Earliest Leak Detection (ELD): A New Concept of Security in Water Leak Detection in Electric Arc Furnaces

Water leakage from water-cooled panels in an EAF is considered to be of high operational and safety risk in the steel manufacturing process, and the early detection of the leak is an essential and necessary factor to minimize and/or eliminate such risks. Large-scale laboratory and industrial tests were carried out successfully, accrediting the technology to market.

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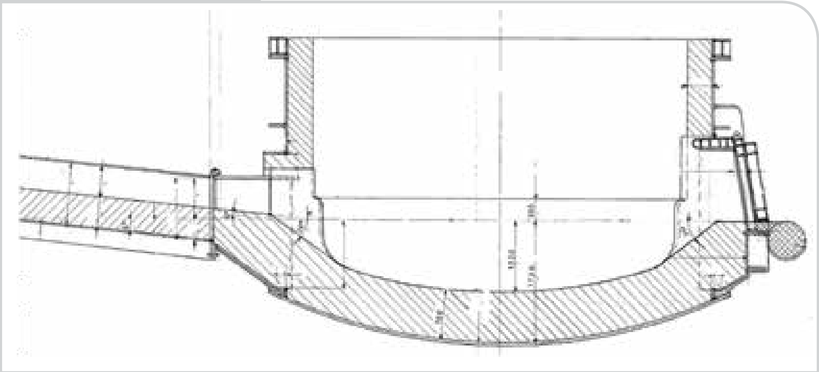
Patented in 1899 in France, the electric arc furnace (EAF) quickly became large-scale industrial equipment to produce liquid steel. In its original constructive conception, the EAF had refractory lining in the lower shell, the upper shell and the roof, as shown in Figure 1.

With the initial purpose of reducing the downtime of an EAF for refractory repairs, water-cooled panels were introduced in specific locations of the sidewalls and upper shell of the EAF. The excellent results achieved led to the expanded use of water-cooled panels throughout the EAF sidewalls, upper shell and roof.

The water-cooled panels are typically installed about 350 mm above the liquid steel level, and their connection to the water cooling system is located at the rear of the panel, through hoses and ball valves.

The initial water-cooled panels were made of special steel plate with an internal system of baffles to direct the flow of water, as shown in Figure 2. These water-cooled panels were known as "box panels." Presently, water-cooled panels are made with steel or copper tubes. These panels are subjected to a pressurized water flow, which typically varies between 10 and 15 m^3/hour for each square meter of panel. The panels are designed so that, during normal operation, the water in its entire path undergoes a temperature rise of between 10 and 35°C, depending on their mounting position. The use of tubular panels allowed a reduction in the volume of circulating

Figure 1



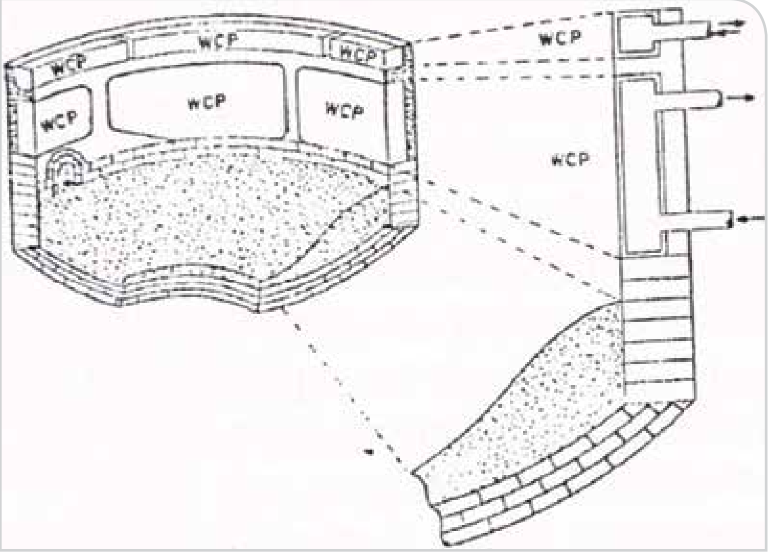
Schematic representation of a typical refractory lining of an EAF.

water, when compared to their predecessor, the box panel.[1]

Some of the advantages obtained with the use of water-cooled panels in the EAF are as follows:

- Increased productivity.
- Elimination of the need to reduce power during refining.
- Reduced downtime to repair refractory material.
- Reduced time to erect a new furnace (refractory lining).
- Reduced consumption of refractory, an important economic advantage.

Figure 2



Schematic representation of the installation of the initial EAF water-cooled panels ("box panels").

Despite the advantages achieved by the use of water-cooled panels in the EAF, at least two factors caused concern among users. The first factor involves the increase of heat losses in the manufacture of liquid steel due to the extraction of heat by water-cooled panels. However, subsequent studies have rejected this argument and proved that the increase in heat loss with the use of water-cooled panels is compensated by the increase of availability of the furnace and the economy in the use of refractory material.

The second factor refers to the risk of water leaks from the panels into the EAF. The flow of water to the panels is continuous, but the heat input that focuses on the panels varies over the heat, making the panels suffer from thermomechanical fatigue of the tubes, resulting from the different expansions and contractions.

The thermal fatigue of tubes gives rise to micro-cracks that propagate and cause minimal water leakage into the EAF. Over time, these micro-cracks expand, increasing the amount of water leakage into the EAF. Other factors can cause water leakage into the EAF, such as holes in panels due to rebound flame, splash oxygen, electrical short circuit and hose breakage.

Even small water leaks inside the EAF can cause accidents in steel plants. These small leaks are typically very difficult to detect even by operational experts and by the detection system, and will cause hydration of the refractory lining, bringing water to the refractory/shell interface, which may cause explosions and/or holes in furnace.[2]

Large water leaks are more easily observed by operators, but can quickly flood the EAF when occurring during a heat. According to Chevrand,[2] perhaps the only signal emitted by this type of leakage that can be visibly observed during the heat (also for dedusting exhaust) is the presence of a blue flame between the electrodes. Large water leaks in an EAF, in general, are responsible for explosions and projections of incandescent material out of the EAF. This occurs when the excess water present inside the EAF is covered with high-temperature liquid material (liquid steel and/or liquid slag), triggering the occurrence of two chemical phenomena: the increased speed of boiling of water to form steam, and the dissociation of hydrogen from water. These phenomena cause a volumetric expansion that it is quickly pressurized within this "blanket" of steel and/or slag. The disruption of this layer of steel and/or slag means an explosion without notice, a function of the speed of the reactions.

Usually the detection of water leaks in an EAF is based on a visual inspection of the EAF, a practice totally dependent on the expertise of the EAF operators. There are also automated systems to detect water leaks from water-cooled panels, but typically these systems are based on measuring pressure and water flow, or on the analysis of exhaust gases from the EAF. These systems, in general, tend to detect only large water leaks, have a low response time and do not indicate the exact location of water leaks.

The new leak detection technology developed by Lumar Metals presents an innovative approach in monitoring and detection of water leaks in water-cooled panels. By analyzing and combining data collected in each individual water-cooled panel, new leak detection technology proved capable of quickly detecting leaks of 3.0 l/minute up to 10 seconds after their occurrence.

Figure 3

Panels mounted for conducting the laboratory tests of new leak detection technology.

Initially, technical and theoretical studies were performed to identify the most relevant parameters for the detection of water leaks in water-cooled panels and which techniques would be used to collect all information necessary to identify the leak. Subsequently, functional tests were performed in the Lumar Metals laboratory.

The first stage of testing consisted of simulating the operation of water-cooled panels where water leaks have occurred. To do that, three water-cooled panels were mounted on a specific device and connected to a cooling system, as shown in Figure 3. Each panel was fed with a water circuit of approximately 24 m^3/hour. The water pressure of the cooling system used during testing was 6.0 kgf/cm^2. The ELD data collectors were mounted on the outlet connection of the panels.

Water leaks in water-cooled panels were simulated by "forced" way, using two different methodologies. First, holes were made at random over the water-cooled panels circuit, and then ball valves (DN 1/2 inch) were installed in each open hole to prevent leakage when the water circulation was in the panel. With the cooling system running (circulating water), leaks in various parts of the water-cooled panels were simulated by opening the ball valves installed in water-cooled panels. Water leaks were simulated at various intensities (outflows), from a small leak that caused only a mist of water up to large spills with the valve fully open.

The second simulation was the thinning of the tube through the panel rotary tool. The tube was chopped until only a thin metal wall was left, and then a sharp tool was used to cause a small hole in the panel.

During the first stage of tests, it was possible to analyze the response of the technology to simulated leaks, repeatability and reliability of the signals. However, this step did not allow the technology to be tested in relation to the weathering process of the EAF, such as exposure to heat, high noise and electromagnetic field, exposure to dust and particulate matter, and other operating conditions. Therefore, the realization of a second stage of practical tests, with the technology installed in an EAF and the testing performed during normal EAF operation, has been set.

The second stage of testing was conducted in an operational EAF with a capacity of 100 metric tons. A device was assembled to the inlet connection of the water-cooled panel to simulate the occurrence of a water leak. The device consisted of a bypass water flow from the main flow of the water-cooled panel where a needle valve and a solenoid valve were set, as shown in Figure 4. The needle valve was used to regulate the

Objective

This paper aims to present how the new leak detection technology can be deployed in an EAF and how the integration of this technology with existing automation systems can be performed. Also, the current development of new leak detection technology, its stages of testing and the results obtained during the development process will be presented.

Method

Generally, a small water leak detected by systems currently used in an EAF is on the order of 30–40 l/minute. Depending on the operating pressure of the cooling system, this leakage may be equivalent to a 5.0- to 9.0-mm-diameter hole in the tube panel. Another feature of these systems is the current turnaround time for confirmation of a water leakage — sometimes this time could be the same as the tap-to-tap time, or longer.

There is no doubt that the characteristics mentioned above contribute to leak detection and the prevention of accidents in steel plants; however, small water leaks that are not detectable by these systems continue to have great potential for accidents during EAF operation, and even large leaks, which are detectable by the systems, leave operators at risk during the period of confirmation of the leak.

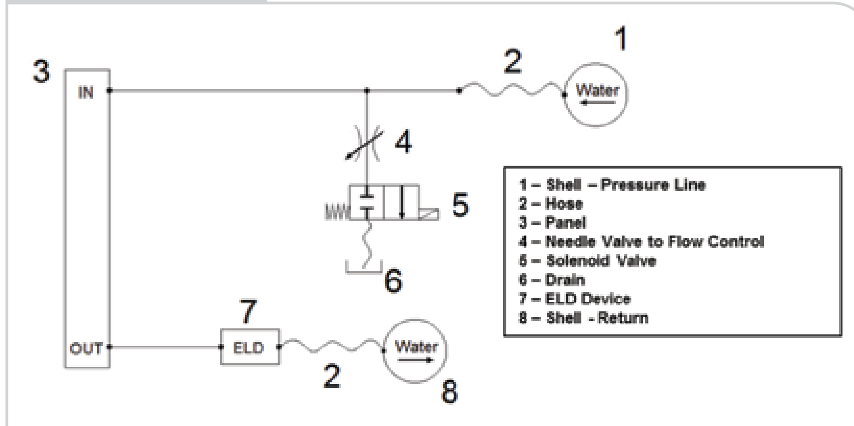
In order to greatly reduce the exposure of operators and equipment to the risks caused by the presence of water inside the EAF, Lumar Metals invested in the development of ELD Technology, initially considering: (1) the development of a system capable of monitoring continuously water-cooled panels (24 hours), and (2) the detection of water leaks with flowrates below 10 l/minute with a response time of less than 2.0 minutes.

flow of water to the desired water leakage simulated, and the solenoid valve (normally closed) was used to remotely induce the simulated water leakage. The needle valve flow was adjusted whenever the solenoid valve was electrically driven to the "open" status, which allowed for the passage of the flow, simulating a water leak in the water-cooled panel. After the removal of the electrical signal of the solenoid valve, it returned to its normal "closed" status and closed the flow of water through the device, eliminating the simulated leak in the water-cooled panel. Thus, tests could be carried out remotely without the need for operator presence around the EAF during the tests.

Due to the risk of the presence of water in the EAF, the entire volume of water generated by simulations of leaks of the water-cooled panels was directed to a secure location through the use of hydraulic hoses. The ELD data collector device was placed on the outlet connection of the water-cooled panels. Figure 5 shows the test devices mounted on the water-cooled panel to perform new leak detection.

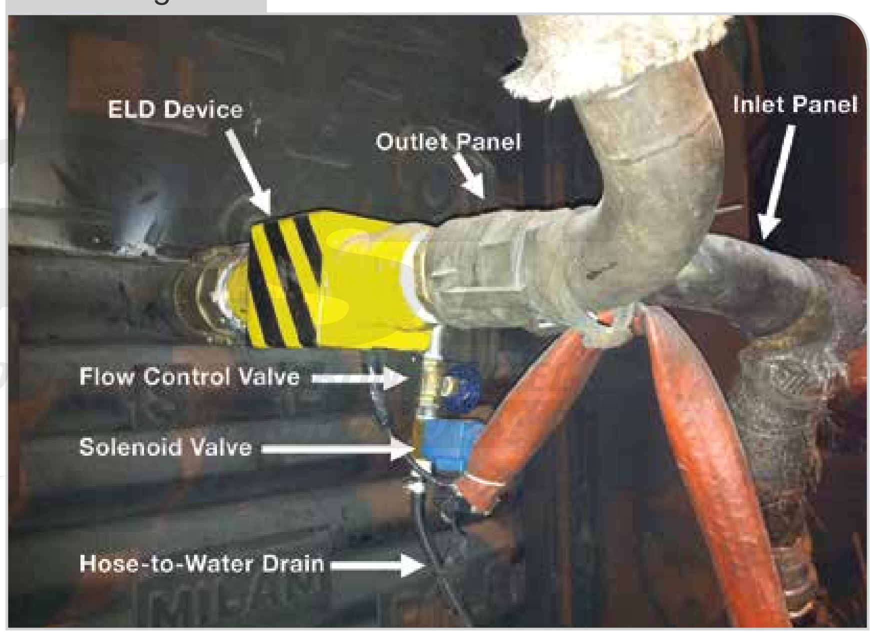
In the second stage of testing, the response to simulated leaks and repeatability and reliability of the signals could be analyzed. The leaks were simulated in a wide range of water flow in order to detect the behavior of the system to this flow variation. The new leak detection technology has also been tested in relation to the installation environment; no interference of the EAF environment was observed.

Figure 4



Schematic drawing of the new leak detection technology device to simulate leaks in water-cooled panels during the operational stage.

Figure 5



New leak detection device installed on the water-cooled panel of an operational EAF to perform the ELD Technology tests.

Results and Discussion

The results obtained during the first stage of the tests were satisfactory. The system detects water leaks with 100% accuracy in all simulated occasions. The rate of false alarms detected by the system was zero.

During the first stage of system testing, it was possible to prove that, in terms of the behavior of the signals collected by the system, there is an equivalence between the captured signal from a water leak caused by a ball valve installed in the water-cooled panel and a water leakage caused by real damage at the water-cooled panel, as shown in Figure 6. In summary, for the developed system, no matter what the source of the water leak, whether caused by opening a valve and/or a crack in the water-cooled panel, the system detects it as "leakage."

The results obtained in the second stage of testing were similar to those results obtained in the first stage; in other words, the system was able to detect

100% of the occurrences of simulated leaks. At this stage, the rate of false alarms detected by the system is also zero. Figure 7 shows a graphical representation of signal data with respect to time. Note that there are two levels of signal intensity: the lower level represents the panel in normal operation (no water leakage), and the upper level indicates that there is presence of water leakage as the circuit was monitored.

These various steps of tests also suggested further improvements to the technology, such as the use of wireless devices to avoid additional cabling around the EAF.

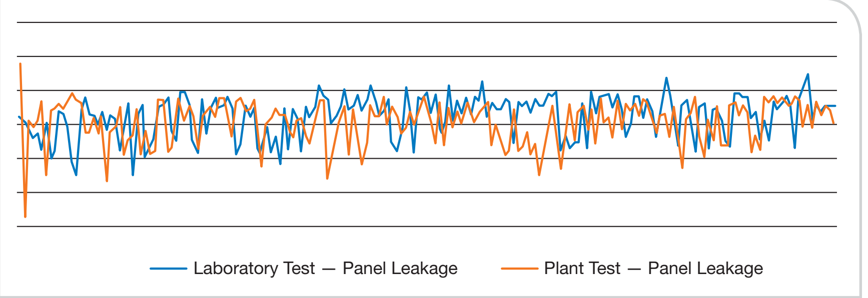
The new leak detection technology consists of the following main components:

- Wireless ELD data collector: These devices are responsible for the continuous monitoring of the water-cooled panels circuits and sending the collected data to the workstation.
- ELD base station: This unit is responsible for receiving wirelessly the data collected by the system and sending the same to the workstation by serial communication protocol.
- ELD workstation: This unit is responsible for the data analysis and issuing alarms.
- Automation system: Supervisory screen, programmed SCADA software, which will continuously present the status of each monitored circuit.

The final new leak detection technology architectural design is shown in Figure 8.

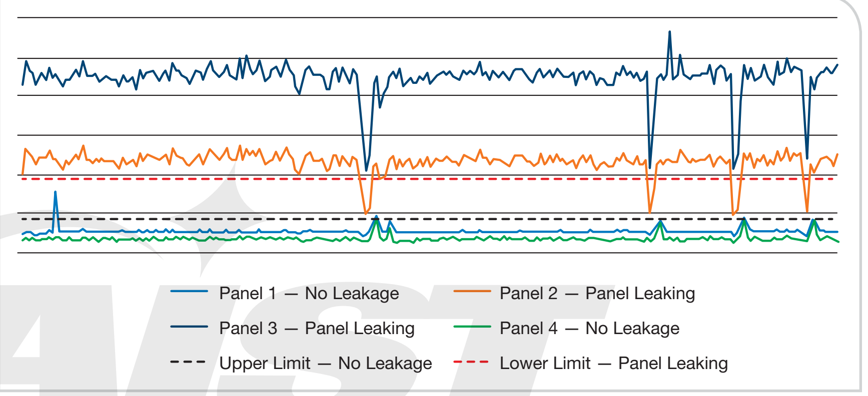
In summary, the sequence of new leak detection technology operation is: wireless ELD data collectors monitor each individual circuit and send the data collected to the base station through wireless technology. The base station organizes and sends the received data to the workstation by serial communication protocol.

Figure 6



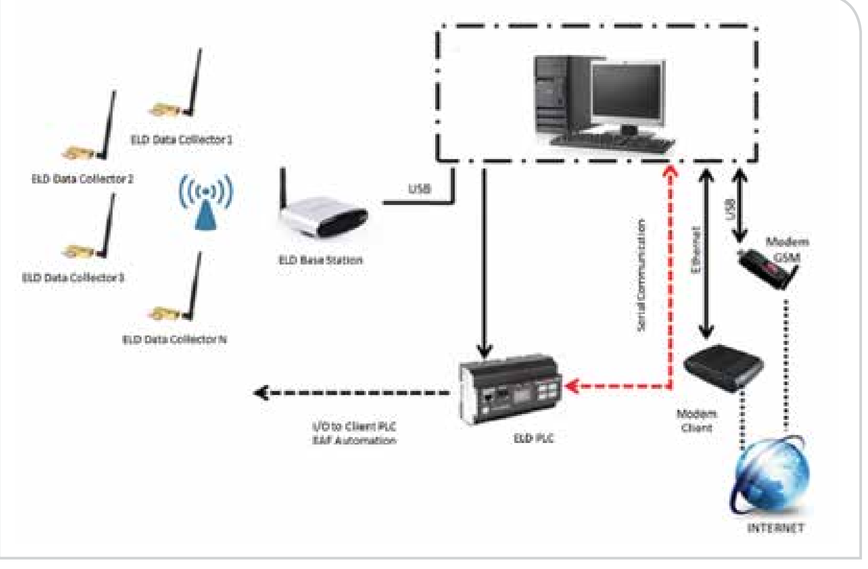
Graphical comparison of the signals collected by the new leak detection technology system during the occurrence of a leak induced by valve and real leak (crack).

Figure 7



Graphical comparison of the signals collected by the new leak detection technology system. Difference between the normal operation and the presence of water leakage in the panel.

Figure 8



Basic architectural design of new leak detection technology.

At the workstation, the data collected from each monitored circuit will be processed through specific software, and the status of each panel will be available for ELD Technology PLC and SCADA software. The status of each monitored circuit is also made available to the customer PLC by digital output in the ELD Technology PLC. The ELD Technology also allows safe, remote access to the system settings, updates and calibration procedures.

Conclusion

Although all tests of the new leak detection technology have been conducted in water-cooled panels, the application of this technology should not be restricted only to these devices. The new leak detection technology can also be used in dedusting ducts, injectors, copper blocks, etc.

The main features of the new leak detection technology are:

- Easy installation — it does not require design changes of the water-cooled panels.
- Continuous monitoring — 24-hour on-line monitoring and data processing on a dedicated workstation.
- Wireless communication protocol.
- Easy integration with the existing automation systems.
- Fully automated system that requires no operator intervention.
- Exact identification of the place of occurrence of the leak.
- Very low response time of the system. Leaks detected within 10 seconds after their occurrence.
- Detection of leaks from 3.0 l/minute.

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This paper was presented at AISTech 2014 — The Iron & Steel Technology Conference and Exposition, Indianapolis, Ind., and published in the Conference Proceedings.