Maximizing Sintering Plant Heat Recovery

1. Energy Balance in Integrated Steel Mill

Fig.1 shows a typical energy balance of Japanese Integrated Steel Mill. Major energy source are various fuels, steam and electrical power.

For fuels, 94% is by-product gases such as blast furnace gas, coke oven gas and LD gas, remaining 6% is purchased fuels. Within the consumed fuels, 49% are directly consumed in the production process and 51% is utilized in power generation plant.

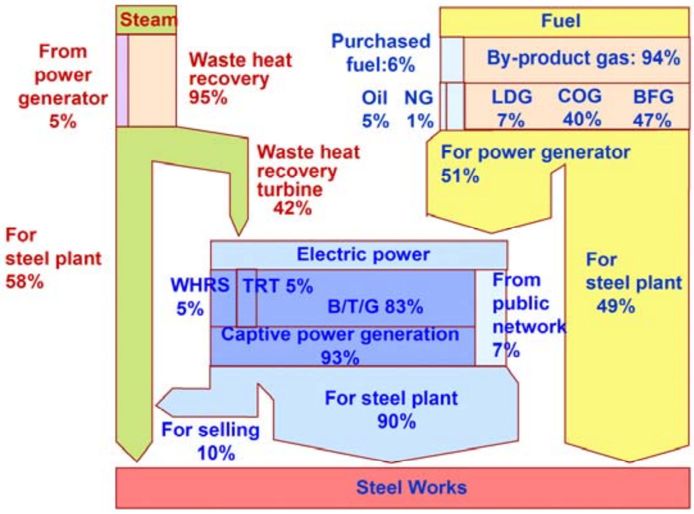


Fig.-1 Energy Balance of Typical Japanese Integrated Steel Mill

For steam, 95% is generated through off gas heat recovery and remaining 5% are generated through power generation process. 58% of the steam is utilized in the production process and remaining 42% are utilized for power generation.

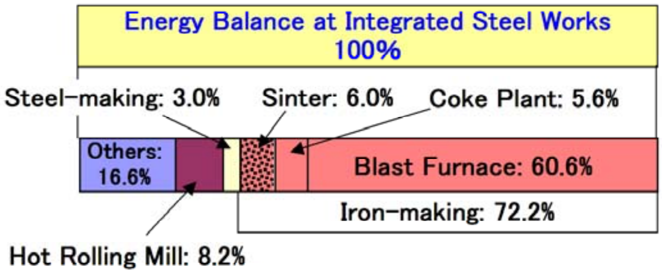


Fig.-2 Energy Consumption Ratio if Production Process in Integrated Steel Mill

Fig.2 shows the ratio of the energy consumed in each production process. Iron making process is the largest consumer by-far, consuming 72.2% of total energy, consequently emitting large amount of exhaust energy. It is clear that iron making process is the key for energy saving or heat recovery.

Followings are the technologies utilized for the heat recovery in iron making process;

Blast Furnace: TRT (top pressure recovery turbine); power generation utilizing the blast furnace gas pressure and temperature

Coke oven: CDQ (cokes dry quenching system); steam and power generation through heat recovery from smothered red hot cokes

Sintering Plant: WHRS (waste heat recovery system); steam and power generation through heat recovery from sintered ore cooling process

In this paper, heat recovery technology from sintering plant is introduced.

2. Heat Recover Technology from Sintering Plant

Sintering plant consists of two measure sections, sintering section and sintered ore cooling section. Heat recovery from both parts has been developed from sintering section exhaust gas and from cooling section cooling gas.

Fig.-3 shows the gas temperature distribution of both sections. As shown in fig.-3, there is large temperature difference depending on the position of the section. Average gas temperature in both sections is in the level of 100-150 deg.-C, too low for effective heat recovery. Heat recovery shall be limited to high gas temperature zone, the final part of sintering section and primary part of cooling section, where gas temperature of 300 deg.-C or higher is available. Although heat recovery zone is limited, the gas volume of sintering process is large enough for practical heat recovery in commercial base.

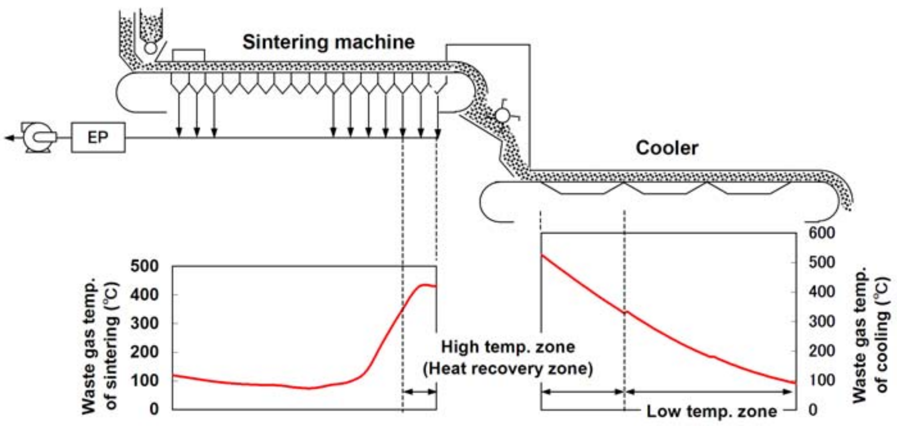


Fig.-3 Gas Temperature Distribution in Sintering Plant

3. Facility Configuration of Waste Gas Heat Recovery System and its Efficiency

Fig.-4 shows the facility configuration of the waste gas energy recovery system. It consists of hood, dust catcher, heat recovery boiler, circulation fan and de-aerator.

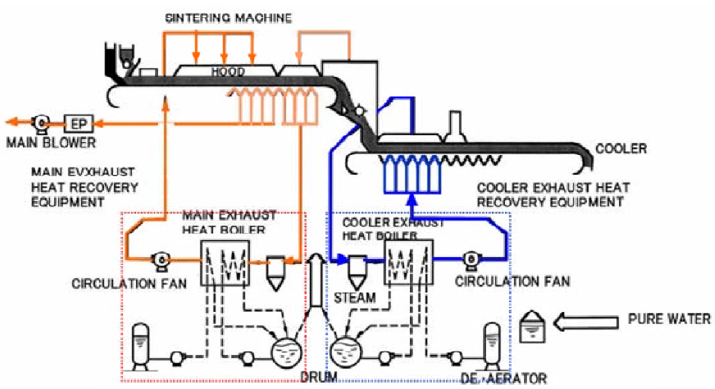
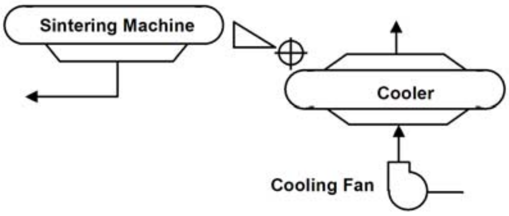


Fig.-4 Facility Configuration of WHRS

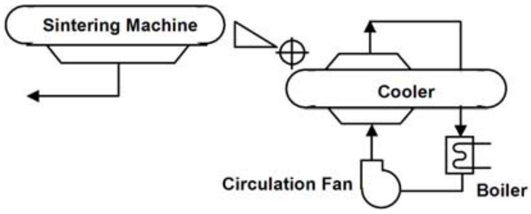
Sintering machine exhaust gas is corrosive containing some dusts. Heat recovery is generally limited to high gas temperature zone as aggregated average temperature is low for heat recovery. At the same time, due to its corrosiveness, the gas temperature after heat recovery must kept above acid due point of the gas.

Cooling gas is basically atmosphere air containing some dust. Same as sintering machine heat recovery, due to gas temperature distribution along with the cooler, heat recovery is limited to high gas temperature zone.

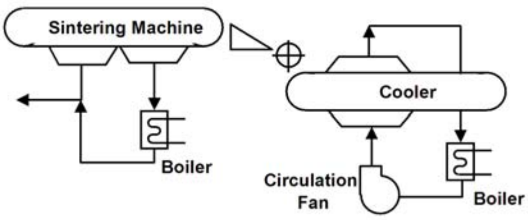
Sintering machine exhaust gas heat recovery can be categorized to circulation type and non-circulation type. In circulation type, gas after heat recovery are circulated to sintering machine as cooling gas replacement, whereas in non-circulation type, the gas after heat recovery is lead to gas treatment facility directly. Circulation type is adopted to improve heat recover efficiency. Fig.-5 shows the combination of the sintering plant heat recovery system and cooler gas heat recovery.



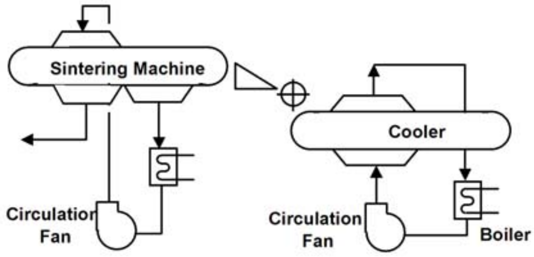
Case-1: Without WHRS



Case-2: Cooler WHRS



Case-3: Sinter &
Cooler WHRS



Case-4: Sinter & Cooler
Gas Circulation WHRS

Fig.-5 Various Facility Configuration of WHRS

Typical heat balance is shown for each case of the sintering plant heat recovery in Fig.-6.
It is said that input energy of sintering process is in the level of 145 to 150 MJ/t-Sr. Heat source is solid fuel combustion such as cokes fine, blast furnace ash and etc. As shown in Fig.-6, effective thermal energy of the output thermal energy is approx. 38%, which includes lime reaction heat, material moisture evaporation heat. Energy loss through off gas carry over reaches up to 49%.

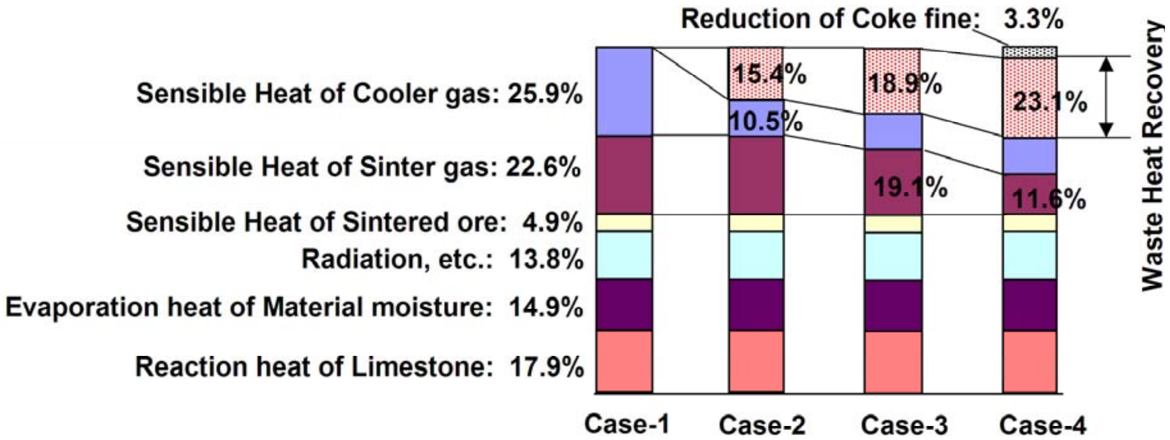


Fig.-6 Heat Balance of Various WHRS

Fig.-6 clearly shows that WHRS effectively recycles enormous amount of the sensible heat of sintering plant gas, both sintering machine off gas and cooler gas. Heat recovery of each case against case-1 is compared hereunder;

Case-2 Cooler gas heat recovery (circulation)

Cooling gas contains 25.9 % of the out put thermal energy, within 60 % is recovered. 15.4 % of total out put energy is recovered.

Case-3 Cooler gas heat recovery (circulation) and sintering machine off gas heat recovery

Sintering gas containing 22.6% of the total out put thermal energy, within 15% is recovered. Together with 15.4% recovered from cooler gas, total 18.9% of off gas thermal energy is recovered.

Case-4 Cooler gas heat recovery (circulation) and sintering machine off gas heat recovery with gas-recirculation

Addition to case-3, sintering gas is circulated to sintering machine. 7.5% of the total output energy can be recovered. Also, coke breeze consumption can be decreased in the extent of 3.3 % of the off gas total calorie.

4. Cooler Gas Heat Recovery

In this section, some methods to augment heat recovery system to existing sintering plant are introduced. Cooler heat recovery shall be highlighted considering practicality of facility modification, as cooler gas is air, not corrosive and as a result practical for facility modification.

Cooler heat recovery can be categorized in circulation type and non-circulation type as shown in Fig.-7.

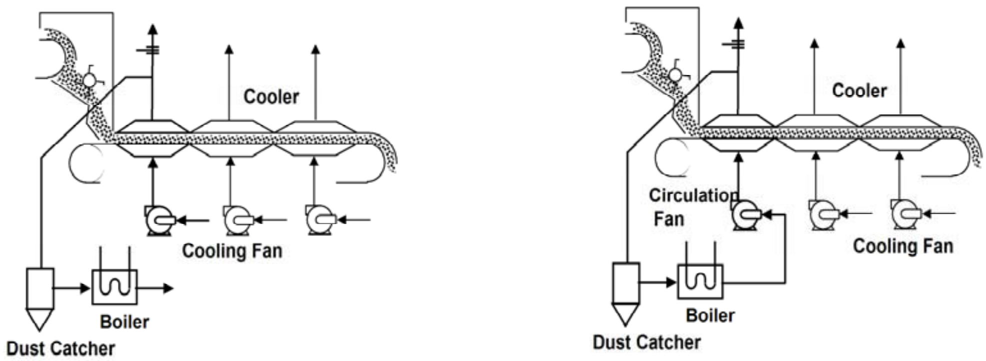


Fig.-7 Sinter Cooler Heat Recovery Facility Configuration

Non-Circulation type;

After heat recovery from hot gas zone, cooling gas are emitted to atmosphere. As cooling gas temperature do not change with heat recovery system, cooling capability do not change before and after augmenting heat recovery system

Circulation type;

After heat recovery from hot gas zone, cooling gas is lead to cooler and reused for sintered ore cooling. Cooler gas temperature rises through recirculation and consequently results to higher heat recovery. On the other hand, cooling gas temperature rises up to the level of 180 deg.-C, cooling capability may decrease.

Fig.-8 compares the temperature of ore and gas in both types. Sintered ore temperature at outlet of cooler rise approx. 30 deg.-C in circulation type. Temperature difference is small enough not to affect sinter plant commercial operation.

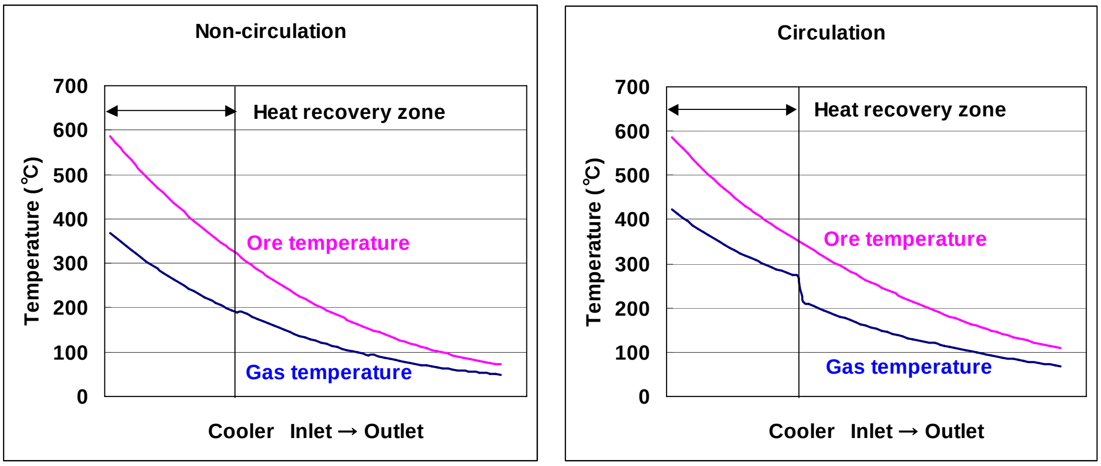


Fig.-8 Temperature Comparison;
Circulation Type and Non-Circulation Type

Table- 1 Circulation type and non-circulation type is compared hereunder

Items				Circulation		Non-circulation	
Cooler	Temperature Zone			High	Low	High	Low
	Sinter Ore	Input	t/h	800		800	
		Temp. at inlet	°C	600		600	
		Temp. at outlet	°C	108		72	
	Cooling Gas	Flow rate	$m^3{}_N$/h	650,000	800,000	480,000	970,000
		Temp. before	°C	180	25	25	25
		Temp. after	°C	444	225	425	190
	Leakage Ratio	under trough	%	30	30	30	30
		Above trough	%	20	20	20	20
	Fan Power		kW	2,690		2,000	
Boiler Turbine Generator	Off Gas	Flow rate	$m^3{}_N$/h	568,750		420,000	
		Inlet Temp.	°C	352		337	
		Outlet Temp.	°C	200		205	
	Recovered Steam		t/h	40		26	
	Recovered Power		kWh	7,100		4,600	

Recovered energy increase by 50% in circulation type compared to non-circulation type. Fan power consumption is larger in case of circulation type, however, recovered power is far larger.

Leakage ratio in the table shall be explained hereunder;

Cooler consist of stable structure such as cooling air duct, air chamber and etc. and movable equipments such as trough containing ore. Although some seal material is set up in between, generally sliding seal is applied which cannot avoid leakage perfectly. Some atmosphere air will be sucked into the hood from the gap between trough and hood. Cooling gas increases and its temperature lowers at the entrance of boiler.

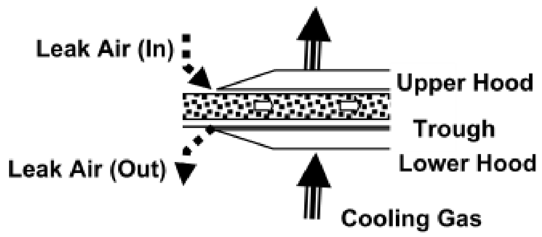


Fig.-9 Image of Leakage

Leakage ratio largely affects the heat recovery. Fig.-10 compares gas temperature and recovered energy by different leakage ratio. Leakage ratio is in the range of 10-15 % for newly installed conventional type sinter cooler. Leakage ratio gradually increases due to thermal deformation of equipments. It is generally said the leakage ratio increases up to 20-30 %, shown in right end column. Gas temperature lowers 20 deg.-C approximately, consequently decreases recovered energy by 13% approximately.

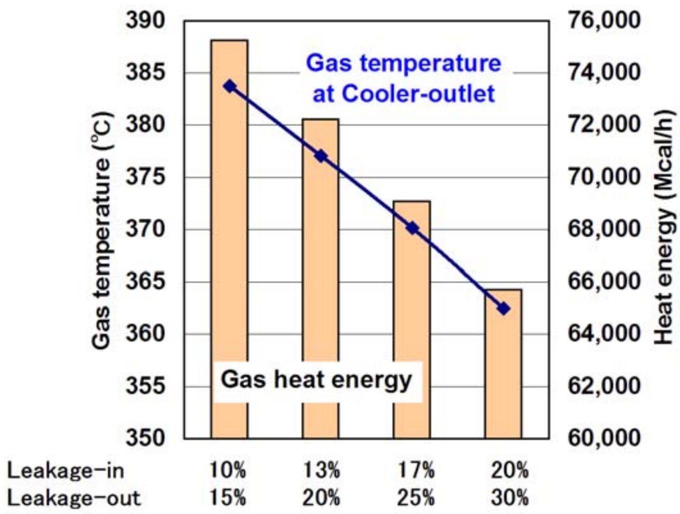


Fig.-10 Relation of Leakage Ratio v.s. Gas Temperature and Recovered Energy

5. Water Seal for Sinter Cooler

Water seal system was developed to minimize the leakage ratio over the lifetime of the sinter cooler, to improve sinter cooling capability, energy consumption, maintainability and etc.

Fig.- 11 shows the equipment configuration of the water seal system. Leakage and sealing material erosion are minimized. Leakage ratio of less than 5% is confirmed in actual commercial plant.

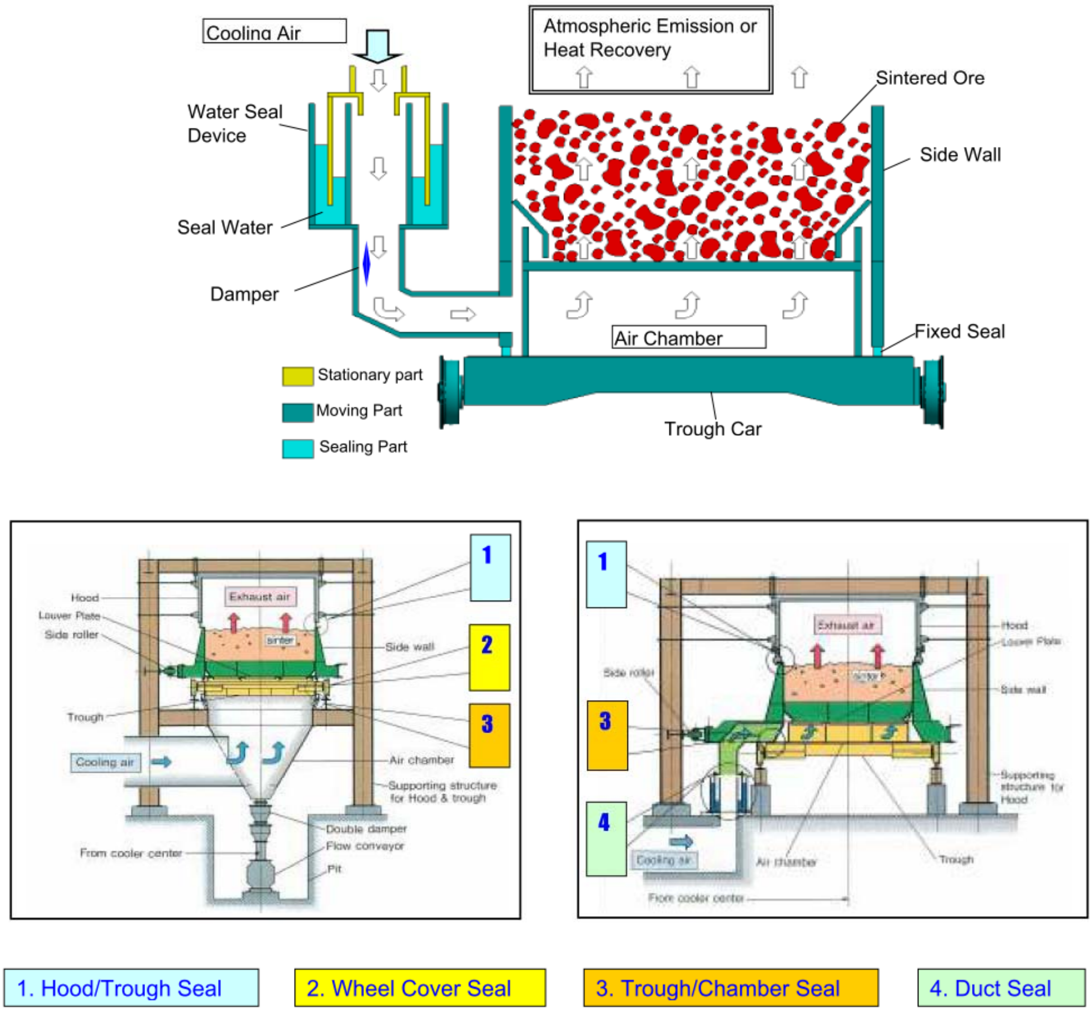


Fig.-11 Equipment Configuration of Sinter Cooler water Seal

Water seal type and conventional type cooler is compared hereunder;

Table-2 Heat Recovery from Water Sealed Cooler and Conventional Cooler

Items				Water Sealed		Conventional	
Cooler	Temperature Zone			High	Low	High	Low
	Sinter Ore	Feed Rate	t/h	800		800	
		Temp. at inlet	°C	600		600	
		Temp. at outlet	°C	110		108	
	Cooling Gas	Flow Rate	m^3_N/h	475,000	584,000	650,000	800,000
		Temp. before	°C	180	25	180	25
		Temp. after	°C	445	227	444	225
	Leak Ratio	under Tough	%	5		30	
		above Trough	%	5		20	
	Fan Power		kW	1,950		2,690	
Boiler Turbine Generator	Exhaust Gas	Flow Rate	m^3_N/h	485,000		568,750	
		Inlet Temp.	°C	414		352	
		Outlet Temp.	°C	183		200	
	Recovered Steam		t/h	51		40	
	Recovered Power		kWh	9,000		7,100	

Cooling gas amount has been reduced approx. 30% thanks to the leak gas volume decrease. Recovered steam and power increased approx. 30% as boiler inlet gas temperature rose 60 deg.-C increase although gas amount itself decreased.

6. Results

First water sealed sinter cooler was put into operation in 1996, second in 1996. 7 years later in 2003, sinter cooler was modified to circulation type. After solving initial issues caused with dusty cooling gas and higher cooling gas temperature, water sealed sinter coolers are successfully working achieving full expectation of high efficiency and stable operation.