THE APPLICATION OF OPTICAL PYROMETERS IN OPEN RING-TYPE ANODE BAKING FURNACES

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Abstract

Albras has five open ring-type furnaces with a total of eleven fires, with three burner bridges each. Since startup in 1985, type “S” thermocouples with silicon carbide protection tubes were used for flue temperature measurement and control. With the objective for reducing maintenance time and costs, an extensive test of various combinations of thermocouple and protection tubes types and optical pyrometers was made. The optical pyrometers were found to be a viable alternative. At present two fires are controlled with two color pyrometers without protection tubes.

This paper compares the use of different types of thermocouples, single color pyrometers, with and without protection tubes and two color pyrometers. It also shows the advantages of measuring flue wall temperatures as to flue gas temperatures.

These thermocouples are handled with every fire cycle, 24 hours in our case, therefore a fire move practically every two hours. With flue temperatures at over 1200 °C due to thermal and mechanical shock we have a high rate of thermocouple failures. Figure 1 shows the average failures per month during the period of 1993 to 2000.

Thermocouple Failure Rate

<table>
<thead>
<tr>
<th>Year</th>
<th>Failure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>32.3%</td>
</tr>
<tr>
<td>1994</td>
<td>35.4%</td>
</tr>
<tr>
<td>1995</td>
<td>17.2%</td>
</tr>
<tr>
<td>1996</td>
<td>22.3%</td>
</tr>
<tr>
<td>1997</td>
<td>12.1%</td>
</tr>
<tr>
<td>1998</td>
<td>23.7%</td>
</tr>
<tr>
<td>1999</td>
<td>19.0%</td>
</tr>
<tr>
<td>2000</td>
<td>23.7%</td>
</tr>
</tbody>
</table>

Figure 1

In figure 2 we see that of the 189 installed thermocouples we had 1054 failures, whereof 62% of the failures were due to actual thermocouple junction failure, 31% due to protection tube failure and 6% due to complete loss of the unit.

Total Defects 1998 and 1999

<table>
<thead>
<tr>
<th>Failure Type</th>
<th>Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element Failure</td>
<td>658</td>
</tr>
<tr>
<td>Protection Tube Failure</td>
<td>328</td>
</tr>
<tr>
<td>Assembly Scraped</td>
<td>68</td>
</tr>
</tbody>
</table>

Figure 2

In figure 2 we see that of the 189 installed thermocouples we had 1054 failures, whereof 62% of the failures were due to actual thermocouple junction failure, 31% due to protection tube failure and 6% due to complete loss of the unit.

The thermocouple failure can be grouped in three types of failures as shown in fig. 3. The main cause was found to be hot junction contamination, due to internal or external protection tube failure. This causes the thermocouple wire to become hard and brittle and therefore resulted in calibration errors. The thermocouple is replaced in this case.

In second place was open hot junction caused by a variety of problems such as over heating, incorrect handling, end of useful life or incorrect assembly. That is, not leaving enough space between the thermocouple junction and the end of the capillary or the end of the internal protection tube.

The third cause is due to open cold junction which we can say is caused by mishandling or incorrect assembly or installation.

Introduction

During the period of 1993 to 1997 we had many process and procedure changes so that we used the period of 1998 to 1999 to analyze the types of failures.
Thermocouples
The thermocouples used are assembled using an external protection tube of re-crystallized silicon carbide for mechanical protection, an internal ceramic protection tube to protect the element from contamination, a capillary tube and the thermoelement as shown in figure 4.

With this rate of thermocouple failures we require a technician exclusively for the maintenance and installation which during the two year period comes to 1618 man hours at a rate of US$11.33 per hour, plus material costs added up to US$419,000.

To reduce the maintenance cost alternatives were tried. A short test was performed with type “K” thermocouples and a variety of protection tubes and was soon regarded as unviable as the thermocouples could not last more than a few cycles. Tests were also performed with two sizes of type “N” thermocouples, 6mm and 8mm mineral insulated. Although the lower cost of the thermocouple element the lifespan was found to be much lower than the type “S” thermocouples. The 6mm thermocouples had a failure rate five times more and the 8mm ones 2.5 times that of the type “S” thermocouples. The same re-crystallized silicon carbide was used for all the thermocouple types. Metal protection tubes of various types were tried at an earlier stage and were found not to have a suitable life span.

Optical IR Pyrometers
Without an economical alternative for thermocouples, optical pyrometers were considered as a possibility. At first we tested a single color optical pyrometer using the same silicon carbide protection tube used with thermocouples with a slightly larger inner diameter as shown in fig. 6, an fig. 7.
For a period of one year we had installed seven units and had four maintenance calls, one for a broken protection tube, two for realignment of the focus point and one of a detector problem which the manufacturer promptly replaced. Warping of the protection tubes was a problem that we noticed before the test was performed. Increasing the inner diameter and selecting a good manufacture of the protection tube solved this.

The cost of a single color optical pyrometer and the increased diameter silicon carbide protection tube is such that a two color pyrometer with its advantages become a very attractive option and therefore was tested.

An optical pyrometer with fiber optic measuring head was chosen so as to keep the electronics away from the heat. The fiber is passed through a hose that serves to protect the fiber and to supply compressed air to maintain the optics clean and cool. For a year we tested a complete fire with twenty-one pyrometers without protection tubes. After three years of operation we had to replace one pyrometer due to mishandling with a damaged fiber.

Soon after the initial tests we noticed the potential gains of using two color optical pyrometers and later prove to be correct.

The fact that the temperature measurement now is not flue gas temperature but actual refractory temperature as shown in Fig 8, this with the optimization of the control software reduced the fuel consumption. This was first noticed by the fact that the flue temperature at the manifold at an average was about 50°C colder than that of a fire using thermocouples or pyrometers measuring flue gas temperature. We used the same draft and fire control system used with thermocouples, only changing the heat-up control curve, which was derived from the anode temperature curve. The differences in the fuel consumption during the firing cycle can be seen in figures 9 and 10. The average difference in fuel flow rate comparing the pyrometer or thermocouple controlled fire was found to be 59 verses 74 pulse per minute respectively per burner bridge

Using an Lc analysis to measure final anode baking temperature and heat distribution is checked. This can also be done by real density or anode specific electrical resistivity analysis.

The refractory also benefits with this because of the guarantee that there is no overheating of the refractory. In our case the maximum refractory temperature achieved is 1220°C with the pyrometer whereas fires controlled by flue gas temperature could reach 1400 °C at certain points. Depending on the fuel or burner type and the draft control, when measuring only flue gas temperature higher temperatures can be achieved, so reducing the refractory life.
Figure 11 shows a anode pit temperature profile using equivalent temperature measurement using the Le method.
Another bonus from the two-color pyrometer is the capability of measuring attenuation. Valuable information can be extracted from this, such as a dirty lens or better still, smoke due to a defective burner, in the case of oil fired furnaces.

Difficulties encountered:
The fact that the optical pyrometers are extremely fast in response compared with thermocouples interference from the burners are encountered, especially using pulse type oil burners. This was minimized with the implementation of a special filter in the firmware done by the pyrometer supplier.
The second problem is the fact that the surface temperature changes very quickly when one turns off or on a burner, for operational or for maintenance necessities, due to the colder flue gas passing through the flue walls without combustion. This has to be taken in account for with the control software, essentially in the fire move routine.
Due to the fact that the flue wall refractory, anodes and packing coke have a very large thermal inertia one has to be careful not to overheat the refractory at the flame area in the flue. This effect happens in the cold section, just after a fire move. Monitoring the heat-up rate and amount of energy supplied to that flue controls this.

Conclusion.
Although we do not as yet have any accurate indication as to the flue life, comparing the actual state of the furnace with the thermocouple controlled furnaces we expect a life of over 170 fire cycles.
Due to the physical construction and the elimination of the protection tube, the risk of the operator being burnt accidentally during a fire move is practically eliminated.
The reliability of the pyrometer and very low maintenance burden on the production crew makes the pyrometer a viable investment.