

## Auto Retract Technology for Pneumatic Breakers and Feeders in INALUM Cells

Zulfiqar Ridho Baihaqi<sup>1</sup>, Ivan Ermisyam<sup>2</sup>, Ismadi Y. S. Jenal<sup>3</sup>, Ferdy Rahadian<sup>4</sup>,  
Ari Purwanto<sup>5</sup> and Aghnia Pangeran Siregar<sup>6</sup>

1. Superintendent Minor Maintenance POT

2. Operational Director

3. Executive Vice President Operational Smelter Group

4. Senior Vice President Reduction and Casting Department

5. Vice President Reduction Preparation Section

6. Manager Minor Maintenance Sub Section

PT Indonesia Asahan Aluminium (INALUM), Kuala Tanjung, Indonesia

Corresponding author: [zulfiqaridho@inalum.id](mailto:zulfiqaridho@inalum.id)

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### Abstract

In aluminium smelters, such as at INALUM, emergency situations like power outages (blackouts) can cause significant disruptions. One of the critical issues is the shutdown of the compressor plant, which results in a loss of air pressure in the pneumatic system. This can cause pneumatic cylinders to fail, leading to the dropping of the breaker chisel, which can submerge into molten bath. This increases the iron content in the metal and decreases metal purity.

To address this problem, this paper introduces the Auto Retract technology. The system is designed to detect the air pressure drop below 200 kPa and automatically opens a valve on a backup air tank, which allows compressed air to refill the cylinders and restore the breaker chisel to its proper position, locking it safely above the molten bath. This technology not only prevents damage to the pneumatic cylinders but also serves as a stabilizer for air pressure, ensuring the system remains stable even during fluctuations in pressure. By maintaining stable air pressure, the auto retract technology enhances the overall efficiency of the aluminium smelting process, leading to better operational stability and improved aluminium quality.

The Auto Retract technology has been successfully implemented at INALUM in Potline 3, Pot R669 since January 2023. Its application is expected to significantly improve both safety and operational efficiency, particularly during emergency situations such as power blackout.

**Keywords:** Auto Retract technology, Aluminium smelting technology, Blackout safety, Pneumatic system stability, Operational efficiency.

### 1. Introduction

In aluminium smelting operations emergency situations like compressor plant shut down due to auxiliary power outage or AC/DC current shut-down (blackout) can lead to significant operational disruptions. One of the most critical challenges during blackout is the shutdown of the compressor plant which results in a sudden loss of air pressure. The loss of pressure in the breakers and feeders leads to dropping of breaker chisels into the bath, where it will remain until the power is restored. This not only affects the safety of the operation but also increases the iron content in the metal, thereby diminishing the overall quality of the aluminium. The need for the reliability of power supply to the aluminium reduction cells is well known [1–5]. Not only in INALUM, power outages also occur in other smelters in the world as shown in Figure 1.

Year of Outage	Smelter and 1 <sup>st</sup> Potline Startup Year	Cause of Failure	Outage Hours	Decrease in Production (Cells Stopped)	Comments
Dec. 18, 2010	Alcoa Fjardaál, Iceland, 2008	Transformer explosion and fire	2.25	0	Total power loss in plant; no cells were shutdown due to the power outage.
Sept. 1, 2010	Century Aluminum, Grundartangi, Iceland, 1998	36 kV breaker for potline 1 failed; power plant did not restart	2	0	One rectifier transformer was under repair at the time; no cells were shutdown due to power outage.
Aug. 9, 2010	Qatalum, Qatar, 2010	Power plant shutdown; did not restart	5	100%, (444 of 706 cells)	Began restarting cells Sept. 2010; estimated completion in 1st quarter 2011.
July 7, 2010	Laterrière, Canada, 1989	2 transformer failures and explosion	>24	50%, (216 of 432 cells)	Began restarting cells August 1, 2008; Sept. 30, 2010, 25,000 t loss production.
Nov. 9, 2008	NZAS, Tiwai Point, NZ, 1971	Transformer failure	>24	33%, (206 of 618 cells)	Gradual restart began mid-May, 2009.
Nov. 2, 2008	Dubal, UAE, 1979	Thermal overload of its power plant	>2	42%, (660 of 1565 cells)	Began restarting cells after 1 month; capacity was restored in 2.5 months.
June 12, 2008	Anglesey, England, 1971	132 kV transformer failure-fire	4	67%, (211 of 316 cells)	1 <sup>st</sup> potline restored in late July; 2 <sup>nd</sup> potline in August 2008; smelter closed Sept. 2010.
May 2008	Keao Aluminium, Zoucheng, China, 2003	No supply of power from grid system	5	0	180 cells (300 kA), power only for automaton and lighting, no cells were shutdown due to power outage.
Jan. 1, 2008	Noranda, U.S., 1968	Broken power transmission lines	>24	75%, (377 of 508 cells)	Restarted Lines 1 & 2; gradual restart in Line 3.
April 16, 2007	Alcoa, TN, U.S., 1969	Broken power transmission lines	4	50%, (164 of 328 cells)	Began restart of Line 1 May 28 and completed June 2007.
July 18, 2003	Alumar, Brazil, 1984	2 rectifier failures	>24	40%, (250 of 710 cells)	Began restart Oct. 13 and completed Nov. 14, 2003
Sept. 14, 2001	Hillside Aluminum, BHP, South Africa, 1995	Temp. lost power from grid; air compressors failed to re-start	5.2 (L1), 6.3 (L2)	21%, (123 of 576 cells)	Air off for 4 hour, gas TC off for 5 hrs, and fume TC off for 9 hrs.
March 10, 2000	Alcoa, Mt. Holly, U.S., 1980	Aluminum bus failure	5	25%, (90 of 360 cells)	Began restart almost immediately.

**Figure 1. Power outages (blackout) in aluminium smelter around the world from 2000-2010 [1]. Power outages until May 2018 are given in [2].**

To resolve the issue of breaker chisel dropping in the bath, we introduced the Auto Retract technology for pneumatic breakers and prevent their malfunctioning. The system works by automatically triggering a valve connected to a buffer tank and releasing compressed air to the pneumatic cylinders to restore their operational pressure. This action ensures the breaker chisel is returned to its correct position and securely locked above the molten bath instead of falling into the bath.

The implementation of Auto Retract Technology at the INALUM has enhanced operational reliability and safety. The technology prevents damage on pneumatic cylinders and promotes

efficiency aluminium production during emergency situations like power blackouts. It not only maintains the quality of the aluminium but as well prevents deterioration of essential parts of pneumatic systems which can improve the longevity and operational stability of pneumatic components.

The original design of INALUM cells (S170 Sumitomo technology) had centre bar breakers, one per cell. Mass upgrading to point breakers started in 2023 and continues to this day in Potlines 1 and 3, although several pilot tests of point breakers had been tested earlier. Potline 2 has been upgraded to SAMI technology, using point breakers.

In this paper we aim to highlight the technical aspects of the Auto Retract technology to aluminium smelting operations particularly in mitigating the negative impacts of blackouts. Auto Retract technology, described in this paper, is installed on one point-breaker cell in Potline 3, Cell R669.

## **2. Blackout and Compressed Air Supply Failure in the Smelter**

Failure of the compressed air supply to the reduction plant can result in dipping crust breaker chisels into the bath as shown in Figure 2. This can increase Fe content in the metal and lower its quality. The failure of the compressed air supply can be caused by the compressor inability to supply compressed air or by a blackout, which can make the compressor plant shut down and stop the compressed air supply. A blackout in an aluminium smelter occurs when there is no auxiliary and DC current, which can be caused by natural disruptions such as storms, lightning, or other causes of equipment failure or electrical faults. Blackouts in aluminium smelters are more frequent today than in the past [3]. A blackout can lead to operational failures of the potlines.

One of the most critical issues during a blackout is the failure of the breaker cylinder operation in the cells. The breaker cylinders maintain the feeder holes open for alumina and aluminium fluoride feeding. A sudden power blackout can cause the pneumatic system to fail, leading to the breaker blade in bar-breaker cells or breaker chisels in point breaker cells dropping into molten bath. At INALUM, in December 2022, the majority of the cells were still having bar breakers. There was a failure of the compressor which caused many bar breaker blades to dip into the bath and cause an increase in Fe concentration in the metal, shown in Figure 3. It is estimated that nearly 20 % of the breakers dipped into the bath, increasing the Fe in the metal above 0.5 %. In a blackout, it is estimated that the compressor plant shut down can cause at least 50 % of point breaker chisels or bar breaker blades to dip into the bath. This underscores the critical need for reliable systems to prevent or mitigate the effects of blackouts.

All blackouts affect the cell operation [4]. Blackouts also cause other damages to the cell. For example, a blackout can cause abnormal cell conditions in bath temperature, voltage noise, Fe content or other key parameters, which may damage cell equipment over a long period of time. In some cases, if the blackout is long, the potline is shut down, resulting in a longer and expensive restart.



Figure 2. Breaker chisel submerged into liquid bath when in operation.

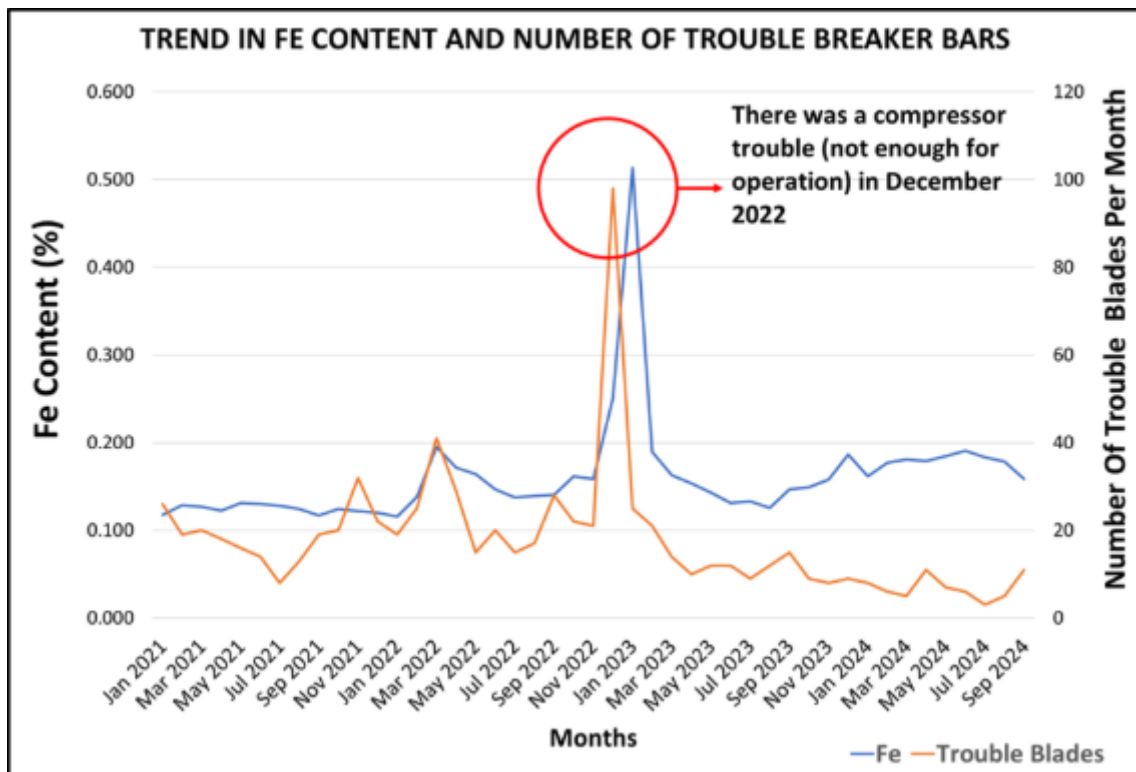
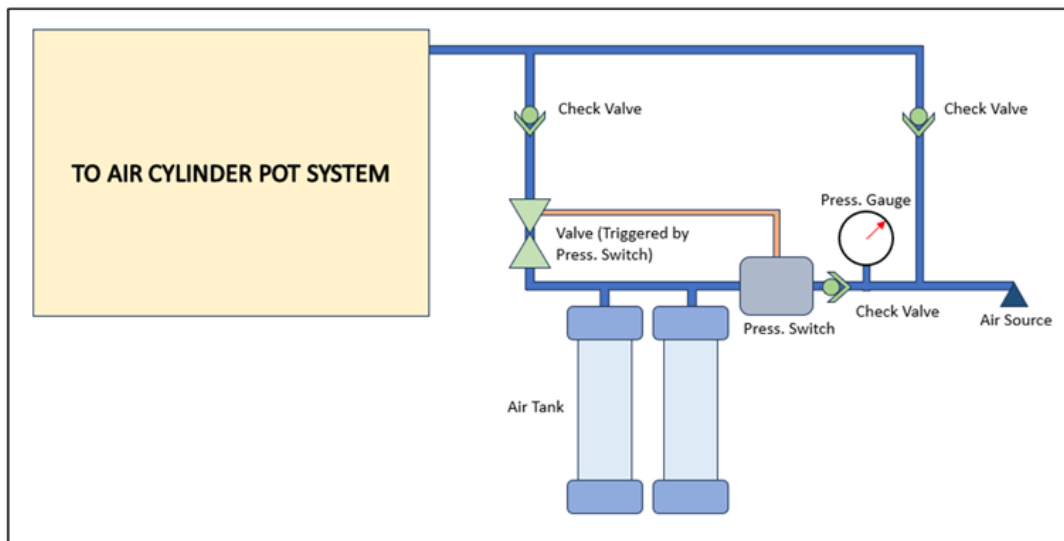


Figure 3. Trends in Fe content and number of breaker troubles per month, when blades (bars) fall into the bath.

### 3. Auto Retract Technology Concept

Auto Retract technology advances the design and operation of pneumatic systems in the cell. It addresses one of the most significant challenges in smelting operations - the loss of air pressure in the pneumatic system during emergency situations, such as blackouts. In aluminium smelters pneumatic systems are essential for controlling operational components, including the breaker cylinders that keep the position of the breaker chisels above the molten bath. These systems are crucial for the safe and efficient operation of the cells. When the power goes out the loss of compressed air in the pneumatic system can result in serious operational failures. The most critical is the dropping of the breaker chisel into the liquid bath. This can cause contamination, loss of metal quality, and significant operational disruptions posing both safety risks and production losses.

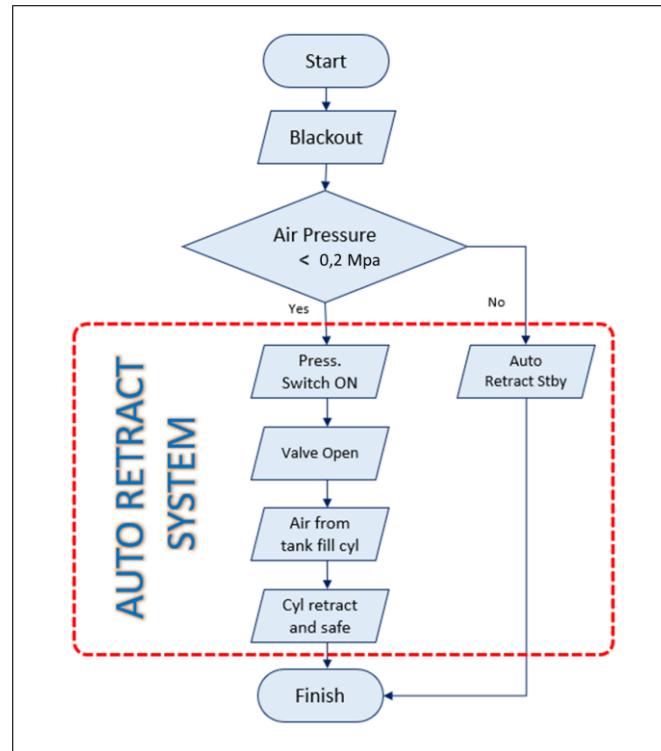
Auto Retract technology protects pneumatic cylinders when the pressure is lost, by providing a secondary safety system. In this case pneumatic cylinders can operate even if the compressed air supply has been turned off (when blackout happens) as illustrated in Figure 4. The system has a buffer tank acting as a backup air source. The buffer tank supplies air when the pneumatic air pressure drop to below 200 kPa. The system indicates that the buffer tank valve is activated by a pressure switch that measures and monitors air pressure. The buffer tank supplies a reserve of air pressure automatically so that pneumatic cylinders are pressurized and the breaker cylinder operation continues uninterrupted.



**Figure 4. Auto Retract technology concept.**

A feature of the Auto Retract system is its use of a pressure switch which is mechanically operated and highly sensitive to pressure fluctuations. This pressure switch is constantly monitoring the air pressure levels and when it detects a drop in pressure in the compressor and triggered into action. Activation the pressure switch opens an automatic valve that connects the pneumatic system to the buffer tank. The valve allows the air pressure in the buffer tank to flow into the pneumatic system directly into the operating breaker cylinders with the necessary air pressure as shown in Figure 5.

Once the pneumatic cylinders are filled with air from the buffer tank, the breaker chisel is automatically raised and locked into position using the system's auto locking mechanism. This ensures that the breaker chisel stays securely above the liquid bath preventing it from falling into the liquid bath. The automatic restoration allows the smelting operation to continue without interruption even when the primary air supply is dropped.



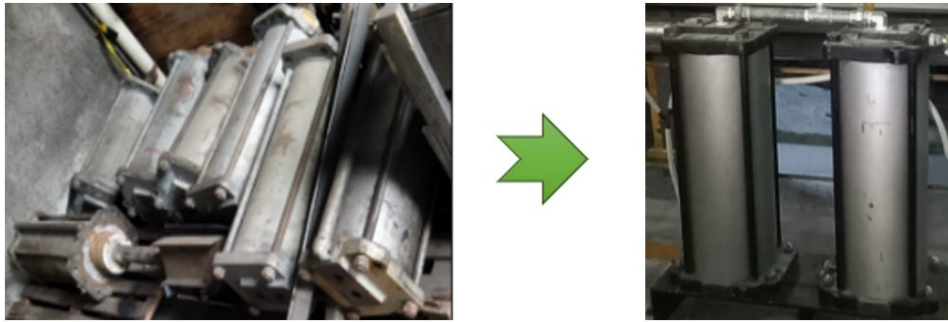
**Figure 5. Auto Retract flow process.**

The benefits of the Auto Retract system is preventing the failure of the breaker cylinders. In addition to restoring the breaker chisel position the system stabilizes the air pressure of the entire pneumatic system, including the cell system. In smelting operations, maintaining consistent and stable air pressure is essential to ensure the smooth functioning of mechanical components. If air pressure is not maintained properly the entire operation can disrupt the pot operation. The Auto Retract system solves these issues by acting as a buffer against air pressure drops and makes sure that the pneumatic system remains operational even during blackouts, compressor failures, or other unforeseen events.

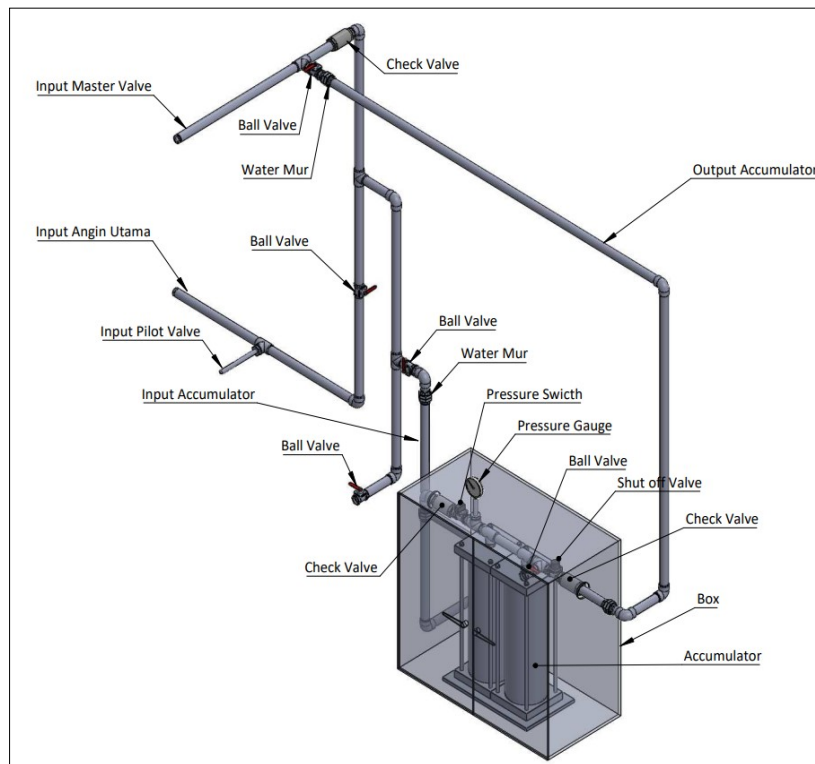
#### **4. Installation of Auto Retract Technology**

Auto Retract technology has been successfully implemented in Potline 3, Cell R669 at the duct end. It was installed in this specific location to provide a backup system in the air pressure loss due to the power blackout or equipment failure.

The installation was made more cost-effective by utilizing spare parts from used bar-breaker buffer cylinders shown in Figure 6. These cylinders were cleaned, tested, and modified for the compressed air backup of the pneumatic system. The buffer tanks were connected to the pneumatic system as shown in Figure 7.



**Figure 6. Used bar-breaker cylinders for Auto Retract air tanks.**



**Figure 7. Auto Retract design.**

The breaker cylinders are vital components in the superstructure as shown in Figure 8. The Auto Retract system is designed to detect pressure drop below 200 kPa using a pressure switch which automatically triggers the valve; the pressurized air fills the breaker cylinders and raises the breaker chisels and locks them securely with the auto lock mechanism. This prevents breaker from falling into the liquid bath. The system also stabilizes air pressure in the cell system and prevents potential damage to the pneumatic cell equipment. The system automatically restores pressure without any operator intervention; this reduces the involvement of operators in emergency and improves safety.

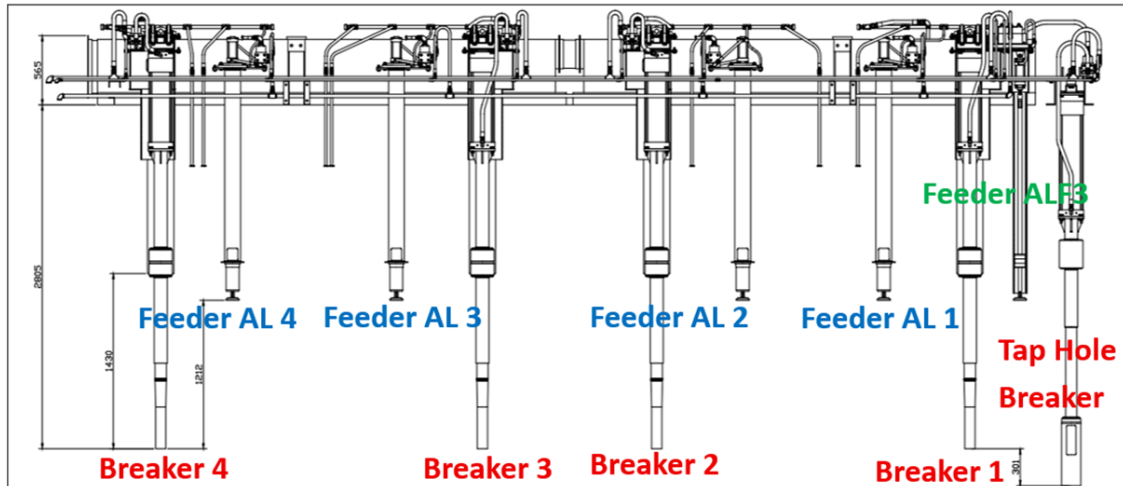


Figure 8. Positioning cylinder for Auto Retract.

## 5. Auto Retract Implementation Results

To validate the functionality of the Auto-Retract system, the system was tested under controlled conditions. During the test the main air supply valve was closed, simulating the primary air pressure loss due to power blackout failure of the main compressor. When the pressure in the system dropped to 200 kPa, the pressure switch system activated, which opened the valve allowing compressed air from the buffer tank to flow into the operating cylinder. The validation showed how effectively the system restores pressure and protects the breaker chisel. The following points outline the sequence of steps taken during the test, shown in Figure 9:

1. **Direct control valve is pressed and held**  
The test begins by manually pressing and holding the direct control valve which activates the pneumatic system.
2. **Pressure gauge shows normal pressure**  
Pressure gauge displays a normal reading confirming that the system is operating at the expected pressure level.
3. **The main air supply valve is closed**  
To simulate a pressure loss the main air supply valve is closed. This action cuts off the primary air source and triggers a pressure drop in the system.
4. **The breaker is operating**  
With the main air supply full up air cylinder, the breaker chisel is still in operation. But due to the lack of air pressure, it fails to retract, potentially causing operational issues.
5. **The pressure gauge shows pressure drop to 200 kPa**  
The pressure gauge shows a significant pressure drop to 200 kPa, indicating that the air pressure has dropped.
6. **Auto retract system activates**  
Upon detecting the pressure drop the Auto Retract system is automatically triggered. The pressure switch activates valves and initiates the buffer tank to restore air pressure in the cylinder.
7. **Breaker retracts with backup air from Auto Retract buffer tank**  
The compressed air from the buffer tank enters the system, immediately causing the breaker chisel to retract and lock above the molten bath.

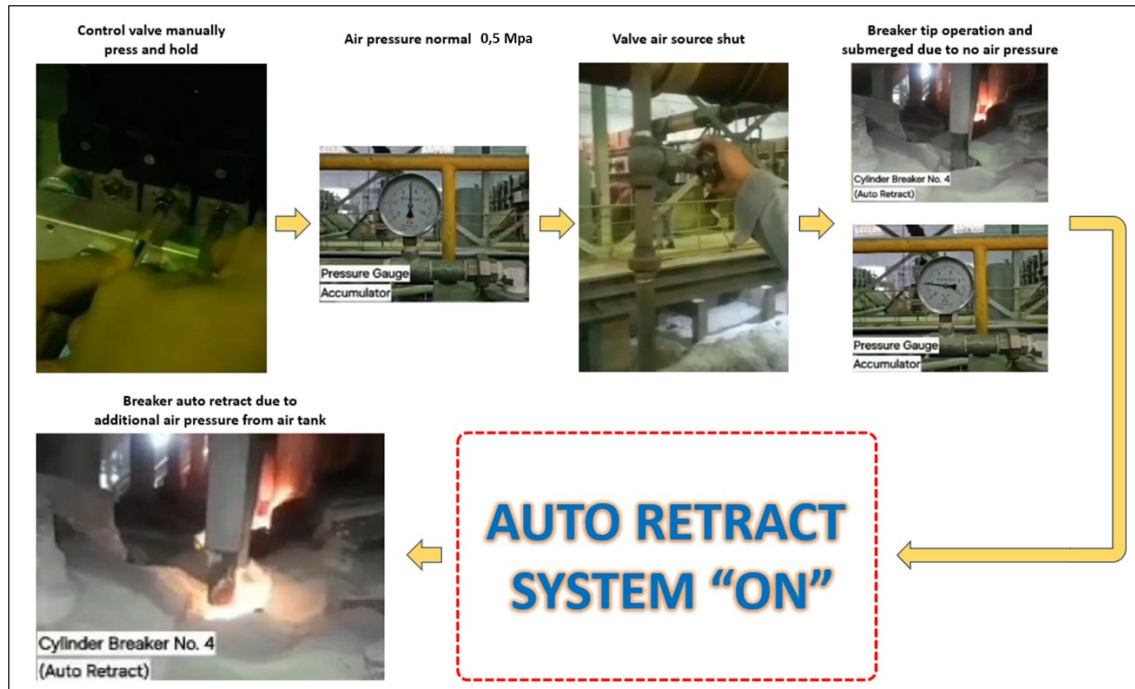


Figure 9. Flow load test implementation Auto Retract.

In the buffer tank shown in Figure 10, pressurized air entered the cylinder, the pneumatic system was able to restore the pressure and the position of the breaker. The Auto Retract system not only retracted the cylinder and raised the chisel above the liquid bath but also locked it through auto-locking mechanism.



Figure 10. Air tank in Auto Retract installation.

## 6. Conclusions

The Auto Retract system implemented at INALUM has significantly increased safety and system reliability. The Auto Retract system guarantees that the breaker chisel is safely positioned above the liquid bath, eliminating the possibility of iron contamination in the metal due to submerged breaker chisel when air pressure or power supply fails. The key points of the Auto Retract implementation are:

1. **Improved safety**

This system makes sure that the breaker chisel retracts and locks safely above the liquid bath for all emergencies including blackout and loss of air pressure.

2. **Reliable backup air supply**

By reusing air cylinder as a buffer tank, the system provides an economic solution when the main air supply fails.

3. **Automatic response to pressure loss**

The Auto Retract system is equipped with a pressure switch that detects air pressure drops to below 200 kPa. When triggered, the system automatically releases compressed air from the buffer tank through a valve and then retracts the cylinder and locks the breaker. This avoids the risk of the breaker chisel falling into the bath.

4. **Operational continuity**

By stabilizing air pressure, the Auto Retract system minimizes operational disruptions and improves the overall efficiency and reliability of cell operation even during unexpected conditions.

5. **Proven reliability**

The test demonstrated that the system works effectively even when the main air supply is cut off and that it performs in emergency as designed.

6. **Cost-effective and sustainable**

Reused cylinders as buffer tanks for backup air storage provide a cost-effective solution.

The successful implementation of the Auto Retract system at INALUM enhances operational safety, assures continuity of operations during emergencies, and maintains aluminium purity. This innovation is a vital step forward in improving the resilience and efficiency of INALUM operations.

7. **References**

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