SMART EMERGENCY BRAKES FOR OVERHEAD CRANES*

Plinio Fagundes[1]
Ronei Vilas Bôas Cândido[2]
Andreas Dulzky[3]
Luiz Carlos Gomes[4]
Felipe Clemente Motta Teixeira[5]
Leandro de Paula Tenório[6]
Melk Edur Franklin do Nascimento[7]

Abstract
Overhead cranes are the most important equipment in steel shop facilities. On board protection systems are designed to prevent disasters when critical events occur, such as mechanical failures or power shutdowns. Even so, these systems are not enough to guarantee operational safety. APLAN developed the APL45 smart emergency brake. This redundant system monitors crane operation, immediately stopping any unsafe load handling or lifting events by accurately interpreting the crane signals. The APL45 can be installed on overhead cranes of various load capacities and on all lifting devices where it is necessary to guarantee absolutely safe and monitored operation.
Keywords: Emergency brakes; Overhead cranes; APL45; APLAN.

1 Automation Engineer/ M.Sc, CEO, Managing, APLAN, Belo Horizonte, Minas Gerais, Brazil.
2 Computer Science/B.Sc, Head of Project & Sales, Managing, APLAN, Belo Horizonte, Minas Gerais, Brazil.
3 Electrical Engineer/B.Sc, Head of Sales Automation & Electrics, Managing, INTECO, Bruck a.d. Mur, Estíria, Austria.
4 Mechanical Technician, Mechanical Supervisor, Sales, APLAN, Belo Horizonte, Minas Gerais, Brazil.
5 Metallurgical Engineer/B.Sc, Production Manager, Managing, Production, Vale Mineração Onça Puma, Ourilândia do Norte, Pará, Brazil.
6 Automation Engineer/B.Sc, Engineering and Maintenance Planning and Control Manager, Maintenance, Vale Mineração Onça Puma, Ourilândia do Norte, Pará, Brazil.
7 System Analysis and Development/Technologist, Automation Analyst, Automation, Vale Mineração Onça Puma, Ourilândia do Norte, Pará, Brazil.

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1 INTRODUCTION

Safety is the most important value across industrial segment, particularly in mining and molten material environments like steel shops and foundries. Even with many facilities designed or refurbished with advanced on board technologies aimed at ensuring safety, some unexpected unsafe incidents are still unavoidable.

Dewani [1] discussed material overload as the second most significant cause of overhead crane accidents. According to OSHA, 80% of crane accidents occur as a direct result of overload, causing irreparable damage to the crane and harm to both the operator and the other onsite personnel. Statistics indicate that one overload accident occurs every 10,000 work hours.

Aiming to solve the issues involving overhead cranes, APLAN developed the APL45, a smart emergency brake system designed for installation on overhead cranes of various load capacities across all lifting devices.

Emergency brakes are devices that are only activated when the overhead crane's main lift hoist reaches overspeed due to failures within its electrical, electronic, or mechanical drive systems, or when the overhead crane's emergency buttons are pressed. They guarantee total braking and load stoppage in an emergency state. Emergency brakes, however, are not service brakes as overhead cranes are equipped with rheostatic brakes for deceleration and electro-hydraulic brakes for parking.

The APL45 was installed in the refinery overhead crane at Vale Mineração Onça Puma. The package included the concept, basic and detailed engineering (mechanical, electrical, instrumentation and automation) such as a static analysis of a cranetrolley with 160t/50t/5t load.

An automation system was developed to modify the PLC application, including brake actuation logic (compatible with previous logic) and the development of the overhead crane communication interfaces with the process automation system (new signals for monitoring the brakes and any crane diagnostic signals).

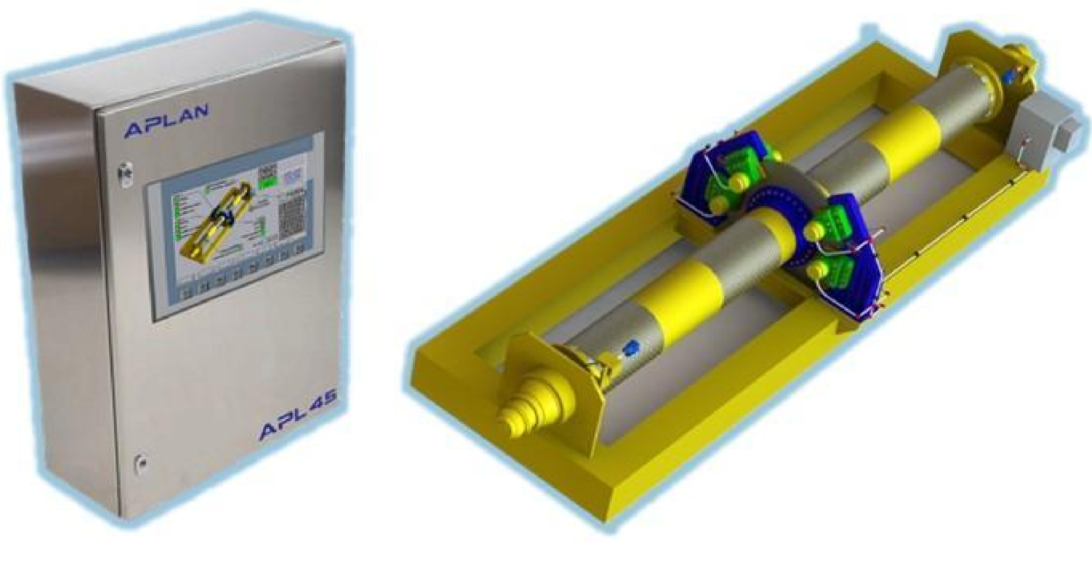

Figure 1. APL45 - Smart Emergency Brake System.

2 DEVELOPMENT

The development of the APL45 design was divided into three steps: conceptual, basic and detailed engineering.

The premises of the development were as follows:

Concept and definitions:
- Brakes open = Hoist free = Hydraulic valves energized.
- Brakes closed = Hoist braked, blocked = Hydraulic valves de-energized.

The brakes:
- Each overhead crane has 3 brakes. Each brake includes:
  - o 2 “open / closed” position sensors connected in series.
  - o 2 sensors for worn pads connected in series.
  - o 2 pads with worn pad indication connected in parallel.
- Nominal pressure of the hydraulic system = 120 bar to 150 bar.

Conceptual engineering involved developing the network architecture, a functional description, and conducting a finite element study (static analysis of a cranetrolley).

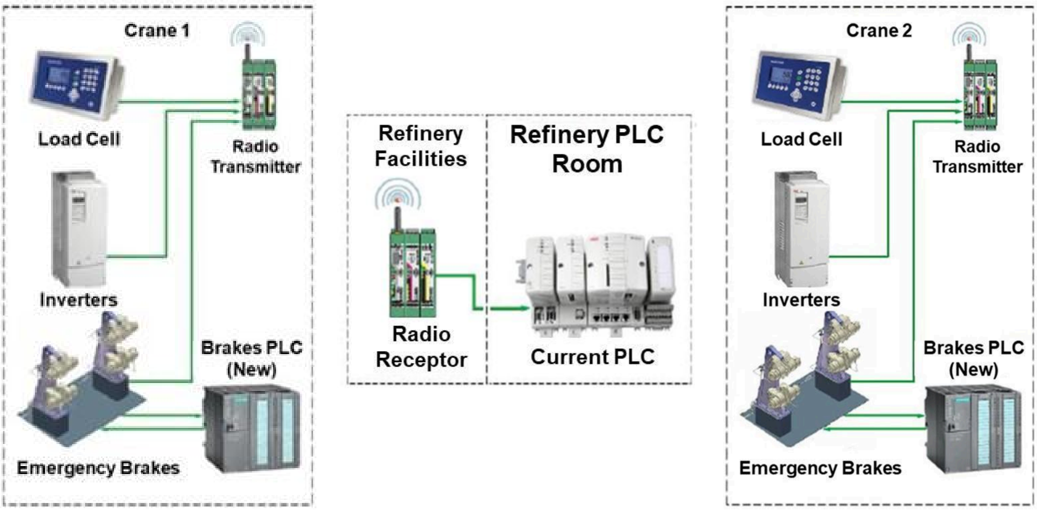

Figure 2. Network Architecture.

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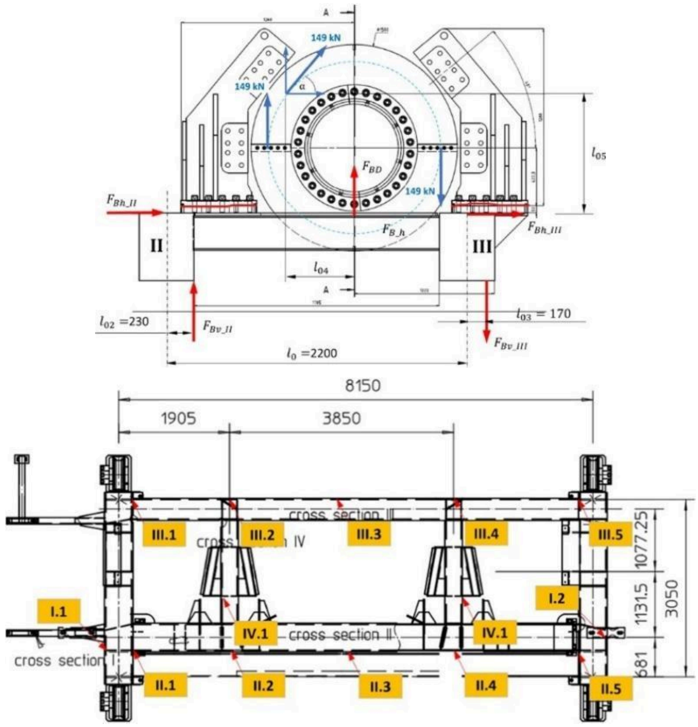

Figure 3. Static Structural Analysis.

Basic engineering develops layout and infrastructure design.

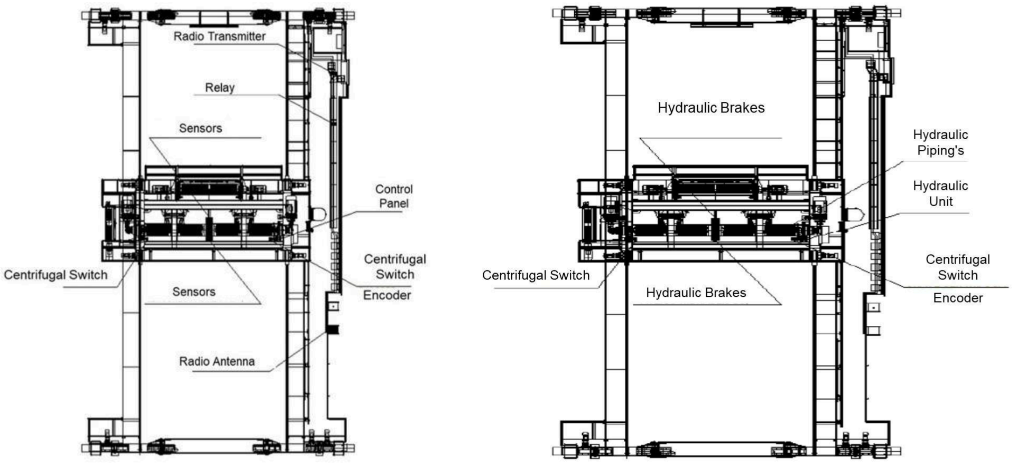

Figure 4. Layout and Infrastructure design.

Following a feasibility study, it was decided to design an emergency braking system to be mounted in the center of the main lift's hoist. Its braking disc should be set to a coupler cover that should then be welded to the hoist.

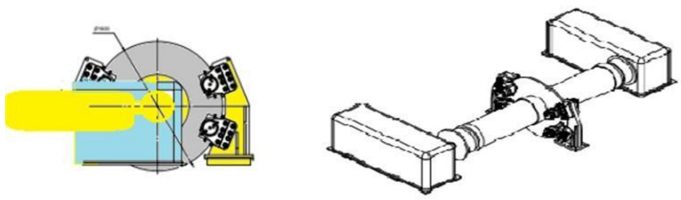

Figure 5. Emergency brake layout.

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Having defined the conceptual and basis engineering, a detailed engineering of APL45 was designed to include:

- Mechanical detailing.
- Hydraulic detailing.
- Electrical interconnection diagram.
- Specification of mechanical equipment.
- Specification of electrical components.
- Specification of automation hardware.

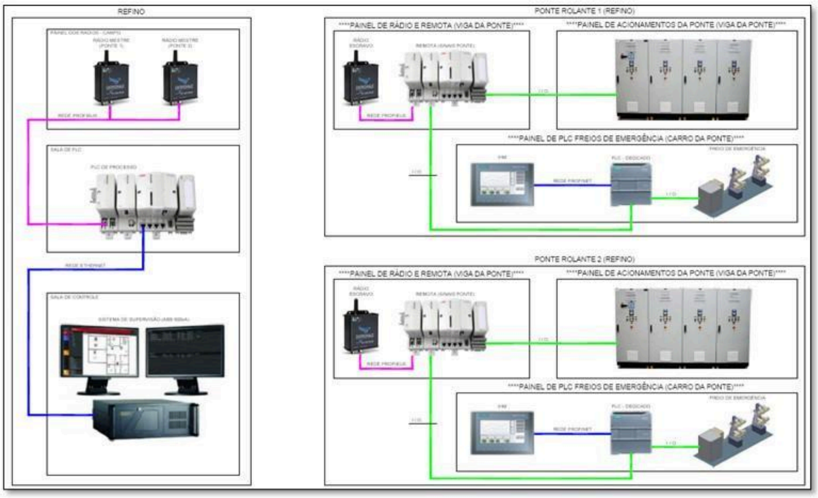

Figure 6. Electrical and Instrumentation System Architecture.

Once the detailed specifications were finalized, the automation application was developed.

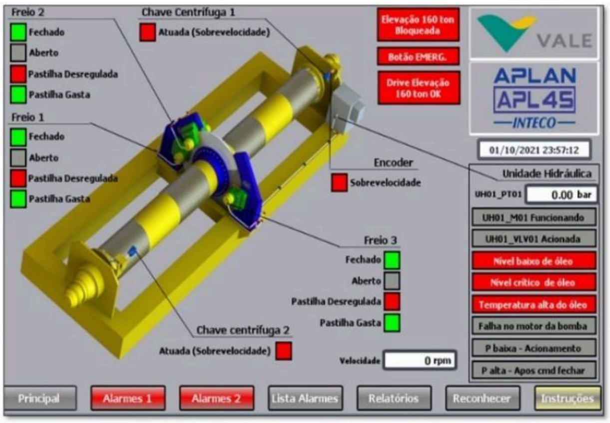

Figure 7. IHM Main Screen.

Upon completing all engineering and IHM development phases, the state of art was a product capable of preventing failures in overhead crane operation. This system monitors the overhead crane operation, immediately stopping any unsafe load handling or lifting event by correctly interpreting the signals coming from the crane, it functions as a redundant system, in the event the others devices cannot detect or fail.

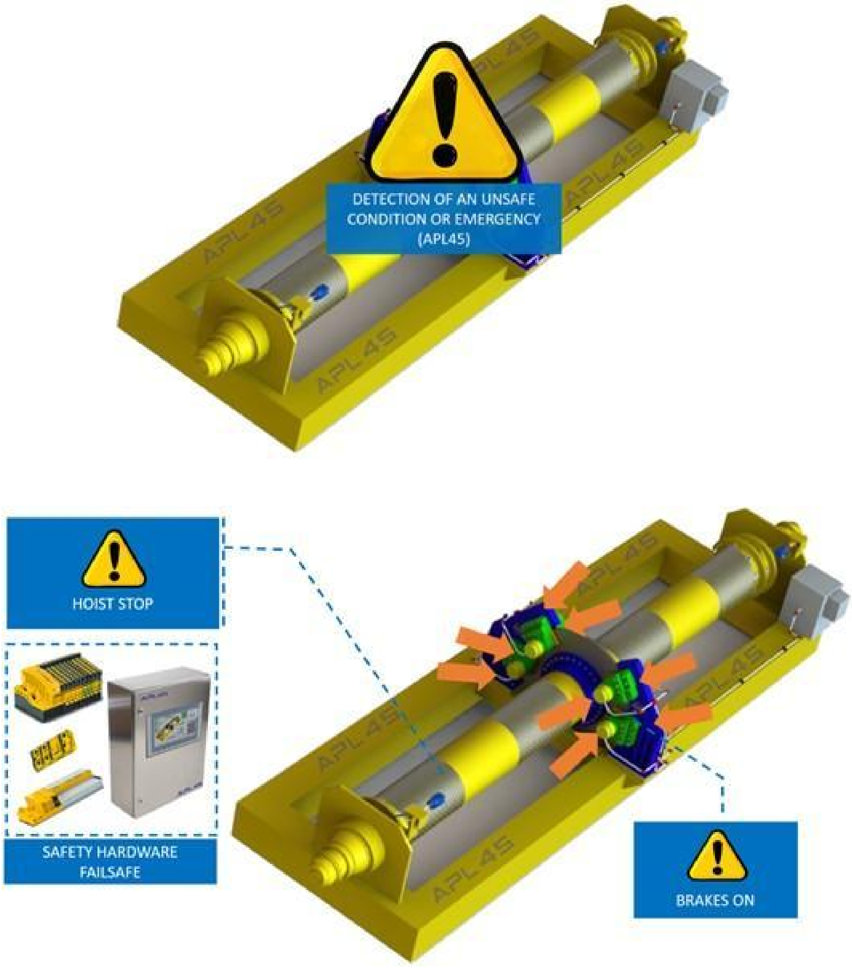

Figure 8. Illustrations of APL45 operation design.

Figure 9. Illustrations of APL45 IHM design.

The emergency brake is controlled by the hydraulic unit. Whenever the hydraulic pump and valve are activated, the emergency brake opens (pressurized system), releasing the overhead crane for operation.
If the hydraulic pump and valve are not activated (depressurized system), the emergency brake is closed, and the overhead crane cannot be operated.

Table 1 describes the alarms that cause the emergency brake to immediately close, only releasing it open once the situation normalizes. The situations below only occur in emergency conditions, i.e. they require immediate maintenance attention to ensure the safe operation of the crane.

Table 1. Alarms list

Alarm N°.	Type of Fail
1	Safety relay actuated
2	Control interlock relay fault
3	24 VDC power fault
4	Emergency button pushed
5	Fault in the main lift frequency inverter
6	Overspeed detected by the centrifugal switches
7	Fault in the 440 V voltage of the hydraulic pump
8	Failure to start or stop the hydraulic pump
9	Critical oil level in the hydraulic unit
10	High temperature in the hydraulic unit
11	Low pressure after starting the hydraulic unit
12	Slow depressurization of the hydraulic unit
13	Overspeed detected by encoder
14	Encoder detects movement with service brakes closed
15	Encoder detects movement without operator commands
16	Failure to open any of the brakes
17	Failed to close any of the brakes
18	Detection of a worn brake pad

2.1 Assembly and Commissioning at Vale Mineração Onça Puma.

Vale Mineração Onça Puma is a FeNi producer, utilizing the RKEF process. The mine and industrial plant are in Brazil in the state of Pará.

There are two overhead cranes at the refinery, designed with load capacities of 160 t/50t/5t, where molten material is handled.

To improve safety and eliminate potential failures, the company decided to install the APL45 – Smart Emergency Brakes System as preventive measure on board overhead crane #1 and overhead crane #2 within refinery facilities.

The following figures illustrate the main mechanical parts.

Figure 10. Emergency brake and brakes pads.

Figure 11. Hydraulic Unit.

The following figures illustrate the panels and electronic parts.

Figure 12. APL45: Main panel (PLC panel).

Figure 13. Remote panel and interface (crane→ABB 800xA refinery control system) Slave RF modules.

Figure 14. Interface panel (crane → ABB 800xA refinery control system) Master RF modules.

The following figures illustrate the electrical and instrumentation parts.

Figure 15. Encoder and centrifugal switches.

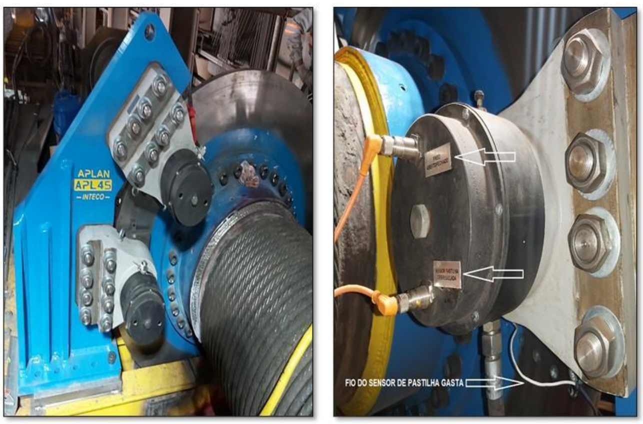

Figure 16. Brake sensors.

2.2 Static & Dynamic Tests

Static tests were carried out on the main lift hook using a load of 162.3 tons.

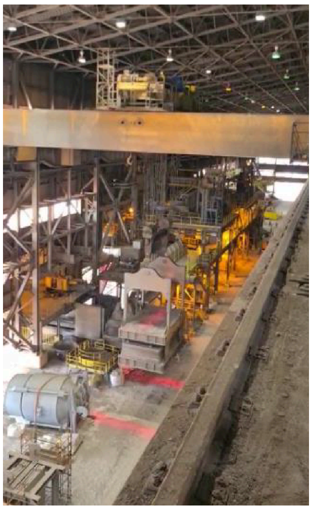

Figure 17. Load 162,3t lifted.

The static tests began by lifting the load over 1.5 meters from the floor. After reaching this height, lifting was stopped, and tests were carried out simultaneously using both the emergency and service brakes.

Figure 18. Service brake on.

The service brakes were off, leaving only the emergency brakes on. The load remained stationary, thus the test was satisfactory.

Figure 19. Service brake off.

The dynamic tests on the main lift hook were designed by staggering the load in 05 stages. The loads used were 13.5 - 44.7 - 104.4 - 120.3 and 162.3 tons.

The lifting speed of the hook/load and the total displacement of the braking disk were monitored according to table 2.

Table 2. Dynamic Test

Stage	Load (t)	Lifting speed on the encoder shaft (RPM)	Brake disk displacement (mm)
1°	13,5	96,6	0
2°	44,7	64	30
3°	104,4	44	60
4°	120,3	41	80
5°	162,3	19	100

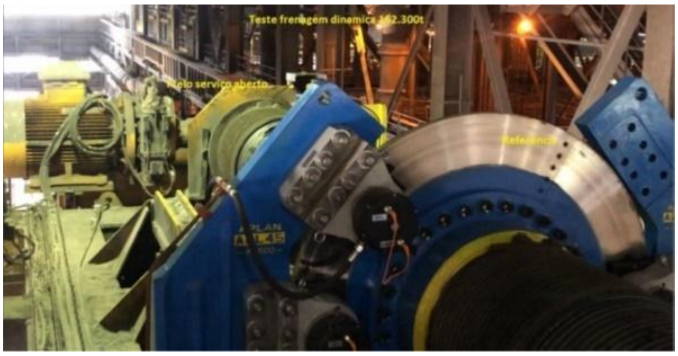

Figure 20. Dynamic braking 162.3t - service brake off.

3 CONCLUSION

The APL45 was designed as a smart solution to address the concerning lack of awareness regarding the importance of installing emergency brakes on board the overhead cranes.

The engineering design was executed according to the highest technological standards for overhead crane systems.

The company, Vale Mineração Onça Puma, successfully installed the APL45 smart emergency brake system on its overhead crane, thereby improving the operational safety as well as upgrading the equipment.

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