The Development and Introduction Examples of the High-efficiency Single-ended Radiant Tube Burner SRTN Series

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1. Preface

TOHO GAS is a city gas provider which supplies natural gas to approximately 2,300,000 customers in the Tokai area including Aichi Prefecture located in the center of Japan.
In the three prefectures of the Tokai area, many automobile-related companies concentrate, the automobile industry has become one of the key industries, and a vast amount of thermal energy is being consumed in heat treatment and cast processes at the manufacturing stage of metal materials and parts. As demands for energy saving and CO_2 reduction have increased recently from the viewpoints of global-scale environmental conservation, etc., activities for these purposes have been promoted even in the field of such industrial furnaces. In order to contribute to those activities, our company has focused not only on promoting wider use of natural gas, which is an environmentally-friendly energy source, but also on developing and providing high efficiency equipment as a technology for highly efficient use of the gas, and has proposed the equipment to our clients as a solution tool. This report is intended to provide information on the high-efficiency single-ended radiant tube burners (SRTN series), which have been developed jointly with Narita Techno Co., Ltd. so that our customers in the field of industrial furnaces can achieve further energy saving.

2. Overview of High-efficiency Single-ended Radiant Tube Burners (Model: SRTN series)

This chapter outlines the SRTN series we have developed recently.

2.1 Development Background

One of the industrial furnaces is a heat treating furnace used to, for example, reinforce the hardness of metal parts such as automobile parts (refer to Figure 1). When a heat treating furnace is used, an atmospheric gas whose main components are carbon monoxide, etc. is introduced into the furnace in some cases in order to create an intended atmosphere, and then radiant tube burners or electric heaters that indirectly heat products with radiant heat are widely used to prevent combustion gases from disturbing the atmospheric gas composition. The radiant tube burner is a burner that forms flames within a tube (diameter: 3 to 8 inches approximately) called a radiant tube (hereinafter, "RT"), heats RT from inside, and thereby heats a product with radiant heat from the heated RT surface. For this reason, it can apply even to heat treating furnaces, such as anti-oxidation heaters, carburizing furnaces, and nitriding furnaces, using special atmospheric gases similarly to electric heaters. Our company has commercialized RT burners, with a built-in heat exchanger, for heat treating furnaces in the past (refer to Figures 2, 3, and 4), and already sold 2,700 or more RT burners in total. To respond to requests for further energy saving and CO_2 reduction, however, the development of much higher efficiency equipment is required.

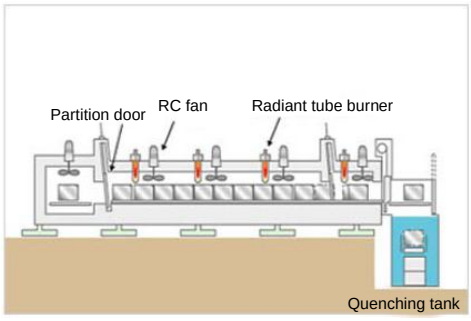

Figure 1: Schematic view of Continuous Heat Treating Furnace

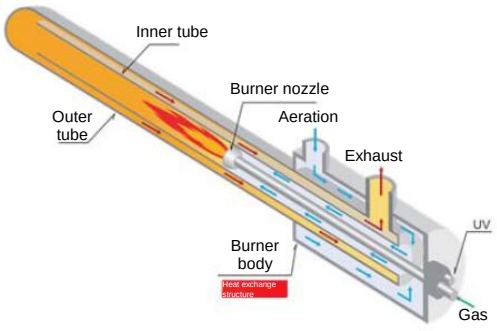

Figure 2: Internal Structure of Burner in Single-ended RT Burner

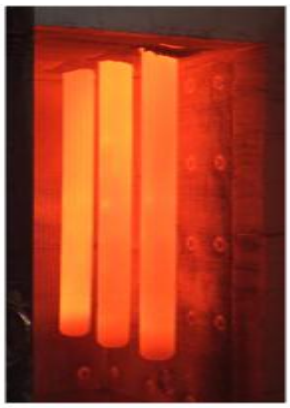

Figure 3: Single-ended RT Burner Installations within Furnace

Figure 4: Single-ended RT Burner Installations in Furnace Body

2.2 Development Goals

1) Development target

We have determined from the background described above to develop a more efficient single-ended RT burner targeted for atmosphere heat treating furnaces (such as quenching furnaces and carburizing furnaces), which are in higher demand than other industrial furnaces in the service district of our company. We have adopted the range of 750 to 950°C for in-furnace temperatures as the operating temperature range, and the range of 10 to 32 kW per burner for the combustion amount. In addition, we have selected three RT diameters, 3, 4, and 6 inches, considering the demand within our service district.

2) Higher efficiency

Generally, the single-ended RT burners provide a thermal efficiency of approximately 65% (based on the exhaust loss standard), but we have manufactured a lineup of high efficient burners with a thermal efficiency of 70% through our efforts in the past. In this effort, to promote further energy saving and CO_2 reduction, we have decided to enhance the structure of the heat exchanger within the burner body and improve the heat exchanging performance between exhaust gas and combustion air with the aim to achieve a thermal efficiency of 75% or higher (based on the exhaust loss standard).

3) NOx reduction

As NOx is one of the factors of the environmental problem, an attempt to achieve NOx reduction is an important challenge in the burner development.

NOx contains thermal NOx generated from oxidizing nitrogen in the air and fuel NOx generated from oxidizing nitrogen compounds in the fuel. The followings are typical techniques to reduce the thermal NOx:

- Exhaust gas recirculation combustion
- Two-stage air combustion
- Two-stage fuel combustion
- Lean premixing combustion
- Rich-lean combustion
- Steam spraying combustion

As the exhaust gas recirculation combustion technique has been adopted for the existing burners and is capable of bringing comparatively high effect among the NOx reduction techniques listed above, we have also adopted it for the SRTN series. Generally, increase in exhaust gas recirculating ratio tends to improve the NOx reduction effect but make the combustion less stable; for this reason, the optimal recirculation ratio must be set. Note that the following formula (1) is used to calculate the exhaust gas circulating ratio:

Exhaust gas circulating ratio = (20.95-a)/(a-b)•100 (%)--- Formula (1)

a: O2 concentration in the combustion air after exhaust gas is mixed (%)

b: O2 concentration in the exhaust gas (%)

2.3 Structure and Specifications of Burner

1) Nozzle structure

Generally, a cup-type nozzle considered to have good flame holding performance is used for the burner nozzle section of the single-ended RT burner. For the recently-developed SRTN series, plate-type nozzles (patent applied for) have been selected not only to ensure good flame holding performance, but also to achieve more cost reduction than that of cup-type nozzles.

2) Burner structure

Figure 5 shows the appearance of an SRTN series. We have designed the structure of the

aeration and exhaust channels as shown in Figure 6 in the burner body, and thereby improved the heat exchange performance between the combustion air and the exhaust gas, and achieved a thermal efficiency of 75% or more (based on the exhaust loss standard and at an in-furnace temperature of 900°C).

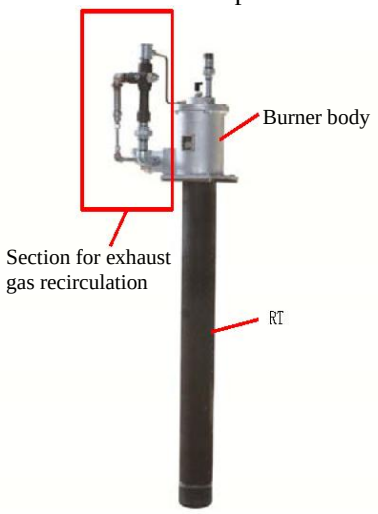

Figure 5: Appearance of SRTN Series

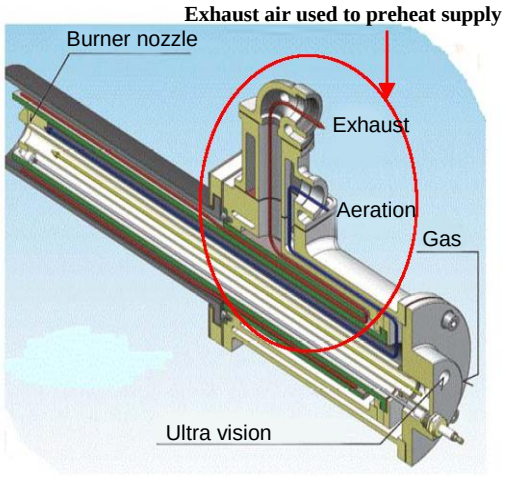

Figure 6: Internal Structure of SRTN Series

3) Burner lineup

Table 1 lists a lineup of the developed burners.

Table 1: SRTN Lineup

Model	SRTN-80	SRTN-100	SRTN-150
RT diameter	3 inches	4 inches	6 inches
Standard outer tube effective length (mm)	1000	1100	1700
Standard rated combustion amount (kW)*1	10.8	14.8	32.0
Proper adjustment air ratio*2	1.20 or more		
Gas supply pressure	10 kPa or more		
Control method	Position-proportional control/time-proportional control		

*1: The rated combustion amount depends on the RT effective length. (LHV standard)

*2: Even with an air ratio of 1.2 or less, a favorable combustion can be provided (refer to 3.3 Burner Combustion Performance), but 1.20 or more has been adopted for the proper adjustment air ratio because the deterioration-over-time, etc. could occur.

3. Basic Functions of SRTN Series

This chapter describes performance evaluation results of thermal efficiency, NOx concentration, combustion range, combustion sound, and durability as to the SRTN series. The tests were conducted with our test furnace and under the following conditions listed in Table 2:

Table 2: Test Conditions

Model	SRTN-80	SRTN-100	SRTN-150
Combustion amount (kW)	10.8	14.8	32.0
Air ratio	1.15		
Furnace wall thickness (mm)	300		
Total length of outer tube (mm)	1260	1400	1985
Effective length of outer tube (mm)	960	1100	1685
Ceramic inner tube diameter (mm)	ϕ53	ϕ66	ϕ102
Ceramic inner tube length (mm)	1350	1560	2100

3.1 Thermal Efficiency

Figure 7 shows the relationships between furnace temperatures and thermal efficiencies for SRTN-80, -100, and -150. As indicated in the figure, any of the models shows a thermal efficiency of 75 [%] or more at a furnace temperature of 900°C (based on the exhaust loss standard). The comparison was made based on the assumption that an electric heater and the SRTN series were used with the same furnace and that our burners could reduce the amount of CO2 emission approximately by 50% using the factors listed in Table 3, as shown in Figure 8.

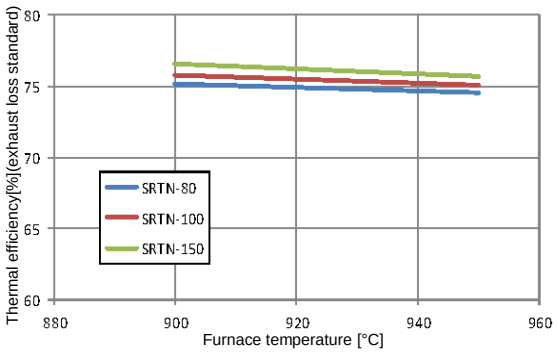

Figure 7: Relationships between Thermal Efficiencies and In-furnace Temperatures for SRTN Series

Table 3: Factors Used for Estimation

	Electronic heater	This burner
CO2 emission factor*1	0.550 kg-CO2/kWh	2.36 kg-CO2/m3N

*1: This burner (Source: "Environment and Society Report 2013"

published by TOHO GAS)
Electric heater (Source: Greenhouse Gas Emissions According to the GHG Emissions Accounting, Reporting, and Disclosure System by the Ministry of the Environment)

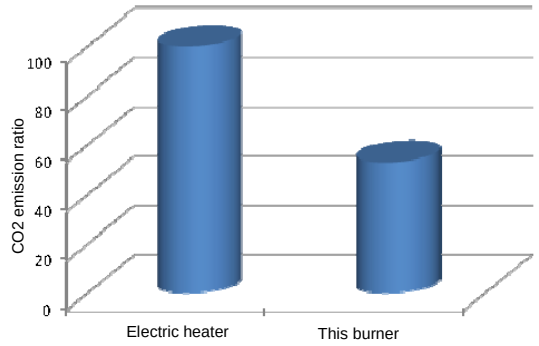

Figure 8: Comparison between Amounts of CO2 Emission from SRTN Series and from Electric Heater

3.2 Combustion Performance

Figures 9 to 11 indicate each lower combustion limit of SRTN-80, -100, and -150 at a cold temperature (at a furnace temperature of 100°C or less). Each burner shows a favorable combustion with an air ratio of 1.2 or less between the rated combustion amount and one-third of it, which means that they are a burner that can ensure a turn down ratio of 3:1 (a ratio of the lowest combustion amount to the rated one).

On the other hand, as to the upper combustion limit at cold temperature, each model shows a favorable combustion even at an air ratio of 1.5 with the combustion amount when the turn down ratio is assumed to be 3:1, which indicates that they are a burner that can provide a favorable combustion in a wide range. As the combustion range becomes wider, the combustion at lower loads can be made possible and the number of times the burner is turned OFF can be controlled. Therefore the efficiency for the partial load combustion is improved.

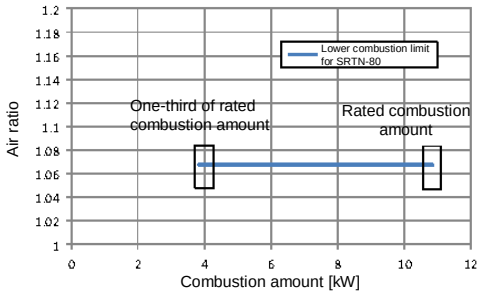

Figure 9: Lower Combustion Limit for SRTN-80

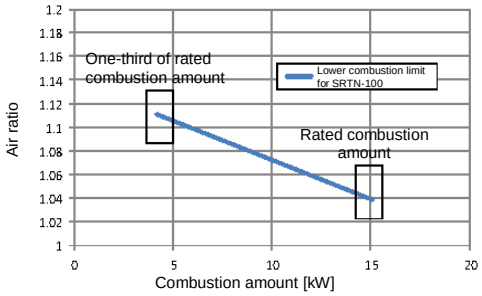

Figure 10: Lower Combustion Limit for SRTN-100

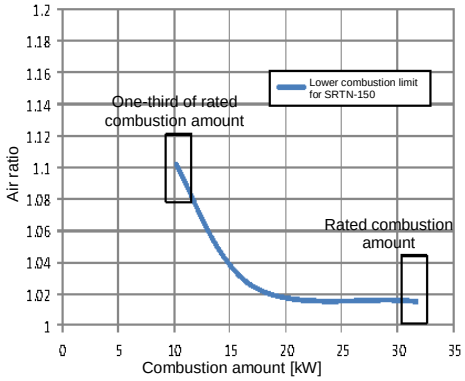

Figure 11: Lower Combustion Limit for SRTN-150

3.3 Combustion Sound

Generally, the combustion within a tube may generate unpleasant noises due to the combustion sound. For example, our tests indicated that burners tended to generate high-pitched combustion sounds when they had too good flame holding performance. The SRTN series records a noise value of 75 dB (A) or less (at a distance of approximately 0.5 m from the exhaust tube) when the gas burner is burning, and does not generate unpleasant combustion sounds by optimizing their nozzle shapes.

3.4 Durability

Durability plays the same important role in evaluating burners as the combustion performance described above. Our company now continues to evaluate the durability of the burner bodies and burner nozzles, and the following describes how they have been evaluated. Table 4 lists the evaluation conditions.

The burners keep a favorable combustion without causing conspicuous damage and misfire for the burner bodies and nozzles. We also evaluate the durability of spark rods by forcibly turning them ON and OFF repeatedly, and we do not witness any spark failure. For this reason, we assume that they are sufficiently capable of dealing with the ON-OFF control in the time-proportional control, in addition to the position-proportional control. We evaluate these results, and conclude that replacing parts due to aging is not required so often, and they are burners excellent in maintainability.

Table 4: Our Durability Evaluation Conditions

Furnace temperature (°C)	950
Air ratio	1.20
Combustion amount (kW)	Two values: 14.8 (rated value) and 4.5 (one-third of the rated value)

*The data in Chapter 3 only indicate the test results with our test furnace, and may be different depending on an actual operation environment.
-Definition in this document-
Thermal efficiency of SRTN = {(Lower calorific value - Calorific value taken away by exhaust gas)
/Lower calorific value} × 100 (%)

4. Sales Results and Case Examples of Saving Energy

In July 2013, we launched the SRTN series, our newly developed products, in all models. However, SRTN-100 (4-inch outer tube diameter type), which had been developed ahead of the other models in the series, was launched in July 2012, and has achieved the sales results shown in Table 5. Through cooperation with Hidaka Kogyo Co., Ltd., which introduced the first product of SRTN-100, we measured and compared the fuel unit consumption and exhaust gas temperature between this developed product and one of our existing products (with a catalog thermal efficiency of 70%). Figure 12 and Tables 6 and 7 show and list the comparison results. Note that the measurement and comparison were conducted on the furnaces with the same processing ability, processing temperature, and combustion amount, and the comparison was conducted under the condition that the developed product and existing type burner had the same combustion volume (14.8 kW) and the same oxygen concentration in the exhaust gas (5%). We confirmed that the SRTN series had fuel unit consumption reduction effect and saving energy performance improvement by approximately 7%, compared to the existing burner.

Table 5: Sales Results of SRTN-100

	Introduction date	Products	Furnace shape
Hidaka Kogyo Co., Ltd.	July 2012	10	Batch type carburizing furnace
		10	Batch type carburizing furnace
	May 2014	10	Batch type carburizing furnace
Company B	February 2013	10	Batch type carburizing furnace
	February 2014	10	Batch type carburizing furnace

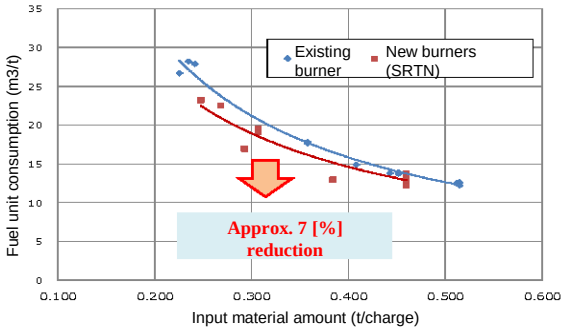

Figure 12: Comparison on Fuel Unit Consumption between Existing Burner and SRTN-100

Table 6: Thermal Efficiency of Existing Burner in Actual Operation

Existing burner			
Position	Temperature (°C)	Exhaust gas loss (kcal/m3)	Burner efficiency
R1	556	4,198	71.2%
R2	550	4,199	71.2%
R3	538	4,337	70.3%
R4	541	4,363	70.1%
R5	530	3,939	73.0%
L1	571	4,269	70.8%
L2	533	3,850	73.6%
L3	541	3,981	72.7%
L4	528	3,833	73.7%
L5	549	4,092	72.0%
Average	543.7	4,100	71.9%

Table 7: Thermal Efficiency of SRTN-100 in Actual Operation

New burners (SRTN)			
Position	Temperature (°C)	Exhaust gas loss (kcal/m3)	Burner efficiency
R1	445	2,763	78.0%
R2	440	2,638	79.0%
R3	457	2,813	77.6%
R4	470	2,884	77.0%
R5	445	2,732	78.2%
L1	430	2,601	79.3%
L2	430	2,586	79.4%
L3	423	2,526	79.9%
L4	426	2,589	79.4%
L5	445	2,708	78.4%
Average	441.1	2,682	78.6%

5. Conclusion

We have developed single-ended RT burners (model: SRTN), which have an exhaust heat recovery function within their burner body, adopt an exhaust gas recirculation combustion method, and are excellent in energy saving performance and have confirmed the following results:

1) Thermal efficiency: 75% or more (based on the exhaust loss standard)
2) Wide combustion range with a turn down ratio of 3:1
3) Quiet combustion sound with a noise value of 75 dB (A) or less
4) Approx. 50% reduction expected on the amount of CO_2 emission, compared to that of electric heaters
5) Approx. 7% improvement in energy saving performance in production was demonstrated, compared to one of our existing burners (with a catalog thermal efficiency of 70%)

Finally, we would like to express our deepest appreciation to Narita Techno Co., Ltd. as the joint development manufacturer of this burner and to Hidaka Kogyo Co., Ltd. for their cooperation in demonstration and evaluation of the product.

Note that this burner has received the Japan Machinery Federation President Award in the fiscal 2013 Commendation System for Excellent Saving Energy Equipment (hosted by the Japan Machinery Federation (General Incorporation Foundation))

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