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THERMAL BAKE-OUT OF REDUCTION CELL CATHODES - ADVANTAGES AND PROBLEM AREAS

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Electrical bake-out of reduction cell cathodes is the predominant method of preparing cathodes for the start of electrolytic operations. Several electrical methods are employed, including resistor coke bed, graphite "candle" and aluminum metal baking.

Most electrical methods do not produce thorough, even heat-up of the whole carbon mass. Cathodes heated by these methods usually show uneven temperature distributions (surface and internal) and areas of unbaked green paste at the completion of bake-out. In extreme cases, poor bake-out will reduce cathode life.

Thermal bake-out, involving the use of gas or oil fired burners placed in the carbon cathode cavity, appeared a possible solution. The results of thermal bake methods and realized advantages are discussed. Problem areas and possible solutions are indicated.

Based on several years operating experience, thermal bake-out is considered a viable solution to the problems encountered in electrical resistance bake-out of cell cathodes.

INTRODUCTION

Reduction cell cathode carbon preheating, or bake-out, prior to the start of electrolytic operations, is practiced by most aluminum producers. The bake-out methods and equipment used vary quite widely according to cell design and operating philosophy, but can generally be classified as follows:

- Electrical - metal bake
- Electrical - resistor bake
- Thermal bake

Combinations of these three general methods are common.

The importance of cathode bake-out to cell life and operation is a topic of some disagreement between aluminum reduction technical personnel, often within the same company. A literature survey of cathode bake-out related papers illustrates this point (1,2).

We believe that the bake-out process does have a significant effect on cell life. Correct cell design, well controlled cathode construction and potroom operations and good quality carbon/insulation materials are all critical factors in the achievement of long pot life. Incorrect bake-out practices can negate all these positive factors.

Work done at the Kaiser Mead plant in Spokane, Washington indicates that "a lack of uniformity in pot baking can be a major factor in producing the wide range of potlives experienced with apparently identical (monolithic) potlining." (3)

The objectives of a good cell bake-out are:

- To heat the carbon refractories to cell operating temperature (950-980°C) at a rate low enough to avoid thermal stress within the cathode materials.
- To heat evenly across the working face of the cathode so that thermal stresses are avoided on the surface (minimize surface gradients).
- To ensure pitch/binder pyrolysis of green rammed paste occurs in all green paste areas at a rate that results in optimum baked paste properties.

Kaiser Aluminum & Chemical Corporation (KACC) has traditionally used metal and resistor bake-out methods at its various domestic (USA) and overseas aluminum smelters. Shunt baking has been employed but usually bake-out is carried out at full line load.

For prebaked cathode cells, resistor baking at full line load was standard until 1979. Localized overheating and underbaking during the bake-out was considered normal. Cathode surface temperature measurement at the end of bake-out indicated severe temperature gradients across the cathode surface - up to 800°C per metre (See Fig. 1).

Temperatures of over 1300°C are not uncommon on parts of the cathode surface of a resistor baked cell, while temperatures as high as 1600°C have been measured.

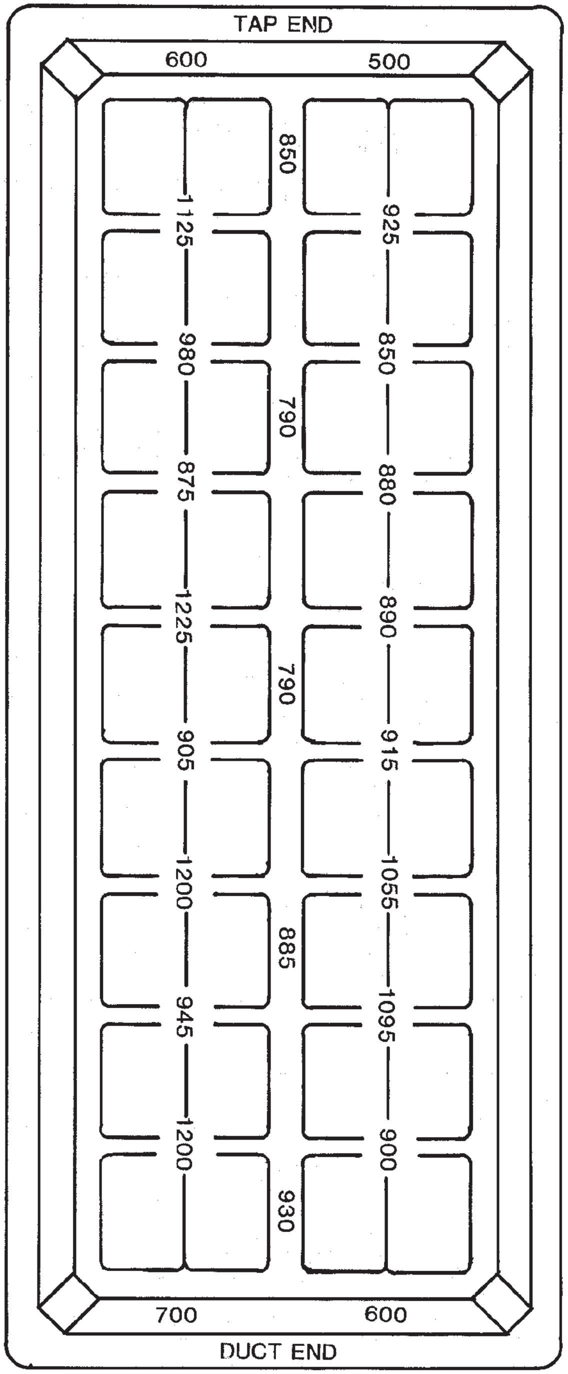


FIG. 1 RESISTOR BAKE
SURFACE TEMPERATURES BEFORE FLUXING

Thermal bake out appeared to provide a possible solution to the objectives for good cell bake-out. (4,5) A diesel fuel burner system was purchased by Comalco Ltd. (an Australasian affiliate of KACC) for use at the Tiwai Point smelter in 1979. (5) Heat up rates and temperature distributions obtained were encouraging and the plant was converted to 100% thermal baking in 1981. The system has been successfully introduced into two further KACC plants.

Thermal Bake System

The cells on which detailed studies were carried out are 150 KA pre-baked anode, prebaked cathode design with rammed carbon paste sidewalls. Alumina feed is by centre channel crust breaking.

Equipment

The system was designed and supplied by Hotwork Development Ltd. (U.K.) based on their experience with preheating aluminum cell cathodes. The equipment comprises two burners, a fuel source and supply system, air and fuel lines, a control unit, control thermocouples and heat insulation shields. The burners have gas or diesel firing capability and initial work was carried out with the diesel firing option.

Bake-out Operation

The prebaked anodes are adjusted to provide a firing cavity for the burners. Burners are positioned so as to ensure maximum hot gas circulation and minimum flame impingement on carbon surfaces. A thermocouple is located in the firing cavity and connected to the control unit. Heat insulating shields are placed across anodes in the centre trench and between anodes and the cell sidewalls on the cell sides and ends. The normal cell fume hoods are placed in position once heat shield installation is complete.

The burners are lit and adjusted manually until a satisfactory flame condition is observed. A fuel rich mixture is essential to minimize the possibility of carbon airburn.

Once satisfactory burner alignment and flame conditions are obtained, the system is switched to automatic control. The input from the thermo-couple in the centre of the pot controls the fuel/air output to the burners via a microprocessor. The processor is programmed to heat the cell at a predetermined rate.

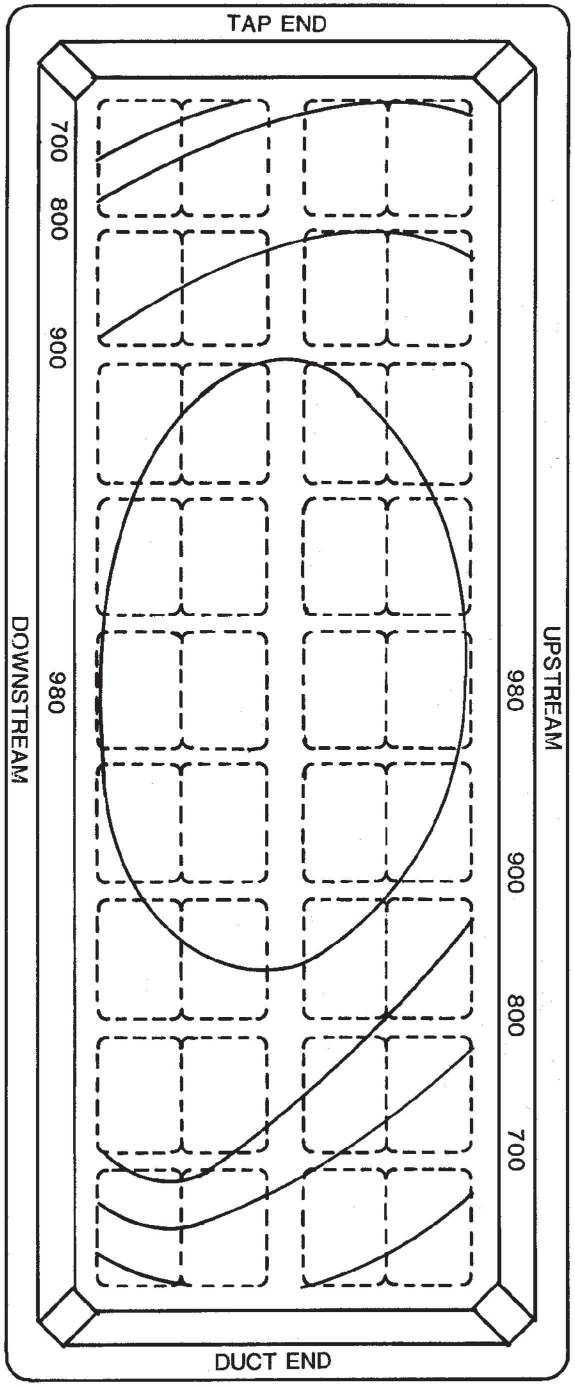
Cell Start-Up

At the completion of bake-out, the fuel/air supply system is shut down and the burners and heat shields are removed. The anode bus is lowered to allow the anodes to be repositioned for start-up. A simultaneous flux (molten cryolite addition) and cell cut-in is performed.

Results

Temperature Profile Studies (5)

Surface temperature and subcathodic temperature measurements taken during bake-out by resistor and thermal methods indicate the following (see Figs. 1, 2, 3 and 4):



THERMAL BAKE

FIG. 2 TYPICAL SURFACE ISOTHERMS

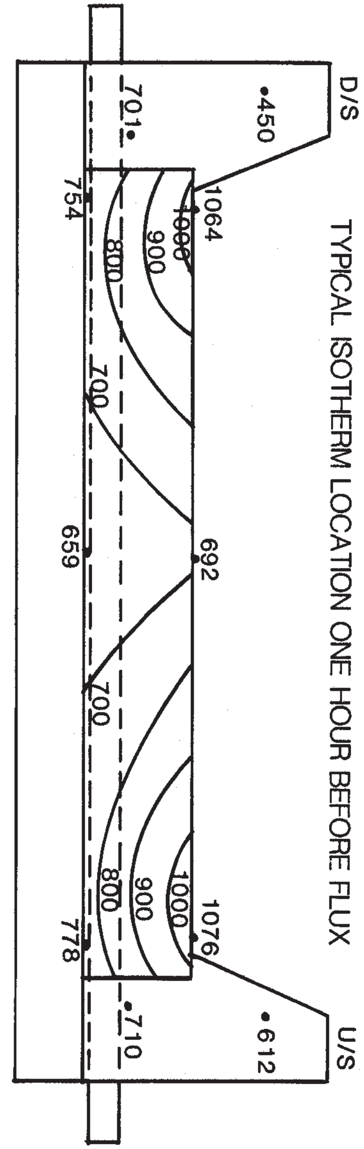


FIG.3 EXAMPLES OF ISOTHERM LOCATIONS

(RESISTOR BAKE)

TYPICAL ISOTHERM LOCATION ONE HOUR BEFORE FLUX

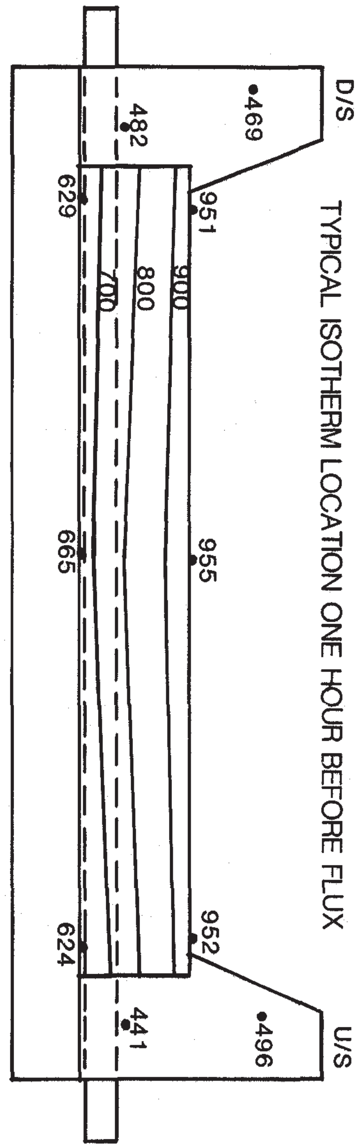


FIG.4 (OIL FIRED BAKE)
TYPICAL ISOTHERM LOCATION ONE HOUR BEFORE FLUX

Resistor Bake

- Rapid rise in early surface temperatures - up to 200°C/hr. in localized zones.
- Uneven temperature distributions on the cathode surface (up to 700°C along the length of a cathode) and at the cathode base (up to 200°C along the length of a cathode).
- Large temperature gradients through the cathode during bake (over 600°C).

Thermal Bake

- Even heat up of the cathode surface over the duration of the bake. Heat up approximates programmed ramp rate.
- The subcathodic temperature difference over the length of a cathode is usually less than 40°C.
- Temperature gradients through the cathode reach a maximum of 400°C during bake.

Subcathodic temperature measurements are similar for both bake methods at the completion of bake-out.

It is worth pointing out that just prior to the introduction of thermal bake, extensive technical and operations effort was directed at improving resistor bake methods and equipment. This effort resulted in a marked improvement in bake-out practices and results. The temperature studies described were taken on cells baked with the improved resistor bake methods.

Potlife

Over 200 cells have been baked using the thermal bake method at KACC plants. The oldest cells are over 1200 days and while premature (less than 1000 day) failures have occurred, the frequency is less than that experienced for resistor baked cells (2.5% for thermal bake, greater than 5% for resistor bake). Careful examination of each premature failure indicated that failure was most likely due to causes other than bake-out.

Discussion

For prebaked cathode cells, our experience has indicated that thermal bake-out has the following advantages over the traditional resistor bake-out method:

- Less severe temperature gradients across the cathode surface and through the cathode body, resulting in less thermal stress.
- No power is consumed during bake-out (increased metal production).
- Anode airburn is reduced.
- The bake-out operator environment is markedly improved. Exposure to radiant heat and pitch fumes is reduced as the bake is fully hooded. The resistor bake practice of clamping/unclamping anodes during the bake is eliminated.

. Cathode surface cracks have not been observed at completion of bake-out.

. New pot operation is better as no skimming of resistor coke is required and a "fast change out" of bake-out anode carbon is not necessary.

Further to the above, it is thought that the more controlled bake-out of cathode rammed paste will result in reduced paste expansion in the early stages of heat up and correspondingly lower shrinkage in the later stages. The more even heat up results in the total volume of a seam (for example) undergoing bake-out changes, rather than different areas undergoing changes at different times thus resulting in cracks between adjacent underbaked/overbaked areas. This effect was proposed by Johnson (3) in monolithic cathodes. The system, however, has some disadvantages:

. The potential for airburn damage of cathode carbon is high and does occasionally occur. Airburn of rammed seams is common.

. Although sidewall green paste bake-out is achieved, vertical cracking and surface spalling have been observed.

. Cathode heave does occur during baking and has been measured at up to 16 mms. from horizontal at the cathode centre.

. The fluxing/cut in operation is more complex than for resistor bake.

. An anode effect of 20 to 30 volts, lasting for about 20 minutes, is usually experienced shortly after cell cut in.

. The heat shields and burners are difficult to handle particularly when hot.

. Heat shields and burners are high maintenance items.

. The bake-out takes longer than for resistor bake (lost metal production).

. Operation and control of the bake-out is more complex than for resistor bake.

These problems are currently being addressed and possible solutions include:

. Shielding of green paste areas during bake-out - bake achieved by conduction.

. Adjustment of the ramp/soak control programme to minimize green paste "puffing" and shrinkage and reduce cathode heaving.

. Redesigning shields and burners for mechanical handling.

The anode effect experience after start-up is related to a high resistance between the anode and cathode surface. Resistances within the cathode body are normal as compared to resistor baked cathodes.

Although there is insufficient statistical data to confirm an improvement in potlife, autopsy of a "healthy" thermally baked cell indicated excellent cathode carbon quality with minimal cracking and good baked paste properties. (5)

Conclusion

Thermal bake-out of reduction cell cathodes offers significant advantages over resistor bake-out in terms of control of the heat up rate and significantly improved thermal gradients during the baking process. Localised "hot spots" are eliminated. These improvements are likely to result in reduced thermal stress and thus reduced cathode cracking.

A reduction in early bath and metal leakage into the cathode is expected. Assuming consistent standards of cell construction, raw material quality and cell operation, potlife should increase on conversion from resistor to thermal bake-out.

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