Thermo Scientific
ARL 3460 Metals Analyzer

Improving Productivity of Your Operations

The worldwide reference in optical emission
More than 5000 units installed since launch

Excellent sensitivity, reproducibility and accuracy

Best stability and reliability, minimal argon consumption and lowest total costs of ownership

Line selection in the range 130 to 780 nm, allowing analysis from low C, N and O to alkaline elements
**ARL 3460**

**Exceptional History**

For over 70 years, our company has set the standard for instrumental analysis of metals. A continuous stream of innovative products using optical emission and X-ray spectroscopy has been the cornerstone around which that long and successful tradition of leadership has been built. The first model of the Thermo Scientific ARL 3460 was launched in 1982 and it is, since then, the most widely used optical emission spectrometer in the world. The delivery of the 5000th unit was celebrated at the beginning of 2005.

**Fast and Accurate**

As a multi-channel optical emission spectrometer, the Thermo Scientific ARL 3460 is designed for fast, accurate metals analysis in:
- Primary metal producing plants
- Foundries, forges, mini-mills
- Casting operations
- Incoming material control
- Metals QC and R&D laboratories

The ARL 3460 is custom designed for meeting any customer specific requirements.

**Unrivaled Reproducibility, Reliability and Stability**

A well proven, one meter Paschen-Runge optics mounted into a vacuum stabilized cast iron body is at the heart of the system, providing unrivaled reproducibility, reliability and stability over both the short and long term. This brings the following advantages:
- Less time spent on recalibration
- More time available for the productive analyses

The cabinet is also ergonomically designed to allow the sample and its identification to be rapidly input by a standing operator, thus avoiding wasted seconds and further optimizing result turnaround times.

**Highest Productivity, Lowest Costs of Ownership**

Over the years the ARL 3460 has undergone constant improvements in analytical performance and has become the best tool in increasing your productivity. Due to continuous evolution of the optical components, electronics and software, we were able to decrease all costs of ownership.

**Unparalleled Performance**

Our company has a wealth of experience in analyzing almost every type of metal and thereby can only provide an exceptional product that meets or exceeds every customer’s requirements.

This experience extends to the less common metallic materials. When it comes to the analysis of materials producing toxic vapours, such as zinc and lead, the special exhaust system of the ARL 3460 ensures maximum safety of the operator.

**Nitrogen/Oxygen Analysis**

Traditionally handled by combustion analyzers, the analysis of N and O can now be performed by optical emission spectrometers. Today, more than 1000 installed ARL 3460 analyze nitrogen in steels and many analyze oxygen in steel and copper alloys.
**Turn-Key Operation**
The ARL 3460 is configured and calibrated in the factory before delivery.

We are fully aware that accuracy, which depends on the calibration of the instrument, is the most important figure of merit required from a spectrometer. Our factory calibrations performed with CARL (a very sophisticated multi-variable regression software tool that corrects for matrix effects as well as for spectral interferences), ensures the customer the highest possible accuracy. CARL provides an immediate “turn-key” instrument ready to analyze customer samples on the installation day.

**WinOE Software: Simplicity Itself**
WinOE software is a well recognized, highly easy-to-use, powerful and reliable software for metals analysis by OES:

- **WinOE** integrates the latest HTML/Internet technologies to simplify work with the spectrometer
- Shortcuts make it possible to start analysis with just one click or keystroke
- With large user-friendly icons, all functions are easily accessible
- Routine tasks are achieved quickly and efficiently by use of “push button” automated functions to guide the operation, or via “blackbox” intelligent modules running in the background with minimum (or no) user intervention

These are just a few of the many features contributing to the fast routine operation of WinOE.

**Your Partner In Productivity**
Our company is not only your supplier, but also your partner in productivity who offers you complete analytical solutions backed up by the following statements:

- Regular “firsts” in spectrometry, software and automation for over 70 years
- Tens of thousands of OES & X-ray systems already supplied in the world
- Continuous improvements of analytical performance and shorter analysis times
- Easy integration to increase productivity
- Unrivaled reputation for quality, stability, reliability and long lifetime
- Easy to use, easy to upgrade
- The OES/X-ray manufacturing facility in Ecublens, Switzerland is ISO 9001:2000 certified
- Worldwide customer support network

To keep you informed about our latest developments, please visit [www.thermo.com/oes](http://www.thermo.com/oes).

**Improve The Quality of Your Products**
The design of the Thermo Scientific ARL 3460 combines high performance with rugged construction and operational convenience with reliable operation. The productivity needed by a modern metals production is optimized by the system providing fast, accurate results, day-by-day, month-by-month and year-by-year. This will ensure the best quality of your own products.
ARL 3460 Specifications

Spectrometer
Spectrometer design: Paschen-Runge vacuum polychromator made of special cast iron and temperature controlled to ± 0.1° at 38° C. Maximum 60 channels.

| Focal length: | 1 m |
| Primary slit width: | 20 µm |
| Secondary slit width: | 20, 25, 37.5, 50, 75, 100, 150 µm |
| Type of detector: | Photomultiplier tube 28 mm, 10-stage side window tubes, fused quartz, glass or MgF₂ windows |
| Grating type: | 1080, 1667 or 2160 gr/mm, selected by analytical task |
| Resolution: | Dependent on grating, secondary slit and spectral order |
| Sample stand: | Argon flushed, water-cooled table with self-contained, closed loop cooling system |

Electronics
Spectrometer control: ARL MM8 386 Microprocessor utilizing CMOS technology with Status Measuring Card. A/D converters and attenuators included for each channel.

| Programmable attenuators: | Up to 24, available as an option |
| Dynamic range: | 10⁻¹ |
| Enclosure: | Built-in dust protection with high capacity cooling fans |

Requirements
Ambient temperature: 16-30°C (62-86°F); maximum gradient 5° C/hour
Relative humidity: 20-80 %
Voltage: 230 V (+10 %/-15 %), single-phase with protective ground (5kVA regulator required if fluctuations exceed ±10 %)
Current: 12 A, including PC, screen and printer
Frequency: 50 or 60 Hz
Grounding: < 1 Ω
Argon: > 99.96 % maximum 5 ppm oxygen (maximum 2 ppm oxygen for samples with high Si content). Optional argon purifier available and recommended for low carbon analysis. For VUV lines (nitrogen, oxygen, chlorine), argon purifier included

Consumption
Electrical power: Max 3.5 kVA
Argon: 3.5 l/min during analysis, 0.35 l/min stand-by
Compliance to norms: 96/37/EEC Machinery
73/23/EEC Low voltage material
89/336/EEC Electromagnetic compatibility

Dimensions and weight
Overall dimensions: 166.5 x 91 x 119 cm or 65 x 47 x 36 inches, including excitation stand
Weight: 450 kg. or 992 lb approximately

Accessories and options:
Small samples analysis kit
Argon purification systems
Voltage stabilization systems
Uninterruptible Power Supply (UPS)
Suction device accessory to exhaust toxic fumes
Stand upgrade for semi-automatic operation
Data communication software options
Analytical results processing software options

In addition to these offices, Thermo Fisher Scientific maintains a network of representative organizations throughout the world.

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Thermo Electron SA, Ecublens, Switzerland is ISO certified.
ARL 4460 Metals Analyzer

The Ultimate Performance in Optical Emission

The most advanced instrument for quick quantitative metals analysis from alloys to ultra-pure metals

Ultimate sensitivity and reproducibility
Excellent accuracy, stability and reliability

Best detection levels for carbon, nitrogen and oxygen in steels
Best detection levels for phosphorus in aluminum

Fast identification of inclusions in metals
Cleanliness assessments

Lowest costs of ownership
The Thermo Scientific ARL 4460 combines several advanced technologies into the world’s best established optical emission spectrometer to bring your metals analysis to the tightest specifications. Launched in 1994, the ARL 4460 has undergone continuous improvements to provide enhanced analytical performance and shorter analysis time. With more than 1000 units operating in the field, the ARL 4460 is truly the most advanced instrument in the market for high performing metal analysis.

**Your Best Partner to Stay within Specifications**

The ARL 4460 has been designed to meet all metals analysis requirements from routine use to metals research. In varying laboratory conditions or in a hostile environment, this Thermo Scientific spectrometer is the solution for outstanding analytical performance.

Increasing regulations require new partnerships in quality control. Proficiency testing and laboratory accreditation are becoming mandatory. Continually improving capabilities to allow rapid, reliable quality control of metals, we can provide guidance to a program that will meet these demanding requirements and help you to stay within specifications, even the most demanding.

**Stable, Reliable and Accurate**

Rugged construction guarantees years of instrument stability, reliability and accurate analysis in any metals laboratory or foundry operation. User demands are providing ever increasing challenges for metal producers - wider elemental concentration ranges, more accurate analyses and tighter controls.

To meet these product demands, the total system concept of the ARL 4460 has embodied critical success factors:

- Speed and accuracy, even for ultimate trace analysis
- Capability to identify and count inclusions and to calculate cleanness indexes
- Unmatched stability and reliability
- World class factory calibration
- Widest range of metals analysis
- Most advanced software technology
- Easy operation
- Automatic sample manipulation systems (optional capability)
- Advanced technical/service support and laboratory accreditation guidance
- Continuous upgrade possibilities to optimize performance and productivity

**Proven Applications**

Thanks to several years of application work, the ARL 4460 has undergone significant advances that enhance the ease and accuracy of analysis for all metal products. Comprehensive application notes are available separately for all major metals. Each note gives specific performance guarantees for detection limits, reproducibility, stability and analysis time.

Some examples of common products analyzed with the ARL 4460 are:

- Low alloy steel with lowest concentrations of carbon, nitrogen and oxygen for the automotive industry
- Stainless steel: Food and pharmacology handling equipment
- Super alloy: Jet turbine blades
- Cast iron: Auto engines
- Magnesium: Luggage and car wheels
- Aluminium: Airplanes
- Copper: Tubing and wire
- Lead: Batteries
- Zinc: Galvanizing
- Precious metals: Jewellery
C, N, O Analysis

The ARL 4460 is capable of determining carbon, nitrogen and oxygen in steels at very low levels using the CNO option. As an example, the typical DL for carbon is 0.4 ppm (2 ppm without CNO option) and the guaranteed DL 1 ppm (5 ppm without CNO option). The typical reproducibility of carbon at 10 ppm is of 0.5 ppm and such an analysis is performed in less than fifty seconds. A separate application note provides further details.

Cost-effective and Fast

Optical emission spark analysis is, by far, the most widely used, industry accepted technique to provide chemical analysis for both alloying and trace elements in metals. The reasons are many:

• Versatility: Analyze any metal in many shapes and forms
• Speed: Duplicate analysis in less than 50 seconds
• Range: From trace (sub-ppm) to alloy concentration levels
• Accuracy: With certified type standards - accuracy nominally better than 1% relative
• Savings: Low capital investment and operating costs

Unique Spark-DAT Option

The Spark-DAT option measures intensities during each elemental spark, allowing ultra fast on-line counting of inclusions and identification of their type. Inclusion analysis includes Al₂O₃, CaO, Al₂O₃-CaO, CaS and TiN in steels, TiB₂, MgO and NaCl in aluminum. Metal cleanliness can be controlled in a few seconds during production and in parallel with elemental analysis. A separate application note is available providing further details.

WinOE Software: Simplicity itself

WinOE software is, quite simply, the most powerful software available today for metals analysis by OES:

• Graphical user interface through HTML pages and Internet Explorer
• Shortcut icons to start an analysis with just one click or keystroke
• Large, user-friendly icons to reach the functions at a glance
• Routine tasks are achieved quickly and efficiently by use of “push button” automated functions to guide the operation, or via “blackbox” intelligent modules running in the background with minimum (or no) user intervention

These are just a few of the many features contributing to the fast routine operation of WinOE.

Two Techniques for Ultimate Performance

Our company has always set the standard for excellence of instrument design and analytical performance. The Thermo Scientific ARL 4460 continues that tradition with its two innovative techniques: the patented Current Controlled Source (CCS) and Time Resolved Spectroscopy (TRS), which extend the range of capabilities. Their combination significantly improves all facets of analytical performance (accuracy, sensitivity, reproducibility, analysis time).
### ARL 4460 Specifications

#### Spectrometer

**Spectrometer design:** One meter, Paschen-Runge vacuum polychromator made of special cast iron and temperature controlled to ± 0.1° at 38° C. Maximum 60 channels.

- **Primary slit width:** 20 µm
- **Secondary slit width:** 25, 37.5, 50, 75 µm
- **Photomultiplier tubes:** Ø 28 mm, 10-stage side-on-type, MgF2, UV glass, borosilicate glass or synthetic silica windows
- **Grating type:** Spectrometer provided with one of the following gratings, appropriately selected for the analytical task: 1080, 1667 or 2160 gr/mm
- **Resolution:** Dependent on grating, secondary slit and spectral order
- **Sample stand:** With self contained, recirculating coolant system. Argon flushed table. Argon pulsed regime before and after analysis for improved dust evacuation and instrument autonomy
- **CCS and TRS:** Current Controlled Source (CCS) and Time Resolved Spectroscopy (TRS) to extend the range of analysis capabilities

#### Electronics

**Spectrometer control:** ARL MMB 386 Microprocessor utilizing CMOS technology with Status Measuring Card. A/D converters and attenuators included for each channel.

- **Programmable attenuators:** Up to 24, available as an option
- **Dynamic range:** Proportional to measuring time, typically 2*10^6 counts/sec
- **Enclosure:** Built-in dust protection with high capacity cooling fans

#### Requirements

- **Ambient temperature:** 16-30°C (62-86°F); maximum rate of change 5° C/hour
- **Relative humidity:** 20-80 %
- **Voltage:** 230 V (+10 %/-15 %), single-phase with protective ground (5kVA regulator required if fluctuations exceed ±10 %)
- **Current:** 12 A, including PC, screen and printer
- **Frequency:** 50 or 60 Hz
- **Grounding:** < 1 Ω
- **Argon:** > 99.996 % maximum 5 ppm oxygen (maximum 2 ppm oxygen for samples with high Si content). Optional argon purifier available and recommended for low carbon analysis. For VUV lines (nitrogen, oxygen, chlorine), argon purifier included

#### Consumption

- **Electrical power:** 2.6 kVA
- **Argon:** 4 l/min during analysis, 0.7 l/min in stand-by
- **Compliance to norms:** 98/37/EEC Machinery, 73/23/EEC Low voltage material, 89/336/EEC Electromagnetic compatibility

#### Dimensions and weight

- **Overall dimensions:** 169 x 91 x 122 cm or 67 x 36 x 48 inches, including excitation stand
- **Weight:** 540 kg or 1190 lb approximately

#### Accessories and options

- **Spark-DAT, single Spark Data Acquisition and Treatment**
- **CNO for ultimate low measurement of carbon, nitrogen and oxygen in steels**
- **Small and pin samples analysis kit**
- **Argon purification systems**
- **Voltage stabilization systems**
- **Uninterruptible Power Supply (UPS)**
- **Suction device accessory to exhaust toxic fumes**
- **Stand upgrade for semi-automatic operation**
- **Data communication software options**
- **Analytical results processing software options**

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[www.thermo.com](http://www.thermo.com)
CNO Option -
Analysis of Low C, N and O in Steels
by Optical Emission

*ARL 4460 Metals Analyzer*

**Introduction**
Significant progress has been realized in the analysis of low concentration C, N and O in steels by optical emission spectrometry. The concentration of these elements, as well as those of P, S and H should be reduced to obtain so-called “clean steels”, or controlled, as they have individually or together - dramatic effects on steel properties, such as strength, formability, toughness, weldability, fatigue resistance, etc. For car body sheets for instance, C, N and O must be typically lower than 20 ppm each. The constant amelioration of steel cleanliness being necessary to produce always improved and more competitive steel products, there is a demand for quantitative analysis at lower and lower levels. The new performance obtained with the ARL 4460 fulfills the latest analytical requirements of steel producers regarding C, N and O.

**ARL 4460 Metals Analyzer**
The patented Thermo’s Current Control Source (CCS) of the ARL 4460 presents significant advantages in comparison to any other spark generator used in OES (Optical Emission Spectrometry). The computer controlled current waveform provides a high degree of flexibility in selection of parameters that enables optimization of the sensitivity.

Thermo’s Time Resolved Spectrometry (TRS) offers important features in comparison to other acquisition systems. Selecting the appropriate time window for integrating the light emitted by the individual sparks allows data acquisition with the best sensitivity, precision and reduction of spectral interference.

The ARL 4460 Metals Analyzer can quantitatively determine about 40 elements in irons and steels. With the CNO option, a typical analysis is performed in less than fifty seconds. Analytical performance of low C, N and O obtained with this option is detailed in this application note. Performance of these elements at higher levels and on the other elements can be found in application summary AN 41220 “Analysis of Iron and Steel by Optical Emission – ARL 4460 Metals Analyzer”. It is the case also for P and S that are now offered in the standard analysis as they were in the former “CNOPS option”. H still cannot be measured satisfactorily in steels by OES.

**CNO option**
The CNO option includes:
- A mechanically improved analysis stand minimizing the various contaminations that are critical for these three elements
- The most sensitive analytical lines
- Special photomultiplier tubes

**Sample preparation**
Paper grinding is possible in most of the cases, but for lowest C and O levels, milling is recommended. Simple and reasonable care must be taken during and after sample preparation, e.g.:
- The prepared surface must be flat in order to avoid air penetrating in the stand during the analysis
- Grinding paper change at well defined time intervals
- Exposure of sample surface to dust must be avoided
- Avoid touching the prepared surface

**Sample analysis time**
The analysis time, from the start of the analysis to the display of the result, is 22 s.
Factory calibration

The ARL 4460 equipped with the CNO option can be factory calibrated for micro-alloyed steels with the best reference samples available on the market. For C, N and O, the following calibration ranges are given:

- C from 4.5 to 900 ppm
- N from 9 to 200 ppm
- O from 75 to 1000 ppm

Improved performance obtained with the CNO option is also beneficial for the standard low alloy steel calibration, where downwards extensions of C, N and O calibrations are possible. Please contact your nearest Thermo office for more details on the calibrations with the CNO option.

Performance guarantee

The precision values shown in the graphs of the next sections are typical values. Values guaranteed by Thermo when using homogeneous samples and recommended sample preparation are 1.5 times higher.

The precision is calculated from the formula:

\[
SD(\sigma) = \pm \sqrt{\frac{\sum (X_i - \bar{X})^2}{n - 1}}
\]

where:
- \(X_i\) is the individual readings
- \(\bar{X}\) is the arithmetic mean of the individual values
- \(n\) is the number of determinations

The DL (Detection Limit) is defined as three times the standard deviation of the background of a pure iron sample expressed in concentration units. The guaranteed DL (Detection Limits) is calculated at the 95% confidence limit.

The values will be updated as improvements are announced. Please contact your nearest Thermo office or consult our web site at www.thermo.com/elemental for the most recent values.

Precision is only one part of providing accurate analyses. Other factors include the accuracy and the quality of the calibration standards. These are achieved through the development of the calibration curve relative to a specific analytical task.

Carbon analysis

The typical DL is 0.4 ppm (2 ppm without CNO option) and the guaranteed DL 1 ppm (5 ppm without CNO option). The figure below shows the improvement in precision obtained for C below 100 ppm with the CNO option:

The next example illustrates the accuracy of the factory calibration:

<table>
<thead>
<tr>
<th>REFERENCE MATERIAL</th>
<th>CERTIF. CONC. (PPM)</th>
<th>UNCERTAINTY u (PPM)</th>
<th>MEASURED CONC. (PPM)</th>
<th>ABS. VAL. RESIDUAL (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSS 1005</td>
<td>9.6</td>
<td>0.3</td>
<td>8.8</td>
<td>0.8</td>
</tr>
<tr>
<td>BS 50E</td>
<td>10</td>
<td>3</td>
<td>6.5</td>
<td>3.5</td>
</tr>
<tr>
<td>BS 50C</td>
<td>12</td>
<td>4</td>
<td>6.7</td>
<td>5.3</td>
</tr>
<tr>
<td>JSS 1007</td>
<td>23.6</td>
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<td>23.9</td>
<td>0.3</td>
</tr>
<tr>
<td>JSS 1001</td>
<td>37.4</td>
<td>0.2</td>
<td>37.4</td>
<td>0</td>
</tr>
<tr>
<td>BS LC5</td>
<td>108</td>
<td>6</td>
<td>104</td>
<td>4</td>
</tr>
<tr>
<td>BAS 431</td>
<td>190</td>
<td>9</td>
<td>192</td>
<td>2</td>
</tr>
<tr>
<td>BS 250</td>
<td>220</td>
<td>10</td>
<td>203</td>
<td>17</td>
</tr>
<tr>
<td>BS XAAS</td>
<td>410</td>
<td>11</td>
<td>426</td>
<td>16</td>
</tr>
<tr>
<td>BS 233</td>
<td>710</td>
<td>17</td>
<td>723</td>
<td>13</td>
</tr>
<tr>
<td>BS 3972</td>
<td>1950</td>
<td>19</td>
<td>1898</td>
<td>52</td>
</tr>
<tr>
<td>BS 4971</td>
<td>2510</td>
<td>21</td>
<td>2465</td>
<td>45</td>
</tr>
</tbody>
</table>
Nitrogen analysis
The typical DL is 1.5 ppm (2.7 ppm without CNO) and the guaranteed DL 3 ppm (4.5 ppm without CNO option). The next figure shows the improvement in precision obtained for N below 100 ppm with CNO option.

The example shown below illustrates the accuracy of the factory calibration:

The next table illustrates it numerically:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BS 234</td>
<td>13</td>
<td>2.1</td>
<td>13.2</td>
<td>0.2</td>
</tr>
<tr>
<td>BS 50C</td>
<td>19</td>
<td>4</td>
<td>13.2</td>
<td>5.8</td>
</tr>
<tr>
<td>BS 250</td>
<td>24</td>
<td>2.1</td>
<td>24.8</td>
<td>0.8</td>
</tr>
<tr>
<td>BS XAAS</td>
<td>37</td>
<td>2</td>
<td>38.5</td>
<td>1.5</td>
</tr>
<tr>
<td>BS 231</td>
<td>45</td>
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<td>41.9</td>
<td>3.1</td>
</tr>
<tr>
<td>BS 230</td>
<td>48</td>
<td>3</td>
<td>42.6</td>
<td>5.4</td>
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<tr>
<td>BS 232</td>
<td>56</td>
<td>3.7</td>
<td>50.9</td>
<td>5.1</td>
</tr>
<tr>
<td>BS 3972</td>
<td>65</td>
<td>2.2</td>
<td>63.8</td>
<td>1.2</td>
</tr>
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<td>BS 2932</td>
<td>80</td>
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<td>2.0</td>
</tr>
<tr>
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<td>89.0</td>
<td>3.0</td>
</tr>
<tr>
<td>BS 4971</td>
<td>99</td>
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<td>97.6</td>
<td>1.4</td>
</tr>
<tr>
<td>BS 233</td>
<td>107</td>
<td>4.3</td>
<td>107.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Oxygen analysis
Oxygen is the most difficult element to measure due to contamination. The typical DL is 8 ppm (20 ppm without CNO option) and the guaranteed value 25 ppm (30 ppm without CNO option). The figure below shows the improvement in precision obtained for O with CNO option:

The example shown below illustrates the accuracy of the factory calibration:

The next table illustrates it numerically:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BS 230</td>
<td>24</td>
<td>3.1</td>
<td>21.1</td>
<td>2.9</td>
</tr>
<tr>
<td>BS 231</td>
<td>38</td>
<td>7.8</td>
<td>34.0</td>
<td>4.0</td>
</tr>
<tr>
<td>BS 3972</td>
<td>38</td>
<td>3.6</td>
<td>30.6</td>
<td>7.4</td>
</tr>
<tr>
<td>BS 4971</td>
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<td>BS 250</td>
<td>570</td>
<td>14</td>
<td>551</td>
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</table>

Stability
Stability of the instrument is of the utmost importance when performing routine analysis. Mid-term stability measured over one day shows that the standard deviation achieved is below two times the guaranteed precision value, which is excellent. The following examples show the typical stability over 24 hours of carbon at 25 ppm and nitrogen at 21 ppm. The values almost never went outside the 95 % confidence interval (delimited by red lines) which is ± 2.1 ppm for C and ± 2.4 ppm for N.
Oxygen analysis with Spark-DAT

The CNO option can be combined with the Spark-DAT option (see application note 41232 “Spark-DAT option – On-Line Single Spark Acquisition and Treatment - ARL 4460 Metals Analyzer”). In steel oxygen is mainly present in the form of oxides (of Al, Mg, Ca, Si…). Therefore it is possible to quantify the oxygen content in a steel sample by evaluating the number of oxygen-containing inclusions it contains. For some bearing steels for example, an excellent correlation was found between the oxygen measured by combustion and by Spark-DAT (see graph below).

![Graph showing oxygen analysis results](image-url)

In this case, the preparation of the samples and the decontamination of the spectrometer are greatly simplified. Potentially lower levels of oxygen can also be measured than with the traditional method. Please contact your nearest Thermo office if you are interested in oxygen detection at lower levels than those described in this application note.

Benefits

Thanks to the CNO option and to the best possible use of digital excitation and acquisition technologies of the ARL 4460, the main requirements of the steel market regarding the analysis of the elements C, N and O at low concentrations are met:

• A high level of repeatability
• A very accurate analysis
• A short analysis time

The CNO option is the best opportunity to provide a more efficient control of steel production:

• The analysis is faster than with traditional combustion analyzers
• Time is saved, as all the elements, even ultra-low C and N, are analyzed on a single instrument
• Necessary investments and operating costs are reduced compared to combustion analysis
• Optical emission spectrometers are easier and cheaper to automate
Spark-DAT Option
On-Line Single Spark Analysis
ARL 4460 Metals Analyzer

Introduction

- Do you need to determine the soluble/insoluble parts of Al, B or other elements in steel?
- Do you need a fast method to evaluate the cleanliness of your products?
- Do you need a very fast evaluation of the number of inclusions?
- Do you need quick information on the size and composition of these inclusions?
- Do you want to solve contamination problems and improve your elemental analyses?

Would you like all this and much more to be feasible in a couple of minutes with your optical emission spectrometer? This is possible thanks to Spark-DAT (Spark Digital Acquisition and Treatment), an option of the Thermo Scientific ARL 4460 Metals Analyzer.

OES is a widely known and accepted, fast, simple and mature technique to determine the chemical content of metallic samples. Traditionally the light emitted by the samples excited through a few thousand sparks is integrated over the total excitation period and the signal transformed into concentrations.

Spark-DAT, sometimes referred to as PDA/OES (Pulse Discrimination Analysis/OES), is based on different acquisition and treatment principles. With Spark-DAT, instead of being integrated, the light intensities corresponding to the individual "single" sparks are acquired separately. Since each single spark hits a very small area of the sample, the individual light components contain information on the material composition of a multitude of such small areas. This enables differences of composition at the microscopic scale to be monitored, offering new potentials to OES, for instance the evaluation of non-metallic inclusions.

Benefits

The OES elemental analysis is sometimes complemented with analyses performed with other expensive and time consuming techniques that make the full analytical process complex. For example cleanness indices or inclusions are usually determined with optical or scanning electron microscopes. The sample preparation is long and the counting tedious, making this method unsuitable for process control.

The possibility to obtain the elemental analysis and information on inclusion contents with a single OES instrument drastically reduces investment and operating costs. This also simplifies and shortens the analytical process, making it suitable for production control.

After its launch as an off-line tool in 1999, it rapidly became clear that full benefit would be obtained with an on-line version of the Spark-DAT. In 2000, acquisition electronics and treatment algorithms were therefore integrated in the instrument and its software. Since then, the software WinOE handles Spark-DAT results like conventional OES results: stores them, prints them, checks them against product specifications, transmits them on-line to process control computers, etc. In this way a single analysis can simultaneously provide overall concentrations from the conventional analysis as well as information about inclusions or soluble/insoluble distribution from Spark-DAT.

Success with Spark-DAT analyses strongly relies on the excitation conditions. The CCS (Current Controlled Source) allows the optimal control of the more adapted spark discharge form. In addition, the TRS (Time Resolved Spectroscopy) technology allows the light components to be collected when the signal-to-noise ratio is optimal or interferences are minimal.

The combination and full integration of the three technologies (Spark-DAT, CCS and TRS) make the ARL 4460 the spectrometer with the broadest capabilities and potential.

Principles of Spark-DAT

As explained above, Spark-DAT intensities are representative of the composition of the sample at the positions hit by the corresponding spark. If the concentration of an element is locally higher, it is monitored as an intensity that is higher than the average. This is typically the case when a spark hits an Al-containing inclusion (e.g. Al2O3) in a low alloy steel sample: the Al concentration is higher in the particle than in the matrix, giving rise to a higher intensity or a "peak" in a graphical display of the Al channel record. This is illustrated by the following spectrum-like "sparks diagram" or "pulsogram" representing the Al intensity as a function of the spark number.
In this diagram, the ground signal is proportional to the concentration of Al dissolved in the matrix and a peak to the amount of Al in the material ablated at a position where one (or several) Al-containing inclusion(s) is (are) present. Consequently, the number of peaks is related to the number of such inclusions and their height to factors such as the inclusion size and the concentration of Al in the inclusion.

If these peaks are easily identified by the human eye, dedicated algorithms based on statistical principles are necessary to valorize the recorded information as rapidly as possible. Some very popular of these algorithms allow counting inclusions peaks or peaks appearing simultaneously on two, three or four element channels.

These simple numbers can provide solutions to replace the complementary methods mentioned in the previous paragraph, for example cleanness index measurement. In fact, their potential to replace analyses that determine characteristics or properties that depend on the presence of inclusions is enormous. If for example inclusions affecting the fatigue properties of some steel quality can be monitored by Spark-DAT, then it is possible to replace long and costly fatigue tests with fast and low cost Spark-DAT. Other examples are given in this application note.

**Integration of Spark-DAT**

The Spark-DAT includes hardware, software and algorithms. The digital acquisition and processing system of Spark-DAT physically runs in parallel with the conventional signal acquisition and integration stages.

Spark-DAT can acquire the typical 2000 individual intensity values corresponding to the traditional integration of up to 32 channels simultaneously. Therefore a matrix of 32 * 2000 digitized (64K) values is then available for on-line processing through fast algorithms, the process being so fast that the user doesn’t see it.

The values calculated are then supplied to the analytical software which can handle them like conventional channels: they can be included in any analytical program, associated with any analytical condition and integrated in calibration curve computations. Standard samples can be attributed for the calibration of Spark-DAT channels, and setting-up samples for their drift correction. In this way a single steel analysis can simultaneously give overall concentrations from the conventional analysis as well as information about inclusions or soluble/insoluble distribution from Spark-DAT in less than 30 s.

**Soluble/insoluble analysis**

While most of Spark-DAT investigations and discussions concern the subject of inclusions, a very popular and common application is the determination of the concentration of the soluble or insoluble part of aluminum or boron. This analysis is already possible with an OES methods called PIM2, but while PIM2 is accurate enough in number of cases, its sensitivity can be insufficient and alternative techniques like atomic absorption spectrometry are used when more accurate results are necessary.

As explained above, Spark-DAT can discriminate signals due to presence of Al in inclusions from those of the Al dissolved in the matrix. It therefore allows evaluating the proportion of the soluble and insoluble parts of Al. Another way to display the result of a Spark-DAT acquisition is shown in the following “intensity distribution” diagram of Al measured in a low alloy steel sample. The asymmetrical shape of the distribution is due to the presence of insoluble Al. The intensities from the soluble part follow a normal distribution and they are delimited by the Gauss curve. The intensities outside of the Gauss curve, on the right hand side of the distribution, are due to inclusions intensity peaks and correspond to the insoluble part.

In the next figures, PIM2 and Spark-DAT methods are compared to AAS. The Standard Error of Estimates (SEE) is drastically reduced from 58 to 20 ppm by using Spark-DAT, showing the capacity of an optical emission spectrometer equipped with Spark-DAT to determine soluble Al very accurately, even at lowest concentrations.

The Spark-DAT method can potentially be used in many other cases, like for instance the determination of the concentration of soluble Ti in steel or Pb in brass. Ask your Thermo Fisher Scientific representative for detailed information.

**Inclusion analysis**

The simplest application of Spark-DAT consists in counting peaks to evaluate the number of inclusions containing given elements in a sample. This provides very quick assessments on sample cleanness for instance, as shown in next paragraph.
It is also possible to clearly identify inclusions by correlating the peaks observed on different channels. For example, peaks appearing simultaneously on the Al and O channels can be attributed to Al$_2$O$_3$ inclusions. Correlations can also be made with more than two elements, for example between Al, Ca and O, in order to identify calcium aluminate inclusions.

The next figure shows the simultaneous recording of the two channels Al and Ca on a low alloy steel sample.

In this case, peaks present on Al only correspond to Al$_2$O$_3$ inclusions, Ca peaks to CaO inclusions, while peaks appearing simultaneously on both channels can be attributed to Al$_2$O$_3$-CaO inclusions.

In steel, many other inclusion types can be determined by counting correlations between groups of channels (Spark-DAT algorithms for up to four elements), for example: oxides (TiO$_2$, MgO,...), sulfides (CaS, MnS,...), nitrides (TiN, AlN,...), carbides (TiC,...), silicates, spinels, etc.

The method is not dedicated to steel applications. Inclusions are present in the production of all metals and alloys, and the many principles applied on steel are valid as well. In aluminum, for instance, oxides (MgO, Al$_2$O$_3$,...), salts (MgCl$_2$, NaCl,...), parts of refractory, nitrides (AlN, BN,...), and other various compounds can be observed with Spark-DAT. In the next figure, the presence of TiB$_2$ inclusions in an Al alloy is illustrated by the correlations between peaks of Ti and B channels.

**Steel cleanness**

Cleanliness indices are usually determined by counting the size and the nature of inclusions. Various methods are available for this purpose.

Spark-DAT can also determine the cleanliness index of a metal by simply counting the number of peaks in the intensity records of the channels of interest (Al, Ca, Mg...). The amount of peaks is in many cases well correlated with number of inclusions and therefore with the cleanliness obtained by usual methods.

The sparks diagrams of Al (blue) and Ca (red) channels shown below were measured on samples taken at different stages of the Al killing in the manufacturing process of a steel quality. The Al diagrams are particularly interesting since they illustrate how cleanness can be assessed with Spark-DAT.

In the four samples, Al peaks were counted with an algorithm discriminating signals at the level of 4,000. In sample A, taken before any treatment was applied, 4 relevant Al peaks were counted. In sample B, taken just after the 1st treatment, 30 Al peaks were measured. Aluminum was added in order to remove the oxygen dissolved in the steel by forming Al$_2$O$_3$ particles and as expected, more inclusions were detected in B than in A. These inclusions were then eliminated, by migration into the slag. Sample C was taken just after a 2nd treatment was applied. In this sample, 2 Al peaks were monitored, less and smaller than after 1st treatment, due to less soluble oxygen present after the 1st treatment. In the final product D, no relevant peak was counted, because most of the newly formed Al inclusions migrated to the slag. The final product not only has the smallest oxygen content, it is also the cleanest steel, with the least and smallest Al inclusions.

**Oxygen by Spark-DAT**

The measurement of oxygen at low concentration in steel is difficult, due to various contaminations. Since most of the oxygen is under the form of oxides, its concentration is related to the amount of oxide inclusions (aluminum oxide, calcium oxide, magnesium oxide...) present in the sample. The figure below shows the excellent correlation obtained between the oxygen concentration measured by combustion and the number of inclusions detected by Spark-DAT, in a set of bearing steel samples.

The standard deviation of the eight measurements gives a valuable indication of the homogeneity of the inclusion population in the sample. Several analyses must be performed in order to measure a statistically representative area of the sample.
**Improvements in elemental analysis**

Spark-DAT simplifies detecting and identifying contamination. A first example is for the determination of carbon, nitrogen and oxygen in steel being biased by:

- Surface contamination during sample preparation
- Adsorption of O and C during sample transport from preparation to analyzer
- Exogenous contamination during analysis through remaining traces of the elements to be analyzed (leakages, previous analyses...)
- Endogenous impurities related to the presence of segregations, gas bubbles or inclusions

As another example, the figure below shows the calcium channel measured in an aluminum alloy sample. When freshly milled, the Spark-DAT spectrum shows only a few peaks. If the sample is left in air for one day, it is clearly shown that both the number of peaks and the mean intensity level are increased.

![Ca in aluminum matrix, just after milling](image)

Ca in aluminum matrix, just after milling

![Ca in aluminum matrix, after 1 day](image)

Ca in aluminum matrix, after 1 day

**Conclusions**

The Spark-DAT option increases the versatility of your ARL 4460 spectrometer. It provides fast information that is complementary to the commonly measured concentrations, for example:

- The concentration of the soluble part of an element, for instance Al and B in a low alloy steel
- Numbers of inclusions and determination of the cleanliness of the analyzed metal
- Identification of inclusions or determination of their composition by counting peaks correlated on several channels
- Information about sample homogeneity and inclusions distribution
- Improvement of the performance of the elemental analysis by identifying contaminations

Furthermore, it gives many opportunities to replace long lasting or complex analyses or tests by a quick and simple method.

**Off-line investigations with Spark-DAT**

Spark-DAT intensities can be stored in standard text or comma separated value files. These files can then be used off-line for investigations on inclusions or for research and development of new methods or algorithms for instance. They can be used as input for third party programs or for ARL Sparks, a very useful tool that displays the sparks diagrams and the intensity distributions, and helps for searching correlations.

**New algorithms**

- Your off-line investigations or developments lead to a new algorithm and you would like it to be available for on-line work on your instrument
- Do you need the new algorithms developed by our company?

The open structure of Spark-DAT allows installation of additional algorithms at any time without needing to update the software.

If you have developed a new algorithm, we can implement it for you and install it on your instrument (if necessary for your exclusive use). We also keep developing new algorithms which are compatible with your Spark-DAT software.

Ask your local Thermo Fisher Scientific representative for detailed information.

**Upgrade of your ARL 4460**

As of fall 2000, all ARL 4460 spectrometers are equipped with electronics compatible with Spark-DAT, allowing a direct upgrade of the hardware. Earlier ARL 4460 instruments additionally require the upgrade of the acquisition electronics. Moreover, should extra lines be required, the upgrade of the instrument optics has to be considered. Ask your local Thermo Fisher Scientific representative for detailed information.

**Hardware and technical specifications**

- Spark-DAT with a capacity of 32 acquisition channels
- Instrument acquisition electronics for each channel
- PCI Analog-Digital Converter (ADC) board installed in the WinOE computer for the channels acquisition
- Set of cables and connection box
- Runs with WinOE version 3.0-1 or higher
- File output for off-line data evaluation compatible to TXT and CSV formats (Comma Separated Values) that can be read by numerous data processing software

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Thermo Scientific
ARL SMS-2000
Automated Metals Analyzer

The Intelligent Solution

Better quality analyses available faster
Ultimate analytical performance
Short and constant response times
Increased efficiency, reduced manual labor
An opportunity to seize

Our company identified very early the importance of automating sample analyses to improve quality control operations in the metals industry. In the mid 80’s, we were first in introducing a fully automatic version of our optical emission spectrometers. Since then, the automated Thermo Scientific ARL 3460 and ARL 4460 metals analyzers with SMS (Sample Manipulation System) have established a high standard of excellence in the most demanding applications such as the iron and steel industry. They are recognized today as the reference in terms of reliability, life time and performance.

The latest Thermo Scientific ARL SMS-2000 version sets new performance standards in speed, precision and capacity to meet the most sophisticated applications.

Major productivity gains

With the ARL SMS-2000, the samples are prepared and analyzed at a very rapid, fully sustainable and perfectly predictable rate without operator intervention. Operating and analysis costs are cut significantly:

- The results are available faster to improve production turnover
- More samples can be processed, so frequently eliminating production bottlenecks
- Qualified laboratory personnel can be released from routine duties
- Automatic instrument monitoring functions ensure that instrument performance is permanently under control
- A better usage of standards reduces operating costs even further. Their analysis surface is fully sparked before their automatic re-preparation

Better analysis dependability and quality

Automation with ARL SMS-2000 reduces chemical analysis variation, eliminates many of the causes of measurement errors and fully exploits the analytical performance of modern Thermo Scientific process control spectrometers.

All samples are processed under rigorously identical and reproducible conditions following procedures defined and set up in advance.

Human variables, mistakes, subjective factors influencing analysis results and down times are eliminated. Results are more accurate and more reproducible; difficult samples can be analyzed without performance compromise; less time is lost with sample repeats.

Spectrometer monitoring and control form an integral part of the automatic system. The most complex analysis procedures are applied systematically without the need for any operator intervention.

A very fast payback

- More dependable and less expensive analyses makes for a rapid return on investment (typically less than one year), not only for the automatic system but also for the spectrometer itself
- Smoother production flows with more efficient quality control tools cut manufacturing costs
- The critical phases of production are monitored more effectively, so enabling commitments to be given for compliance with still more stringent product specifications

Proven and recognized technology

Launched in the early 2000’s, the ARL SMS-2000 is the trustworthy successor to the previous generations of SMS systems and a serious challenge to beat for manually operated instruments. Continuously enhanced as a result of customer’s feedback and experience, the ARL SMS-2000 satisfies the full range of metals production control requirements, from large aluminum smelters to the most modern steel works, including foundries with varied capacities and needs.

They are used successfully over years by many well-known companies who rely entirely on our ability to supply reliable automation solutions and to support them efficiently for many years following installation.

Powerful, multi-purpose and entirely customizable

The remarkable quality and speed of the ARL SMS-2000 industrial robot combined with the unique ARL SMS automation software provide an almost unlimited operational flexibility to cover all possible applications. This avoids having to redesign the system each time and guarantees optimum support and evolution.

Personalized configuration

This single product strategy does not limit the choice of the configuration best suited for your specific application and needs.

Options are available to simplify sample registration and introduction as well as for further sample processing such as radioactivity measurement and sample labeling.
Production samples can be registered manually via terminals. Options are available to facilitate and speed up registration such as reading data via network files, bar code readers, selecting from sample lists. On-line registration via network by means of other computers (process computers, laboratory management systems) is also possible to avoid errors and save time.

We offer fully automatic machines for the preparation of metallic samples to provide the surface quality required for reliable analysis by optical emission (iron and steel, cast iron, aluminum, copper, magnesium, zinc, etc). Many options are available such as magazines for sample introduction. High quality, reproducible and reliable sample preparation is an essential component of the automated metals analyzer which influences directly the analytical performance and the system uptime.

The samples can also be prepared outside the system and introduced manually in the ARL SMS-2000 system for automatic analysis.

The analysis results are immediately and automatically transmitted to addressees according to their specific needs.

**Laboratory applications**

The system is fully compatible with centralized laboratories equipped with one or more preparation and analysis lines and linked to sampling locations via air tube systems for sample transport.

Simple and normalized interfaces ease communication with other laboratory and process computers while providing all the necessary functionality.

**In-situ analysis**

When the analysis must be closer to the process, the ARL QuantoShelter is the ideal solution. Also called the lab in a box, it is a container specially designed for housing the automated Thermo Scientific metals analyzer with sample preparation; it is used when no protected premises are available in production to install the system. The system operates very much like a process sensor or an on-stream analyzer. The sample transport times are then reduced to a minimum as the laboratory is brought to the samples rather than the other way around.
A simple, efficient and very fast system designed for easy maintenance

The automated metals analyzer with ARL SMS-2000 is designed to minimize response time and to optimize sample throughput. Each component of the system (spectrometer – SMS system – preparation machine) has its own intelligence and works simultaneously and independently of the other. This distributed processing concept, with each component working at its optimum rate, maximizes the system efficiency; tasks are performed in parallel rather than purely sequentially.

For instance, samples are prepared while other samples are analyzed; the instrument stand cleaning is performed in hidden time by the spectrometer, independently of the SMS robot.

Each system component can also be used manually as a stand-alone device when necessary for maintenance or for back-up purposes.

The SMS system has its own “brain” in the form of an autonomous automation software running in parallel with the analytical software. This distribution of tasks increases the modularity of the software and simplifies testing, diagnostics and maintenance; very few spectrometer extensions are required for automation.

The SMS robot stands on a chassis linked to the ARL metals analyzer. The robot control unit, with its digital signals interface, performs all hardware monitoring functions, which simplifies considerably the automation. It is located under the chassis with the SMS power supplies, electronics and the sample sorting and filing recipients.

High precision brushless AC-servo motors provide for an almost maintenance free robot operation. Integrated absolute encoder technology is used to achieve a position repeatability of ± 0.02 mm. The origin is established once for ever when the unit is powered for the first time and there is no need for complex, time-consuming reference traverses. The arm length is 0.5 m and the maximum speed of 2.1 m per second provide for a sample handling speed no manually operated instrument can cope with.

Waiting positions are also used to further optimize throughput when several production samples have to be processed: prepared samples can be stored temporarily to free the preparation machine for the processing of subsequent samples.

More reliable, accurate and reproducible analyses

The global system reliability being no better than that of the weakest link of the line, each component of the automatic system has been selected based on very strict quality criteria, including the sample preparation machine. The SMS software is subject to the most comprehensive tests ever done by our company.

At the heart of the system is the ARL 3460 or ARL 4460 metals analyzer with its analytical software. The prepared samples are transferred directly by the SMS robot to the spectrometer stand. Their presence is automatically detected. The sample is then automatically clamped onto the stand table during the measurements.

The ARL SMS-2000 robot automatically and very precisely shifts the sample between sparks as necessary to obtain a result representative of the sample.

Bad sparks are automatically rejected. To reduce the processing times for difficult samples, bad burns can be detected early during the pre-integration with the ARL 4460 metals analyzer.

The production samples are automatically sorted and filed. Eight containers are available for this purpose. Production samples can also be returned to the preparation system in large automated applications (for instance for centralized sorting and filing).

The cleaning of the stand table and of the electrode is performed in hidden time before or after analysis, thus ensuring a perfect cleaning and the best analysis cadence. The electrode can also be cleaned between sample sparks.

A command panel is available to operate the automatic stand when the spectrometer is used manually.

Automation tailored to your needs
Automated unattended instrument monitoring and verification procedures

Ensuring that the automated metals analyzer permanently delivers quality results is essential to prevent scrap and rework in production.

Control samples are regularly analyzed and processed by statistical evaluation techniques (SPC) to detect eventual anomalies.

Automatic instrument standardization is triggered by the system when necessary and alarms are produced when manual interventions are required to prevent the system going out-of-control.

For certification purposes, the instrument analytical performance can be permanently recorded and visualized in the form of control charts (SPC-Full option) without operator intervention. The SPC-Full software is not merely limited to instrument monitoring; it can be applied automatically to production control as well for quick review of the performance and identification of possible process improvements.

Type standards can also be used to correct response differences between instrument calibration and the composition of particular alloys.

Conditioning samples can be measured to remove eventual stand contamination when trace elements must be measured following alloys samples or for conditioning of sample preparation grinding belts.

The ARL SMS-2000 magazine for standards is fixed and universal. It can store as many as 45 cylindrical and/or conical setting-up, control samples and type standards of variable diameter. Higher storage capacities are available as options.

When a preparation machine is available, the setting-up, control samples and type standards can be re-prepared automatically in idle time, immediately before analysis or at the request of an operator. A specific preparation program is used to reduce standards consumption and system operating costs.

A rotation device turns the samples by about 45° to avoid any bias in the re-preparation over time and prevent any sample inclination problems.

Full traceability of quality control activities

In addition to the analytical performance, events of interest can be recorded and communicated to other computers. These functions are fully automatic and do not affect system performance.

Greater availability for processing production samples

Authorized users can perform various tasks without interfering with the automatic processing of the production samples:

• Synoptic sample monitoring to display their position and the status of each system component
• Registration of manual samples introduced directly in the ARL SMS-2000
• Examination of the recorded system activities
• Request to run a control sample or to standardize the instrument
• Pre-prepared samples can be introduced manually into the SMS system
• SPC control charts can be displayed and printed
• Analyses or the latest standardization can be examined
• User accounts allocate the system resources and protect the system against unauthorized changes

Sample surface management

The analysis surface of every standard is managed to perform a maximum number of sparks before having to re-prepare (saving on expensive reference samples and making more time available for the processing of production samples).
Automation to advance quality control capabilities

Selective standardization
Only the instrument channels ‘out of control’ are then corrected. The number of samples to analyze is reduced.

Simplified and efficient maintenance
Many on-line diagnosis tools enable system and component tests to be performed to reduce breakdown times. Remote diagnoses are available as a standard facility. The system can be checked via telephone line under the supervision of our specialists and the software can be quickly updated.

Simple restart procedures guide the operator to start the system up again.

To ensure optimum sample manipulation reliability, every type of production, setting-up and control sample is gripped and handled by the robot as a specific sample.

The spark positions are specific to every sample; they can be easily and quickly changed by the user to provide for the best analysis conditions.

Options
A wide range of options is available to satisfy your individual needs:
- Support of up to 5 different production sample shapes
- Labeling of production samples on the analysis surface or on their back
- A vision system to select the best spark positions for difficult samples and reject them without analysis trial when they cannot be measured
- Sample collections and batches software to facilitate the registration and processing of repetitive series of production samples (for instance, samples from aluminum electrolytic baths)
- Security system compliant with ISO safety norms
- Remote control of the automated Thermo Scientific metals analyzer
- Digital signals for communication with external customers devices
- Automatic re-preparation of samples which cannot be analyzed
- Sample radioactivity detection
- Larger standards magazine capacity
- Sample registration via terminal or network
- Registration from the list of production samples announced by other computers or using sample identification parameters recorded on a network disk
- Chronological filing of production samples on slide(s)

A flexible and extremely powerful automation tool
To satisfy the requirements of the most varied applications with a standard solution, very comprehensive functionality and total operational flexibility are incorporated into the automated metals analyzer software. This permits us:
- To propose, with the ARL SMS-2000, the first generic spectrometer automation solution and concentrate on testing a single software version for all customers
- To release the most thoroughly verified software components ever produced for spectrometer automation applications requiring high reliability and uptime
- To ensure the full durability of the customer investment and simplify after-sales support of a product strictly identical for all applications
- To permit short installation and commissioning times

We configure and customize every SMS system according to your particular needs before delivery.

Additionally, all the functions and operating flexibility of the system remain accessible after its installation. The ARL SMS-2000 can be further fine-tuned to take advantage of your experience in using it and to handle changing or new requirements which are difficult to anticipate. This greatly reduces dependency on the supplier once the system is commissioned.
A strong, multi-purpose platform
The ARL SMS-2000 system benefits directly from synergy effects with other XRF and fire assay applications. It is designed, industrialized, documented, manufactured and maintained according to ISO 9001-2000 procedures. The result is unmatched features and performance with the most advanced automation system available today.

Updates are regularly made available by our company, as and when new possibilities arise. This expandability protects the ARL SMS-2000 system from obsolescence and keeps it in pace with the fast evolution of the technology.

A unique automation product range
The ARL SMS-2000 system is not merely limited to optical emission applications. The same system is used for the automation of X-ray fluorescence spectrometers (XRF) and fire assay analyzers (FAA):
- ARL SMS-2000 XRF version for the ARL 9800 and ARL 9900 XRF spectrometers
- ARL SMS-2000 for the ARL Fire Assay Analyzers

The other Thermo Scientific automation products include:
- The ARL SMS-Omega and SMS-XY entry level systems for XRF spectrometer automation
- The ARL SMS-3000 for twin OES and XRF spectrometer automation

To keep you informed about our latest developments, please visit www.thermo.com/oes or www.thermo.com/xray.

New perspectives for users of Thermo Scientific automated spectrometers:
- One single partner and sole responsibility for metallurgical applications requiring different analysis techniques (optical emission and X-ray fluorescence)
- Standardization of production monitoring tools to reduce the complexity of automatic laboratories and supervisor training needs
- Automation expertise, support and services worldwide
### Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals analyzers supported</strong></td>
<td>Models ARL 3460 and ARL 4460</td>
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<tr>
<td><strong>Sample weight</strong></td>
<td>Max. 900 grams</td>
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<tr>
<td><strong>Production samples</strong></td>
<td>Shape: Lollypop single and dual thickness, spemis, disks, cylindrical or conical (max. 3° cone angle)</td>
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<tr>
<td><strong>Dimension</strong></td>
<td>Within ± 1 mm</td>
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<tr>
<td><strong>Height</strong></td>
<td>8 mm minimum (after preparation)</td>
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<td><strong>Setting-up, control, conditioning samples and type standards</strong></td>
<td>Shape: Disks, cylindrical or conical (max. 3° cone angle)</td>
</tr>
<tr>
<td><strong>Dimension</strong></td>
<td>30-50 mm in diameter</td>
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<tr>
<td><strong>Height</strong></td>
<td>8.64 mm</td>
</tr>
<tr>
<td><strong>Magazine for setting-up, control, conditioning samples and type standards</strong></td>
<td>Capacity of 45 samples: 5 columns of 5, 7 or 9 positions each with respectively up to 64, 45 or 30 mm thick standards</td>
</tr>
<tr>
<td><strong>Sample preparation system</strong></td>
<td>For ferrous samples: Milling, Dual belt grinding, Cup wheel and belt grinding</td>
</tr>
<tr>
<td><strong>Options:</strong></td>
<td>Sample introduction systems</td>
</tr>
<tr>
<td><strong>For non-ferrous samples:</strong></td>
<td>Dual milling or cutting and milling</td>
</tr>
<tr>
<td><strong>Options:</strong></td>
<td>Sample introduction systems</td>
</tr>
<tr>
<td><strong>Sample preparation time and transfer to the ARL SMS-2000</strong></td>
<td>Depends on the type of sample preparation [25-75 sec]</td>
</tr>
</tbody>
</table>

**Typical Production Sample Manipulation Times:**

- **Transfer to the metals analyzer stand:** 7 sec
- **Sample shifting for another spark:** 5 sec (6 sec for the ARL 3460)
- **Sample filing and robot move to the next sample:** 8 sec (10 sec for the ARL 3460)
- **Sample labeling (option):** 8 sec
- **Sample surface analysis by a vision system (option):** 2 sec
- **Stand and electrode cleaning:** In hidden time (except for the cleaning between sparks – programmable – about 5 sec). Operates in parallel and independently of the robot

**Response time and cadence**

- **Typical response time (ARL 4460) with two sparks of 24 seconds each (including the result calculation time):** 60 sec (62 sec with vision)
- **Maximum analysis cadence per hour (ARL 4460 without sample preparation):** 60 production samples without marking and vision
- **51 production samples with marking and vision**

**Various**

- **Floor space requirements including the ARL SMS-2000 (in mm):**
  - **Length:** 2800
  - **Width:** 840 (1170 with optional extension table)
  - **Max. height:** 1350-1600 (with vertical robot arm)

**ARL SMS-2000:**

- **Weight:** 200 kg
- **Supplies:** 0.2 m³ air per hour at 6-10 bar
- **Power:** 230 VAC ± 10 %, 50/60 Hz ± 2 %, earth < 1 Ohm, 1.5 – 2.5 KVA
- **Operating conditions:** Laboratory (except for the sample preparation machine)
The Thermo Scientific ARL SMS-3000 is a high-end, affordable alternative to single spectrometer automation solutions. The automation of multiple spectrometers and preparation machines offers new opportunities for users requiring more comprehensive and integrated automation solutions in the metals and mining industries.

**ARL SMS-3000**
Automation of twin OES and XRF Spectrometers

*An evolution of existing automation solutions*
Thermo Scientific robotized spectrometers have been continuously enhanced since the early 90’s as a result of customer’s feedback and experience. Today, the automated spectrometers with ARL SMS-2000 have established a very high standard of excellence in the most demanding environments such as the iron and steel industry.

The new ARL SMS-3000 builds on this success and shows:
- Our commitment to focus at customer applications and respond to their expectations
- Our capacity to use a variety of internal competences and products to deliver new products

*Single source – One partner, one competence, one responsibility*
Our company is unique in designing and manufacturing X-Ray Fluorescence spectrometers (XRF), Optical Emission Spectrometers (OES) and Fire Assay Analyzers (FAA) with their automation system including the robot.

Our competence is not merely limited to one analytical technique or automation but covers complete systems.
An affordable solution to double your analytical power

**Combined XRF and OES analysis**
In high alloy and stainless steel or copper, brass and bronze applications, a single analysis is produced with high concentration alloy elements from the ARL ARL 9800 or 9900 XRF spectrometer and trace and light elements from the ARL 4460 metals analyzer.

- **Very short response times**
  Just a few seconds are needed for the ARL SMS-3000 robot to move samples between the system components.

- **Increased reliability**
  Complex and time consuming electro-mechanical transfer systems are eliminated. In addition to significant productivity gains related to labor savings, the results are available much faster, which improves production turnover.

**Double OES configuration**
This is typical of iron and steel laboratories where two instruments are necessary to permanently provide analysis services and assure fast response times when several urgent samples have to be processed simultaneously.

- **High sample throughput and analysis dependability**
  In metals applications, this permits to cope with heavy sample workloads. The ARL SMS-3000 is an affordable alternative to the higher cost of two fully duplicate and separate automated lines, each with its own robot.

**Double sample preparation machine support**
This reduces response times, increases sample processing cadence and improves the availability of automatic sample preparation in highly critical production control environments.

**Latest Thermo Scientific robotics technology with proven SMS software**
The ARL SMS-3000 uses the latest version of Thermo Scientific SMS software with enhancements to work simultaneously with two spectrometers and two preparation machines. It is equipped with one of the best industrial robots available today.

This high end Thermo Scientific CRS F3 robot has an impressive potential and is ideally suited for twin spectrometers automation:

- Its large work volume with an arm length of 0.84 m and 6 or 7 degrees of freedom permits direct access of twin OES and XRF spectrometers.
- Samples of up to 1.2 kg are moved at speed up to 4 m/s. Given usual production sample weights, this means less solicitation and reduced wear, increased reliability and longer lifetime.
- Minimum maintenance is required as the Thermo CRS F3 uses high-precision, brushless AC-servo motors and internal cabling. Absolute encoder technology establishes the mechanical origin once for ever when the unit is first turned on.

**An automation product designed with its users in mind**

- **Simplicity of operation**
The same analytical software is used for the XRF and OES applications and automation is based on the proven and reputed ARL SMS software. One screen provides access to the full range of sample tracking and automation user functions. A single registration device and introduction location is necessary, the production samples being automatically dispatched to the relevant system components.
Partners in productivity

**Flexible instrument integration and comprehensive analysis modes**

When two equivalent spectrometers are used with two preparation machines, the samples can be prepared and analyzed simultaneously; to ensure optimum availability around the clock and 365 days per year, they can also be processed by any of the two preparation machines and spectrometers. Sequential processing applies to twin XRF and OES configurations. Any spectrometer can be used off-line for analytical method development and tests, or simply for the analysis of product samples with irregular shapes. The instrument accesses for operator and robot are automatically controlled by the SMS software; a simple software command allows switching equipments between automatic and manual modes.

**Increased work volume with a linear track robot version**

And the choice is not merely limited to a single stationary version where the robot stands on a chassis; a 2 meters linear track permits to increase the ARL SMS-3000 robot working range by adding a 7th degree of freedom. The two spectrometers can then be installed aside each other rather than at 90°. This simplifies also sample transfer to and from the sample preparation machines.

**Full compliance with security regulations**

The ARL SMS-3000 safety enclosure is designed according to the applicable CE conformity standards. The system is also compatible with robotics and electromagnetic norms. A separate control box is used to temporarily interrupt the robot operation and unlock the access doors for a manual intervention in the system. The automatic operation can then be quickly resumed without having to restart the system.

**Easy service and maintenance**

The system provides easy and direct access to the various components for maintenance purposes or manual work. Each instrument or preparation machine can be quickly disconnected without interruption of the automatic operation. In addition, the spectrometers can slide to a separate park position for service or for manual operation over longer time periods. This is done without having to disconnect the spectrometers supplies.
An affordable solution to double your analytical power

Even more features and capabilities than the other ARL SMS versions

With the new ARL SMS-3000 system, the family of ARL SMS automation products consists of:

- The ARL SMS-XY and ARL SMS-Omega manipulator based systems for XRF applications
- The ARL SMS-2000 EL entry level for OES applications
- The ARL SMS-2000 robotized system for single OES or XRF spectrometer automation and sample preparation
- The ARL SMS-3000 for the automation of twin OES and XRF spectrometers with double preparation machine support

The same set of core ARL SMS-2000 software sources is used to generate any of these versions.

This maximizes the synergy between applications, reduces development and testing efforts and facilitates maintenance work. This strategy assures full maintainability and upgradeability to protect the system from obsolescence and keep pace with the fast evolution of the technology. The result is the most advanced automation solution with unmatched features, performance and reliability.

The ARL SMS-3000 shares the same options than the other ARL SMS-2000 versions, namely:

- Choice of the sample preparation machine to obtain high quality, reproducible sample analysis surfaces
- Support of oxides associated with metal production (mineral ores, sinters, baths, slags and blast furnace slags)
- Up to 5 different production sample shapes
- Sample registration via terminal or network
- Registration from the list of production samples announced by other computers
- Registration using sample identification parameters recorded on a network disk
- Labeling of production samples on the analysis surface or on their back
- Vision system to evaluate prepared sample surface quality and reject bad samples without analysis trials. For OES, selection of the best spark positions in case of difficult samples
- Sample collections and batches; to facilitate the registration and processing of repetitive series of samples (for instance, samples from aluminum electrolytic baths)
- Remote control of the automated OES and XRF spectrometers
- Digital signals for communication of alarms to external visual or acoustic devices
- Automatic re-preparation of samples which cannot be analyzed
- Sample radioactivity detection
- Chronological filing of production samples on slide(s)
- Manual single sample introduction slide
- Manual sample introduction magazine for systems without automatic sample preparation

In addition, the ARL SMS-3000 provides as standard:

- Complete safety enclosure with computer controlled operator access doors and control box
- Comprehensive instrument monitoring procedures to ensure that the spectrometers permanently deliver quality results, avoiding scrap and rework in production
- Early detection of sample presence
- Waiting positions for the temporary storage of samples to further optimize throughput
- A large magazine for up to 90 setting-up, control samples and type standards which can be shared between the two spectrometers or dedicated to a specific instrument. Sections of the magazine can also be used for manual sample introduction
- Support of conditioning samples for cleaning purposes
- Rotation of standards before re-preparation using any of the two preparation machines, to avoid any bias in the prepared surface over time
- UPS for the ARL SMS-3000 automation system including the robot; with computer controlled shut-down procedure when the power holding time is elapsed

Sample labeling system
A unique productivity enhancement tool for metals and mining applications

The ARL SMS-3000 is an opportunity to apply productivity enhancement tools at the leading edge of technology to advance production Quality Control solutions.

With nearly 400 robotized Thermo Scientific spectrometers installed around the world, our company has an undisputed reputation of performance and durability.

- **An affordable automation solution**
  Expensive peripherals like vision or sample labeling can be shared between two instruments. A single set of up to 90 standards is necessary for the monitoring of the two instruments. A single robot and SMS automation workstation are necessary. Expensive electro-mechanical sample transfer devices are not needed anymore.

The right automation solution for your specific application

The family of Thermo Scientific SMS automation solutions sets new standards for manually operated instruments to match, and makes automation even more indispensable to advance your quality control capabilities. You can now choose the automation solution best suited to your needs. Thermo automation specialists are available to evaluate your application and to advise on solutions.

This is another example of our continuous commitment to help customers improve productivity.
## Product Specifications

### SPECTROMETERS

<table>
<thead>
<tr>
<th>Type</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Emission Spectrometer (OES)</td>
<td>ARL 4460</td>
</tr>
<tr>
<td>X-Ray Fluorescence (XRF) spectrometer</td>
<td>ARL 9800 and ARL 9900 series</td>
</tr>
</tbody>
</table>

### SAMPLES

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Weight</th>
<th>Shape</th>
<th>Dimension</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production samples -</td>
<td>Max. 1'200</td>
<td>Lollypop single and dual</td>
<td>Within ± 1 mm</td>
<td>8-55 mm for OES, 8-30 mm for XRF (after preparation)</td>
</tr>
<tr>
<td>Metals</td>
<td>grams</td>
<td>thickness, oval (spemis),</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>disks, cylindrical or</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>slightly conical. Parallel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>surfaces required for XRF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production samples -</td>
<td></td>
<td>Pellets in steel rings (51.5 x 8 mm or 40 x 14 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powder</td>
<td></td>
<td>Fused beads on metallic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting-up samples,</td>
<td></td>
<td>Metals: disks, cylindrical</td>
<td>32-52 mm in</td>
<td>8-60 mm for OES, 8-30 mm for XRF</td>
</tr>
<tr>
<td>control samples,</td>
<td></td>
<td>or conical (max. 3° cone</td>
<td>diameter, smaller</td>
<td></td>
</tr>
<tr>
<td>type standards (SCT)</td>
<td></td>
<td>angle)</td>
<td>samples (&gt;25 mm)</td>
<td></td>
</tr>
<tr>
<td>Conditioning samples</td>
<td></td>
<td>Powder: Pellets in steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>rings, fused beads on</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>metallic supports</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### SAMPLE PREPARATION

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Grinding</th>
<th>Milling</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>For ferrous samples</td>
<td>Cup wheel -</td>
<td>Cup wheel and belt - double</td>
<td>Sample introduction systems</td>
</tr>
<tr>
<td></td>
<td>Cup wheel</td>
<td>belts grinding.</td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For non-ferrous</td>
<td>Dual milling</td>
<td>Cutting and milling</td>
<td>Sample introduction systems</td>
</tr>
<tr>
<td>samples</td>
<td>Options</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For powder samples</td>
<td>Grinding mill</td>
<td>Pelletizing press, Fusion</td>
<td>Crusher, sample introduction systems</td>
</tr>
<tr>
<td>Options</td>
<td>Options</td>
<td>machine</td>
<td></td>
</tr>
<tr>
<td>Preparation time</td>
<td>Depends on</td>
<td>the type of sample preparation</td>
<td></td>
</tr>
<tr>
<td>including transfer</td>
<td>the type of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to the ARL SMS</td>
<td>sample</td>
<td>preparation</td>
<td></td>
</tr>
</tbody>
</table>

### Contact Information

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