

Lecture No. 3-4

## Recent trend in the usage of recovered heat energy arising from cupola melting practice in Japan with an example of latest foundry plant

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### SUMMARY

Gradually increasing concern toward energy saving and environmental conservation has made the Japanese foundry industry to adopt the new technology for making full use of waste heat energy of cupola melting operation. The technology is based upon the one developed by Würz GmbH Germany, and modified in a fashion unique to each foundry. The detailed operating procedure and substantially favorable performance obtained are illustrated. All the foundries exemplified including the latest state-of-the-art one are enjoying great advantages attained by introduction of this technology which has not been brought into operation in Japan until now.

### KEYWORDS

usage of recovered heat energy

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## 1. INTRODUCTION

T. Ishino et al. have reported on the progress of the development of cupola melting technology and related system technologies in Japan. [1]-[4]

Now that we have entered the 21st century, recovering and utilizing waste heat from cupolas is of growing importance, and we will discuss this issue by describing some recovery systems in use in Japan, their efficiency, and future trends.

In addition to waste heat recovery systems in Japan, we will also describe an advanced greenfield foundry that began operating in 2000 but is a fitting plant for the 21st century.

## 2. WASTE HEAT RECOVERY, PAST AND PRESENT

It is a known fact that increasing the hot blast temperature in a cupola furnace increases melting efficiency, increases hot metal temperature, reduces coke ratio and improves material quality. [5]-[8] Early attempts to use cupola waste heat to preheat blast air centered mainly around the use of sensible heat, as typified by Cameron's hot blast furnace of in the 1830s in which a wind box was embedded in the furnace wall lining. However, as cupola furnaces grew in size, the principle was changed to one which utilizes the latent heat of combustion by leading the exhaust gas to a heat exchanger installed separately. Such systems as the multiple pipe system of Griffin-Weel (USA) and Dr. Schack (Germany), and the dual piping structure of Escher (Australia) and GHW (Germany), which comprise steel pipes and make use of radiation and convection for heat exchange, came into use. In Japan, K. Ishikawa made a detailed report [9] in 1940 about the structure of a cupola with a multi-pipe heat exchanger and the effect of hot blast temperature on the material properties.

However, all these systems have drawbacks in relation to the durability of the system and its maintenance, and the hot blast temperature is limited up to ca. 500 °C. Because increasing the blast temperature has a significantly favorable effect, steps were taken to create a system with greater durability, easier maintenance, greater heat recovery rate, and more ways for using the recovered heat for purposes other than preheating the blast.

As a system that conformed to this purpose, we tried to apply in Japanese foundries: (1) a heat exchanger using ceramic pellets as the heat transfer medium, or (2) a heat exchanger system with compact units and a reduced installation area, that recovers the exhaust heat for use for other purposes. Efforts were made to adapt these systems for domestic foundries by modifying various details, and they have been installed in several automotive parts casting and cast iron pipe manufacturing plants with successful results.

## 3. HEAT EXCHANGERS USING CERAMIC PELLETS AS HEAT TRANSFER MEDIUM

E. Murata, et al. gave a presentation [10] at the second AFS Cupola Conference in 1998 about the examples of the operation of this type of the system, used at the foundry of Company A (in Fukushima Pref.) for a 15t/h liningless cupola [11]. A flow diagram of the system is shown in Fig. 1.



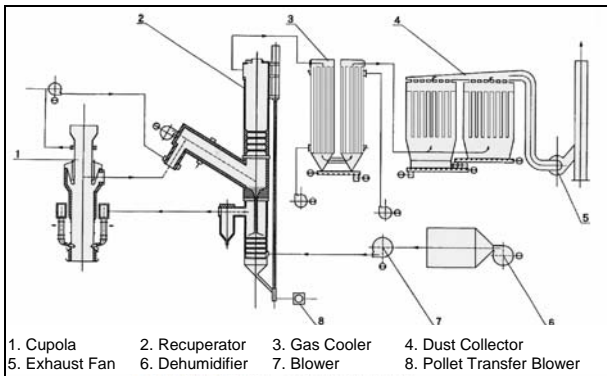


Figure <1> System diagram (company A)

Fig. 2 shows the heat balance of the entire system. As is shown in this figure, nearly 50% of the total amount of the heat energy carried away in the exhaust gas can be recovered. Final heat efficiency is 42.9%, CO<sub>2</sub> gas emissions are as low as 160 Nm<sup>3</sup> per ton of molten iron due to the effects of the increased hot blast temperature and decreased coke ratio, which is a reduction by 50% compared with cold blast (40°C) operation. The same type of system is also being successfully operated at Company B [12] (in Iwate Pref., 15t/h liningless cupola), Company C (in Iwate Pref., 20t/h liningless cupola installed in 1996) and Company D (in Hyogo Pref., 60t/h liningless cupola) in Japan.

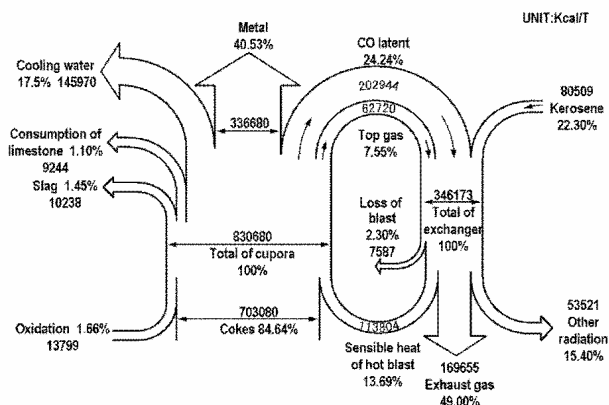


Figure <2> Thermal balance of cupola-recuperator system (company A)

#### 4. HORIZONTAL UNIT TYPE, HIGH-EFFICIENCY HEAT EXCHANGERS

In a new type of heat exchanger developed by Würz GmbH in Germany, horizontal unit recuperators and a gas cooler are incorporated in one tower, and the lower temperature exhaust gas heat, after preheating blast air, is absorbed by thermal oil to be used for various applications. This system is a highly efficient way to recover waste heat energy, and is very attractive for Japanese foundries. The structure is shown in Fig. 3.

Five of these systems are currently being operated in Japan ; Company E in Saitama Pref. (25t/h liningless cupola, installed in 2000), Company F in Mie Pref. [13] (18t/h liningless cupola, installed in 2001), Company G in Aichi Pref. (16t/h liningless cupola, installed in 2001), Company H in Niigata Pref. (18t/h liningless cupola, installed in 2003), and Company I in Osaka Pref. (40t/h liningless cupola, installed in 2003).

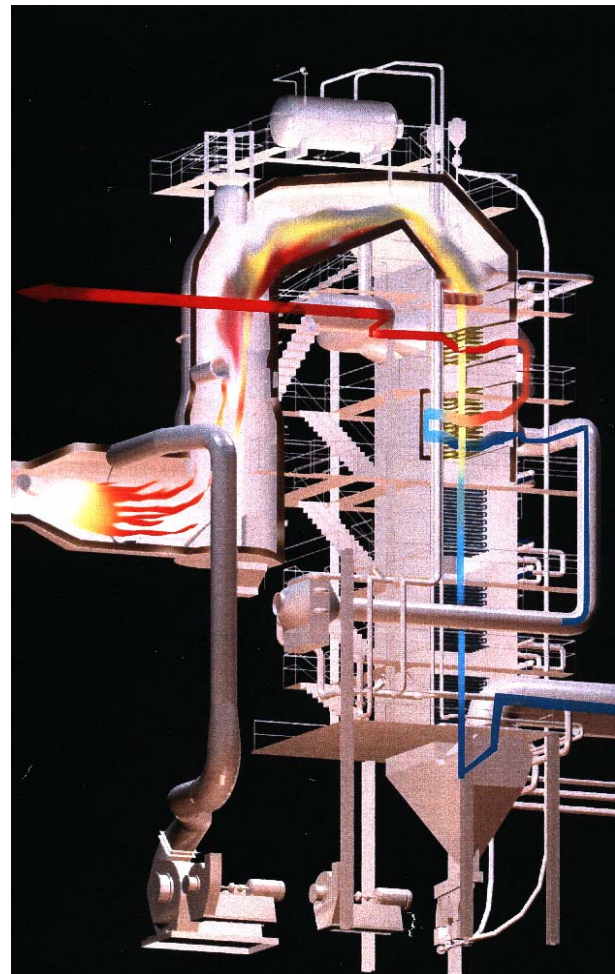


Figure <3> Structure of Würz Type Heat Exchanger

Company E (NIPPON CHUTETSUKAN K.K.) mainly produces ductile cast iron pipe. It was the first company in Japan to introduce this type of system, and it is utilizing the exhaust gas energy most efficiently. The system flow of its plant is shown in Fig. 4[14].

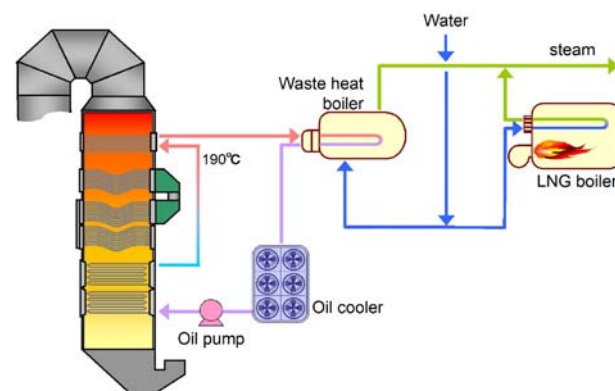


Figure <4> Waste heat recovery system (company E)

In the upper part of tower, there is a blast air bundle that preheats the blast air. The blast air is heated to around 600 °C and conveyed to the cupola tuyeres. Above and below the blast air bundle, there is an oil bundle in which thermal oil absorbs the heat. The oil is circulated at the rate of 240 Nm<sup>3</sup>/h inside the bundle tubes, is heated to 210~240 °C at the heat exchanger outlet, and is sent to a (steam) boiler. The heat from the boiler is



fed to the workshop as the source for heating the curing water, which has reduced or almost eliminated the use of conventional LNG boiler. The heat balance obtained after the installation of this system is shown in Fig. 5.

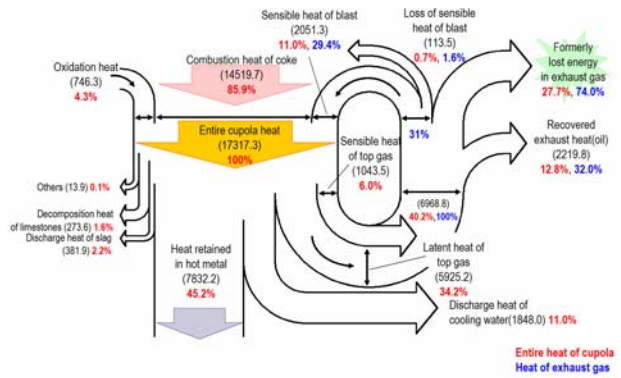


Figure <5> Heat balance of the cupola after installing Würz system (company E)

Before installation of this system, only 26% of total exhaust gas energy was recovered. The figure shows, 31% of the energy is used to increase the blast temperature, and 32% is recovered by the thermal oil, which means that exhaust gas energy loss is only 37%, which is considered to be significantly efficacious. Fig. 6 shows how much discharge heat loss was reduced.

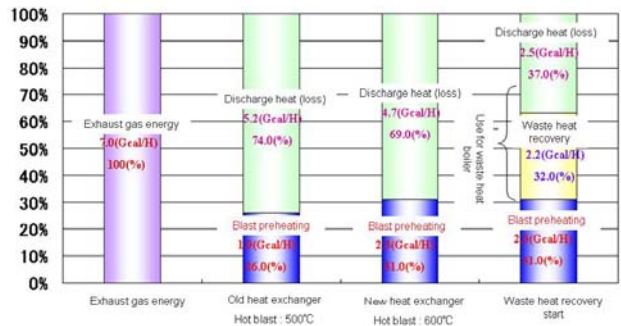


Figure <6> Utilization of exhaust gas energy (company E)

Company H also uses this type of heat exchanger system, and the planning is in progress by which, in order to utilize the exhaust gas heat energy more efficiently, the thermal oil that has absorbed the exhaust heat is not sent to a boiler, but is utilized directly.

Fig. 7 is a diagram of this process and the energy balance. In this system, oil/air and oil/water heat exchange produces warm air (150 °C) and hot water (95 °C). The air is used to preheat the combustion air, and dehumidify the cupola blast. The water is used as warm water for air conditioning. As a result of the installation of this new heat exchanger system, 32.4% of the exhaust gas heat can be used directly for cupola blast preheating, and 36.7% can be recovered through thermal oil heat exchange and put to various uses.

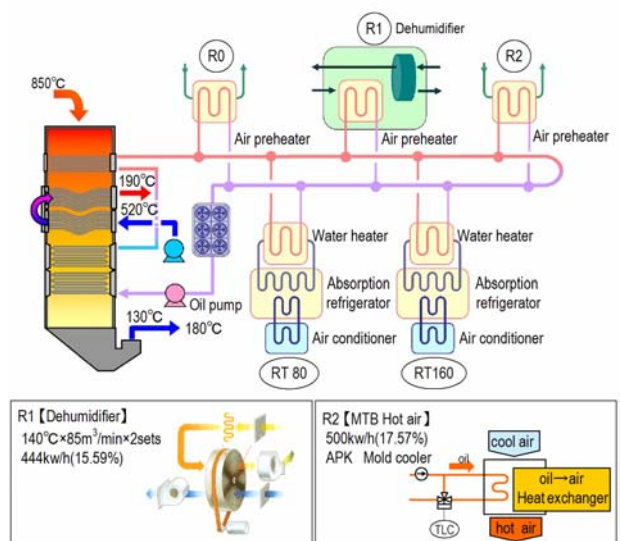


Figure <7> The scheme of waste heat energy application (company H)

At Company G, studies on how to make the most effective use of heat energy recovered by thermal oil are now under way, and the targets are recovering 35.3% of exhaust heat for hot blast, and reducing exhaust gas energy loss to 15% by means of heat recovery by thermal oil. This plant is described in detail below.

5. STATE-OF-THE-ART FOUNDRY (COMPANY G)

5-1 FEATURES

The features of this plant are illustrated in Fig. 8. The company (TOYOTA INDUSTRIES CORPORATION) wanted to establish a human- and earth- friendly environment based on well-thought-out-plan and careful consideration for others, so it introduced a rational plant structure, ideal working conditions, and environmental equipment.

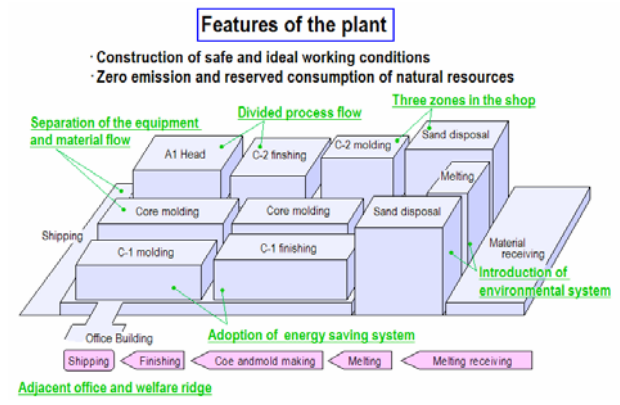


Figure <8> Features of the plant (Company G)

The main products of this plant are shown in Fig. 9. The total production amounts to 5,800 tons per month, most of which is automotive parts or textile machinery parts.



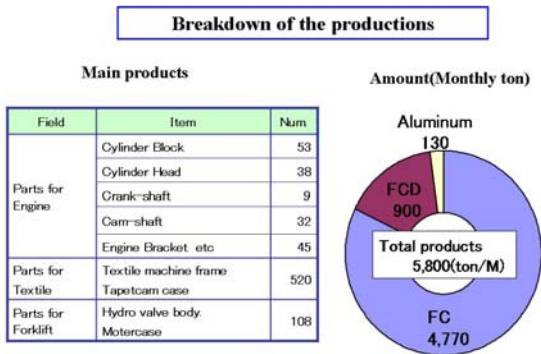


Figure <9> Main products of the plant (Company G)

The layout, shown in Fig. 10, is divided into three zones; materials yard, melting zone, and pouring zone.

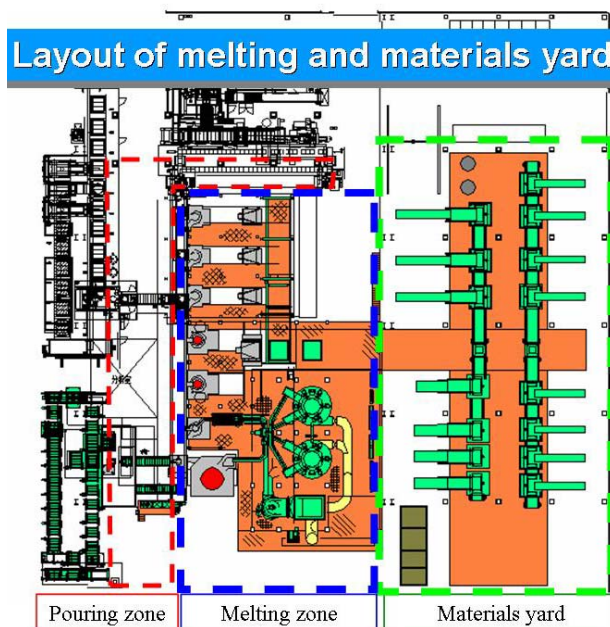


Figure <10> Layout of the plant (Company G)

5-2 MELTING PROCESS

- (1) Consistent handling of return materials  
By designating the material when charging, it can be fed into the relevant bunker automatically after crushing.
- (2) Through the integrated supply of materials for the cupolas and electric furnaces and transport with "green" vehicles, the materials are fed to two cupolas and five electric furnaces via a material hopper, oscillating conveyor, planning hopper, conveyor belt, and charging bucket. All the places where dust is generated are given a secondary dedusting.
- (3) The integration of the process flow allows molten metal to be supplied to three lines for different materials with flexibility by transfer crane.
- (4) Würz heat exchanger  
In order to control the components variation by maintaining

stable hot blast temperatures, Würz heat exchanger is used. The blast is supplied with a combustion gas temperature of 800 °C, and the hot blast to the wind box is 600 °C. To prevent a decrease in efficiency caused by the adherence of zinc powder on the pipes, a shot cleaning device is used as a very effective measure.

- (5) Dry slag treatment  
Instead of the conventional wet-type slag treatment, dry-type treatment using a slag conveyor is used to reduce the amount of discharge water. After the slag has solidified, it is sold as roadbed material.
- (6) Constant monitoring of cupola operation  
Over 36 items are monitored, and the operational data are stored to construct a database

5-3 ENVIRONMENTAL PRESERVATION MEASURES

As is shown in Fig. 11, the levels of emissions and solid waste generated by this new plant is significantly lower than at a conventional plant.

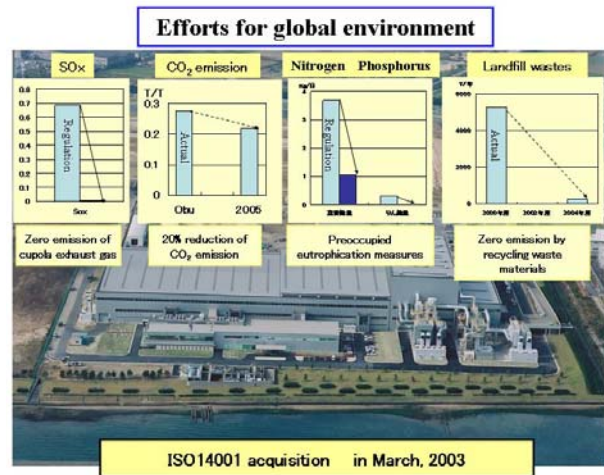


Figure <11> Environmental measures (Company G)

The goal of this company is to become the number one casting plant and to provide a production facility that is friendly to people and the environment.

6. SUMMARY

In this paper, we described two new systems : a heat exchanger system using ceramic pellets as the heat transfer medium, and a system with horizontal units incorporated to recover exhaust heat after heating the blast air that is compact and highly efficient.

(1) COMPARISON OF HEAT EXCHANGERS

Table 1 [15] lists the characteristic features of three types of heat exchanger ; the type using steel pipes for heat exchange by radiation and convection, the type using ceramic pellets as the heat transfer medium, and the type developed by Würz by which the lower temperature exhaust heat after heating the blast air is recovered and used for other purposes.

(2) HEAT EXCHANGER USING CERAMIC PELLETS AS HEAT TRANSFER MEDIUM

The system that uses ceramic pellets as the heat transfer medium makes it possible to apply the high temperature gas from the combustion chamber to heating the pellets without being cooled. So the blast air can be sent to the cupola sufficiently



heated to a higher temperature (600-650 °C). Secondly, it has the advantage of long-term durability due to the refractory structure. However, this system has several disadvantages such as (a) the initial investment is rather high, (b) the consumption of ceramic pellets is unexpectedly rapid and constant resupply is necessary, (c) and the periodic replacement of the tray and distributor is required.

Table <1> Comparison of three kinds of heat exchange systems

		Metal fin-tube type	Econo-therm type	Würz-type
Hot blast temp. (recuperator outlet)	°C	450~550	550~700	550~650
Exhaust gas temp. (recuperator inlet)	°C	700~750	800~950	650~800
Pressure loss (blast)	mmAg	150~200	150~300	200~300
Pressure loss (exhaust gas)	mmAg	50~100	50~80	50~100
Longevity	years	5~10	10~	10~15
Maintenance		Not possible	possible	possible
Consumables		None	Heat transfer medium	Steel shot ball

Furumiya et al. reported that measurements taken during operation revealed that cupola blast air has little to do with blast rate, but depends upon the circulation rate of the pellets [11]. This fact indicates that the higher the circulation rate, the larger the area of heat transfer, and therefore the higher the hot blast temperature will be. In this way, the features of this type of heat exchanger have clarified, and this system has been applied for purposes other than the recovery of cupola exhaust heat, such as for the incineration of general waste material.

### (3) HIGH-EFFICIENCY HORIZONTAL UNIT TYPE HEAT EXCHANGER

This system, based on that developed by Würz, has such advantages as (a) two units, one for preheating the blast air and the other for recovering exhaust heat by thermal oil heat transfer, are incorporated into one compact unit, and the high temperature gas sent from the combustion chamber can be cooled to about 120-200 °C through this unit, (b) the heat absorbed by the thermal oil can be widely utilized for purposes other than heating the blast air, (c) a shot blast cleaning device is operated periodically to prevent the dust contained in the exhaust gas from sticking to the surfaces of the equipment, (d) the system is being unitized, so the recovery capacity can be adjusted by changing the number of the units.

Regarding the application of the recovered heat for purposes other than heating the blast air, a number of uses can be feasible, such as the sources of heat for the workshop as applied by Company E, but also including the generation of steam for a laminated wood fabrication plant, the generation of electric power based on the generated steam [16]. The application for generating electric power may be somewhat unrealistic at this time considering the economy, but in the near future this process may be implemented on the basis of developed engineering, and this will enhance the heat recovery efficiency furthermore.

Japan has few natural energy resources, and we must continue to try to utilize to the fullest extent the input heat energy and to minimize the heat discharged with the exhaust gas.

The advanced foundry described in this paper exemplifies the direction we must take.

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