approximately 25 metres by 25 metres with a height of approximately 10 metres. The detailed site layouts indicate an expanded boiler footprint of approximately 90 metres by 30 metres with a filter height of 15 metres and total stack height of 30 metres as shown on a revised Figure 2.1.



Paper Size A4
0 12.5 25 50 75 100
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



LEGEND

- Boiler location
- Gas easement
- Steam pipeline indicative alignment
- Site Layout



Dongwha Timbers
Bombala Sawmill Section
75W Modification PEA

Job Number | 21-23466
Revision | A
Date | 16 Dec 2014

Site layout

Figure 2.1

The detailed layout includes a dedicated woodchip and residual timber bunker and conveyor to service the boiler together with other ancillary equipment including the control room, water softener and water tanks as shown on the layout diagrams included in Appendix A.

The proposal will continue to be located entirely within the previously approved sawmill site which has been previously disturbed as a part of the progressive development of the site and the ground surface consists of hardstand, concrete or pavement. Remaining assumptions in regards to the construction of the boiler remain consistent with the EA.

2.2 Air Quality assessment

2.2.1 Capacity of the boiler

Dongwha initially proposed the establishment of a 20 MW boiler as part of the modification. However, following a review of the energy requirements for the GOS kilns and the redry kilns, the capacity of the boiler was reduced to 18 MW as proposed in the project application. References to 20 MW within the assessment are typographical errors relating to an earlier version of the EA and all modelling and detailed assessment has been completed based upon the proposed 18 MW configuration.

2.2.2 Representative Meteorological data

The EPA's submission requested an examination of representative meteorological data to determine representative years for modelling impacts and justification of this choice.

A meteorological review was undertaken as part of the air quality assessment process based upon a detailed analysis of the last five years of data from the BoM Bombala AWS. The year chosen for modelling in the air quality assessment was 2009.

A detailed analysis of the meteorological data is presented in Appendix B of this submissions report.

2.2.3 Emissions Estimates

The EPA's submission stated that emission estimation needs to be based on the performance of the boiler to be installed for the fuel to be used using manufacturer's specifications and any available measurements of operational emissions.

Manufacturer supplied information is available for PM₁₀, CO, SO₂, and NO₂ and presented in Appendix A and summarised below in Table 2-1.

Table 2-1 Boiler supplier emission data

Pollutant	Actual (mg/m3)	Class 6 limit (mg/m3)
Dust as PM10	5.9	50
CO	27.1 (22 ppm)	125
SOx	0	-
NOx	164 (81 ppm)	500

PM_{2.5} is assumed to be 50% of PM₁₀ as there is no supplier data available. NPI¹ emission factors assume a 50% reduction from PM₁₀ to PM_{2.5} using a multiclone without fly ash reinjection for wood/bark fired boiler.

¹ National Pollutant Inventory Emission estimation technique manual For Combustion in boilers Version 3.6 December 2011

VOCs PAH, dioxins and furans which are all several orders of magnitude under the criteria have been based on NPI emission factors. The levels are not significant and have only been reported to be consistent with previous assessments at the facility.

2.2.4 Careful presentation of model parameters

GHD are aware that there was an error in the reporting of PM_{2.5} data in the Air Quality Assessment submitted with the EA. This error has no implication in the assessment findings and has been rectified in the results presented in this report.

The TAPM grid level spacing shown in Table 2 in Appendix C should have been shown as follows in Table 2-2.

Table 2-2 - TAPM model parameters

Parameter	Value
Modelled Year	2009
Domain centre	UTM: 55H 699385 m E, 5912523 m N
Number of vertical levels	25
Number of Easting Grid Points	25
Number of Northing Grid Points	25
Outer Grid Spacing	30,000 m x 30,000 m
Number of Grid Levels	4
Grid Level Spacing	Level 2 – 10000 x 10000 m Level 3 – 3000 x 3000 m Level 4 – 1000 x 1000 m

The air quality assessment adopted the same assessment criteria as presented in the previously approved sawmill expansion EA. Based on advice from the EPA, the PM_{2.5} 24 hour criterion has been reduced from 50 µg/m³ to 25 µg/m³. It is noted that the national Environment Protection (Ambient air quality) Measure also sets 25 µg/m³ as an advisory guideline for 24-hour PM_{2.5}.

2.2.5 Modelling of impacts

The EPA's submission requested Modelling of the impact of the proposed wood-fired boiler using emission estimates representing operation as noted above and representative meteorology.

The AUSPLUME models have been updated based on the emission calculation sheet supplied by the preferred boiler supplier with further details of the emissions estimates included in the model is included in Appendix C and the results are summarised below in Table 2-1.

The revised modelling indicates that the maximum predicted concentrations from the operation of the proposed boiler are expected to continue to comply with the impact assessment criteria at all surrounding receivers and the site boundary where relevant. The predicted levels for most pollutants are one or more orders of magnitude below the respective impact assessment criterion.

Consideration of wind direction was included in the meteorological analysis used as input to the dispersion modelling to assess the impacts on nearby receivers. There is not anticipated to be a notable reduction in air quality at surrounding receivers due to the high level of emission controls adopted as part of the proposal.

Table 2-3- Predicted pollutant concentrations at sensitive receivers

Receiver	Model Predictions	Assessment Criterion
<i>Particulate matter - PM₁₀ 24 hour µg/m³ 100th percentile prediction</i>		
1	0.07 µg/m ³	50 µg/m ³
2	0.07 µg/m ³	50 µg/m ³
3	0.09 µg/m ³	50 µg/m ³
4	0.16 µg/m ³	50 µg/m ³
5	0.07 µg/m ³	50 µg/m ³
<i>Particulate matter – PM_{2.5} 24 hour µg/m³ 100th percentile prediction</i>		
1	0.035 µg/m ³	25 µg/m ³
2	0.035 µg/m ³	25 µg/m ³
3	0.045 µg/m ³	25 µg/m ³
4	0.08 µg/m ³	25 µg/m ³
5	0.035 µg/m ³	25 µg/m ³
<i>Carbon Monoxide - CO 1 hour mg/m³ 100th percentile prediction</i>		
1	2.03 mg/m ³	30 mg/m ³
2	1.87 mg/m ³	30 mg/m ³
3	1.52 mg/m ³	30 mg/m ³
4	2.80 mg/m ³	30 mg/m ³
5	2.82 mg/m ³	30 mg/m ³
<i>Nitrogen Oxides - NO₂ 1 hour µg/m³ 100th percentile prediction</i>		
1	12.3 µg/m ³	246 µg/m ³
2	11.3 µg/m ³	246 µg/m ³
3	9.2 µg/m ³	246 µg/m ³
4	17.0 µg/m ³	246 µg/m ³
5	17.1 µg/m ³	246 µg/m ³
<i>Sulfur dioxide SO₂ 1 hour µg/m³ 100th percentile prediction</i>		
1	0 µg/m ³	570 µg/m ³
2	0 µg/m ³	570 µg/m ³
3	0 µg/m ³	570 µg/m ³

Receiver	Model Predictions	Assessment Criterion
4	0 µg/m ³	570 µg/m ³
5	0 µg/m ³	570 µg/m ³
<i>Volatile Organic Compounds VOC 1 hour mg/m³ 99.9th percentile prediction</i>		
Property boundary	0.001 mg/m ³	3.2 mg/m ³
1	0.000815 mg/m ³	3.2 mg/m ³
2	0.000548 mg/m ³	3.2 mg/m ³
3	0.000572 mg/m ³	3.2 mg/m ³
4	0.000710 mg/m ³	3.2 mg/m ³
5	0.000659 mg/m ³	3.2 mg/m ³
<i>PAH 1 hour mg/m³ 99.9th percentile prediction</i>		
Property boundary	0.000016 mg/m ³	0.004 mg/m ³
1	0.000012 mg/m ³	0.004 mg/m ³
2	0.0000083 mg/m ³	0.004 mg/m ³
3	0.0000086 mg/m ³	0.004 mg/m ³
4	0.000011 mg/m ³	0.004 mg/m ³
5	0.0000097 mg/m ³	0.004 mg/m ³
<i>Dioxins and furans DFs 1 hour mg/m³ 99.9th percentile prediction</i>		
Property boundary	4.5E-12 mg/m ³	2E-9 mg/m ³
1	3.7E-12 mg/m ³	2E-9 mg/m ³
2	2.5E-12 mg/m ³	2E-9 mg/m ³
3	2.6E-12 mg/m ³	2E-9 mg/m ³
4	3.2E-12 mg/m ³	2E-9 mg/m ³
5	3.0E-12 mg/m ³	2E-9 mg/m ³

2.3 Noise

The EPA's submission has requested additional data in regards sound power level that is likely to be emitted and details of the proposed boiler operations. Community submissions also highlighted noise generated by the operation of the sawmill as a key issue for the nearby residents.

The EA provided an outline of existing compliance with EPL limits associated with the existing operation of the sawmill. This included acknowledgement of exceedance of criteria on

occasions at the two closest receivers located 780 m and 560 m respectively from the proposed boiler location within the site. Previous exceedances have been in relation to operation on the log in feed and sorting chain, green mill and dry mill. The proponent has implemented a number of measures to reduce noise emissions from the site and is proposing to undertake a further round of detailed compliance monitoring in February or March in 2015 prior to submission of the EPL annual return.

The proposal involves installation of an 18 MW boiler to replace four boilers which form part of the existing operation. The proposed boiler is not anticipated to result in noisy operations or represent a dominant noise source in comparison to the operation of the remaining plant and machinery at the sawmill.

The key emission source from the operation of the boiler is anticipated to be the blower fan noise which has confirmed to have a maximum sound pressure level of 85 dB(A) at a 1 metre distance. With up to 3 fans operating this would equate to a sound pressure level of 90 dB(A) and would be similar to the existing measured blower fan noise source sound power level of 98 dB(A)² from the existing wood-fired boiler on site. Based on noise propagation according to ISO 9613, and considering a ground absorption factor typical of grassed land and a temperature inversion, the noise levels from the new three fans would be less than 25 dB(A) at 560 m (which is the nearest sensitive receiver). This level of noise is well below the noise criteria of 35 dB(A) and therefore would not contribute to noise emissions from the site.

The proposal is therefore considered to pose minimal risk to surrounding receivers as it would not result in a significant increase in potential emissions in comparison to the existing approved boiler configuration.

The emissions from the boiler fans will be more than 10 dB below the dominant noise sources at the sawmill site during daytime operations which have sound power levels ranging from 104 dB(A) to 111 dB(A). A contribution of 85 dB(A) from the fans associated with the new boiler is not considered to contribute to site noise emissions during the day-time and evening period and would not be audible at the surrounding residential receivers.

During the night time the potential emissions will be similar to the existing emissions from the heat plant and are also anticipated to comply with the assessment criteria. It should be noted that there have been no noise complaints associated with the existing standard night operations, with the exception of an early start of the log sorting chain which has now been rectified.

The ongoing management of compliance associated with emissions from the remainder of the sawmill operations is being separately investigated in liaison with the EPA and the proponent will continue to seek reasonable and feasible measures to reduce the overall level of noise emissions from the site.

Noise during construction will be managed in accordance with the Interim Construction Noise Guidelines and the objectives of the Industrial noise policy.

2.4 Waste

2.4.1 Ash

The EA indicated that additional ash would be generated through the operation of new boiler and the EPA has requested further details upon anticipated volumes and management strategies in regards to the management of the Ash.

² (Marshall Day Acoustics 28 October 2009)

Estimation of ash generation is included within the boiler suppliers calculation sheet included within Appendix A and is summarised below. The following ash types are anticipated to be produced by the proposed boiler:

- Ash from combustion chamber = 319.54 kg/h. This ash is collected via a number of discharge points onto a belt type conveyor discharging into an ash container
- Ash discharged from cyclones = 1.66 kg/h. This ash has a dedicated screw type conveyor discharging into a dedicated ash container
- Ash discharged from baghouse = 4.73 kg/h. This ash has a dedicated screw type conveyor discharging into a dedicated ash container.

This results in a total of 325.93 kg/h of ash is produced over around 8500 hours per year i.e. 2770 tonnes per year of dry ash.

The calculation sheet also documents 4.93% ash production on dry basis from combustor feedrate of 8.2t/h which represents a 3436 tonnes per year of dry ash. It is therefore anticipated that in the region of 2,800 – 3,400 tonnes per year dry ash will be produced by proposed boiler.

Wetted ash will occupy around 1.6 tonnes per cubic metre and would be initially stored in a concrete bunker on-site prior to reuse or disposal.

The ash produced from a biomass boiler is relatively clean and considered suitable for a range of potential reuse opportunities including use as fertiliser or as a liming agent for forest soils. Dongwha are currently in preliminary negotiations with a waste disposal contractor for use of the ash for input to a fertiliser supply company.

If reuse opportunities cannot be negotiated then the ash will be disposed of as a waste in accordance with EPA's *Waste Classification Guidelines* (DECCW, 2009).

2.4.2 Wastewater

The EPA's submission requested additional information in regards to whether any additional wastewater will be generated by the proposal and management strategies proposed for the water.

The estimated water use and wastewater generation assessed as part of the overall sawmill expansion project is documented within Appendix C of the Soil, Groundwater and Surface Water Management Plan prepared by Peter J Ramsay and Associates and included as Appendix D to the overall sawmill expansion EA.

The approved heat plant configuration EA results in the generation of 14.043 m³/yr of process water from the boilers. Process water consisting of steam condensate and blowdown water is currently directed to a large underground storage vessel known as the TTSA storage located centrally within the site.

Process water within the TTSA storage is reused with the treatment plant at the mill and is topped up from stormwater run-off from the existing stormwater detention pond No. 3. The TTSA storage also has an emergency overflow to stormwater detention pond 3.

To determine the potential for the generation of additional wastewater from the proposed boiler a water balance investigation has been undertaken. Technical data used in the development of the water balance for the proposed boiler is summarised in Table 2-4.

Table 2-4 Proposed boiler technical specifications

Parameter	Units	Value
Furnace heat capacity	MW	18
Steam produce capacity	Ton/hr	25
Operation steam pressure	Bar	16
Efficiency	%	80

The steam header is piped to kilns/heat exchangers as part of the timber preparation process. It is proposed that the spent steam /condensate which is estimated at 20% of total steam production capacity or 5 t/h will be returned to the boiler for reuse.

The water preparation, condensate recovery and blowdown system will be optimised in order to make maximum use of condensate return water, blowdown flash steam recovery and minimisation of blowdown volumes as shown schematically on Figure 2-2.

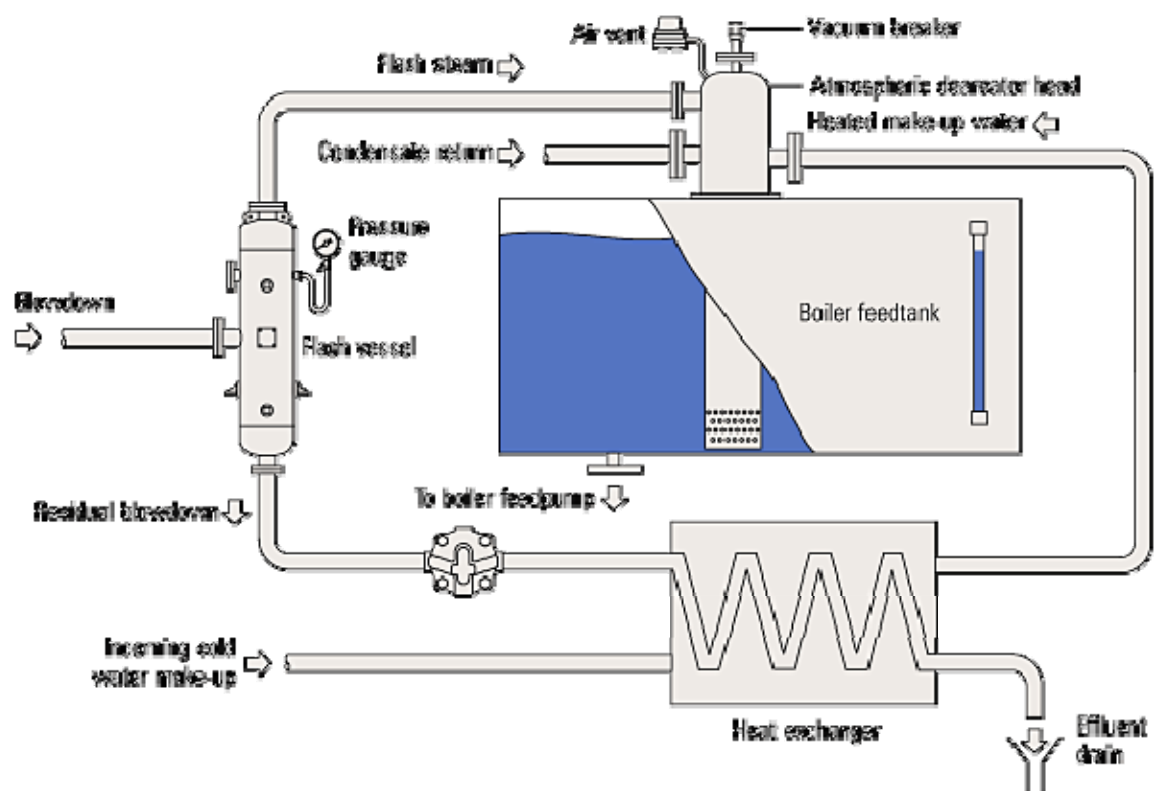


Figure 2-2 Boiler condensate and blowdown

Condensate water is proposed to be returned to the boiler feed water tank. Condensate water is clean water which reduces the requirement for the treatment and softening of the feedwater stream and reduces the boiler blowdown rate from approximately 5 t/h to 1.7 t/h as a result of the lower TDS content in the condensate water. A dedicated condensate return pipeline is required to deliver to the boiler feed water tank.

The blowdown rate of 1.7 t/h can be further reduced by utilising the heat content to flash off steam. Flashing of 18% of the 1.7t/h blowdown water is achieved by using the contained heat content of the condensate using a dedicated flash vessel/valve is required to obtain the extra condensate for reuse. The energy efficiency is maximised by utilising condensate at 90°C to pre-heat feed water from 10°C.

The use of a condensate recovery and blowdown flashing system will reduce the blowdown to 1.4 t/h which results in an anticipated blowdown production of 11,710 m³/yr, which is proposed

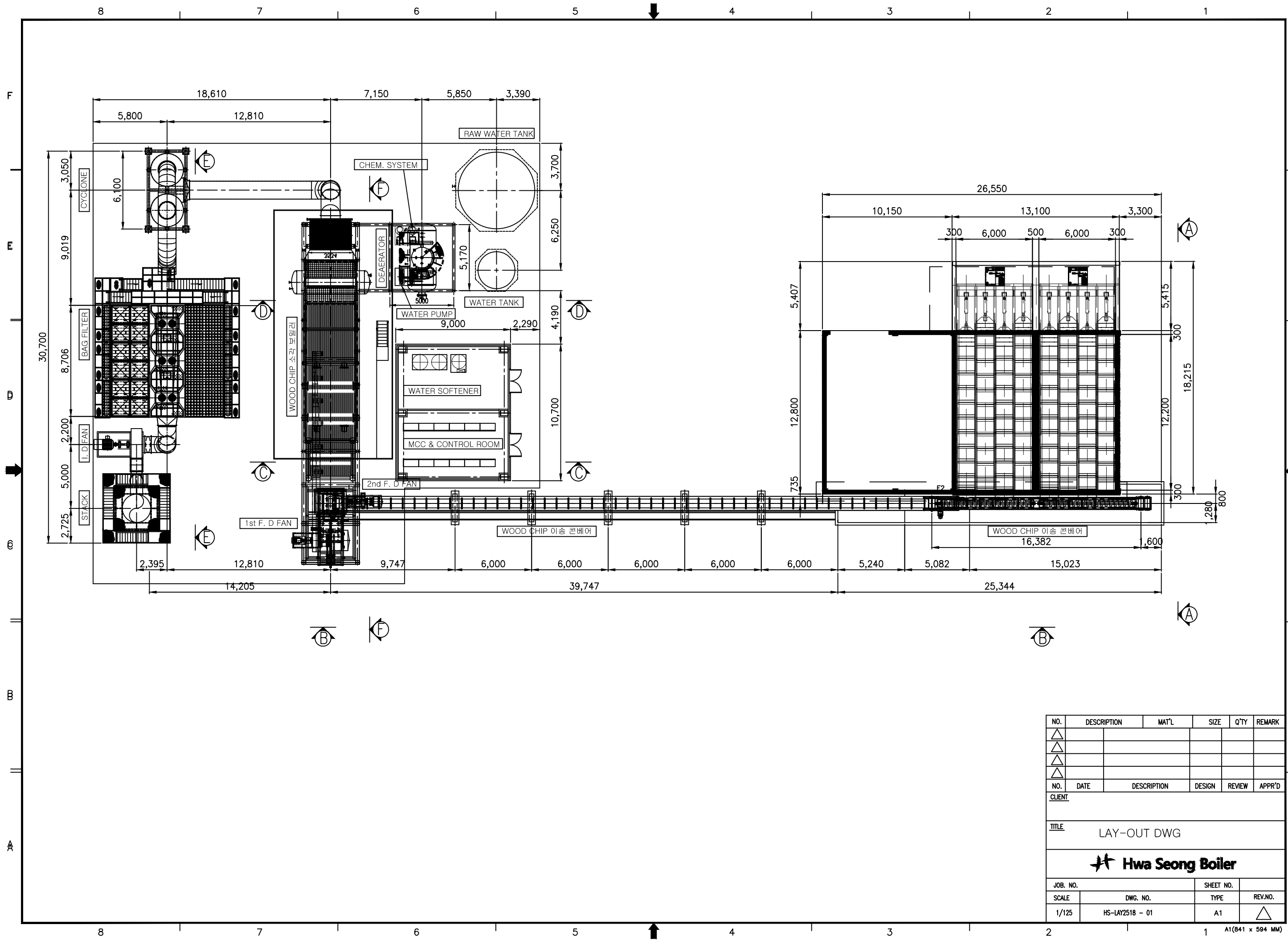
to continue be directed to the TTSA storage. This represents a reduction of approximately 2,333 m³/yr of wastewater from the currently approved heat plant configuration.

2.5 Licence variation

Dongwha acknowledges the requirements to obtain a variation to the existing EPL and to update the monitoring conditions as part of this proposal.

Appendices

Appendix A – Design Plans and Calculations



NO.	DESCRIPTION	MAT'L	SIZE	Q'TY	REMARK
△					
△					
△					
△					
NO.	DATE	DESCRIPTION	DESIGN	REVIEW	APPR'D
CLIENT					
TITLE					
LAY-OUT DWG					
Hwa Seong Boiler					
JOB. NO.			SHEET NO.		
SCALE	DWG. NO.		TYPE	REV.NO.	
1/125	HS-LAY2518 - 01		A1	△	

8 7 6 5 4 3 2 1

F

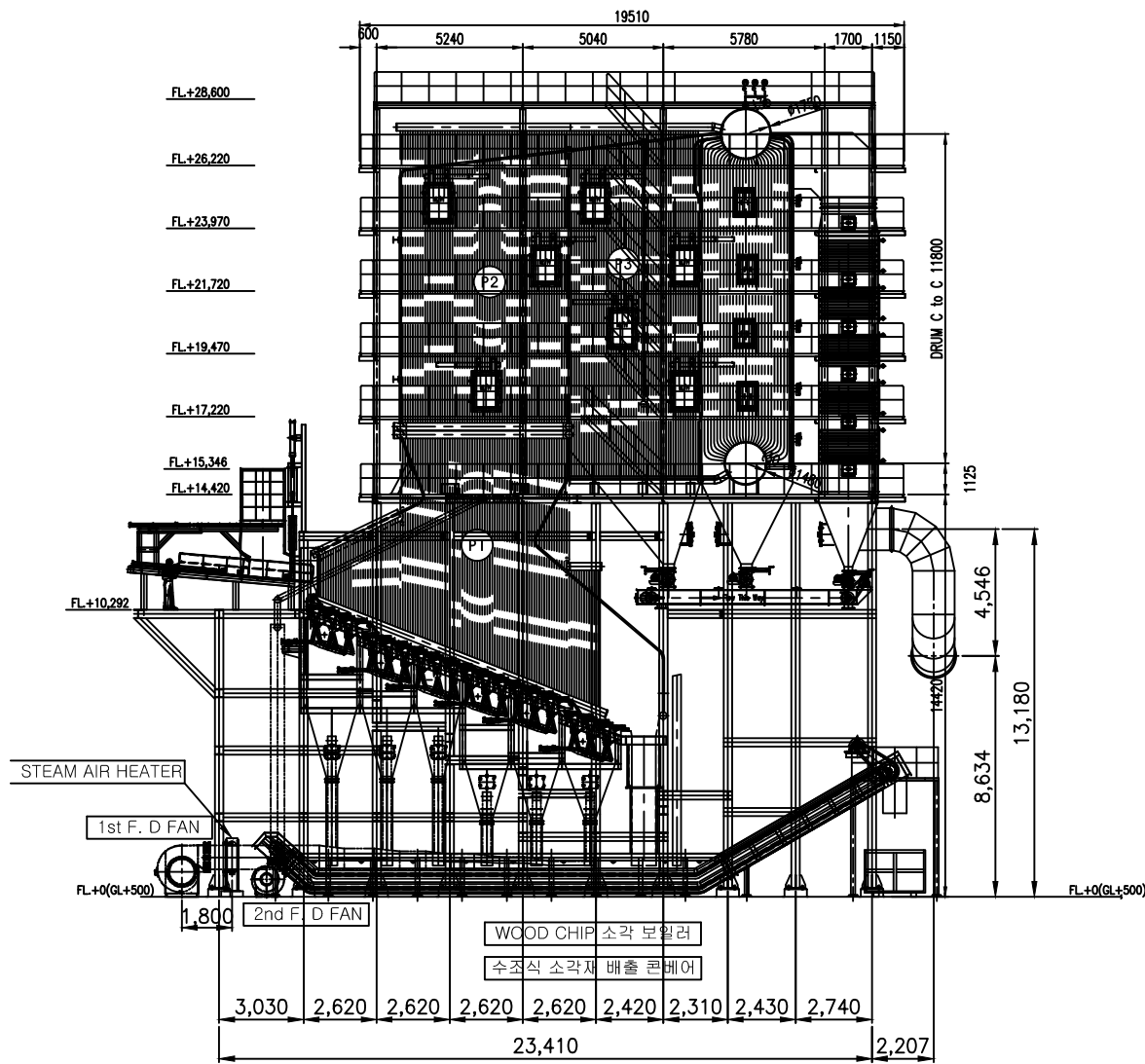
E

D

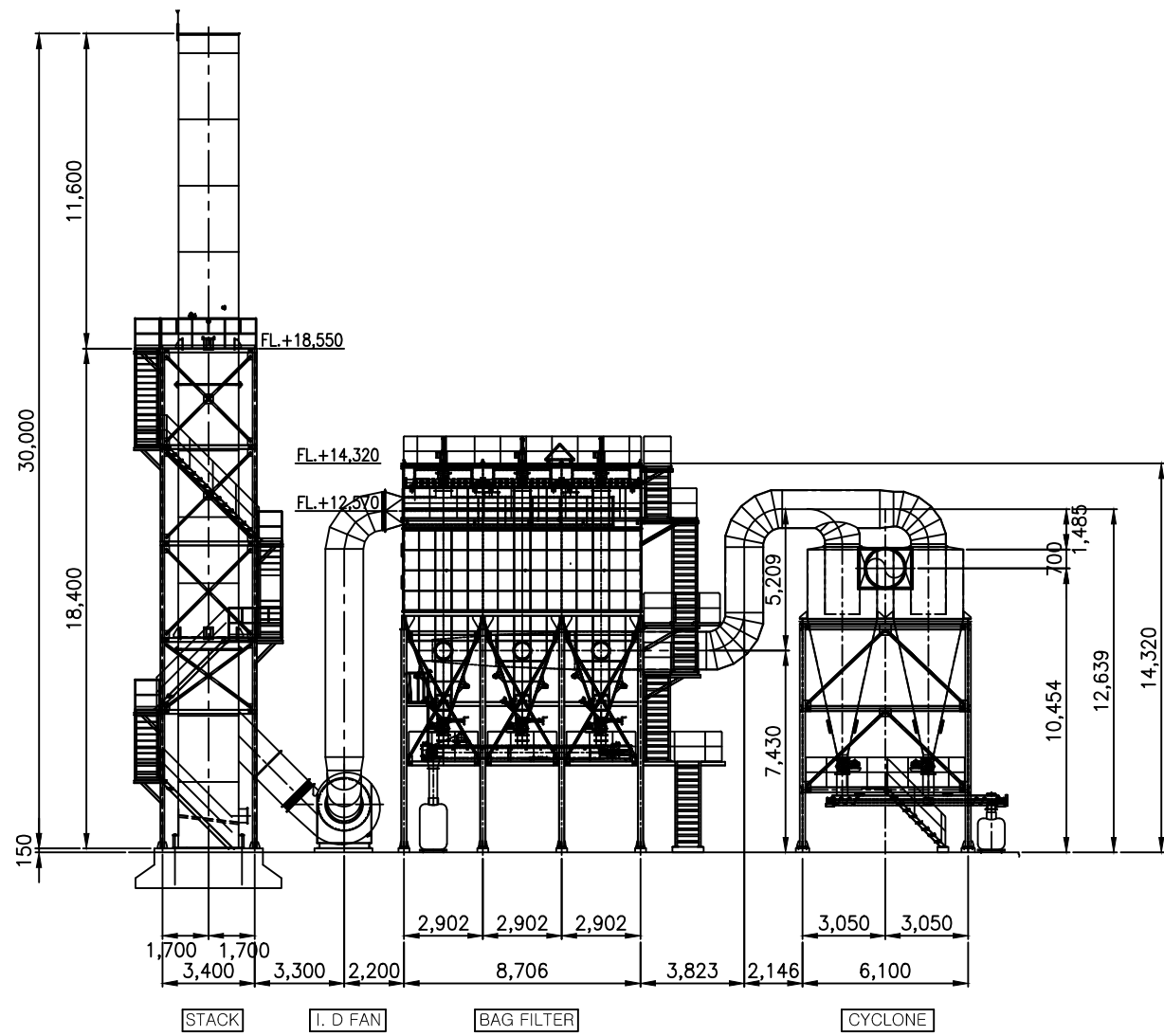
C

B

A



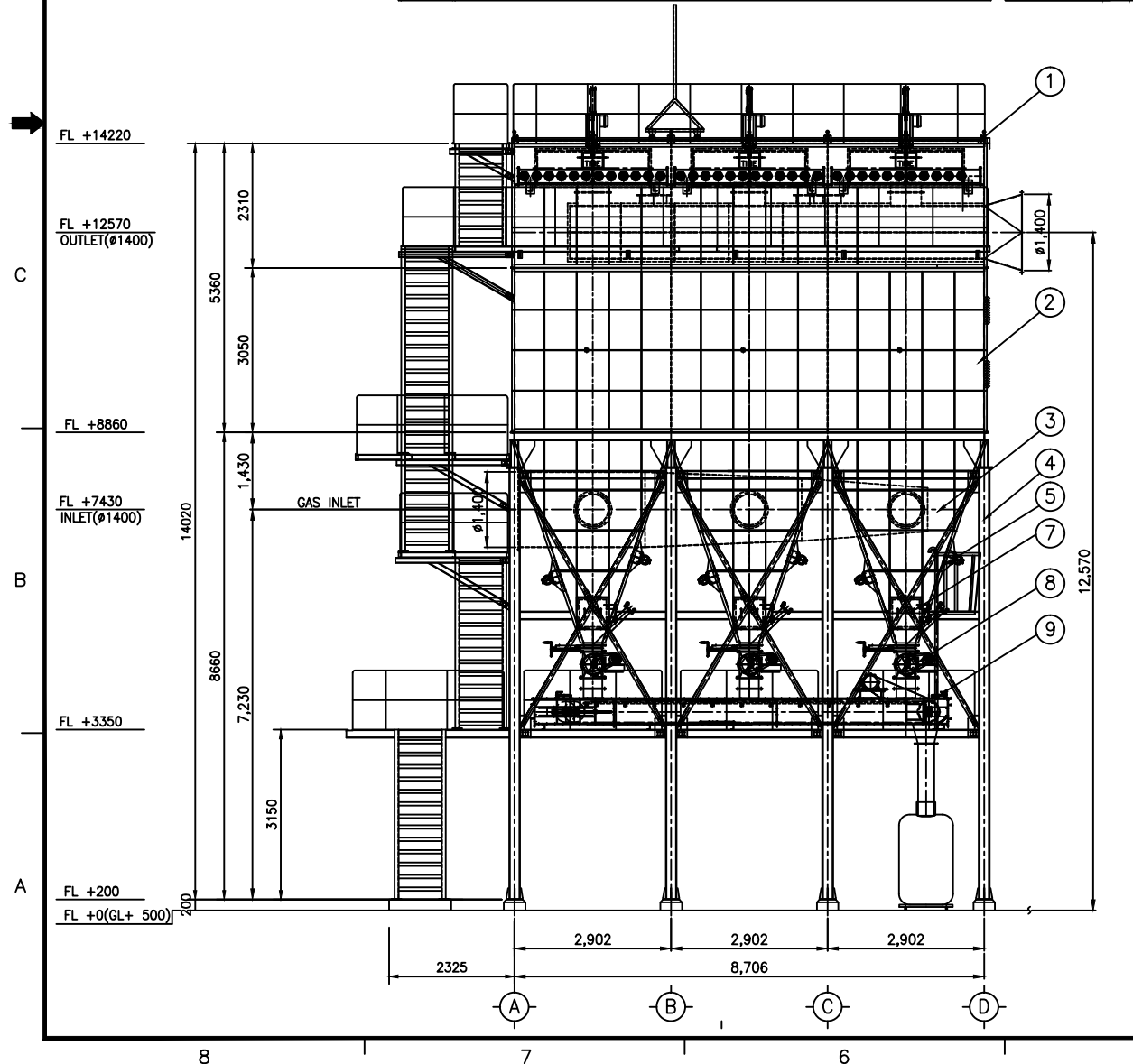
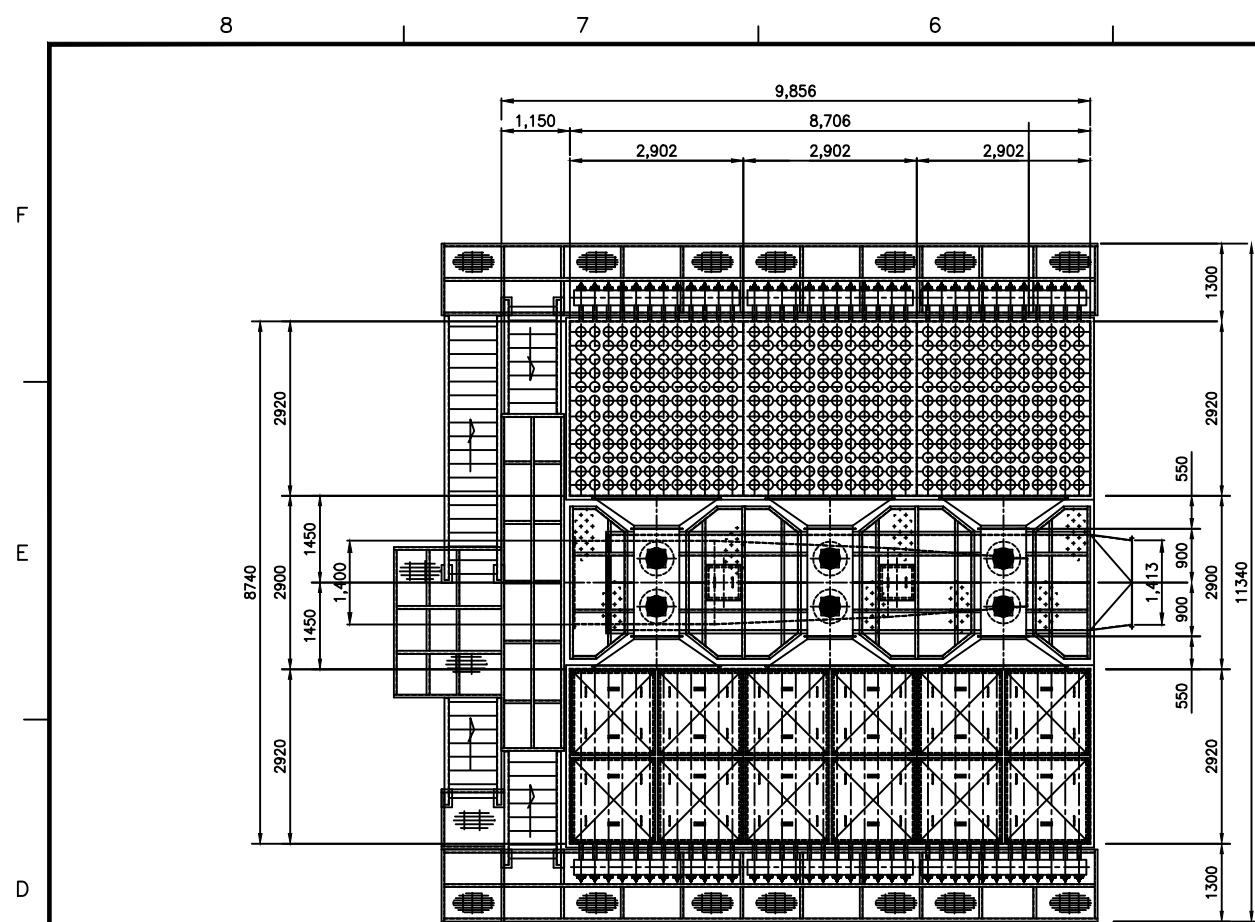
F-F VIEW



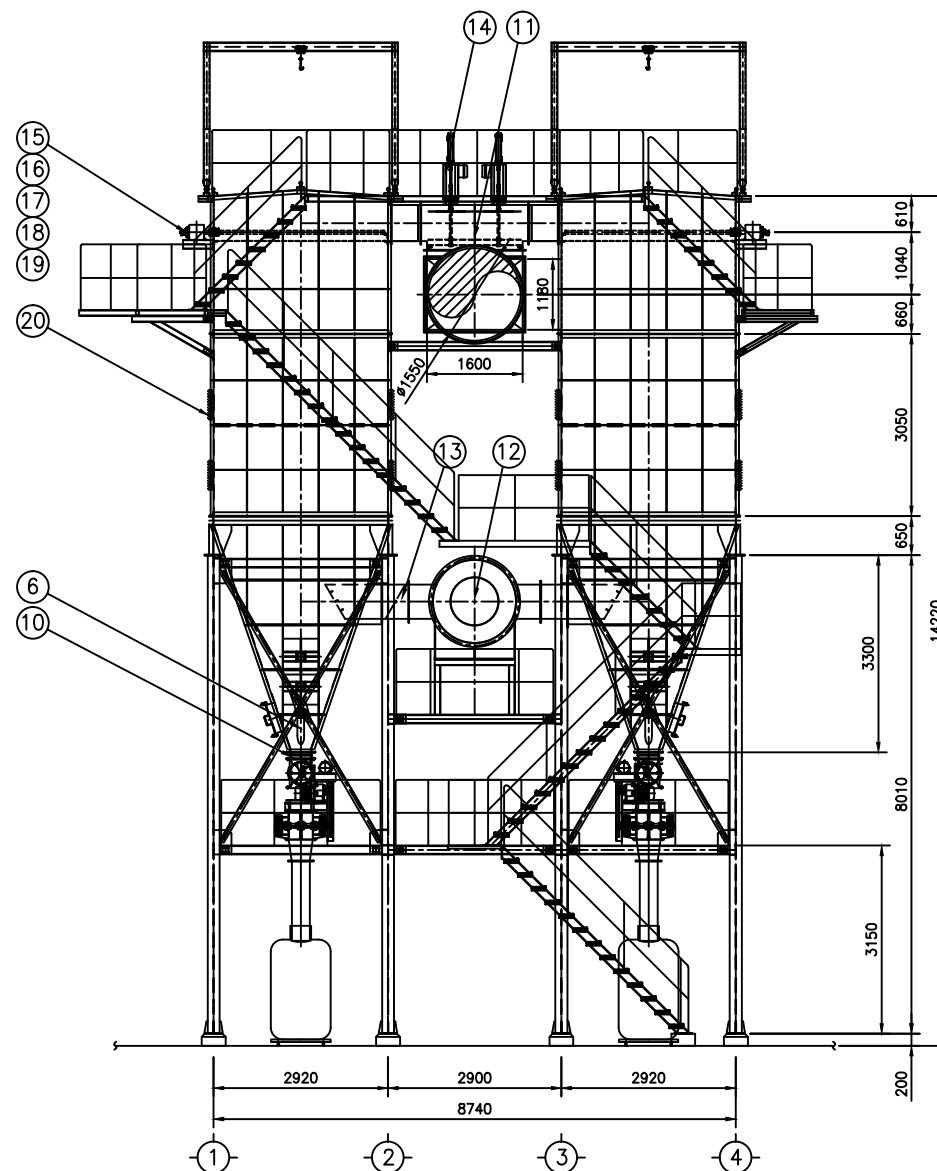
E-E VIEW

NO.	DESCRIPTION	MAT'L	SIZE	Q'TY	REMARK
△					
△					
△					
△					
NO.	DATE	DESCRIPTION	DESIGN	REVIEW	APPR'D
CLIENT					
TITLE					
SIDE VIEW DWG-2					
Hwa Seong Boiler					
JOB. NO.			SHEET NO.		
SCALE	DWG. NO.		TYPE	REV.NO.	
1/125	HS-LAY2518 - 03		A1	△	

8 7 6 5 4 3 2 1 A1(841 x 594 MM)

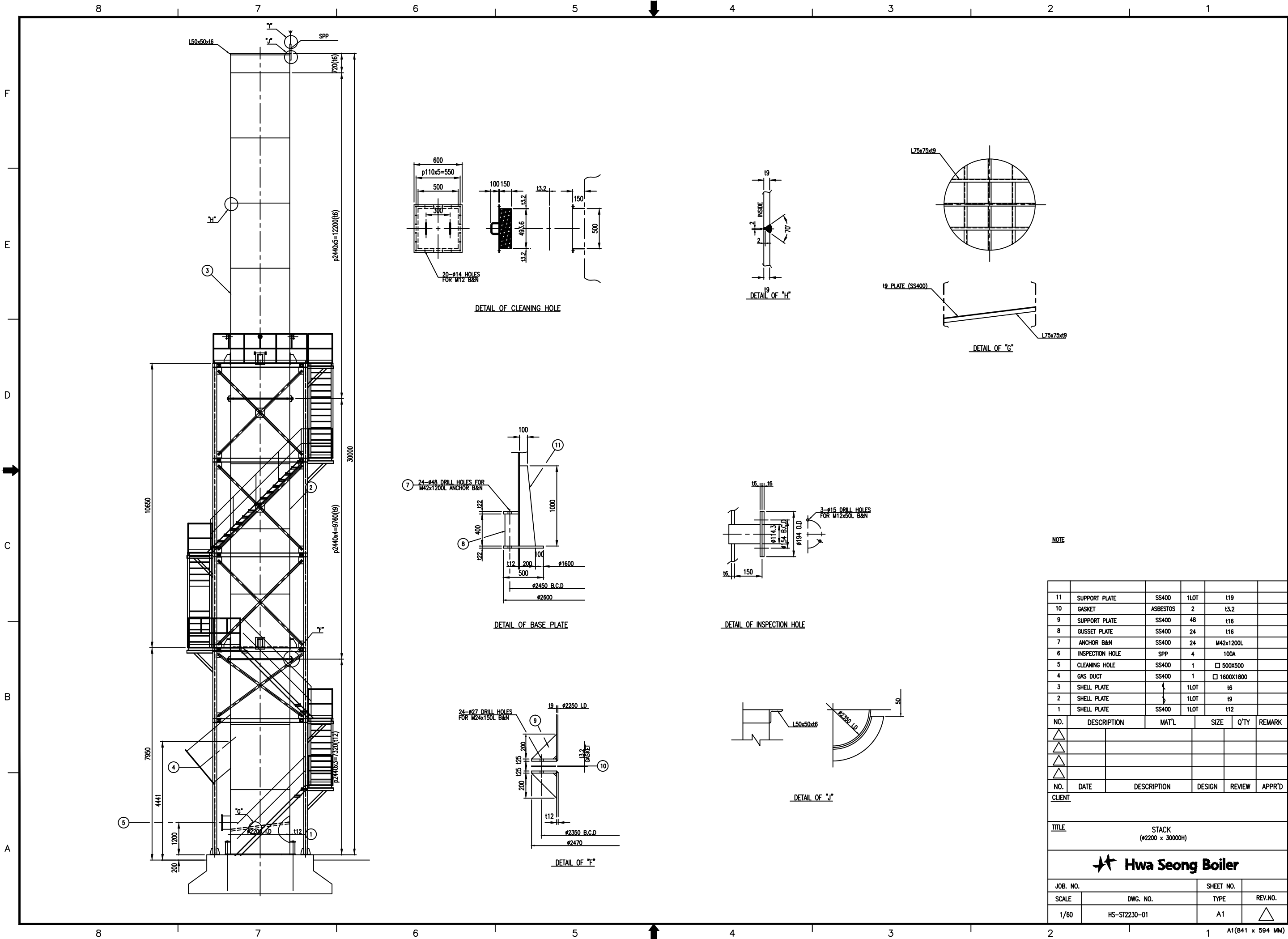


BAG FILTER SPECIFICATIONS	
TYPE	OFF-LINE AIR PULSE JET CLEANING
GAS VOLUME	1350m ³ /min(=225m ³ /min x 6)
PRESSURE DROP	200mmAq
TEMPERATURE	150 °C
BAG SIZE	Ø156x4500L
BAG Q'TY	12x12=144EA , 144x4CH=864EA
FILTERING VELOCITY	NET 0.72m ³ /min, GROSS 0.8m ³ /min
PULES VALVE	50A (12EA x 6CH = 72EA)
REQ. COMP. AIR	5kg/Cm ² G



ITEM	DESCRIPTION	SIZE	MATERIAL	Q'TY	WT(Kg)	REMARKS
1	TOP CASING	8706Wx2920Lx2310H	SS400,STS304	2		PL 4.5t,PL 4t
2	MID CASING	8706Wx2920Lx3050H	SS400	2		PL 4.5t
3	HOPPER	2902Wx2920Lx3950H	SS400	6		PL 6t
4	STRUCTURE	7580Wx8740Lx8010H	SS400	2		H200
5	VIBRATOR	0.2Kw	SS400	12		
6	POKE HOLE	100A	SGP	6		
7	MANHOLE	SQ350x125H	SS400	6		
8	ROTARY VALVE	SQ350	SS400	6		
9	CHAIN CONVEYOR	400Wx475Hx7680L	SS400	2		
10	SLIDE GATE VALVE	SQ350	SS400	6		
11	OUTLET DUCT	1600Wx980Hx7670L	SS400	1		
12	INLET DUCT	1400/ 700x7590L	SS400	1		
13	MANUAL DAMPER	620Wx760L	SS400	6		
14	POPPET DAMPER	570	SS400	6		
15	PULSE V/V	50A	AL	72		
16	FILTER BAG	156x4500L FIBER GLASS PTFE MEMBRANE	864			MADE IN USA
17	VENTURI	151	AL	864		
18	BAG CAGE	151x4500L SWRM, 4-20WIRE	864			
19	PULSE TIMER	12P		6		
20	INSULATION	100t	ROCK/W	1		

NO.	DESCRIPTION	MAT'L	SIZE	Q'TY	REMARK
△					
△					
△					
△					
NO.	DATE	DESCRIPTION	DESIGN	REVIEW	APPR'D
CLIENT					
TITLE					
BAG FILTER ASSY' DWG					
Hwa Seong Boiler					
JOB. NO.			SHEET NO.		
SCALE	DWG. NO.		TYPE	REV.NO.	
1/250			A1	△	



CALCULATION SHEET

(SAW DUST INCINERATION BOILER SYSTEM)

1. CALCULATION OF THE COMBUSTION PRECESS
2. CALCULATION OF THE DESIGN

1. Calculation of the combustion process

① Fuel component ratio & Throughput

Fuel	Ratio(%)	Throughput (kg/Hr)	Re-mark
Bark	10.00	820	
Saw dust	90.00	7,380	
Total	100.00	8,200	

[1] Composition of the Fuel

Fuel	C	H	O	N	S	Cl	Ash	W	Rstio	
Bark	52.60	7.69	34.50	1.60	0.00	0.00	3.61	30.00	10.00	
Saw dust	54.00	7.45	33.42	0.05	0.00	0.00	5.08	51.00	90.00	
Dry base	53.86	7.47	33.53	0.21	0.00	0.00	4.93			
Wet Base	27.52	3.82	17.13	0.10	0.00	0.00	2.52	48.90	100	

[2] Calculation of the heat budget

a. Heating value calculation

1) Higher heat value (Hh : kcal/kg)

$$H_h = 8100 C + 34000 \left(H - \frac{O}{8} \right) + 2500 S$$

$$= 2,799.7 \text{ kcal/kg}$$

2) Lower heat value (Hi)

$$H_i = H_h - 600 \left(9 H + W \right)$$

$$= 2,300 \text{ kcal/kg}$$

b. Amount of combustion air calculation

1) Theoretical combustion air (Ao)

$$A_o = 8.89 C + 26.7 \left(H - \frac{O}{8} \right) + 3.33 S$$

$$= 2.89 \text{ Nm}^3/\text{kg}$$

2) Actual combustion air (AO2 = 8%)

$$A = m A_o \quad (\text{Air ratio } m = 1.7)$$

$$= 4.92 \text{ Nm}^3/\text{kg}$$

c. Calculation of the combustion gas

1) Estimated gas amount

$$\begin{aligned}
 \text{CO}_2 &= 1.867 \text{ C } [\text{Nm}^3/\text{kg}] \\
 &= 0.514 [\text{Nm}^3/\text{kg}] \\
 \text{O}_2 &= 0.21 (m - 1) \text{ Ao } [\text{Nm}^3/\text{kg}] \\
 &= 0.426 [\text{Nm}^3/\text{kg}] \\
 \text{N}_2 &= 0.8 \text{ N } + 0.79 \text{ mAo } [\text{Nm}^3/\text{kg}] \\
 &= 3.888 [\text{Nm}^3/\text{kg}] \\
 \text{H}_2\text{O} &= 11.2 \text{ H } + 1.244 \text{ W } [\text{Nm}^3/\text{kg}] \\
 &= 1.036 [\text{Nm}^3/\text{kg}] \\
 \text{SO}_2 &= 0.7 \text{ S } [\text{Nm}^3/\text{kg}] \\
 &= 0.0000 [\text{Nm}^3/\text{kg}] \\
 \text{HCl} &= 0.63 \text{ Cl } [\text{Nm}^3/\text{kg}] \\
 &= 0.0000 [\text{Nm}^3/\text{kg}]
 \end{aligned}$$

2) Gas composition ratio

Gas	Yield	Ratio	Te-mark
CO ₂	0.514 Sm ³ /kg	8.76	
O ₂	0.426 Sm ³ /kg	7.26	
N ₂	3.888 Sm ³ /kg	66.31	
H ₂ O	1.036 Sm ³ /kg	17.67	
SO ₂	0.000 Sm ³ /kg	0.00	
HCl	0.000 Sm ³ /kg	0.00	
Total (G)	5.86 Sm ³ /kg	100.00	

d. Calculation of the specific heat

1) Specific heat per Temperature (Cpg)

Gas \ Temp.	1400	1200	1000	300	250	200	0
CO ₂	0.553	0.543	0.537	0.448	0.4385	0.429	0.382
O ₂	0.359	0.355	0.35	0.324	0.316	0.319	0.312
N ₂	0.343	0.338	0.333	0.313	0.312	0.311	0.31
H ₂ O	0.432	0.421	0.409	0.367	0.3645	0.362	0.354
SO ₂	0.567	0.561	0.549	0.481	0.4725	0.464	0.425
Dired air	0.346	0.341	0.336	0.315	0.314	0.313	0.311

e. Auxiliary fuel

1) Compisition (lite oil)

Compisition	C	H	O	N	S	Moisture	Ash
Ratio(%)	0	0	0	0	0	0	0

2) Heating value calculation

① Higher heat value (Hh : kcal/kg)

$$H_h = 8100 C + 34000 \left(H - \frac{O}{8} \right) + 2500 S$$

$$= 0.0 \text{ kcal/kg}$$

② Lower heat value (Hi : Kcal/kg)

$$H_i = H_h - 600 \left(9 H + W \right)$$

$$= - \text{ kcal/kg}$$

3) Calculation of the combustion gas

① Theoretical combustion air (Ao)

$$A_o = 8.89 C + 26.7 \left(H - \frac{O}{8} \right) + 3.33 S$$

$$= 0.00 \text{ Sm}^3/\text{kg}$$

② Actual combustion air (A)

$$A = m A_o \quad (\text{Air ratio } m = 1.2)$$

$$= 0.00 \text{ Sm}^3/\text{kg}$$

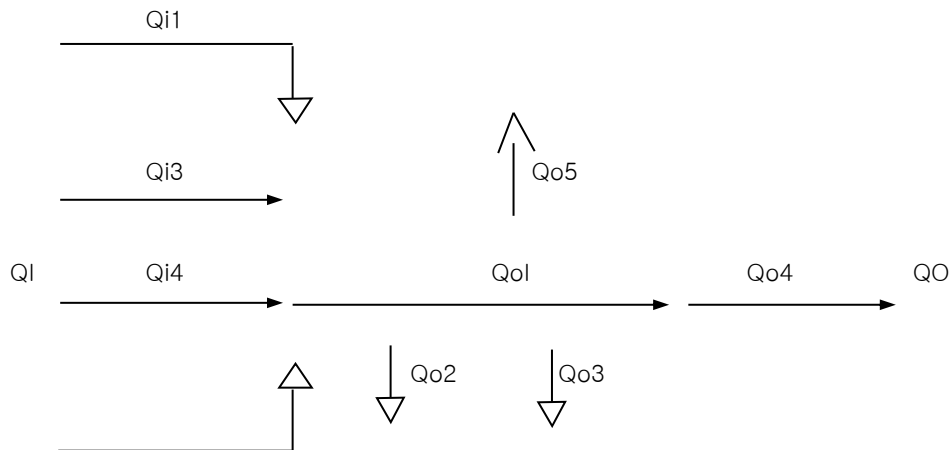
4) Gas composition ratio

Gas	Yield	Ratio	Te-mark
CO ₂	0.000 Sm ³ /kg	0.00	
O ₂	0.000 Sm ³ /kg	0.00	
N ₂	0.000 Sm ³ /kg	0.00	
H ₂ O	0.000 Sm ³ /kg	0.00	
SO ₂	0.000 Sm ³ /kg	0.00	
Total (G)	0.000 Sm ³ /kg	0.00	

[3] Calculation of the mass balance

A. Estimated exhaust gas temperature at the each outlet

1) Combustion chamber heat balance



Description		
Qi1 : Sensible heat	[Kcal/kg]	
Qi2 : Lower heat value	[Kcal/kg]	
Qi3 : Combustion air heat value	[Kcal/kg]	
Qi4 : Auxiliary fuel heat value	[Kcal/kg]	
QI : Qi1 + Qi2 + Qi3 + Qi4 (Total heat input)		[Kcal/kg]
Qo1 : Required heat value up to ignition	[Kcal/kg]	
Qo2 : Incomplete combustion loss	[Kcal/kg]	Total heat input per 5%
Qo3 : Residue heat value	[Kcal/kg]	1%
Qo4 : Radiation heat value	[Kcal/kg]	Total heat input per 1%
Qo5 : Exhaust gas effective heat value	[Kcal/kg]	
Qo : Qo1 + Qo2 + Qo3 + Qo4 + Qo5 (출열총계)		[Kcal/kg]

- Heat input (Qi)

. Fuel sensible heat

$$\begin{aligned}
 Qi1 &= \{ 1 \times W + Cpg20(1-W) \} \times t \\
 &= \{ 1 \times 0.49 + 0.33 (1 - 0.489) \times 20 \} \\
 &= 13.15 \quad [\text{Kcal/kg}]
 \end{aligned}$$

$$0 \sim 300^{\circ}\text{C} \text{ Average specific heat} \quad 0.33 \quad [\text{Kcal/Nm}^3 \cdot ^{\circ}\text{C}]$$

. Fuel lower heat value

$$Qi2 = 2,300 \quad [\text{Kcal/kg}]$$

. Feed air heat value (Feed air temperature : 80°C)

$$\begin{aligned}
 Qi3 &= A \times Cpg20 \times \Delta t \\
 &= 4.92 \times 0.310 \times 80 \\
 &= 122.04 \quad [\text{Kcal/kg}]
 \end{aligned}$$

. Auxiliary fuel heat value

$$Qi4 = 0.0 \times L \quad [\text{Kcal/kg}]$$

. Total heat input

$$Q_i = Q_{i1} + Q_{i2} + Q_{i3} + Q_{i4}$$

$$= 2,435.26 + 0.0 \quad L \quad [\text{Kcal/kg}]$$

– Heat output (Qo)

. Require heat value up to fuel ignition point

$$Q_{o1} = \{ 1 \times W + C_{pg}300(1-W) \} \times t$$

$$= \{ 1 \times 0.49 + 0.33 (1 - 0.489) \times 300 \}$$

$$= 197.29 \quad [\text{Kcal/kg}]$$

. Incomplete combustion loss

$$Q_{o2} = Q_i \times 0.05$$

$$= 2,435.26 \times 0.05$$

$$= 121.76 \quad [\text{Kcal/kg}]$$

. Residue heat value

$$Q_{o3} = H_L \times 0.01$$

$$= 2,300.1 \times 0.01$$

$$= 23.00 \quad [\text{Kcal/kg}]$$

. Radiation heat value of the combustor wall

$$Q_{o4} = Q_i \times 0.01$$

$$= 24.35 \quad [\text{Kcal/kg}]$$

. Exhaust gas heat value

$$Q_{o5} = G_w \times C_{pg} \times \Delta t$$

$$= 5.86 \times C_{pg} \times \Delta t$$

. Total heat output

$$Q_o = Q_{o1} + Q_{o2} + Q_{o3} + Q_{o4} + Q_{o5}$$

$$= 366.41 + 5.86 \times C_{pg} \times \Delta t$$

– Combustion chamber outlet temperature

$$Q_i = Q_o$$

$$2,435.26 = 366.41 + 5.86 \times C_{pg} \times \Delta t$$

$$C_{pg} \cdot \Delta t = 352.82 \quad [\text{Kcal/Nm}^3]$$

$$\Delta t = 1048 \quad ^\circ\text{C}$$

– Auxiliary fuel useage

$$2,435.3 + 0.0 \quad L = 366.4 + (0.00 * 0 * #####)$$

* Nil

Gas composition

Gas	Throughput	Composition ratio	Gravity
CO ₂	4,213.52 Nm ³ /H	8.76	0.17205236
O ₂	3,489.23 Nm ³ /H	7.26	0.103596032
N ₂	31,884.71 Nm ³ /H	66.31	0.828827473
H ₂ O	8,495.76 Nm ³ /H	17.67	0.10212601
SO ₂	0.00 Nm ³ /H	0.00	0
HCl	0.00 Nm ³ /H	0.00	0
Total (G)	48,083 Nm ³ /H	100.00	1.206601875

**** O₂ % Concentration in the flue gas

$$\begin{aligned}
 \text{O}_2 \% &= (\text{O}_2) \text{ in the flue ga} / (\text{Total flue gas}) \times 100 \\
 &= 3,489.23 / 48083.2 \times 100 \\
 &= 7.26 \%
 \end{aligned}$$

2) Heat balance

– Heat input(QBi)

$$\begin{aligned}
 \text{QBi} &= G_w \times C_{pg} \times \Delta t \\
 &= 48,083 \times 0.364 \times 1048 \\
 &= 18,345,583 \text{ [Kcal/hr]}
 \end{aligned}$$

– Heat output (QBo)

. Radiation heat : Heat input 1.5 %

$$\begin{aligned}
 \text{QBo1} &= \text{QBi} \times 1.5\% \\
 &= 275,184 \text{ [Kcal/hr]}
 \end{aligned}$$

. Recovery heat value

$$\text{QBo2} = \text{Enthalpy gap(Kcal/hr)} \times \text{Rated evaporation(kg/hr)} \times \text{efficiency } (\eta)$$

. Exhaust gas effective heat at the outlet

$$\begin{aligned}
 \text{QBo3} &= G_w \times C_{pg} \times 160 \\
 &= 48,083 \times 0.3297 \times 160 \\
 &= 2,536,486 \text{ [Kcal/hr]} \quad 13.8 \%
 \end{aligned}$$

. Total heat output

$$\begin{aligned}
 \text{QBo} &= \text{QBo1} + \text{QBo2} + \text{QBo3} \\
 &= 275,184 + 2,536,486 + \text{QBo2}
 \end{aligned}$$

– Calculation of the estimated heat recovery

$$\begin{aligned}
 \text{QBi} &= \text{QBo} \\
 18,345,583 &= 2,811,670 + \text{QBo2} \\
 \text{QBo2} &= 15,533,913 \text{ [Kcal/hr]}
 \end{aligned}$$

3) Heat balance at the outlet of the cyclone

– Heat input (QCi)

$$\begin{aligned} Q_{Ci} &= Q_{Ho3} \\ &= 48,083.2 \times 0.3297 \times 160 \\ &= 2,536,486 \text{ [Kcal/hr]} \end{aligned}$$

– Heat output (QCo)

. Radiation heat loss: Total heat input 3 %

$$\begin{aligned} Q_{Co1} &= Q_{Ci} \times 0.05 \\ &= 76,095 \text{ [Kcal/hr]} \end{aligned}$$

. Exhaust gas effective heat value

$$\begin{aligned} Q_{Co2} &= G_w \times C_{pg} \times \Delta t \\ &= 48,083.2 \times C_{pg} \times \Delta t \text{ [Kcal/hr]} \end{aligned}$$

. Total heat output

$$\begin{aligned} Q_{Co} &= Q_{Co1} + Q_{Co2} \\ &= 76,095 + 48,083.2 \times C_{pg} \times \Delta t \end{aligned}$$

. Temperature outlet of the cyclone

$$\begin{aligned} Q_{Ci} &= Q_{Co} \\ 2,460,392 &= 76,095 + 48,083 \times C_{pg} \times \Delta t \\ C_{pg} \times \Delta t &= 49.59 \text{ [Kcal/hr]} \\ \text{Here } C_{pg} &= C_{pg190} = 0.326 \text{ [Kcal/Nm}^3 \cdot ^\circ\text{C]} \end{aligned}$$

So

$$\Delta t = 152$$

Estimated cyclone outlet temperature is around 152 °C

4) BAG FILTER Heat balance

– Heat input (QFi)

. Effective heat value at the inlet

$$\begin{aligned} Q_{Fi} &= Q_{So2} \\ &= 2,460,392 \text{ [Kcal/hr]} \end{aligned}$$

– Heat output (QMCo)

. Radiation heat loss : To 5 %

$$\begin{aligned} Q_{Fo1} &= Q_{Fi} \times 0.05 \\ &= 123,020 \text{ [Kcal/hr]} \end{aligned}$$

. Effective heat value of the exhaust gas

$$\begin{aligned} Q_{Fo2} &= G_w \times C_{pg} \times \Delta t \\ &= 48,083 \times C_{pg} \times \Delta t \text{ [Kcal/hr]} \end{aligned}$$

. Total heat output

$$\begin{aligned} Q_{Fo} &= Q_{Fo1} + Q_{Fo2} \\ &= 123,020 + 48,083 \times C_{pg} \times \Delta t \end{aligned}$$

. Calculation temperature at the outlet of the bag filter

$$Q_{Fi} = Q_{Fo}$$

$$2,460,392 = 123,020 + 48,083 \cdot C_{pg} \cdot \Delta t$$

$$48,083 \cdot C_{pg} \cdot \Delta t = 2,337,372$$

$$C_{pg} \cdot \Delta t = 48.610968$$

$$\text{Here } C_{pg} = C_{pg180} = 0.323 \quad [\text{Kcal/Nm}^3 \cdot ^\circ\text{C}]$$

So

$$\Delta t = 150$$

Estimated temperature at the outlet of the bag filter is around 150 °C

B. Estimated calculation for the exhaust gas amount at the each outlet

1) Combustion chamber outlet

* Normal state exhaust gas amount

$$G_w = 48,083 \quad \text{Nm}^3/\text{H}$$

* Actual exhaust gas

$$G_{wa} = \frac{48,083 \times (273 + 1048)}{273 \times 60} = 3,878 \quad [\text{Am}^3/\text{min}]$$

2) Boiler outlet

* Normal state exhaust gas amount

$$G_b = 48,083 \quad \text{Nm}^3/\text{H}$$

* Actual exhaust gas amount

$$G_{ba} = \frac{48,083 \times (273 + 160)}{273 \times 60} = 1,271 \quad [\text{Am}^3/\text{min}]$$

4) Cyclone outlet

* Normal state exhaust gas amount

$$G_b = 48,083 \quad \text{Nm}^3/\text{H}$$

* Actual exhaust gas amount

$$G_{ba} = \frac{48,083 \times (273 + 152)}{273 \times 60} = 1,248 \quad [\text{Am}^3/\text{min}]$$

5) Bag filter outlet

* Normal state exhaust gas amount

$$G_f = 48,083 \quad \text{Nm}^3/\text{H}$$

* Actual exhaust gas amount

$$G_{fa} = \frac{48,083 \times (273 + 150)}{273 \times 60} = 1,242 \quad [\text{Am}^3/\text{min}]$$

C. Calculation of the pollutant concentration at the each outlet

Exhaust equipment	Fuel	Pollutant emission factor [unit : kg/ton]		
		Dust	SO2	Nox
Solid fuel	Natural wood	0.86	1.7	1.49
Solid fuel	Natural wood	5.85	0.045	1.8

* Emission factor in Australia

* Emission factor in Korea

a) Concentration of the dust

Apply emiss 0.86 g/kg

$$\begin{aligned} \text{Partulate} &= \frac{0.860 \text{ [g/kg]} \times 8,200 \text{ [kg/hr]}}{48,083 \text{ [Nm}^3\text{/hr]}} \times 1000 \\ &= 147 \text{ [mg/Sm}^3\text{]} \end{aligned}$$

* Normal state O2 concentration 7 %

O2 concentration : 7.26 %

$$\begin{aligned} \text{Dust} &= 147 \times (21 - 7) / (21 - 7.26) \\ &= 96 \text{ (7)[mg/Sm}^3\text{]} \text{ (O2 7% Base)} \end{aligned}$$

* Combustion chamber outlet

$$\text{TSPw} = 147 \text{ [mg/Nm}^3\text{]}$$

2) Boiler outlet stucked tube 3 %

$$\begin{aligned} \text{TSPb} &= \text{TSPw} \times (1 - 0.03) \\ &= 142 \text{ [mg/Nm}^3\text{]} \end{aligned}$$

3) Economizer outlet + Air pre-heater outlet Sticked tube 3 %

$$\begin{aligned} \text{TSPb} &= \text{TSPw} \times (1 - 0.03) \\ &= 138 \text{ [mg/Nm}^3\text{]} \end{aligned}$$

4) Cyclone outlet

Dust amount in the exhaust gas efficiency 25 %)

$$\begin{aligned} \text{Ss1} &= \text{TSPm} \times (1 - \eta) \times \text{Gw} \div 10^6 \\ &= 138 \times (1 - 0.25) \\ &= 103 \text{ [mg/Nm}^3\text{]} \end{aligned}$$

5) Bag filter outlet efficiency 95.0 %

$$\begin{aligned} \text{TSPi} &= \text{TSPb} \times (1 - \eta) \\ &= 103 \times (1 - 0.95) \\ &= 5.2 \text{ [mg/Nm}^3\text{]} \end{aligned}$$

b) CO concentration

1) CO concentration at the 1st combustion chamber outlet

$$\begin{aligned}
 \cdot \text{CO}_2 \text{ Volume} &: 4213.52 \quad [\text{Nm}^3/\text{H}] \\
 \cdot \text{CO}_2 \text{ Cocentrat} &: 4213.52 \div 48,083.22 \times 1,000,000 \quad [\text{PPM}] \\
 \cdot \text{VDS I} &: 5 \% \\
 \cdot \text{QCC} &= \text{CO}_2 \times \text{I (VDS)} \quad \text{VDS : Volatile Dissolved Solids} \\
 &= 4,381 \quad [\text{PPM}]
 \end{aligned}$$

2) CO concentration at the 2nd combustion chamber (lg : incomplete corr 0.5 %)

$$\begin{aligned}
 \cdot \text{QCC} &= \text{QCO1} \times \text{lg (VDS)} \\
 &= 22 \quad [\text{PPM}]
 \end{aligned}$$

c) SO₂ Concentration

Apply emiss 0 g/kg

$$\begin{aligned}
 \text{SO}_2 &= \frac{0.000 \text{ [g/kg]} \times 8,200 \text{ [kg/hr]}}{48,083 \text{ [Nm}^3\text{/hr]}} \times \frac{22.4}{64} \times 1000 \\
 &= 0 \quad [\text{PPM}]
 \end{aligned}$$

* Normal state O₂ concentration 7 %

O₂ concentration 7.26 %

$$\begin{aligned}
 \text{SO}_2 &= 0.0 \times (21 - 7) / (21 - 7.26) \\
 &= 0 \text{ (7) [mg/Sm}^3\text{]} \quad (\text{O}_2 \text{ 7\% Base})
 \end{aligned}$$

1) SO₂ Amount at the combustion chamber

$$= 0.0 \quad [\text{PPM}]$$

d) NO₂ concentration

Apply emiss 1.49 g/kg

$$\begin{aligned}
 \text{NO}_2 &= \frac{1.490 \text{ [g/kg]} \times 8,200 \text{ [kg/hr]}}{48,083 \text{ [Nm}^3\text{/hr]}} \times \frac{22.4}{46} \times 1000 \\
 &= 124 \quad [\text{PPM}]
 \end{aligned}$$

* Normal state O₂ concentration 7 %

O₂ concentration 7.26 %

$$\begin{aligned}
 \text{NO}_2 &= 123.74 \times (21 - 7) / (21 - 7.26) \\
 &= 81 \text{ (7) [mg/Sm}^3\text{]} \quad (\text{O}_2 \text{ 7\% Base})
 \end{aligned}$$

1) NO₂ amount at the combustion chamber

$$= 81 \quad [\text{PPM}]$$

e) Concentration of the HCl

1) HCL Gas amount at the combustion chamber

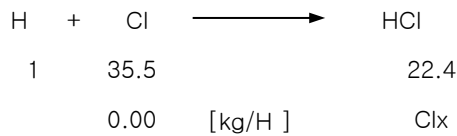
. Total CL amount from the fuel

$$= \text{Fuel} \times \text{Cl content}$$

$$= (8,200 \times 0.0000)$$

$$= 0.00$$

. Reaction formula



$$\text{Clx} = \frac{0.00 \times 22.4}{35.5} = 0.00 \quad [\text{Nm}^3/\text{H}]$$

$$\begin{aligned} \text{HCl} &: 0.00 \div 48,083.22 \times 1,000,000 \quad [\text{PPM}] \\ &= 0 \quad [\text{PPM}] \\ &= 0 \quad [\text{PPM}] \end{aligned}$$

f) Smoke concentration

It happen In case of the incomplete combustion. The grade around 3 refer to Ringelman smoke chart.

after treated grade 1

g) Actual emmissioning amount & Acceptable standard

Pollutant	Actual(ppm)	Acceptable(AUS) (mg/Nm ³ ,ppm)	Result	Re-mark
DUST	5.9 [mg/Nm ³]	50	Accept	
CO	22	125	Accept	
SOX	0.0	–	–	
NOX	81	250	Accept	
HCL	0.0	–	–	
Smoke	grade 1	grade 2	–	

D. Ash amount at the each outlet

1) Asn amount at the combustion chamber

* Total ash amount

. Ash amount from the noncombustible

$$A_{H1} = \text{NC} \times \text{G} \quad [\text{KG/HR}]$$

$$= 0.03 \times 8,200$$

$$= 206.70 \quad [\text{KG/HR}]$$

. Ash amount from the incomplete: I (5 %)

$$A_{H2} = \text{C} \times \text{G} \times \text{I} \quad [\text{KG/HR}]$$

$$= 0.275 \times 8,200 \times 0.05$$

$$= 112.84 \quad [\text{KG/HR}]$$

. Total ash amount

$$\begin{aligned} \text{AHw} &= \text{AH1} + \text{AH2} \\ &= 206.70 + 112.84 \\ &= 319.54 \quad [\text{KG/HR}] \end{aligned}$$

2) Asn amount at the cyclone outlet

. Inlet concentration : 138 [mg/Nm³]
. Outlet concentration : 103 [mg/Nm³]
. Discharge ash amount :

$$\begin{aligned} \text{As1} &= (\text{TSPc} - \text{TSPs}) \times \text{Gw} \div 10^6 \\ &= (138 - 103) \times 48,083 \div 1,000,000 \\ &= 1.66 \quad [\text{KG/HR}] \end{aligned}$$

. Total ash amount at the cyclone

$$\begin{aligned} \text{AS} &= \text{AS1} \\ &= 1.66 \quad [\text{Kg/hr}] \end{aligned}$$

3) Ash amount of the bag filter

. Inlet concentration : 103 [mg/Nm³]
. Outlet concentration : 5.2 [mg/Nm³]
. Ash amount :

$$\begin{aligned} \text{Af} &= (\text{TSPm} - \text{TSPd}) \times \text{Gw} \div 10^6 \\ &= (103 - 5.2) \times 48,083 \div 1,000,000 \\ &= 4.73 \quad [\text{KG/HR}] \end{aligned}$$

2. Calculation of the combustor design

1. Combustor

1) Combustion chamber specification

① Title : Moving grate combustor

② Type : Direct combustion

③ Capacity

A. Dimension :

B. Heat capacity : 250 kg/m³.H

C. Heat load : 150,000 kcal/m³.H

④ Auxiliary fuel

. Startin : Light oil

2. Calculation of the combustion chamber

a) Volume

$$V = \frac{G \{ HL + A \cdot C_{pa} \cdot (t_a - t_o) \} + F \cdot FL}{K}$$

$$= \frac{8,200 \{ 2,300 + 4.9 \times 0.3 \times (20 - 20) \} + 0.0 \times 0.0}{150,000}$$

$$= 125.7 \text{ m}^3 < 133.3 \text{ m}^3$$

G Fuel throughput	[kg/hr]	8,200
HL Lower heat value	[kcal/kg]	2,300.1
K Heat load at the chamber	[kcal/m ³ .hr]	150,000
A Combustion air per kg fuel	[Nm ³ /kg]	4.92
FL Auxiliary fuel heat value	[kcal/kg]	0.0
F Auxiliary fuel useage	[kg/hr]	0.00
C _p Specific heat at contant pressure of ai	[kcal/Nm ³ .°C]	0.311
T Air input temp. – air temp.	[°C]	20–20

b) Calculation of the heat surface

$$A = \frac{G}{M}$$

$$= \frac{8,200}{250}$$

A Heat surfce (m²)

M Heat load 250 [KG.m²/H]

G Combustion amount 8,200 [KG/HR]

$$= 32.80 \text{ m}^2 < 36.9 \text{ m}^2 \quad \text{L12300 x W3000}$$

c) 2nd combustion volume

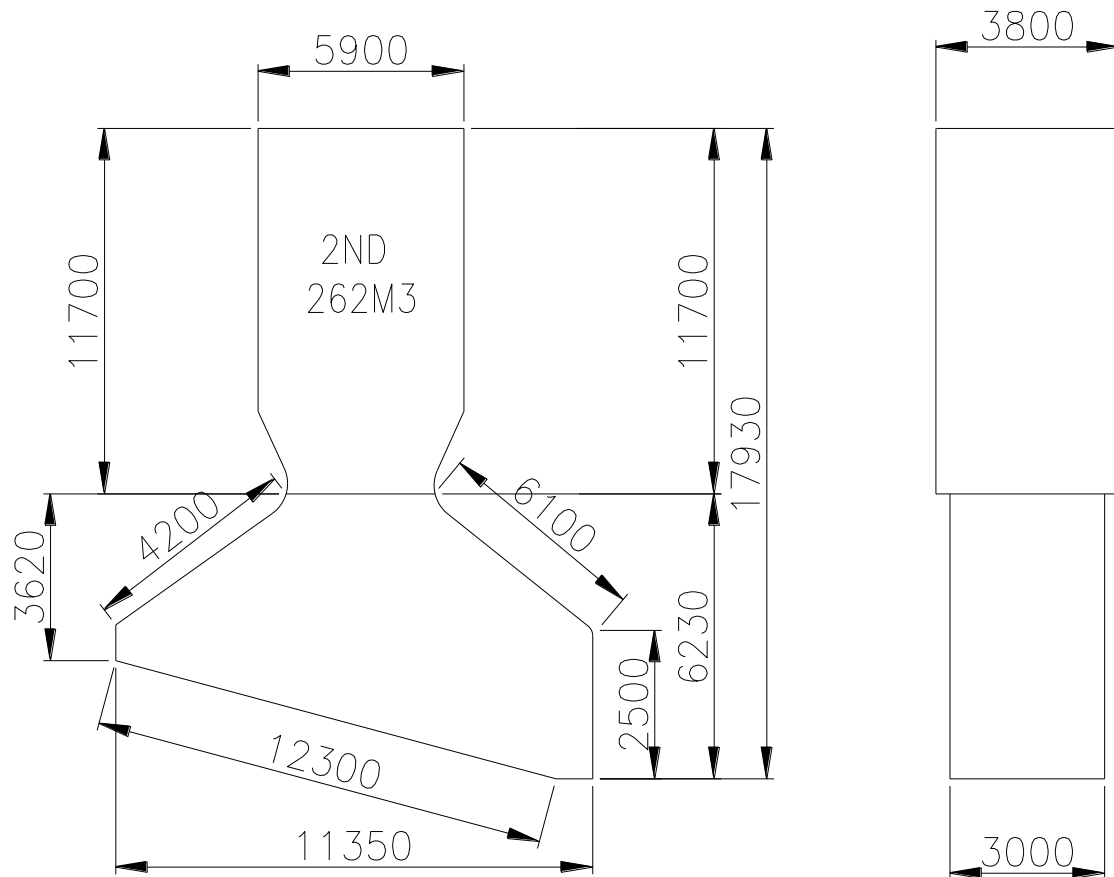
$$Q = 48,083 \text{ [Nm}^3\text{/HR]}$$

$$Q_1 = 48,083 \times (273 + 850.0) / 273 \times 1 / 60$$

$$3,297 \text{ [A m}^3\text{/min]}$$

$$V2 = Q1 \times t2 \quad \text{Retention} \quad 2 \quad \text{SEC}$$

$$= 109.88 \text{ m}^3 < 262.0 \text{ m}^3 \quad 4.8 \text{ SEC}$$



3. Calculation of the boiler design

- a) Title : Water tube boiler
- b) Require heat capacity : $18\text{MW} \times 860\text{Kcal/kw} \times 1000 = 15,480,000 \text{ Kcal/hr}$
- c) Heat recovery : 15,533,913 KCAL/Hr
- d) Steam enthalpy : 667.1 KCAL/kg (16 kg/cm²)
- Water enthalpy : 90.0 KCAL/kg (90 °C)
- d) Equivalent ev (Q) :

$$Q = \frac{15,533,913}{577.1} = 26.9 \text{ t/h}$$

$$\text{Steam Ca} \quad 25.0 \quad \text{TON/HR}$$

5. Cyclone

- a) Title : Cyclone
- b) Type : Tangential entry type
- c) Body design & Specif

④ Raw gas amount (Q)

$$Q = \frac{48,083 \times (273 + 160)}{273 \times 60}$$

$$= 1,487 \text{ Am}^3/\text{min}$$

Safety factor considered $744 \text{ Am}^3/\text{min} \times 2 \text{ EA}$

⑤ Gas input velocity : 15 m/sec

⑥ Body calculation

. Inlet area (A) = $\frac{Q}{V} \text{ m}^2$

$$A = \frac{744 \div 1}{15 \times 60} = 0.8262 \text{ m}^2$$

. Inlet height (a)

$$a = \sqrt{(2 \times A)} = 1.2855 \text{ m} \approx 1285 \text{ mm}$$

. Inlet width (b)

$$b = \sqrt{(A/2)} = 0.6427 \text{ m} \approx 643 \text{ mm}$$

. Outer shell diameter (D)

$$D = 4 \times b = 2.5709 \text{ m} \approx 2571 \text{ mm}$$

. Outer shell length (L)

$$L = 1.00 \times D = 2.5709 \text{ m} \approx 2571 \text{ mm}$$

. Inner shell diameter (d)

$$d = D/2 = 1.2855 \text{ m} \approx 1285 \text{ mm}$$

. Cone section length (H)

$$H = 2 \times L = 5.1418 \text{ m} \approx 5142 \text{ mm}$$

. Dust discharge area diameter (d')

$$d' = 0.3 \times D = 0.6427 \text{ m} \approx 643 \text{ mm}$$

6. Calculation of the dust collector design

(1) Title : Bag filter

(2) Type : Pulse air jet

(3) Bag filter calculation

① Raw gas amount

$$Gb = \frac{48,083 \text{ Nm}^3/\text{H} \times (273 + 150)}{273 \times 60 \text{ min/hr}}$$

$$= 1,357 \text{ [Am}^3/\text{min]}$$

$$= 22.6 \text{ [Am}^3/\text{sec]}$$

② Specification

a. Filtration velocity : $0.2 \sim 6 \text{ m/min}$ [**0.80** m/min]

b. Filtering area : $A = Gt \div V = 1357 \div 0.8 = 1,696 \text{ m}^2$

- c. Tamis dimension : ϕ 156 x 4,500 L
- d. Tamis area per piece : $a = 0.156 \times 3.14 \times 4.5 = 2.21 \text{ m}^2$
- e. Require tamis amount : $N = 769 \text{ EA}$
- f. Tamis arrangement(NE : $12 \times 12 \times 6 = 864 \text{ EA}$
- g. Pulse valve spec. : 50 A
- h. Total pulse valve amo : 72 EA
- j. Total chamber amount : 6 EA
- k. Total tamis amount : 864 EA (Net tamis amount is 770ea but considered safety factor 864

7. Calculation of the supplementary

1) Chimney diameter (refer to attached #1 : Stack Calculation Sheet)

① Raw gas amount

$$\text{FLUE GAS} = 1357 \text{ [A}\mathring{\text{m}}^3/\text{min]}$$

$$Q = 1357 \div 60 \text{ min/sec} = 22.62 \text{ A}\mathring{\text{m}}^3/\text{sec}$$

② Chimney velc : 8 m/sec

③ Chimney diar :

$$D = \left(\frac{4 \times 22.62}{8 \times 3.14} \right)^{0.5} = 1.90 \text{ M}$$

Considered safety factor

2,200 x 30mH

(In case of chimney height is 40m chimney diameter is 1900mm -- Refer to attached #2 : Stack Calculatio

2) Blower design

(1) F.D FAN (Combustion air feeding : 1st air 60%, 2nd air 40%)

① Required cobmustion air

$$\begin{aligned} A &= 4.92 \text{ Nm}^3/\text{kg} \times 8,200 \text{ kg/hr} \div 60 \\ &= 673 \text{ Nm}^3/\text{min} \\ &= 673 \times (273 + 20) \div 273 \\ &= 722 \text{ A}\mathring{\text{m}}^3/\text{min} \text{ (20}^\circ\text{C)} \end{aligned}$$

③ Blower design

No	Volume (Nm ³ /min)	Pressure (mmAq)	Re-mark
1.	404 520	350	1st air
2.	269 300	400	2nd air
계	673 820		

④ 1st blower power

$$\begin{aligned} \text{HP} &= \frac{Q \times H}{102 \times 60 \times \eta} \times \alpha \\ &= \frac{520 \times 350}{102 \times 60 \times 0.7} \times 1.1 \\ &= 46.73 \text{ KW (62.3 HP)} \end{aligned}$$

$$= 75 \text{ HP}$$

⑤ 2nd blower power

$$\begin{aligned} \text{HP} &= \frac{Q \times H}{102 \times 60 \times \eta} \times \alpha \\ &= \frac{300 \times 400}{102 \times 60 \times 0.7} \times 1.1 \\ &= 30.81 \text{ KW (41.1 HP)} \\ &= 50 \text{ HP} \end{aligned}$$

(2) I.D FAN Design

① Capacity

$$\begin{aligned} A &= 48,083 \times \frac{(273 + 150)}{273 \times 60} \\ &= 1242 \text{ Am}^3/\text{min} \\ &= 1500 \text{ Am}^3/\text{min} \end{aligned}$$

② Pressure : 550 mmAq

③ Power

$$\begin{aligned} \text{HP} &= \frac{Q \times H}{102 \times 60 \times \eta} \times \alpha \\ &= \frac{1500 \times 550}{102 \times 60 \times 0.7} \times 1.1 \\ &= 211.83 \text{ KW (275 HP)} \\ &= 300 \text{ HP} \end{aligned}$$

#1. CHIMNEY CALCULATION SHEET

NO	DESCRIPTION	UNIT	RESULTS	REMARK
1	Boiler capacity	kg/hr	25,000	
	Fuel Consumption	kg/hr	8,200	
2	Exhaust Gas Data			
	Exhaust Gas Flow rate(Wet)	Nm3/hr	48,083	
	Exhaust Gas Flow rate(@Stack inlet)	Am3/hr	74,503	
		Am3/min	1,242	
	Exhaust Gas Flow rate(@Stack outlet)	Am3/hr	66,401	
		Am3/min	1,107	
	Exhaust Gas Pressure @Stack	ata	1.03	
	Exhaust Gas Density @Stack inlet Tem	kg/m3	0.732	
	Exhaust Gas Density @Stack outlet Ter	kg/m3	0.821	
	Exhaust Gas Density @Nm3	kg/Nm3	1.13400	
	Air Density	kg/Nm3	1.293	
		kg/Nm3	1.140	
	Exhaust Gas Temp. @Stack inlet	deg.C	150	
	Exhaust Gas Temp. @Stack outlet	deg.C	104	
	Avg. gas temp.	°K	400	
	Ambient air temp.	°K	293	
3	Velocity			Max limit : 20m/s
	@ Stack inlet	m/s	5.447	
	@ Stack outlet	m/s	4.855	
4	Stack			Base from 30m
	Inside diameter @ Bottom	m	2.200	
	Inside diameter @ Top	m	2.200	
	Inside diameter @ Avg	m	2.200	
	Height (From gas entrance)	m	25.000	
5	Calculation			Max limit : 25mmAq
	Theoretical Draft Power(Zt)	mmAq	4.96	
	Draft loss(h)		2.37	
	– Outlet loss(ho)	mmAq	0.99	
	– Top Shape loss(ht)	mmAq	–	
	– Friction loss(hf)	mmAq	1.39	
	– Bend loss(hb)	mmAq	–	
	Effective Draft Power(Za)	mmAq	-2.59	

Conclusion

실제통풍력은 -2.59mmAq 로 최대 25mmAq 이하를 만족함 따라서 연돌 높이 30m

내경은 2.2m로 선정함

#2. CHIMNEY CALCULATION SHEET

NO	DESCRIPTION	UNIT	RESULTS	REMARK
1	Boiler capacity	kg/hr	25,000	
	Fuel Consumption	kg/hr	8,200	
2	Exhaust Gas Data			
	Exhaust Gas Flow rate(Wet)	Nm3/hr	48,083	
	Exhaust Gas Flow rate(@Stack inlet)	Am3/hr	74,503	
		Am3/min	1,242	
	Exhaust Gas Flow rate(@Stack outlet)	Am3/hr	66,401	
		Am3/min	1,107	
	Exhaust Gas Pressure @Stack	ata	1.03	
	Exhaust Gas Density @Stack inlet Tem	kg/m3	0.732	
	Exhaust Gas Density @Stack outlet Ter	kg/m3	0.821	
	Exhaust Gas Density @Nm3	kg/Nm3	1.13400	
	Air Density	kg/Nm3	1.293	
		kg/Nm3	1.140	
	Exhaust Gas Temp. @Stack inlet	deg.C	150	
	Exhaust Gas Temp. @Stack outlet	deg.C	104	
	Avg. gas temp.	°K	400	
	Ambient air temp.	°K	293	
3	Velocity			Max limit : 20m/s
	@ Stack inlet	m/s	7.303	
	@ Stack outlet	m/s	6.509	
4	Stack			Base from 40m
	Inside diameter @ Bottom	m	1.900	
	Inside diameter @ Top	m	1.900	
	Inside diameter @ Avg	m	1.900	
	Height (From gas entrance)	m	35.000	
5	Calculation			Max limit : 25mmAq
	Theoretical Draft Power(Zt)	mmAq	6.95	
	Draft loss(h)		4.19	
	– Outlet loss(ho)	mmAq	1.78	
	– Top Shape loss(ht)	mmAq	–	
	– Friction loss(hf)	mmAq	2.42	
	– Bend loss(hb)	mmAq	–	
	Effective Draft Power(Za)	mmAq	-2.75	

Conclusion

실제통풍력은 -2.75mmAq 로 최대 25mmAq 이하를 만족함 따라서 연돌 높이 40m

내경은 1.9m로 선정함

Appendix B – Meteorological assessment

Methodology for the Assessment of Meteorological Inter-annual Variability

The nearest available meteorological monitoring station to the project area is operated by the Bureau of Meteorology at Bombala. Meteorological data recorded at Bombala were analysed to determine a representative year for use in the dispersion modelling assessment. The meteorological parameters, dataset time period and analysis conducted are summarised below.

Table B1 Meteorological data assessed at Bombala

Parameter	Time period assessed	Data	Analysis
Wind speed	2009 – 2013	Half hourly data points from AWS	Comparisons of: Frequency distributions (as probability density functions) as year on year and each year against the mean of all five years; Correlation statistics (R2).
Wind direction			
Wind vector U component			
Wind vector V component			
Temperature			
Relative humidity			
El Nino Southern Oscillation (ENSO)	2009 – 2014	Annual classification	SOI classification and strength

The selection process was based on determining which years provided the closest representation of the average state of the climate based on the variation of each meteorological parameter from the mean and each other year. For meteorological modelling and air quality assessment purposes, the key parameters that influence pollutant dispersion are wind speed, wind direction and atmospheric stability, with stability a function of the atmosphere's vertical temperature profile and the wind speed. Notwithstanding this, these parameters are strongly influenced by the overall state of the climate such as ENSO, rainfall and the resulting soil and atmospheric moisture content. The analysis considered the following:

- A year with a strong ENSO classification should be avoided, where possible.
- The distributions of wind speed and direction should be as close to the mean distribution as possible, both in terms of the frequencies of low, moderate and high wind speeds, and in the overall correlation statistics. This includes the analysis of wind in its U and V vector components.
- The distributions of temperature should be as close to the mean distribution as possible, in terms of low nocturnal and daytime high temperatures.

Analysis of Meteorological Inter-annual Variability

Wind speed

The annual and mean frequency distribution (probability density function [pdf]) of wind speed of the five-year period, 2009 to 2013, is presented in the Figure B1 below.

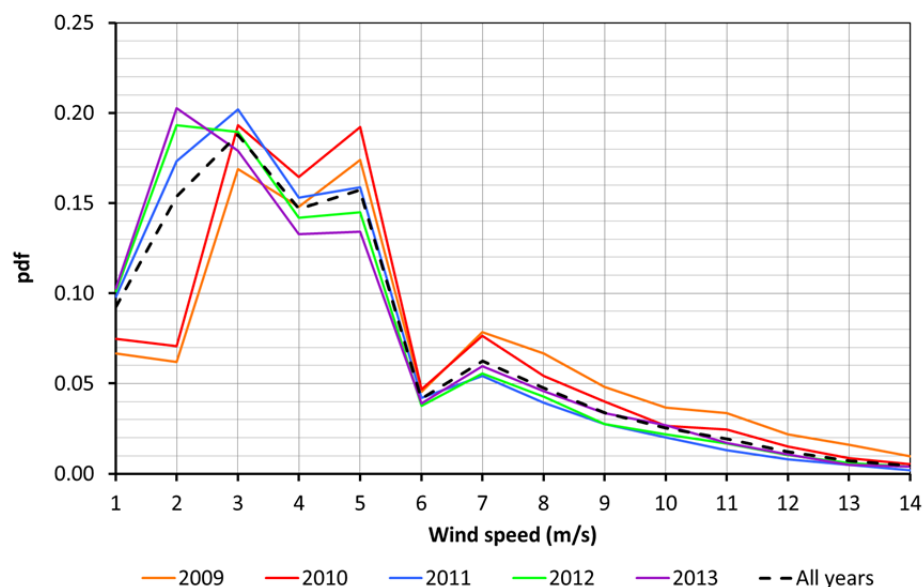


Figure B1 Comparison of annual observed wind speed frequency distributions to all years

The R^2 correlation statistics for each year on year, and each year versus the mean of all years, are summarised in Table B2 below.

Table B2 Correlation coefficients matrix of the distributions of wind speed

Period	2009	2010	2011	2012	2013	All years
2009	1					
2010	0.9958	1				
2011	0.8845	0.9093	1			
2012	0.8379	0.8638	0.9941	1		
2013	0.8048	0.8301	0.9836	0.9969	1	
All years	0.9122	0.9315	0.9974	0.9878	0.9757	1

Wind direction

The annual and mean frequency distribution (probability density function [pdf]) of wind direction of the five-year period, 2009 to 2013, is presented in the Figure B2 below.

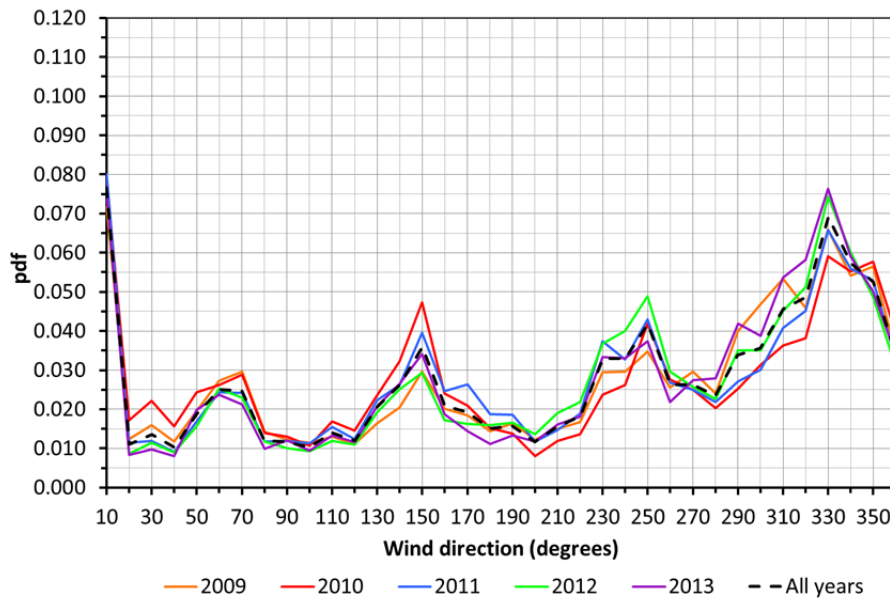


Figure B2 Comparison of annual observed wind direction frequency distributions to the mean

The R^2 correlation statistics for each year on year, and each year versus the mean of all years, are summarised below in Table B3.

Table B3 Correlation coefficients matrix of the distributions of wind direction

Period	2009	2010	2011	2012	2013	All years
2009	1					
2010	0.9056	1				
2011	0.9361	0.9517	1			
2012	0.9513	0.8949	0.9677	1		
2013	0.9714	0.8935	0.9498	0.9747	1	
All years	0.9734	0.9460	0.9860	0.9859	0.9844	1

Wind vector U component

The annual and mean frequency distributions (probability density function [pdf]) of the wind vector U component of each year to the mean of the five-year period, 2009 to 2013, are presented in Figure B3 below.

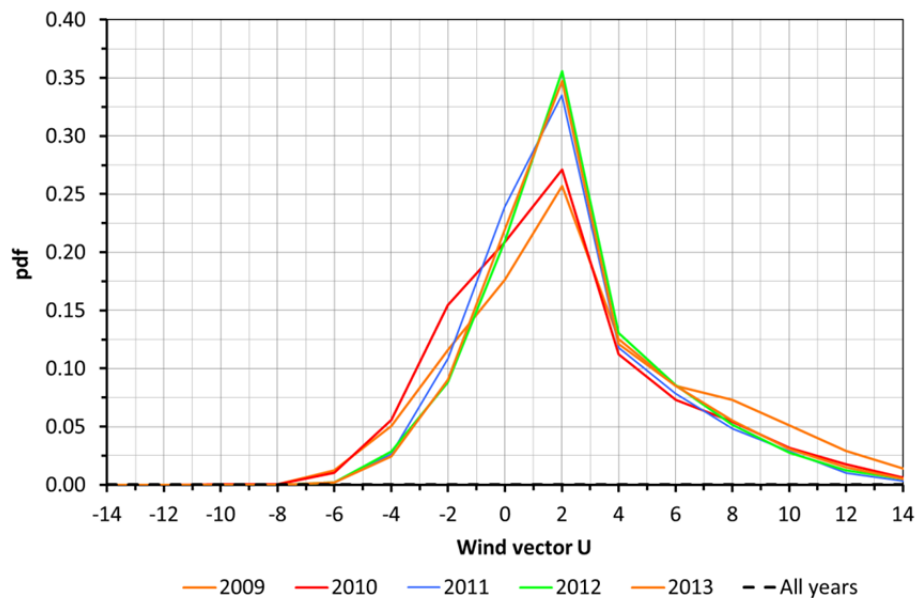


Figure B3 Comparison of annual observed wind vector U frequency distributions to the mean

The R^2 correlation statistics for each year on year, and each year versus the mean of all years, are summarised in Table 4 below.

Table B4 Correlation coefficients matrix of the distributions of wind vector U component

Period	2009	2010	2011	2012	2013	All years
2009	1					
2010	0.98602	1				
2011	0.97855	0.98016	1			
2012	0.97572	0.96406	0.99382	1		
2013	0.97706	0.96774	0.99676	0.99904	1	
All years	0.98633	0.9826	0.99848	0.99619	0.99764	1

Wind vector V component

The annual and mean frequency distribution (probability density function [pdf]) of the wind vector V component of the five-year period, 2009 to 2013, is presented in Figure B4 below.

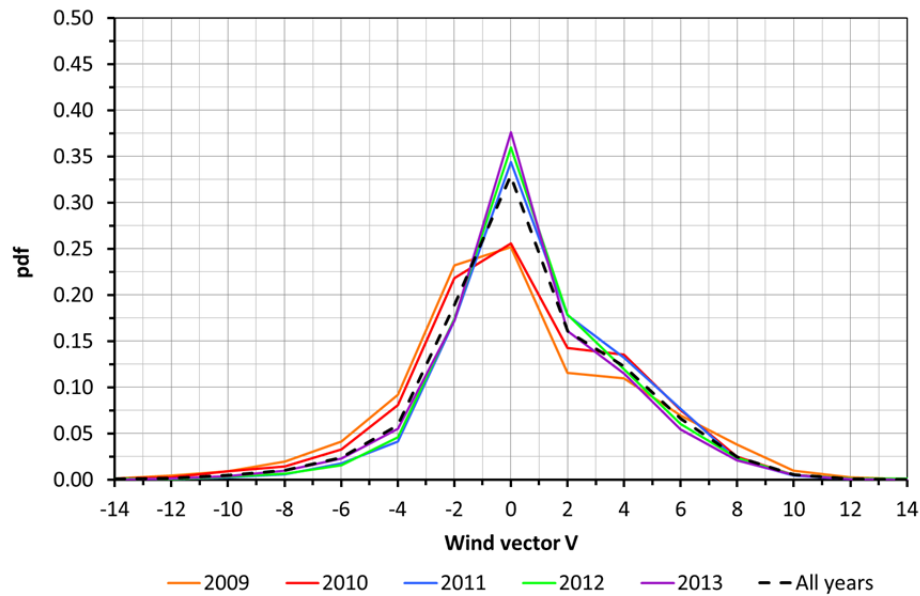


Figure B4 Comparison of annual observed wind vector V frequency distributions to the mean

The R^2 correlation statistics for each year on year, and each year versus the mean of all years, are summarised in Table B5 below.

Table B5 Correlation coefficients matrix of the distributions of wind vector V component

Period	2009	2010	2011	2012	2013	All years
2009	1					
2010	0.99149	1				
2011	0.93903	0.96265	1			
2012	0.93627	0.9558	0.99803	1		
2013	0.93663	0.95056	0.99336	0.99763	1	
All years	0.9625	0.97705	0.99636	0.99618	0.99429	1

Temperature

The annual and mean frequency distributions (probability density function [pdf]) of temperature of the five-year period, 2009 to 2013, are presented in Figure B5 below.

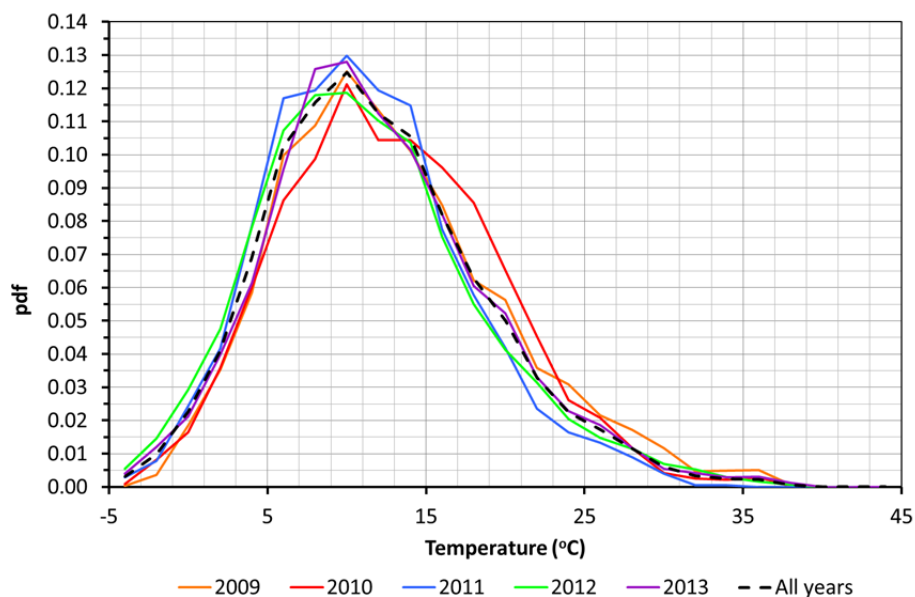


Figure B5 Comparison of annual observed temperature frequency distributions to the mean

The R^2 correlation statistics for each year on year, and each year versus the mean of all years, are summarised in Table B6 below.

Table B6 Correlation coefficients matrix of the distributions of temperature

Period	2009	2010	2011	2012	2013	All years
2009	1					
2010	0.9838	1				
2011	0.9841	0.9580	1			
2012	0.9817	0.9570	0.9972	1		
2013	0.9934	0.9760	0.9887	0.9896	1	
All years	0.9947	0.9790	0.9950	0.9948	0.9972	1

Relative humidity

The annual and mean frequency distributions (probability density function [pdf]) of relative humidity of the five-year period, 2009 to 2013, are presented in the figure below.

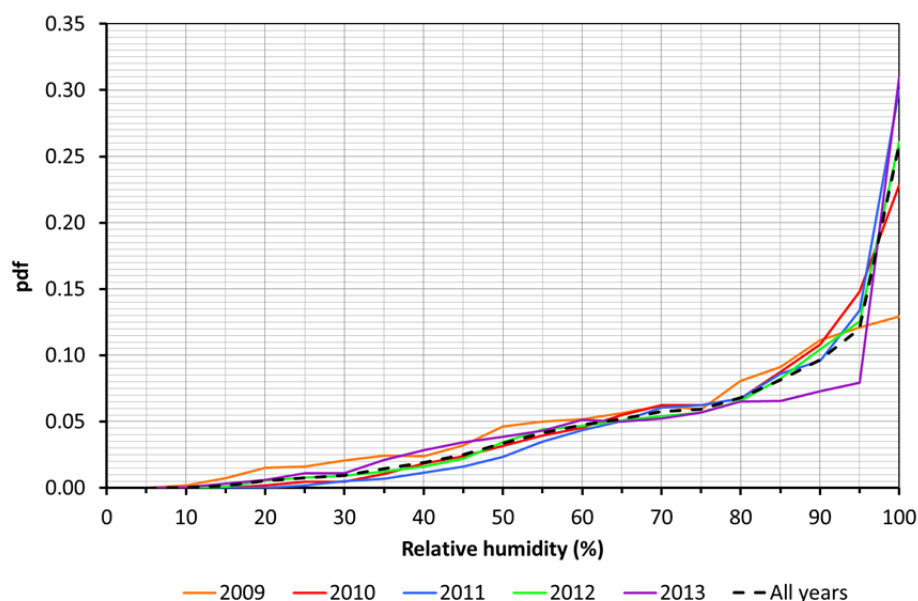


Figure B6 Comparison of annual observed relative humidity frequency distributions to the mean

El Nino Southern Oscillation

The El Nino Southern Oscillation (ENSO) classification and strength according to the Bureau of Meteorology for the period assessed, March 2008 – February 2014, are presented in Table B7 below.

Table B7 Annual El Nino Southern Oscillation classifications

Year	Classification
2008-09	La Nina (weak)
2009-10	El Nino (moderate)
2010-11	La Nina (strong)
2011-12	La Nina (weak)
2012-13	Neutral

Representative meteorological year selection

The most representative year of the five-year period investigated, March 2009 – February 2014, was selected by:

- ranking each of the key meteorological variables according to their correlation with the mean of the five year period,
- comparing the shape and fit of the distributions against that of the mean of the five year period,
- evaluating the variation of annual and monthly rainfall from the mean of all years of data, i.e. 2002-2014, and
- taking into consideration the ENSO classification for the year.

A summary of the rank of the correlation statistic (R^2) for each year against the mean of the five-year period is presented below in Table B8.

Table B8 Meteorological variable correlation ranks

Year	Wind speed	Wind direction	Temperature	Relative humidity	Wind vector U component	Wind vector V component	Aggregate ranking	Final rank
2009	3	1	1	1	2	4	12	1
2010	2	3	3	5	1	2	16	2
2011	5	2	2	4	5	1	19	3
2012	4	5	4	2	4	3	22	5
2013	1	4	5	3	3	5	21	4

Conclusion

The analysis found that the:

- The year 2009 was the closest to the mean in terms of wind direction, temperature and humidity.
- The year 2013 had the closest correlation in terms of wind speed.
- The year 2009-10 was characterised by a moderate strength La Nina, while the year 2011-12, which had a lower correlation for winds, was characterised by a weak strength El Nino.

Based on this assessment, the year 2009 was selected as a representative period for the meteorological modelling simulation.

Appendix C – Emissions Estimates

Bioler fuel: Wood

Wood proposed

42955

 tonnes/annum

Proposed diameter m

2.2

 m
Proposed exit velocity m/s

4.855

 m/s
Proposed exit temp (deg C)

106

 C

Proposed area (circle) 3.801327111 m²
Proposed volume flow rate 18.45544312 m³/s

Proposed Flow rate normalisation multiplier

(Q = QN × (Pref/Pa) × (T/Tref))

1.388065166

Energy and fuel usage

Relevant emission factors for wood- from Table 33 of manual

Species	EF ⁻¹ (kg/tonne)	Species
PM10	8.60E-01	PM10
PM2.5	4.30E-01	PM2.5
NOX	1.49E+00	NOX
SO2	1.70E-01	SO2
PAH	1.78E-03	PAH
CO	4.08E+00	CO
TVOC	1.20E-01	TVOC
Polychlorinated dioxins and furans	5.29E-10	Dioxins and furans

Proposed 18MW 4.9 tonnes/hr

Emission rates

Data Source	mg/m3	g/s	Model g/s
Supplier	5.9	0.078445247	0.078
Supplier	2.95	0.039222623	0.039
Supplier	164	2.180511944	2.181
Supplier	0	0	0.000
NPI	0.00242	0.182	0.002
Supplier	27.1	0.360316303	0.360
NPI	12.293	0.16	12.293
NPI	0.000000054	7.20548E-10	0.0000000007

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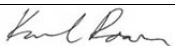
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