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APPLICATIONS OF HIGH EFFICIENCY GAS BURNERS TO CONTRIBUTE TO ENERGY SAVING IN INDUSTRIAL FIELD

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ABSTRACT

This paper details the examples of various kinds of high efficiency Osaka Gas' burners to contribute reduction of energy consumption and CO_2 emission.

Main fuel for industrial use in Japan had been heavy oil for years, because of the difference in prices between natural gas and heavy oil. Further attention to high efficiency burner is being seen with the recent increased interest in reducing CO_2 emission from the industry. In energy-intensive industries, such as metal heating furnaces, response to energy saving, laborsaving and adjustment to multi kind small productions are said to be a subject.

In compliance such needs, Osaka Gas is contributing to an economical furnace operation by developing gas burners. For metal heating furnaces, regenerative burners have been developed and installed widely with 4 types of variations, especially for small and medium sized furnaces. On development of compact regenerative burners, we focused on the following concepts to try to increase performance; 1) low cost, 2) compact size, 3) energy saving, and 4) low NO_x.

A glass melting furnace, another energy-intensive industry, is extremely high in temperature from 1,500^{o}C to 1,600^{o}C, and the radiation of flame is mainly used to melt raw material of glass. In Japan, natural gas and heavy oil vary in cost, and it becomes an obstacle. Therefore Osaka Gas has developed some types of burners for glass melting furnaces with development of the structure of gas nozzles and technique of slow combustion method.

Osaka Gas has focused on not only high efficient gas burners, but also controlling systems to achieve energy saving and high efficient furnace operation. Easy Burner Control System (EBC-i) is the precise controlling system for air ratio, which can easily conduct the optimization for furnace operation condition by setting up the air ratio at some combustion load. Impulse Burn System is the effective burner controlling system that burners are set at rated combustion rate and ON-OFF control is installed to each burner in time proportion. High speed burners are used with high speed exhaust gas stirring.

The subjects relating to usages of gas burners are as follows:

- Background
- Regenerative Gas Burners
- Gas Burners for Glass Melting Furnaces
- Others
- Conclusion

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1. Background

Throughout the world today, further attention to high efficiency burner is being seen with the recent increased interest in reducing CO_2 emission from the industry. In energy intensive industries, such as metal heating furnaces, response to energy saving, laborsaving and adjustment to multi kind small productions are said to be a subject. In compliance such needs, Osaka Gas is contributing to an economical furnace operation by developing gas burners, such as regenerative burners for metal heat treating, gas burners for glass melting furnace and other various kinds of gas burners from low temperature usages to high temperature applications.

This paper gives an outline and reports on actual achievements and energy saving technique of natural gas combustion for regenerative burners, burners for glass tank furnaces, and some controlling systems.

2. Regenerative Gas Burners

Regenerative burners have been developed mostly for large heating furnaces such as hot rolling, and they have contributed to efforts of energy saving and reduction of CO_2. In order to install them into the small sized furnaces, high efficiency of energy saving and compact size are especially required. Regenerative burners have complicated burner system and piping arrangement compared to a single burner system, and in order to flow the high temperature preheated combustion air, burner bodies themselves are made large at high initial cost. Therefore, Osaka Gas has developed 4 types of compact sized regenerative burners, shown in Fig.1, for small and medium sized high temperature furnaces such as directly fired heat treating furnace, non ferrous metal furnace, and indirectly fired heat treating furnace.

On development of compact regenerative burners for small and medium sized furnaces, we focused on the following concept to try to increase performance.

1) Low cost

It is necessary to decrease an initial cost of the burners and equipments with keeping their performance and durability.

2) Compact size

Not only burners themselves, but their equipments should be compact totally. It is required to ensure maintenance area in small and medium sized furnaces to place burners.

3) Energy saving

Selecting appropriate regenerator and changeover time, high energy saving performance is achieved as well as normal-sized regenerative burners.

4) Low NO_x

Low NO_x techniques other than the slow combustion are adopted in each model.

2-1. Twin type Regenerative Burner (TREG)

TREG burner (shown in Fig.2) is the ordinary regenerative burner for high temperature furnaces as hot rolling and forging, consisting of a pair of burners as one system, which has a heat reservoir and switching valves. Two burners make combustion alternately, then high temperature preheated air is produced by regenerative heat exchange between exhaust gas and fresh air. In this process, regenerative burner system is possible to provide high energy saving.

To lower NO_x, two-staged combustion system is adopted. In two-staged combustion system, combustion air is divided into primary and secondary air, and air ratio is lowered in the vicinity of burner with the primary air. The secondary air is provided away from the burner to complete combustion. In general, higher the secondary air makes lower NO_x, but flame in low temperature tends to be unstable. The high turn-down burner originally designed by Osaka Gas is inserted, so that the flame stability in low temperature is ensured and low NO_x is also ensured at time of combustion with the preheated combustion air.

TREG burner has the following special points.

1) Extremely high efficiency.
2) Compact and low cost with simplified structure.
3) High durability by gas gun not to be set in high temperature.
4) Alternate combustion makes uniform temperature distribution.

Table 1 shows the specifications of TREG burner. TREG burner can be applied to heat treating furnaces higher than 1,100^{o}C, and extremely high efficiency can be achieved. At furnace temperature of 1,200^{o}C and air ratio of 1.1, energy saving gets closer to 50% compared to that without exhaust heat recovery system.

2-2. Insert type Regenerative Burner (IREG)

IREG burner has been developed for directly-fired heat treating furnaces. In directly-fired heat treating furnaces, a large number of compact burners are generally required in order to equalize the temperature distribution in furnaces. IREG burner has the following special points.

1) Inserting regenerator in a furnace wall portion makes burner compact.
2) Switching valves are specially developed for a simplification of piping.

3) Low NO_x is achieved by dividing flame.
4) Energy saving rate is about 35% compared with the normal case.

Generally heat reservoirs in regenerative burners are made of alumina balls. However, IREG burners, shown in Fig.3, have ceramic porous materials as heat reservoir elements. They provide large specific surface area compared to alumina balls. Therefore, it is possible for them to reduce the volume into about 1/5 of that of the balls. Additionally, as they provide low pressure loss compared to alumina balls, compact positive blower and exhaust blower, which have low power consumption, can be adopted. Heat reservoirs are incorporated in heat chamber portions and inserted into furnace wall portion. Only burner heads and wind boxes are located outside the furnace.

Main flame is retained by pilot flame of auxiliary burner that is premixed. To achieve low NO_x, main flame is divided into two on a plane. Divided flames make the two specific areas that are consist of the gas fuel-rich conditions and gas fuel-lean conditions. It is similar to the phenomena of thick and thin fuel combustion. In addition, the slow combustion makes low NO_x. And those flames have large superficial area, and then heat transfer area is large. Table 2 shows the specifications of IREG burner.

The following shows a case to adopt IREG burners to a pot-type gas-carburizing furnace (furnace temperature condition is 800^{o}C or 960^{o}C). This furnace treats products such as gears at a rate of 8.75t/charge. Four pairs of IREG-100K burners are installed in it. Eight burners are arranged tangentially in two-tiered array. The flames spurt in one direction. In this furnace, wide length of combustion chamber is limited in only 300mm. But it is possible to avoid superheating the inner muffle by its divided flat flame.

The actual temperature distribution data of this furnace is shown in Fig.4. The flame length of this burner is about 1.5m. And the main air spurts at 5m/s (when the preheated air temperature is 700^{o}C). Compared to our high-speed burners for this kind of furnace, it has about 1/10 in outer-velocity of combustion air port. However, as mentioned above, divided flame of this burner has large superficial area. Therefore, uniform temperature distribution is obtained satisfactorily. The exhaust gas temperature is 230^{o}C. In this case, 31.4% energy saving is achieved.

2-3. Insert-type Self Regenerative Burner (SREG-i)

SREG-i burner has been developed in order to expand the applicable range of the regenerative burner system to small-size furnaces such as cast-iron pot/crucible type non-ferrous metal melting/holding furnaces. It has the following special points.

1) Two burners are integrated into one unit.
2) Heat reservoirs are arranged in furnace wall portion.

3) The energy saving rate is about 35%.
4) The package-type furnace is developed simultaneously. We call it “EcoMelter”.

Generally, regenerative burner system consists of two burners which have heat reservoir respectively. As shown in Fig.5 SREG-i burner has two sets of heat reservoirs at the right and left side of one burner body. A gas-fuel gun is arranged in the lower middle part of the burner, and spurts main gas-fuel for right and left in direction alternately. The change-over operation can be performed by only one burner. This greatly helps to reduce the total cost and space.

Main flame is retained by auxiliary burner. Main gas-fuel is spurted into two directions transversely, and at the 45-degree upward angle in parallel to the front face of the burner tile with being assisted by auxiliary high-pressure air (shown in Fig.5). It is possible to avoid superheating the cast-iron pot.

Four-way switching valve is combined in it. “On/Off control system” is adopted as temperature control method. Generally four-way valve has advantage for simplifying piping, however it cannot interrupt air when the burner is off by controlling. Then, “intermediate stop mode” is specially developed, that it forced the switching valve to keep at the neutral position while main burner stops combustion in controlling. Then, the combustion air is allowed to escape to the exhaust port without entering heat reservoir and the furnace inside. To prevent from making furnace inside pressure negative by air draft, the resistant blade is installed on the change-over plate.

Energy can be saved about 27% adopting this “intermediate stop mode” as compared to using regular switching valve. Table 3 shows the specifications of SREG-i burner.

A cast-iron pot-melting furnace including piping, accessory, furnace body and SREG-i burner has been totally developed. It names specified as “EcoMelter”. This furnace has aluminum melting performance at a rate of 250kg/charge. The exhaust gas temperature is 220^{o}C on average when combustion chamber temperature is 1050^{o}C. The thermal efficiency reaches about 90%. And 35% energy saving is achieved.

2-4. Radiant Tube Regenerative Burner (RTR)

RTR burners have developed for indirectly-fired heat-treating furnaces. It has been for the low cost and compact to appropriate for the furnaces with a large number of burners. It has the following special points.

1) Using the direct ignition system enables simplification of piping.
2) Special-purpose 4-way valve not only enables simple piping but also contributes to

energy saving.

3) “Exhaust gas recirculation combustion technique” makes low NOx.
4) The energy saving rate is about 35%.

RTR burner (shown in Fig.6) is adopted direct ignition system. It is advantage that pilot burners including piping and various accessories such as electromagnetic valves are not necessary. It has ceramic porous materials as regenerator elements. As mentioned above, they provide low pressure loss less than 0.5kPa. Therefore, exhaust gas blower is eliminated since the furnace pressure is in the allowable range.

Flame is not affected by specifications of a radiant tube because its retention is secured in the heat chamber, which is located in the base of a radiant tube. To achieve low NO_x, exhaust gas recirculation combustion technique is adopted. By adopting regenerative radiant tube burner system, uniform temperature distribution on the tube surface is obtained compared to conventional radiant tube burner system. “On/Off control system” is adopted as temperature control method. And four-way switching valves interrupt the air supply when burners are off by controlling. It is possible to reduce heat loss when burners are off. Energy saving rate is about 35% compared with the normal one. Table 4 shows the specifications of RTR burner.

The following shows a case to adopt RTR burners to continuous bright annealing furnace (furnace temperature is 900^{o}C). One pair of RTR-100A burners are installed in it. It is adopted in high-intensity area. In addition, as a special design, they are set horizontally. The exhaust gas temperature is 300^{o}C. In this case, about 35% of energy saving is achieved.

2-5. Achievement and foresight

Since Osaka Gas has developed compact regenerative burners, numbers of burner sales are increased significantly, as shown in Fig.7.

74 pairs of TREG burners have been installed to 48 furnaces.

62 pairs of IREG burners have been installed to 27 furnaces.

34 pairs of SREG-i burners equipped with “EcoMelter” have been installed.

54 pairs of RTR burners have been installed to 17 furnaces.

Total rated combustion capacity amounts to 74,720 kW by the end of fiscal 2010 year.

In development of compact regenerative burners which make high energy saving rate, reliability is most required. Durability and maintenance performance will be further developed as well as normal ones. This system requires electromagnetic valve to 500,000 switching per year. Accessories used on exhaust gas lane are exposed to high temperature. Considering their use and condition, environment of usage is not always clean and comfortable, so that reliability is highly required by improvement of burners themselves, engineering to protect accessories and periodical maintenance.

3. Gas Burners for Glass Melting Furnaces

3-1. Difficulties of fuel switching for glass tank furnaces

In glass industry, it is said to be more important to reduce not only CO_2 emission but also NO_x emission. In fact, natural gas has been used in many cases for feeder furnaces and rare furnaces which are the secondary process of glass formation. However, natural gas has not been used in Japan as the main fuel in the large sized glass melting furnaces (glass tank furnaces).

The main reason is that glass tank furnaces use around 70% of all plant heat demand and highly priced natural gas has not been used as the primary fuel for glass manufacturing. In general, the radiation of flame is sensitively affected by C (soot) in fuel components. Natural gas has the major component of CH_4 that is difficult to generate soot, in other words natural gas is inefficient compared to heavy oil used mostly. In addition, because combustion air is preheated more than 1,200^{o}C in regenerative glass tank furnaces, NO_x in exhaust gas is almost entirely composed of thermal NO_x. It means the superiority of natural gas that does not include N component is hardly appeared.

Generally fuel switching from oil to natural gas causes the following phenomena.

1) Increase of energy consumption
2) Increased temperature in regenerator (if glass tank furnace has regenerator)
3) Reduction of production efficiency
4) Increase of NO_x

Those phenomena are mainly caused by the difference of flames between natural gas and heavy oil. In glass tank furnaces, the maximum temperature is set at the center of furnace, and the melted raw materials flow complexly. As a result, this temperature distribution has a huge effect on the specific energy consumption and material yield, therefore the adjustment of temperature distribution is significantly important. In fact, if the actual visible flame lengths produced by natural gas and heavy oil are same, it is not true that the temperature distributions are equal to each other. It is the most important factor how the temperature distribution is duplicated with the flame produced by natural gas as well as improvement of the luminosity of natural gas flame. Fig.8 shows a heavy oil flame on the left and natural gas flame by an ordinary gas burner which is often used in overseas on the right, blowing from right to left in actual furnaces.

3-2. Applications of Osaka Gas burners

Under such circumstances, Osaka Gas has developed natural gas exclusive combustion burners for glass tank furnaces, and has been successful in operating glass tank furnaces by natural gas exclusive combustion for the first time in Japan. Our development procedure is shown below.

1) Verification of existing furnace specification
   - Products, Volume of products, Primary fuel, Heat requirement
   - Dimensions of combustion air port
   - Combustion space
   - Regenerator
   - Melting area, Melting volume
2) Estimation of heavy oil combustion in the experimental furnace
   - Flame shape
   - Temperature distribution
   - Components of exhaust gas
3) Development of natural gas burner in the experimental furnace
   - Improvement of luminous intensity by development of burner nozzle
   - Improvement of flame cover ratio by development of burner nozzle
   - Optimization of combustion air amount
   - Lowering of influent fresh air
4) Estimation by simulation
   - Optimization of combustion space, port design, burner tile, and burner location
5) Estimation in the actual furnace

Osaka Gas has developed 3 types of natural gas burners corresponding to various types of existing glass tank furnaces with different flame shapes. These burners make possible to achieve high luminous intensity by soot generated with slow combustion method, and lower NO_x. Their characteristics are shown in Table 5, and temperature distribution by each burner is shown in Fig.9. It is found that the temperature near the burner is lower with the ordinary gas burner compared to that of oil burner. With 3 types of developed gas burners, different temperature distributions are produced.

With development of these 3 types of Osaka Gas natural gas burners, the number of fuel switching from heavy oil to natural gas is 32 furnaces and by switching fuel to natural gas amount is about 0.2 billion m^3/year. Improvement of energy consumption results in up to 5%, and reduction of NO_x results in up to 10% of reduction. By switching fuel, CO_2 emission has become suppressed about 70,000 ton/year. Market share of Osaka Gas expanded by switching fuel has reached 70% in the service area by the end of fiscal 2010 as shown in Fig.10.

For glass tank furnaces, fuel switching from heavy oil to natural gas has a concern of an increase of energy consumption and NO_x, but with the development of Osaka Gas burners they are about equal or more improved compared to those of heavy oil.

4. Others

Osaka Gas has focused on not only high efficient burners, but also controlling systems to achieve energy saving and high efficient furnace operation.

Heating furnaces for heat treating of metal are required to keep the temperature distribution and atmosphere in the furnaces uniform to manufacture high-quality products. Recently, pollution control and energy conservation have been promoted, and the application of heat treating has been diversified. Therefore, burner combustion control has become a significantly important factor.

4-1. Easy Burner Control System (EBC-i system)

EBC-i System consists only of controller, control valve and pressure sensor. The control mechanism employs the composite throttling control to realize high-precision flow rate control. General-purpose control devices are used to reduce the cost. The condition setting unit uses a touch panel to facilitate the operations.

On this system, the control valve is regarded as the orifice meter with a variable port. The flow coefficient, V (relationship between flow rate and pressure loss), is calculated at each valve travel in advance and input to the controller. A composition of the flow coefficient and the burner flow coefficient, N, is regarded as the composite throttle flow coefficient, and the flow rate is calculated by the following formula, and its system is shown in Fig.11.

$$Q = \sqrt{\frac{N^2 * V^2}{N^2 + V^2} * P_0}$$

where Q: Flow rate, N: Burner flow coefficient, V: Valve flow coefficient, and P_0: Burner fore pressure.

EBC-i system has the following features.

1) Applicable burners; 100 to 2000kW class with turn-down ratio of 1:10.
2) Possible to set combustion conditions (8 patterns) with touch panel.
3) High precise control with temperature and pressure correction function.
4) Air ratio never misaligned in transition periods of flow rate changes.

As the result of the turn-down performance test, it is clear that the air ratio can be regulated within the range of the set air ratio ± 0.02 under any combustion conditions with turn-down of 1:10. This proves that EBC-i System can control the air ratio with high precision regardless of combustion conditions.

This system enables high-precision air ratio control and gives various advantages. The system can be applied to a wide range of facilities in any industrial field.

4-2. Impulse Burn System

Impulse Burn System is the effective burner controlling system that burners are set at rated combustion rate and ON-OFF control is installed to each burner in time proportion. High-speed burners are used with high-speed exhaust gas stirring.

With Impulse Burn System and high speed burners, it is achieved to uniform the furnace temperature distribution, lower NO_x production, and easily set up the different combustion conditions by partitioning combustion load to each burner. Therefore, it is possible to apply one furnace to various kinds of heat treating.

This system can be applied to any kinds of furnaces where multi burners are used. Fig.12 shows the basic system configuration and the outline of its control.

Impulse Burn System has the following specifications.

1) Uniform temperature distribution produced by the high-speed exhaust gas.
2) Low NO_x with the technique of self exhaust gas recirculation.
3) Energy saving without waste superheating.
4) High turn-down by changing ON-OFF control time rate.

In the application example to a heat treating furnace, uniform temperature distribution is achieved from low to high temperature.

5. Conclusion

Osaka Gas has developed various kinds of high efficiency burners to contribute reduction of energy consumption and CO_2 emission and the industrial demand of natural gas is about 4,500 million m^3/year (40.6MJ/ m^3). Now, we are developing a high efficiency gas burner, and expect gas firing to be increasing more and more in the future.

REFERENCES

1. T. Wakabayashi, K. Aoki, “Development of high efficiency compact regenerative burner to contribute to energy saving”, 24th World Gas Conference, Buenos Aires, Argentina, 2009
2. M. Hirano, “Energy saving technique of natural gas combustion for regenerative glass melting furnace”, IGRC 2004, Vancouver, Canada, 2004

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Table 1 Specification of TREG burner

Model TREG-___K	250	400	800	1400	1700	Remarks
Fuel	Natural gas					
Firing Rate [kW]	250	400	850	1400	1700	including pilot burner
Pilot Burner Firing Rate [kW]	12	23	29	41	46	
Main Gas Fuel Pressure [kPa]	1.5	1.1	3.6	2.0	2.0	Air/Fuel Ratio = 1.2
Main Air Pressure [kPa]	2.4	3.0	1.9	2.1	1.8	at 1250^{o}C
Max. Furnace Temp. [^{o}C]	1300					
Temperature Control	Time Proportional On/Off Control					
Change-over Time [sec]	30					

Table 2 Specification of IREG burner

Model IREG-___K	50	100	Remarks
Fuel	Natural gas		
Firing Rate [kW]	58	116	
Pilot Burner Firing Rate [kW]	2	4	Pre-mixed / Continuously
Main Gas Fuel Pressure [kPa]	3.4	3.2	Air/Fuel Ratio = 1.2
Main Air Pressure [kPa]	0.37	0.54	at 1050^{o}C
Max. Furnace Temp. [^{o}C]	1100		
Temperature Control	Time Proportional On/Off Control		
Change-over Time [sec]	30		

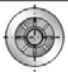
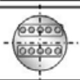
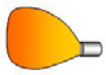
Table 3 Specification of SREG-i burner

Model	SREG-100K-i	Remarks
Fuel	Natural gas	
Firing Rate [kW]	112	
Pilot Burner Firing Rate [kW]	11	Continuously
Main Gas Fuel Pressure [kPa]	1.6	Air/Fuel Ratio = 1.2
Main Air Pressure [kPa]	0.6	at 1000^{o}C
Max. Furnace Temp. [^{o}C]	1100	
Temperature Control	Time Proportional On/Off Control	
Change-over Time [sec]	30	
Auxiliary Air Pressure [MPa]	0.3	

Table 4 Specification of RTR burner

Model RTR-___A	80	100	125	Remarks
Tube size [inch]	3	4	5	
Fuel	Natural gas			
Firing Rate [kW]	35	52	75	
Main Gas Fuel Pressure [kPa]	2.5	2.5	2.5	Air/Fuel Ratio = 1.2
Main Air Pressure [kPa]	2.0	2.5	2.5	Furnace Temp. = 950°C
Recommended tube length [m]	3.0	4.5	5.0	
Max. Furnace Temp. [°C]	950			
Temperature Control	Time Proportional On/Off Control			
Change-over Time [sec]	30			

Table 5 Characteristics of Osaka Gas burners

Burner type	Burner shape	Flame shape		Feature	Remarks
		From above	From side		
Round hole double jet (DJ)	 Patented			Long and narrow flame Ordinary oil burner	Suited for longitudinal furnaces
Elliptical hole double jet (DJ)	 Patented			Flame rather short and broad in horizontal direction	Suited for horizontal furnaces
Flat flame	 Applied for patent			Flame short and broad in horizontal and vertical directions	Suited for furnaces with high ceiling

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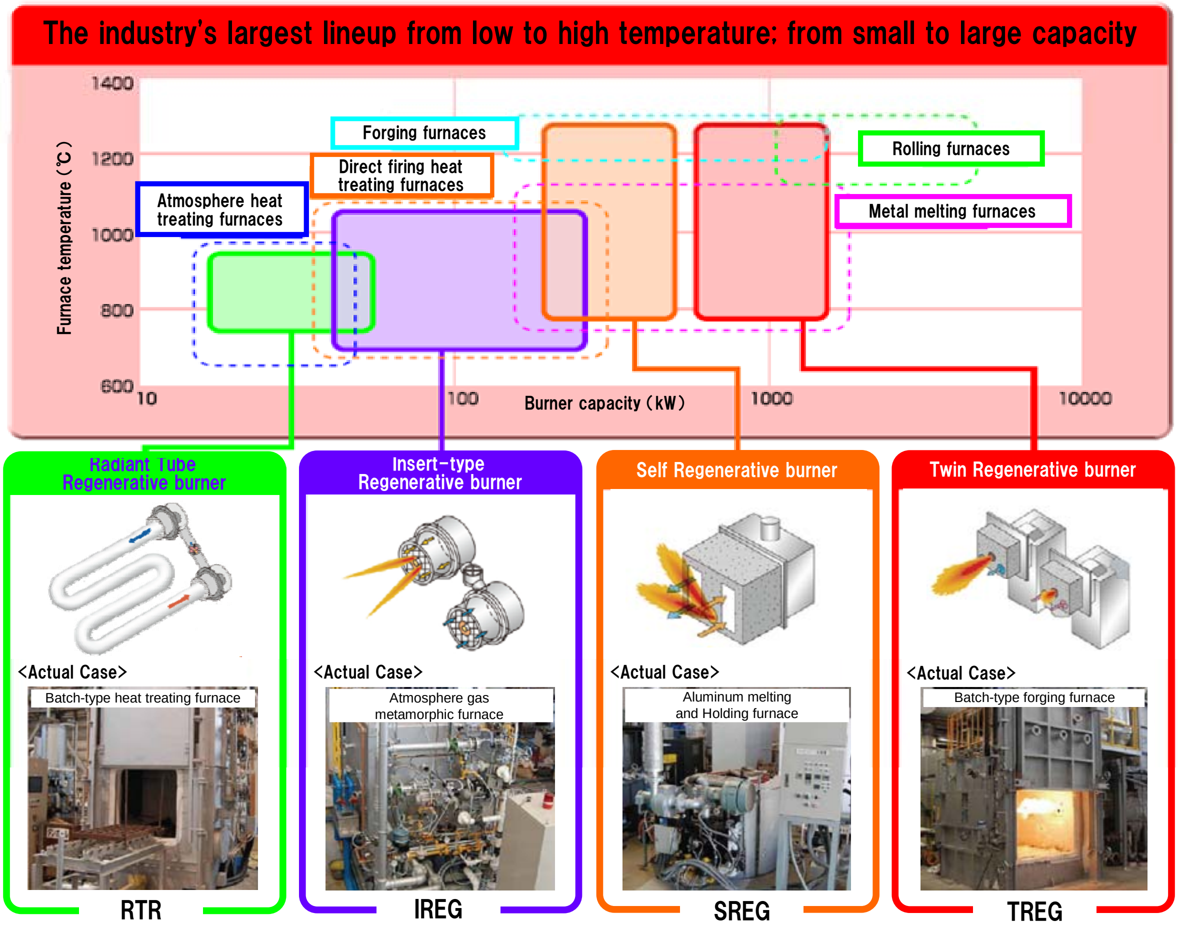


Figure.1 Line-up of Osaka Gas Regenerative burners

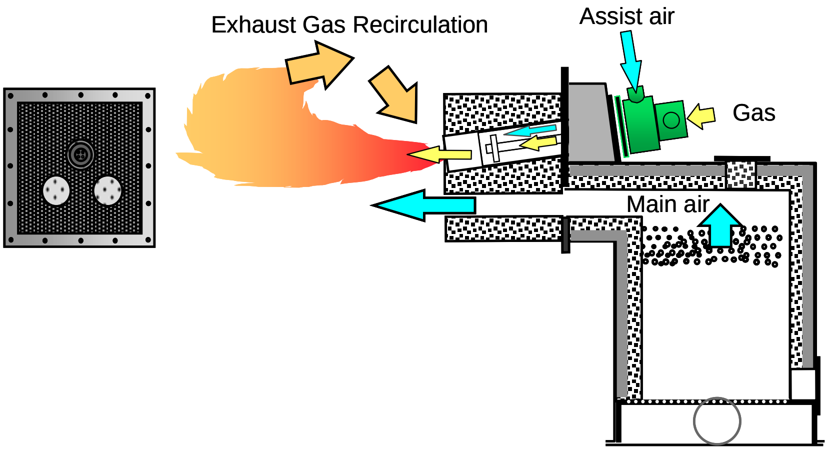


Figure.2 TREG burner structure

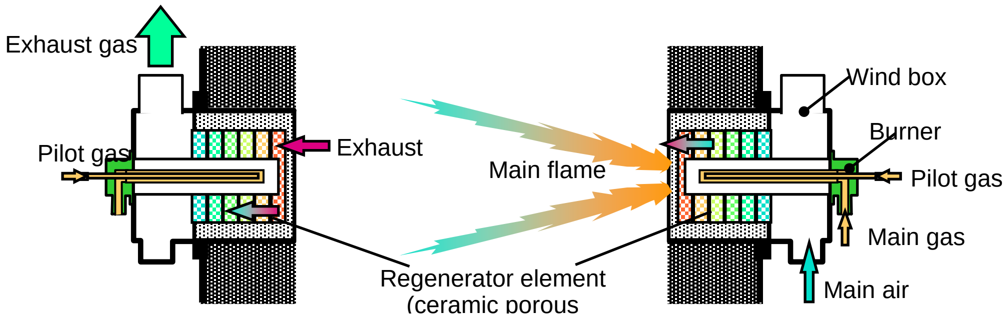
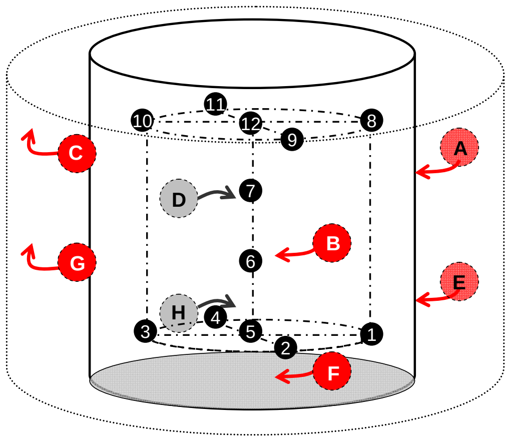


Figure.3 IREG burner structure



set / point	Temperature (°C)		
	706	836	996
①	705	837	1001
②	707	840	1004
③	707	839	1000
④	706	837	999
⑤	703	836	995
⑥	703	835	999
⑦	704	835	999
⑧	703	834	997
⑨	705	835	999
⑩	705	836	998
⑪	708	838	1002
⑫	704	834	996
⊿T	5	6	8

Figure.4 Temperature distribution in the carburizing furnace with IREG burners

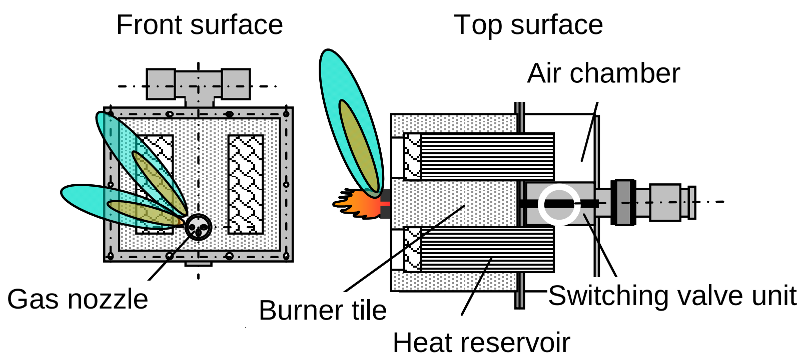


Figure.5 SREG-i burner structure

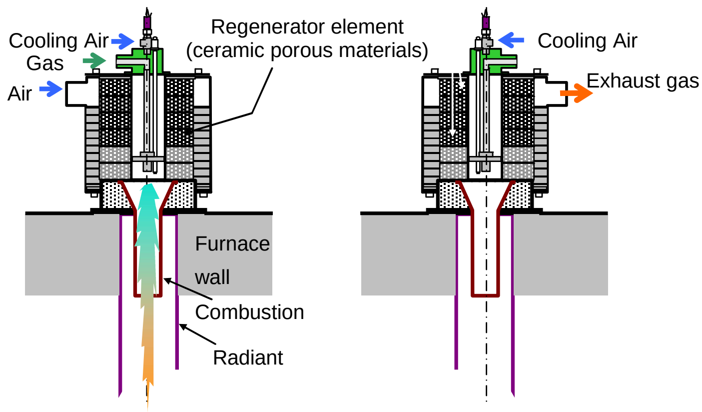


Figure.6 RTR burner structure

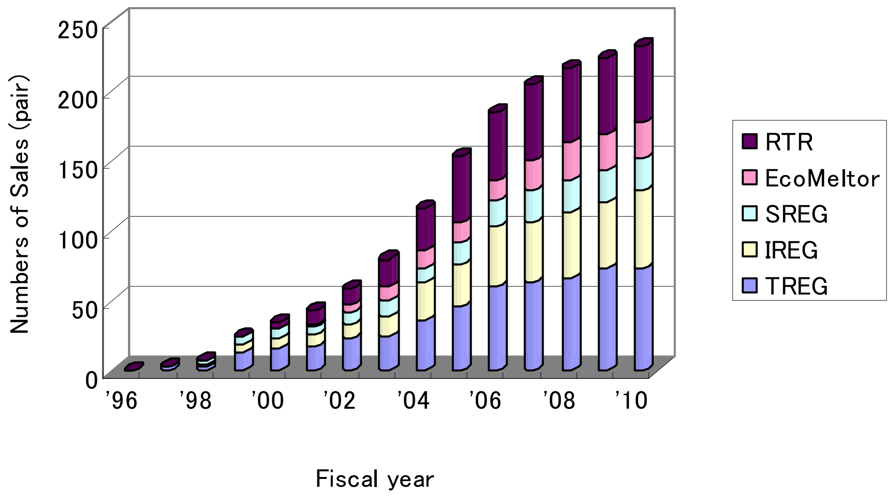


Figure.7 Numbers of regenerative burner sales

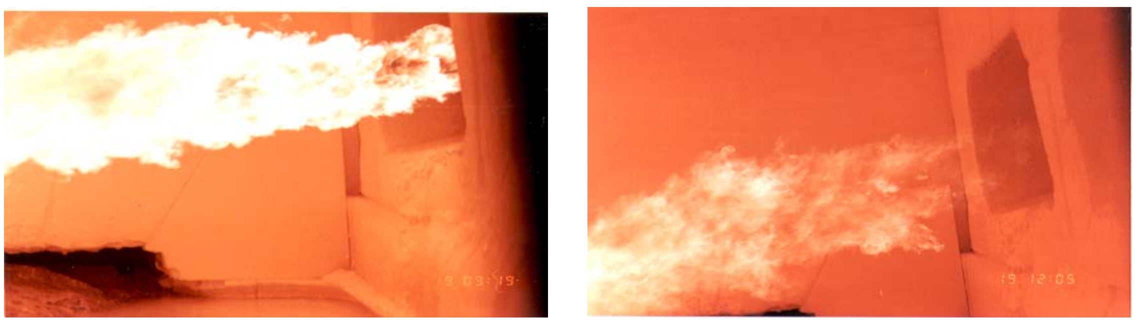


Figure.8 Heavy oil flame and natural gas flame in glass tank furnace

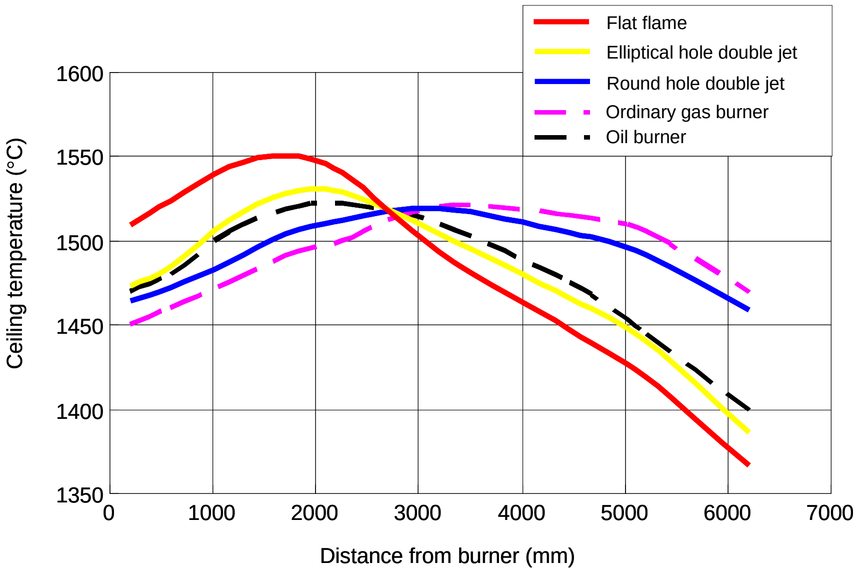


Figure.9 Comparison of temperature distribution

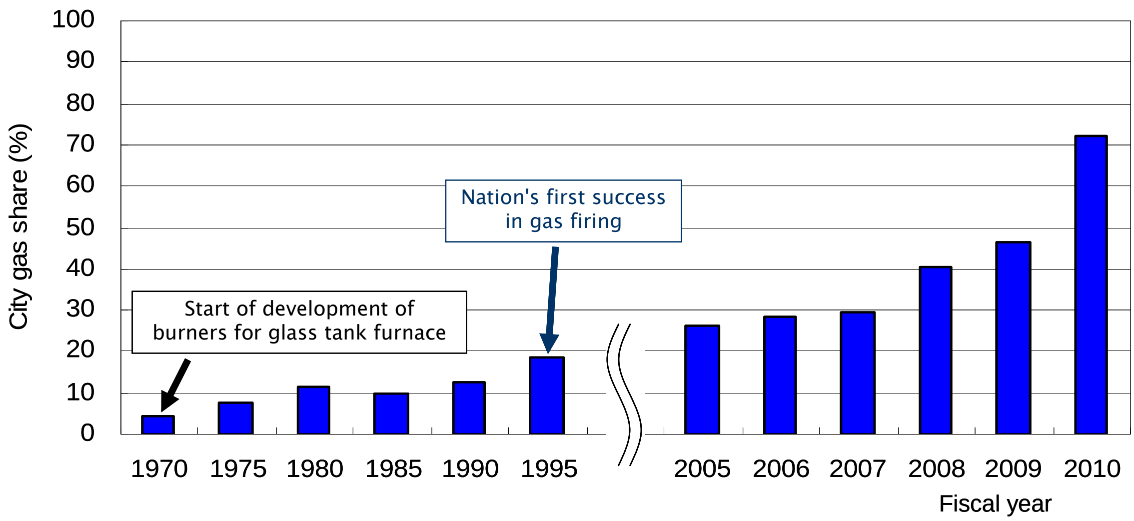


Figure.10 Transition of Osaka Gas share for glass tank furnaces

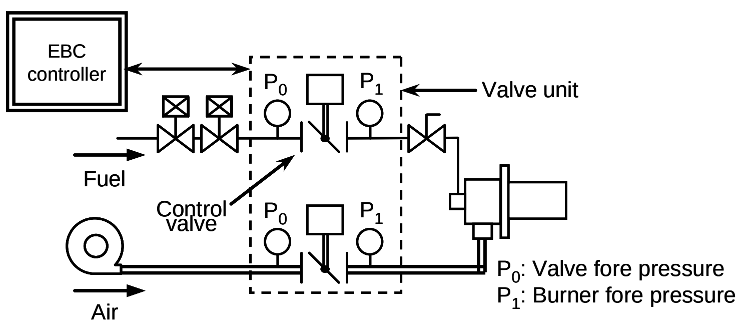
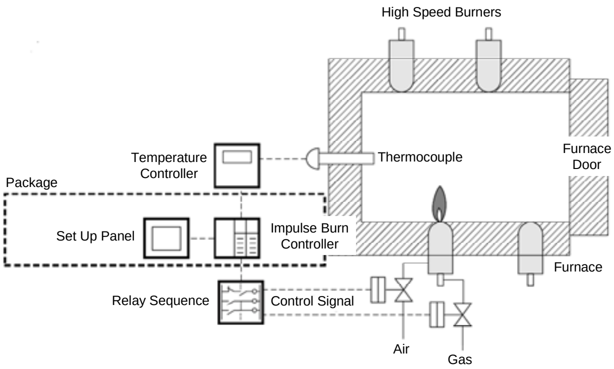
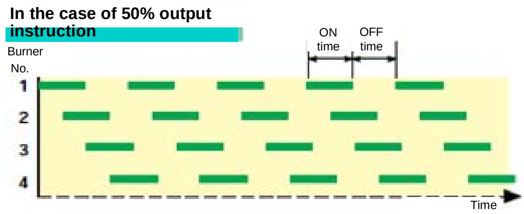


Figure.11 EBC-i system





[1] One burner turns ON for 50% of the time (maximum combustion).

[2] Each burner is changed over by rotation to combust.

[3] To view the whole furnace, two out of four burners are constantly combusted at maximum.

[4] ON time and combustion order of each burner can be freely set and the temperature deviation inside the furnace can be easily adjusted.

Figure.12 Impulse Burn system and outline of control