Environmental Technologies in Steel Works[†]

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Abstract:

JFE Steel is committed to creating a more affluent society through business operations in harmony with the environment. To this end, the company implemented thoroughgoing energy saving measures from an early date, and has positively and continuously carried out activities to reduce/improve environmental loads and recycle resources in its steel manufacturing processes, as well as research and development in related fields. Although JFE Steel has achieved substantial results through these efforts, today's environmental problems, as represented by global warming, extend to the global scale. This paper describes the results achieved by JFE Steel in energy saving as a measure for preventing global warming, environmental protection, and other efforts, as well as the future outlook.

1. Introduction

The steel manufacturing process requires enormous quantities of resources, including iron ore, coal, and water, and large amounts of energy in the form of electric power and fuels. It also uses a variety of chemical substances. To reduce the resulting environmental loads, JFE Steel carried out a diverse range of technical development and implemented environmental countermeasures from an early date.

On the other hand, today's affluent society is faced with new problems, such as the effect of chemical substances on the ecosystem and global warming, which demand maximum use of the technologies and potential possessed by JFE Steel, including timely technical development and equipment/operational measures suited to changing times. In particular, this will mean promoting measures to prevent global warming, which will

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¹ Exective Assistant, Energy & Environment SBU, Technology Planning Dept., JFE Steel become an increasingly important problem in the future.

In these circumstances, JFE Steel supplies environment-friendly iron and steel products which make a large contribution to reducing the environmental loads in industrial society, and is continuing its efforts, including technical development, operational improvement, and introduction of equipment, with the aim of achieving further energy savings/prevention of global warming and reducing environmental loads in each of its steel manufacturing processes.

This paper describes JFE Steel's activities to date in prevention of global warming through energy saving in the steel manufacturing process, measures to reduce environmental loads, and the creation of an recyclingoriented society, and also discusses future efforts.

2. Outline of Environmental Conservation Efforts in Steel Works

Since the second half of the 1960s, JFE Steel has actively developed environmental protection technologies and introduced equipment and implemented operational improvements to reduce/improve environmental loads in its manufacturing processes. Following the first oil crisis, the company positively expanded its development of new energy saving technologies and energy saving promotion activities.

In more recent years, JFE Steel has also made an important contribution to creating a recycling-oriented society by receiving and treating waste from society and other industries, for example, by utilizing waste plastic using the technology and infrastructure of the steel works. As a result, JFE Steel has now constructed an environment-friendly steel manufacturing process which



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Energy conservat	ion technology								
Counter- measures —Facility		Coke dry quenching (CDQ), Coal moisture control (CMC), Combustion control	Sintering cooler waste heat recovery, Ignition furnace line burner	Waste plastics feeding, Pulverized coal injection, Top pressure recovery turbine, Hot stove waste heat recovery, Fuel gas preheating	Gas recovery, Gas sensible heat recovery, Nitrogen jet heater, Ladle heating	Regenerative burner, Direct charging, Low- temperature extraction	Endless rolling, Process coupling	Waste heat boiler, Rotary regenerative heat exchanger	Selection of transportation mode, Shortening of transportation distance, Improvement of load efficiency, Modal shift, Application of IT
		Gas turbine co Power plant fu High efficience	ombined cycle ael preheating o cy air separatio	power plant, levice, n equipment					
Steel production	process	Coke	ven gas	BF BOF gas gas	Oxygen pl	ant Power g	generating		1
	Raw material yard	Coke oven	Sintering plant	Blast furnace	BOF, EF, CC	Reheating	Hot rolling, Cold rolling	Continuous annealing, Coating	Shipment
Generated substance	Dust	Flue gas, Dust, Wastewater (ammonia liquor)	Flue gas, Dust, Wastewater	Flue gas, Slag, Dust, Wastewater	Flue gas, Slag dust, Wastewater	Flue gas, Dust	Rolling wastewater, Pickling wastewater	Coating wastewater	Exhaust gas
Environmental impact	Dust	Dust, NOx, SOx, COD	Dust, NOx, SOx	Dust, SS	Dust, SS	NOx	SS, Waste oil, Waste acid, Iron salt	Metallic ion, etc.	NOx, SPM (suspended particulate matter)
Counter- measures —Facility	Yard water spraying, Belt conveyor dust collection, Laser dust monitoring	Coke oven gas desulfurization, Waste ammonia liquor COD treatment, Chemical by-product recovery	Flue gas desulfurization and denitrification	Gas recovery, Dust collection, Dust treatment, Slag recycling	Gas recovery, Dust collection, Dust treatment, Slag recycling	Low-NOx burner, Use of cleaner fuel	Waste acid and waste alkali treatment, Waste oil recycling, Coagulating sedimentation	Wastewater treatment	Conversion to low- emission vehicles

Table 1	Overview of	energy a	and environmental	conservation #	technologie	s

boasts the world's highest levels of energy efficiency and resource recycling ratios.

Energy saving measures such as waste heat recovery equipment and power generating equipment in each steel manufacturing process, and the main technologies applied as environmental protection measures, including desulfurization/denitrification, dust collecting equipment, and various kinds of water treatment equipment, are shown in **Table 1**.

To systematically promote these environmental conservation efforts, in 1991, the company created an internal Environmental Committee and constructed a company-wide environmental management system under the president. The company also actively promoted acquisition of certification under ISO14001, which is the international standards for Environmental Management Systems (EMS) issued in September 1996, and completed acquisition of the certification for all its iron and steel works in July 1999. At present, activities aimed at continuous improvement, based on EMS, are being developed. One particular objective is to create urban-type steel works which exist in harmony with the environment through voluntary efforts and disclosure of information in order to obtain the full understanding and trust of local communities. Environmental information includes publication of the company's environmental policy, the status of environmental loads, PRTR data, and environmental accounting through Environmental Reports.

3. Efforts to Prevent Global Warming

3.1 History of Energy Saving Activities

As energy saving activities in JFE Steel, the company began its 1st energy saving plan in 1973 and has promoted energy saving activities continuously up the 5th energy saving plan, which is now in effect. An outline of the activities under each plan is presented below. 1st Plan (1973–1978)

Energy saving was promoted mainly through operational improvements, including reduction of the reducing agent ratio at blast furnaces and reduction of fuel consumption at reheating furnaces, etc.

2nd Plan (1979–1985)

Energy saving was implemented by positive introduction of large-scale waste heat recovery equipment, including power generation by the blast furnace toppressure recovery turbine (TRT), sintering cooler waste heat recovery, and coke dry quenching (CDQ) equipment.

3rd Plan (1986-1994)

Energy saving operation was promoted by process continuation/elimination, as exemplified by the continuous casting machine and continuous annealing line, introduction of pulverized coal injection (PCI) for the blast furnace, and coal moisture control (CMC) equipment, and efficient operation of various energyrelated facilities.

4th Plan (1995-2002)

Against the background of the increasing serious global warming problems, the objective of energy saving activities changed from cost reduction to reduction of CO_2 emissions by reducing energy consumption, and the company made efforts to identify new technologies and develop seed technologies from a wider perspective, for example, including environment-friendly technologies (regenerative burner) and waste recycling technologies (blast furnace feed of waste plastic).

5th Plan (2003–)

To implement complete globally warming prevention measures, JFE Steel is developing new energy saving activities through further technical innovation, and is expanding the scope of its efforts to include the development of recovery/use technologies for unused energy and study of comprehensive energy saving through cooperation with regional society and other industries.

Among the results of these activities, as equipment for recovery of energy from steel manufacturing processes, JFE Steel has installed CDQ (15 units), heat



Fig.1 Trend of energy consumption per ton of steel (FY1973 = 100%)

recovery equipment for BOFs (10 units), sintering main waste heat recovery equipment (3 units), sintering cooler waste heat recovery equipment (6 units), and TRT (9 units, which is the total number of operating blast furnaces). As a result, it is now possible to cover 16% of steel works power consumption and 75% of works steam consumption with recovered energy. The results of these energy saving activities can be seen in reduced unit energy consumption (energy consumption per ton of crude steel), as shown in **Fig. 1**. Unit energy consumption was reduced by approximately 33% between the beginning of the 1970s and fiscal year 2003.

3.2 Specific Examples of Energy Saving Measures

This section introduces specific examples of measures in the 1st to 3rd energy saving plans, as mentioned in the previous section.

3.2.1 Examples of waste energy recovery equipment

As one method of achieving high efficiency in processes, reduction of waste energy in the energy collection-and-consuption balance is an important element. Among the methods of reducing waste energy, recovery and reuse of waste energy was implemented with many types of equipment. This can be broadly divided into two methods, the method of using of the recovered waste energy with the same equipment and the method of supplying recovered waste energy to other equipment.

Examples of the former method include blast furnace hot stove waste heat recovery equipment and the high efficiency recuperator for reheating furnaces (preheating of combustion air and fuel gas). These measures can be realized with comparatively small-scale equipment, and were frequently implemented in the initial stage of the company's energy saving activities. Accompanying these measures, development of a low NOx burner was carried out simultaneously because NOx reduction technology is essential in energy saving techniques which involve heating combustion air and fuel gas to high temperatures using high efficiency recuperators in the reheating furnace.

Examples of the latter frequently require large-scale facilities such as the TRT, CDQ, sintering cooler waste heat recovery, basic oxygen furnace (BOF) gas sensible heat recovery equipment, waste heat recovery boiler, etc. By installing these equipments, it was possible to obtain approximately 260 MW of recovered electric power and approximately 790 t/h of recovered steam.

3.2.2 Examples of process continuation and elimination

In iron and steel manufacturing processes, products must be repeatedly heated and cooled a number of times. However, energy savings can be realized by minimizing the temperature drop in this process.

Process continuation and elimination have long been used as means of minimizing temperature drop. To mention several representative examples, these include PCI, in which pulverized coal is injected directly into the blast furnace without passing through the cokemaking process, the continuous casting (CC) machine, which produces slabs directly from molten steel from the BOF, direct rolling (DR), in which slabs produced by the CC are rolled directly, the continuous annealing line (CAL), and continuous pickling/cold rolling lines. Another notable example is the endless rolling process at No. 3 hot strip mill at East Japan Works (Chiba), which is the world's first practical continuous hot rolling process¹). This process eliminates the unsteady parts at the head and tail ends of strips in the finishing mill, and thus dramatically improves the stability of the rolling operation. At the same time, it also substantially improves the quality of hot rolled strip by reducing deviations in the strip thickness and finishing temperature, and also enables a maximum energy saving of 20% during endless rolling.

3.2.3 Examples of high efficiency in energy equipment

High efficiency in energy-consuming equipment has been achieved by the development/introduction of highly efficient equipment as such, and by realizing advanced control systems.

Important examples of high efficiency technologies for the coke oven are the end flue heating burner and CMC^{2}). Installation of the end flue heating burner makes it possible to realize a uniform furnace temperature extending to the two ends of the coke oven, where the temperature had been low in conventional ovens, and thus makes it possible to realize an energy saving by reducing the average furnace temperature. It also has the additional benefit of preventing dust generation during coke pushing. Introduction of CMC reduces coke oven fuel consumption for pre-drying coal, and at the same time, also increases coke strength and improves productivity by enabling increased coal charging, which is possible due to the higher bulk density of the coal.

In the field of energy conversion, facilities which consume large amounts of energy are power plants and air separation plants. As an example of high efficiency in a power plant, in 1987, East Japan Works (Chiba) started up Japan's first large-scale byproduct gas-fueled gas turbine combined cycle power plant³). In comparison with the conventional boiler-turbine type, generating efficiency is improved by approximately 5%. In its air separation plants, JFE Steel has also made every possible effort to improve separation efficiency and reduce oxygen diffusion by installing variable absorption devices.

Examples of high efficiency achieved by adopting advanced control systems include introduction of a carbonization control system for the coke oven, application of fuzzy logic to hot stoves, and building physical properties into products in the production process, which was made possible by the development of a model which enables accurate prediction of the transition in the temperature of steel strips from reheating furnace entry until after rolling.

3.3 Efforts to Prevent Global Warming

In 1996, the Japan Iron and Steel Federation established a Voluntary Action Plan for Environmental Protection by Steelmakers. Beginning with its 4th energy saving plan, JFE Steel has been developing further energy saving activities bearing in mind the importance of preventing global warming based on the philosophy of the Kyoto Protocol, and began introduction of regenerative burners and receiving of waste plastic for blast furnace feeding. The company also promoted optimization of energy supply-and-demand, including regional society and plants in other fields outside the steel works. The followings are representative examples of these efforts.

(1) Introduction of Regenerative Burner

The regenerative burner is a technology which dramatically improves the recovery rate of waste energy in reheating furnaces and other equipment. As shown in Fig. 2, the regenerative burner incorporates a regenerative-type heat exchange system in individual burners, enabling efficient recovery of the sensible heat of reheating furnace flue gas. However, this technology involved problems of reduced equipment reliability and increased NOx concentrations resulting from the higher temperature of the combustion air. JFE Steel therefore developed various practical technologies which solved these problems, including, the direct flame-type regenerative burner for the continuous reheating furnace, and a ladle heating system and non-oxidizing heating device for the tundish (N2 gas jet burner) for the steelmaking process^{4,5)}. These



Fig.2 Regenerative burner

technologies have been applied to 21 facilities in the company, achieving important results which include an average energy saving ratio of 17%, energy savings of 2 PJ, and a CO_2 reduction of 230 000 t/y. In particular, with reheating furnaces and heat treatment furnaces in the rolling process, in addition to achieving large energy savings, improved product quality has also been achieved as a result of uniform heating of steel products.

- (2) Receiving of Waste Plastic and Other Wastes
 - JFE Steel has realized a reduction in consumption of coke and other reducing agents by receiving, pretreating and feeding waste plastic into blast furnaces.

The company also receives waste from regional society, which it treats using gasification and melting furnaces that generate virtually no dioxins. The gas generated in this process supplies part of the fuel used in the company's steel works.

(3) Supply of Energy to Outside Users

Taking advantage of the capacity of power plants in its steel works, JFE Steel supplies surplus power to PPS (power producer and supplier: power producers of a designated scale). With the approval of the Minister of Economy, Trade and Industry in January 2005, the company began supplying approximately 10 000 kW of power to an adjoining redevelopment area as Japan's fifth PPS. In addition to this, the company also supplies byproduct gas and steam to outside users.

(4) Supply of Oxygen, Nitrogen, and Argon

Utilizing the steel works' oxygen, nitrogen, and argon manufacturing capacity, the company supplies surplus production of these products to outside users. To ensure a stable supply to outside users, JFE Steel has constructed oxygen and nitrogen liquefaction plants to absorb fluctuations in on-site consumption. These are high efficiency gasification/liquefaction facilities which utilize the cryogenic temperature difference between liquefied oxygen and nitrogen.

(5) Optimization of Energy Equipment for Construction of Optimum Production System

Accompanying the adoption of a one blast furnace

system at East Japan Works (Chiba), which was carried out as part of equipment concentration for the establishment of an optimum production system, the capacity and functions of the related energy equipment were also reviewed to enable optimum operation of this equipment. Various measures were introduced, including strengthening of the blast furnace TRT generating equipment to improve BF gas energy recovery efficiency, construction of liquefaction/gasification equipment and improvement of the oxygen supply system to reduce energy consumption in supplying oxygen to BFs, and improvements to achieve high efficiency in the combined cycle power plant in order to increase the efficiency of BF gas-using equipment. The most suitable and advanced energy saving equipments were constructed as required by the changes in the production system.

3.4 Future Efforts

The Kyoto Protocol took effect in February 2005 following ratification by Russian Federation, and as a result, efforts to prevent global warming have now taken on even greater importance.

While fulfilling its role of supplying environmentfriendly iron and steel products as materials which contribute to preventing global warming, JFE Steel also plans to make further reductions in unit energy consumption as part of its commitment to solving this crucial problem.

For example, the company plans to promote the development and introduction of energy saving technologies by developing a CO_2 emission reduction technology based on injection of city gas in BFs, power saving by introduction of high efficiency oxygen plants, fuel saving by expanded application of regenerative burners, effective utilization of unused energy by development of a next-generation burner which makes it possible to use many kinds of fuels with greatly differing heat values, study of low temperature waste heat recovery, etc., and furthermore, by promoting the development of nextgeneration steel manufacturing technologies.

JFE Steel is also studying measures to prevent global warming from new viewpoints which envision cooperation between companies to realize rational energy utilization in the system as a whole through cooperation between JFE Steel and neighboring companies.

4. Environmental Conservation Efforts

4.1 Efforts to Date

Learning from the pollution problems which it experienced in the 1960s during the era of high economic growth, Japan strengthened its efforts to protect the

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		Sintering	Waste gas	Desulfurization equipment			
Works D	District	plant number	volume (m ³ /min)	Treating method	Start of operation	Desulfurization efficiency (%)	Notes
East Japan Chi Works Kei	Chiba	No.4	16 000	Lime gypsum method	Dec. '76	> 90	Denitrification equipment is furnished. Dioxin is treated with this equipment.
	Keihin	No.1	23 000	Ammonia absorption method	Sept. '76	> 90	Denitrification equipment is furnished. Dioxin is treated with this equipment.
Weat Japan Works		No.2	21 000	Magnesium hydroxide method	July '75	> 90	
	Kurashiki	No.3	27 000	Magnesium hydroxide method	Nov. '74	> 90	Wet EP is furnished in Nov. '02. Dioxin is treated with this equipment.
		No.4	42 000	Magnesium hydroxide method	Nov. '74	> 90	Wet EP is furnished in Nov. '02. Dioxin is treated with this equipment.
	Fukuyama	No.4 No.5	36 000 50 000	Activated coke method Activated coke method	Nov. '01 Mar. '02	> 80 > 80	Dioxin is treated with this equipment. Dioxin is treated with this equipment.

Table 2 Sinter waste gas treating equipments in JFE Steel

environment based on the establishment of environmental laws by the national government. In 1967, when the Basic Law for Environmental Pollution Control was enacted, JFE Steel established environmental control sections in its head office and steel works, and since that time, has actively promoted the development and introduction of pollution prevention technologies to reduce environmental loads accompanying its business operations.

On the subject of air pollution, JFE Steel has made efforts to reduce SOx, NOx, and dust using desulfurization technology for coke oven gas, which is a byproduct in the steel works⁶, desulfurization and denitrification technologies for sintering plant flue gas, low NOx burners⁷, and dust collecting technologies⁸. As one example, **Table 2** shows the condition of installation of sintering plant flue gas treatment equipment at each of the districts of JFE Steel's works. By implementing appropriate equipment measures corresponding to the conditions of the local atmospheric environment, SOx emissions have been reduced to approximately 1/9 (**Fig. 3**) and NOx emissions have been reduced to less than half (**Fig. 4**) those in 1973, before measures were implemented.

For water quality, JFE Steel has implemented water treatment measures corresponding to the properties of the wastewater (metal ions, SS content, oil content, etc.), including coagulation, sedimentation, filtration, and pH adjustment. These technologies include coke oven wastewater treatment technology⁹, COD countermeasures by treatment technology for oil-bearing wastewater from the cold rolling process, and nitrogen countermeasures by recovery of waste nitric acid from stainless steel pickling using an ion exchange resin method. As one example, **Fig. 5** shows the trend in the reduction of COD at East Japan Works (Chiba). In comparison with 1973, COD has been reduced to approximately 40%.

These efforts respond to the legal and regulatory system from the viewpoint of pollution prevention. The results mentioned above have been achieved by



Fig.3 Trend of SOx emission





development/introduction of countermeasure technologies to meet strict regulatory values.

4.2 Current and Future Efforts

The environmental problems of recent years have included some which also have an aspect of being

widely recognized by the general public as matters which directly affect people themselves. For example, while a diverse range of substances are used in society, as in the case of chemical substances, there are still some substances whose risk in the environment has not been clarified. Therefore, in 2002, the PRTR system was introduced, requiring that businesses identify and report the quantities of releases and transfers of these chemical substance to the national government, and there has been heightened public concern about chemical substances.

JFE Steel was quick to respond to these social changes, and has made voluntary efforts to actively reduce environmental risk by taking measures that anticipate problems from the viewpoint of preventing harm before it occurs. The basic policy for these voluntary measures is to implement reduction measures on a priority basis, beginning with the substances with higher toxicity and larger release amounts among the various chemical substances which the company handles. For example, JFE Steel is steadily reducing dioxins and benzene by the following measures.

For dioxins released from the sintering process, the company reduced dioxin emissions by installing a wettype electrostatic precipitator (EP) at West Japan Works (Kurashiki) in 2002 as a sintering flue gas treatment process, and is now expanding the wet-type EP to further reduce dioxin emissions. Fukuyama District of the same works introduced activated coke equipment (**Fig. 6**) in 2002 in order to reduce both dioxin emissions and SOx emissions. As a result of these measures, releases of dioxins by JFE Steel have been reduced by more than half, from 26 g-TEQ in fiscal year 2001 to 12 g-TEQ in FY2003.

As benzene countermeasures, fully-sealed systems have been introduced at coke ovens and chemical treatment plants, which are the main sources of emissions, while measures to remove benzene emissions by suction/



Fig.6 Flue gas treatment with activated coke method

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combustion of gas leaks have been adopted in hard-toseal places. An example of a benzene removal system using a catalytic combustion process at East Japan Works (Chiba) is shown in **Fig. 7**. As a result, JFE Steel's benzene emissions were reduced by more than 50%, from 127 t in FY2001 to 57 t in FY2003.

In recent years, with rapid urbanization of areas surrounding steel works, environmental protection for coexistence with the local community has also become increasingly important. JFE Steel is devoting great effort to environmental measures suitable for urban-type steel works by strengthening dust countermeasures, for example, by expanding and improving its dust collectors and introducing a laser dust monitoring system (**Fig. 8**)¹⁰. In the future, JFE Steel plans to promote environmental protection in its steel works by compliance with the regulatory system and voluntary efforts.



Main component	Catalyst support	Cordierite
Main component	Active metal	Palladium
Operating tempera	ture (maximum)	650°C
Unit size		$150 \times 150 \times 50 \text{ mm}$

Fig.7 Catalytic combustion equipment



Laser	Nd: YAG		
Wavelength	355 nm		
Measurement range	150–3 000 m		
Horizontal scanning angle	±160°		
Horizontal scanning velocity	$0.1 - 0.6^{\circ} s^{-1}$		
Vertical scanning angle	$1^{\circ} \pm 1^{\circ}$		

Fig.8 Schematic view and specification of dust monitoring system

5. Efforts to Create a Recycling-oriented Society

5.1 Zero Emissions Activities in Steel Works (Activities and Results to Date)

The resource recycling flow in JFE Steel in FY2003 is shown in **Fig. 9**. JFE Steel generates 15.6 million tons of byproducts annually. More than 99% of these byproducts are recycled by recycling in the works or by use in society. In the breakdown of byproducts, slag accounts for an overwhelming percentage of 77%. As recycling technologies for slag have been reported elsewhere¹¹, this chapter will describe Zero Emissions efforts for dust and sludge, which account for the next largest percentage (total: 22%) following slag.

JFE Steel promotes recycling under three basic policies: (1) reduction of amounts generated, (2) maximum possible recycling in the works, and (3) use as resources through cooperation with other industries outside the works.

5.1.1 Reduction and promotion of recycling in steel works

(1) Dust Recycling

Dust recycling includes the long-used method of recycling the iron component to the sintering process. JFE Steel also developed the STAR reactor (coke packed bed-type smelting reduction process)¹²) as a recycling technology for stainless steel dust, which contains Cr and Ni, making it possible to separate dust into its individual components for recycling.

Figure 10 shows the hot cyclone system, which reduces steelmaking dust generated by the BOF in the stainless steelmaking process. Among the generated dust, that with a comparatively coarse size is captured near the top of the BOF and returned to the BOF while still at high temperature. This not only reduces dust generation by more than 25%, but also makes it possible to eliminate the conventional dust treatment



Fig.9 Resources recycling flow in JFE Steel (2003FY)



Fig. 10 Hot cyclone system

process. Because dust oxidation is avoided, it also contributes to energy saving.

For recycling of other types of Fe-bearing dust, JFE Steel has developed a technology for using oxidized dust in hot metal pretreatment (use in desiliconizing iron oxides) and a technology for using dust containing metallic iron in the steelmaking process (efficient use of metal). Thus, JFE Steel has established recycling technologies matched to the properties of the dust concerned.

(2) Sludge Recycling

- (a) Reduction of coating wastewater sludge
 - JFE Steel developed technology for reducing the generation of sludge and materialized this technology in equipment. In the treatment of plating wastewater, JFE Steel uses a precipitation/ separation process in which the wastewater is neutralized and dissolved metals are precipitated out as solid hydroxides (sludge). Because this sludge is highly hydrophilic, with the conventional technology, the water content could only be reduced to approximately 75%, even when pressed under strong pressure. This resulted in the generation of sludge with 4 times the dry weight of the solid content. In contrast, with the new method shown in Fig. 11, sludge properties are improved, making it possible to reduce the water content after dehydration to about 50%, thereby reducing sludge generation to 1/2 that with the conventional method.
- (b) Use of sludge as hot metal pretreatment material JFE Steel developed a recycling method for sludge which was difficult to use as a raw material. Because the sludge generated in the stainless steel sheet rolling process contains Cr, use as a material in the blast furnace is subject to restrictions, as it would affect the composition of ordinary carbon steel products. On the other hand, because the material is extremely fine, use in the BOF is also difficult, as it scatters easily. JFE Steel solved this problem by developing a technology

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Fig.11 Sludge reducing waste water treatment method (High density solid method)



Fig. 12 Flow of sludge recycling in hot metal pretreatment

for using stainless sludge as a material in the hot metal pretreatment process, which is an intermediate process between the blast furnace and BOF, and installed the equipment shown in **Fig. 12** (sludge drying equipment capacity: 16 000 t/y). With the hot metal pretreatment equipment, there are no composition-related restrictions because the sludge is used in hot metal for stainless steel products, and scattering is not a problem because the powder is injected into the hot metal. Moreover, the components of the sludge also act effectively as a treatment agent.

5.1.2 Recycling in cooperation with local society and other industries

Because the steel manufacturing process has great potential for recycling, it is important to promote recycling through mutual cooperation between the steel works and local society and other industries while demonstrating that potential.

JFE Steel's recycling technologies are contributing to recycling various substances generated by society, beginning with waste plastics. JFE Steel's recycling technologies and businesses, and the Eco Town Project which



Fig. 13 LCA of HF/HNO3 mixed acid cascade use

the company is promoting with local communities, are described in detail in a report mentioned in the references¹³⁾. Here, therefore, **Fig. 13** shows the results of a life cycle assessment (LCA) of a example of cascade use of mixed waste acid generated by a semiconductor maker in the stainless steel pickling line at JFE Steel's works, together with the effects achieved¹⁴⁾.

5.2 Future Efforts

As described above, JFE Steel has implemented zero emissions activities and is achieving steady results. Nevertheless, many problems still arise in recycling as resources as the recycling ratio increases. Depending on the constituent contained, recycling in the steel works may be difficult (e.g., Cl, Zn, etc. which hinder blast furnace operation). Moreover, there are cases where the cost of recycling far exceeds the value as raw material, and also cases where recycling increases environmental loads such as energy consumption. Accordingly, future efforts to create a recycling-oriented society will demand changes in the manufacturing process itself and technical development which contributes to both recycling and energy saving.

From this viewpoint, JFE Steel is conducting technical development including (1) research and development for recovery of acid from the waste acid discharged by stainless steel pickling lines and recycling use as a pickling agent, (2) applied research on the Hi-QIP type rotating bed furnace, which is under development as a new steel manufacturing process for dust and sludge containing Zn, which had been subject to quantitative restrictions on recycling due to its harmful effect on blast furnace operation.

In the future, JFE Steel will continue to play a key role in the creation of a recycling-oriented society through the development of technologies for recycling in the steel works and cooperation with local society and other industries.

6. Conclusion

As many environmental problems, such as global warming, have grown from single regions to the global scale, the role of the steel works can no longer be limited to supplying environment-friendly steel products which contribute to reducing environmental loads in society, but also must include serving as the base for a regional industrial complex which utilizes the environmental/ energy technologies and potential of the steel manufacturing process.

Further, in the future, JFE Steel will continue to play a responsible role as a good citizen in society as a whole, the industrial complexes where it operates, and the local community. As such, JFE Steel will promote energy saving which contributes to the prevention of global warming, tackle continuously, flexibly, and tenaciously reduction/improvement of environmental loads, and contribute to realizing a society which is capable of sustained development.

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