HYBRID WAY EAF OFF GAS HEAT RECOVERY -ECORECS-

BY

MASANARI YAMAZAKI*1, YASUHIRO SATO*2, RYUTARO SEKI*3

SYNOPSIS

JP Steel Plantech Co. has developed Hybrid system for EAF off-gas heat recovery, with EAF boiler and Waste Heat Recovery Boiler (WHRB) with duct burner installed in series to make the most of EAF off-gas heat available.

Off gas heat energy discharged from EAF accounts 40% of input energy. However this large amount of waste heat energy had not ever been reused for electric power generation due to its batch operation.

This system called ECORECS -ECOlogical and ECOnomical heat RECovery System of EAF- realizes constant superheated steam supply to power generator with minimum fuel consumption against EAF fluctuating operation.

Keywords: EAF, Heat Recovery, Boiler system, WHRB

*1 Manager, Senior Engineer, Ironmaking & Energy Recovery Plant Dept. - JP Steel Plantech Co., Yokohama, Japan
*2 Manager, Senior Engineer, Steel Making Plant Dept.- JP Steel Plantech Co., Yokohama, Japan
*3 Engineer, Ironmaking & Energy Recovery Plant Dept. - JP Steel Plantech Co., Yokohama, Japan

Introduction

Regarding off gas heat recovery, there were few examples of applying boiler system to Electric Arc Furnace for steelmaking. However, This technology has gained much attention for reducing greenhouse gas emissions and improving energy consumption.

We - JP Steel Plantech Co. has conducted feasibility studies about EAF off gas heat recovery from 2006, cooperating with several steelmaking companies. As a consequence of this activity, we found the patterned style of technology may not be adequate to EAF heat recovery, and we should apply the optimum heat recovery method for each EAF, considering the following points (a) to (e); (a) Energy balance of furnace, (b) Heat generation pattern on processing time, (c) Off gas components, (d) How to use recovered energy, (e) Construction time for changing the system. From these aspects, we could generally understand that scrap preheating system is suitable for scrap melting EAF, and heat recovery with boiler system for DRI melting EAF.

In this report, focusing on heat recovery from DRI EAF, We remark why Boiler system is applicable for DRI EAF. Then, we propose EAF boiler system based on OG system –Oxygen converter Gas recovery system- technology developed by us, and finally propose hybrid system with EAF boiler and WHRB that realizes constant superheated steam supply to power generator with minimum fuel consumption against EAF fluctuated operation. We call these systems proposed in this paper ECORECS- ECOlogical and ECOnomical heat RECovery System of EAF-.

Energy balance and Heat discharge pattern

Figure 1 shows typical energy balance for DRI melting EAF on the condition that the raw material is only DRI and charged into furnace at normal temperature. In this figure, Steelmaking energy of 470 kWh/ton (Steel 370 + Reduction 100) accounts only 45% of total input energy of 1050kWh/ton. And second after, off gas energy 430kWh/ton accounts 40% of input energy. Thus, we can understand the key point of energy recovery from EAF is to recover off gas energy as effectively as possible.

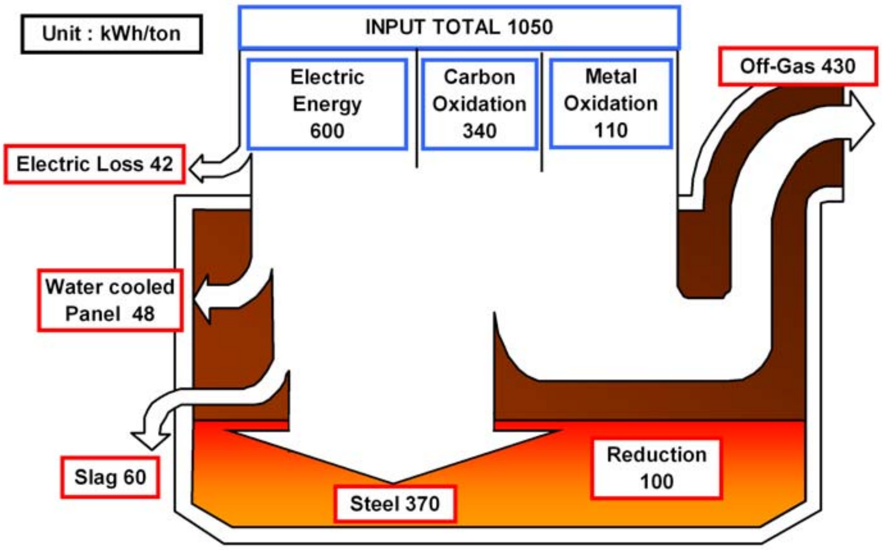
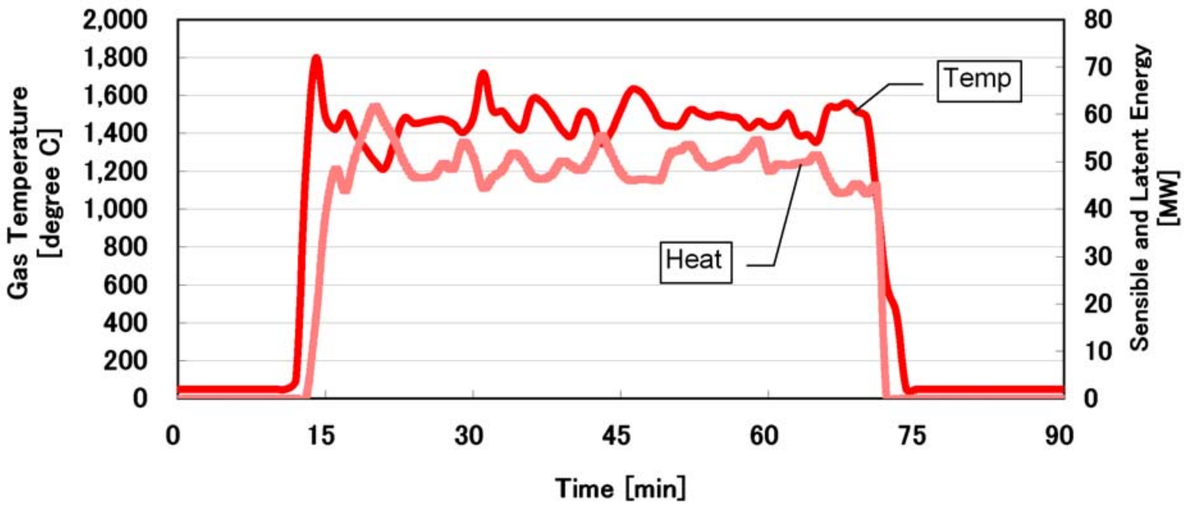


Figure 1. Typical energy balance of DRI melting EAF

Graph 1 shows gas temperature and heat quantity pattern at EAF elbow. DRI is fed to furnace continuously. This graph indicates generated heat and gas temperature of EAF operation during Tap to Tap. The heat generation pattern transitions between 45MW to 55MW, and it doesn't fall down lower than these range. The reason why it keeps stable pattern is that the roof isn't opened for material charging, DRI is charged continuously and off gas always passes through the gas duct during the operation, unlike Scrap melting EAF operation.



Graph 1.　Gas temperature and heat quantity at elbow of DRI melting EAF

From the factor that off gas energy accounts 40% of input energy and the heat pattern is stable during the operation, Boiler system at off gas duct is the best choice for heat recovery. Boiler system is designed at most plausible operating condition. As the heat pattern keeps stable nearly at maximum level, the boiler system functions effectively.

To generate saturated steam from Boiler system

Figure 2 shows the configuration of boiler system for DRI EAF. Boiler is integrated into main duct fabricated by membrane tubular walls and accumulator equalizes the fluctuation of steam flow supply. This system concept fundamentally follows to OG boiler configuration (OG is the converter gas recovery system of our brand).

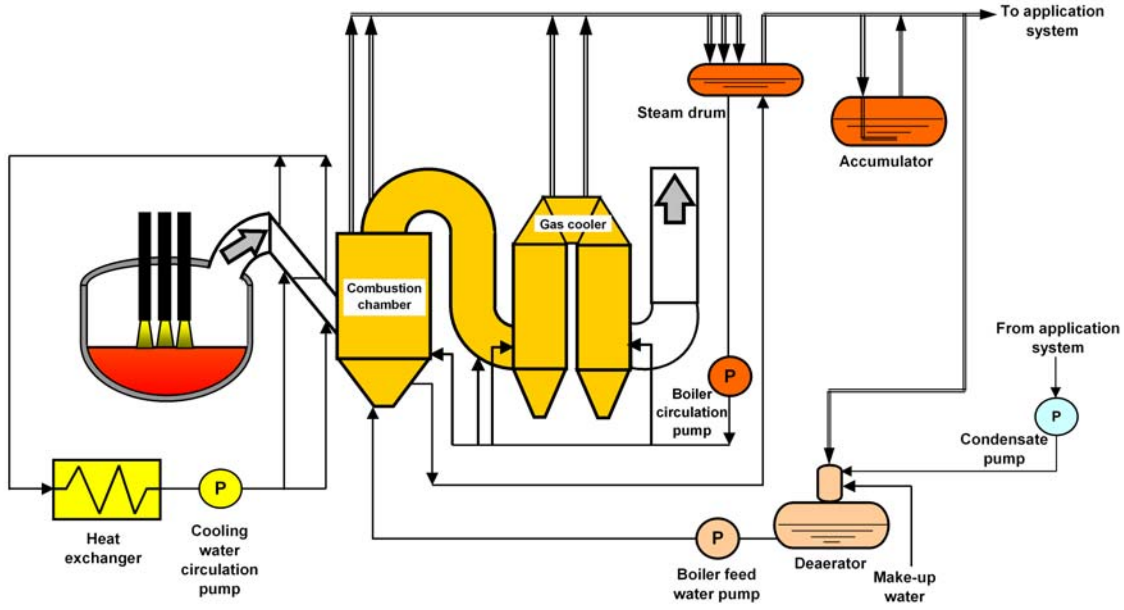


Figure 2. Configuration of boiler system for off gas heat recovery

As the gas duct between elbow and combustion chamber is moving part, it is integrated into closed circulation system separately provided from the boiler system. The boiler system is composed of Deaerator, Steam drum, Boiler type gas cooler (combustion chamber and gas cooler), Accumulator, Feed water pump and Boiler circulation pump. Feed water deaerated in Deaerator is pumped up to Steam drum by Feed water pump. The water circulates into Boiler type gas cooler by Boiler circulation pump. Absorbing Off gas heat at inner surface of gas cooler, the water partially changes to saturated steam, and then, the water with steam returns to Steam drum. In Steam drum, saturated steam and saturated water are separated. The water re-circulates between Steam drum and Boiler type gas cooler. The steam goes to steam network for plant facilities use through Accumulator that equalizes the fluctuation of steam flow rate.

This boiler system is designed to run on maximum pressure of 4.1MPa and maximum temperature of 253 degrees C as design standards. This running condition is considered of facilities and cost efficiency.

Saturated steam of 180kg/(h·t-steel) can be generated at EAF boiler system in the conditions of Figure 3. Utilizing this steam to power plant, the electricity of 17.5kWh/t-steel is generated at back pressure turbine.

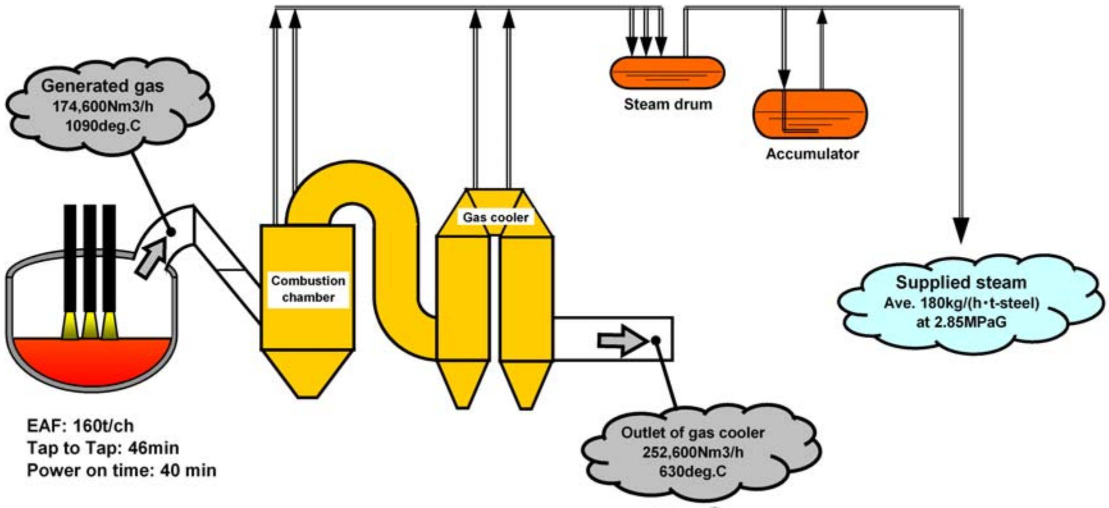


Figure 3. Case study for calculating generated steam

To generate superheated steam from Boiler system

In this chapter, we propose hybrid system with EAF boiler and WHRB.

In case of EAF boiler system, off gas discharged from furnace is cooled to 600 degrees C at radiation heating surface of gas cooler. Spray tower or air taking port is located in series to gas cooler to cool gas below 600 degrees C. Since absorption of heat by radiation varies directly with fourth power of gas temperature and is not effective on lower temperature condition, it is more effective to apply the spray water or air taking system for cooling gas below 600 degrees C.

But it is wasteful to throw away the gas heat by direct evaporation cooling or mixing with air. For utilizing this surplus heat, Waste Heat Recovery Boiler

(WHRB) is installed after EAF boiler. WHRB is composed of super heater, generator, and economizer which functions as convection heat transfer surface, and it is located as shown in Figure 4.

The first, super heater is located after gas cooler. Absorbing the surplus heat of off gas from gas cooler, saturated steam that is generated at gas cooler and equalized at ACC changes to super heated steam and it is supplied to power generator. The second, generator of WHRB is located after super heater, and it also generates saturated steam by absorbing the surplus heat after super heater. The amount of super heated steam increases by combining the steam from ACC with the steam generated at WHRB generator. The third, economizer is located after WHRB generator, and the feed water for generator is preheated in it.

Waste heat of off gas can be recovered to the utmost limit for arranging these equipments like described above.

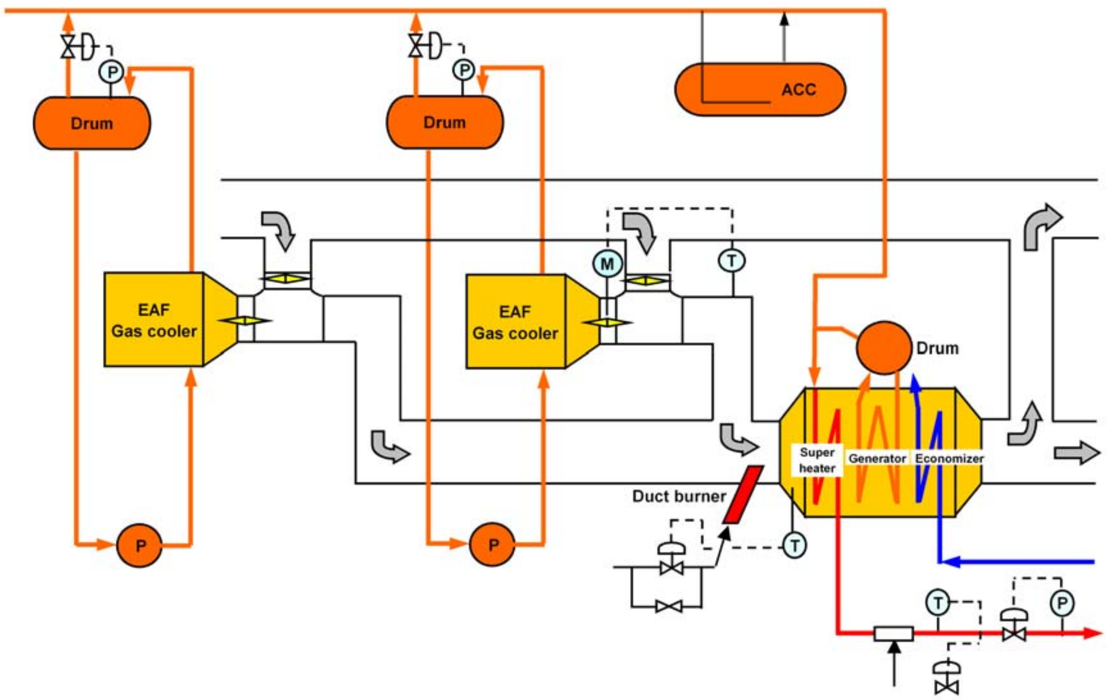


Figure 4. Configuration of WHRB

The spray tower or air taking port located after gas cooler can be removed by applying WHRB. The outlet temperature of WHRB is estimated at approximately 210 degrees C, combining with the gas from secondary de-dusting system, the gas temperature is equalized from 120 to 130 degrees C. And also, as gas volume is reduced by heat exchange at WHRB, it is possible to downsize the bag filter.

Provision against EAF intermittent operation

The biggest problem we concerned about is EAF intermittent operation. In case of applying boiler system that generates saturated steam, equalizing the fluctuation of steam flow at accumulator, continuous steam supply can be realized although EAF has intermittent operation. But, the superheated steam cannot be accumulated even in case of hybrid system with EAF boiler and WHRB. Thus, the countermeasure to realize constant and continuous steam supply must be taken for applying the recovered energy to power plant. We developed 2 ways to resolve this problem.

The fist way is to apply duct burner before super heater. As shown in Figure 5, when high calorific gas doesn't goes to super heater at power off time such as tapping, the heat to generate super heated steam is supplied from duct burner. If the works have a DRI plant, natural gas (NG) can be used as the fuel for duct burner.

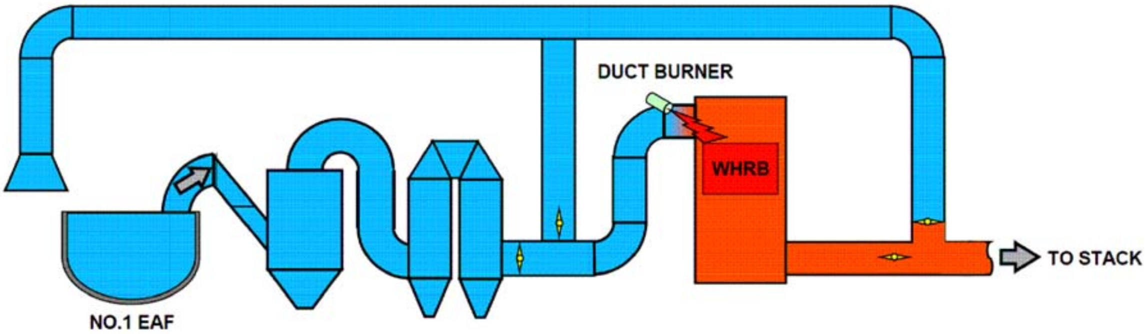


Figure 5. Operating method –1 for WHRB

The second way is to provide common WHRB by combining furnace and prevent cool gas from flowing into WHRB. As shown in Figure 6, open-shut dampers are provided at the end of each furnace gas cooler so that hot gas always goes to super heater by opening the damper that is installed in operating furnace and closing the damper that is installed in non-operating furnace. If the operations of each furnace are integrated into a whole operation, the super heated steam can be generated at WHRB.

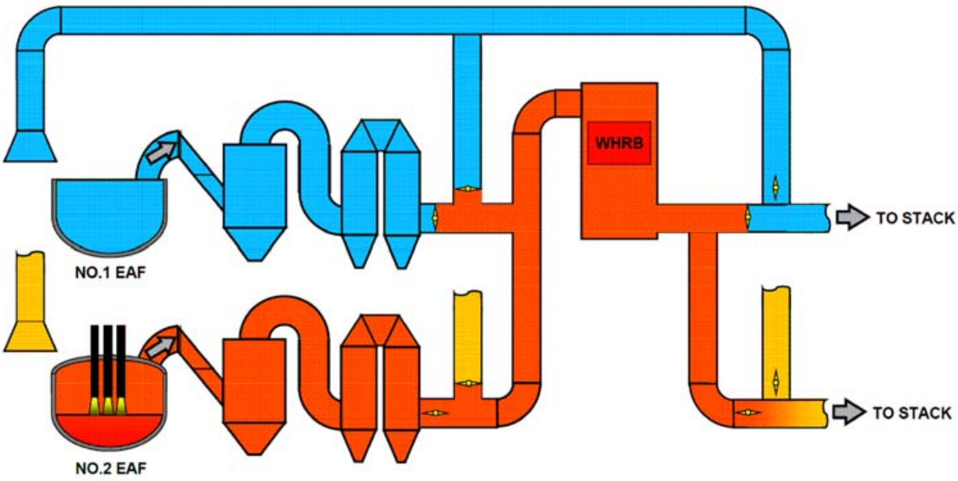


Figure 6. Operating method –2 for WHRB

Super heated steam of 530kg/(h · t-steel) can be generated at EAF boiler system in the conditions of Figure 7. Utilizing this steam, steam turbine always generates 95kWh/ t-steel of electricity on the suggested condition.

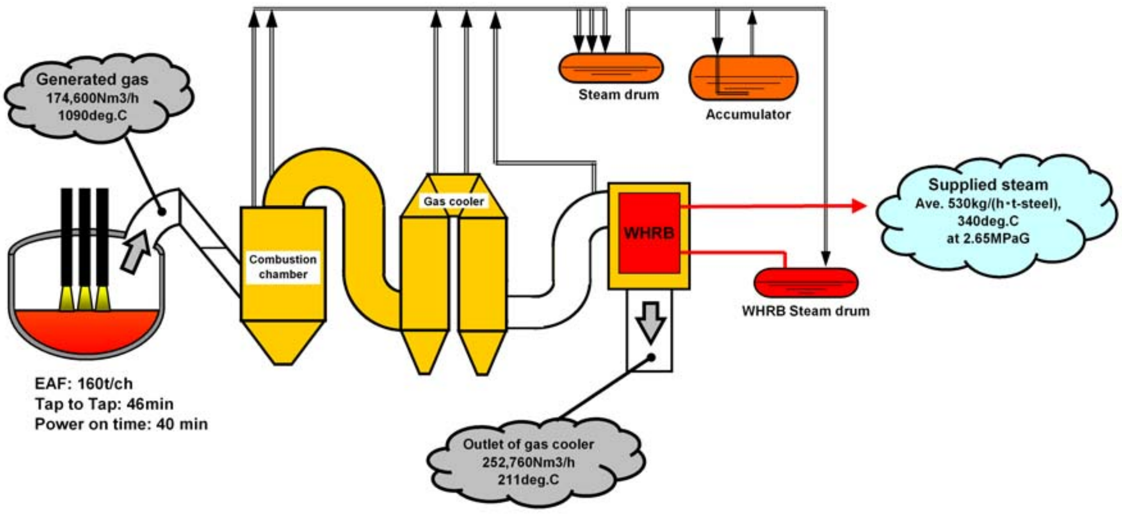


Figure 7. Case study for calculating generated steam for WHRB

Case study of applying steam to Power generator for each EAF run is finalized into Chart 1. Three cases are described in this chart. As the flow rate of NG consumption is varied according to interval time of EAF operation, the flow rate in this chart should be apprehended for reference.

Chart 1. Case study of applying steam to Power generator

	1 EAF run	2 EAF run	3 EAF run
EAF Specification			
Furnace size	160 t/ch		
Operating condition	Power on	1Power on / 1Power off	2Power on / 1Power off
Tap to tap	49 min		
Power on time	40 min		
Off gas conditon			
Flow rate	252,756 Nm3/h	511,210 Nm3/h	631,680 Nm3/h
Temperature	634 deg.C	621 deg.C	519 deg.C
Generated steam at EAF boiler			
Flow rate	31.3t/h	62.6t/h	93.9t/h
Temperature	233 deg.C	233 deg.C	233 deg.C
Pressure	2.85MPa	2.85MPa	2.85MPa
Steam condition at outlet of WHRB			
Flow rate	84.3t/h	158.5t/h	168.4t/h
Temperature	340 deg.C	340 deg.C	340 deg.C
Pressure	2.75MPa	2.75MPa	2.75MPa
WHRB specification			
Qty.	1	1	1
Type	Indipendent type with duct burner		
	(Consist of Super heater, Forced circuration boiler and Economizer)		
Dimension	4,700 x 4000 x 21,810	4,600 x 4,000 x 24,470	6,700 x 4,000 x 23,050
NG consumption			
Flow rate	Ave. 868 Nm3/h	Ave. 865 Nm3/h	Ave. 1555 Nm3/h
Power generator specification			
Steam turbine type	Condensing extraction turbine		
Qty.	1	1	1
Turbine inlet			
Flow rate	84.3t/h	158.5t/h	168.4t/h
Pressure	2.65MPa	2.65MPa	2.65MPa
Temperature	335 deg.C	340 deg.C	340 deg.C
Turbine outlet			
Pressure	11.9kPa	11.9kPa	11.9kPa
Temperature	50 deg.C	50 deg.C	50 deg.C
Extraction specification			
Flow rate	7.1t/h	15.8t/h	16.8t/h
Pressure	0.9MPa	0.9MPa	0.9MPa
Output from turbine	15.3MWh at power on	33.2MWh at power on	42.3MWh at power on
	14.1MWh at power off	30.7MWh at power off	33.3MWh at power off
	Ave. 15.1MWh	Ave. 32.2MWh	Ave. 36.9MWh

Capability of applying boiler system into Scrap EAF

The boiler system also has possibility of being applied into scrap melting EAF. As was mentioned at beginning, we should also concern about heat pattern and components of off gas when we apply heat recovery system into Scrap melting EAF.

The points to be taken for Scarp melting EAF are heat pattern that is fluctuating during operation, and hydrochloric & sulfuric corrosion. Heat recovery is possible although the efficiency is low due to fluctuation operation. And we can prevent the corrosion by maintaining steel wall at non-corrosion temperature range.

Taking these countermeasures, the boiler system can be applied in scrap melting EAF, when it is preferred.

Summary

As mentioned in the opening sentence, the patterned style of technology may not be adequate to EAF heat recovery. We should apply the optimum heat recovery method for each EAF, considering the off gas condition.

To realize Ecological and economical heat recovery, we have studied how to utilize saturated steam or superheated steam to works so that we could advise as need arises from client.

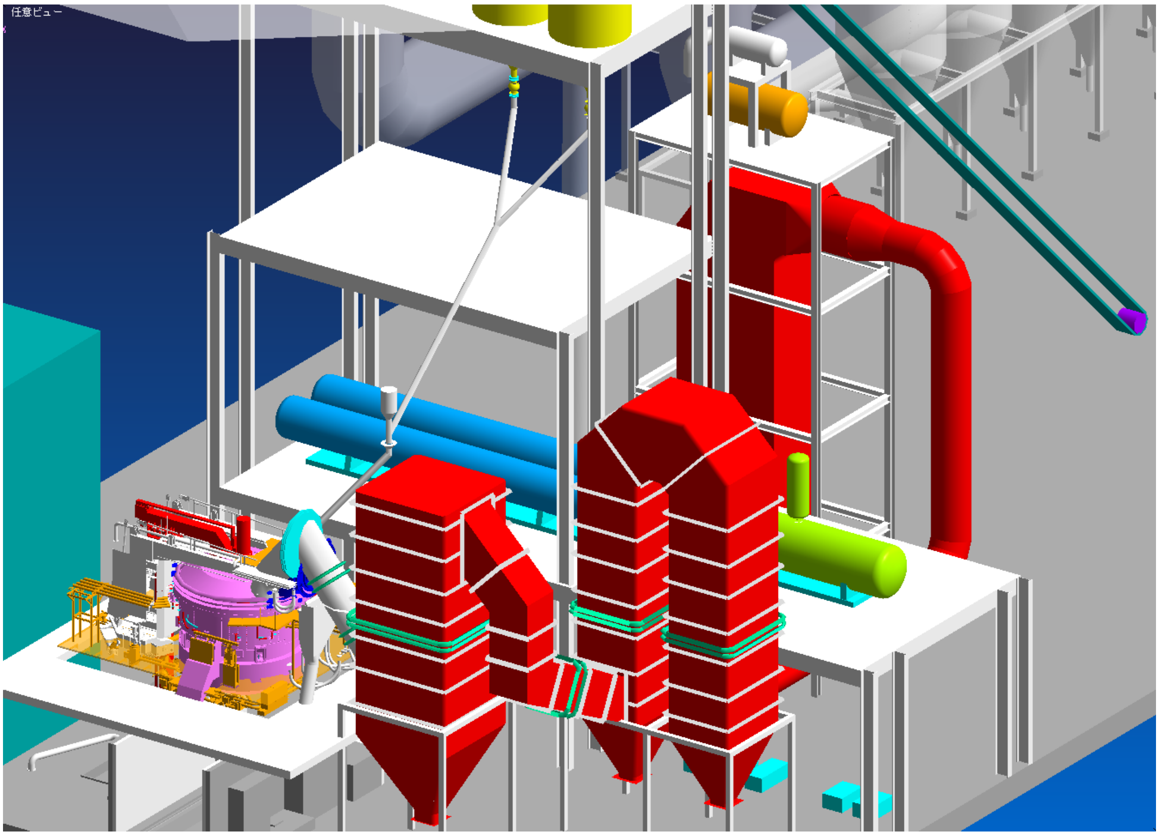


Figure 8. Solid model of boiler system for off gas heat recovery

REFERENCE

1. Masanari Yamazaki, Yasuhiro Sato, Ryutaro Seki, “OPTIMUM ENERGY MANAGEMENT OF ELECTRIC ARC FURNACE”, SEAISI Conference and Exhibition, Vietnam, May 2010