Torpedo Car Monitoring

Thermal Imaging System for a Reliable Condition Monitoring of the Refractory Lining

- Increased Safety for Steel Production
- Prevention of Liquid Metal Breakouts
- Early Identification of Excessive Wear
- Maximization of the Refractory Lining Service Life
- Optimized Refractory Maintenance
The system comprises infrared cameras to cover the complete outer surface of the torpedo cars, an infrared imaging software for data acquisition and system control, a database for the storage of all measured data, a web based user-friendly interface and devices to indicate the status of the inspected torpedo.

**Improved Safety for Steel Plants**

Liquid metal breakouts from a defective refractory lining are a common danger in steel production. The well known consequences are damages of the surrounding equipment, high repair costs and loss of revenue due to production delays. Besides this economical impact, there is always a high risk of personnel injuries or even the loss of life.

The torpedo car monitoring system is designed to effectively prevent hot breakouts, by continuously monitoring the torpedo cars during operation. This way, areas with defects or depletions in the refractory lining are automatically detected long before they become critical.

**Cost Reduction**

The system also helps to reduce the production costs by extending the service life of torpedo refractories. Each time the fireproof lining gets in contact with liquid metal, its condition deteriorates until finally the torpedo must be relined. Generally, the maintenance intervals for refractory material are determined based on experience. For safety reasons, these time intervals are commonly quite conservative.

The monitoring system allows a reliable assessment of the remaining lifetime of the refractory lining. The number of heats can thus be maximized without any safety issues and the re-lining can be scheduled more precisely. Considering the high costs for the refractory maintenance, the system can significantly contribute to a reduction of the production costs of steel.

**How it Works**

The external surface temperature of a torpedo car is a reliable indicator of the condition of its refractory lining. Therefore, infrared cameras are the perfect solution for a contact-free monitoring of the refractory material during operation.

Once a temperature measurement is performed, the thermal data is analyzed and the status of the torpedo is displayed through the web interface of the system. All thermal images, the temperature information and other process related data is stored in the systems database, enabling dedicated analyses of the refractory lining status.
System Setup

Key Features:
- Fully automated measurement sequence; no operator interaction required
- Shape recognition function for monitoring the complete surface on torpedo cars in motion with very high measurement accuracy
- 100% Traceability: Automatic storage of images, measured temperatures and process related data
- Advanced data management and analysis with database and web server
- Various interfaces for connecting to your process control, data management and visualization

Key Advantages:
- Increased transportation safety
- Prevention of liquid metal breakouts
- Early identification of areas with increased wear
- Cost savings: maximization of refractory lining service life without safety risks
- Optimized refractory maintenance planning
- Efficiency comparison of refractory linings

Typical Torpedo Car Inspection Station:
- Two infrared cameras in protective enclosures for monitoring the complete outer surface of the torpedo cars
- RFID or visual camera for automatic recognition of the torpedo car identifier
- Server computer with the monitoring software, database and web server
- Indicating device for displaying the status of the torpedo, e.g. digital output module with signal light

Diagram:

- Thermal Camera
- Torpedo Car
- Server PC with Database
- RFID
- Plant Intranet
- Signal Light
- Operator
- Operator
- Thermal Camera
- Thermal Camera
Temperature Trend Analysis
Based on stored data of previous measurements on a torpedo car, the monitoring system analyzes the temperature as a function of the torpedo service time. A sudden increase in the temperature trend implies a potential breakdown of the refractory and will trigger an alarm. Moreover, the temperature trend also provides a clear information for the progression of refractory wear, allowing to schedule maintenance activities more precisely.

Alarm Colors
Areas of the torpedo, where the temperatures indicate excessive wear or a defect are highlighted with alarm colors in the web-based user interface. This way, the operator gets a clear impression about the location and severeness of a potential problem with the refractory.

Ladle status indication
Depending on the configuration of the system, the torpedo car status is displayed to the operators in multiple different ways:
- A signal light or sound alarm can inform about a critical condition (e.g. “hotspot” detected) in the control room immediately after a measurement has been released.
- Personnel in the control room or the torpedo maintenance personnel may use the pages of the web application, for either viewing the data of the current measurement or to perform a dedicated analysis.
- Other personnel, for example from the maintenance or production department, can access the Pages of the web application from their computer and so get detailed information about all torpedo cars checked by the system.

Various Interfaces
The torpedo car system features various interfaces for connecting to your process control, data management and visualization. This comprises ODBC for connecting to a database as well as a data-telegram server for the exchange of process related data via LAN. With its COM/DCOM automation interface the system can be easily connected to a PLC, a process-visualization, or other computers.

Designed for steel plants: Robust and Fail-Safe
The whole system is designed for reliable 7/24 operation in the harsh environment of a steel plant. Integrated self-diagnostic functions continuously monitor all components. Any possible functional impairment will be immediately detected and indicated. All system states are displayed and stored in a log file in the database which grants for a full traceability. With its intelligent reconfiguration-functions the system is able to eliminate most malfunctions without any user interaction.
The monitoring system comprises the complete functionality for performing the torpedo car inspections, as well as for storing and analyzing the data.

**Completely automated Inspection Procedure**
Inspections are performed fully automatically in the background without any operator actions. An RFID or a visual camera system read the torpedo identifier, starting the measurement sequence. The thermal imaging software utilizes highly accurate shape recognition functions and object tracking routines which determine for each camera individually, if the torpedo is in the optimum position for performing a measurement. The measurement is then released automatically.

**Customizable Inspection**
All settings for temperature measurement and evaluation are completely adjustable with an easy-to-use fully graphical operator interface. This allows an optimum adaptation to the torpedo cars and production conditions of the steel plant. Temperatures are evaluated in individual areas, forming a Measurement-Grid which is matched to the shape of the torpedo within the infrared image. The Measurement-Grid can comprise an unlimited number of these so called Regions of Interest (RoI), to get an arbitrarily fine subdivision for the temperature evaluations on the torpedo surface. During an inspection, the measured temperature data are compared with preset alarm thresholds. Each exceeding of a threshold will trigger an alarm. Temperature data outside the Regions of Interest will not be considered for the evaluation, thus effectively preventing false alerts due to other hot objects in the image.

**Advanced Data Management**
The Torpedo Car Monitoring system includes a powerful database for automatically storing the temperature data, the thermal images and the process parameters (torpedo identifier, heat number, torpedo type, measurement location etc...). This allows a long-term analysis for all torpedo cars. The database may also be connected to the intranet of the plant in order to allow data exchange and to pass the data to other data processing systems.

**Web application for data display and data mining**
A configurable web-application serves for displaying the inspection results and for performing extensive analyzes. With this concept an unlimited number of users can get simultaneous access by just using a standard web-browser. The web-application includes several pages: A Status page gives a complete overview of the currently performed inspection, showing all temperature data, thresholds, thermal images and process-related data. With the Research page the user can perform detailed analyzes for all torpedo cars, based on the content in the database. The SystemLog page lists all status messages, ensuring a complete traceability of all system functions.
**Torpedo Car Monitoring - Technical Data**

### Thermal Cameras

Two maintenance-free thermal cameras with un-cooled detector, located on opposite sides of the rail-track to cover the complete outer surface of the torpedo. The cameras are consistently designed for industrial applications, featuring intelligent processing functions and a Standard-GigE-Interface for data exchange. They are calibrated with an extended measurement range of up to 600°C for measuring absolute temperatures with high accuracy.

<table>
<thead>
<tr>
<th>Type</th>
<th>IRSX-I Industrial Infrared Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Measurement Range</td>
<td>-40°C to +600°C</td>
</tr>
<tr>
<td>Temperature Measurement Accuracy</td>
<td>± 2°C or ± 2% of reading</td>
</tr>
<tr>
<td>Thermal Resolution</td>
<td>0.1°C</td>
</tr>
<tr>
<td>Image Pixels</td>
<td>336 x 256 / 640 x 512</td>
</tr>
<tr>
<td>Field of View</td>
<td>51° x 40° / 85° x 72°</td>
</tr>
<tr>
<td>Frame Rate</td>
<td>9 Hz or 60 Hz</td>
</tr>
<tr>
<td>Detector</td>
<td>Uncooled Microbolometer</td>
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<tr>
<td>Interface</td>
<td>Gigabit Ethernet</td>
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<tr>
<td>Ambient Temperature Range</td>
<td>-40°C to +60°C</td>
</tr>
<tr>
<td>Weight</td>
<td>310 g</td>
</tr>
<tr>
<td>Dimensions</td>
<td>55mm x 55mm x 87mm</td>
</tr>
<tr>
<td>Protection Class</td>
<td>IP67</td>
</tr>
</tbody>
</table>

### Camera Enclosures

Protective enclosure, manufactured from stainless steel. An air barrier installed at the front side effectively prevents dust formations at the durable Germanium window. All connection cables are guided through a high-temperature-resistant hose and enter the enclosure at the rear through one cable gland. Equipped with a wall mount with manually adjustable joint, the enclosure can be easily installed in any required position.

<table>
<thead>
<tr>
<th>Type</th>
<th>IRCamSafe AI 168</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure Material</td>
<td>Stainless Steel</td>
</tr>
<tr>
<td>Germanium Window</td>
<td>Ø70mm x 3mm, DLC coated</td>
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<tr>
<td>Air Barrier</td>
<td>Adjustable air flow, supply pressure 1 - 3 bar</td>
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<tr>
<td>Cable Protection</td>
<td>Heat resistant hose, configurable length. Resistance to thermal load: up to +1640°C</td>
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<tr>
<td>Ambient Temperature Range</td>
<td>-40°C to +60°C</td>
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<tr>
<td>Weight</td>
<td>6 kg</td>
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<tr>
<td>Dimensions</td>
<td>Ø168mm x 505mm</td>
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<tr>
<td>Protection Class</td>
<td>IP67</td>
</tr>
<tr>
<td>Mounting Bracket</td>
<td>Heavy duty bracket with joint, made from stainless steel. Load rating 45 kg.</td>
</tr>
</tbody>
</table>

### Other Components

- **Server Computer**: Industry standard server computer, 19" metal case for rack installation. The server computer hosts the infrared monitoring software, the database and the web-server.
- **IRCamSafe Controller**: Integrated inside the camera enclosure. The board gives a significantly reduced installation effort, allowing a direct connection to mains power and Ethernet without any additional connection cabinet. It features various sensors to continuously monitor the ambient conditions in the enclosure, thus ensuring a safe operation of the camera.
  - 4 Port Switch with 2x LWL-LC 100Base-FX or 2x RJ45(10/100) Up-Links
  - 2 internal sensors for temperature; sensors for pressure and humidity
  - Supports a ring structure of the network for lower cabling complexity
  - Switchable camera power and heater via Modbus-TCP/IP (controlled by the monitoring software)

### Interfaces

- **Web-Server**: Ethernet Link
- **ODBC**: OPC
- **Modbus-TCP**: SQL Database
- **Digital I/O, 24V Input/Output, Potential-Free (Fieldbus Module)**

### Data Link of Cameras and Computer

- **Gigabit Ethernet**
- Up to 90m with Industrial Ethernet Cable
- Up to 500m with Multi-Mode Glass Fiber Cable
- Up to several km with Single Mode Glass Fiber Cable

### Other Solutions for Steel Industry

- **Temperature Monitoring for Continuous Casting**
- **EAF Transformer Monitoring**
- **Slag Detection**
- **Ladle Refractory Monitoring**