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OPERATION OF AN OPEN-TYPE ANODE BAKING FURNACE WITH A TEMPORARY CROSSOVER

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Abstract

As part of the Puerto Madryn smelter expansion project, Aluar Aluminio Argentino has built and now operates an open type furnace designed with Rio Tinto Alcan AP Technology. The furnace was built and put into service in two stages, each of which consisted of 34 sections and 2 fires. In order to allow the erection of the second stage and the connection between both halves of the furnace, a method that had proved to be successful on other projects, was applied. A temporary crossover was used to connect two sections at the end of the first stage. This paper describes the experience gained during the operation under these conditions and the procedure and process control modifications that have been necessary to maintain the anode baking quality.

Introduction

Aluar Aluminio Argentino operates the only aluminum smelter in Argentina. It commenced production in 1974 with a nominal capacity of 140000 t Al/year. After the retrofitting of the original Montecatini cells, using an in-house developed technology, and two expansion projects, the plant has reached its present capacity of 430000 t Al/year (2010). During the last expansion project, a new open type baking furnace was built in order to fulfill the anode requirements from the pot rooms.

The furnace was built in two stages. The first 34 sections, 8 pits, 192 anodes per section stage, was dried out during September 2007. The anode handling equipment and the firing control system, for this two fires furnace, were commissioned during the drying out process.

In the second stage, the furnace was extended by a further 34 sections. The drying out process of these sections started in May 2009. The result is a furnace with 68 sections and 4 fires.

The end sections of the first stage of the furnace have been modified taking into account the work required for the erection and connection of the second stage. Therefore, the end headwalls, heat insulated sidewall in sections 52 and 17 (see furnace scheme in Figure 1) have been designed to reduce and facilitate the modifications required for the furnace extension.

The construction of stage 2 began at the "new" end of the complete baking furnace, namely sections 34 and 35 (Figure 1), and progressed towards the center of the furnace, in order to minimize furnace operation disruption.

The stage 2 works, while the stage 1 furnace was in operation, created many operating constraint which will be described in the following paragraphs.

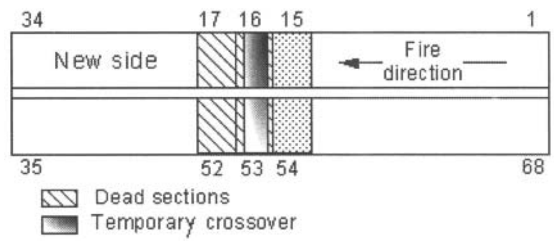

Figure 1. Schematic view of the furnace during temporary connection

The installation of a temporary crossover was one of the main steps for connecting the two halves of the furnace during construction. Twice before Aluar, this type of equipment and methodology was used successfully for anode baking furnace expansions: in 1979 at Sabart, and in 1986 at St Jean de Maurienne, both in France.

More recently this technique was used in 2008 at Tomago Aluminium Company in Australia to rebuild the oldest anode baking furnace, which was started up in 1983. The concrete tub was retained with some strengthening. The heat insulating and refractory were changed. The 74-section furnace was completely rebuilt in a record four months, from the beginning of demolition to laying the last top block. The project was carried out in two steps with one half of the furnace being rebuilt while the other half remained in operation with the use of a temporary crossover. This reduced the need for inventory and external purchases of baked anodes.

Although this type of equipment and methodology were used in these projects, some adjustments and improvements from the originally considered procedures were developed to reduce the impact in the furnace operation. The purpose of this paper is to describe the experience of operating an open type furnace with a temporary crossover during 6 months. As some impacts in the baking process behavior have been observed under these operating conditions, the actions which should have been taken to minimize their effects are described.

Temporary crossover

In an open type furnace, the gases flow along each flue wall line, from the blowing ramp and even the cooling ramp, up to the exhaust ramp. The regulation of the negative pressure downstream of the heating zone and the high pressure in the blowing zone allow the control of the flow inside the flue walls and the fire progression speed.

The typical design of the open type furnace has two metallic ducts, with the inner part lined with insulating materials, which are located at each end of the furnace. These devices, called crossovers, are used to collect the gases from each line of flue walls and to conduct them from one furnace half to the other.

Before the erection of sections 18 and 51, i.e. the "new" sections adjacent to the "old" ones, it was necessary to remove the crossover between sections 17 and 52, and to demolish the end insulation. Modifications of the headwalls between the "old" and "new" sections were also required. In order to allow the normal operation of stage 1 furnace, a temporary crossover was installed between section 16, second flue wall peephole and section 53, third flue wall peephole. Figure 2 shows a scheme of this configuration

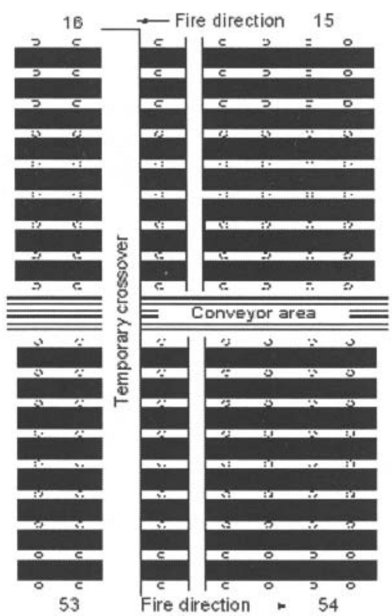

Figure 2: Schematic view of the location of the temporary crossover on the dead sections.

The temporary crossover was made of four metallic separated square section segments. These parts were joined with expansion seams and internally insulated, in order to protect the metal sheet from the high temperatures and reduce the heat loss. The segments were laid with metal legs on the corbel casing and the flue walls. They were connected to the flue walls by rectangular ducts.

Before installing the temporary crossover, the stage 1 furnace needed to be prepared and modified. Sections 16, 17, 52 and 53 were fully loaded with baked anodes and packed with coke. Therefore, four sections of the first stage furnace were not used in the anode baking process during the operation with the temporary crossover. The second top blocks of section 16 and the third top blocks of section 53, as well as some bricks were removed, in order to allow the vertical ducts of the temporary crossover to be installed.

Once the brickwork modifications were finished, the temporary crossover was installed. The metallic connections with the flue walls were not in direct contact with the bricks, allowing free expansion and movement of the different materials. Pressed refractory fiber was used to ensure the tightness between the vertical metallic connections and the flue walls. Figure 3 shows the erection of the temporary crossover after finishing the brickwork modifications.

The gas passage at the central baffle was closed with dense bricks, separating in this way the end sections from the rest of the furnace. In order to avoid any flow of gasses into the furnace, expandable baffles were located at the headwall windows, close to the fourth line of peepholes of section 16 and the first line of section 53.

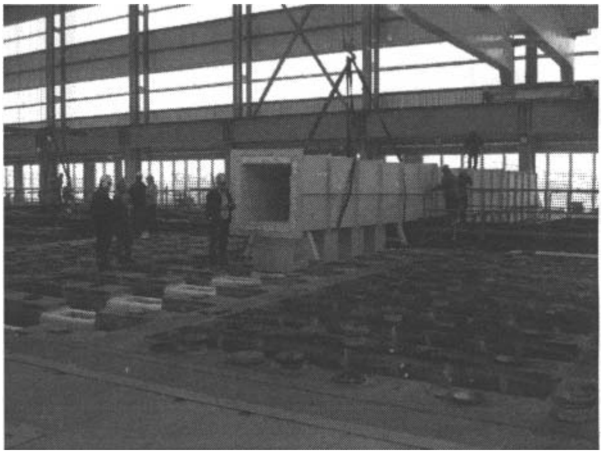

Figure 3: Erection jobs of the temporary crossover.

Figure 4 shows a sketch of a flue wall configuration in section 53. The gas flow is indicated and the brickwork and expandable baffles "blocks" are shown.

It is important to point out that many actions were taken in relation to the interlocks of the movements of the central conveyors and with the furnace tending assembly, in order to ensure a safe operation while the temporary crossover was in operation.

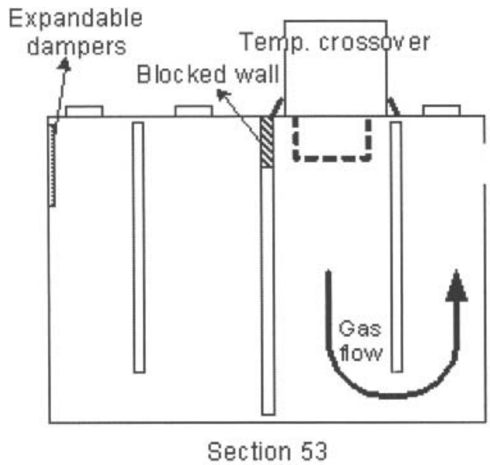

Figure 4: schematic view of the modifications at a flue wall (downstream side)

Steps before installation

Before installing the temporary crossover, several modifications to the operation and process control routines were made. While the anode baking furnace worked with 34 sections, the nominal fire permutation cycle was 24 hours, with 2 fires of 17 sections each. In order to remove the four end sections from the process, it was necessary to create a fire with 15 sections and another with 19 sections. This meant it was necessary to "separate" the end of one fire from the first section of the other. To do this, the cycle time of the two fires was changed to 26 and 28 hours respectively, during approximately 45 days. Once the "long" fire acquired its configuration and reached the end corner of the furnace, the temporary crossover was installed. The cycle time of the two 15 sections fires was then set at 28 hours.

As a consequence of the operation with such short fires, the available area for the load/unload and routine maintenance was significantly reduced. Some measures were therefore taken in order to ensure effective cooling and improve the working conditions in those sections where refractory maintenance personnel had to work:

- *Removal of one "blowing zone section", obtaining an extra empty section.* The two fires configuration was kept with three sections for natural preheating and three sections for forced heating, but the blowing zone or the first cooling area was reduced from four to three sections. As a result, the total cooling time (blowing + forced cooling) was reduced by four hours.
- *Zero point ramp control adjustment.* The shortening of the controlled cooling area required the adjustment of the control parameters of the zero point ramp, decreasing the over pressure set point in the section upstream of the last heating ramp. In addition, the lids of two peepholes lines next to the blowing ramp had to be removed. After this change the maximum temperature measured on the surface of baked anodes during the unloading process did not exceed 350-380°C, as in normal operation.
- *Decreasing of soaking temperature from 1180°C to 1160°C.* As the total soaking time was increased in 12 hours, in order to compensate this "extra" energy input the soaking temperature was reduced in 20°C. The parameters of the original and modified cycles are shown in Table I. No impacts on the baking level or other properties of the baked anodes were observed.

Table I Main parameters for different Fire configurations

Sections/fire	17	15
Cycle time	24	28
Preheat area (hr)	72	84
Fire area(hr)	72	84
Blowing (hr)	96	84
Forced cooling (hr)	48	56
Soaking temperature (°C)	1180	1160

- *Updating of the Fire Control System program.* The SCADA system which managed the firing control system was modified in order to operate with a 30 section baking furnace with two "short" fires. In normal operation, this system, which was supplied by Innovatherm, uses special control algorithms to adapt to process requirements during "corner and pre-corner" situations. The purpose is to have an even temperature distribution along the flues just after the crossover channel. During the operation with the temporary crossover these modules were disabled, until knowledge of the impact of these devices on the process behavior was acquired.

Operation with the temporary crossover

In normal operation, when the exhaust ramp passes from one side of the furnace to the other, draught set point values higher than normal are required, in order to compensate for the energy used to heat the crossover insulating lining as well as the additional pressure drop. In some furnaces the exhaust ramp is moved directly to one section after the crossover, where it remains during two cycles, increasing the heating time of the section after the crossover. This practice is not normally used at Aluar.

In the natural preheating sections, the flue thermocouples used by the firing control system are placed on the fourth peephole line of the first section, and connected to the exhaust ramp local panel. As was described above, an automatic temperature control algorithm follows the crossover situation adjusting the draft set-point values with the object of minimizing the temperature deviation between the flue walls. As a result of the action of this module, at the starting of the baking process in the first section downstream the crossover, usually the temperature is around 280°C, increasing up to 800°C by the end of the cycle. In concordance with this temperature evolution, the draught set points in the exhaust control loop value varies from -140 Pa to -170 Pa.

First movement through the temporary crossover.

As soon as the operation with the temporary crossover was started, some important differences with the normal crossover situation were observed:

- Very low heat-up rate in the section after the temporary crossover.
- The mean flue temperature measured upstream and downstream the temporary crossover showed a difference between 450 and 500°C
- The pressure drop measured with manual devices between both locations was 90-120 Pa.
- The position of all the dampers in the exhaust ramp remained almost completely open, resulting in a poor draught control.
- High temperature deviation between flue walls was observed
- Maintaining the negative pressure and flow from the Fumes Treatment Center (FTC) was difficult. .

The initial attempts to improve the process conditions were directed towards the decrease of the "fresh" ambient air infiltrations from the "dead sections". The upper part of the packing material was removed from all the pits, and a layer made of pressed ceramic fiber was installed and covered with packing coke up to the original level. In addition, the ring main fume collector draught set point was increased at the FTC control loop.

Visual inspections of the flue walls in the section where the crossover was located, showed that a very large part of the heat coming from the sections under fire, was being used to heat the "dead sections", before reaching the operating sections. Excessive heat loss through the crossover was discarded as a cause due to the low temperature measured on the outer metallic walls.

At the time for the next fire advance, the temperature measured in the first section was around 350°C. This value was approximately 450°C below the target. In spite of this abnormal situation, the fire advance was performed as usual.

It was evident that the heating rate downstream of the temporary crossover was extremely low. To increase the heat up gradient in the preheating section, a ramp using the start-up burner kit was installed in the fourth line of peepholes of section 54, downstream the temporary crossover on the second section under preheating. For safety reasons, those burners had a UV detection device to monitor the flame. They were manually controlled.

It was decided to delay the next fire advance until the anode degassing process started on section 54. This situation was reached 55 hours after the previous movement. At that time, even when the temperature measured in the flue walls was lower than expected, the fire advance was performed (see Figure 5).

The "extra" gas injectors helped to heat the flues in the preheating sections, but increasing the draught in order to keep a minimum negative pressure at the heating ramps was necessary. It was evident that these actions should be carefully balanced. In fact, the preheating sections should be heated at a reasonable velocity but not so fast as to cause excessive temperature increase at the exhaust ramp. It was found that once the degassing started, it was very difficult to control the fume temperature increase. The only available action in case of excessive temperature at the exhaust ramp was to move it to the next section earlier than scheduled.

Visual inspections into the flue walls showed an "abnormal" behavior of the degassing front. Normally the progression of the fire front along the flue wall, following the internal "channel" defined by tie bricks and baffles, is observed. In this case, a "quasi instantaneous" ignition of the pitch vapors along the wall occurred. As a result, only the upper part of the flue walls showed small flames while the bottom part remained "dark".

Figure 5 shows the fume temperature evolution (average of the nine flue wall temperatures). The steps in red indicate the number of the section where the exhaust ramp was placed (on the right axis). As a reference, the data from the cycle before the temporary crossover are included. It can be observed that just after the finish of the fourth consecutive fire advance, the fumes temperature reached standard values. At the end of the baking, the maximum fume temperature in the head walls on the section downstream the temporary crossover was in the order of 950°C. This indicated a very poor baking quality of the anodes baked in that section.

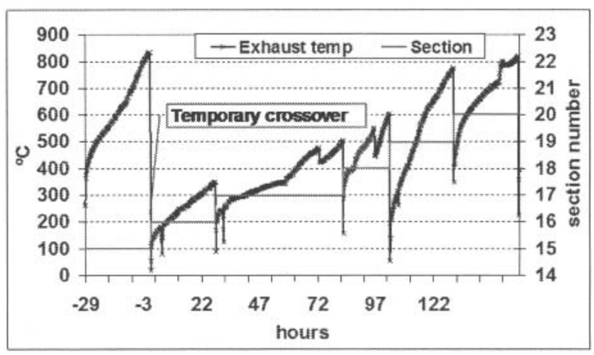

Figure 5: Exhaust temperature evolution during the first advance through the temporary crossover

Second and subsequent advances through the temporary crossover.

To mitigate the difficulties in following the heating curve in the natural preheating sections, several actions were adopted for subsequent baking cycles:

- *The Section downstream the temporary crossover was not unloaded.* It was evident that the anodes in this section were baked at very low temperature. In addition, keeping the already heated anodes and packing material inside the sections, could help to reduce the heat requirement for the next cycle.

- *Reinforce the sealing of the "dead sections".* The upper part of the packing coke and the ceramic wool placed on top of sections 16 and 53 were removed. The packing material was leveled with the top blocks and a metallic cover was placed on the top of each pit. The seams between these covers and the top blocks were sealed with fiber wool.

- *Increase the flow of gas injection.* A manifold with the nine start-up burners was assembled on the temporary crossover. The injectors were located on the first line of peepholes of section 53, which was out of the baking process. The picture in Figure 6 was taken during the assembly of these burners. Another set of nine start-up burners was located in the fourth line peepholes of section 54, as before. Both lines of injectors were then on sections already loaded with baked anodes. They were controlled manually. These start-up burners were part of the equipment available for the drying out of the furnace.

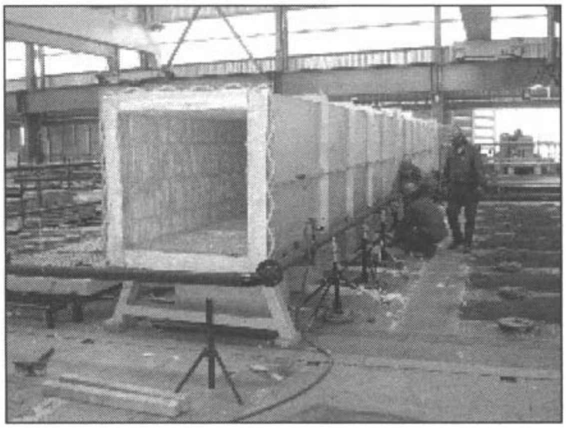

Figure 6: Inspection of the crossover after the first operation and installation of manual burners

- *Double move of exhaust ramp.* The fire advance procedure on the temporary crossover was modified. In the new procedure, the exhaust ramp was moved directly from section 15, before the temporary crossover, to section 55. Then, the next exhaust ramp advance would be delayed by two cycles. The other firing control elements were moved as usual. The effects of this procedure were described earlier.

- *Control routine monitoring:* Many unusual control routines to be performed by the furnace operators were programmed, including follow-up of start/stop events of the start-up burners kit, manual adjustment of the draught set point in the exhaust ramps, temperature measurements between crossover ends.

This set of actions gave the expected results and the baking process quality in the preheating sections showed an important improvement. Figure 7 shows the average fumes temperature measured at the exhaust ramp control during four fire advances through the temporary crossover. The values correspond to the second and fourth passage through the temporary crossover. The only section with a final temperature significantly lower than in normal baking is the one downstream the temporary crossover, which was loaded with baked anodes. The baking curves of the other sections normalized progressively and for the fourth advance through the temporary crossover they were completely normal, reaching 800 °C as expected. These values, as well as the shape of the curves, confirm that the preheating of these sections was normal.

As was mentioned before, section 53 was not unloaded and remained with baked anodes. No degassing occurred in this section, the lack of energy from the burning of pitch vapors was partially compensated by the additional combustion at the supplementary burners and the heat remaining in the load.

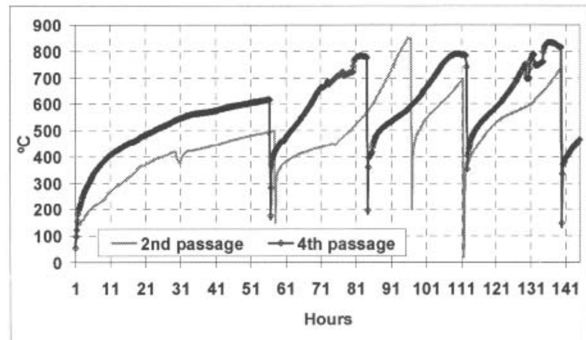

Figure 7: 2nd and 4th passage of the preheating sections by the temporary crossover

A recommended procedure for anode baking level control is to measure the anode temperature during the gas heating stage. Figure 8 shows the evolution of gas and anode temperature in section 55, this is to say the one in which the anode baking quality could be more severely affected by the use of the temporary crossover. For comparison, the values for section 2, which was in an equivalent position to the normal crossover, are shown. As can be seen, there are no significant differences between both sections.

In this figure, the "gas temperature" is the average of the nine fume temperatures measured in each flue wall, while the "anode temperature" is the average of the three anodes located on the top layer of three pits.

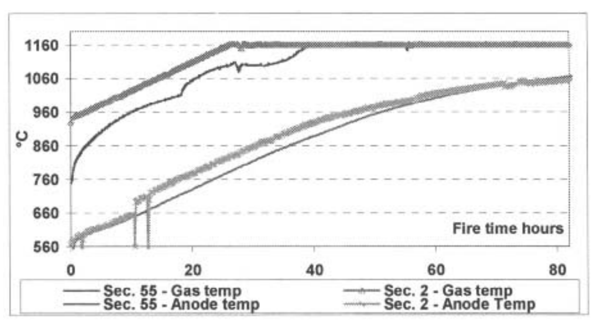

Figure 8: Evolution of gas and anode temperature in sections 55 and 2.

Baking temperatures

Aluar measures the baking temperature using the L_c method [1][1]. Each section is loaded with two samples of green coke stored in a graphite crucible, one on the anode bottom layer and the other on the anode top layer, both on one of the outer pits. After the commissioning of the firing control system, the higher temperatures were obtained on the top layer.

In order to compare the impact of the crossover operation during the complete baking process, the baking temperature of the anodes baked in the sections downstream of the normal and temporary crossovers are shown in Figures 9 and 10 (average ± standard deviation) . In the top layer, the difference between both groups of sections was not significant.

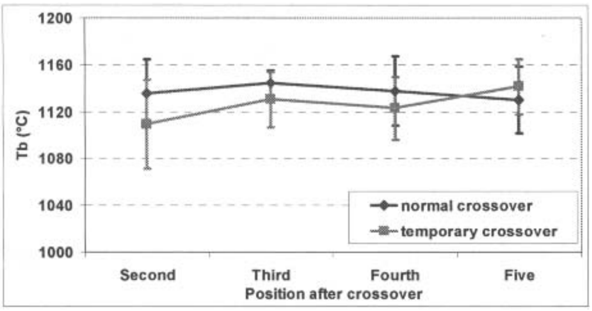

Figure 9: Baking temperature at the top layer

On the contrary, in the worst location (the so called cold position of the section) an important difference can be observed for the second section, where the impact of the temporary crossover is clearly visible. However, the values for the other sections are quite similar. Then with the exception of the cold part of the second section, all the baking temperatures fulfilled the smelter quality requirements.

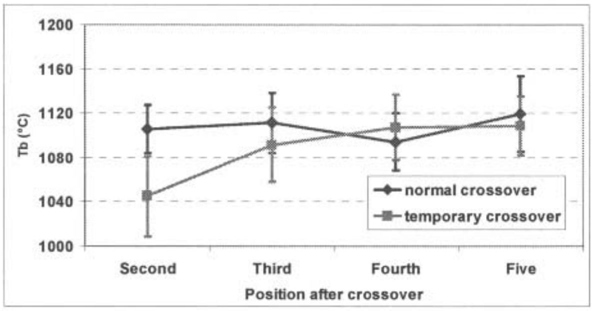

Figure 10: Baking temperature at the bottom layer

[1] The relationship used by Aluar to convert Lc in Tb (baking temperature) was determined in such a way that the resultant value is close to the real maximum temperature reached by the anode [1]. Even when the procedure is similar, Aluar values are different to the "equivalent temperature" as described in the literature [2], which is based on a calibration with shorter soaking times. The numerical values of equivalent temperature are approximately 100-120° higher than the corresponding Tb values.

Conclusions

The experience of an anode baking furnace operation with a temporary crossover was described. It could be concluded that after some adjustments in process control parameters as well as in the operative routines and procedures, there is no significant impact on the quality of the anodes baked in the sections downstream of such device.

In the case described in this paper the procedure allowed the construction and start-up of a four fires baking furnace in two separate stages. The second half of the furnace was erected and connected to the original one with a relatively small loss in production.

The good results that have been obtained allow consideration of the use of similar equipment for other applications, for examples, large brickwork repair jobs on part of a furnace or complete furnace rebuilding in stages as was carried out for the oldest baking furnace at Tomago.

The main problems that have been experienced were due to the increased flow resistance at the corner and to the energy required for heating the sections on which the temporary crossover was installed. Although it has not been experienced, the connection of the temporary crossover to the peephole lines closer to the active headwalls, may help to reduce these problems.

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