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Challenge to Develop Ultimate Ultra-small Energy Holding Furnace

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◎ **Keywords: Rationalization of fuel combustion**
Prevention of heat loss due to radiation and conduction etc.

◎ Outline of Theme

This factory is an aluminum casting factory and it consumes a great deal of fuel. So the innovation of the combustion facilities not only contributed to the factory's profit but also was an important issue in achieving the CO_2 emission reduction goal. Our activities in the long run were composed of step 1) use of waste heat (introduction of energy conservation burners), step 2) innovation of burning characteristics (flame inducing furnace wall) and final step 3) control of heat diffusion loss. As the results of these activities, we successfully developed an ultimate ultra-small energy holding furnace.

The achievements solved all of the problems of conventional energy conservation type burner holding furnaces, covering wide range of issues such as "energy conservation rate 70%", "fine temperature change", "sudden temperature increase", "machine trouble rate 1/10", "safety including earthquake measures", etc.

◎ Implementation Period of the Said Example

March, 1998 – up to now (deploying horizontally) Total 6 years and 5 months

- Planning period: March, 1998 – March, 2004 Total 6 years
- Implementation period:
  March, 1999 – up to now (deploying horizontally) Total 6 years and 5 months
- Confirmation period: March, 1999 – up to now Total 6 years and 5 months

◎ Outline of the Business Establishment

- Production items: Parts for cars (aluminum casting, magnesium casting, resin

molding, etc.)

Transmission cases, delivery pipes, pistons, oil pumps, etc.

- Employees: 1,386 people (As of March, 2004)
- Yearly energy consumption (2003 actual)

LNG	19.333 millionNm^3
LSA	2,416kL
Electricity	105,169MWh

◎ Outline of Target Facilities

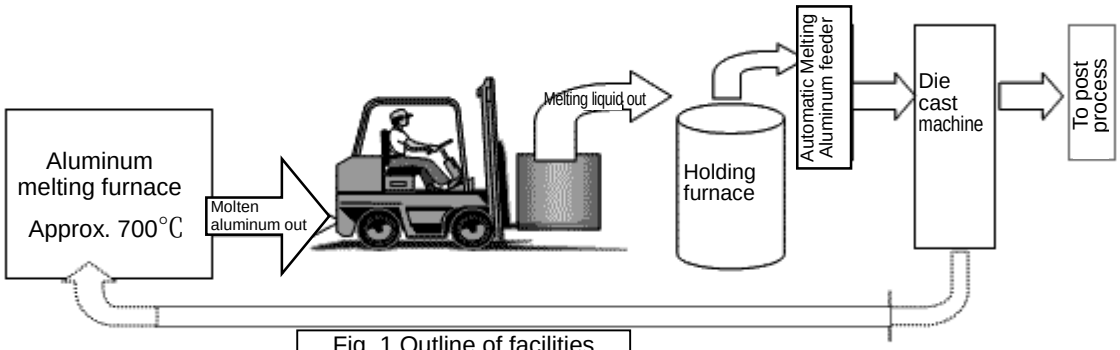


Fig. 1 Outline of facilities

1. Reasons for Theme Selection

As a casting factory which consumes a great deal of energy, we need to rationalize the use of energy consumed by combustion facilities as fast as possible to strengthen our profitable business and to preserve the global environment. As our index, we have the target of reducing CO_2 emissions by 10% by 2010 compared with 1990 level. However, if we take the increase of the energy consumption up to now into consideration, we need to reduce it by 30% or more. In order to have steady achievement, we need to fully deploy valid factors horizontally based on a long term plan.

The combustion facilities are basically classified into 1) melting furnaces and 2) handy holding furnaces, and we decided to develop an ultimate ultra-small energy holding furnace based on a 5 year plan for the 2) handy holding furnaces which are more compact to use.

In this report, we describe only the outline of the “introduction of energy conservation type burners” in the initial stage of our activities, and we describe in details our activities in recent years in relation to the ultra-small energy holding furnace.

Step 1) introduction of “energy conservation type burners” as initial activities

One of the most typical and effective energy conservation items for the handy holding furnace is the regeneration burner which enhances the combustion efficiency by pre-heating the air using waste heat. After we confirmed the effect by introduction on a trial basis, we fully deployed them horizontally and successfully introduced them to all of 90 handy holding furnaces for die casting line.

For the handy holding furnaces whose capacity is small and for which it is difficult to introduce the regeneration burner due to high cost, we introduced burners integrated with heat exchangers which were developed within our company and quickly deployed them horizontally. We finally introduced them to all of 52 handy holding furnaces for gravity casting machines.

	Regeneration burner	Burner Integrated with a heat exchanger
Equipment present at the destination of deployment	Holding furnaces for die cast lines	Holding furnaces for piston casting machines
Number of units deployed	90 units	52 units
Activity period	March, 1999 – August, 2001	June, 2001 – June, 2002
Energy conservation rate	50 – 60%	52%
Total reduction amount	1.692 million Nm^3/year	636 thousand Nm^3/year
Monetary amount of reduction effect	67.68 million yen/year	25.459 million yen/year
Equipment investment amount	108.9 million yen	29.12 million yen
Pay back time	1.6 years	1.1 years

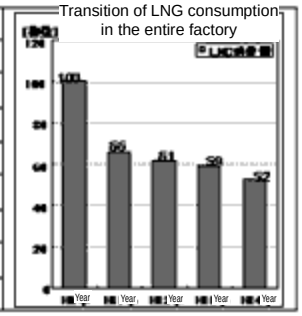


Fig. 2 Type and effect of burner introduced

On one hand, the effect of the energy conservation type burner was obvious, contributing to the LNG reduction of the whole factory. On the other hand, it was noted that the reliability of equipment became low (burning capacity, machine trouble rate) and the energy reduction target was difficult to achieve. So we decided to go one step up, i.e. challenge to innovate the combustion system from its base.

2. Understanding and Analysis of Current Situation

(1) Basic Concept of Activities

The use of energy conservation burners as typical energy conservation technology of handy holding furnaces can certainly reduce the fuel of around 50%, but there are risks as well. The risks are classified into 3 categories, i.e. 1) increase of maintenance cost, 2) increase of machine trouble and 3) decrease of melting capacity (Fig. 3). Especially, the 3) decrease of melting capacity, which cannot follow the rapid change of melting temperature, may cause deterioration of productivity and quality.

Our activities may be ultimate one which contradicts conventional common sense because it requires enhancing the temperature increase capacity as essence of holding furnaces while

reducing the fuel cost. So we focused on 1) innovation of “combustion chamber” to enhance the temperature increase 2) measures to prevent heat loss from “furnace body” aiming to the reduction of fuel cost and 3) improvement of “burners” to reduce the trouble rate.

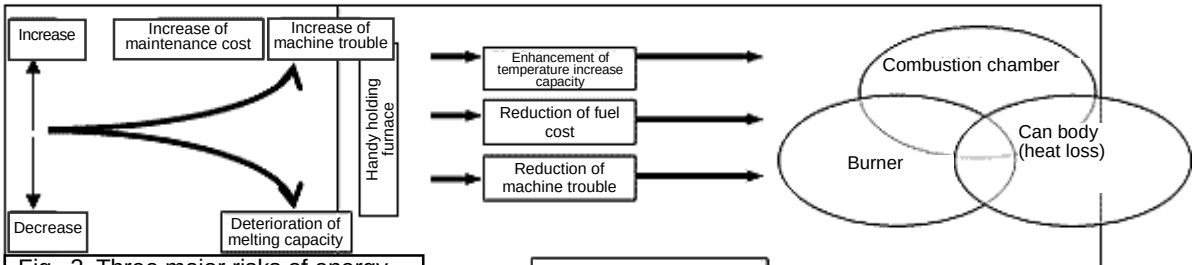


Fig. 3 Three major risks of energy conservation burners

Fig. 4 Activities

(2) Structure of Handy Holding Furnace (with energy conservation type burner)

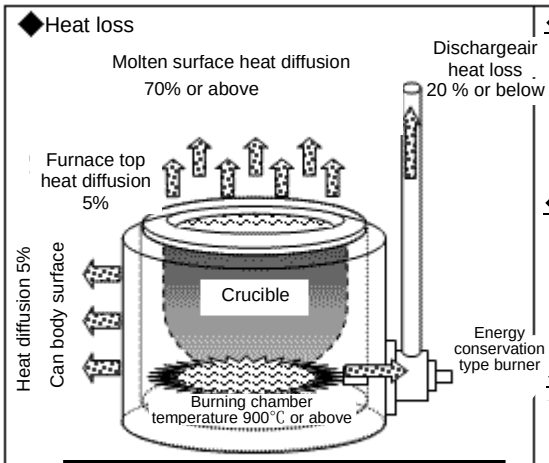


Fig. 5 Structure of holding furnace and heat loss elements Combination with regeneration

◆Handy holding furnace

Heat retention device that heats the crucible with a gas burner to maintain the temperature of molten aluminumat a certain level. When combined with the energy conservation burner, it is designed to enhance the air tightness of the furnace.

◆Energy conservation type burner

With the heat storage element built in the burner, it is designed to collect waste heat. The burning gas of the burner goes through the heat storage element and is discharged from the funnel.

◆Major heat loss elements (Fig. 5)

(1) Heat diffusion from the molten surface 70% or more.
(2) Heat discharge from the funnel 20%
(3) Heat diffusion from the furnace top 5%
(4) Heat diffusion from can body surface 5%

(3) Understanding of Current State1] (Energy conservation type burner and temperature increase capacity)

In case of energy conservation burners, the gas burning amount of the burner is approximately half of that of standard burners. However, actual gas burning strength of the energy conservation type burner is estimated to be 20% - 30% less than that of the standard burner, because the heat loss of the former is less than that of the latter (Fig. 6).

If molten aluminum of the temperature which is lower than the reference temperature is supplied, it takes time twice the standard burner to return the former state. However, once it reaches the reference temperature, there is no substantial difference between the burners.

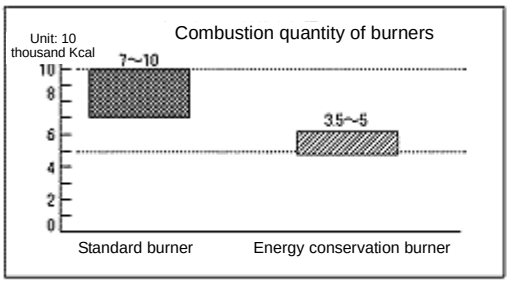


Fig. 6 Comparison of combustion quantity of each burner

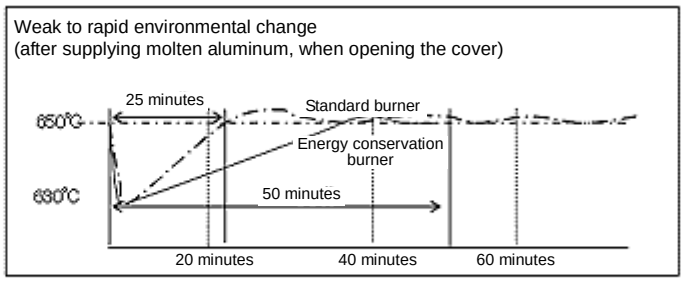


Fig. 7 Change of molten aluminum temperature by burner

(4) Understanding of Current State 2]（If molten aluminum temperature is too high）

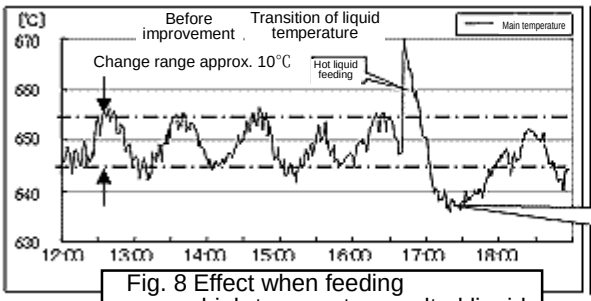


Fig. 8 Effect when feeding high-temperature melted liquid

If the temperature of the molten aluminum is too high to the contrary, the combustion -off time becomes longer and the combustion chamber's temperature comes down. So "rebound phenomena" happens, i.e. the temperature does not increase as soon as the burner is ignited.

Rebound
Because of the high-temperature molten aluminum fed, combustion stops for a long time by the air cooling of combustion

(5) Analysis of Current State 1]（Energy conservation type burner and image of crucible）

The heating power of the energy conservation type burner is weaker than that of standard burners because it keeps the energy loss less. So it is weak to follow rapid change of molten aluminum temperature (temperature recovery ability).

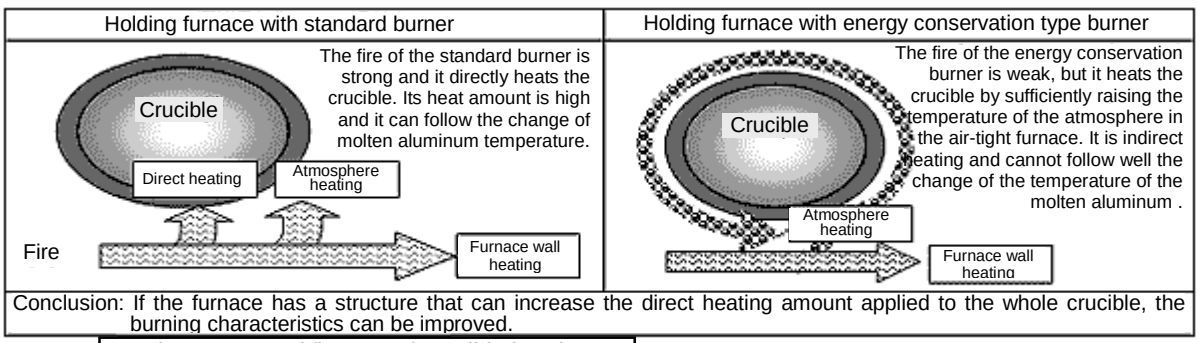


Fig. 9 Image of flame and crucible heating

(6) Analysis of Current State 2]：(Comparison of combustion cost of furnaces and burners)

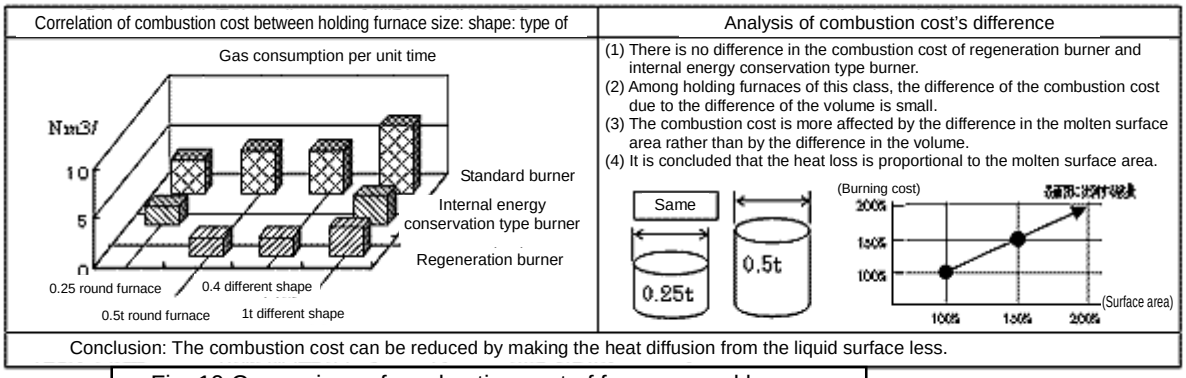


Fig. 10 Comparison of combustion cost of furnaces and burners

3. Progress of Activities

(1) Approach and Implementation Structure

The activities were classified into 3 elements, i.e. “combustion chamber”, “furnace body and molten surface” and ”burner main body”, and we decided to optimize the “combustion characteristics” as the essence of the holding furnace and to minimize the energy consumption.

Then, the environmental technology team took charge of work from 1) outline study to 4) durability test described below and the energy working group undertook the work from 5) introduction to mass production to 7) extended deployment.

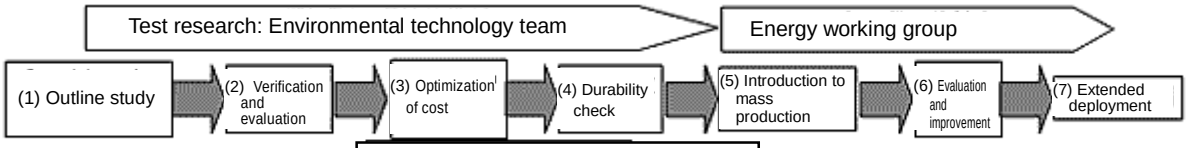


Fig. 11 Activity steps and roles

(2) Target Settings

As the targets, 1) Temperature increase time of 1/2, 2) Energy conservation rate of 70% (compared with standard burner) and 3) Machine trouble rate of 1/10 were picked up.

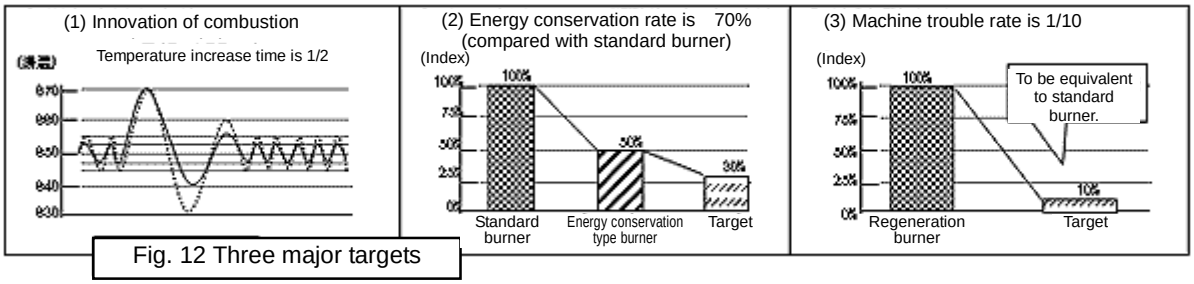


Fig. 12 Three major targets

(3) Problems Points, their Investigation and Improvement

1) To improve burning characteristics

To improve the capability to follow the temperature change of the molten aluminum, which is the weakness of the energy conservation type burner, we studied based on the conclusion of the “analysis of current state 1)”, i.e. “the combustion characteristics can be improved if the furnace has a structure that can increase the direct heating amount applied to the whole crucible”. However, we decided to indirectly increase the heating amount by using the furnace wall because if the flame is applied directly to the crucible, it affects the service life of the crucible.

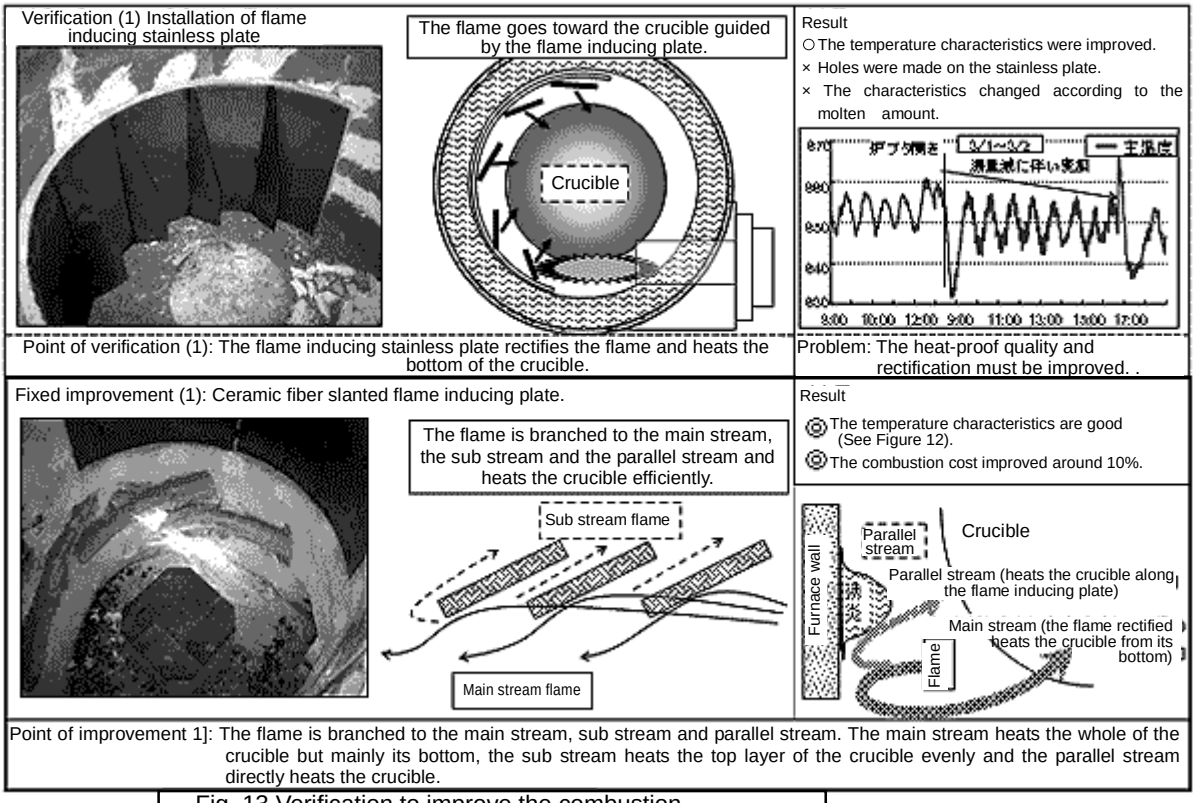


Fig. 13 Verification to improve the combustion characteristics and improvement of furnace wall

Improvement 1]: Upward flame inducing furnace wall

The molten aluminum temperature transition graph of the improvement 1] is below. There are 2 effects. One is that the temperature recovers quickly even if it changes suddenly (Fig.15 (A)). The other is that the temperature started to change finely andthe range of the temperature change is approximately half the conventional range (Fig. 15 (B)).

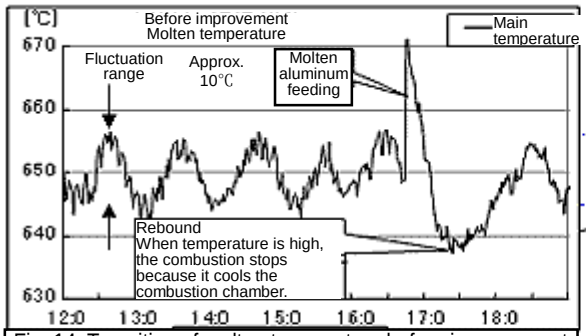


Fig. 14. Transition of molten temperature before improvement

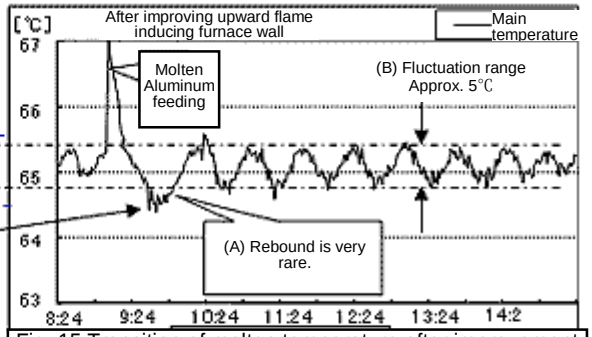


Fig. 15 Transition of molten temperature after improvement

This technology presumes the furnace that installs the energy conservation type burner we developed. We don't know how this technology works if applied to conventional burner furnaces. It must be noted that the regeneration burner may burn unexpectedly because the combustion becomes unstable when the supply and discharge of air changes. It must also be noted that the flame guiding direction and the angle must be adjusted according to the furnace shape.

2) For improvement of heat diffusion loss control

To control the heat diffusion loss from the molten surface, we studied it based on the conclusion of "analysis of current state 2)" confirming that "the combustion cost can be reduced if the heat diffusion area from the molten surface is made smaller". There was a furnace cover, and we didn't know its effect numerically. So we decided to study the energy conservation effect of the cover first.

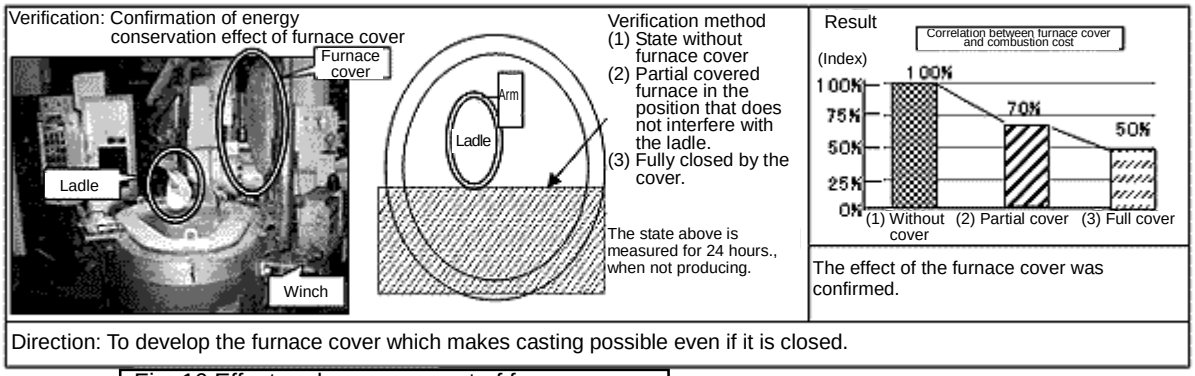


Fig. 16 Effect and measurement of furnace cover

a. Improvement of furnace cover

Improvement 2] Heat diffusion control ultra-small opening furnace cover

By making a necessary minimum opening according to the shape of the ladle on the furnace cover which is used when the furnace is not working such as between shifts or break time,

the casting was made possible even if the cover is closed.

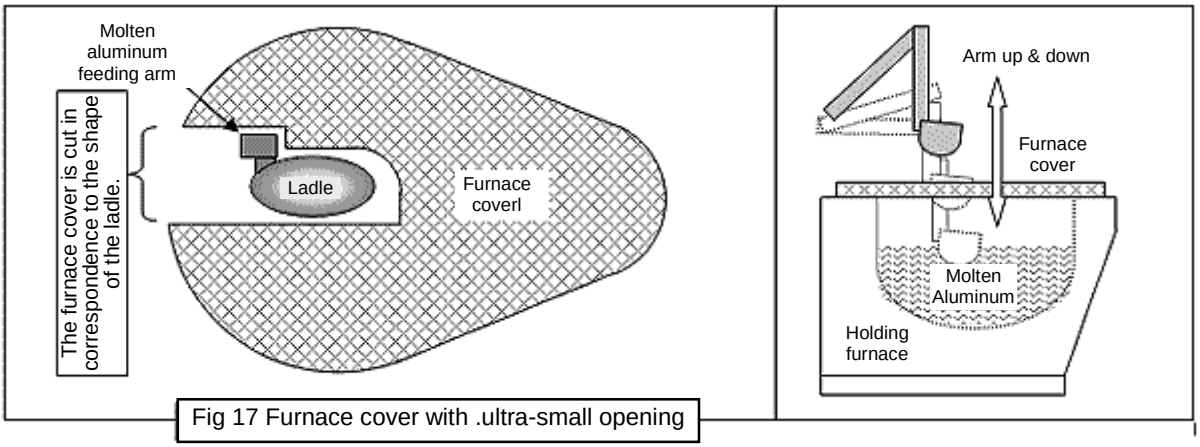


Fig 17 Furnace cover with .ultra-small opening

The heat diffusion loss from the molten surface became less and the fuel was reduced 30% compared with conventional method.

Improvement 3] Electric furnace cover which can be freely opened and closed any time
As shown in Fig. 17, the cover cannot be opened when the molten aluminum feeding arm is at the furnace side because it interferes with the cover. The cover must be opened and closed every 1 to 2 hours to supply the molten aluminum. So we came up with special mechanism that can open and close the cover regardless of the position of the molten aluminum feeding arm. First, the small cover A opens toward the front direction preventing the ladle from being interfered. Then, the big cover B fully opens toward the funnel side. To close it, it moves in the reverse order until it is automatically fully closed. This series of movement is electrically and automatically driven by one-touch operation.

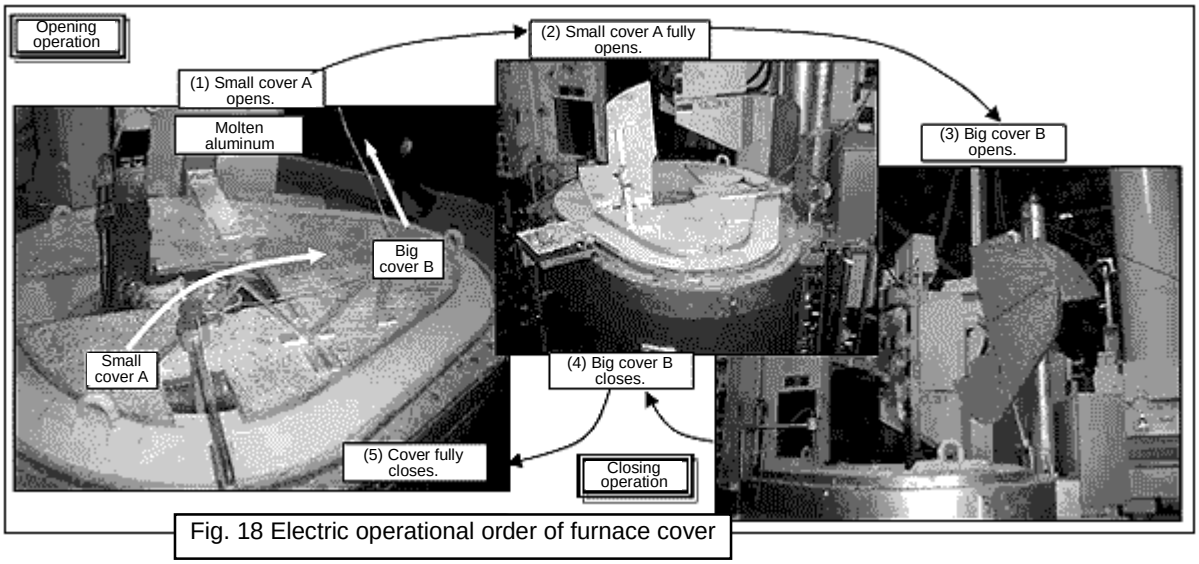


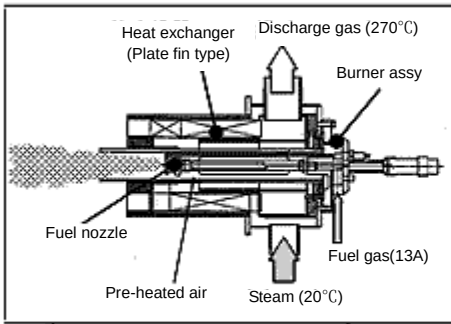
Fig. 18 Electric operational order of furnace cover

3) To reduce machine trouble of energy conservation burner

This plant started to study to introduce energy conservation type burners made by T-company for the handy holding furnaces in 1998 and started to introduce them in 1999. Since then, the introduction has contributed to the reduction of fuel (LNG) in proportion to the number of units deployed (90 units). At the same time, we have developed and introduced (52 units) the energy conservation type burners (burner integrated with a heat exchanger).

Type	Designed burning capacity	Features	Main deployment
Regeneration burner	50 thousand kcal	Small and high efficiency by rotary switching plate of supply and discharge	Die cast line
Burner integrated with a heat exchanger	30 thousand kcal	No mechanical structure using heat exchange technology of stirling engine	Gravity casting line

- Features of integrated burner with a heat exchanger internally developed

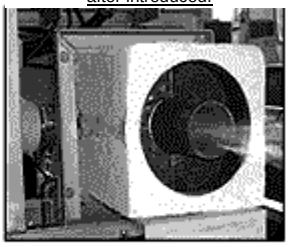


High durability and reliability

Thanks to its mech-less, simple mechanism, machine trouble is rare. The heat exchangers using the technology of the stirling engine are good at durability. Though 3 years have passed since its introduction, all 52 units have no trouble.

* As regards the details of the integrated burner with a heat exchanger, please refer to the report entitled “3 types of energy conservation burners and LNG reduction” announced as 2001 Energy Conservation Excellent Case

Heat exchanger burner in 3 years after introduced.



No deterioration at all.

Fig. 19 Features of integrated burner with a heat exchanger

a. Maintenance and improvement of heat exchange function by high pressure cleaning unit for the integrated burner with a heat exchanger

The most important part of the energy conservation burner is the heat exchanger. If there is clogging in the heat exchanger, the combustion cost rises proportionally with contamination. So we made the “heat storage high pressure air blow unit” which can easily clean the heat exchanger at any time.

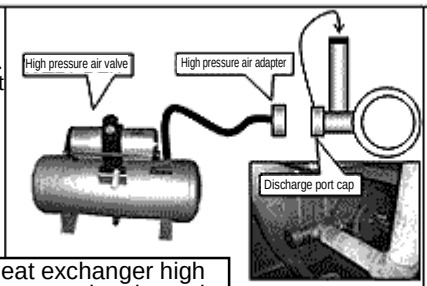


Fig. 20 Heat exchanger high pressure cleaning unit

Procedure (1) Turn out the burner and open the cover.
(2) Remove the discharge port cap and put it to the tip of the funnel.
(3) Install the high pressure air adapter to the discharge port.
(4) Increase the pressure up to 0.6Mpa – 0.7Kpa with the plant air pressure valve.
(5) Open the valve and send the high pressure air at once.
(6) Repeat this 2 to 3 times and finish the cleaning.

- Clean the heat exchanger when the furnace pressure is higher than prescribed level.
- The cleaning is possible even when the burner is working and 70% of function is recovered. By blowing air from the heat storage surface on holidays and the function is recovered almost 100%.

b. Difference of trouble rate between energy conservation type burners and countermeasures

As time passes and the number of units in operation increases, trouble of regenerators and the cost to deal with it became problematic.

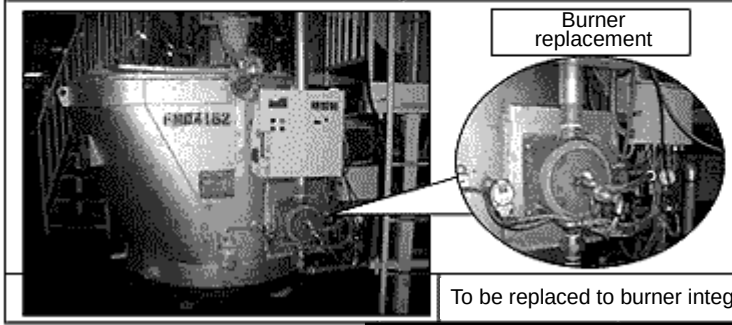
Type	Light trouble (Adjustment level)	Medium trouble (Parts change)	Serious trouble (Main units change)	Average trouble per unit	Yearly cost
Regeneration burner	90 cases *1	22 cases *1	26 cases *1	1.8 cases	Approx. 20 million yen *1,*2
Burner integrated with a heat exchanger	19 cases *1	2 cases *1	None *1	0.4 cases	Approx. 100 thousand yen *1,*2

*1: the above number is the total of one year from February, 2003 to January 2004.
*2: Cost spent for the repair and maintenance except for consumables such as filters.

Since the absolute number of the units installed is different (regeneration 90 units, heat exchanger 52 units), it cannot be simply compared, but the difference is obvious. We could manage to stop the increase of trouble by periodic inspection of the contractor, but the risky factors have not been cleared. Therefore, we decided to review the composition of the equipment aiming to change to the integrated burner with a heat exchanger.

Measures: Replacement of burner from regeneration to heat exchanger

Problems	Measures	Results
(1) Enhancement of combustion capacity (2) Control of replacement cost	(1) Electro-magnetic valve, higher blower capacity (2) Existing control panel and blower are used	(1) Combustion capacity = Max 50 thousand Kcal is kept. (2) Approx. 60% of new installation.



◇Progress
1) December, 2002 DCM6-6 Evaluation test started.
2) February, 2004 DCM3-6 Replacement completed.
3) May, 2004 DCM1-7 Replacement completed.

To be replaced to burner integrated with a heat exchanger occasionally.

Fig. 21 Replacement of burners

4. Total Effects Achieved after Implementing Measures

With the innovation of the combustion characteristics, the temperature became able to recover in time that is about half the conventional time without missing the set temperature of ±10℃, even if there is sudden temperature change. Also, the transition of the heat retention became finer from ±5℃ to around ±2℃. The energy conservation rate achieved the reduction of 70% compared with standard burners. As regards machine trouble, until now there is no trouble at all as a result of adopting energy conservation type burners with high durability developed in the company.

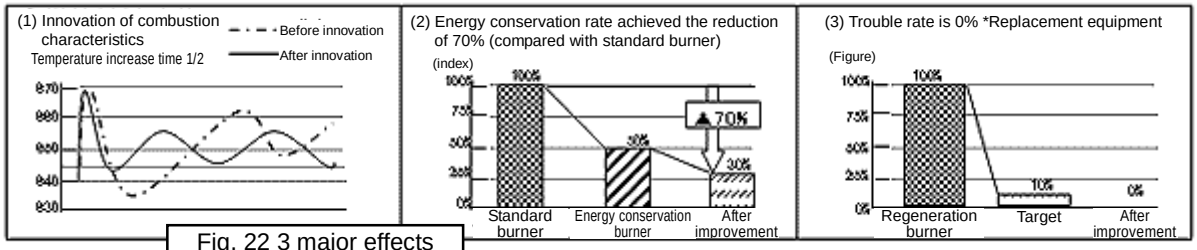


Fig. 22 3 major effects

> LNG reduction amount is (total) 3.024 million Nm^3(108.864 million yen) and 1,943t in CO_2 equivalent

5. Summary

We reflected on the fact that we sacrificed the temperature increase rate as essence of the holding furnace and caused a lot of trouble because we had put too much priority on energy conservation. So we challenged to increase the temperature increase rate and lower the machine trouble rate, and achieved them. Based on that achievement, we started improvement of minimizing the heat diffusion loss and succeeded in making ultra-small opening furnace cover. So we were able to develop an ultimate ultra-small energy holding furnace. Besides, by applying the combustion efficiency technology stored through these activities, we were able to horizontally deploy the technology to holding furnaces with different shape, thus greatly contributing to CO_2 emission reduction.

6. Future Plans

We will deploy the system horizontally to about 140 holding furnaces we have and will pursue further cost reduction and ultimate energy conservation.