# BURNER DEVELOPMENT AND SOLUTIONS PROPOSED BY GAS COMPANY

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## 1. Background

Toho Gas is a city gas provider that supplies natural gas to the Tokai region and Aichi Prefecture in particular, which is located in central Japan. Home to a number of automobile-related corporations, this region's key industry is the automotive industry. There is considerable heat demand in the automotive industry at plants that perform heat treatment of metal parts and at aluminum die casting and non-ferrous metal plants. In addition, due to an increasing focus in recent years on environmental safety on a global scale, demand is increasing for highly-environmentally-friendly energy sources and efficient utilization of these sources.

## 2. Aims

For these reasons, we have been working on a number of energy conservation pursuits including the development of a high-efficiency burner with the aim of maintaining and improving our share in the market of eco-friendly natural gas. Below we will discuss some of the content and achievements we have made with energy-saving solutions for heat-treatment plants and non-ferrous metal plants.

## 3. Methods

### 3.1 Heat-treatment plants

Fig. 1 shows a model of a heat treatment plant for metal parts for automobiles, etc. Our energy-saving approaches for heat-treatment facilities are numerous and include (1) Improving atmosphere heat treatment furnace heating efficiency, (2) Improving heating efficiency for transforming furnaces, (3) Conserving energy by using high-capacity immersion tubes with cleaning tanks, (4) Heat conduction simulations, and (5) Reducing waste heat loss via excess air ratio control.

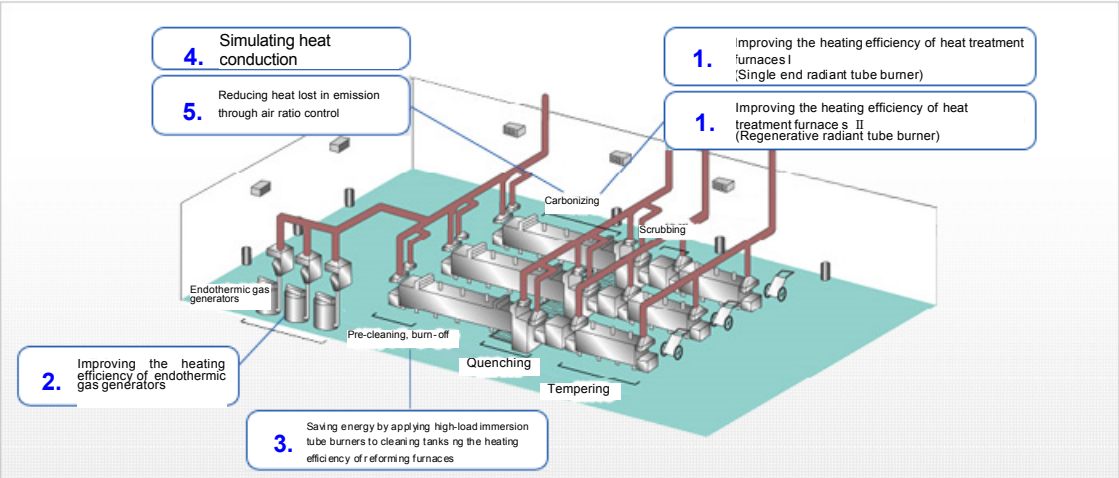



Fig.1 Example ofenergy saving proposals for heat treatment plants

#### 3.1.1 Improving the heating efficiency of heat treatment furnaces (Single end radiant tube burner: CSRT-S series)

Improving atmosphere heat treatment furnace heating efficiency has a greater impact on energy conservation than any other solution. There were once many cases of electric heaters being used for heat sources, but since we developed the single end radiant tube burner (CSRT-S) with built-in heat exchangers as an original high-efficiency burner, we have expanded market share by for implementing solutions during, for example, furnace replacing. Fig. 2 shows the internal structure of this burner.

(1) Advantages

a. Indirect heating burner

The CSRT-S is an indirect heating burner using radiant tube ,and is needed to use our hardening furnaces, carburizing hardening furnaces, and other atmosphere furnaces (furnace temperature: 750-950ºC),which are in high demand within areas

under the serving area of our company.

b. High-efficiency / low NOx

Due to waste heat recovery via a heat exchanger and a nozzle structure that allows combustion at an excess air ratio of less than 1.2, we achieve a thermal efficiency of more than 70%. We also use external EGR (Exhaust Gas Recirculation) to achieve a low NOx emissions. EGR combines part of the waste gas with combustion air, lowers flame temperature by lowering $O_2$ partial pressure inside combustion air, and lowers NOx emissions.

c. Compactness

A structure incorporating a simple heat exchanger reduces size and makes installation and maintenance easy.

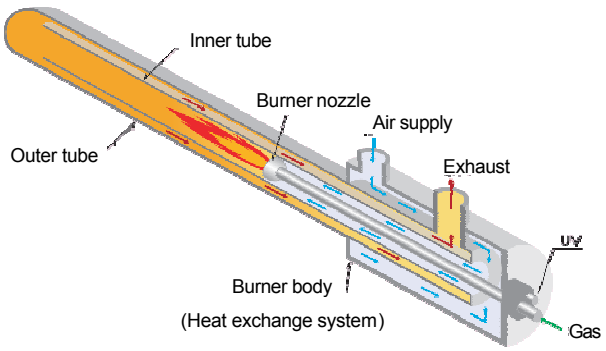



Fig. 2 CSRT-S interior structure

(2) Specifications

Table.1 shows the specifications for this burner.

Table.1 CSRT-S Specifications

| Model | CSRT-S-80 | CSRT-S-100 | CSRT-S-125 | CSRT-S-150 |
|---|---|---|---|---|
| Tube diameter | 3B | 4B | 5B | 6B |
| Rated burning capacity | 10.4kW | 14.8kW | 21kW | 32kW |
| Outer tube effective length | 1,000mm | 1,100mm | 1,300mm | 1,700mm |
| Maximum operating temperature | Furnace temperature of 1,000ºC | | | |
| Gas supply pressure | At least 6kPa | | | |
| Gas type | 13A | | | |

### 3.1.2 Improving the heating efficiency of heat treatment furnaces (Regenerative radiant tube burner: RSTB series)

We have also developed and added to our lineup the regenerative burner, as the even more efficient burner. Fig. 3 shows the outside of this burner.

(1) Advantages

a. Indirect heating burner

The RSTB is, like the CSRT-S, an indirect heating burner using a radiant tube, and is needed to use the atmosphere furnaces, which are in high demand within areas under the serving area of our company.

b. High-efficiency / low NOx

Starting from the initial RSTB development, in order to reach the goals of energy conservation and $CO_2$ reduction, we adopted thermal storage burners with the potential for greater than 85% thermal efficiencies (based on exhaust-gas losses). With the choice of an indirect heating regenerative burner, we envisioned that the amount of NOx discharged would increase, as described above, and consequently we adopted a two-stage combustion method for the reduction of NOx in the RSTB. At the rated combustion capacities, NOx values were kept below 200 ppm (11% $O_2$ basis value). When compared to prior regenerative radiant tube burners that did not employ NOx reduction technologies, this represents a reduction of approximately 50%.

c. Enhancing maintainability

From maintenance considerations, durable ceramic balls were selected for use as the heat storage elements.

Fig. 3 RSTB exterior

d. Flexibility of installation orientation

From a structural standpoint, there have been cases where previously commercialized regenerative radiant tube burners from other suppliers could only be oriented horizontally. Based on our new design of the internal structure, the burners of our RSTB can be installed in either the horizontal direction or the vertical direction.

(2) Specifications

Table.2 shows the specifications for this burner.

Table.2 RSTB Specifications

| Model | RSTB-125 | RSTB-150 |
|---|---|---|
| Tube diameter | 5 inches | 6 inches |
| Rated combustion capacity | 64kW | 93kW |
| Thermal efficiency | 85% (based on exhaust –gas losses) | |
| Maximum operating temperature | 950°C furnace temperature | |
| Gas supply pressure | At least 10kPa | |
| Gas type | 13A | |

### 3.1.3 Improving heating efficiency of endothermic gas generators (Twin Cyclo regenerative burner: CTR series)

Endothermic gas generators are equipment for producing atmospheric gas inside heat treat furnaces. And as heat treat furnace fixtures, that need to be compact, many of them have traditionally been electrically heated. Because gas heating has required a larger space than was needed for electric heaters, the use of the generator has not been as convenient. However, with the development of the twin cyclo regenerative burner (CTR), which enables combustion in a small combustion space, we have stepped up the move to replacing electricity with city gas. Fig. 4 shows the outside of a CTR.

(1) Advantages

a. High-efficiency

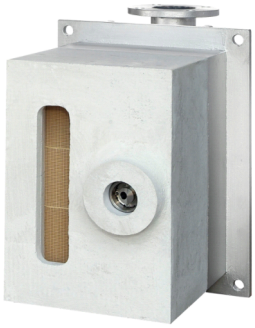
The CTR is alternately combusted in pairs over set intervals and recovers exhaust gas heat in the heat storage elements. As the CTR is a regenerative combustion type burner, that preheat air for combustion, a burner thermal efficiency of 85% is achieved.

b. An even heating possible even for small combustion spaces

Swirling-flow burners along the furnace wall prevent objects from being local heated, even in small spaces (combustion chambers of around 200 mm).

c. Compactness

Because heat storage elements are contained within burners, and burners are installed into furnace walls, burners appear to take up little space when installed into furnaces.



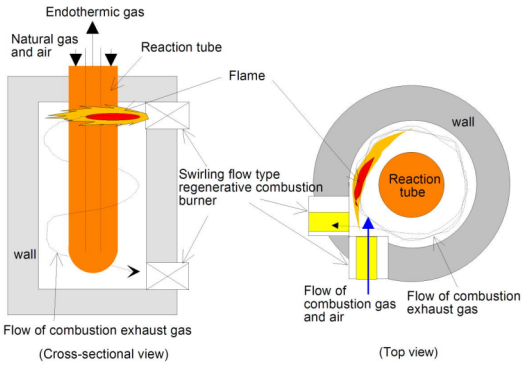



Figure1: Heating by swirling regenerative combustion burner of endothermic gas generator

Fig. 4 CTR exterior and installation for the gas generators

(2) Specifications

Table.3 shows specifications for this burner.

Table.3 CTR Specifications

| Model | CTR-50 | CTR-80 |
|---|---|---|
| Rated combustion capacity | 50kW | 80kW |
| Thermal efficiency | 85% (based on exhaust –gas losses) | |
| Maximum operating temperature | 1080ºC furnace temperature | |
| Gas supply pressure | At least 8kPa | |
| Gas type | 13A | |

### 3.1.4 Improving heating efficiency of cleaning tanks (Immersion tube burner: KGSI series)

Electrical heaters are often used in machine-parts cleaning processes to heat cleaning tanks ,and to maintain, a certain temperature. In this field as well, we have strengthened our position in the city gas market by developing and adding to our lineup a highly compact and efficient gas burner.

(1) Advantages

KGSI is a packaged burner that is compact and easy to install and maintain, and

achieves a thermal efficiency of 85% or more.

(2) Specifications

Table.4 shows specifications for this burner.

Table.4 KGSI Specifications

| Model | KGSI-5N | KGSI-10N | KGSI-20N |
|---|---|---|---|
| Rated burning capacity | 58kW | 116kW | 233kW |
| Standard immersion tube diameter | 2 1/2B | 3B | 4B |
| Outer tube effective length | 10m | 12m | 15m |
| Gas supply pressure | 2kPa | | |
| Gas type | 13A | | |

### 3.1.5 Simulation

To answer customer needs, we perform a variety of simulations including heat transfer simulations, combustion simulations, and fluid simulations and provide support in optimizing the design and operation of burner combustion and industrial furnaces.

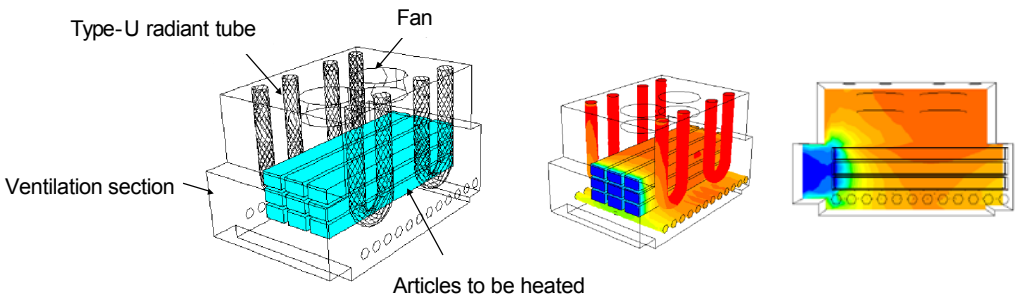



Fig. 5 Heat transfer simulation

## 3.2 Non-ferrous metal plants

Fig. 6 shows a model for non-ferrous metal plants, which deal primarily with aluminum die casting. While we have a number of energy-saving approaches for non-ferrous metal facilities, the four primary approaches are: (1) Enhancing heating efficiency, (2) Reducing waste heat loss, (3) Reducing heat loss, and (4) Enhancing operating conditions.

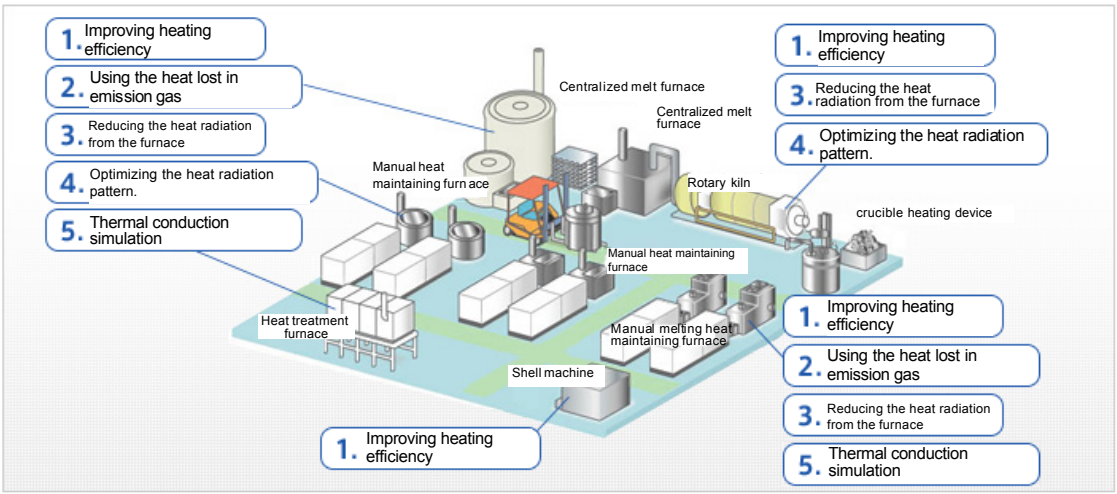



Fig.6 Example proposal for energy saving at aluminum casting treatment plants

### 3.2.1 Enhancing heating efficiency

By optimally setting the amount of energy used (city gas burning capacity) and the excess air ratio in accordance with our customers' equipment and treatment volume, we are able to maintain a high operational efficiency. As Fig. 7 shows, it is important to maintain the optimal flame angle and length with tower-style melt furnaces, as per the diagram that depicts the melting of aluminum with direct heat.

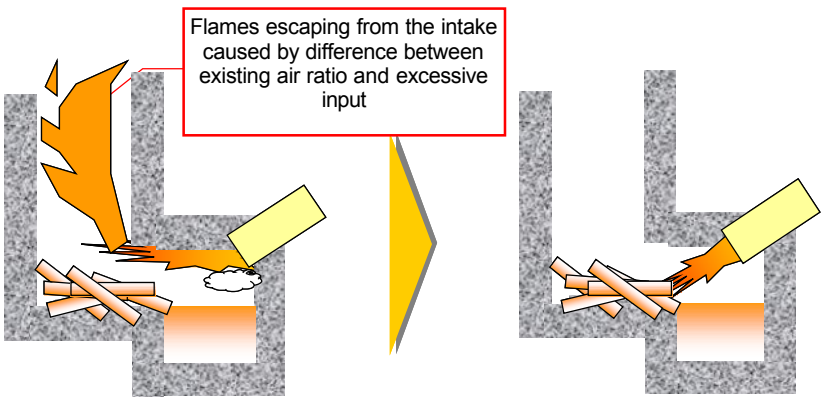



Fig. 7 Combustion adjustment allows optimal flame shape for tower furnaces

### 3.2.2 Reducing waste heat loss

Through a variety of methods, we restrain the amount of heat that has traditionally been lost along with exhaust gas or otherwise reduce the amount lost by recovering it, allowing us to conserve energy.

#### 3.2.2.1 Waste heat loss reduction for crucible furnaces (Packaged recuperating burner: TKR series)

Targeting crucible furnaces for melting or holding the temperature of aluminum (the most commonly used furnace at non-ferrous metal facilities), we developed a packaged burner that incorporates a heat exchanger for collecting waste heat.

(1) Advantages

a. High efficiency

With existing crucible furnaces and burners, exhaust gas is emitted from a chimney in the furnace body, and high-temperature exhaust gas is wasted during combustion. Efficiency is improved with this burner by collecting this waste heat that is thrown away in the heat exchanger. Fig. 8 and 9 show the exterior and interior of this burner. Exhaust gas from combustion returns to the inside of the burner from outside the burner's heat chamber and flows into the bottom of the heat exchanger. When exhaust gas passes through the heat exchanger, heat exchange turns this gas into air for combustion.

c. Compactness

This burner is a packaged burner that comprises combustion control devices, blowers, and other incidental equipment along with heat exchangers for collecting waste heat. This burner's compactness and ease of installation and operation makes it simple to replace other burners in existing crucible furnaces.


Fig. 8 TKR exterior

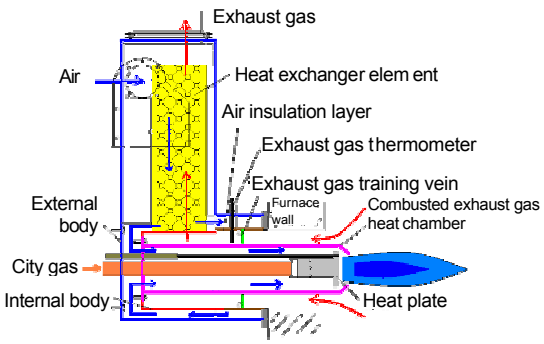



Fig. 9 TKR interior

(2) Specifications

Table.5 shows specifications for this burner.

Table.5 TKR Specifications

| Model | TKR-7N | TKR-10N (under development) |
|---|---|---|
| Combustion control | High-Low-Off (includes Hi cut control) | |
| Burning capacity (Hi/Lo) | 81kW / 46kW | 116kW / 46kW |
| Maximum operating temperature | 1000ºC furnace temperature | |
| Heat exchanger | Countercurrent plate | |
| Gas supply pressure | 2 kPa | |
| Gas type | 13A | |

### 3.2.2.2 Waste heat loss reduction for tower-type furnaces

The tower-type furnace has both a melting burner and a holding burner installed, and exhaust gas is emitted from the chimney. By using that exhaust gas and performing preheating before melting aluminum ingots (the raw material) ingots, lost heat can be recovered. As shown in Fig. 10, when not loading in aluminum ingots, the temperature of exhaust gas coming from the chimney is between 700 and 800ºC; When loading in aluminum ingots, exhaust gas temperatures fall between 400 and 600ºC. The temperature difference here corresponds to the amount of heat recovered. While this energy conservation method is not new, operators loading in aluminum ingots often do not know about this method. In such cases, a sensor installed in the furnace detects when ingots have run low and informs operators with a buzzer. We propose this solution to our customers as part of efforts to assist in improving operator awareness.

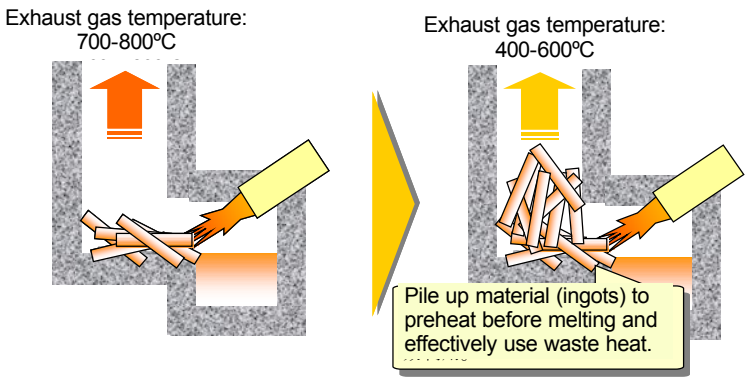



Fig. 10 Waste heat loss reduction by loading ingots into a tower-type furnace

Also, because aluminum ingots must be loaded into them, chimneys have a large diameter. A hatch with a hole to allow a minimal amount of exhaust to be released after ingots are loaded in maintains the inner-pressure of the furnace and reduces air coming in from access holes. This allows for warming and emitting incoming air, thus making it possible to reduce waste heat loss.

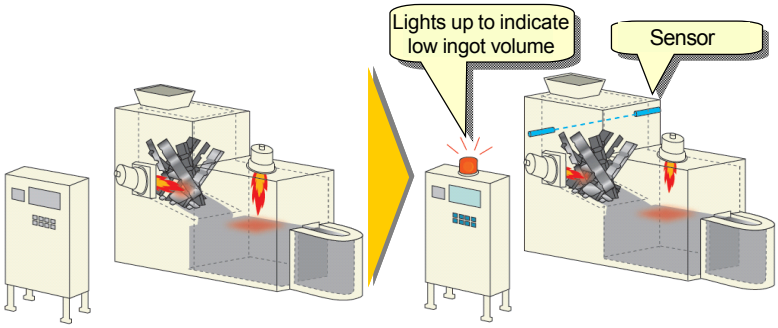



Fig. 11 Using a sensor to detect volume of ingots loaded in

### 3.2.3 Reducing heat loss

Reducing heat loss from the surface of furnaces and molten aluminum is another effective way of conserving energy. Heat loss from furnaces can be monitored with a thermal viewer and, as Fig. 12 shows, peeling silver paint, holes that open up as a result of thermal deformation of the furnace cause heat loss.

Moreover, as Fig. 13 shows, when the molten aluminum eats into the firebrick in the furnace wall, furnace wall insulation is degraded, the temperature of the furnace surface rises, and the amount of heat loss increases. An effective way to prevent this is to apply a material that repels molten aluminum as a coating to the furnace surface.

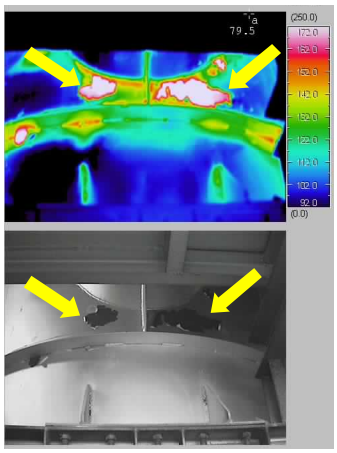


Fig. 12 Silver paint peeling away from the furnace surface

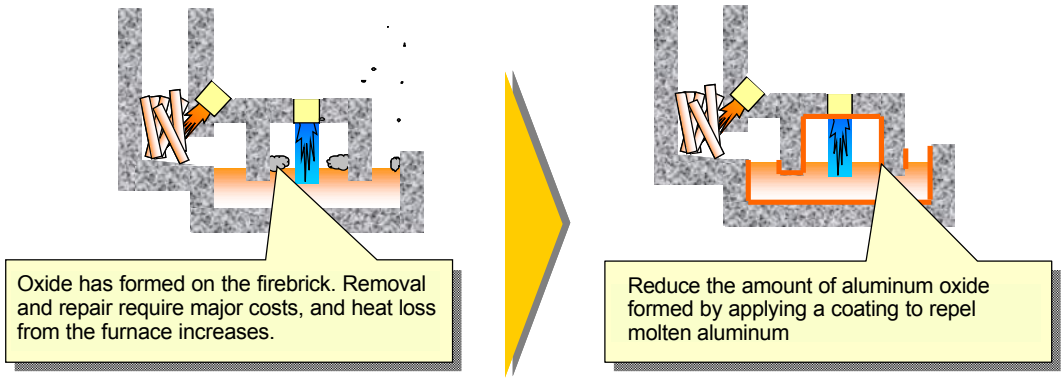



Fig.13 Preventing the adherence of aluminum oxide

### 3.2.4 Improving operating conditions

As shown in the Fig.15, when the temperature of molten aluminum has considerable hunting for the target temperature, or when it's temperature has an excessive rising, heat loss can be reduced by setting optimal conditions for burner burning capacity and temperature control devices.

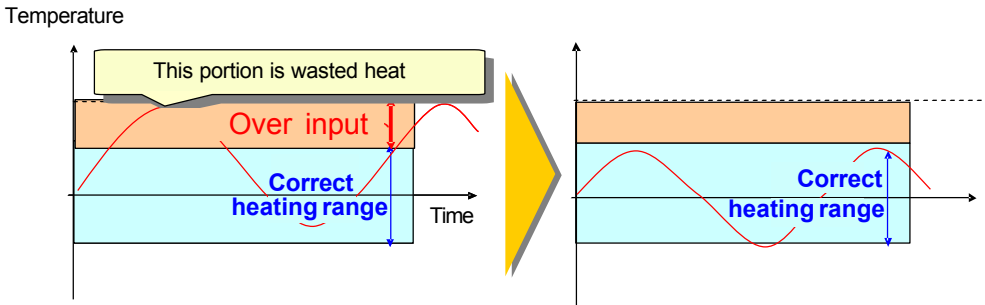



Fig. 14 Correcting molten aluminum temperature overshoot

## 4. Results

### 4.1 Heat-treatment plants

As previously mentioned, our main solution for heat treatment plants has been to implement burners that we have developed.

We have already introduced more than 2000 of our proprietary burners to our customers. In our current lineup, the previously-mentioned RSTB series is the newest type of the burner. Our first RSTB-125 inch unit has been in use by a customer in their actual operation since April 2010. There are 12 burners (six sets) installed in the heating zone of a continuous quenching furnace, and they are operated continuously 24 hours a day at temperatures in the range 830° - 880°C. Under actual operating conditions, the thermal efficiency is approximately 90% (based on exhaust-gas losses; maximum gas temperature = 250°C), and the NOx level is less than 180 ppm (11% $O_2$ basis). This operation thus verifies the high efficiency and low NOx emissions of the burner, and results are good for this first unit.

The first six RTSB-150 units (three sets) were introduced into heating zones for continuous hardening surfaces in October 2011, and have just begun operation at a furnace temperature of 880ºC.

With these and other burners, we plan to continue to introduce proprietary burners in order to improve our position in the market with regards to heat treatment.

### 4.2 Non-ferrous metal plants

While past energy-saving solutions for non-ferrous metal plants have primarily been related to maintaining and optimizing furnaces because of the relatively low investment involved, we are now proposing a method to greatly increase energy conservation for traditional burners with a set investment using the TKR series burners, which we developed in 2007, and others.

Fig. 15 shows the results of optimally adjusting flame angle and burning capacity by cleaning the inside of the furnace and removing aluminum oxide from around the burner for tower-type furnaces shown in 3.2.1. While this is only one case, we cut energy usage by approximately 17%.

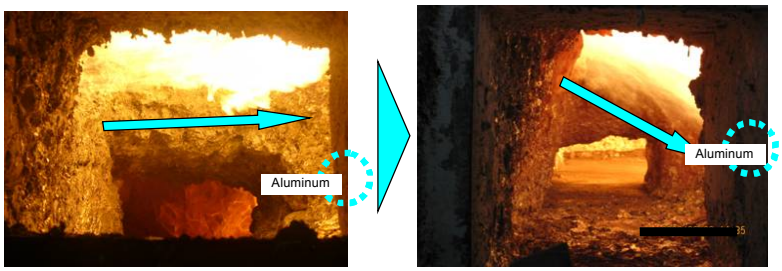



Fig.15 Improving the heating efficiency of an aluminum melt furnace

Since the introduction of our first proprietary TKR series unit in February 2007, we have introduced these burners at four other occasions. For three of these we introduced our TKR-7N, used with for crucible furnaces that hold molten aluminum melted. Table.6 shows an example of the amount of gas used by this burner and traditional burners. While there was variation in the types of aluminum ingots used, melting temperatures, and operating conditions, gas usage was reduced by an excellent 23-33%. And now, we began proposing our TKR-10N, a high-capacity burner that can melt aluminum ingots, in June 2011.

Table.6 Gas usage comparisons between TKR and traditional burners

| | | Traditional burner | TKR-7N |
|---|---|---|---|
| Exhaust gas temperature (Average ) | | Approx. 640℃ | Approx. 340℃ |
| During production | Gas usage (13A) | 3.4 $m^3N/h$ | 2.3 $m^3N/h$ |
| | % reduction | – | 33% reduction |
| Holding (overnight) | Gas usage (13A) | 2.2 $m^3N/h$ | 1.7 $m^3N/h$ |
| | % reduction | – | 23% reduction |

## 5. Summary

Operating primarily in Aichi Prefecture as well as its environs, Toho Gas is a gas business company with the automotive industry as its key industry. Our areas of focus are heat treat plants and non-ferrous metal plants where heat demand is high, and we have worked on a number of power-saving endeavors such as the development of high-efficiency burners. We will continue to devise a variety of solutions tailored to customer needs to maintain and enhance our position in the city gas market.