New Technologies Harmonized with Global Environment

Part 1 – Activities of Environmental Industries Engineering Division

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NKK is tackling with the development of environment-friendly technologies and is now supplying plants, technologies and products harmonized with nature to create rich and rewarding human environments. At the beginning, NKK started environmental businesses by means of introducing overseas technologies and improving them into advanced NKK versions, and built up the business basis as the Japan's top manufacturer of environmental plants. Recently, NKK is receiving increasingly large amounts of orders and continuously securing high profitability in this field. This paper reports the history of NKK's pioneering businesses in the environmental field, and unique plants and technologies developed and commercialized by NKK's Environmental Industries Engineering Division and Water & Wastewater Engineering Division.

1. Introduction

1.1 The 1970's - progress in incineration technology within the context of pollution control regulations

The volume of wastes began to increase rapidly in Japan during the period of high economic growth in the 1960's, creating the need for modernizing the waste treatment facilities. The Ministry of Health and Welfare formulated the "Plan for Modernizing Waste Treatment Facilities" in an effort to answer this need, and adopted a policy to systematically implement new incineration facilities.

NKK began full participation in the waste treatment field when it completed the construction of the Tokyo Kita Waste Incineration Plant (300 tons/day×2 furnaces) in 1968. In 1970, it introduced stoker furnace technology from the Danish company Volund. In 1974, the construction of the Yokohama Konan Plant (300 tons/day×3 furnaces) was completed, soon followed by the completion of the Tokyo Itabashi Plant (300 tons/day×4 furnaces) in the same year. Both of these plants are large-scale facilities equipped with waste heat boilers and power generators, and are the predecessors of modern waste treatment technology. The furnaces installed in these plants are characterized by accelerated mixing of flue gas using the two-way gas flow system to achieve complete combustion, and the post-combustion kiln to achieve complete combustion of incinerator ash. When the presence of dioxins in flue gas later became problematic in the 1990's, NKK's methodology allowed concentration of dioxins in the incinerator flue gas reduced to less than 1 ng-TEQ/Nm^3 without requiring any special measures, thus proving the adequacy of the original incinerator design concept.

During this period of the 1970's, the Waste Disposal and Public Cleansing Law was enacted in the so-called "Environmental Pollution Diet", and environmental preservation measures were strengthened as represented by the enforcement of the Air Pollution Control Law, making the installation of incineration plants essential requirements.

NKK developed a range of unique technologies including NOx concentration reduction technology using the combination of the non-catalytic denitrification system and new combustion technology, and the semi-dry hydrogen chloride removal system named NKK LIMAR.

The technology to achieve complete combustion while reducing NOx concentration was later developed into a sophisticated technology to control dioxins and NOx at the same time through combustion management.

Technologies particularly worthy of note on which development work was commenced during this period are two revolutionary incinerators that have roots in iron and steel making. One is a direct melting furnace that uses a coke bed to incinerate wastes, and the other is an ash-melting furnace that uses submerged arc to melt bottom ash discharged from waste incinerators. Wastes in those days, however, were not so difficult to treat qualitatively, and social needs for recycling bottom ash as a useful material were considerably less stringent than is currently the case, and more than 20 years were elapsed before practical implementation of these technologies.

1.2 The 1980's - combustion technology for increased volume of wastes

The volume of wastes in Japan continued to increase throughout the 1980's. The volume of municipal wastes incinerated increased by a factor of approximately 1.5 during this decade. In addition to the increase in volume, changes in lifestyle and an increased proportion of waste plastics resulted in the increase of the calorific value of wastes. This increase in calorific value led to the increase in combustion temperature, requiring measures to prevent formation of clinker inside the incinerators. It also posed a problem of decreasing the throughput capacities of the incinerators.

NKK developed the water- and air-cooled wall structures for combustion chambers to deal with the increased calorific value of wastes. Furthermore, as waste power generation technology matured, demand increased for automated combustion control systems to handle the complex operation required for stabilizing power generation, boiler steam generation, and combustion, all at a same time.

NKK developed a sophisticated combustion control technology employing hybrid ACC (Automatic Combustion Control) based on a combination of the fuzzy control technology and the control method using a model that simulates combustion state in the furnace, achieving remarkable results. Advances in computer technology have been applied not only in automated operation of incinerators. Waste feeding cranes have also been automated. Further, significant results have been achieved with instrumentation and control systems for the entire range of waste incineration facilities (e.g., advanced data processing and vehicle traffic control systems).

In addition to the mainstream stoker furnaces, NKK also engaged in development of fluidized bed furnaces. Subsequent work achieved marked advance in the treatment technologies not only for municipal wastes but also for industrial wastes. These proprietary technologies developed in-house by NKK were also exported overseas.

The stoker furnace technology has been continuously improved over many years based on the original technology obtained from Volund, and the development of a hyper grate furnace originated by NKK was commenced combining the characteristics of two-way gas flow combustion with a horizontal grate system. This initiative led to the completion of industrial-scale plants in the 1990's, and became a link to the development of the next-generation stoker furnace. Thus, the decade of the 1980's was a period of considerable innovation and transition in view of combustion technology.

1.3 The 1990's - combustion technology for new environmental requirements

The volume of wastes, which had continued to increase in the 1980's, leveled off during the 1990's. The Japanese economy during this decade had various facets. In view of waste treatment, it is characterized by increased environmental awareness and social change, which gave rise to the needs of new treatment systems and technologies. In addition to changes in technology, changes also occurred in the perceived value of the environment and criteria for evaluating it. The national budget for environmental protection doubled during this decade, and a considerable volume of environment-related legislation was also established, bringing the environment into focus as never before.

Major issues pertaining to waste incineration systems include the measures to be incorporated into incineration facilities to suppress the emissions of dioxins, measures required to reduce the volume of wastes as a result of increasing difficulty in finding final disposal sites, and the function of incineration within the context of the various recycling-related legislation designed to promote the development of the recycling-oriented society. NKK responded to these issues with the introduction of a number of large-scale hyper grate incinerators (e.g., Osaka Hirano Plant - 450 tons/day×2 furnaces), and new electric resistance ash-melting furnace developed from the submerged arc furnace.

The National Emissions Survey conducted by the Ministry of Health and Welfare in 1997 unexpectedly revealed the superiority of NKK's combustion technology for the control of dioxins. Dioxin control measures consist not only of combustion technology, but also extend to the development and implementation of waste gas and ash treatment systems.

In the technological field for promoting the efficient use of energy, NKK developed and implemented such technologies as high-efficiency power generation employing high-temperature, high-pressure steam, and production and use of RDF (Refuse Derived Fuel).

In 1992, work began on the development of the high-temperature gasifying & direct melting furnace as a new technology to replace the stoker furnace based on a new concept. The progress was not limited in the technology related to the equipment itself. As incineration facilities were increasingly built in urban areas, it was desired to use these facilities as an integral part of the urban amenities. These moves resulted in considerable progress in architectural design technology.

In order to accelerate the development work for meeting the customer requirements in a timely manner in the age of rapid social changes, in 1996 NKK established the “NKK Environmental R&D Center” at its Tsurumi Works in Yokohama. By collectively locating a series of next-generation demonstration plants at a single site, it was intended for this facility to function as a showroom for advanced waste treatment technologies. To improve the efficiency of engineering operations, a system has been developed to computerize planning and design work for waste incineration plants and to centrally manage relevant technical information. Design work for individual projects has also been streamlined by such means as the introduction of CAD systems to allow 3D piping design for a specific project. In terms of quality management, ISO 9001 certification has been obtained for waste incineration plants designed for continuous operation.

1.4 Incineration technology for the 21st century

Photo 1 shows the Kanazawa Plant completed in Yokohama City in 2001. The facility consists of three 400 tons/day furnaces. A high-temperature, high-pressure boiler generates 35 MW of power at high efficiency. A low-temperature bag filter and denitrification catalyst system provide advanced flue gas treatment for removing dioxins and NOx. An electric resistance ash-melting furnace makes incinerator ash harmless and recycles all slag. This plant represents the final, completed version of the technologies developed and refined in the 20th century.

The year 2000 was the first year in which orders for gasifying & melting furnaces exceeded those for the stoker furnace that had formerly constituted the mainstream of incinerators. The stoker furnace, considered to be the most stable technology up to that point, was now required to make a giant leap and transform itself into an advanced next-generation stoker furnace technology.

Photo 2 shows the Fukuyama Recycle Power Plant, scheduled to begin operation in 2004. In this project, municipal wastes collected from 16 municipalities in Hiroshima Prefecture will be processed into RDF at seven locations, and transported to the power plant. The power plant employs one unit of NKK’s high-temperature gasifying & melting furnace capable of handling 314 tons of RDF per day, while generating 20 MW of power. The project is gathering attention as a model case of RDF power generation to be realized by wide-area cooperation of multiple municipalities. It is also regarded as a model of a public-private sector cooperation with a wide range of investors including Hiroshima Prefecture, local municipalities, the Hiroshima Prefecture Environmental Protection Corporation, and NKK.

Photo 1 Kanazawa Waste Incineration Plant in Yokohama City

Photo 2 Fukuyama Recycle Power Plant

The following describes in detail two technologies noted above for waste treatment - the high-temperature gasifying & melting furnace, and the next-generation stoker furnace.

2. Development of high-temperature gasifying & direct melting furnace

2.1 Progress of development

High-temperature gasifying & direct melting technology is designed to treat solid wastes without giving impact on the external environment, while at the same time recovering resources and energy at high levels of efficiency. Research in this field began in 1992, with elemental experiments on the conditions for dry distillation and combustion of wastes[1].

A demonstration plant of practical scale capable of treating 24 tons/day of wastes was constructed in 1995. The plant was operated for more than 400 days, during the period more than 5000 tons of solid wastes were treated, verifying the ability to maintain stable combustion over a long period. In July 1998, a technical appraisal report was issued by the Japan Waste Research Foundation, an organization affiliated with the Ministry of Health and Welfare, and full-scale sales activities were commenced. In May 2000, the first order was received from Kagamigahara City of Gifu Prefecture for a plant with a capacity of 192 tons/day. It was followed by further orders from Amagi-Asakura District of Fukuoka Prefecture, Saiki District of Oita Prefecture, Morioka-Shiwa District of Iwate Prefecture, Fukuyama City of Hiroshima Prefecture, and Kasama, totaling to seven orders.

The following describes the technical characteristics and primary performance verified.

2.2 Technical characteristics and outline of demonstration plant

2.2.1 Characteristics and furnace structure

This furnace employs a new combustion technology developed from a combination of the melting technology employed in blast furnaces and nurtured through ironmaking operation, and fluidized bed combustion technology well proven in waste incineration.

The furnace has the following characteristics[2].

(1) Stable treatment of a wide variety of solid wastes:

The use of coke as a supplementary heat source allows stable gasification and melting of a wide range of solid wastes without being affected by their ash rates and calorific values.

(2) Minimal environmental load during treatment:

Two-stage control comprising high-temperature reduction combustion in the melting furnace and high-temperature oxidization combustion in the secondary combustion furnace allows for control of dioxins. The use of limestone for basicity control ensures a low hydrogen chloride concentration.

(3) Reduction of waste volume and minimization of treatment costs:

Non-combustible components of the wastes form a high-quality slag that is recovered for use in a variety of applications. Thus the volume of materials remaining is considerably reduced, and only fly ash from the dust collector requires final disposal. The use of low air ratio combustion in the furnace improves the power generation efficiency.

Fig.1 shows the structure of the high-temperature gasifying & direct melting furnace. The introduction of oxygen-enriched air from the primary tuyeres promotes high-temperature combustion in the high-temperature combustion & melting zone at the lower portion in the furnace, thus melting the non-combustible components of the wastes. Introduction of air from the secondary tuyeres, and the combustion gas from the high-temperature combustion & melting zone, ensures that combustion is maintained at a temperature of between 650 and 750˚C in the partially fluidized gasifying & pyrolysis zone at the middle portion in the furnace, thus drying and pyrolyzing the wastes. The non-combustible components fall into the high-temperature combustion & melting zone at the lower portion in the furnace, while the volatile components are gasified and move upwards. Introduction of air from the tertiary tuyeres ensures that a high-temperature reducing atmosphere is maintained at a temperature of more than 850˚C in the freeboard zone towards the top of the furnace, thus controlling the generation of dioxins in the gas, and pyrolyzing the tar component to produce a gas which is easily handled.

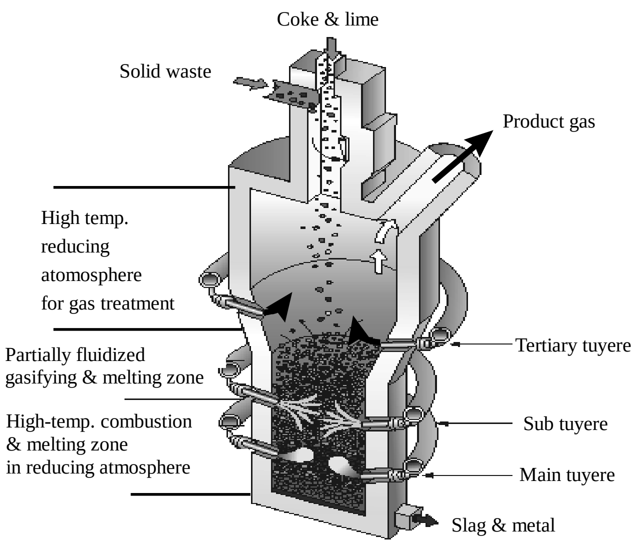

Fig.1 Schematic diagram of high-temperature gasifying & direct melting furnace

2.2.2 Demonstration plant outline and characteristics of solid waste used

The demonstration plant capable of treating 24 tons/day of wastes was constructed at the NKK Environmental R&D Center in the Tsurumi Works. It consists of a refuse pit, wastes and sub-materials (limestone and coke) feeding system, high-temperature gasifying & direct melting furnace, continuous slag tapping system, secondary combustion furnace, boiler, gas cooling tower, bag filter, and flue gas treatment system.

The results of approximate analysis of the primary wastes used for testing are shown in **Table 1**. MWS is standard municipal waste. MWL is low-quality municipal waste prepared by mixing vegetable waste with standard municipal waste, thus reducing its calorific value. CSD is car shredder dust. IA is incinerator ash. LFW is waste recovered from final landfill disposal sites, and includes plastics, however the majority is dirt and sand.

Table 1 Properties of tested wastes

Refuse		MWS	MWL	CSD	IA	LFW
Moisture	wet%	39.6	63.1	7.4	9.5	18.8
Ash	wet%	11.2	5.5	37.9	88.0	66.4
Combustibles	wet%	49.2	31.4	54.7	2.4	14.8
FC (Fixed Carbon)	wet%	6.8	4.5	5.5	0	0.7
FC/Ash	-	0.6	0.8	0.1	0	0.01
CaO/SiO_2	-	0.3	0.3	0.5	0.3	0.1
Calorific value	kcal/kg	2200	1130	4300	0	970

When these waste materials are melted, the ratio of fixed carbon and ash is important in terms of calorific value, and the basicity (CaO/SiO_2) of the ash is important to secure the ease of slag melting and fluidity of slag generated. The ratio of fixed carbon to ash in each of the tested wastes is shown as FC/Ash in the table. Standard municipal waste (MWS) has a FC/Ash value of approximately 0.6, while low-quality municipal waste (MWL) has a smaller proportion of ash in comparison to standard municipal waste (MWS), therefore a higher FC/Ash value, suggesting that it will be easy to treat in terms of calorific value. The FC/Ash value for CSD (Car Shredder Dust) is low, with a low calorific value contributing to melting, despite a large non-combustible component to be melted. It is therefore anticipated that a considerable amount of supplementary fuel will be required for combusting CSD in comparison with municipal waste. IA (Incinerator Ash) and waste recovered from final landfill disposal sites (LFW) have further low FC/Ash values, thus requiring a greater amount of supplementary fuel (coke) for combustion.

The basicity (CaO/SiO_2) of the ash produced from the wastes shown in the table varies between 0.1 and 0.6 depending upon the properties of the wastes tested. With the newly developed method, lime is added to obtain a basicity of approximately 1.0 to adjust the melting point and viscosity of the slag for realizing stable slag tapping, and also to provide the slag with physical properties advantageous to converting it into a useful material.

2.2.3 Testing conditions

Typical testing conditions for the various waste materials are shown in **Table 2**. Municipal wastes were treated throughout the year, however that shown in the table is for autumn only.

Table 2 Typical testing conditions

Refuse		MWS	MWL	CSD	IA	LFW
Treatment rate	kg/h	1114	1160	594	405	450
Coke ratio	kg/t	82	52	126	247	148
Lime ratio	kg/t	62	25	71	388	264
C/A	-	0.67	0.89	0.56	0.29	0.26
Flow rate from main tuyere	Nm^3/h	356	468	280	400	391
O_2 % of main tuyere flow	%	39	41	39.5	42	43

Coke ratio = [Coke feed rate(kg/h)]/[Refuse feed rate(t/h)]
Lime ratio = [Lime feed rate(kg/h)]/[Refuse feed rate(t/h)]
C/A = [coke rate]/[Ash rate in coke, lime & refuse]

As described in **2.2.2**, the variable amounts of fixed carbon and ash in the waste, and its basicity, require adjustment of the coke ratio (kg of coke per ton of wastes treated), the lime ratio (kg of lime per ton of wastes treated), and the oxygen concentration at the primary tuyeres in order to maintain stable combustion within the furnace, and thus to maintain continuous and stable melting operation of non-combustible components, and gasification of combustible components.

2.3 Typical testing results

2.3.1 Combustion state

Typical results of testing are shown in **Table 3**. The amounts of ash in IA (Incinerator Ash) and waste recovered from final landfill disposal sites (LFW) are considerably larger than those in other types of wastes. However, the temperatures of the slag produced from all wastes treated were maintained between 1450 and 1600˚C by adjusting the coke ratio and oxygen concentration. The slag ratios (amount of slag discharged vs. amount of ash fed) were 85% or higher for all wastes treated, verifying that the non-combustible components were melted and turned into slag. The temperatures of the gas produced from all treated wastes were adjusted to 850˚C or higher by controlling the air flow rate from the tertiary tuyeres. The volume reduction ratio illustrates the extent to which this technology enabled a reduction in the fly ash volume, and therefore the final disposal volume of wastes. As shown in the table, this technology can reduce the volume of municipal wastes that need to be finally disposed of to less than 1/200 of their original volume, thus contributing to easing the loads on final disposal sites.

Table 3 Typical results for tested wastes

Refuse		MWS	MWL	CSD	IA	LFW
Temp. of molten slag	℃	1513	1472	1599	1495	-
Slag & metal rate	kg/h	151	76	220	386	318
Gas temp. of freeboard	℃	1055	868	1074	963	945
Slag ratio	-	88.1	88.2	85.8	85.5	86.1
Volume reduction ratio	1/x	228	283	51	20	-

Volume reduction ratio = [Fly ash volume]/[Refuse volume fed]
Slag ratio = [Slag volume discharged]/[Ash volume fed]

2.3.2 Properties of product slag

Properties of slag produced by the high-temperature gasifying & direct melting furnace are shown in **Table 4**. When slag is used as a resource, its qualities are evaluated in terms of leaching of heavy metals, and the concentrations of metals are therefore important indexes.

Table 4 Properties of product slag

Item		MWS	CSD	IA	LFW
SiO_2	%	37.9	31.8	34.5	48.0
CaO	%	38.6	35.4	44.6	44.1
MgO	%	4.44	4.01	2.42	3.08
Al_2O_3	%	15.5	24.6	20.4	18.1
Fe	%	0.13	0.21	0.32	1.13
Cu	%	0.02	0.05	0.05	0.04
Na	%	0.69	0.11	1.61	2.36
K	%	0.16	0.01	0.32	0.82
Pb	mg/kg	<10	<10	<10	<10
Zn	mg/kg	<10	16	13	<10
Mn	%	0.12	0.09	0.05	0.08
CaO/SiO_2		1.02	1.11	1.29	0.92

The use of coke in this technology ensures strong reducing power associated with melting inside the furnace, so that Fe and slag are readily separated, and heavy metals are not oxidized and are not included within the slag. Tests on leaching from slag based on the Environmental Protection Agency Notification No.46 showed that, irrespective of the types of wastes treated, leaching was within the specified limits on all items, thus satisfying the relevant environmental standards for soil. The slag recovered with this technology is of high quality, and its properties ensure that it is able to be readily recycled as a useful material.

2.3.3 Properties of product gas and combustion gas

The composition of gas produced by the high-temperature gasifying & direct melting furnace, and that of combustion gas generated by the secondary combustion furnace, is shown in **Table 5**. Treatment conditions are as shown in **Table 2**.

The primary components of the combustible gas produced from wastes that contain volatile matter such as municipal waste (MWS), CSD, and waste recovered from final landfill disposal sites (LFW) are CO and H_2. The calorific value for CSD, which has a high content of volatile matter, is 1100 kcal/Nm^3, and 251 kcal/Nm^3 for LFW, which has a low content of volatile matter. IA (Incinerator Ash) has no volatile content and the freeboard temperature is maintained with the gas produced by combustion of coke so that there is almost no combustible gas at the outlet of the melting furnace. CO concentrations of the combustion gas at the outlet of the secondary combustion furnace are less than 10 ppm, irrespective of the types of wastes treated, and this gas is readily combustible. NOx and SOx concentrations are controlled to less than 100 ppm and 10 ppm respectively, and HCl concentrations are less than 40 ppm for CSD, and 30 ppm for municipal waste (MWS). Actual measurements confirmed that concentrations of dioxins were 0.0058 ng-TEQ/Nm^3 at the smokestack outlet during treatment of municipal wastes.

These results are considered to be attributable to the ability to independently control the temperatures in the fluidized zone and freeboard zone inside the gasifying & melting furnace by controlling the air flow through the secondary and tertiary tuyeres. The lime added to adjust basicity is also considered to be effective for removing sulfur and HCl from flue gas.

Table 5 Properties of product gas and combustion gas

		MWS	CSD	IA	LFW
Product gas in freeboard of gasifying & melting furnace					
CO	%	11.8	15.4	0	7.2
H_2	%	5.2	10.6	0	1.3
CO_2	%	18.4	13.7	17.7	24.9
Calorific Value	kcal/Nm^3	946	1100	23	251
Combustion gas in secondary-combustion furnace					
CO	ppm	9.4	5.5	2	8.0
NOx	ppm	97.0	92	66.0	21.0
SOx	ppm	6.0	0.7	<2	9.0
HCl	ppm	21.0	32.0	<1	10.0
Exhaust gas in stack					
DXN	ng-TEQ/Nm^3	0.0058	0.026		

3. Development of the advanced next-generation stoker system

3.1 Progress of development

Measures such as low air ratio combustion and flue gas recirculation have become the subject of much attention in view of reducing the amount of substances that give environmental impact in the waste incineration process, and the effective use of energy. Furthermore, demands are increasing for the stabilization of the ash discharged in association with waste incineration, and reduction in the costs of treating this ash. In order to resolve these problems, it is necessary to have a fundamental clarification of the combustion phenomena occurring within the process, and to develop a new combustion technology to eliminate the combustion instabilities unique to waste incineration and ash treatment. The application of high-temperature air combustion technology could provide solutions to these problems.

This development work is focused on the application of high-temperature air combustion technology for resolving fundamental problems in combustion technology resulting from the versatility and heterogeneity of waste materials. This work is aimed at the development of an integrated waste treatment system covering all aspects from incineration of wastes to treatment of the resulting ash with high efficiency and reduced environmental impact. In order to systematically investigate combustion characteristics of wastes, a 12 tons/day demonstration plant has been constructed and run for more than 5000 hrs using model pyrolysis gas, model wastes, and actual municipal wastes. In addition, numerical calculations were performed to verify the validity of the experimental results[3)-7)].

The following reports on the primary results of the combustion trials using model wastes and actual municipal wastes.

3.2 Proposed system

The conceptual diagram for implementing the proposed system is shown in **Fig.2**, and that for the flame pattern in the vicinity of the high-temperature air nozzles is shown in **Fig.3**. The expected benefits of high-temperature air are the possibility of realizing a low air ratio of less than 1.3 through superior combustion stabilization in the incinerator, while at the same time reducing the amount of substances that give environmental impact. In practice, the mixture of high-temperature air and flue gas is injected at high velocity (30 - 40 m/sec) from opposite walls of the incinerator to form a stable high-temperature zone in the combustion initiation region above the wastes. The aim of this air-gas mixture counter-flow injection is to avoid fluctuation and localized extinguishing of the flame, while at the same time heating the wastes directly with the flame to promote gasification.

An integrated incineration and ash treatment system is designed to reduce equipment costs and labor requirements while significantly reducing supplementary fuel costs for ash treatment.

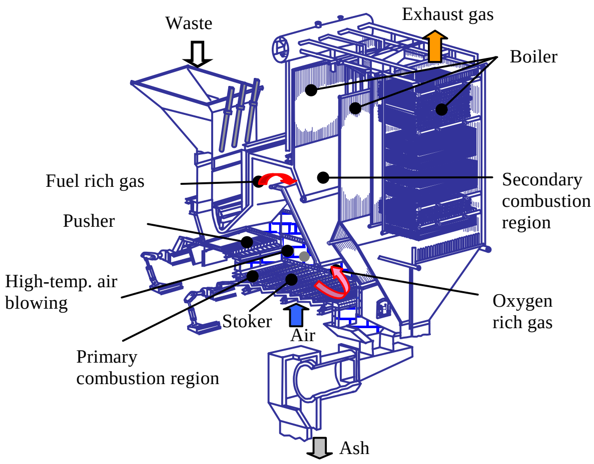

Fig.2 New NKK two-way flue gas incinerator

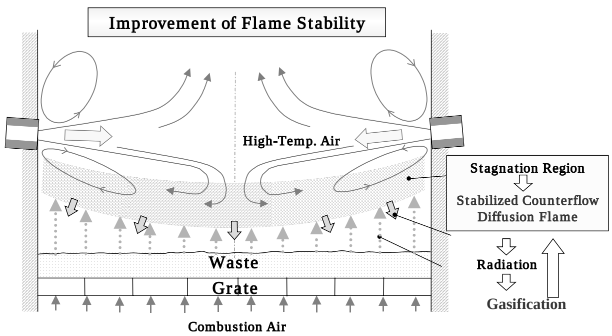

Fig.3 Flame stabilization image in the combustion initiation region

3.3 Incineration test results

A systematic combustion test was conducted using model wastes (RDF manufactured from municipal wastes, with added moisture) prior to actual municipal waste incineration trial in order to evaluate the effects of injecting the mixture of high-temperature air and flue gas with minimal influence of other factors.

The correlation between temperature at the incinerator outlet and NOx concentration for the conventional combustion method (air ratio $\lambda = 1.7$, high-temperature air not introduced) is compared with that for the advanced combustion method with high-temperature air injection (air ratio $\lambda = 1.3$) in **Fig.4**.

As shown in the figure, the NOx concentration when high-temperature air is injected is less than one-half that of the conventional combustion method. This is conceivably attributable to the fact that the primary components of the combustible gas directly above the waste layer becomes CO and H_2 due to high-temperature air injection, and thus conversion of fuel-N to NOx is suppressed. Another conceivable reason is that the localized high-temperature regions are disappeared due to the mixing effect of high-temperature air injection. As shown in **Table 6**, the concentration of dioxins in the flue gas at the incinerator outlet is controlled to less than 50% by high-temperature air injection.

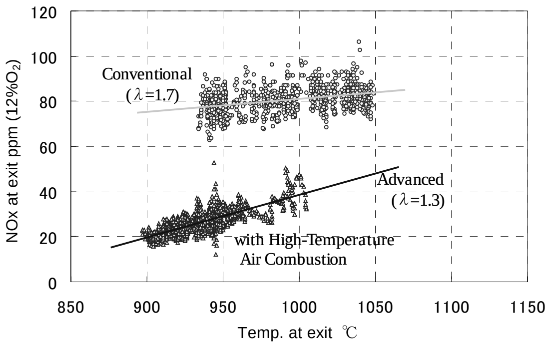

Fig.4 Effects of introducing the mixture of high-temperature air and flue gas on NOx concentration

Table 6 Dioxin concentration at incinerator outlet

	Conventional*		Advanced**
Air ratio, -	1.7	1.3	1.3
DXNs conc., ng-TEQ/Nm^3	0.59	1.3	0.29

* without high-temperature air
** with high-temperature air

3.4 Test results of integrated incineration and ash treatment

Actual municipal wastes, coarsely crushed to suit the small size of the incinerator, were treated for a total of 2000 hours for evaluating the performance of the integrated incineration and bottom ash treatment system. This testing verified that heat treatment without melting the ash at temperatures between 1200 and 1300˚C, and ash melting treatment at temperatures of 1300˚C or higher are both realizable. The testing also confirmed that it is possible to control the concentration of dioxins in the treated ash to less than 0.0001 ng/g-TEQ.

Lead in the ash is problematic in treating incinerator bottom ash. The behavior of lead in the treated ash was investigated. The results are summarized in **Fig.5**. As shown in the data marked with △ in the figure, the use of this proposed ash-melting treatment system has been shown to simultaneously satisfy both current soil standards, and future Tokyo Metropolitan Government standards, for lead. Other tests showed that the proposed system was also able to satisfy soil standards for heavy metals other than lead.

A portion of this R&D program was conducted as part of NEDO's High-temperature Air Combustion Control Technology Research and Development Project. The authors wish to express their gratitude to NEDO.

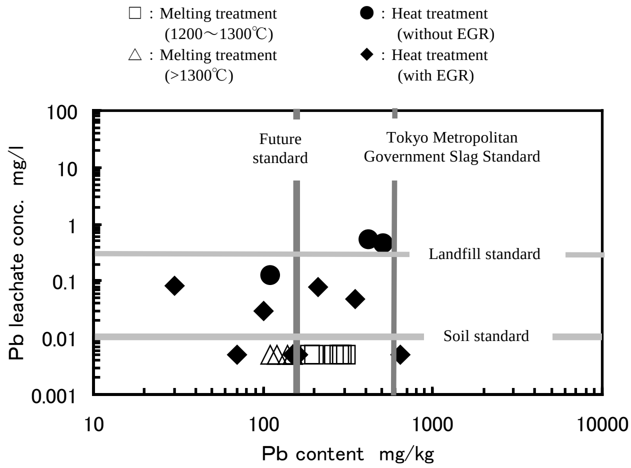

Fig.5 Correlation between lead content of ash and lead leachate concentration

4. Conclusion

This paper has described the progress of development of environment-friendly technologies at NKK from its beginnings to the most recent developments.

The high-temperature gasifying & direct melting furnace is a resource-recovery-type technology with the three-fold advantages of (1) reducing the volume of wastes, (3) eliminating harmful substances, and (3) recovering energy. Due to these advantages, this technology is currently being rapidly adopted by local authorities throughout Japan. Since 2000, the orders received are at a level equal to those for the previously mainstream stoker furnace. NKK has already received orders for seven waste treatment facilities using the gasifying & direct melting furnace system. Another program is currently underway to develop a process that gasifies the wastes and make effective use of the gas thus produced[8).

NKK's advanced next-generation stoker furnace system that incorporates unique technology developed in-house for injecting the mixture of high-temperature air and flue gas. This new technology has succeeded in simultaneously reaching the final targets of 30% reduction in energy consumption, 30% reduction in NOx emissions at the furnace outlet, and 50% reduction in concentration of dioxins at the furnace outlet. Sales operations are currently underway for securing the first order.

In April 2003, NKK's engineering division and Kawasaki Steel's engineering division will be consolidated to form JFE Engineering Corporation. We aim at consolidation and fusion of both companies' environmental technology at early stage. After the consolidation, we will promote aggressive R&D activities in order to create a new technology for growing market, and run as a leading company in the field of environmental product technology.

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