NEXT GENERATION OF ELECTRICAL LADLE HEATERS: A CASE STORY

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ABSTRACT

Sandvik is now introducing its next generation of Kanthal® electrical ladle heaters. By heating ladles with electricity instead of gas, aluminum producers and steel foundries can benefit from lower energy costs, increased process control, reduced CO_2 emissions, and a cleaner working environment. The in situ testing of a Kanthal electrical ladle heater system compared to a conventional gas heated ladle heater shows that energy savings of 50% can be achieved in conjunction with better temperature uniformity in the ladle.

1. INTRODUCTION

Sandvik is now introducing its next generation of Kanthal® electrical ladle heaters. By heating ladles with electricity instead of gas, aluminum producers and steel foundries can benefit from lower energy costs, increased process control, reduced CO_2 emissions, and a cleaner working environment. The following report will introduce the reader to the benefits of electrical ladle heating through an in situ test at a customer site where the customer's existing gas heated ladle heater's performance is compared to a new electrical ladle heater supplied by Sandvik heating technology.

Figure 1 Kanthal electrical ladle heater

1.1 High net efficiency:

Kanthal electrical ladle heaters offer significantly higher net energy efficiencies compared with traditional gas heating. Their design enables the same heater tube to be used for both heating and holding. The heating elements are arranged in a reflector, allowing the radiation to be more accurately directed towards the target area.
The uniform temperature profile achieved when using electrical elements to heat the ladle, and the fact that there is no flame or streaming hot exhausts, will prolong the lifetime of the refractory, typically by 10–15%.

1.2 Innovative monitoring and control:

An advanced heater monitoring and control system optimizes performance and prolongs the lifetime of the heater by eliminating overheating. The system ensures maximum and consistent power, which reduces process times.

Kanthal electrical ladle heaters are supplied as complete installations, comprising heating elements in a reflector casing, and control and regulation equipment. Commissioning and technical support are provided on site by Sandvik heating experts.

1.3. Complete range:

Sandvik offers a broad portfolio of Kanthal electrical heating systems, for a range of applications in the primary aluminum industry, typically rodding shops, in secondary aluminum in foundries, and in steel foundries. We also provide systems for glass production and R&D purposes. See table 1 for a description of the full range of standard Kanthal electrical ladle heaters.

Table 1 Standard range of Kanthal ladle heaters

Ladle heaters

Product portfolio

Model	Ladle size A [mm] (inch)	Phases	Power [kW] (BTU/h)	Supply voltage [V]	Heater Dimensions	
					OD [mm] (inch)	H [mm] (inch)
5–7	500-700 (20"-28")	1-phase	30 (102 400)	230	1150 (45,3")	700 (27,5")
	500-700 (20"-28")	1-phase	45 (153 500)	230		
	500-700 (20"-28")	1-phase	66 (225 200)	400		
7–9	700-900 (28"-35")	1-phase	66 (225 200)	400	1350 (53,1")	700 (27,5")
	700-900 (28"-35")	3-phase	90 (307 000)	400		
9–11	900-1100 (35"-43")	3-phase	90 (307 000)	400	1550 (61")	700 (27,5")
	900-1100 (35"-43")	3-phase	135 (460 600)	400		
11–13	1100-1300 (43"-51")	3-phase	90 (307 000)	400	1750 (68,9")	700 (27,5")
	1100-1300 (43"-51")	3-phase	135 (460 600)	400		
13–15	1300-1500 (51"-59")	3-phase	90 (307 000)	400	1950 (76,8")	700 (27,5")
	1300-1500 (51"-59")	3-phase	135 (460 600)	400		
	1300-1500 (51"-59")	3-phase	200 (682 400)	400		
15–17	1500-1700 (59"-67")	3-phase	135 (460 600)	400	2150 (84,6")	700 (27,5")
	1500-1700 (59"-67")	3-phase	200 (682 400)	400		
17–19	1700-1900 (67"-75")	3-phase	135 (460 600)	400	2350 (92,5")	700 (27,5")
	1700-1900 (67"-75")	3-phase	200 (682 400)	400		
19–21	1900-2100 (75"-83")	3-phase	135 (460 600)	400	2500 (98,4")	700 (27,5")
	1900-2100 (75"-83")	3-phase	200 (682 400)	400		
	1900-2100 (75"-83")	3-phase	270 (921 300)	400		

2. IN SITU COMPARISON BETWEEN GAS AND ELECTRICALLY HEATED LADLE HEATER

The comparative test described in this paper was conducted at a well-known car manufacturer´s aluminum foundry in Japan. The prerequisites, method and results are presented in the following text.

2.1 Prerequisites:

<u>Gas burner system</u>

The customer’s previous system was of the type “open flame”-burner and with specifications as below, see figure 2 for a descriptive photograph of old ladle heater

- Heating cycle: Room temperature to 850ºC in one hour. Hold for 3 hours. 4 hours total cycle.
- Gas type 13A, Energy content: 41,7 MJ/m^3
- Gas consumption: 6 Nm^3/hr (24 Nm^3 per cycle)

Figure 2: Customers previous ladle heater system

<u>Electrical ladle heater system</u>

The new system supplied by Sandvik comprises of a patented Kanthal Super 3D element situated in a steel framed reflector in combination with hydraulic hoist system and control equipment. Specifications as per below, see figure 3 for descriptive photographs of the ladle heater system.

- Heating elements made of Kanthal® Super RA (12/24) with 3D configuration
- Heater unit is automatically raised and lowered hydraulically
- Heater specification 54kW/600A
- Attachments on both sides to minimize heat loss from the spouts

Figure 3: Kanthal ladle heater system

3. METHOD AND EVALUATED PARAMETERS

The same ladle was used in both tests and was equipped with thermocouples at 7 different measuring points to reflect the temperature change over time during both tests, see figure 4 for placement of thermocouples. The data from the thermocouples would be used in the formation of the energy balance for each test case and also as a visualization method for the temperature uniformity within the ladle during each heating cycle for both of the tests.Tnd thus will be used to calculate the amount of energy that is lost through the exhaust gases.

The thermocouple signals were measured every 30 seconds.

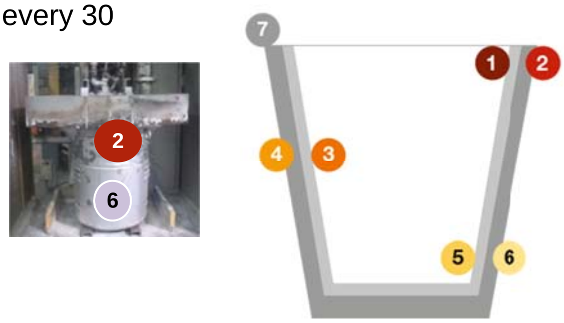

Figure 4: Thermocouple placement on test ladle

Thermal imaging was used to measure the temperature on the outside of the ladle as the temperature changes over the test cycle of both tests, the data from thermal imaging would be used to estimate thermal losses through the ladle wall due to convection and also used to calculate the energy balance, see figure 5 for examples of thermal imaging from the tests.

To account for the thermal losses through cables, controller etc. during the test with the electrical ladle heater current measuring devices was placed both on the primary and secondary side of the transformer.

4. RESULTS

4.1 Thermal imaging:

Thermal imaging was performed during both tests after the same duration of time for a comparison of the ladle outer shell temperature uniformity, the results are presented below.

<u>After 1 hour</u>

As the images show, see figure 5, one can detect that after one hour of preheating there is a raise in temperature at the top of the outside of the ladle using the gas burner system, this is due to that the exhausts from the burner is heating the top of the ladle when exiting the same. The electrical heater system is well insulated against the top of the ladle preventing heat losses.

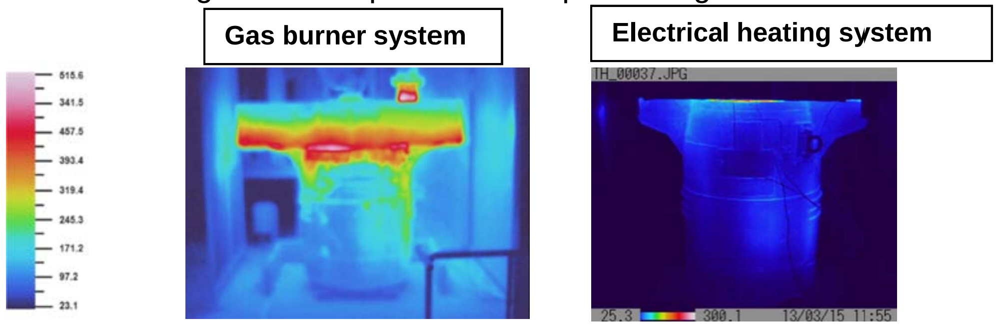

Figure 5: Comparison of ladle outer shell temperature after 1 hour of heating

<u>After 2 hours</u>

After two hours of heating, see figure 6, the temperature of the outer shell is starting to raise, the effect of the exhaust gases can be seen in the images as the temperature of the top of the ladle outside is higher using the gas burner system.

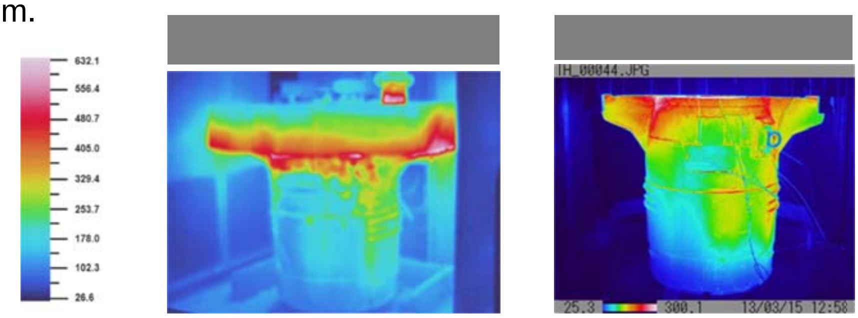

Figure 6: Comparison of ladle outer shell temperature after 2 hours of heating

After 4 hours

As seen in figure 7, after four hours of heating one can see that the temperature uniformity using the electrical ladle heating system is better that the gas heating system.

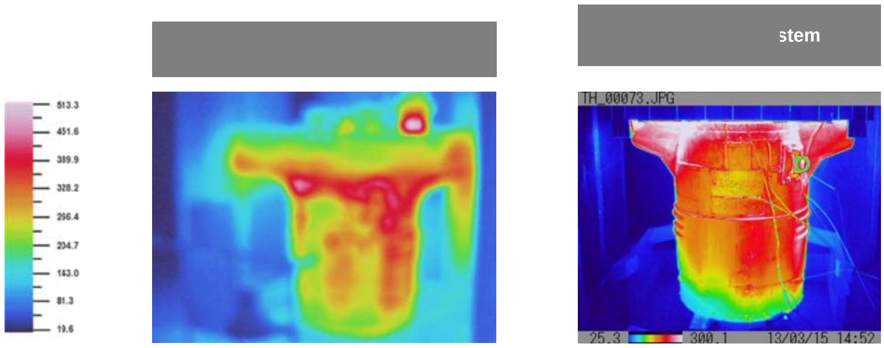

Figure 7: Comparison of ladle outer shell temperature after 4 hours of heating

4.2 Thermocouple readings:

See figure 8 and 9 for a representation of temperature within the ladle during the heating cycle for the two different systems.

A number of conclusions can be drawn from the results:

- CH ② (gas) is unstable due to the position which means the TC picks up exhaust gas. For the reference, CH ④ and ⑥ are preferable
- CH ① (electrical) shows higher temperature than TC (setting temperature) due to the proximity effect from the heater
- Both tests reached same temperature at CH ④ after 4 hours preheating (gas 253°C / electrical 239°C)
- The electrical heating system showed better temperature uniformity in the outer shell and inner wall

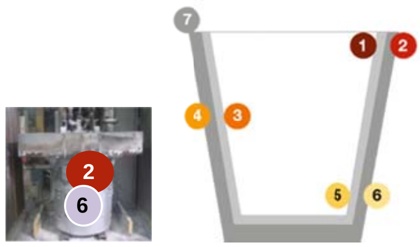

Figure 8: Thermocouple placements

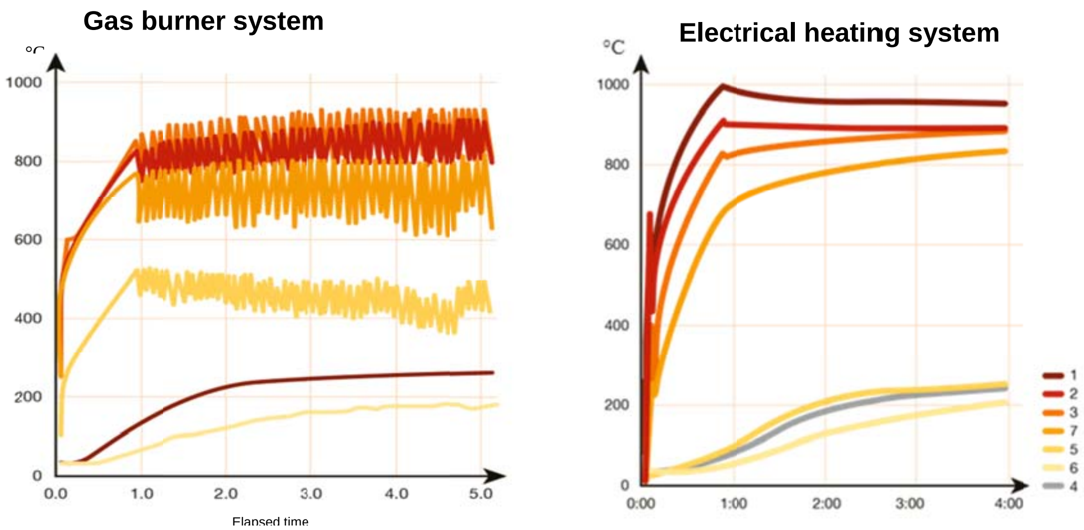

Figure 9: Logged temperature data from ladle TC's over the heating cycle of each test.

4.3 Energy balance:

An energy balance for each heating method was performed to get an accurate comparison between the two different heating systems. For each heating method all losses where estimated and calculated as per the following:

<u>Gas burner system</u>

Energy going in to the gas burner system comes from the energy content in the combustion gas as below, (A)

ENERGY IN: 41.7MJ / Nm³ x 24 / 860 = **Total in (A)) 277.7 kWh**

ENERGY OUT: See table 2

The different contributions to energy losses are described in figure 11 below. All estimations and basis for calculations are described in figure 10.

Table 2: Energy going out from the gas burner system

B) Heat radiation	Side	70.0 kWh
	Bottom	2.2 kWh
C) Exhaust gas		88.3 kWh
D) Heat accumulation	Side	89.3 kWh
	Bottom	13.6 kWh
	Steel Case	5.0 kWh
Total out (B) + C) + D) **)**		**268.5 kWh**

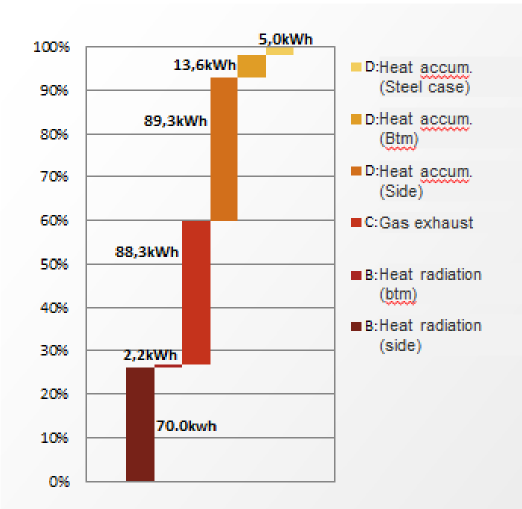

Figure 11: Energy losses in the gas burner system

Calculation base

Heat radiation

- Accumulated heat radiation every 30 sec at unsteady condition

Heat loss by exhaust gas

- (sensible heat) = (amount of gas) x (specific heat for the gas) x (deltaT)

Heat accumulation

(Inner wall) = 850℃

(Outer wall) = average temperature of CH ②④⑥

- Linear approximation of the temperature inside the refractory
- Accumulated heat for each 1 mm from inside to outside

Figure 10: Basis for estimations and calculations for the energy balance of the gas heater system.

<u>Electrical ladle heater system</u>

Energy going in to the electrical heating system is the energy supplied by the power supply on the primary side of the control cabinet.

ENERGY IN (A): Power on the primary side (measured by amp meter): 131 kW
(total energy consumption during heating cycle, measured)

ENERGY OUT: see Table 3

The different contributions to energy losses in the electrical heating system are described in Figure 12. Basis for estimations and calculations are described in figure 10.

Table 3: Energy losses of the electrical heating system

B) Heat radiation	Side	25.7 kWh
	Bottom	2.7 kWh
C) Power loss not except for heater		7.6 kWh
D) Heat accumulation	Side	82.2 kWh
	Bottom	12.5 kWh
	Steel Case	4.2 kWh
Total out (B) + C) + D))		**134.9 kWh**

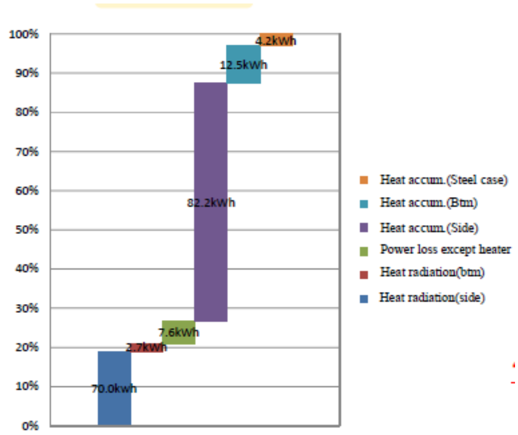

Figure 12: Energy losses in the electrical heating system

4.4 Comparison energy efficiency between gas and electrically heated ladle:

Putting the two energy loss estimations next to each other the conclusion can easily be made that the electrical heating system is significantly more energy efficient than the gas heated system, the biggest difference being that with the electrical heating system there is no exhausts that transports heat energy away from the ladle and not contributing to the heating process. When comparing the energy need of heating the ladle to the desired temperature one can see that in the case of the gas heated system the customer previously needed to supply gas with an energy content of almost 278 kW to complete the heating cycle whereas the electrical heating system supplied from Sandvik will only require an electrical power of 134 kW to perform the same task.

From a pure energy perspective one can see from the data that an energy saving of 50% is achieved with the electrical heating system, see figure 14.

- In the same preheating conditions, the heat balance is as shown in the graph
- Pure efficiency improvement 50%
  (278 kWh / 134 kWh)

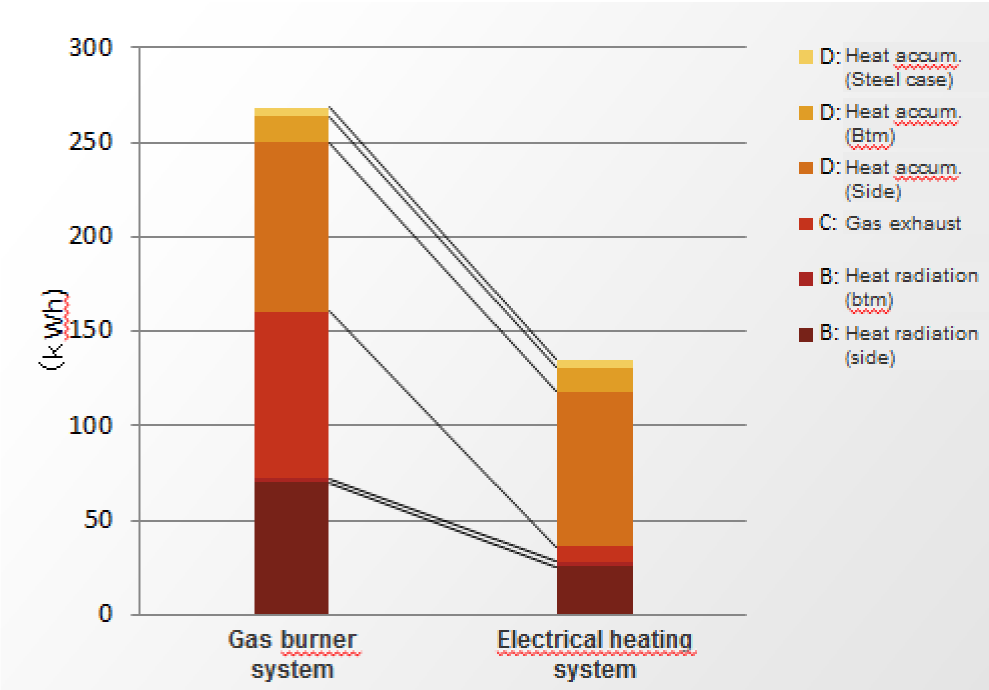

Figure 13: Energy balance comparison between the customer's previous gas fired ladle heater compared to the electrical ladle heater supplied by Sandvik.

5. Summary

Sandvik has launched their new generation of high efficient ladle heater systems to the market with a wide range of standard heaters. The high net efficiency of Kanthal electric ladle heater systems offers significant advantages, aluminum producers and steel foundries can benefit from lower energy costs, increased process control, reduced CO_2 emissions, and a cleaner working environment.

This report describes a test at a customer site where their previous gas heated ladle heaters performance was compared to a new electrical system supplied by Sandvik Heating Technology.

Sandvik replaced the existing ladle heater which had a gas consumption of 6 Nm3/hr (278 kW per heating cycle) with an 54 kW electrical heating system comprising of , heating elements made of Kanthal® Super RA (12/24) with 3D configuration, an automatic hydraulic hoist configuration and a state of the art control system.

The tests confirmed that the electric ladle heater system reached the customer target temperature of 850ºC while at the same time offering better temperature uniformity both inside and outside of the ladle, this was confirmed by thermal imaging together with thermocouple readings, and a significant energy efficiency improvement.

A detailed energy balance for both systems was set up to take into account all losses for both system.

The test results show that an energy efficiency improvement of 50% was achieved.