Hydraulic Wedge Puller Device "Quick Start" for Removing Wedges when Energizing an Electrolysis Cell in Aluminium Smelter

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Abstract

In the aluminum electrolysis, the electrolytic cells need to be replaced at old age with newly relined cathodes. The shutdown and restart of these electrolytic cells remains to be a very important and extremely critical part of the process. In EGA cell technologies, wedges are installed between busbars of a pot to be shut down and busbars of an adjacent upstream pot to by-pass electrical current and stop a particular pot. The wedges are extracted during the cell restart. The extraction of these wedges should be quick and accurate in order to prevent arcing on the conductor contact faces and avoid possible overheating/fusing of the last wedge left in the process. The execution of wedge extraction/pulling is a laborious task involving a lot of manpower and movement in a congested hazardous area considering heat, fumes and other equipment. The hydraulic wedge puller is part of a wedge extraction device. It is a jacking system used to remove up to ten inserted wedges. It uses a single hydraulic tank unit coupled with three pneumatically operated high-pressure hydraulic pumps of which two pumps are operated at a time and a standby pump ready to kick in case of any failure. This device is fitted with two operating stations to start and stop the system. The pressures exerted on the ten jacks are equal at all times in order to balance the forces exerted on the wedges to separate them. The quick isolation valve isolates the jack(s) on wedges already pulled out and diverts the pressure to other jacks pulling the remaining wedges. High pressure hose reels dedicated to each jack are installed for easy pull-out, pull-retract of the hoses. This newly developed hydraulic wedge puller system addresses the problems and issues faced by operators in the conventional jacking system and improves the safety of the startup process and equipment operation.

Key words: Cell start-up wedge puller device, hydraulic wedge jacking device, jacking device, cell bypass removal device, electrical short circuit removal device.

1. Introduction

Aluminium production is a continuous process. An aluminium smelter consists of large number of pots connected electrically series so that the same DC electric current flows through one pot, then on to the next one and so on to the end of the line. Continuity of the current path has to be guaranteed, otherwise an open circuit will be created and will cause a lot of damage unless the potline current is quickly shut down. A typical potline has from 300 to over 400 pots (EGA Al Taweelah Potline 3 is the longest in the world with 444 pots). When a pot is shut down the current has to bypass it; for this special short circuiting either wedges or some kind of bypass shunts are used. In EGA cell technologies, wedges are installed between busbars of a pot to be shut down and busbars of an adjacent upstream pot. An example is shown in Figure 1 for DX+ Pot Technology. The wedges have to be extracted during the cell restart and this is done with equipment called wedge puller, which is the subject of this paper.

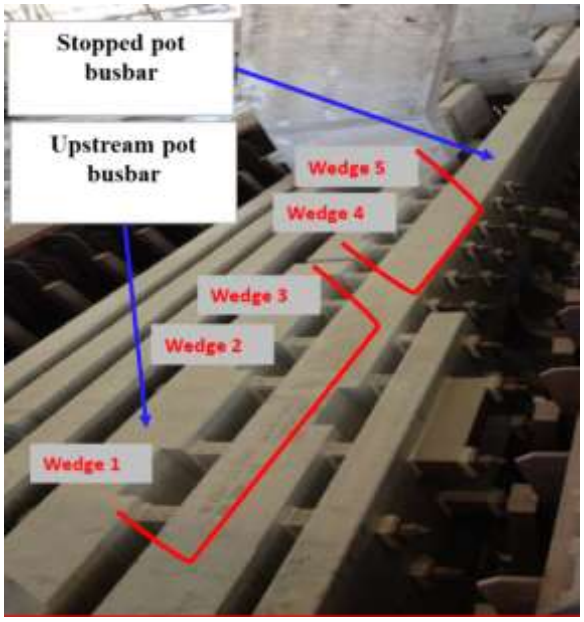

Figure 1. Wedge positions for cutting out a DX+ pot (one half of pot is shown). A total of 10 wedges are used per pot.

Pot shutdown and restart operations are among the most dangerous and critical operations in a potline in any pot technology especially due to the fact that it requires human involvement. The cutout can be either planned or un-planned. To cut out the pot the operators have to manually drop short-circuiting wedges between the electrical conductors of two adjacent pots and hammer them in position for good contact in the wedges. However, to remove the wedges for pot cut-in a lot of power and high speed of removal are needed and this can only be provided with a machine, a wedge puller. The extraction of these wedges should be quick and accurate in order to prevent arcing in the contacts between wedges and busbars and avoid possible overheating/fusing of the wedge pulled out last. The working area between the pots with wedge operations puts the operators in a tough and hazardous situation. The operator is exposed to the harsh environment of potrooms i.e., heat, high current, noise, fumes/dust and magnetic field.

In this paper we describe a new innovative hydraulic wedge puller system which solves the problems and issues faced by operators in the conventional jacking system and improves the safety of the startup process and equipment operation.

2. Pot Cut-out and Restart

In most aluminium smelters pot start-up or cutout operations are performed every week and in some every day when pot replacement is taking place. In a new smelter four to five pots are typically started per day and sometimes even more. There are planned shut-downs when a pot is designated to be shut down by pot replacement schedule or some specific problem known ahead of time and un-planned, such as tap-outs. The actions for an unplanned shut down must be very rapid.

During the restart of the pots, the wedges are withdrawn one by one and speed of the extraction is a vital parameter as the current density flowing through the wedges increases when the number of wedges still in place decreases. It was quite common for the operators to help in the removal of the last wedge, stuck to the busbars due to the high current and thermal expansion of the wedge. This can be avoided with good equipment design and enough power.

With new modern high amperage technologies, it has become essential to provide a safer and cost-effective solution, to design and provide a tool which is able to perform most of the activities in wedge pulling and which reduces the exposure of operators to hazards and preserves the integrity of the conductors.

In EGA, wedge extraction system consists of:

- Wedge extractor unit (A-frame) shown in Figure 2a,
- Wedge puller hydraulic unit (Figure 2b) which provides hydraulic pressure and control of the extraction unit comprised of hydraulic jacks, hydraulic pumps and air motor driving the hydraulic pumps.

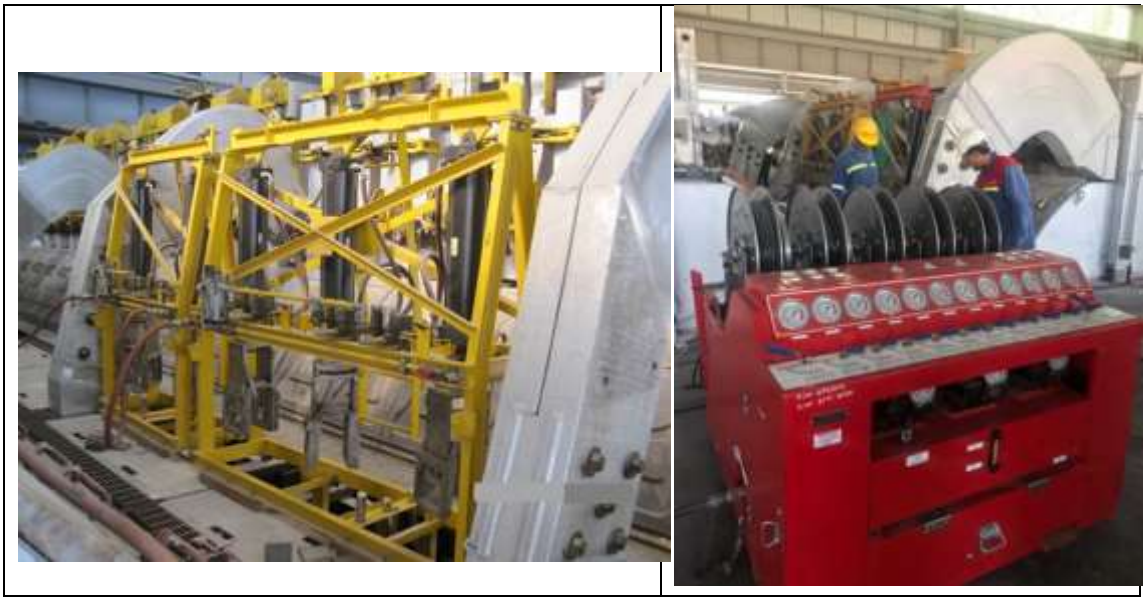

Figure 2. Wedge extraction system. Left: wedge extractor (A-frame). Right: wedge puller hydraulic unit (front) and wedge extractor installed for action. On the reels are the hoses that connect the two units and provide hydraulic oil to extraction jacks.

3. Current Situation and Root Cause/Improvement Opportunity Analysis

The original wedge pullers for DX+ Pot Technology in Potline 3 of EGA Al Taweelah have the following features (Figure 3):

- The wedge puller unit had 3 independent hydraulic pumps with 2 in use and 1 spare. Each pump supplies 70 MPa (700 bar) pressure to 5 jacks (Figure 3).
- In the event of pump failure during the cut-in, the failed pump has to be depressurized to remove the hose connection and install it to the stand-by pump. In case of hose rupture or failed jacks, no spare lines are available for connecting a new hose or jack, which again required depressurizing the line and could take several minutes to complete.
- The 10 needle valves shown in Figure 4, used to control the oil flow to each of the 10 jacks, take 6 to 8 turns to shut a line and divert oil flow to a particular jack(s).
- The air motor driving the hydraulic pump does not have a lubrication arrangement which makes the air motor running dry and getting seized during the operation.
- The ten 50-tonne single acting jacks are load holding that take 15 minutes to retract the cylinder to its home position.
- These jacks have different hose lengths which are dedicated to respective locations of the wedges ranging from 5 meters to 18 meters, of which longer hoses can only be used in shorter distances and not vice versa.

- Manual laying and keeping of the hydraulic hoses and connecting /disconnecting the hydraulic jacks as shown in Figure 5.

Figure 3. Original wedge puller hydraulic unit in EGA AT Potline 3.

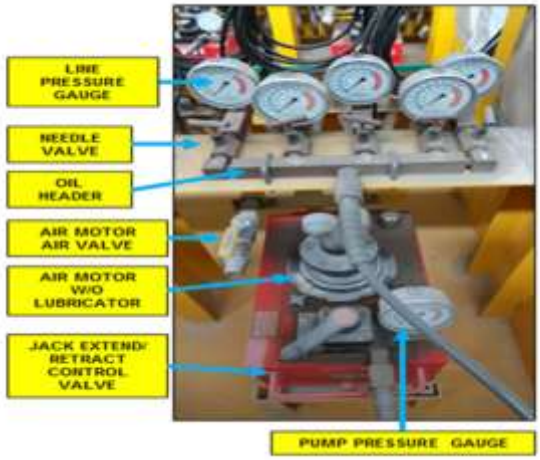

Figure 4. Wedge puller components

Figure 5. Manual laying of hydraulic hoses in the original wedge puller.

4. "Quick Start" – Wedge Puller Device

The solution invented, designed and tested by EGA AT teams consists of (Figure 6):

- Ten hydraulic jacks in a power pack unit,
- Three pneumatically operated high pressure pump systems,
- Three directional control valves for each pump,
- One common high pressure oil receiver/distributor,
- Retractable hose reels,
- Two sets of pneumatic control boards for activating each pump,
- Pressure monitoring gauges,
- High pressure ball valves directing the oil to activate the jacks

Figure 6. New hydraulic wedge puller. Left: back view, Right: front view.

5. Operation and Benefits

To cut out a pot, the aluminium wedges are inserted between two separated parallel busbars, which in normal pot operation are electrically insulated from each other as shown in Figure 1. These two busbars have flat upper horizontal faces. The wedge pockets have one vertical face and the other angled with larger opening at the top. This design provides pressure in the contact surfaces when the wedges are jammed in and allows for easy removal. For wedge removal, the pneumatic wedge puller device shown in Figure 2, left is positioned on the floor along the wedges. The device has a pneumatic jacking cylinder for each wedge, positioned vertically in-line above the wedge. When the jacks are activated, the device pulls out wedges one after the other at high speed so that only minimum arcing can occur.

6. Solution/Improvement

In this section we list and illustrate the features, functions and improvements of the Quick Start wedge puller system:

1. Using spring retractable reels without removing hydraulic jacks (Figure 7). The operator can pull the hose with jacks, lock at that position and pull again to automatically retract.
2. All hydraulic pumps were installed into a common tank with common outlet header to have interchangeability of the pump operation without disconnecting any hose (Figure 8). If one pump is defective, just close that pump and run the other without any delay. In case, three pumps can run simultaneously to back up the pressure requirement or jacking speed.
3. Needle valves (Figure 9, top left) to control (open/close) oil flow to respective hydraulic jacks were replaced by a high pressure ball valves (Figure 9, bottom left) that with one stroke the valve can be opened or closed.
4. Installed an oil return pump pneumatic driven with interlocks to the pressure pumps (Figure 9 right).
5. Lines were standardized to 22 meters to assure interchangeability between lines and/or in case of jack/hose failure the other can be used in different locations.

Figure 7. Wedge puller hydraulic unit with retractable reels.

Figure 8. Three individual hydraulic pumps (left) with common outlet header (right).

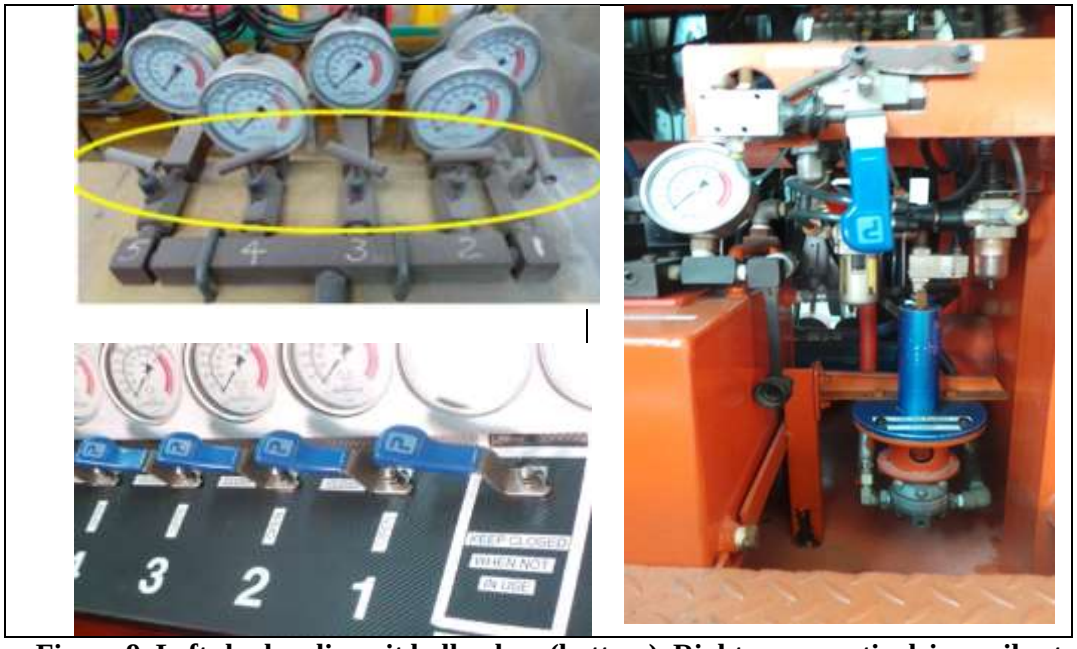

Figure 9. Left: hydraulic unit ball valves (bottom), Right: pneumatic driven oil return pump.

6. Lubrication system for air motors driving the hydraulic pump and oil return pump were incorporated to extend equipment life and reduce maintenance cost (Figure 10).

Figure 10. Air motors lubrication system.

7. Two spare emergency hose lines were added ready for connection in case of unforeseen scenarios (Figure 11 left).
8. The ball valves, used to switch on/off a particular pump, were replaced by push buttons controlled by directional valve for quick and fast changeover (Figure 11 right).

Figure 11. Left: emergency hose line, right: push buttons.

7. Implementation, Results Verification and Certification-:

The old manual operated wedge puller unit was transformed into a semi-automatic pneumatic controlled unit. One main control station for a single operator and local control station for two operators are also incorporated, of which hydraulic pumps can be switched on and off in either stations with pump running indicator for operator's confirmation.

The new generation of hydraulic wedge puller was then designed and fabricated in-house by our teams, carefully considering size, weight and operability, leading a compact design. Each component was carefully assembled and all jacks were load-tested to 70 MPa (700 bars) to check for any connection leakages and load confirmation prior to testing the unit on a live cut-in. The wedge puller was certified by Hi-Force Hydraulic Tools (Figure 12).

The new unit was tested initially to cut-in 25 pots without failure or any single incident. It generated a smooth operation. It is easier and faster to operate with less effort, reduces workload (three people can do the job) and saves a lot of time as the activity is completed in 30 minutes.

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This is to certify that the below detailed item was tested by a competent person in accordance with documented test procedures relevant to the equipment detailed. The equipment described below has been carefully examined to verify that it conforms to the specified and stated requirements. All measurements obtained are traceable to the National Physical Laboratory via a series of Namas Lab Numbers.

Where this certificate relates to hydraulic products these are individually proof tested to 100% of safe working Pressure as stated on the equipment

Product Description:	**HYDRAULIC WEDGE PULLER HPU**		
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Rated Load Capacity:	**0 TONNE**	Rated Pressure:	**700 BAR**
Test Load:	**0 TONNE**	Test Pressure:	**700 BAR**

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Figure 14. Certification of the wedge puller.

8. Health, Safety and Environment (HSE) and Cost-Reducing Targets

The new semi-automatic wedge pulling device "Quick Start" minimized the manual intervention and eliminates failures in potlines. This reduces employees' exposure to the harsh environment of potrooms including heat, high current, noise, fumes/dust and magnetic field. The risk of exposure to residual energy was eliminated as there was no need to depressurize the hoses in the line as independent pumps were incorporated and spare hoses/jacks were considered. Hazards of laying hoses on the floor which earlier led to damages were eliminated by introducing retractable hose reels concept, even helping in eradicating tripping hazard. Manpower spent in wedge extraction was drastically reduced by introducing "Quick Start" unit. The number of operators involved is reduced to three, who typically spend 30 minutes in the activity.

9. Conclusion

The reduction pot start-up and shutdown solution designed by EGA Al Taweelah Reduction Maintenance team is an innovation that significantly contributes to HSE of the operators and is costs-effective, while ensuring reliability, efficiency and rapidity of the wedge extraction process.