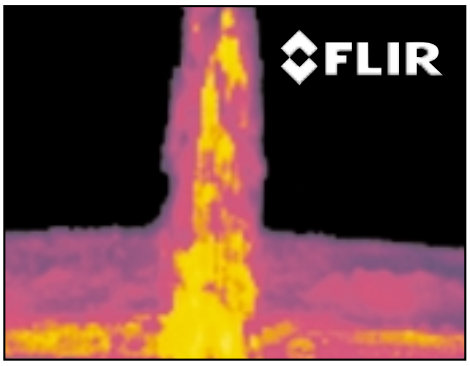
Automation Application Note

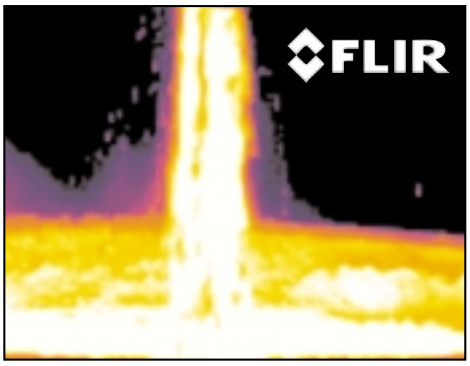
Infrared Machine Vision Systems Ideal for Slag Detection

One way to increase the quality of steel is to control slag carry-over from the steel-making furnace to the ladle. Slag is a mixture of calcium oxide, magnesium oxide, manganese oxide, silica, and iron oxide formed during the production of steel. Excessive amounts of slag can decrease steel quality, increase aluminum and alloy consumption, and damage ladle lining refractory.

Traditionally, the steel industry relied on three techniques and systems to identify slag: human vision, balls and darts and electromagnetic coils. Recently, a new technology, thermal imaging, emerged in the steel industry as a viable slag-detecting tool. Thermal imaging systems, which are basically cameras that produce "heat pictures", are fast becoming viable and cost-effective replacements to traditional methods of detecting slag.



ThermoVision infrared image of steel pouring into the ladle



ThermoVision clearly identifying "hot" slag

Conventional Slag Detecting Techniques

Human Vision

Many steel making facilities depend on highly skilled operators to visually detect slag flowing in the stream of molten metal. Poor visual conditions surrounding the molten stream caused by smoke, dust, and debris, can obstruct an operator's ability to detect slag in the tap stream. While skilled operators perform this visual detection, there is still substantial subjectivity involved.

Balls and Darts

Balls and darts are floating elements that have a density greater than slag but less than steel; this enables the elements to sink through the molten slag and float on the molten steel. When positioned above the tap hole, a mechanical arm drops a ball-shaped or dart-shaped element into the molten steel bath, slowing the tap stream. Balls and darts have a good success rate, however, their success depends on a several key factors: mechanical arm operation, conditions surrounding the tap, and operator skill. When furnace slag is heavy, balls and darts fall short of reaching the slag-metal interface reducing the effectiveness of this slag detection method.

Electromagnetic Coils

Electromagnetic sensors can be installed around the tap hole to create a magnetic field that senses the flow of steel. When slag is present in the tap stream, these sensors detect the absence of steel, transmitting a signal to an operator to raise the furnace, terminating the pour. Electromagnetic sensors are susceptible to burn damage due to their close proximity to the tap hole. Repairs to electromagnetic sensors can take place only during lengthy furnace outages, reducing steel production and diminishing revenue.

ThermoVision® Infrared Slag Detecting Cameras

All objects above absolute zero emit IR radiation that can be detected with a FLIR Systems ThermoVision infrared imaging camera. The structure, surface properties, and temperature of an object determine the amount of infrared radiation it emits. The efficiency of an object to emit infrared energy is called its *emissivity*. If two objects have the same temperature but different emissivities, the object with a higher emissivity will

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appear "hotter" to the ThermoVision infrared imaging system than the object with the lower emissivity.

At tap, steel and slag are approximately the same temperature. Because slag has a higher emissivity value than steel, molten slag pouring into the ladle appears much "hotter" and more pronounced than steel when viewed with the ThermoVision. The ThermoVision transmits a signal to a monitor displaying the stream of molten metal. Once slag is detected in the stream, an operator observing the monitor can quickly terminate the pour.

There are two types of infrared imaging cameras: longwave, which detects radiation in the 8-12µm region, and shortwave which detects radiation between the 3-5µm region. The difference in the emissivities between steel and slag are greater in the longwave region of the infrared spectrum as opposed to the shortwave region. As a result, the detection of slag can be made sooner and with more confidence with a longwave infrared imaging system. Moreover, a shortwave system suffers more attenuation by gases in the atmosphere and scattered particles and smoke than a longwave system. The longwave region of the infrared spectrum offers the widest window with least atmospheric interference. Without parallel, the longwave, 8-12µm range, is the best wavelength for infrared slag detection.

ThermoVision IRMV™ 320V Optimized for Slag Detection

The FLIR Systems ThermoVision IRMV 320V is the first longwave IR imaging system specifically designed for online infrared machine vision (IRMV) applications, such as slag detection. Applying the latest solid-state, longwave "uncooled" microbolometer infrared detector technology, the ThermoVision is the most reliable IR camera available. Sealed in a rugged all-metal body with an IP65 rating, the ThermoVision IRMV can withstand even the harshest environments. Real-time video and digital display can be viewed in either color or black and white through a monitor located in a safe, convenient location.

Thermal Imaging Yields Savings and Efficiencies in Slag Detection

The ThermoVision IRMV 320V is a reliable, low maintenance, self-contained slag detecting system. When incorporated into the steel making process, a ThermoVision system can reduce slag carry-over with increased consistency and efficiency compared to visual detection, balls and darts, and electromagnetic coils. The ThermoVision IRMV 320V provides steel-making operations with a low-maintenance, reliable, user-friendly, automated system necessary to minimize slag carry-over and maximize iron yields.

IR At Work

Bethlehem Steel

Bethlehem Steel uses several Thermovision IRMV systems at their Burns Harbor, IN and Sparrows Point, MD facilities for slag detection.

"The ThermoVision IRMV System permits the furnace operators to easly detect slag at tap. When you don't have IR, it's very difficult to detect slag. The ThermoVision IRMV has proven to be reliable, low maintinence, and easy to use." said Bethlehem Steels Dan Goldstein, Ph.D.

"Consistency, automation, and skilled operators are the future for slag detection at Bethlehem Steel," noted Dr. Goldstein. Additionally, Bethlehem Steel installed an audio alarm system that signals the operator when the ThermoVision detects streaking slag in the stream of molten steel.

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