value
from
waste

Waste Fired Power Plant

The new standard for recovery of sustainable energy,
metals and building materials from urban waste

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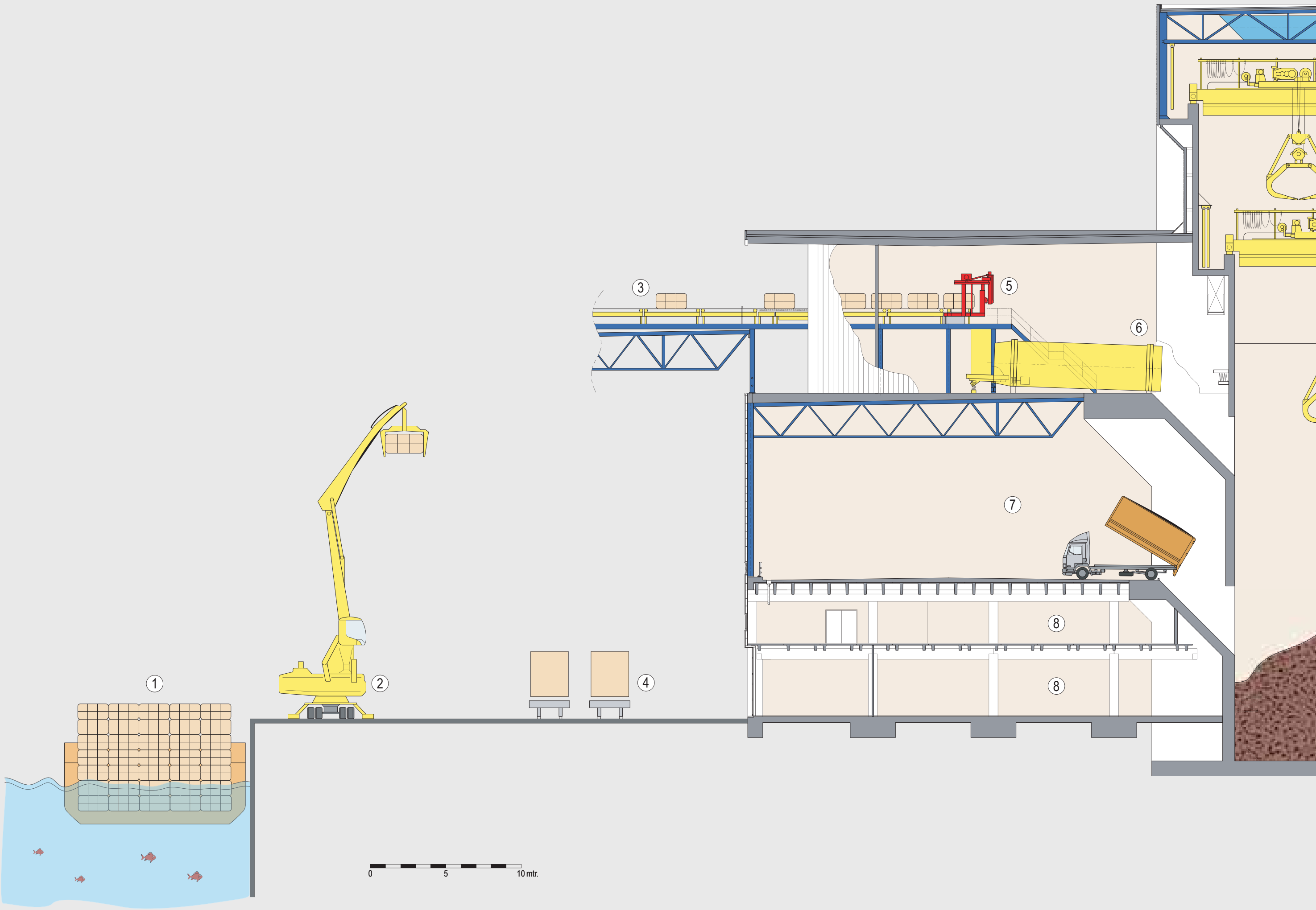
City of Amsterdam
Waste and Energy Company

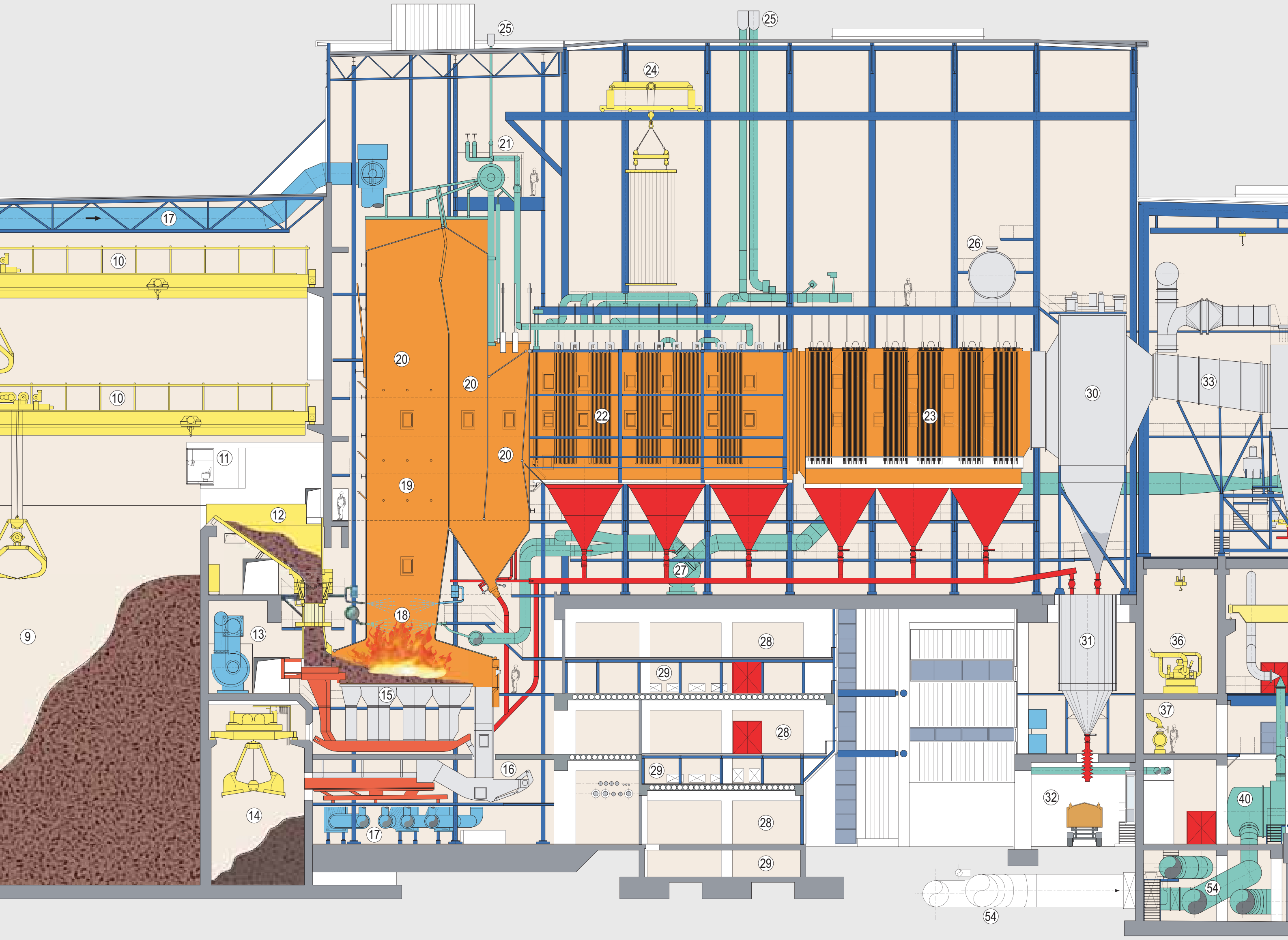
High-efficiency Waste Fired Power Plant (WFPP)

1 delivery bales
2 mobile crane
3 bale conveyor
4 railway track
5 bale opener
6 homogenizing drum
7 dumping hall
8 stockroom
9 waste bunker
10 waste crane
11 crane cabin
12 waste hopper
13 tertiairy air fan
14 slag bunker
15 grate
16 slag discharger
17 primary air
18 injection reci-gas and tertiairy air

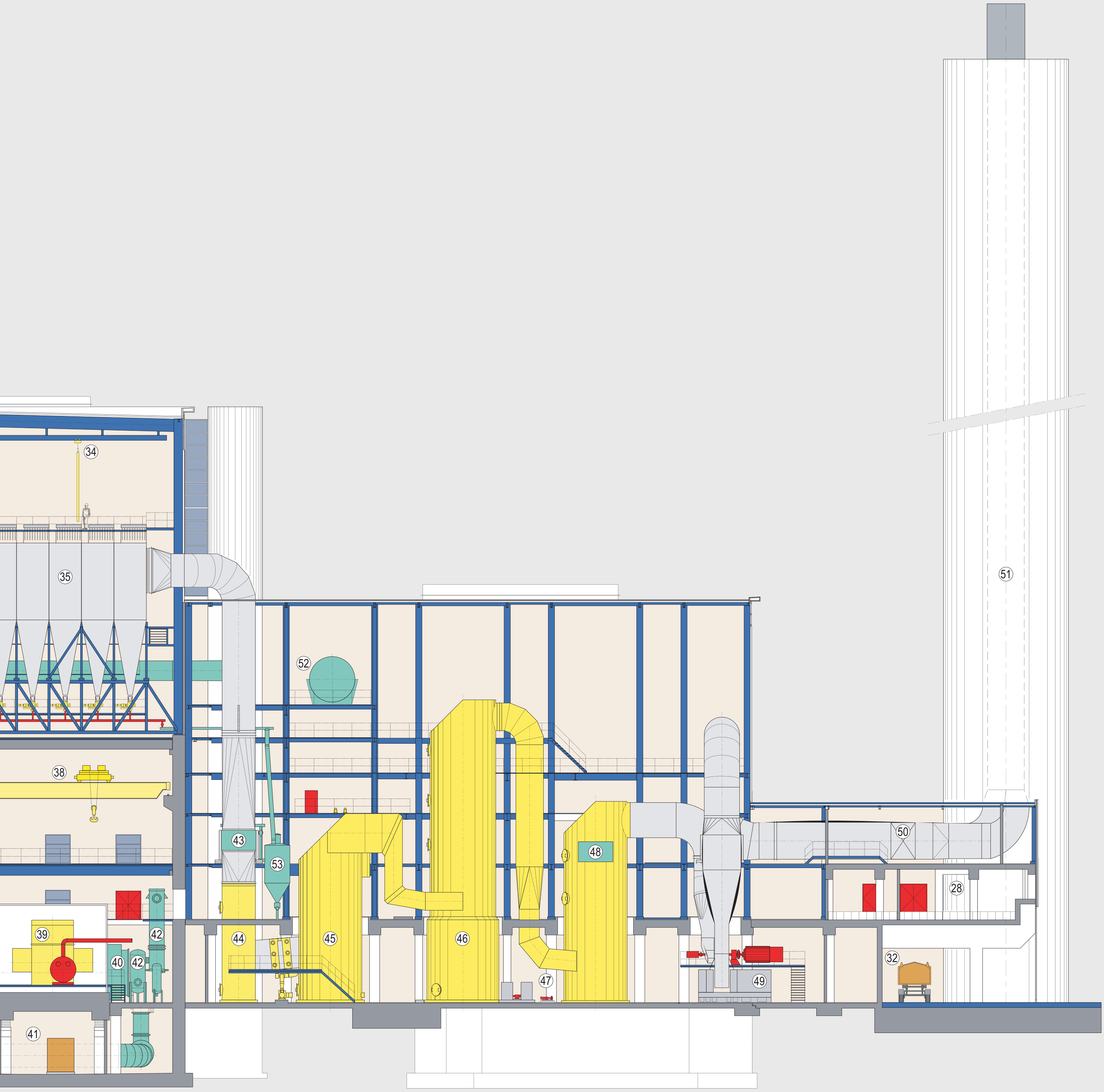


19 injection ammonia for $DeNO_x$
20 boiler (1st, 2nd and 3rd radiation chamber)
21 boiler drum
22 boiler, superheater section
23 boiler section economizer 1 (ECO 1)
24 boiler service crane
25 safety valves
26 deaerator
27 reci-gas fan
28 electrical and control rooms

29 cable room
30 electrostatic percipitator
31 fly-ash silo
32 loading station
33 active coal injection
34 service hoist filterelements
35 fabric filter
36 feedwater pump
37 steam headers
38 turbine service crane



39 turbogenerator
40 main condenser
41 turbine oil room
42 reheater
43 economizer 2 (ECO 2)
44 quencher
45 HCl scrubber
46 SO_2 scrubber
47 economizer 3 (ECO 3)
48 polishing scrubber
49 ID-fan
50 emission monitoring
51 stack
52 emergency-watertank
53 residue buffer silo
54 main cooling water



Colophon

Foreword

Since 1993, the City of Amsterdam's Afval Energie Bedrijf (Waste and Energy Company) has run a Waste-to-Energy Plant in the city's western port district that has a processing capacity of more than 800,000 tonnes per year. This plant has been a success since the day it opened, both in terms of environmental performance, technology and business results. Its capacity is being used to the full and emission requirements are satisfied with room to spare. Over the past five years, average availability has been more than 94% and the average net efficiency of electricity has been more than 22%.

In order to be able to operate just as successfully in the future, the Afval Energie Bedrijf (AEB) continues to examine critically the market in which it operates and its position in that market. In 1998, AEB produced a master plan to develop an advanced Waste-to-Energy Plant with an incineration capacity of approximately 500,000 tonnes per year. An innovative basic principle behind the plan was to 'design for output'. Increased electrical efficiency and developing new products from residues were primary objectives.

This has resulted in the development of a Waste Fired Power Plant (WFPP) that, in one leap, will raise the state-of-the-art electrical efficiency of 22% to 30%. In doing so, it will turn the Waste-to-Energy Plant into a Waste Fired Power Plant.

This brochure presents and explains the background and the technology of this new power plant. To avoid confusion, I would like to emphasise that the existing power plant is referred to as the Waste-to-Energy Plant and its innovative successor as the Waste Fired Power Plant. Both plants will operate together from 2007.

The building of the WFPP is yet another part of the Eco-Port® concept, a sustainable industrial complex based on recycling and processing waste from urban regions. With this technical glimpse behind the scenes, we would like to present you with a view of new, challenging perspectives.

Dr. K. D. van der Linde
Managing Director, Afval Energie Bedrijf City of Amsterdam

Reading guide and key figures

Chapters 1 and 2 are intended for the reader with a general interest in the concept of the WFPP. Combined with Chapter 3, they also provide for the needs of readers with a general technical interest. The other chapters have been written for readers with a more detailed interest.

Chapter 1	'Introduction' describes the history and vision that led to the WFPP.
Chapter 2	'WFPP' describes the concept and the basic principles.
Chapter 3	'Process' goes into the technical aspect in more depth.
Chapter 4	'Project' describes the realisation.
Chapter 5	'Architecture' deals with the construction and layout of the plant.
Appendices	Technical specifications, lots, studies and literature, plans and drawings.

fig. 1 Key figures

Capacity		**Per year**
Waste-to-Energy Plant (design)	2,400 tonnes/day	765,000 tonnes of waste
Waste-to-Energy Plant (2004)	2,800 tonnes/day	850,000 tonnes of waste + 25,000 tonnes of sludge
WFPP (design)	1,600 tonnes/day	530,000 tonnes of waste
Afval Energie Bedrijf (total in 2008)	4,400 tonnes/day	1,400,000 tonnes of waste + 100,000 tonnes of sludge

Energy (net delivery)		
Waste-to-Energy Plant (design)	59 MW	450,000 MWh elect.
Waste-to-Energy Plant (2004)	67 MW	530,000 MWh elect. + 150,000 GJ heat
WFPP (design)	57 MW	420,000 MWh elect.
Afval Energie Bedrijf (total in 2008)	125 MW	1,000,000 MWh + 250,000 GJ heat

Investment	
Waste-to-Energy Plant (1993)	€ 450 M
WFPP (2004)	€ 370 M

Turnover	
Waste-to-Energy Plant (waste, 2004)	€ 85 M
Waste-to-Energy Plant (energy, 2004)	€ 17 M
Afval Energie Bedrijf (total, 2004)	€ 110 M

1 Introduction

1.1 Afval Energie Bedrijf

The Afval Energie Bedrijf (Waste and Energy Company) is a service branch of the City of Amsterdam that operates as an independent company. The City of Amsterdam is the sole shareholder. This means that the Afval Energie Bedrijf (AEB) must operate independently on a normal, competitive basis on the waste, energy and raw materials markets.

For more than 10 years the incineration tariff, linked to AEB's cost price, has been one of the lowest on the market. Why that is so is explained in AEB's mission statement:
"To be the best in processing raw materials, with a focus on generating the maximum benefit and the highest possible environmental efficiency from waste at the lowest possible cost, creating added value for our stakeholders. We achieve this thanks to the mutual respect and dedication of all our staff. In short, we make the most of waste".

In order to achieve its mission, AEB has set itself strategic objectives that must be realised by the year 2010 at the latest. The foremost objectives and tasks are as follows.

A pioneering role in Europe

The Afval Energie Bedrijf and the City of Amsterdam are pursuing a proactive environmental policy. They constantly strive for improvement of the environmental performance. This explains their mission to be Europe's top environmental performer, and also its low cost-price leader. Both the Afval Energie Bedrijf and the City of Amsterdam put the interests of the people first. They firmly believe that citizens are entitled to the lowest possible tariffs. As befits a non-profit organisation, these are based directly on the cost price.

fig. 2 **The Afval Energie Bedrijf, Amsterdam**

Optimum development and growth

Supplying quality depends on the effective collaboration of expert, motivated and quality-conscious employees. Key elements in this are openness, honesty, an active attitude, safety and mutual respect.

A service organisation

The Afval Energie Bedrijf has a statutory duty to process waste in Amsterdam. This duty extends to the collecting and sorting of small-scale chemical waste, coarse waste and electrical appliances discarded by households and businesses. In addition to this, electricity and heat are supplied to city departments, businesses and private citizens.

Catchment area

Being a municipal organisation, the Afval Energie Bedrijf has as its primary catchment area the city of Amsterdam itself and 19 affiliated municipalities in the region. Since the WFPP will increase AEB’s capacity, long-term contracts have now been concluded with waste-collection organisations from other regions. This means that optimum use of the enlarged processing capacity has been guaranteed for the next fifteen years.

Business units

In addition to the Waste-to-Energy Plant, AEB comprises various business units and a joint venture:

- The Hazardous Waste Depot, for the collection and recycling of chemical and hazardous waste.
- The Regional Sorting Station, for the collection and dismantling of discarded electrical and electronic appliances.
- Waste Collection Points: six sites in the city for receiving coarse hazardous and/or recyclable waste.
- Westpoort Warmte (WPW): a joint venture in which the Afval Energie Bedrijf works closely with Nuon energy company to distribute heat. The joint venture supplies heat to businesses in the western port area and will soon supply approximately 15,000 households in the Amsterdam Nieuw-West district.

One business unit of increasing importance is the slag reprocessing facility where bottom ash is sorted into building materials and metals. A trial project, and future expansion, will ensure production of increasingly more high-quality metals and primary building materials such as sand and grit.

1.2 History

The Afval Energie Bedrijf has grown out of the former Stadsreining Amsterdam (Amsterdam City Cleaning Department) which was founded in 1885. Around 1900, growing concern about hygienic waste processing – to prevent the spreading of diseases – led to studies for building a waste incinerator. The first waste incinerator in Amsterdam entered service in 1919, with a capacity of 150,000 tonnes per year. In 1969, this plant was replaced by a new one with an ultimate capacity of 500,000 tonnes per year.

The present Waste-to-Energy Plant entered service in 1993, with a design capacity of 765,000 tonnes per year. This plant was the first to be purpose-designed to satisfy the new, very strict emission requirements. This third-generation plant is one of the seven biggest waste-to-energy plants in the world.

In its first 10 years of service, the present Waste-to-Energy Plant was systematically optimised. This led to improved operation, reduced emissions and less use of chemicals, paving the way for the next generation. In line with government objectives, special attention was paid to improving the electrical efficiency. In fact, a host of projects, large and small, were carried out to this end. Thanks to these projects, the net amount of electricity supplied has increased by 20% from 450,000 MWh in 1993 to 530,000 MWh in 2004. District heating now supplies heat to users in the neighbouring area.

1.3 From the Waste-to-Energy Plant to the WFPP

In drawing up its new plans, AEB carefully considered the essential function of waste incineration for society. This led to the conclusion that plants were not so much replaced because they were written-off, but more so because society's frame of mind had changed to such an extent that the plants were obsolete. In the current situation it is easy to be completely clean and comply with emission regulations. This, however, is insufficient as there is a new awareness that sustainability is essential for increasingly more activities (fig. 3).

Once this conclusion had been established, it led AEB to the conclusion that, instead of being just a waste-disposal solution, conventional waste incineration would have to develop in the direction of complete reuse of energy and materials. The thinking behind the fourth-generation waste-to-energy plants is: 'Design for output.' The result of this new paradigm is a Waste Fired Power Plant that achieves 30% net electrical efficiency. Bottom ash is washed to supply clean sand and grit and to reclaim the maximum of metals. The change in the way of thinking may seem subtle, but when translated into practice it leads to very real results in the reuse of energy and materials (fig. 4).

fig. 3 **Generations of waste incineration**

Generations of waste incineration in Amsterdam

–	1885	–	open incineration
1.	1917	150,000 tonnes/year	oven, no flue-gas cleaning
2.	1969	500,000 tonnes/year	dust separation
3.	1993	800,000 tonnes/year	chemical flue-gas cleaning
4.	2006	+ 500,000 tonnes/year	design for output

1.4 Incineration grate technology

In drawing up the 1998 master plan mentioned earlier, a lot of attention was devoted to future developments in the waste market and their associated technologies. With this in mind, a strategic choice was made to concentrate on core business: the integral incineration of household waste. Every variation of technological developments, including fluid bed, pyrolisis and gasification was considered. This comparison led to the conclusion that incineration grate technology had the most to offer for mixed household waste. Despite the ‘moratorium’ (a ban on building conventional technology using incineration grates that was in force at the time) a start was made on designing an improved incineration grate furnace that would match with basis assumptions of government policy. A new concept was developed that primarily focused on maximising electricity production. Separate projects were started for recycling materials. You can read more about this – particularly about recycling bottom ash – on pages 10 and 11.

1.5 Total recycling

The approach described above is based on the philosophy that a waste-to-energy plant which focuses only on ‘removing waste’ does not provide society with sufficient added value. Social awareness is leading to increased attention to useful applications. To acquire long-term social support, waste-to-energy plants must develop from facilities for ‘removing waste’ into facilities for ‘total recycling’. (fig. 5)

With the knowledge and experience acquired in operating and optimising the energy efficiency of the existing Waste-to-Energy Plant, thirty measures were united in a single concept. This mostly concerned using available technology in a much-improved form. To complete the concept, innovative ideas were applied. Together, all of this led to the plant described in this brochure.

fig. 4 **Waste processed and energy produced in Amsterdam**

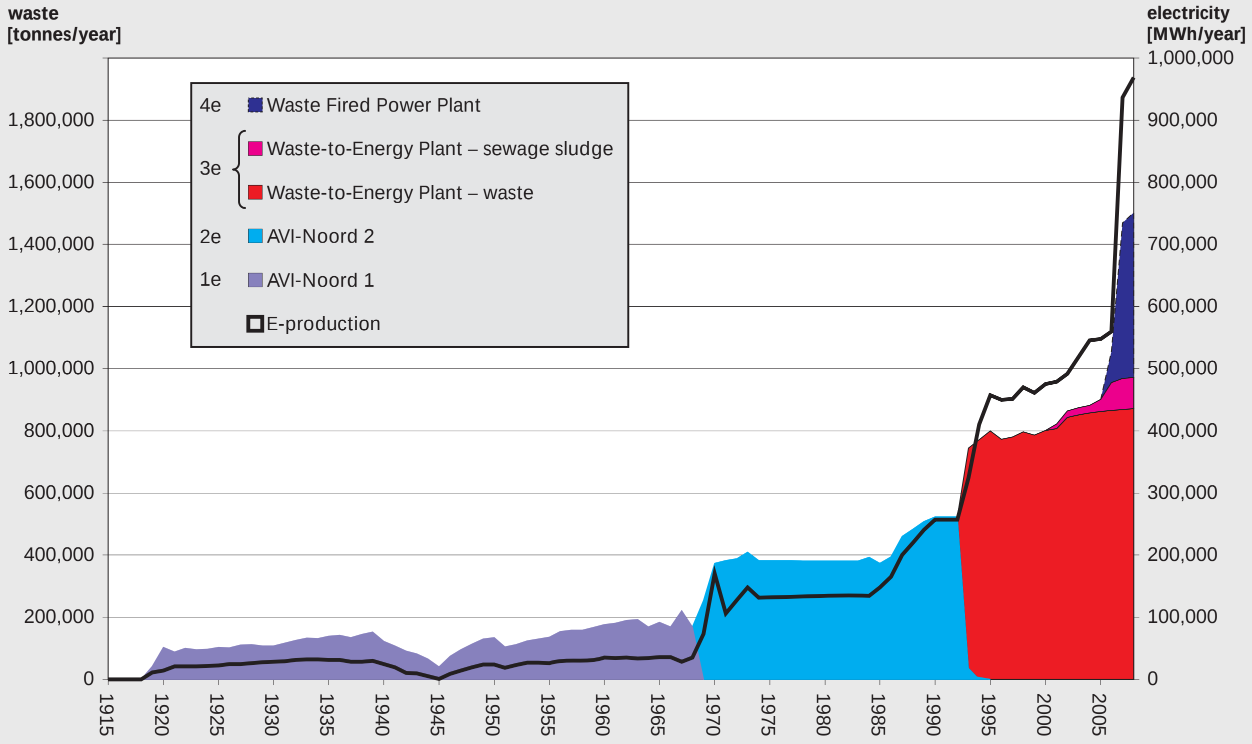
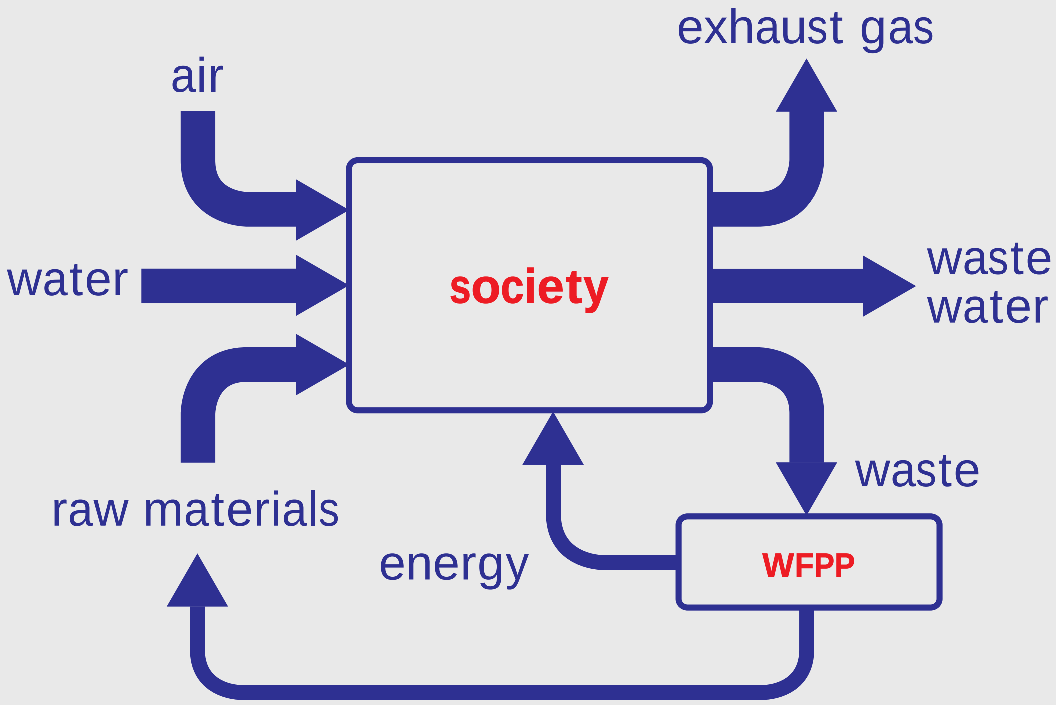


fig. 5 **Closing the loop**



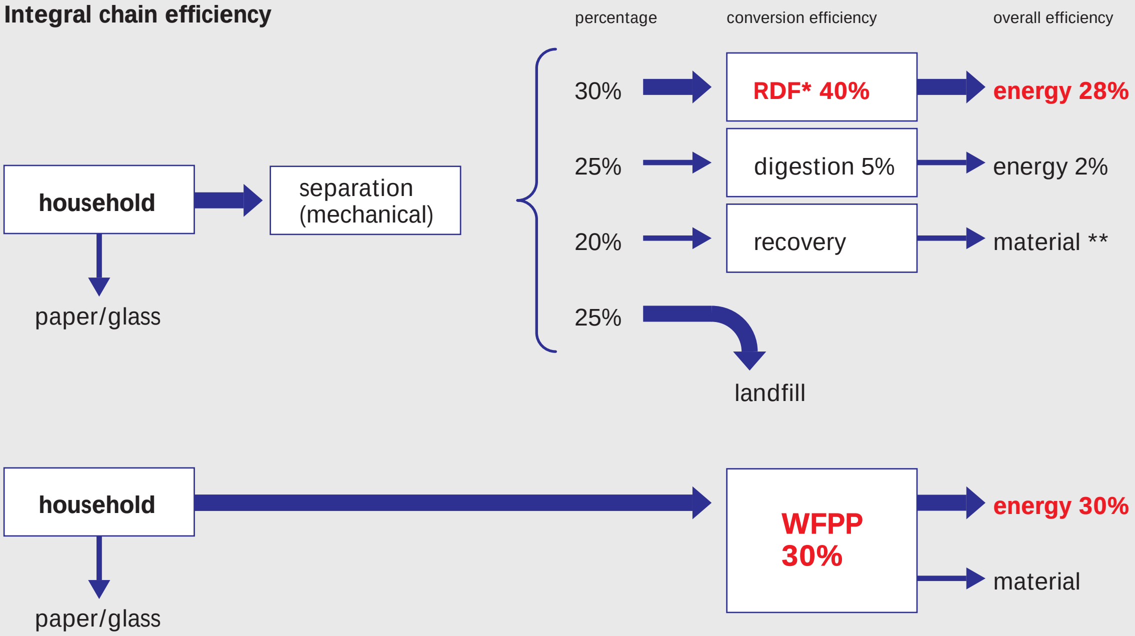
This facility, called the Waste Fired Power Plant (WFPP), is currently being built by the Afval Energie Bedrijf. From the end of 2006, the AEB will operate both this plant and the existing Waste-to-Energy plant. The principle behind the WFPP is maximum electricity generation.The objective is to build and operate a full-scale plant based on maximum electricity production. Naturally, this should also include satisfying the commercial, environmental and operational requirements set by the market for every competing full-scale plant. The WFPP concept exceeds the principles established in the EU reference for Best Available Technology (BREF 2003).

Compared with other technologies, the WFPP achieves optimal recycling. This is largely due to the integral incineration of waste which leaves no residue for low-yield reprocessing or even dumping. The National Waste Management Plan provides Life-Cycle Analyses for household waste. These indicate that the integral incineration concept in a WFPP scores just as high as the most ideal concepts based on sorting facilities. The big advantage of the WFPP lies in its robustness and its low costs. This applies particularly to challenging, mixed waste flows such as municipal solid waste (fig. 6).

1.6 Slag reprocessing

In addition to realising the WFPP, which focuses on energy generation, AEB is working on improved recycling of materials. In slag, inert components such as sand, stone and metals remain, so a separate programme has been set up for sorting and washing bottom ash using a wet process. This wet-sorting process includes the advanced step of using kinetic gravitational sorting in water.

fig. 6 **Separation versus integral incineration**



Integral chain efficiency

*RDF (refused derived fuel) **coïncineration in coalfired power plant

This has led to a pilot facility that produces clean, high-quality raw materials and semi-products from the bottom ash:

- Ferrous metals: recycling of iron.
- Non-ferrous metals: recycling of aluminium, copper, zinc, lead, etc.
- Granulates fraction (stones, earthenware, etc.): reused in concrete.
- Sand fraction: reused in sand-lime brick.
- Small-scale residual fraction (sludge): as yet, still residue.

The results of this pilot facility are very good. With the aid of new technology developed in co-operation with Delft University of Technology, it is possible to sharply increase the percentage of reclaimed materials while achieving good (pure) quality. The pilot plant has now been up-scaled to 50 tonnes/hour. It is expected that a full-scale plant (with a capacity of over 300,000 tonnes/year) will be in service within a few years. This will mean that the objective of total recycling will be almost entirely achieved.

2 The Waste Fired Power Plant

2. 1 Objectives

The following objectives have been set for the WFPP:

1. The WFPP will achieve a net electrical efficiency of 30%.
2. Availability will be ≥ 90% of the time.
3. The processing capacity will be ≥ 530,000 tonnes per year.
4. The technology will be incineration grate technology for the integral incineration of municipal solid waste without pre-treatment.
5. The WFPP will be designed according to the BAT (Best Available Technology) principle.
6. Complete reuse of residual materials.
7. Despite an increased supply of waste, the number of road kilometres made to transport it will not increase.

In this way, the Afval Energie Bedrijf's 90 years' experience in waste incineration serves as a basis for creating a new generation of waste incinerators that set a new standard for energy production and material recovery.

Net efficiency of 30%

Thanks to optimisation, the existing Waste-to-Energy Plant supplies electrical power with a net electrical efficiency of more than 22%. This means that the plant enjoys a technologically leading position. To arrive at a net electrical efficiency of 30%, the amount of electricity generated per tonne of waste must be increased by more than a third. In thermodynamic terms, it seems obvious to raise the steam parameters (pressure and temperature) in order to increase the efficiency. But in waste-to-energy plants, higher steam parameters are always accompanied by chlorine corrosion and the increase in steam temperature drastically reduces the life span of the superheater. This is not compatible with the aim of creating an optimally available, efficient plant. So the question is how these conflicting objectives can be harmonised. In the end, the following measures were combined in order to achieve higher efficiency without additional risks:

a. Thanks to years of positive experience gained in treating critical heat surfaces in the boiler by lining with Inconel®, corrosion in the WFPP can be better controlled. This high-quality nickel-chrome alloy is the basis of a number of measures designed to increase efficiency and take the boiler and water-steam cycle to a higher level.

b. A higher steam temperature in waste-to-energy plants is critical owing to the sharp increase in corrosion to the superheaters. In the WFPP, it was decided to use a steam temperature of 440°C instead of the usual 400°C, with the option of raising this to 480°C in future. The boiler design was optimised to minimise corrosion and erosion.

c. Increasing the steam pressure makes a significant contribution to raising efficiency but this can only be done proportional to the steam temperature owing to the condensation of steam in the low-pressure turbine. All the same, attempts to raise the steam pressure in the WFPP have been successful. The pressure has been raised from 40 to 125 bar. This has been made possible by the following crucial modification:

d. Reheating using saturated steam from the boiler's drum. Intermediary superheating of the turbine steam is a process that is used in facilities like coal-fired power stations to achieve higher efficiency. This is done with a heat exchanger operating directly in the flue-gas. But this has big disadvantages for a waste fired power plant. The flue-gas temperature in the boiler would need to be raised so high that the risk of corrosion increased strongly. The solution to this problem was found in using an external heat exchanger for reheating with saturated steam. This process, which is used extensively in nuclear power stations, is now being used in waste incineration for the first time. The principle is shown in the following diagram. (fig. 7).

Saturated steam from the boiler's steam drum is used to raise the temperature of the steam for the second step turbine. Generating saturated steam in a waste fired boiler creates fewer problems than generating superheated steam.

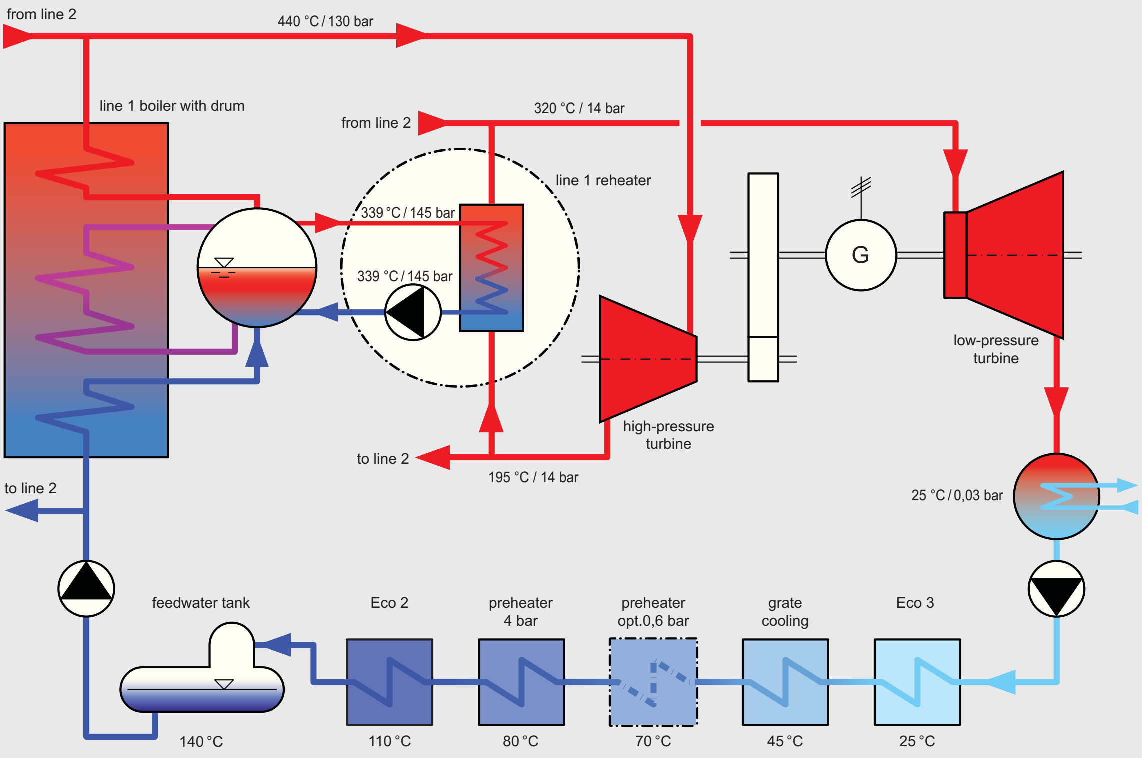
e. Minimising the oxygen level in burning. In waste-to-energy plants, a flue-gas oxygen level of 8 to 11% is usual. Thanks to flue-gas recirculation, the WFPP achieves an oxygen level of 6%. Because of this, the volume of flue-gas is reduced by approximately 40% and the amount of heat lost via the stack is minimised.

f. Maximum use of flue-gas energy. Usually, the energy of the flue-gases is no longer used after they have left the boiler. In the WFPP, the residual energy is used as follows:

- The temperature of the flue-gas on leaving the boiler is lowered in relation to the usual 200-240°C and is kept at a constant 180°C by enlarging the economiser (ECO 1) in the boiler.
- A corrosion-resistant heat exchanger is fitted before the first flue-gas scrubber (the quench) in order to preheat the condensate (ECO 2).
- In the last polishing scrubber, the flue-gases are cooled until the water condenses. This heat is also used for preheating the condensate (ECO 3).

g. Minimising the steam pressure after the turbine. Reheating the turbine steam and cooling the condenser with harbour water makes it possible to have a very low steam pressure after the turbine. This enables maximum turbine efficiency.

fig. 7 **Reheating and water-steam cycle scheme**



The design was finished off with various additional measures such as the 0.6 bar condensate preheater (optional), the use of separately adjustable air preheaters for each grate zone and the use of variable-speed drives (using frequency converters). This was introduced where there was a possibility of saving electricity according to the design and operational specifications.
The combination of these measures and the ability to raise the steam temperature to 480°C, has made it possible to achieve a gross electrical efficiency of about 34%, resulting in a net electrical efficiency of 30%, which was the target. This means that the WFPP is setting a new standard for the recovery of energy from waste.

90% availability

High availability is a primary requirement for operating a waste-to-energy plant profitably. Most of all, it is unscheduled shutdowns that lead to high costs and a reduction in income. In order to optimise the availability of the WFPP in spite of its innovative character, the following measures were taken, among others:

- The entire first and second boiler radiation chambers will be protected with a high-quality nickel alloy (Inconel cladding).
- In the event of wear, every superheater set can be replaced within 72 hours.
- All components are built for uninterrupted operation (journey time) of 24 months instead of the usual 12 months. This means that they can operate for two years between major servicing. Thanks to these measures, the duration of this scheduled servicing work has been shortened from 21 days to 14 days.
- Systematic analyses to identify shortcomings in safety and operational reliability, allowing improvement measures to be taken at an early stage. Paragraph 4.6 provides a summary of these analyses. They have resulted in a large number of detailed optimisations that have been included in the engineering.
- Making a special effort to involve AEB employees in all the design work has guaranteed that experiences with the existing plant have been included in the plans and that possibilities for optimisation have been exploited to the full.

530,000 tonnes of waste per year

The WFPP consists of two incineration lines, each with a thermal capacity of 93.3 MW. At an average calorific value of 10MJ/kg, this corresponds to a nominal throughput of 33.6 tonnes/hour of waste, or 1,600 tonnes/day combined. Compared with other waste-to-energy plants, these are very large units. For waste incineration, their size has the major advantage that fluctuations in the waste burned can be easily absorbed. Variations in the composition of the waste have less effect and the boilers can operate steadily and without disruptions.

Grate incineration technology

The waste is incinerated on a horizontal grate fitted with a water-cooling system. This cooling system is part of the water-steam cycle, ensuring that no heat is lost. Only the first half of the grate surface is cooled in this way, to prevent burning of the grate bars and also to enable the incineration of industrial waste with a high calorific value. One big advantage of water cooling is that it extends the life of the grate bars.

Flue-gas cleaning

The AEB constantly strives to improve its environmental performance. For this reason, the flue-gas cleaning process has been designed for selective product separation in which harmful residues can be converted into usable materials to be sold as products.

In addition to the emission limits imposed under the Dutch Environmental Management Act, AEB also used the even better operating parameters of the existing Waste-to-Energy Plant as a starting point. Surpassing these limits led to a design for the flue-gas cleaning system based on BAT (Best Available Technology).

In the diagram, the guaranteed performance of the WFPP (grey and red) is compared with the expected (green) performance as a percentage of the legally permitted limit. Naturally, the expected performance is lower than the guaranteed performance (fig. 8).

The Dutch emission limit for nitrogen oxides is one third of the EU standard. Owing to ammonia use, the optimum from an environmental technology viewpoint is operation using a setpoint for nitrogen oxide emission that is just below the Dutch standard. For all other components, the operational emission values are far below the Dutch and EU standards.

Maximum use of residual materials

The innovative nature of the WFPP is shown all the more in the practical uses to which the various residual materials are put:

a. The bottom ash is processed in the slag reprocessing facility.
b. Boiler ash can be selected according to quality.
c. Fly ash is separated in the electro-filter.
d. The chlorine (hydrochloric acid) is processed into calcium chloride in the salt factory.
e. The sulphur (sulphur dioxide) is processed into gypsum.

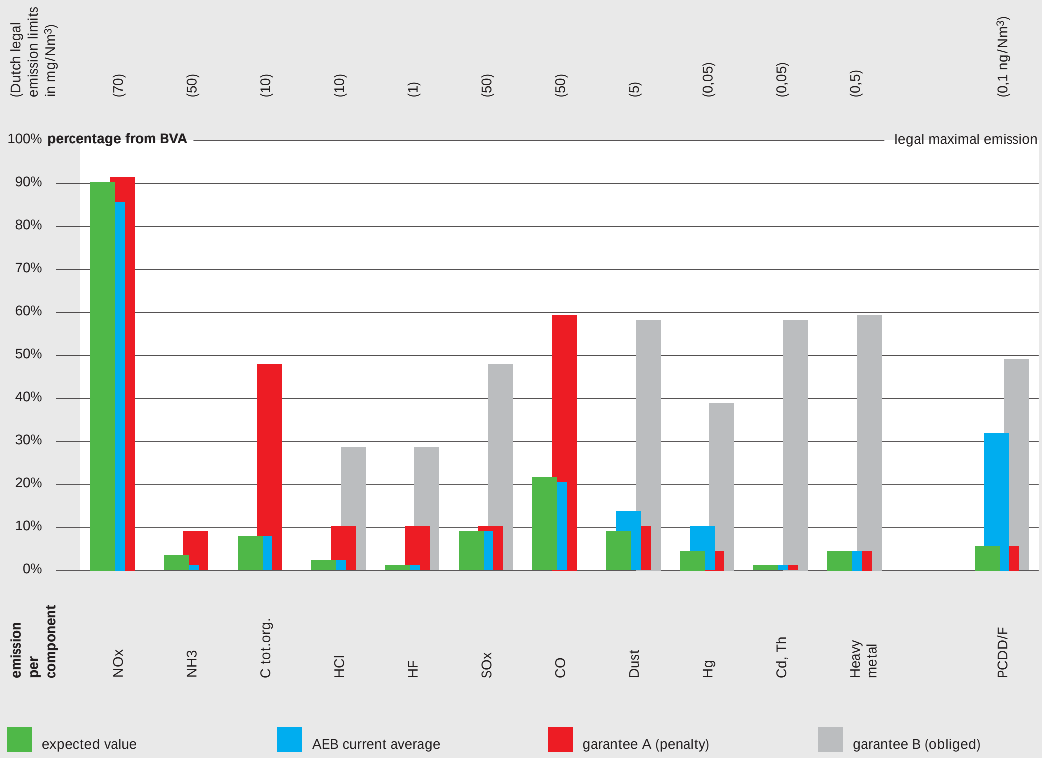
Only the residual materials from the fabric filter will still have to be dumped for the time being.

Bottom ash. After incineration, the inert material remains behind in the form of bottom ash. This bottom ash is processed in the slag reprocessing facility and must conform to the Dutch Building Materials Order. The AEB is focussing on the highest-quality use of bottom ash. Various techniques can be used to reclaim iron and very valuable non-ferrous metals. Using the wet process, clean sand and grit are produced that can be used for producing sand-lime bricks and concrete. See also page 10.

Boiler ash. Depending on the temperature, the properties of the boiler ash during flue-gas cleaning in the boiler will differ. For the ash that is gathered in the hoppers under the superheaters and the ECO, a choice can be made as to whether the contents of each hopper should be processed as fly ash or bottom ash.

fig. 8

Emission values



Fly ash. For environmental reasons, it has been decided to use an electro-filter for pre-separation of fly ash before the fabric filter. In terms of process technology, there is no need to do this but, thanks to this method, the fly ash is kept apart from the flue-gas cleaning residue separated in the fabric filter, as a “better” product. This enables its use in asphalt concrete and avoids dumping.

Salt. The acids in the flue-gases in the quench and in the hydrochloric acid scrubber, react with limestone ($CaCO_3$) to make a calcium salt solution ($CaCO_2$). A brine plant has been built that cleans the polluted salts and evaporates them down to a clean solution for reuse in such things as salt for roads or for use in the chemical industry.

Gypsum. The gypsum produced in flue-gas cleaning is comparable with gypsum from coal-fired power stations. It can be used in the production of building materials, plaster blocks and plasterboard walls.

Water. The plant is free of waste water. The water produced is internally recycled for use in other process steps or evaporated in block 10/20.

Fabric filter. Before the fabric filter, a mixture of active carbon and limestone is injected. This ensures very effective separation of heavy metals and dioxins so that the products of the wet flue-gas cleaning emerge in a clean form. The residue from the fabric filter is the only waste from the facility that has to be dumped. In terms of quantity, the residue is less than 1% of the quantity of incinerated waste. In the future, further investigation will be conducted into how this residue can be processed for reuse.

Emissions. Emissions from the WFPP will be lower than those of the present Waste-to-Energy Plant. In order to achieve this, a fabric filter has been placed before the scrubbers in the WFPP’s flue-gas cleaning facility. This separates dust and other components more effectively than the electro-filter in the existing Waste-to-Energy Plant. It also means that the salt and gypsum reclaimed in the plant are already fairly clean. For the emission figures for each component, see page15.

Less road traffic

The AEB has set itself the objective of ensuring that transport of waste by road will not increase as a result of the expansion. For this reason, preference has been given to bringing waste to the WFPP by barge. All other optimisation tools such as improved circulation of waste collection trucks and the use of bigger vehicles will be exploited to the full. Transport of waste by rail will be maintained and the existing rail connection to the ACTS terminal can be extended when needed.

2.2 Environment

The Afval Energie Bedrijf has an environmentally friendly attitude and tradition. It was granted a framework environmental permit based on the company effectively monitoring its impact on the environment itself. In addition to this, there is a best-effort obligation to continuously improve the environmental performance in the course of time.

A framework permit has also been granted for the Waste-to-Energy Plant as a result of AEB’s active attitude towards the environment. The components required for a framework permit are:

- A certified corporate environmental care system based on ISO14001.
- Audit by an external agency every three years.
- An annual environmental report.
- An approved corporate environmental plan.
- Satisfactory observance of environmental regulations.
- External transparency of the organisation.

Part of the permit for the WFPP is a comprehensive Environmental Impact Report in which all of the effects of the WFPP on soil, water, air and noise are examined. In this phase, many issues have been harmonised with local residents and involved parties. These investigations and surveys have formed part of the basis for the AEB's ambitious environmental aims, which have gained a great deal of support as a consequence. For this reason, there were no external objections to the final application and the permit was approved as planned.

2.3 'Green status'

The AEB has received the so-called 'green status' for the WFPP, which makes it fiscally attractive for banks and their clients to invest in the plant. The WFPP requires investments of roughly € 55 million (15%) more than a conventional waste-to-energy plant. The green status will make it possible to obtain the necessary additional means. Financial support has also been provided based on the CO_2 Reduction Plan. Under the MEP (Environmental Effectiveness of Energy Production) scheme, a fixed subsidy will soon be granted for every MWh produced in a ten-year period. The province of Noord-Holland is also providing a substantial environment-related contribution. In addition to this, a major European subsidy was obtained under the 'Energy, environment and sustainable development' programme.

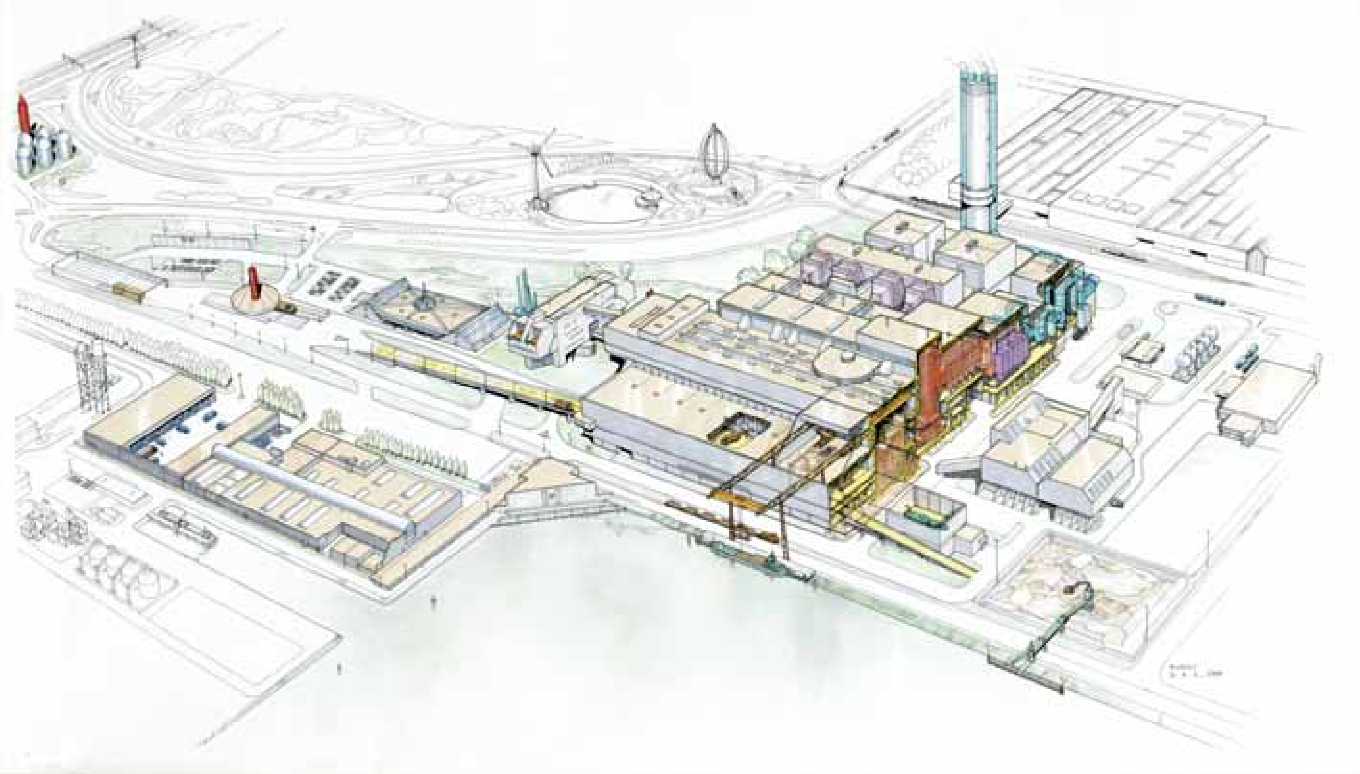
2.4 Eco-Port® (fig. 9)

The WFPP will be built on the AEB site as an extension to the existing plant in the industrial and port area of Amsterdam. This will make it possible to use the available infrastructure, particularly the access roads, railway line and harbour.
The WFPP is part of a broad approach to the maximum reuse of waste from our society. AEB is also striving to continuously improve its processes in order to bring about as much reuse as possible. In this respect, a lot of attention is being devoted to exploiting the synergy between different waste flows and processes. With this in mind, AEB is actively searching for possibilities for locating the activities of other companies close by. The building of a new waste-water purification facility for the entire city of Amsterdam by Waternet (the former Water Management and Sewage Department of Amsterdam) on the site immediately adjacent to AEB is a major step towards achieving this objective.

The construction of the new waste-water purification plant in the immediate vicinity of the Afval Energie Bedrijf will be used to utilise waste and save energy as a collaborative effort:

1. The sewage sludge will be pumped directly to the Waste-to-Energy Plant and injected into the incineration grate through 30 nozzles, where it will burn on top of the waste.
2. The biogas released by fermentation in the waste-water purification process will be used in the Waste-to-Energy Plant's biogas engines to generate electricity. All heat generated will be supplied to district heating.
3. Additional synergy will be achieved by using the exhaust gases from the biogas engines for drying waste. This means that 95% of the energy in the biogas will be used.
4. The Waste-to-Energy Plant will supply heat and electricity to the waste-water purification plant.
5. In the future, there will be an option for pre-warming waste-water. This will stimulate biological activity in the waste-water purification process, which will improve performance. Nitrogen removal in the winter months will be particularly optimised in this way. Connections will be provided for a future link to the turbine condenser. In theory, it is also possible to use flue-gas heat for this purpose (fig. 10).

fig. 9 Artist's impression Eco-Port® Concept



Preparations are now being made to work with companies using materials reclaimed from slag. The search for synergy with other branches of industry involved in the Eco-Port® concept is a continuing focus of attention. Recycling activities and industries with significant energy needs, or a lot of waste or waste water, can provide immediate benefits of synergy. Examples of this are the paper, concrete, lime-brick and chemical industries.

2.5 Patents

Above all, the WFPP uses proven technology. The Afval Energie Bedrijf has devoted a lot of energy to the systematic optimisation of its existing power station. The know-how acquired in this way has been used to design the new plant as well as possible. Patent applications have now been submitted for the key innovations and have been obtained nationally and internationally:

- Detergents in flue-gas cleaning for dioxin reduction (NL1005578 A method for removing pollutants from a gas using a gas-cleaning agent).
- Salt factory for recycling residues from flue-gas cleaning (NL 1006515 Method and layout for reprocessing flue-gas residue).
- Reheater concept for increasing the efficiency of waste-to-energy plants (NL 1015438 High-efficiency waste-to-energy plants).
- Flue-gas recirculation/use of exhaust gas for improved drying and incineration (NL 1015519 Flue-gas recirculation in a waste-to-energy plant).
- Improved design of steam superheaters (NL 1019612 Steam superheater).
- Wet non-ferrous separation from bottom ash with Magnus effect and density separator (three international patents in collaboration with Delft University of Technology).

- Linking a waste-to-energy plant to a waste-water purification plant (NL 1017009 Method and layout for cleaning waste water).

The Afval Energie Bedrijf is striving for a broad application of this know-how and other knowledge acquired. Licensing agreements are being marketed internationally for this purpose. This will lead to further promotion of our own developments and knowledge.

3 Process technology

3.1 Blocks 10/20 and 30

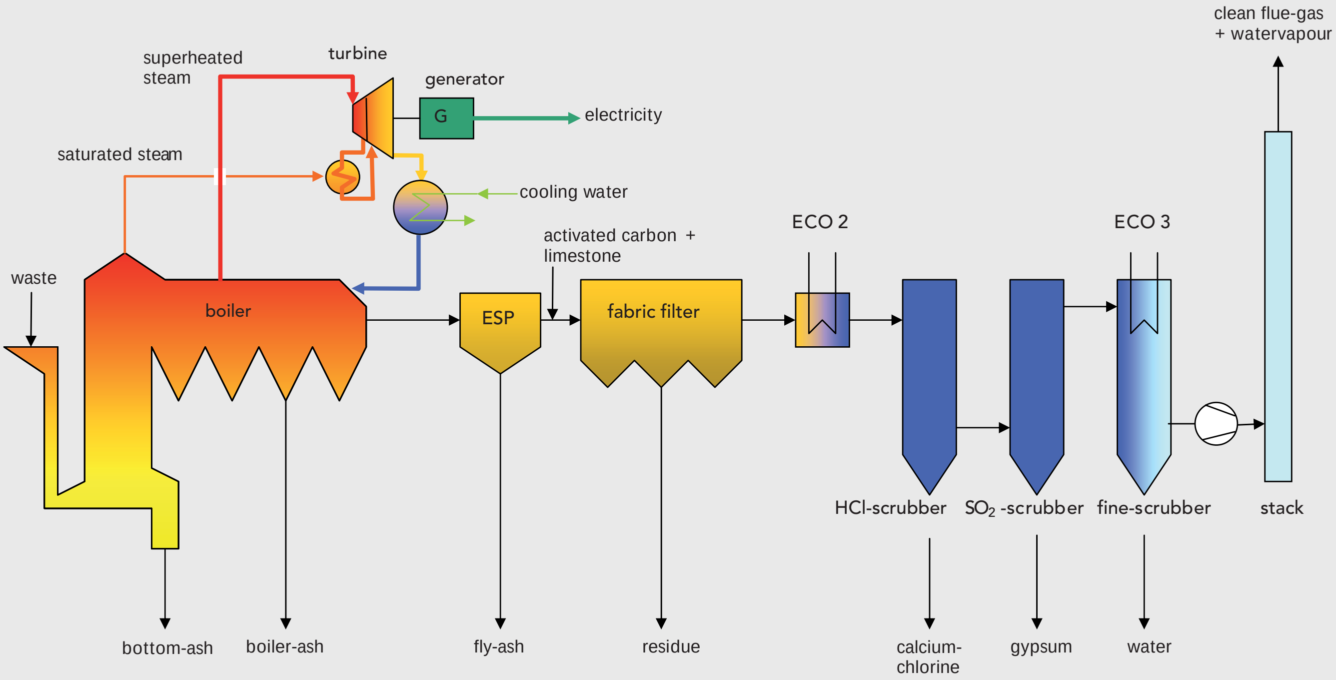
The WFPP has been added to the existing Waste-to-Energy Plant as block 30. The Waste-to-Energy Plant consists of blocks 10 and 20. Block 30 can operate independently of blocks 10 and 20. Links remain limited to supplying such things as chemicals and water. There are buffers with sufficient capacity to ensure independent operation for at least 48 hours. The existing Waste-to-Energy Plant (blocks 10 and 20) consists of four identical lines numbered 11, 12, 23 and 24. The WFPP (block 30) consists of two identical new lines numbered 35 and 36. Each of the two lines consists of waste supply, incineration grate, boiler, flue-gas cleaning and stack. The lines can be operated independently of each other. Block 30 has one turbine generator. If the turbine is not operational, the steam generated is piped to the emergency condenser via a reducer. The following diagram shows the most important components and functions of the WFPP (fig. 11).

3.2 Design fundamentals

In the WFPP, combustible household waste and comparable industrial waste will be incinerated. Based on analyses and prognoses, the average calorific value has been set at 10 MJ/kg and the processing capacity at 530,000 Mg/year with an availability of 90% (1,600 tonnes/day). The thermal capacity of WFPP can be deduced from this. The relationship is shown in the firing diagram for one of the two incineration lines (fig. 12).

The optimum is shown at point A and corresponds to a thermal efficiency of 93.3 MW = 100%. The calorific value at this point is 10 MJ/kg and the throughput is 33.6 Mg/h per line. At lower calorific values, the

fig. 11 **Process diagram**



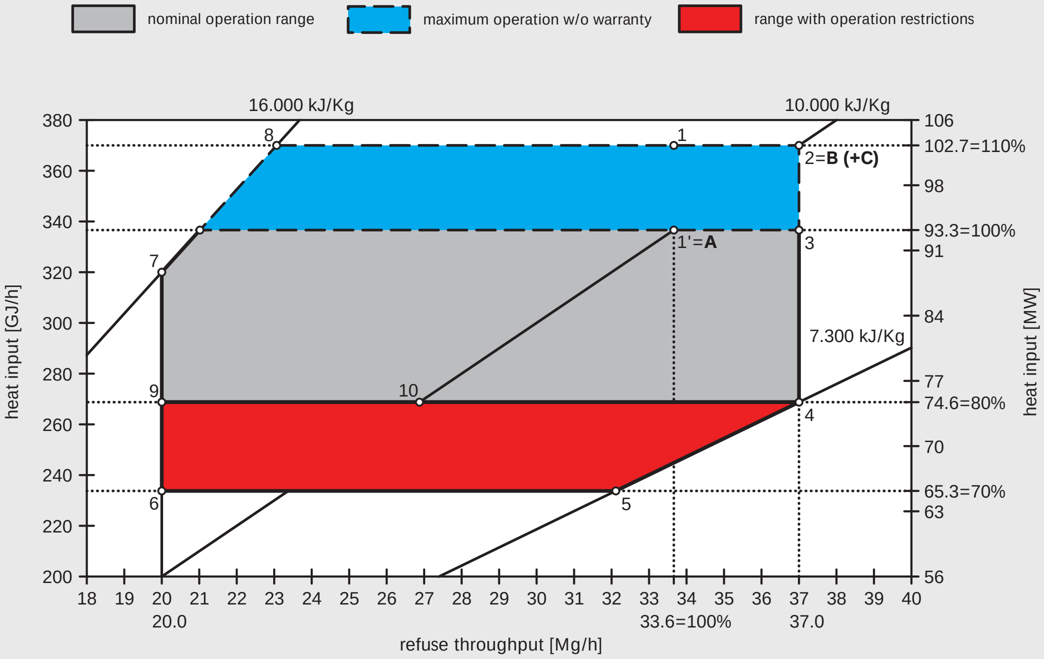
throughput capacity increases to a maximum of 37 Mg/h. Higher calorific values of up to 16 MJ/kg can also be processed by the WFPP, making it possible to incinerate a wide range of industrial waste.
The WFPP has been designed with full guarantees at point A: both boilers operating at 100% capacity. In addition, point B is possible, which means that all components are able to run at up to 110% load. This level will not be covered by guarantees but can be achieved on expiration of the guarantee period. Then, based on experiences and possible optimisations, we shall see how technically and economically feasible it is to achieve this extra capacity. The same applies to point C, at which the temperature of the fresh steam is raised to 480°C to increase efficiency even further.

3.3 Waste delivery

A new dumping hall and bunker will be erected as an extension to the existing dumping hall and bunker. In addition to existing delivery by truck and rail, there will also be facilities for delivery by barge. Separate dumping chutes on the roof of the dumping hall enable direct access to the bunker. One of the two new cranes in the bunker can also transfer waste between block 10/20 and block 30.

The waste cranes are equipped with hydraulic multi-tine grabs. These are fully automated and can be operated unmanned – an advantage that will be used mostly at night. The cranes have an advanced bunker-management system. In the new two-storey “swallow’s nest” a repair crane has been fitted with which parts of the travelling grab can also be assembled.

fig. 12 **Firing diagram**



3.4 Grate and deslagger

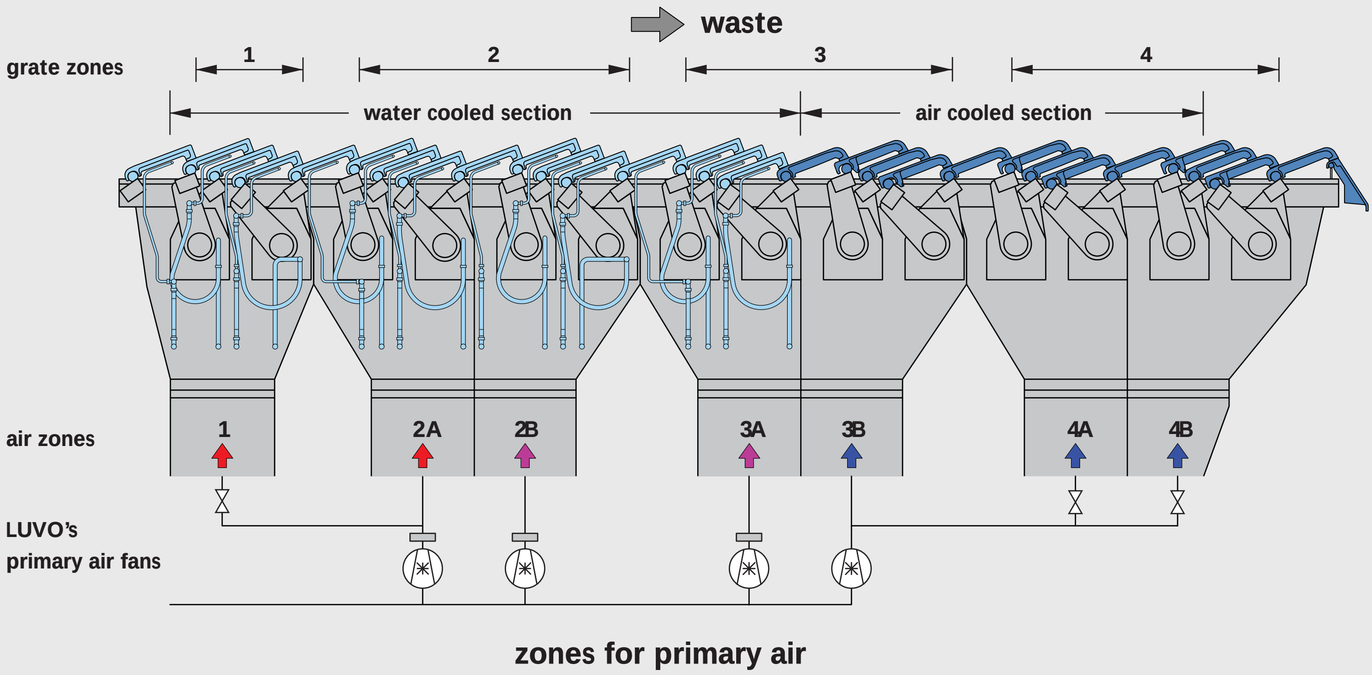
The hoppers that feed both incineration lines are filled by the waste cranes. The waste drops through a water-cooled intake shaft onto the dosing ram. The waste is burned on horizontal grates that are identical to the existing ones but are partially water-cooled. The grate is of the double-motion overthrust type and comprises three parallel runs, each with seven air zones (fig. 13).

Water-cooled grate bars

The grate cooling system is connected to the water-steam cycle so as to use this heat too. The cooling pipes are cast into the grate bars and the connection between the grate bars consists of fixed pipes with flexible tubes on the extremities only that connect to the hot water circuit. The first half of the grate surface is cooled in order to counteract burning of the grate bars and to enable incineration of high-calorific industrial waste. The biggest advantage of water cooling is that it reduces wear on the grate bars, which increases bar life. It also enables incineration with less excess air. Detailed reliability investigations have been carried out into the grate properties needed to guarantee two years' uninterrupted operation.

The bottom ash produced during waste incineration drops down the slag shaft into a water-filled deslagger. Each grate has three of these (one per grate run). Transport on to the slag bunker is by entirely enclosed oscillating conveyors. Water vapour is sucked out of the deslagging system by the tertiary air exhaust system.

fig. 13 **Grate**



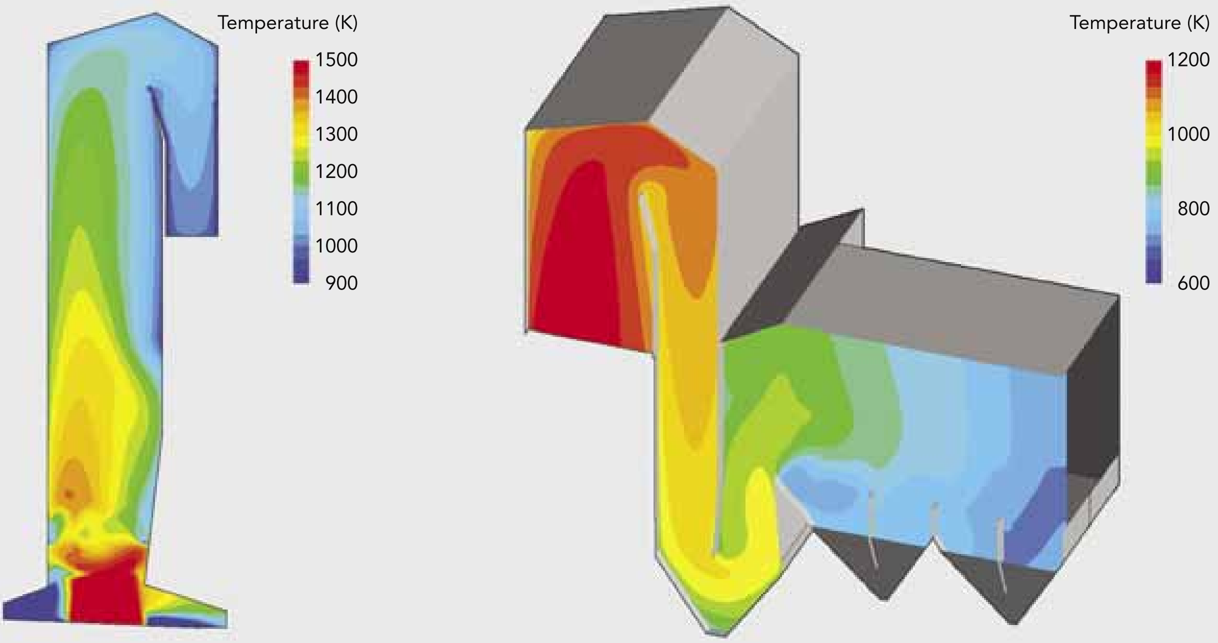
3.5 Combustion air (fig. 14)

Achieving maximum efficiency means having as little excess air as possible. To combine this with efficient waste incineration and obtain thoroughly burnt flue-gas and bottom ash, the air is injected in stages:

- Primary combustion air is blown in from under the grate and the bottom layer of waste. Every zone can be independently heated to the desired temperature. Pressure and air amount can be individually adjusted for each section (bank/zone).
- Flue-gas that has passed through the bag filter is re-circulated as secondary air. Large nozzles are used to make sure that the flue-gas is thoroughly mixed. This results in a lower temperature and a more even profile. The combination of low-oxygen flue-gases reduces the production of nitrogen oxides.
- Tertiary air provides a second mix, this time with oxygen from the air, so that good combustion is possible with only 6% oxygen.

The air injection has been designed using CFD (Computational Fluid Dynamics) in order to guarantee the optimum turbulence in the combustion zone and a stable, even flue-gas flow in the boiler. Figure 14 shows the results. The first illustration shows the first radiation chamber and the second illustration the other sections in the boilers.

fig. 14 **Temperatures in 1st chamber (left) and 2nd, 3rd and 4th chamber (right)**



3.6 Boiler (fig. 15)

The high-efficiency boiler has three empty radiation chambers and a horizontal convection section with tube banks for the steam superheaters and economisers (ECOs). To achieve the maximum possible reliability and capacity margin, the furnace is spacious with large heat-exchange surfaces. The designed velocity of the flue-gas is also low, as is the temperature of the flue-gas before it reaches the first steam superheater banks. This becomes very clear when one compares the size of the first radiation chambers with those of the existing Waste-to-Energy Plant. The greater volume helps reduce the amount of dust in the flue-gas and also lowers the temperature. It also increases the reliability of the steam superheater banks and the economisers. The spare capacity also contributes to the flexibility needed to separately generate saturated steam for the intermediary superheating.

The first and second boiler radiation chambers are fitted with Inconel cladding, as too are the membrane walls under the brickwork. One of the reasons for this is that, because of the high pressure, the temperature of the membrane walls reaches some 340°C instead of the usual 270°C. It is possible to also fit cladding in the third boiler radiation chamber but whether this will be done depends on the amount of corrosion of the membrane walls in practice.

The boilers have no ignition or support burners but are lit using a gas lighter. However, they are preheated with hot feed-water, steam, primary air and recigas, particularly to avoid condensation in the fabric filter. This makes a bypass through the fabric filter superfluous.

In designing the horizontal convection section, including the exterior piping, it was borne in mind that it would have to be possible to replace all the superheater tube banks. This would optimise availability in the case of corrosion or erosion of the pipe banks. It takes only 72 hours to completely replace a bank.
The superheater can thus be regarded as an entirely replaceable part.

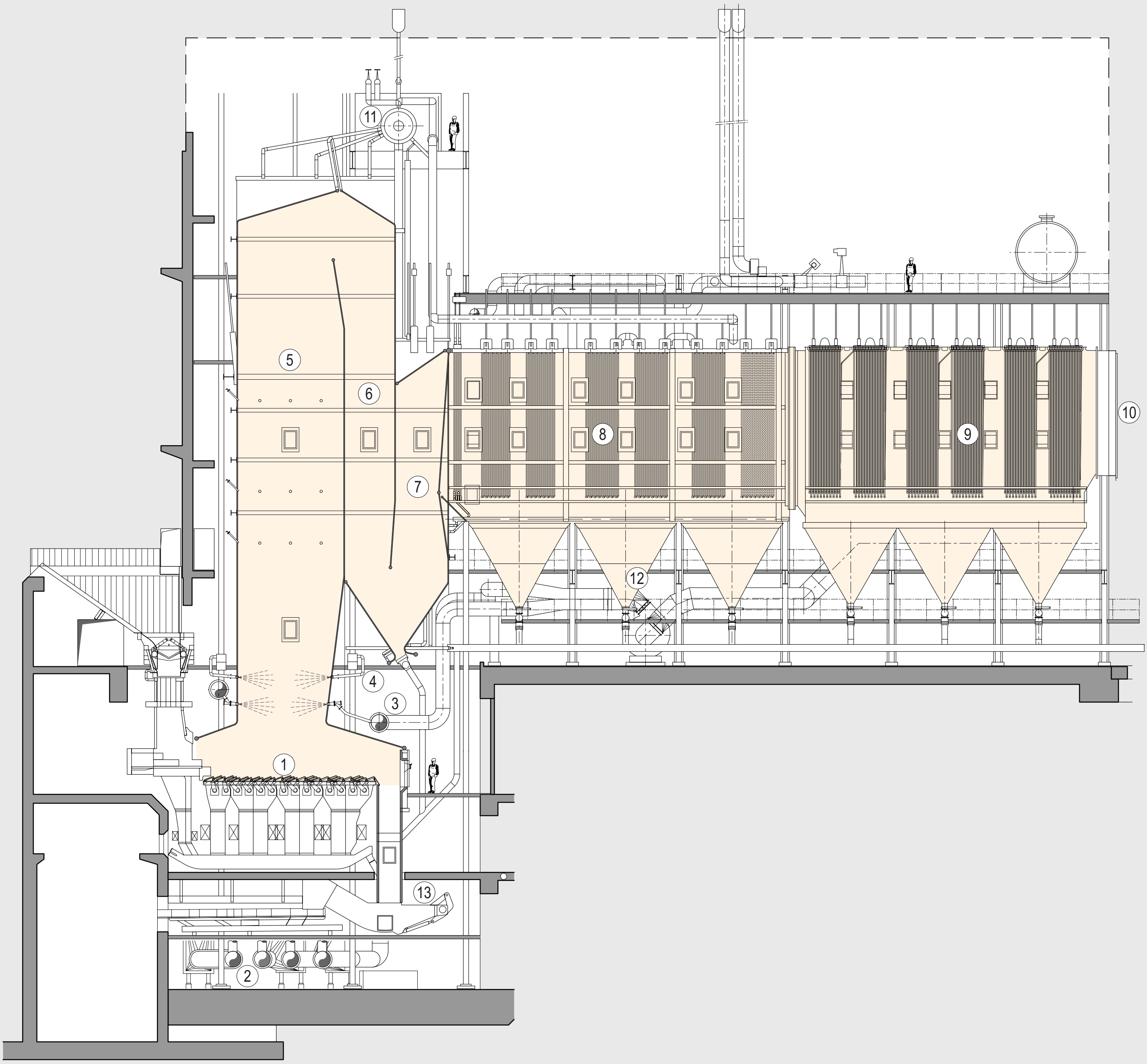
The heating surfaces are connected in a classical way. This means that only the two final superheaters are connected for co-current flow and the other banks are connected for counterflow. In front of the final superheater there is a vaporiser bank to distribute the flue-gas evenly for the superheater bank. There are two injection coolers to accurately adjust the steam temperature (fig. 17).

The boiler has been designed with an empty space between the superheater and ECO sections. This space can be used for an extra tube bank so as to achieve an even higher fresh-steam temperature of 480°C. This could further increase the WFPP’s total efficiency in the future. With this in view, it is also possible to connect the superheater tube banks entirely for counterflow. The choice will depend on practical experience, in other words, the extent of damage to the tube banks. Only if the degree of wear through corrosion/erosion remains within practical limits higher steam temperatures will be used.

A chain conveyor has been installed under the tanks for the horizontal boiler section.
For each tank, it can be decided whether its boiler ash should be added to the bottom ash or the fly ash. In this way, the first part of the boiler ash can be used along with the bottom ash, on condition that the quality criteria are satisfied. The boiler ash from the last part of the boiler will be removed together with the fly ash from the electrostatic fly-ash filter.

fig. 15 Boiler illustration

1 grate
2 primary air
3 recigas (secondary)
4 tertiary air
5 1st chamber
6 2nd chamber
7 3rd chamber
8 4th chamber: Steam superheaters
9 4th chamber: Economiser
10 boiler outlet
11 steam drum
12 boiler ash hoppers
13 bottom ash deslagger



3.7 Reheater (fig. 16)

The reheater is a steam-steam heat exchanger. This reheating has never before been applied in a waste-to-energy plant. The steam emerges from the high-pressure turbine at a pressure of 14 bar and goes to the low-pressure turbine after reheating. During normal operation, in which both boilers are running, the two reheaters work in parallel to provide reheated steam for the turbines.

On the high-pressure side, each of the two reheaters is connected to one boiler. This enables the most effective response to the individual operating conditions of both boilers. Saturated steam from the boiler drum condenses on the high-pressure side of the reheater, after which the condensate is fed directly back into the boiler drum. Owing to the high pre-pressure, a special pump without stuffing box and with an encapsulated rotor is needed. Because of the high temperature, it must also be water cooled. Based on the RAM/FMECA analysis (see page 41) every reheater has only one condensate return pump without redundancy.

3.8 Turbine generator and main condenser

There is one turbine generator set. Because of intermediary superheating, the steam turbine has a separate high and low-pressure section. The generator is fitted between these sections. A gearbox between the high-pressure section and the generator ensures that the high-pressure rotor can rotate faster, thus increasing energy efficiency. The turbine housing of the high-pressure section is the drum type while the low-pressure housing is split horizontally. The high-pressure section and the gearbox are both insulated against noise.

The turbine is fitted with extractions for all required steam pressures, in other words, nominal pressures of 14.4 and 0.6 bar. The condenser vacuum is 30 mbar (absolute) in order to maximise the efficiency of the turbine in combination with the low-pressure rotor. Because of this, the diameter of the last rows of blades is approximately four metres (fig. 17).

The main condenser, which is cooled with water from the harbour, is at the same level as the low-pressure turbine and axially linked. This is to reduce outflow losses to a minimum. The condenser consists of two independent halves on the cooling water side fitted with titanium condenser tubes. To prevent contamination of the pipes, a cleaning system with polystyrene balls has been installed.

The emergency condenser, which is also cooled with water from the harbour, constitutes the turbine’s redundancy. Thanks to these measures, it is possible to have both boilers running at 100% even though the turbine is not available.

3.9 Water-steam cycle, energy generation, emergency condenser

The water-steam cycle of block 30 is completely separate from the existing Waste-to-Energy Plant and comprises two deaerators, three boiler feed water pumps and the other necessary equipment such as a storage tank for boiler water, reducing stations, an emergency condenser, etc. The boiler feed water pump which is normally used, is an electric pump with a frequency converter, allowing feed-water pressure to be controlled during normal operation. This limits losses. There is another fixed e-pump for redundancy plus a steam-driven turbo pump that is used mostly for emergency situations such as power failures.

In general terms, the water-steam cycle is set up in much the same way as the existing Waste-to-Energy Plant. To provide the greatest possible energy efficiency and reliability, condensate preheating is completed in four steps: ECO 3 and ECO 2 use residual heat from the flue-gas cleaning, while the grate cooler takes heat from the waste incineration bed in the boiler and an optional 0.6 bar steam-condensate

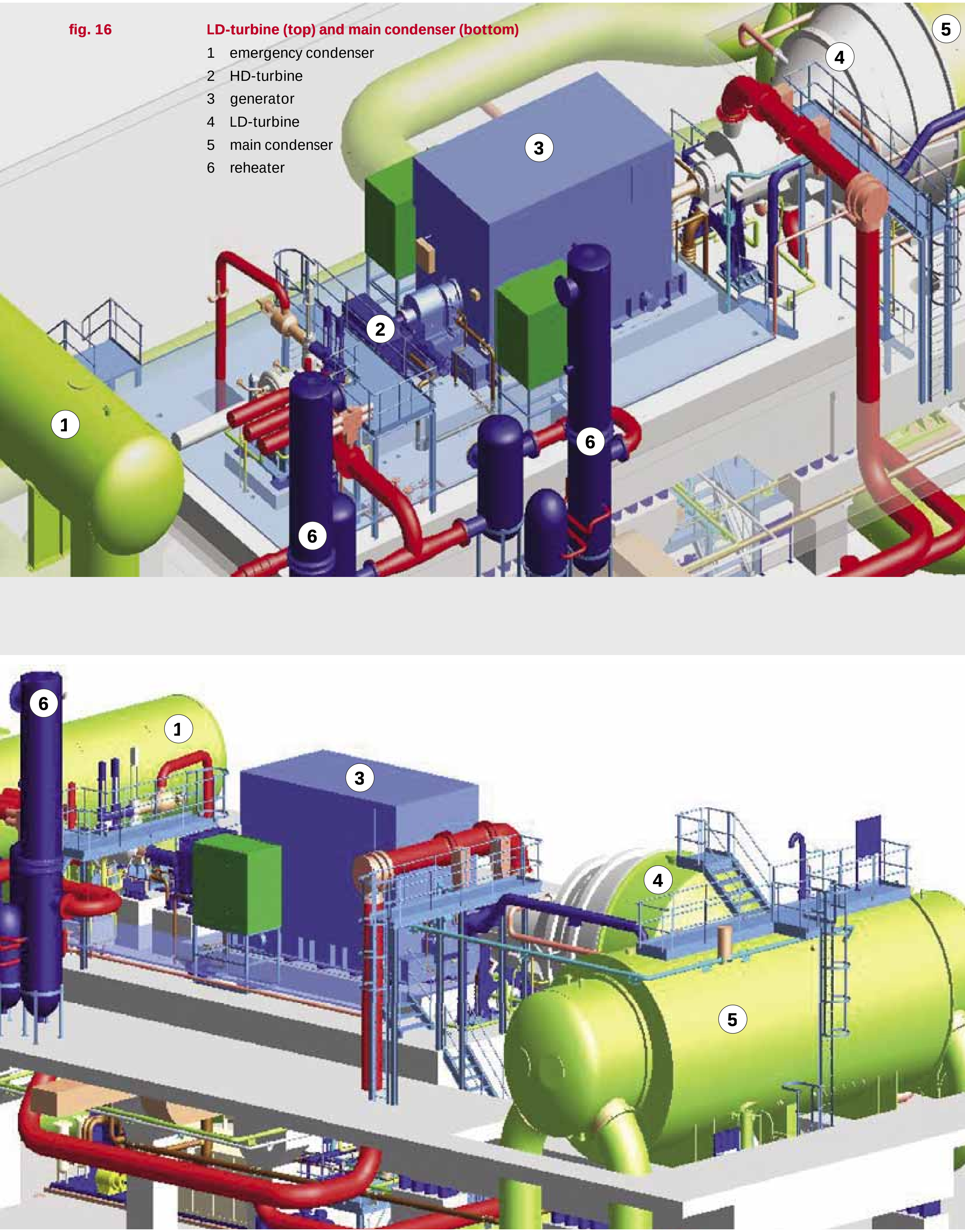


fig. 16 LD-turbine (top) and main condenser (bottom)

1 emergency condenser
2 HD-turbine
3 generator
4 LD-turbine
5 main condenser
6 reheater

fig. 17 Rotor

preheater absorbs fluctuations in the grate cooler. This minimises the use of discharged steam from the turbine for condensate preheating to 4 bar steam for the deaerator.

Steam extracted from the turbine at 14 bars, from before the preheater, will be used for steam tracing and for preheating the primary air in the first zone. Steam extracted at 4 bars will be used for the primary air for the second and third zones. The salt factory also uses 4 bar steam for evaporating the salt solution.

If the turbine is out of operation, all the steam pressures mentioned can be maintained via reducing stations. If both lines are idle, the 14 bar and also partially the 4 bar steam can be fed by 12 bar steam from blocks 10/20 for preheating on starting up the plant.

3.10 Flue-gas cleaning

It was not the emission limits under Dutch law (Incineration of Waste Materials Act) that constituted the criteria for designing the flue-cleaning system. Instead it was the excellent operating parameters of the existing Waste-to-Energy Plant. This raised the bar in relation to what was prescribed by law.

As in the existing plant, Selective Non-Catalytic Reduction (SNCR) is used for nitrogen oxide reduction. To help optimise efficiency, compressed air and not steam is used for injecting ammonia, diluted with softened water.

For the pre-separation of fly ash, an electrostatic precipitator has been fitted after the boiler outlet. Thanks to this filter, in combination with the boiler’s two-way ash conveyance system, the maximum amount of fly ash can be reused.

A fabric filter has been fitted to remove fine particles. Fine powdered activated carbon or blast-furnace coke is blown in as the adsorption medium for the filter. Powdered limestone is added to the coke injection to eliminate the risk of fire and explosions. It also forms a filtering layer on the filter bags. The coke adsorption medium separates out dioxins and furans right at the beginning of the flue-gas cleaning process. Heavy metal content is also reduced to such an extent that products from the wet flue-gas cleaning process can be reused.

As in the existing plant, a flue-gas heat exchanger (ECO2) is used to preheat the condensate after the fabric filter. Under the heat exchanger is the quench, where the hot flue-gases are cooled to saturation point. This is done by injecting an over-measure of water. The evaporation of this water in the quench also ensures that the acid solution from the next scrubber is concentrated and goes to the salt factory as a 10% solution (fig. 18).

The hydrochloric acid and sulphur dioxide scrubbers are the next stage in cleaning acid components and ammonia from the flue-gases. The hydrochloric acid scrubber is a packed bed scrubber that captures the acid remaining in the flue-gas after the quench. The spray from the hydrochloric acid scrubber is sent to the quench as a concentrated hydrochloric acid solution. The sulphur dioxide scrubber is an open scrubber in which lime-milk solution is added as a neutraliser. At pH 6, this scrubber captures sulphur dioxide that reacts in the scrubber to form a gypsum slurry. By using a fabric filter, relatively clean gypsum can be produced that is suitable for reuse. A centrifuge separates the gypsum from the slurry as a dry product that is stored in a container for transport and reuse.

After the sulphur dioxide scrubber is a separate polishing scrubber that also functions as a heat exchanger. The scrubber consists of a packed bed over which water circulates that is cooled by the ECO3 water-water heat exchanger. This cooling leads to condensation of the water in the flue-gas, further reducing emissions. The recovered heat is used in the first stage for preheating the condensate. By super-cooling the flue-gases, the polishing scrubber with ECO3 produces virtually pure condensation water that can be reused in the flue-cleaning system, mainly in the hydrochloric acid scrubber and the quench.

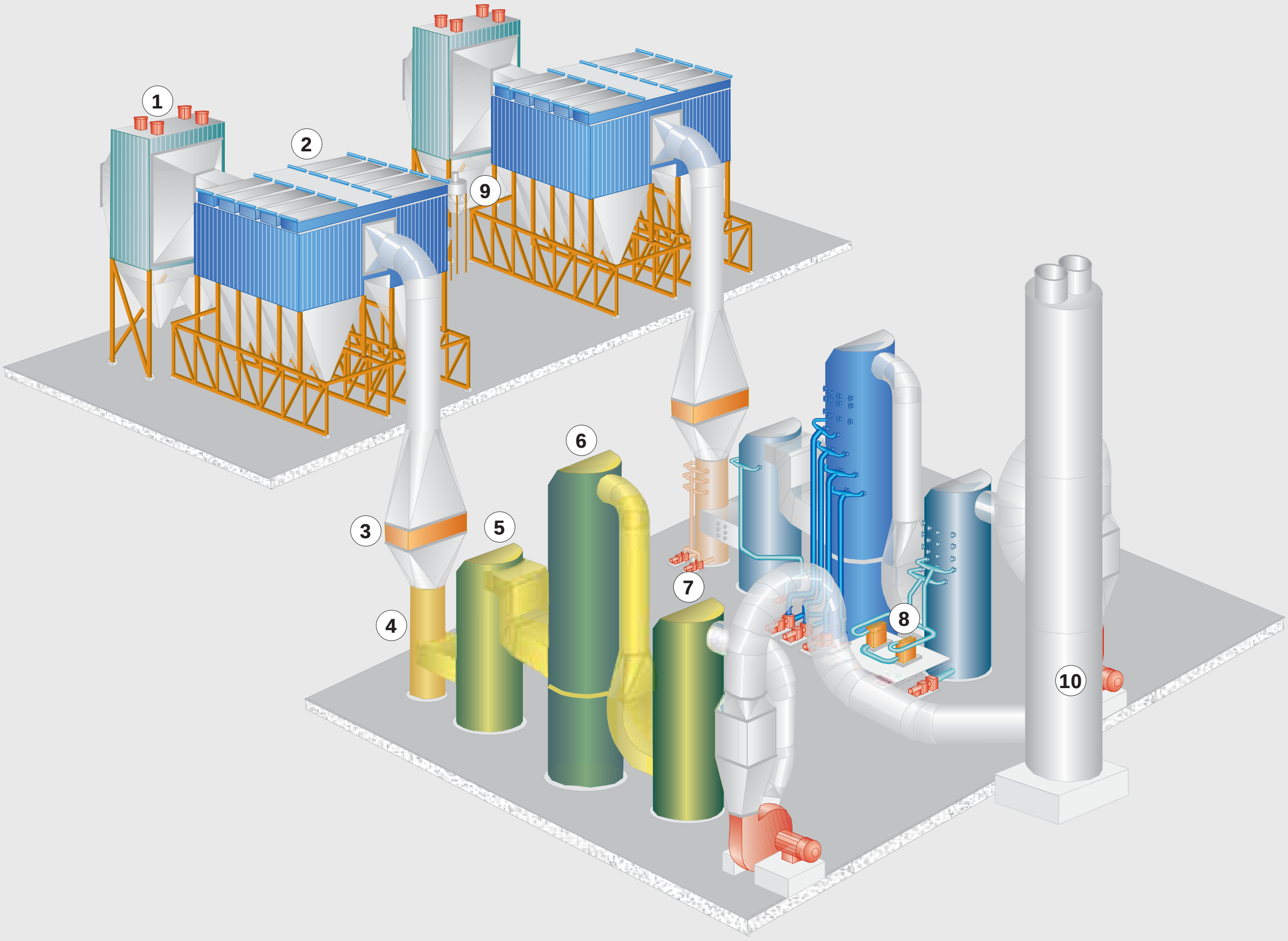
Finally, the purified flue-gas is kept at underpressure by an induced draught fan. This runs ‘wet’ in the saturated flue-gases that pass through a drip tray and emissions monitoring equipment to the chimney stack.

3.11 Salt factory (brine plant)

The blowdown from the quench and hydrochloric acid scrubber is neutralised with limestone ($CaCO_3$). The pH is increased further by the addition of lime milk ($Ca(OH)_2$) and caustic soda (NaOH). The addition of hydrogen sulphide produces a sulphide (H_2S) precipitation of heavy metal. This slurry is separated and transported to the filter press in blocks 10/20. An evaporation plant strips any ammonia from the solution and recycles it for ammonia injection in the boiler (SNCR). A sand filter, ion exchanger and active carbon filter together constitute the polishing stage that guarantees the quality of the salt. Then an evaporator heated with 4 bar steam is used to thicken the solution to a 40% concentrated salt solution that can be marketed as a product. Any surplus can be piped to the (brackish) harbour.

fig. 18 **Flue-gas cleaning**

1 fly-ash electrostatic precipitator
2 fabric filter
3 heat exchanger Economizer 2 (ECO 2)
4 quench
5 HCl-scrubber
6 SO_2-scrubber
7 polishing scrubber
8 heat exchanger Economizer 3 (ECO 3)
9 HOK-adsorbent system
10 stack



3.12 Biogas engines (fig. 19)

The Sewage Treatment Plant (RWZI) of Waternet will be built immediately next to AEB. The RWZI cleans sewage water equivalent to 1,000,000 residents and produces approximately 1,000 m^3/h of biogas. This biogas is piped via a gas cleaner to gas engines in the AEB complex. The gas cleaner removes hydrogen sulphide in two scrubbers. By cooling to -20°C, the biogas is dried and siloxanes are removed. This effective gas cleaning increases the efficiency of the engines and prevents damage to the engines by corrosion and deposits of silicone dioxide.

Four gas engines are used to generate electricity from the scrubbed biogas. Three engines are needed to process the available gas while one is on stand-by. The engines can also function as an emergency power source in the exceptional case that both the Waste-to-Energy Plant and the WFPP were faced with a total power failure. They can also run on natural gas as a back-up for biogas delivery and to make it possible to supply electricity at peak hours.

The heat from the engine cooling circuit and hot engine exhaust gases is piped to heat exchangers that produce hot water at 100°C for district heating (Westpoort Warmte) and for heating block 30. Heat at 70-80°C is supplied to Waternet by blocks 10/20 for heating the sludge fermentation tanks.

The exhaust gases from the biogas engines go to blocks 10/20 at a temperature of 150°C to 250°C as primary air for the first zone. In the first zone, the hot air dries out the waste without risk of its igniting because of the low oxygen percentage. This makes it burn better in the second zone and also saves steam for preheating the primary air. There is an emergency exhaust system for the event of exhaust gases not being able to be processed in the boilers of blocks 10/20.

3.13 Cooling water system

The main cooling water system supplies cooling water to the main and emergency condensers. The water comes from the Aziëhaven docks and is purified through lattices and drum sieves before being pumped to the main and emergency condensers by one of the three pumps. The cooling water outlet leads into the ADM harbour, 2.6 kilometer away. This distance prevents recirculation of the newly warmed surface water. Owing to the enormous amount of water contained by the whole system, exhaustive waterhammer analyses had to be carried out to prevent pressure waves when the pumps are turned off.

The primary internal cooling water system pumps water from the harbour to redundant heat exchangers. The WFPP's secondary internal cooling water system is a closed recirculation system using clean water, which supplies cooled water to various parts of the plant.

3.14 Auxiliary facilities

Of the Waste-to-Energy Plant, the demineralised water plant, the raw mains water reservoir, the waste-water purification equipment and the supply facilities for storing chemicals like ammonia are shared with the WFPP. Newly built systems, with a possibility to combine both plants for redundancy are:

- Compressed air system.
- Communication systems such as telephone, camera installation and fire alarm installation.

The use of existing systems of the Waste-to-Energy Plant, extended to the WFPP, applies to:

- Demineralised water storage.
- Raw mains water.
- Chemicals.
- Specific infrastructure including a drainage system and buffer bassin 7.

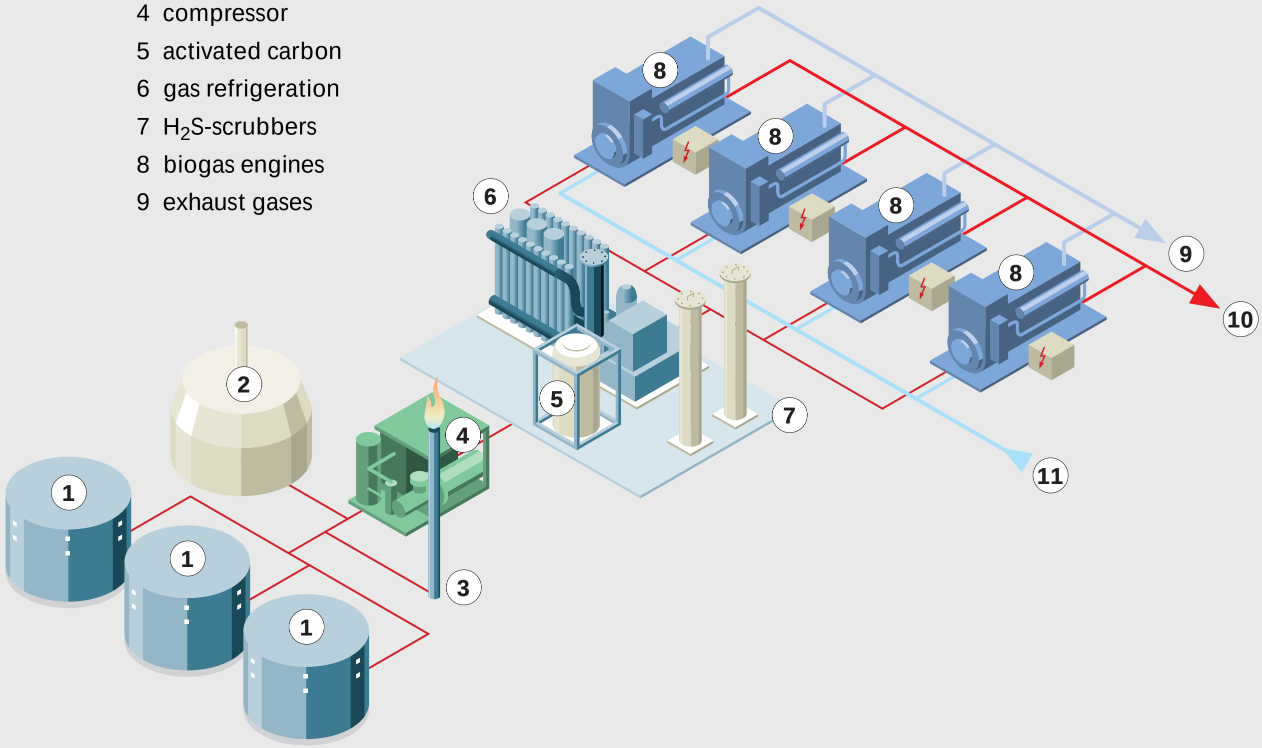


fig. 19 **Biogas system**

1 sludge digestion tanks
2 gas buffer
3 flare
4 compressor
5 activated carbon
6 gas refrigeration
7 H_2S-scrubbers
8 biogas engines
9 exhaust gases
10 district heating hot
11 district heating cold

- Fire-fighting system.
- Vacuum-cleaning installation.

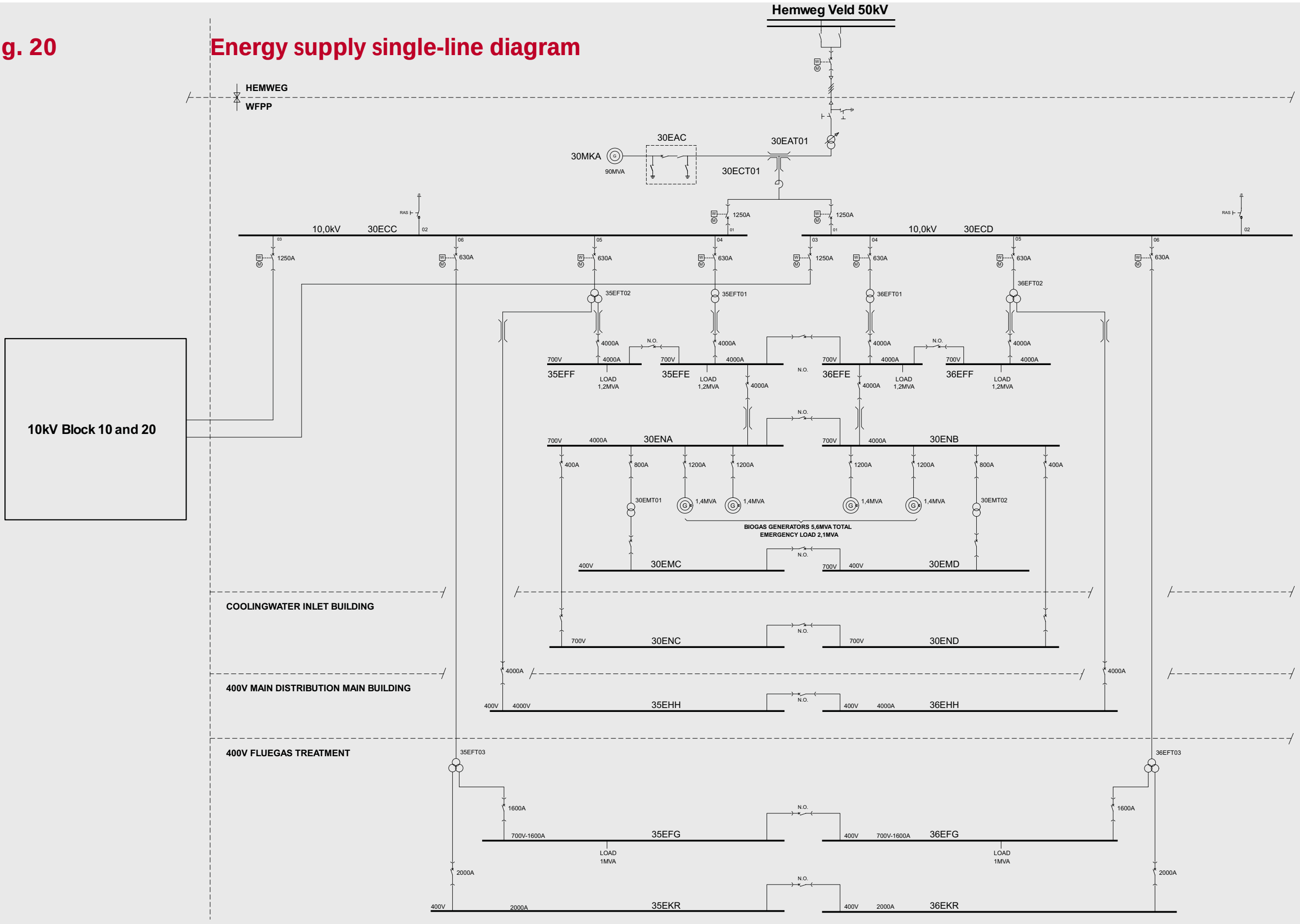
Separate installations of the WFPP are the ventilation, heating and air-conditioning systems (HVAC), the internal cooling water system and the service cranes. The laboratory, which has been replaced, serves both plants. The WFPP has no workshops but only additional storage space to extend present capacity. The demand for space has thus been anticipated.

3.15 Electrical systems

Following the concept of the existing plant, there are decentralised electrical facilities. For example, flue-gas cleaning and the cooling water inlet building each have their own electrical installations including the associated HVAC facilities. The WFPP (block 30) will be completely electrically independent from the existing Waste-to-Energy Plant (blocks 10/20). Emergency connections will be only at 10 kV.

The machine transformers supply the Hemweg switching station with a maximum of 75MW / 90MVA for the national grid. A seven-kilometre-long, 50 kV underground cable link will be built for this. If this grid connection fails, the WFPP can continue to operate in island mode. In the case of a total black-out, the biogas engines can be used as an emergency power supply. The capacity of one of the four gas engines is enough for a safe shutdown. With two of the total of four gas engines, the plant can be safely and securely shut down so that a quick restart is possible. With all four engines, it is even possible to keep one line in operation and restart a turbine.

fig. 20 Energy supply single-line diagram



The transformers for the WFPP's own power have been designed for the existing voltage levels of 10 kV, 700 V and 400 V. For the boiler house, flue-gas cleaning and the cranes, there is a separate facility for power distribution. The rail system is divided symmetrically into two. Each half can supply one line. There are connections between both halves to absorb transformer failures.

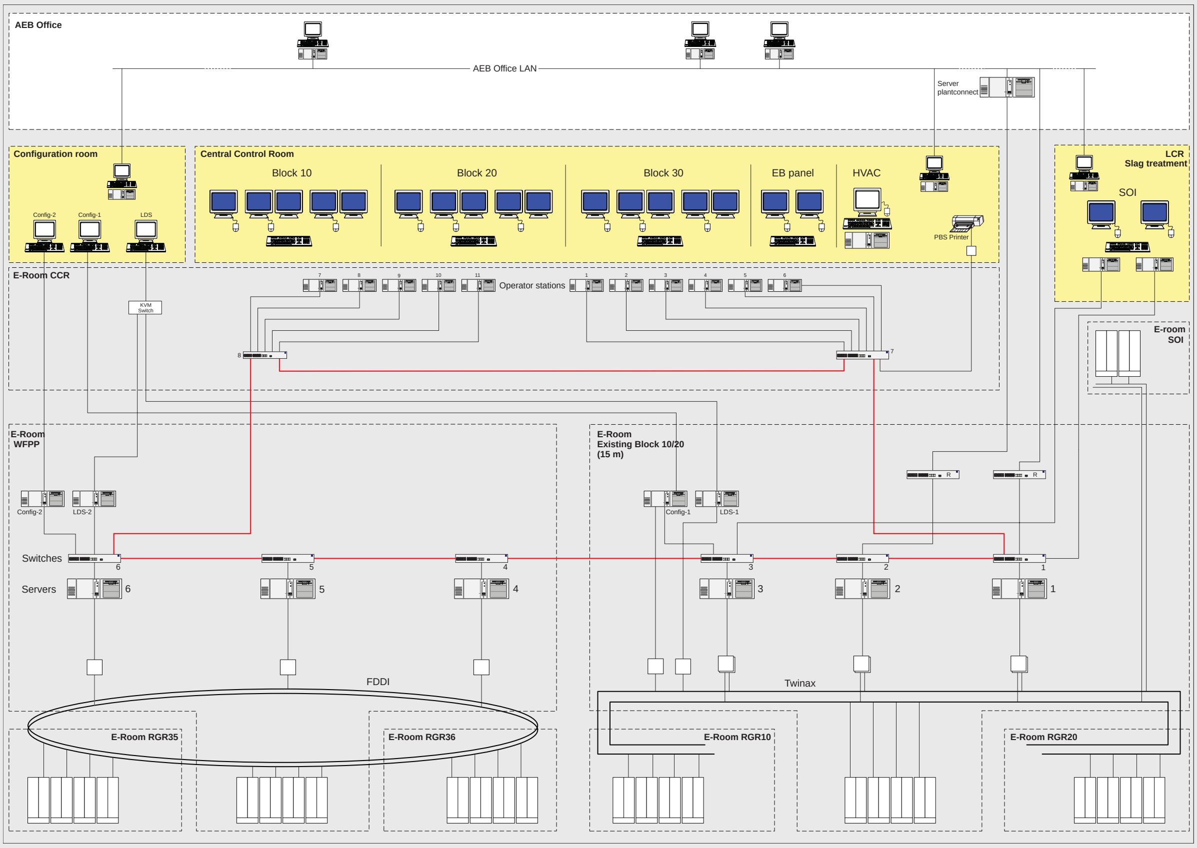
With regard to energy optimisation, the use of control valves is minimised by the use of variable-speed pumps and fans. A large number of frequency converters have been fitted for this, including one unit with 3.3 KV supply and twelve-pulse rectifier to reduce unwanted frequencies (harmonics) in the grid (fig. 20).

3.16 Measurement and control systems

For the WFPP's measurement and control systems, it has been decided to use the same control and visualisation system as in the existing plant. The new central control room houses one integrated system for operating both the existing Waste-to-Energy Plant and the WFPP. The system is state-of-the-art and includes a video wall showing all six incineration lines and the three turbine generators, which provides a complete overview of the entire plant.

The measurement and control philosophy of the existing plant has also been used for the WFPP. There will be an identical Distributed Control System (DCS) with its own network and equipped with up-to-date hardware. The system will operate independent of the existing Waste-to-Energy Plant. The process control and control software will also follow the proven principles of the existing Waste-to-Energy Plant as closely as possible. The connection of engines and instruments is also standardised in accordance with the existing Plant. Typicals of a number of standard control configurations have been made for this.

fig. 21 **DCS scheme**



There are two separate DCS rooms for boiler house and flue-gas cleaning, where the equipment is in a conditioned environment. A 24-volt battery also supplies the control equipment with power in the event of failures in the electricity supply and guarantees control of the plant. In principle, the DCS comprises all process control for the plant. Some decentralised black-box controls, which are actually separate from the normal DCS controls, have been realised in such a way that the process status as a whole can be monitored in the control room (fig. 21).

Compared with the existing Waste-to-Energy Plant, start-up sequences in function groups and normal shutdown sequences will be further automated to guarantee consistent startup and shutdown procedures. Seen from the operator’s desk, these sequences behave like an interactive flowchart. This applies particularly to a hot start for the turbine or water-steam cycle, for example.

4 Realisation

4.1 Principal of Commissioning agent

The principal for the realisation of the WFPP is the Afval Energie Bedrijf on behalf of the City of Amsterdam. An engineering consortium has been formed for the design, engineering and project management. The people in this consortium work together in an office on the building site. The consortium has hired in a number of experienced people from AEB to support the engineering and to guarantee transfer of know-how from AEB.

Before building started on the WFPP, AEB concluded contracts with three national waste collectors/transporters, representing an annual quantity of waste of 495,000 tonnes over 15 years. This means that 95% of the capacity of the WFPP has been contracted for the entire write-off period of the Plant.

Supply of waste

The waste for the WFPP will not come from the immediate Amsterdam area alone but will be supplied from the whole of the Netherlands. Agreements have been made with the suppliers to keep road mileage to the present level, in spite of the increased supply, by using transport by barge, train and/or waste-presses.

Together with the suppliers, an investigation will be carried out to determine whether this transport will take place in containers or bales. Three dumping chutes have been built into the roof of the dumping hall that, in the case of sufficient container/bale supply, will be used to load the waste directly into the bunker from barges.

Extra rail deliveries via the existing ACTS container terminal remain possible. Six new dumping bays as an extension of the dumping hall are planned for supply by truck. By using large trucks with waste-presses, the amount of road use will be reduced.

4.2 Costs and financing

The most important objectives underlying the expansion of processing capacity are the improvement of environmental performance and lowering the cost price. The decision to proceed to an expansion of the processing capacity is therefore partly based on business economics.

A reduction of 5% in the cost price per tonne of waste is expected in comparison with the existing plant, which already has a low cost price. This will be realised through the high availability and the high energy efficiency of the Plant. Because of its innovative and environmentally friendly character, the WFPP will receive various incentive subsidies.

Investment amount

The construction of the WFPP wil require an investment of € 370 million. This amount includes some € 290 million for the plant itself with the other € 80 million earmarked for design and management, additional costs, unforeseen items and building interest. The depreciation time has been set at 15 years. The technical life span will be at least 20 years.

Method of financing

The WFPP will be financed entirely by loans. An amount of € 80 million will be available through “green” financing. The European Investment Bank (EIB) has supplied a credit facility of € 170 million.

Subsidies

Owing to the environmentally friendly, innovative nature of the WFPP, various European subsidies have been secured:

- An EU 5th framework programme subsidy was obtained on a number of essential parts that differentiate the WFPP from a traditional waste-to-energy plant.
- Over a period of 10 years, the so-called MEP (Environmental Effectiveness of Energy Production) scheme will provide a contribution per kWh to further stimulate the generation of sustainable energy from waste (among other things).
- Because of the ‘green status’, financing at lower interest is possible.
- The CO_2 reduction plan of the Province of Noord-Holland is making a contribution.

4.3 Schedule (fig. 22)

1998	Start of Master Plan
1999	‘Hochleistungskessel’ study
2000	First budget application to municipality for € 1.7 million
	Application for patent on WFPP
2001	Study phase
	Second budget application to municipality for € 17 million
	Engineering tender
2002	Environmental Impact Report
	Programme of requirements
	Basic engineering
2003	Specification engineering for main lots
	Environment permit granted
	Tendering of three main lots
	Budget application to municipality for € 338 million
	Building preparation (including moving slag reprocessing facility)
2004	Building starts
	Specification engineering for other lots
	Detailed engineering for main lots
	Tendering of other lots
2005	Start of apparatus construction
	Civil structure ready
	Startup of Sewage Treatment Plant of Waternet, biogas engines in operation
2006	Mechanical completion
	Commissioning
2007	Transfer
	Function test
2008	Optimisation
2009	End of guarantee period

fig. 22 Construcion of the WFPP

4.4 Tendering

The plant is divided into lots. The three main lots – grate/boiler, flue-gas cleaning and turbine – were offered for tender first because they influence the technology, design and basic principles of the other lots to a major degree. The definition of the lots is tuned to the usual market activities and tasks of the companies in the market. This allows companies to make offers that correspond optimally to their experience. For each lot, a choice was made for the manufacturer with the best offer in terms of technology and costs. Costs were evaluated as total-cost-of-ownership; the total of investment and operational costs. In addition to the three main lots, another 30 lots were offered for tender. Appendix A shows the contractors selected and the service providers involved in the building of the WFPP.

4.5 Availability and safety

In waste incineration, dealing with wear caused by the aggressive process is extremely important. This applies even more so in the case of the WFPP because exceptional process conditions occur as a result of striving for high efficiency. For this reason, the highest possible availability of the plant has had specific attention since the beginning. To guarantee the objective of 90% availability, intensive monitoring was set up in the form of a protocol called RAMSHE.

RAMSHE

The acronym RAMSHE stands for: Reliability, Availability, Maintainability, Safety, Health and Environment analysis. This is a comprehensive, systematic approach to improving the reliability, availability and maintainability of the plant. In this approach, the aspects of safety, health and the environment are given the highest priority. The RAMSHE analysis comprises the following activities:

- FMECA (Failure Mode and Effect and Criticality Analysis): a systematic inventory of problem situations with their risk and consequences. The process is systematically checked for possible problems based on the detailed process diagrams. All situations identified are evaluated and possible measures are identified that can be worked out in the engineering.
- HAZOP (Hazard & Operability): a study focusing on risk and operability in which necessary preventative and practical measures are identified.
- SIL (Safety Integrity Levels): an analysis for instrumental safety.

A large number of actions have arisen from these analyses that have been systematically incorporated in engineering and construction.

The availability of the entire plant is more than 90%. Of course, this figure is substantiated with calculations and refers to two-year revision interval. This starting point is based on experience acquired with the present Waste-to-Energy Plant. For this objective, investment was mostly made in the Inconel cladding for the boiler walls and in water-cooled grates. In addition to the optimised cleaning of the pipe banks for the superheaters and ECOs with beaters, the boilers will also be cleaned with explosives in order to limit boiler contamination.

The duration of maintenance work for the WFPP will also be reduced from the usual three weeks to two weeks, including cooling off and startup time. A host of measures will be taken, down to the smallest detail, to enable this reduction in time. The maintenance companies have been brought in as advisors on this. For example, a ventilation system will be installed to make it possible to work in the flue-gas cleaning system while cleaning work in the boilers is still being carried out. Work can be carried out at different levels in the boiler simultaneously.

5 Architecture

5.1 Architectural concept

Architecturally, the technical standard was the starting point for design, use of materials and choice of colours. The WFPP forms a logical, visual whole with the existing Waste-to-Energy Plant. The most important basic principles have been retained in the present design. The existing heights of floors and roofs have been adopted as much as possible for the WFPP in order to create a complex unity within the complex. That also applies to the widths and the ordering of the facades.

The architectural size of the WFPP has clearly increased compared with the existing Waste-to-Energy Plant. This applies most of all to the 60 metre high boiler house. The structure of the buildings will be determined by the direction of the process. In other words, there will be a clear lengthways direction from the dumping hall to the stack. The walls standing parallel to the process direction will be largely enclosed walls of the necessary height. The concrete walls taper at an angle of 45°. Light strips have been fitted to the walls perpendicular to the process direction. They also feature ventilation openings.

5.2 Lay-out of site and buildings

The order of the process lines runs parallel to the existing Waste-to-Energy Plant. This allows the existing waste and bottom-ash bunkers to be extended at the same size. Other parts of the process have been ordered, wherever possible, as in the existing plant to make orientation and operation easier and more efficient.

To free up the site next to the Waste-to-Energy Plant, the slag reprocessing facility had to be moved. To keep interruption of business activities to a minimum, the building was transported to its new site as a whole. With about 6,600 tonnes on 1,200 wheels, this was one of the biggest building transports in the world (fig. 23).

The WFPP will be connected to the existing plant so that the waste and slag bunkers will be extended. This will retain the western control room for the existing waste bunker. At the narrowest point, the distance between the buildings is 12 metres and 20 metres at the widest point. This makes it possible to retain the existing roads on the site. Both plants are connected to each other by various walkways.

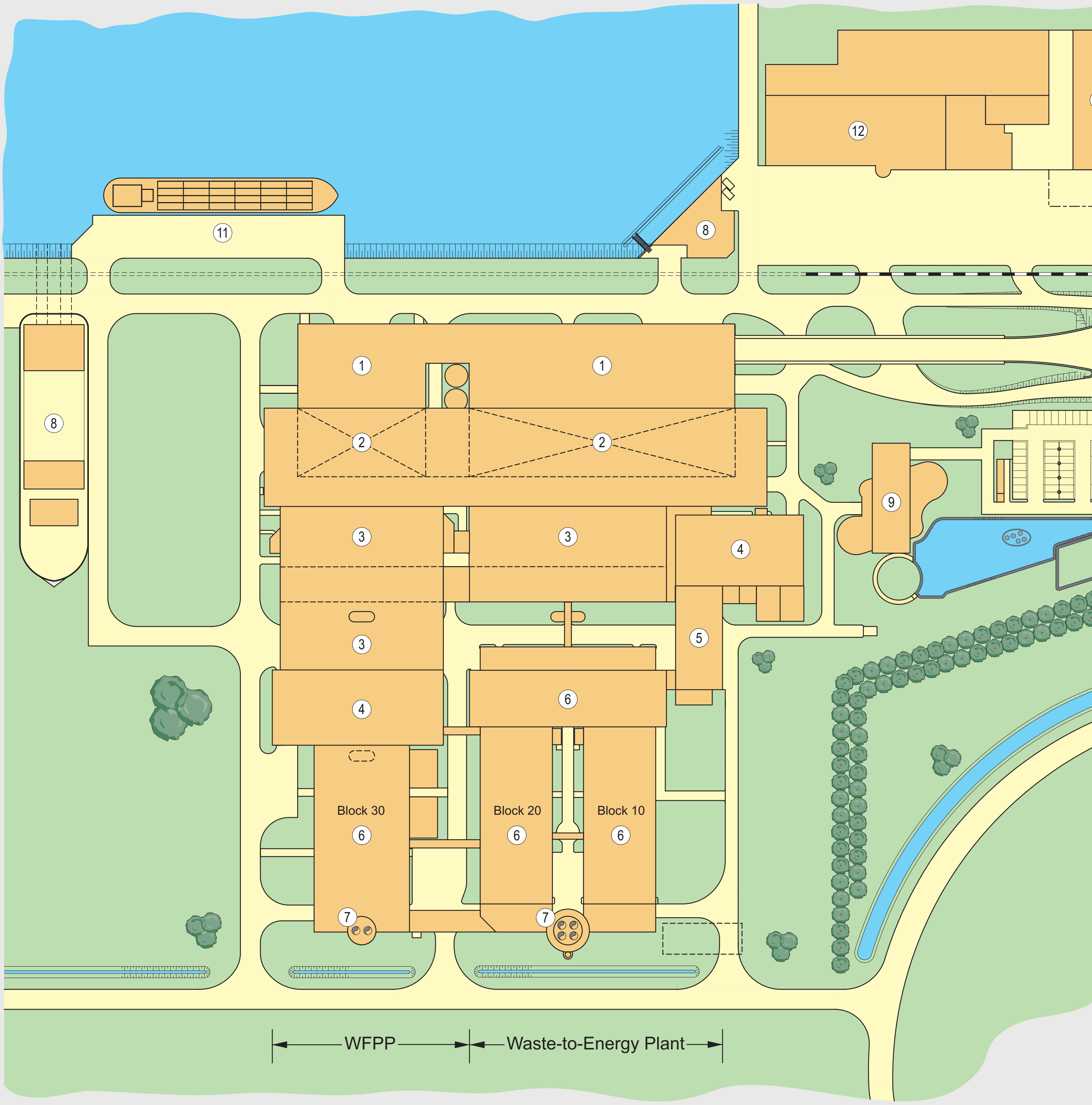
The existing Waste-to-Energy Plant will be extended with the addition of a new control room for the complete plant, in other words for all six incineration lines. The new central control room connects directly to the existing one which will be used as an auxiliary room for the new one after completion.

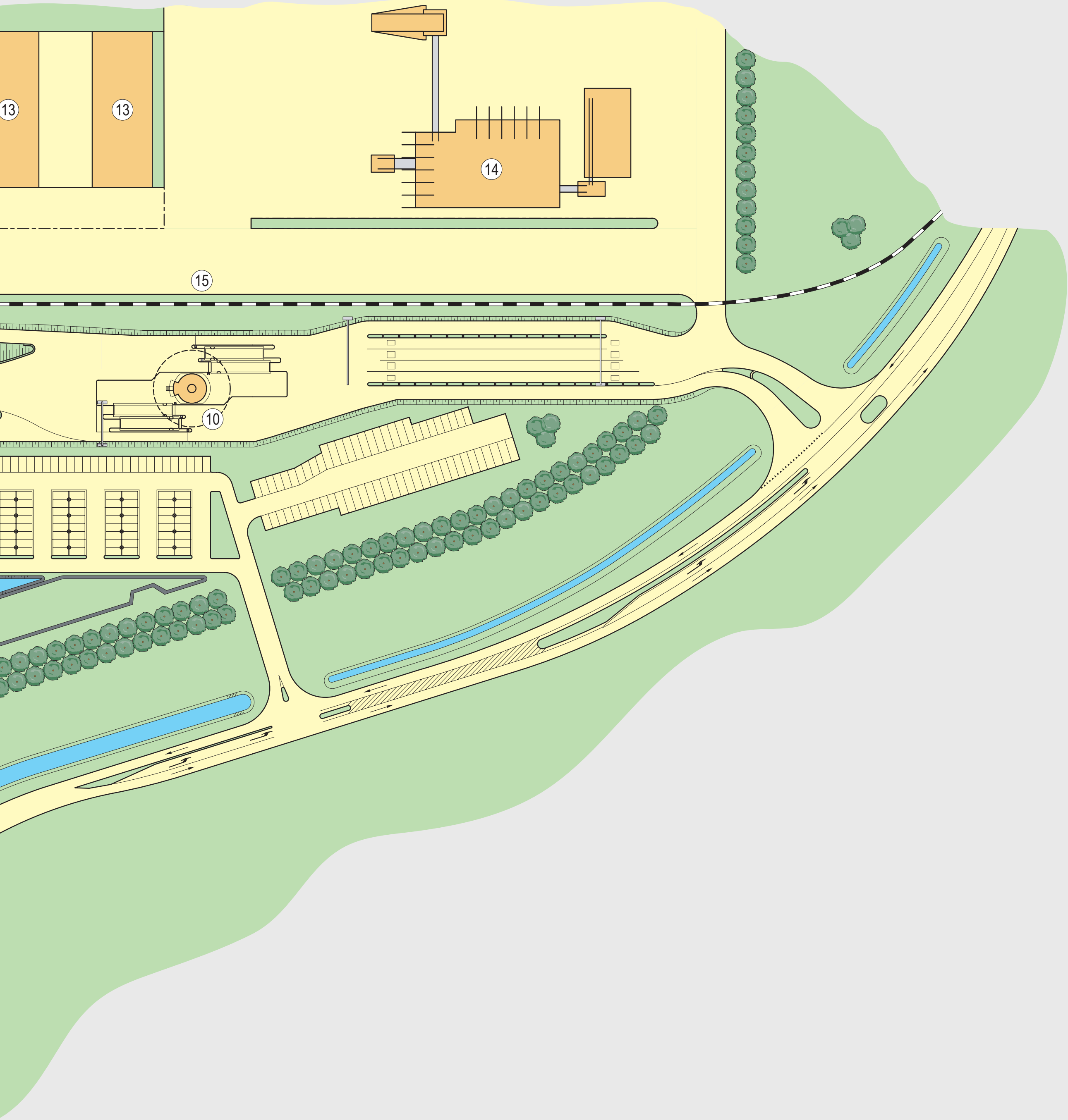
There is a wharf for transport by barge with a crane to transport bales and/or containers to the roof of the dumping hall. This is equipped with an installation for opening the bales and/or containers and depositing them directly in the dumping bunker. The high point for loading waste into the bunker makes it possible to user a greater volume of the bunker effectively.

The cooling water inlet building is located on the western edge of the site. It is slightly distanced from the harbour in order to allow access to the bank-side. This means that the rails and the street can be extended to neighbouring plots. The adjacent plot on the western side has been purchased by AEB and is available for future expansion and other activities (fig. 24).

fig. 23 **Site layout**

1 dumping hall
2 bunker
3 boiler house
4 turbine hall
5 monitoring station
6 flue-gas cleaning
7 stack
8 cooling water inlet
9 office
10 porter’s box
11 wharf
12 Depot hazardous waste
13 ROS (regional sorting station)
14 slag reprocessing
15 ACTS terminal

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10

fig. 24 Moving the slag reprocessing facility, 18 October 2003

5.3 Building plan and construction

The basic principle underlying the design of the buildings was an independent layout to serve the various sections such as the dumping hall, the boiler house and flue-gas treatment. Logically, the bunker building with its waste and slag bunker is an extension of the existing one, including its dumping hall. The biggest difference in the waste bunker is the extra height that enables a higher crane level above the existing rails inside an enclosed room. The installation foreseen for emptying the containers and/or bales above the dumping hall will also be new. On account of this, the construction has been changed on certain points but adheres to the same principles as those of the existing Waste-to-Energy Plant.

The design of the buildings focused on two aspects. Firstly, an important wish is to bring the civil engineering construction into line with the various installations so as to ensure an uninterrupted building programme for both disciplines. Secondly, there was a need to design a logical layout comparable with the existing Waste-to-Energy Plant. This would create easy access to the various installations and also provide short, clearly marked escape routes. The result is that both incineration lines are arranged in such a way that in the centre of each there is a four metre wide strip kept free as an access path, transport route and for the construction of piping systems. Escape stairs have been placed on the outside, easy to reach in emergency situations.

All of the buildings are built on piles. For the central control room, bored piles have been used to prevent failure of the turbines due to vibration (fig. 25).

The dumping hall

The dumping hall has three levels. On the two lower levels are the storage rooms, connected by a heavy-duty lift. At a height of 6.40m, an electrical facility is planned for power supply and controlling neighbouring machines such as cranes and bale openers. Space has been reserved for the electrical installation of a sixth waste crane. The most important level is the extension of the existing dumping floor at a height of 10.20m where trucks can deliver their loads. On the roof of the dumping hall there are three dumping chutes. A fixed crane can lift containers from barges to these dumping chutes to deposit them straight into the bunker.

Bunker

The existing ‘swallow’s nest’ for crane maintenance on the western side of the Waste-to-Energy Plant is the starting point for extending the WFPP. This ‘swallow’s nest’ will be retained and will form the link with the extended waste bunker after the removal of the west façade. The crane rails of the existing waste bunker have been extended and run through the WFPP. This makes it possible for the new crane 40 to operate in block 30 as well as in blocks 10/20. This achieves redundancy and the possibility of moving waste between the Waste-to-Energy Plant and the WFPP.

Above this crane rail, a second crane rail has been built. The upper crane 50, which is intended only for the WFPP bunker, can overtake the lower crane 40 in the course of normal waste-processing activities.

For operating the crane, there is a crane cabin between the two hoppers. For maintaining the existing cranes, the present catwalk on the eastern side between blocks 20 and 30 will remain available. On the western side of the new bunker, there will be a new ‘swallow’s nest’ at both crane levels for maintaining cranes 40 and 50.

Slag bunker

The existing slag bunker and the rails for the slag crane will be extended to the WFPP. Both blocks 10/20 and block 30 will be served by the existing crane.
The bottom ash will be loaded onto trucks using the slag crane on the eastern side of block 10 for transport to the Slag Reprocessing Facility. A conveyor will be installed for this in the future. This conveyor will transport the bottom ash straight to the Slag Reprocessing Facility, which has now been moved to a point 300 metres to the north east of the Waste-to-Energy Plant.

fig. 25 The construction of the Waste Fired Power Plant, September 2005

Boiler house

Just like the existing one, the new boiler house has been designed as a coated steel construction. Only the wall dividing it from the bunker is made of concrete. This wall acts as fireproofing between the bunker and the boiler room and stabilises the boiler room.

As far as is feasible, the levels of the floors are at the same height as those of the existing boiler house. The height of the WFPP boiler house is 60 metres owing to the height of the first convection section. Above the horizontal convection section, the boiler house is also the same height in order to enable the complete tube banks to be replaced. In order to be able to replace these banks within 72 hours, a crane has been installed above the two horizontal convection sections. Tube banks can be loaded directly from the boiler onto a truck through maintenance trapdoors in the 19.6 metres floor.

The boiler house can be accessed via four stairwells. The stairwell on the eastern side is fitted with a heavy-duty lift that is primarily intended for such things as transporting grate bars with a fork-lift truck.

Owing to the enormous dimensions of the high-efficiency boiler, the boiler house had to be built in a different way to the existing one. The part of the building with the empty radiation chambers consists of a steel structure that forms one unit with the boiler support. This structure rests directly on a one-piece base-plate. The lower section of the empty radiation chambers hangs in the boiler support while the upper section stands on top of it. This enables the boiler to expand freely with minimum differences in relation to the horizontal chamber. At the horizontal chamber, the building is formed by a steel structure erected independent of the boiler support.

The boiler's horizontal chamber rests on a concrete floor at a height of 19.6 metres, which is also the roof of the service building and forms a bridge to the turbine hall. This structure turns the loading street into a covered area between the service building and the turbine hall that is open on the eastern and western sides.

Service building

The service building is laid out in the same way as the existing Waste-to-Energy Plant. In other words, one half of the building will be used for mechanical equipment and the other half for electrical equipment and operating equipment. The three floors of the mechanical department mainly contain the biogas engines, water systems and the compressed-air systems, heating, ventilation, air-conditioning and cooling. The electrical department comprises the transformers on the ground floor and the switching and control equipment on the other two floors.

Turbine house

The turbine house is a separate building with a basement for the cooling water pipes and the auxiliary systems for the turbine. The steam turbine and main condenser are at ground floor level, as are the emergency condensers and the reheaters. The turbine, including the generator and the condenser stand on a separately constructed turbine table that is spring-shielded from the building to prevent vibrations. This stands at a height of 1.40 metres on a concrete floor that encloses the turbine table.

The basement of the building mostly houses the cooling water pipes, the oil supply for the turbine and the condensate pumps. Next to and above the loading street, there is space for various mezzanine floors housing feed-water pumps, the central steam-collection headers, and various plant components of the water-steam cycle. Because of this, only short sections of piping are needed for the most important components. The roof height matches that of a platform for the boiler house. The entire turbine house is a concrete structure, mostly owing to its heavy load. The crane rails rest on concrete supports that also act as static reinforcement for the wall.

Fabric filter hall

The fabric filters are located in a hall as a steel structure above the turbine house. This section also houses the flue-gas circulation pipes, the heating installation for the fabric filter and the injection of coke and limestone powder into the flue-gases. The height of the roof of the filter hall makes it possible to replace the filter elements entirely with the aid of a monorail crane.
The load on the fabric filter is directly relayed to the walls of the turbine hall through a bridge structure. The span also roofs in the solo building above the extended loading street.

Wet flue-gas cleaning building

The flue-gas cleaning building also houses the flue-gas scrubbers, the electrical facilities, the analysis room and the salt factory. The flue-gas scrubbers with circulation water pumps and the induced draught fans are on the ground floor. The electrical facilities for power supply and frequency converters are behind the fans. Above these, between the fans and the chimney, is the emission monitoring equipment.

The ground floor has been designed as a floor with drainage to the reservoirs and tanks in the basement. The flue-gas cleaning installation has been built as a concrete structure with a height of 8 metres. The hall above this is a steel structure with cladding. The central stairwell with lift is intended for access to the turbine house and the flue-gas cleaning installation. This is a concrete structure to reinforce the steel structure.

Stack

From the outside, the stack is identical to the existing chimney but has been constructed without a measuring platform. On the inside, the stack contains two pipes that take the flue-gas to a height of 100 metres above sea level. This is much higher than is required by environmental legislation but is the same as the existing height. The concrete structure of the chimney contains two fibreglass-reinforced polyester flue-gas pipes supported by a steel structure.

On the ground floor, in the empty section of the stack are the tanks for the purified calcium chloride salt solution. At the end of the flue-gas cleaning installation, blocks 10/20 and block 30 are connected by a bridge. The biogas cleaning installation will be built on this bridge with half-open shielding.


fig. 26 Building of the stack, October 2005

Central control rooms

The new building for the central control room spans the road to the south of the existing control room next to block 10 at a height of 8 metres. This connects the boiler house to the flue-gas cleaning installation of the existing Waste-to-Energy Plant. The control room for all six incineration lines is located in one big room at a height of 8 metres. In addition to this, there are rooms for the manager and for the process automation department. The control room is equipped with screens and a projection wall in an ergonomic design. A laboratory is planned for one floor higher at a height of 15 metres, together with the electrical facilities and the HVAC installation. The existing control room will be converted into several separate auxiliary rooms.

Postscript

In this brochure, the Amsterdam Afval Energie Bedrijf hopes to have informed you about the technical background of the WFPP, which will be operational in 2007 in the western port area of Amsterdam.
For more general readers, there is also a less detailed brochure available. If you have any questions or comments, you are welcome to contact the Public Affairs en Corporate communication Department of AEB. Here you can make an appointment for a guided tour or talk to the experts involved in the project.
Telephone +31 (0)20 5876299, e-mail: info@afvalenergiebedrijf.nl and www.afvalenergiebedrijf.nl.

Appendices

- A Technical specifications
- B Lots, contractors and service providers
- C References
- D Plans and drawings

A

Technical specifications

All data are per component unless stated otherwise.

Civil engineering

Length of wharf	88 m
Number of piles	c.1,200
Platforms in the boiler house	10,000 m^2
Chimney height	100 m
Boiler house roof height	58.6 m
Overall length	c.120 m
Overall width	c.70 m

Waste bunker

Length x width	44 m x 20 m
Volume (filled with water)	20,000 m^3
Dumping areas for trucks	6
Dumping areas for barges	3

Waste cranes

Number	2
Spanning bridge below/above	28.5 m/31 m
Lifting capacity	23 Mg
Grab volume	12 m^3

Grate

Number	2
Gross heat efficiency	93.36 MW
Nominal throughput capacity	33.6 Mg/h @ 10 MJ/kg 806 Mg/day, 9.33 kg/sec
Maximum throughput capacity	37 Mg/h
Grate width	12.8 m
Grate length	9.3 m
Number of grate beds	3
Number of drive sections per grate bed	4
Water-cooled/Air-cooled grate bars	16/13

Combustion air

Number of air zones per grate	4 flow-regulated, 3 manually adjusted
Excess air coefficient	1.39
Primary air flow	95,000 m^3/h
Recirculation gas (secondary gas)	40,000 m^3/h
Tertiary air flow	37,000 m^3/h
Air preheating zone 1	160°C (14 bar)
Air preheating zones 2 and 3	120°C (4 bar)

Boiler

Number	2
Boiler load (thermal waste input) nominal/max.	93.6 MW/102.7 MW
Fresh steam temperature	initial 440 °C, design 480°C
Fresh steam pressure	nominal 130 bar, max. 162 bar
Fresh steam (nominal, point A)	28 kg/s = 102 ton/h
Fresh steam (maximum, point B)	31.6 kg/s = 113.8 ton/h
Water content, normal level	+/- 250 m^3
Boiler roof height from grate	31 m
NH_3 injection for Nox reduction	3 levels x 8 nozzles
Furnace volume	930 m^3
Total heating surface	7,930 m^2
Radiation surface	4,400 m^2
Convector area, roof included	1,200 m^2 OVO
	1,050 m^2 ECO
	1,280 m^2 tanks
Flue-gas speed first chamber	3.2 m/s
Lined with Inconel	1,330 m^2
Gas flow at boiler exhaust	200,000 m^3/h
Flue-gas temperature before banks	630°C
Number of OVO banks	5
Number of ECO banks	6
Flue-gas temperature at boiler exhaust	180°C
Gas flow at boiler exhaust (incl. reci-gas)	200,000 Nm^3/h
Boiler efficiency	87.14%

Reheaters

Number	2 (1 per boiler)
Steam from turbine	27 kg/s @ 14 bar
Reheating of turbine steam	from 195°C to 320°C
Steam quantity from boiler	7.1 kg/s @ 138 bar
Heat transfer per superheater	9 MW
Size L x W	6.5 m x 1.2 m
Design pressure	162 bar
Max. reheater condensate pump pressure	7.0 bar

Turbine

Number	1
Consumption	64 kg/s = 230 Mg/h @ 125 bar
Exhaust pressure high-pressure	14 bar
Exhaust pressure low-pressure	0.030 bar (abs)
Diameter at last row of blades/exhaust surface	3.86 m/9.6 m^2
Weight	low-pressure 135 Mg
	high-pressure 18 Mg
Turbine table	30 x 9 m

Generator

Number	1
Power output peak	74 Mwel/86.8 MVA
Power output nominal	66 MWel
Power output minimum	5 Mwel (min. turbine load)
Generator voltage	10.5 kV
Weight	130 Mg

Condenser

Number of main/emergency condensers	1/1
Main condensate pipes	1,100, each 12 m x 18 mm diameter
Active cooling surface of main condenser	8,200 m^2
Material	titanium
Main condendate pumps	2 x 200 kW

Cooling water

Number of pumps	3
Cooling water flow main/emergency condenser	22,400/22,400 m^3/h
Oil and internal cooling water	1,570 m^3/h
Average temperature of inflowing water	17.5°C
Delta-T cooling water main/emergency	5°C/7°C
Transport pipe	DN 2000, 2.6 km
Recirculation pipe	DN 1600

Water and steam cycle

Number of feed-water pumps	2 electric, 1 steam-powered
Installed power per pump	1.2 MW
Deaerators	2 x 55 m^3

Electrostatic precipitator

Number	2
Quantity of flue-gas	220,000 Nm_3/h
Dust level at intake/exhaust (8% O_2)	4,050/500 mg/Nm_3

Fabric filter

Number	2
Number of chambers	10
Quantity of flue-gas	220,000 Nm_3/h
Flue-gas temperature	180°C
Dust level at intake/exhaust	500/<5 mg/m^3

ECO 2

Number	2
Structure type	tube banks enamel+teflon
Thermal power	3 MW

Quench + HCl scrubber

Number of quenches/HCl scrubbers	2/2
Structure type HCl Scrubber	packed bed
Quantity of flue-gas	190,000 Nm_3/h

SO_2 scrubber (Gypsum scrubber)

Number	2
Structure type	open tower
Additive	limestone ($CaCO_3$)
Quantity of flue-gas	190,000 Nm_3/h

Polishing scrubber

Number	2
Structure type	open tower
Additive	caustic soda
Quantity of flue-gas	190,000 Nm_3/h

ECO 3

Number	2
Structure type	plate heat exchanger
Thermal power	2.2 MW
Nominal condensation quantity	9.3 m^3/h

Induced draught fan

Number	2
Temperature/humidity	61°C/20.9%
Nominal flue-gas quantity (dry/wet)	140,000/176,000 Nm$_3$/h
Nominal physical debit @ pressure difference	229,000 m^3/h @ 6.9 kPa
Maximum physical debit @ pressure difference	287,000 m^3/h @ 9.8 kPa
Electrical output	945 kW

Biogas engines

Number of units	4
Installed power of each	1.044 MW electrical 1.0 MW thermal 0.4 MW in flue-gas
Emergency power supply critical/nominal	0.8/1.6 MW
Expected power generated per year	22,000 MWh

Electrical systems

Number of engines	650
Installed power	91 MW
Nominal simultaneous output	8 MW
Installed power in frequency converters	7.5 MW

DCS - Control

Switched engines (on/off)	580
Controlled engines (frequency converter)	32
Opening/closing valves (engine-driven)	185
Control valves (engine-driven)	92
Magnetic valves	225
Digital inputs	675
Analogue inputs	910

Auxiliary facilities

Compressed air capacity	3 x 1,800 Nm$_3$/h
Internal cooling water nom./max.	5.7 11 MW thermal
Internal cooling water debit	1,120 m^3/h

B Lots, contractors and service providers

Nr.	Lot	Contractor	Town	Country
Principle lots				
31	Grate/boiler	Martin-NEM Combination (MNC)	München	Germany
32	Flue-gas treatment	FLSmidth Airtech A/S	Valby, Copenhagen	Denmark
33	Turbine (equipment)	Siemens	Finspong	Sweden
33.2	Turbine (erection)	Fabricom GTI	Moerdijk	Netherlands
Lots				
34.1	Condensate-steam-cycle	Fabricom GTI	Moerdijk	Netherlands
34.2.1	Reheater	Bronswerk Heat Transfers B.V.	Nijkerk	Netherlands
34.2.2	Reheater pumps	Hayward Tyler	Glasgow	UK
34.3	Reheater system (erection)	Fabricom GTI	Moerdijk	Netherlands
35.1	Waste & slag cranes	NKM Noell Special Cranes GmbH & Co KG	Würzburg	Germany
35.2	Service cranes	Konecranes	Purmerend	Netherlands
35.3	Hoists (cranes)	Konecranes	Purmerend	Netherlands
36	-	-	-	-
37	Cooling water system	BAM Tebodin HR AVI VOF	Velsen-Noord	Netherlands
38	Fire Fighting system	Ingenieursbureau Wolter & Dros	Amsterdam Z-O	Netherlands
39	Water systems	Fabricom GTI	Moerdijk	Netherlands
40	Heating, ventilation & airco (HVAC)	Ingenieursbureau Wolter & Dros	Amsterdam Z-O	Netherlands
41	-	-	-	-
42	-	-	-	-
43.1	Compressed air	Fabricom GTI	Moerdijk	Netherlands
43.2	Vacuum cleaning system	Ingenieursbureau Wolter & Dros	Amsterdam Z-O	Netherlands
44	Electrical systems	Imtech Projects Industry B.V.	Wormerveer	Netherlands
44.2	Earthing	Imtech Projects Industry B.V.	Wormerveer	Netherlands
44.3	Cable Hemweg	NACAP	Barendrecht	Netherlands
45.1	Control systems	ABB Utilities GmbH	Mannheim	Netherlands
45.2b	Normal & analytical instruments	ABB Utilities GmbH	Mannheim	Netherlands
46.1	Communication phone/Intercom	Imtech Projects Industry B.V.	Wormerveer	Netherlands
46.2	Fire alarm system	Imtech Projects Industry B.V.	Wormerveer	Netherlands
46.3	Camera (CCTV)	Imtech Projects Industry B.V.	Wormerveer	Netherlands
47	-	-	-	-
48.1	Control room building	BAM Civiel Noordwest	Amsterdam	Netherlands
48.2	Excavation and piling	Voorbij Funderingstechniek	Amsterdam	Netherlands
48.3	Main civil works	Ballast Nedam Infra	Amsterdam	Netherlands
48.5	Cool water inlet building	Ballast Nedam Infra	Amsterdam	Netherlands
49	Steelstructure	Rijndijk Steel Contracting B.V.	Hoogvliet	Netherlands
50.1A	Cooling water pipes on site	Nelis Infra B.V.	Zwanenburg	Netherlands
50.1B	Cooling water pipes off site	Ooms Avenhorn B.V.	Schoorl	Netherlands
50.2	Pipe drilling	Ooms Avenhorn B.V.	Schoorl	Netherlands
50.3	Infrastructure	Ballast Nedam Infra	Amsterdam	Netherlands
50.4	Quay	-	-	-
50.5	Railway	-	-	-
51	-	-	-	-
52	Slag treatment	-	-	-
53	-	-	-	-
54	Biogas engines, CHP gas scrubber	HABO B.V.	Bodegraven	Netherlands

55.2	Sludge silo foundation	Ballast Nedam Infra	Amsterdam	Netherlands
56	Stack pipes	BAM Tebodin HR AVI VOF	Velsen-Noord	Netherlands
57	Waste delivery (bales/containers)	-	-	-

	Services	Offices	Place	Country
Services				
-	Advisors electrical + thermodynamics	KEMA	Arnhem	Netherlands
-	Advisor/engineering	Wandschneider + Gutjahr	Hamburg	Germany
-	Advisors RAMSHE	CBO	Rotterdam	Netherlands
-	Architect	Visser en Withag architecten	De Steeg	Netherlands
-	Engineering Koelwater + RAMSHE	DHV	Amersfoort	Netherlands
-	Environmental impact study	Arcadis	Arnhem	Netherlands
-	Lawyer	Nauta Dutilh	Amsterdam	Netherlands
-	Planning	Aram Planning Consultants	Rotterdam	Netherlands
-	Project control	AT Osborne	Utrecht	Netherlands
-	Project management/engineering	Ingenieurs Combinatie Fichtner Cumae	Stuttgart	Germany
-	Security	Falck Security	Rijswijk	Netherlands
-	Waterhammer	Waterloopkundig Lab	Delft	Netherlands

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8 High efficiency waste incinerator: European Patent: EP 1.164.330.A1, 14-6-2000

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10 "Municipal Solid Waste Management, Strategies and technologies for sustainable solutions" (p184-196), Editors: C. Ludwig, S. Hellweh, S. Stucki, Springer verlag Berlin, 2003, ISBN 3-540-44100-X.

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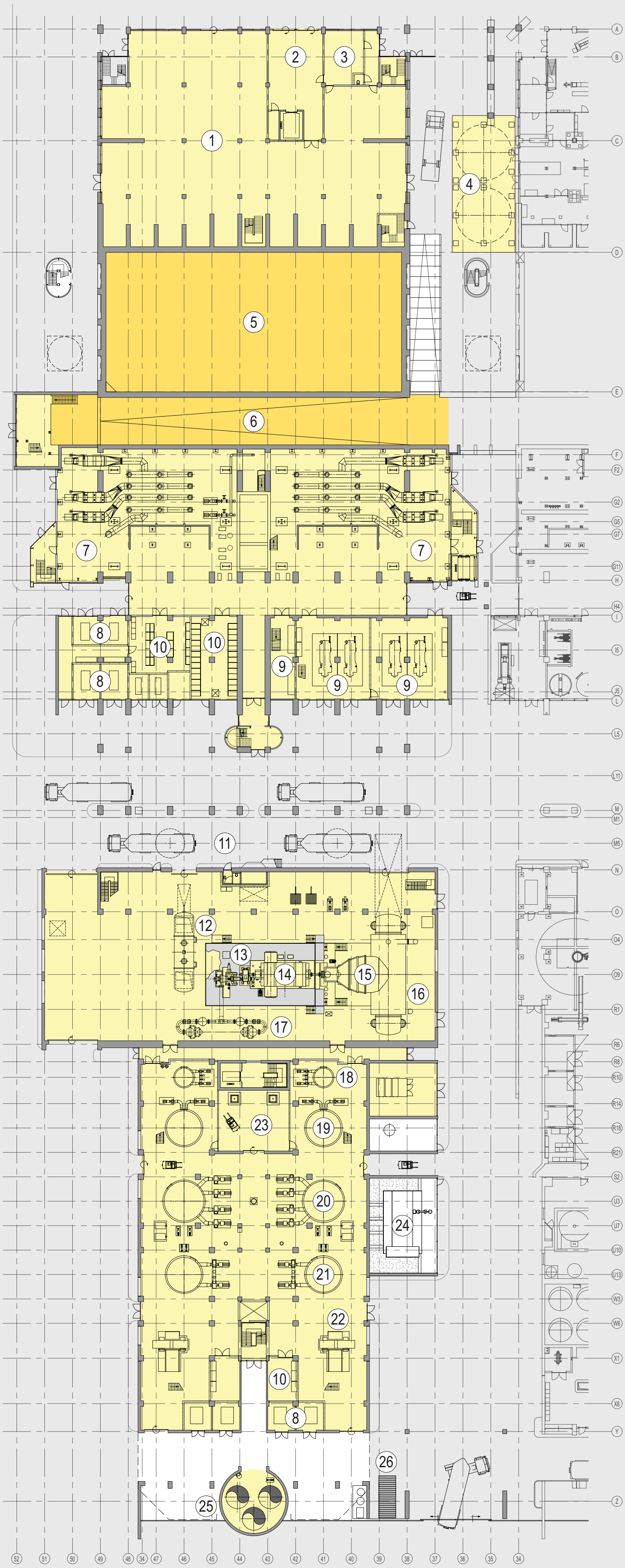
D Plans and drawings

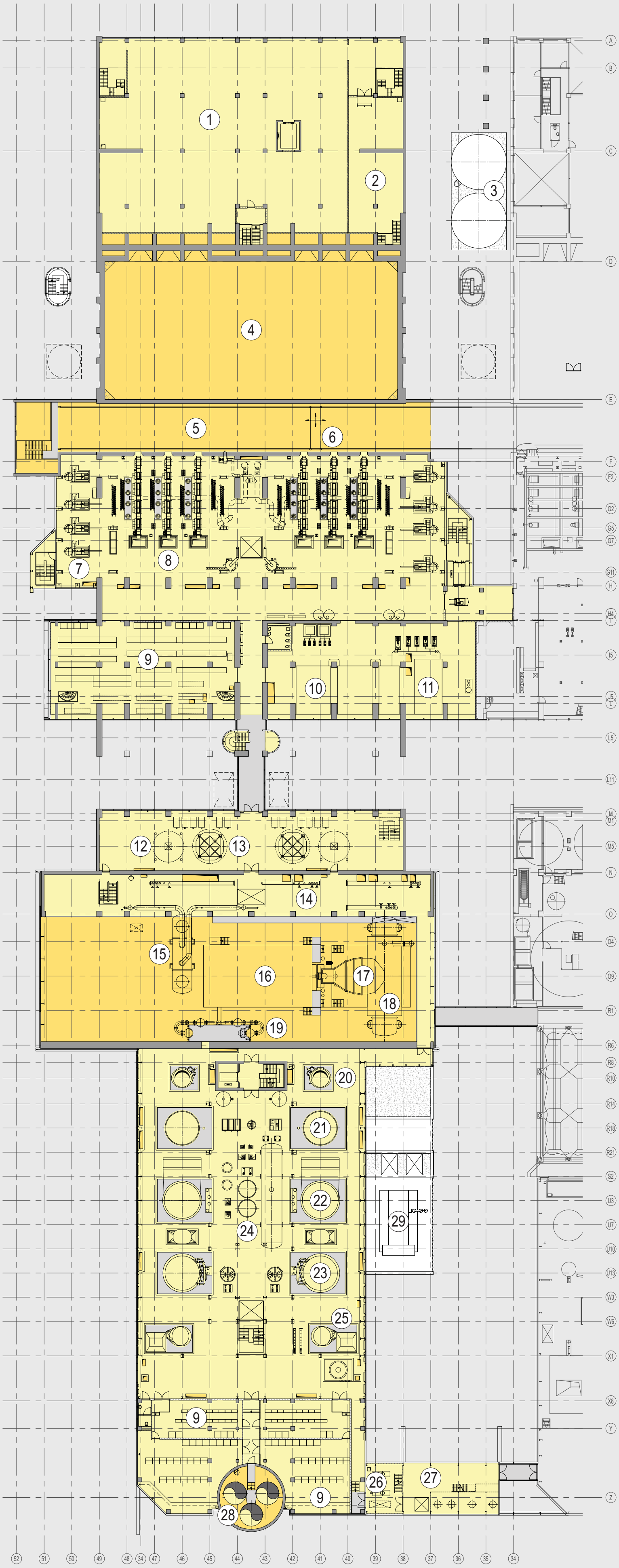
Level +1.40 metres

1 storeroom
2 storeroom access
3 office
4 sludge pumps
5 waste bunker
6 slag bunker
7 primary combustion air
8 transformers
9 biogas engines
10 instrumentation, controls and electrical systems
11 fly-ash discharge
12 emergency condenser
13 HP turbine
14 generator
15 LP turbine
16 main condenser
17 reheater
18 quenches
19 hydrochloric acid scrubber
20 sulphur dioxide scrubber
21 polishing scrubber
22 induced draught fan
23 residue buffer silo
24 machine transformer
25 salt tanks
26 gypsum storage



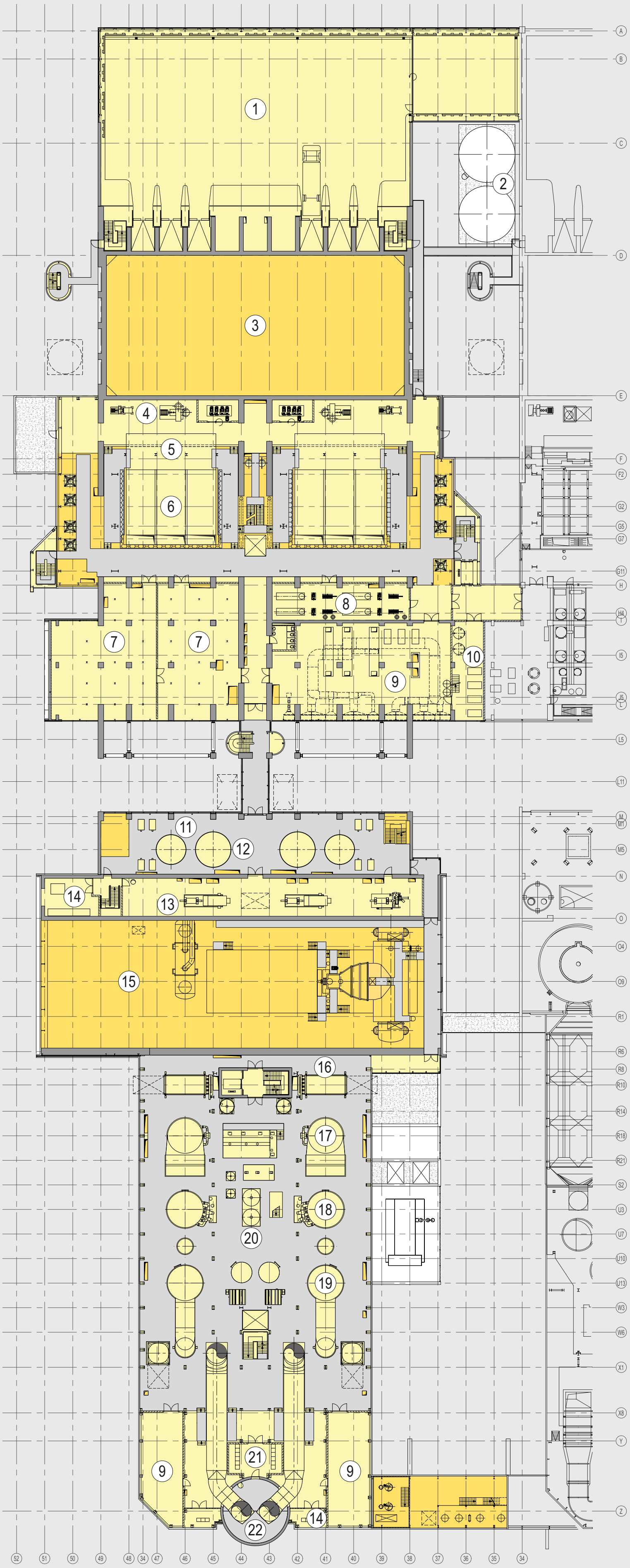
Level +8.00 metres

1 storeroom
2 mobile crane
3 sludge silo
4 waste bunker
5 slag bunker
6 slag crane
7 primary combustion air
8 grate slag shaft/deslagger
9 instrumentation, control and electrical systems
10 boiler discharge tank
11 demineralised water tank
12 fly-ash silo
13 limestone silo
14 steam header
15 emergency condenser
16 turbine noise insulation hood
17 LP turbine
18 main condenser
19 reheater
20 quenches
21 hydrochloric acid scrubber
22 sulphur dioxide scrubber
23 polishing scrubber
24 waste water treatment
25 flue-gas ducts
26 gypsum centrifuge
27 biogas purification
28 salt tank
29 machine transformer



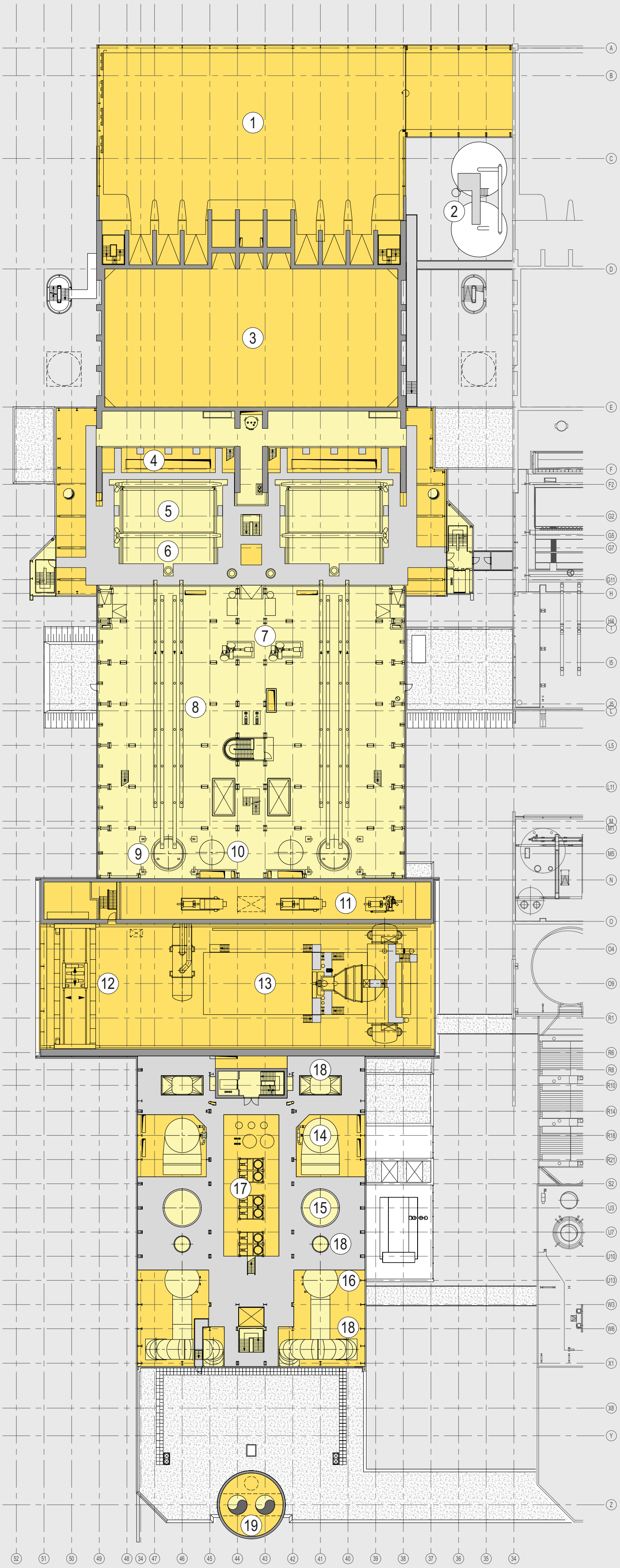
Level +12.40 metres

1 dumping hall
2 sludge silo
3 waste bunker
4 tertiary air
5 grate dosing system
6 grate
7 cable cellar
8 biogas heat production
9 ventilation room
10 compressed air system
11 fly-ash silo
12 limestone silo
13 feed-water pumps
14 instrumentation, control and electrical systems
15 turbine hall
16 ECO 2 heat exchanger
17 hydrochloric acid scrubber
18 sulphur dioxide scrubber
19 polishing scrubber
20 waste water treatment
21 emission monitoring
22 chimney stack



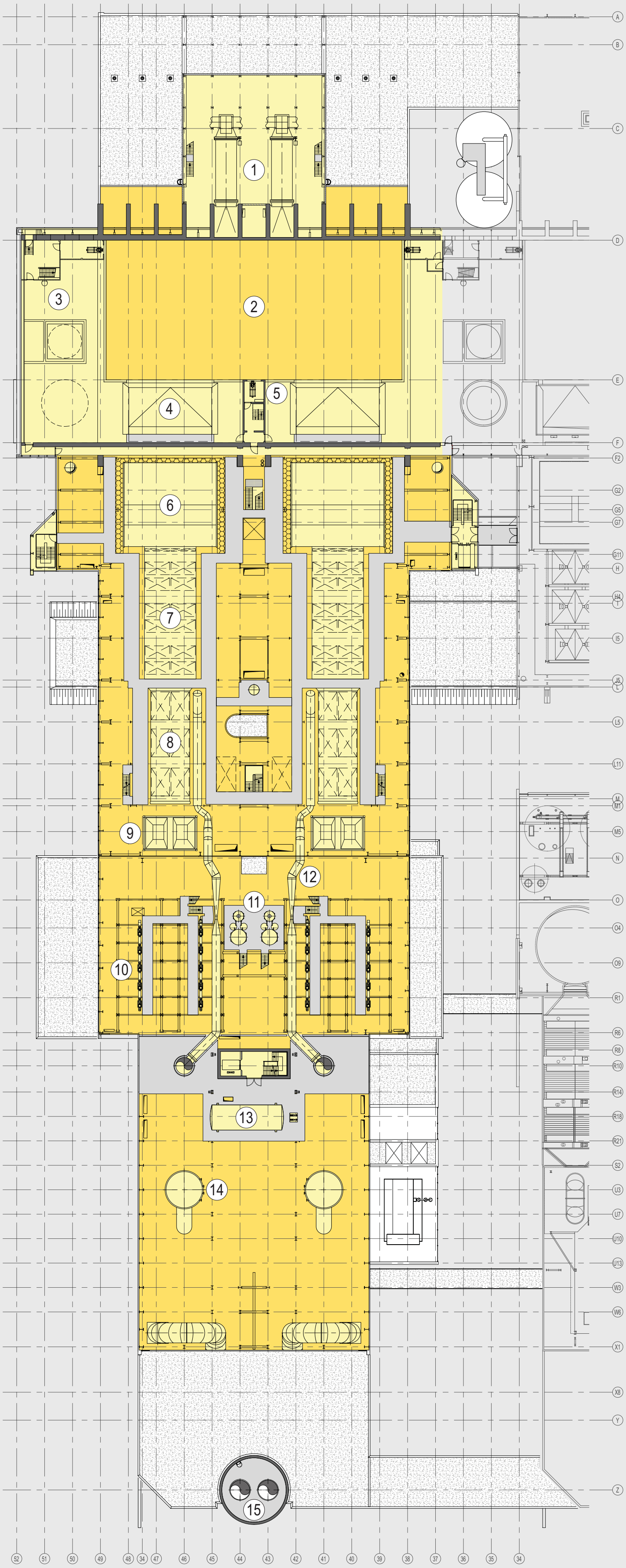
Level +19.60 metres

1 dumping hall
2 sludge silo
3 waste bunker
4 waste hopper
5 boiler, 1st radiation chamber
6 boiler, 2nd radiation chamber
7 recigas fan
8 boiler ash discharge
9 fly-ash silo
10 limestone silo
11 feed-water pumps
12 turbine service crane
13 turbine hall
14 hydrochloric acid scrubber
15 sulphur dioxide scrubber
16 polishing scrubber
17 salt factory
18 flue-gas ducts
19 chimney stack



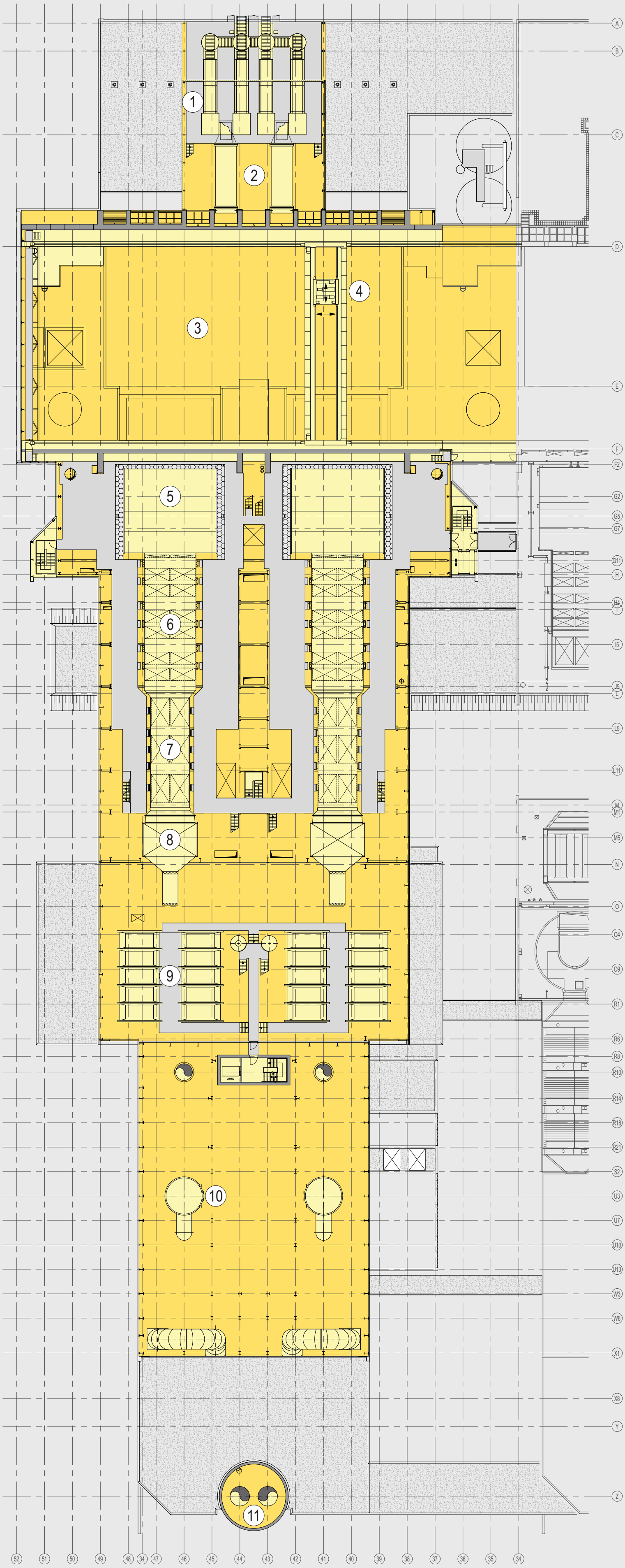
Level +25.00 metres

1 delivery by barge
2 waste bunker
3 ‘swallow’s nest’
4 hopper
5 crane cabin
6 boiler, empty chamber
7 boiler, superheater section
8 boiler, Economizer section
9 electrostatic filter
10 fabric filter
11 adsorbance silos
12 recigas duct
13 water tank
14 sulphur dioxide scrubber
15 chimney stack



Level +31.20 metres

1 delivery by barge
2 barge unloading
3 waste crane
4 boiler, empty chamber
5 boiler, superheater section
6 boiler, Economizer section
7 electrostatic filter
8 fabric filter
9 sulphur dioxide scrubber
10 chimney stack



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