

ARL 9900 series



**X-ray fluorescence spectrometers with
integrated XRD capability**



Cement



Aluminum



Copper



Iron & Steel



Mining

ARL 9900 series X-ray spectrometers

A complete laboratory in one instrument

The ARL 9900 series of X-ray spectrometers are the most capable and most versatile yet offered for process control by Thermo, pioneers and leaders in X-ray analysis.

The key to their versatility is the patented technology which allows two X-ray techniques – X-ray fluorescence (XRF) and X-ray diffraction (XRD) – to be combined in one instrument. This makes the ARL 9900 highly productive as it can take the place of two separate instruments. It permits the rapid and very precise analysis of solid samples of various kinds. And it enables the ARL 9900 to detect the presence of up to 83 elements (from B to U, 5 to 92 in the periodic table) in concentrations ranging from parts per million to 100%. Advanced integrated software reports the results as soon as the analysis is performed.

Modular construction and a range of options allow the ARL 9900 to be specified to suit a particular application. Installation requirements are straightforward and can be easily accommodated in most industrial environments.

A high degree of automation and digital control make the ARL 9900 easy to use. Specified with the appropriate automatic sample introduction equipment, it can even be programmed to conduct continuous process monitoring unattended.

It comes with the world-wide aftersales support of the Thermo Electron Corporation.

The ARL 9900 series in summary

Every analytical requirement met

- Choice of generator power according to your application demands: 1200 W (ARL 9900 OASIS), 3.6 kW (ARL 9900 XP) or 4.2 kW (ARL 9900 XP+)
- Versatility, convenience and productivity brought by the combination of two X-ray technologies in one instrument.
- Modular construction allowing the instrument to be specified to suit the particular requirements of the application.
- Full sequential and diffraction capabilities integrated in one multichannel instrument cover any analytical needs.
- Fast, simple and highly reliable sample introduction system.
- Easily upgraded to handle evolving analytical requirements.
- Successor instruments to the proven and highly successful Thermo ARL 9800 range.

ARL 9900 applications

A wide range

The ARL 9900 range is designed to meet the requirements of industries where process monitoring is critical to quality control.

Among them, those producing or processing

- metals: iron, steel, aluminum, copper and their alloys, slags, sinters
- mining: ores, minerals, limestone, beach sands
- cement
- by-products
- refractories and others

ARL 9900 versatility

High performance in every application

Although the ARL 9900 is capable of detecting a large number of elements, many applications require it to concentrate on just a few. The modular design of the instrument allows it to be closely tailored to the intended use.



ARL 9900 technical features

XRF and XRD capability in one instrument

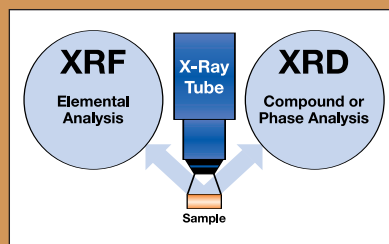
Productive, precise, patented

X-ray fluorescence (XRF)

analysis determines the elemental composition of a sample but mineralogical information is only available through

X-ray diffraction (XRD)

In a typical crystalline sample, XRF might measure the total Ca concentration, for example. XRD permits analysis of the phases or compounds in crystalline materials such as rocks, minerals and oxide products. So in the same sample, XRD could take the analysis a stage further and give information about the CaO, CaCO₃ and Ca(OH)₂ content.



Integration of XRF and XRD in the same instrument: one sample, one instrument, one analysis for two techniques

Undertaking both types of analysis has traditionally called for two separate X-ray instruments, maintained and operated at significant cost to the user.

But the integration of an innovative X-ray diffraction system allows both techniques to be included in the same ARL 9900 instrument. The patented system is capable of making qualitative scans and quantitative analysis thanks to the high precision of its Moiré fringe positioning mechanism. Accurate sample positioning and parallel beam X-ray geometry prevent

the sample alignment problems often encountered in diffractometry.

Separate data sheets are available describing how the advantages of a combined instrument can be applied to process monitoring in industries such as cement (Total Cement Analyzer), iron and steel (Total Iron X-ray Analyzer), aluminum (Total Aluminum X-ray Analyzer) as well as other mining processes involving iron ores, limestone, slags, sinters and beach sands among others.

X-ray system

Designed for effectiveness and reliability

- Optical system optimized to give very precise measurement, high sensitivity and stable analysis.
- The X-ray tube is mounted vertically at 90° above the sample preventing damage to the instrument with defective samples such as fragile pellets. *Maximum reliability and durability in service is assured by careful and robust design.*
- Close proximity of the X-ray tube to the sample brings increased sensitivity and lower limits of detection for all elements.
- A Rh anode gives effective excitation of the whole spectrum without interfering with the most common elements.
- Thin window (75 microns) standard, extra-thin window (50 microns) optional if increased sensitivity to elements of lower atomic weight (less than potassium) is required. *In both cases, the thin beryllium window allows higher transmission of efficient radiation.*
- The analysis takes place within a vacuum chamber closed by a single lid. *The number of vacuum seals is therefore minimized and hence the risk of leakage. Constant temperature control as well as regulated vacuum pressure assure excellent short and long term stability.*

Fixed monochromators

High speed simultaneous analysis

Fixed channels offer fast analysis, high sensitivity and rapid processing because each one is dedicated to detecting and analysing just a single element. The ARL 9900 series can be equipped with up to 32 monochromators for simultaneous analysis.

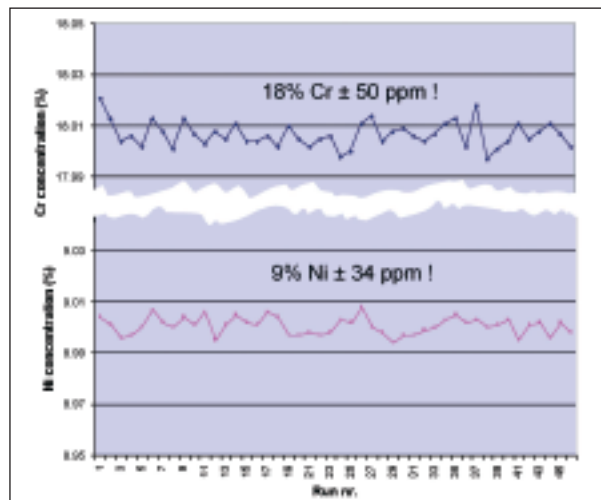
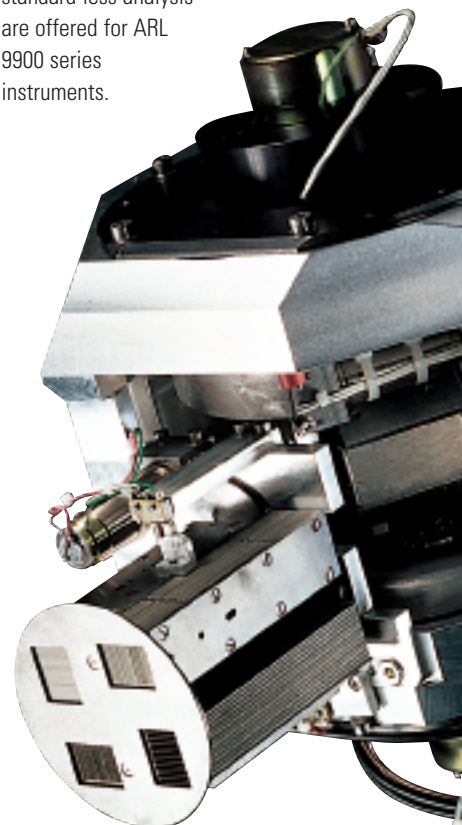
Compact slit-crystal geometry optimizes the sensitivity and spectral background levels to permit detection of elements at very low concentrations. The latest detectors ensure a wider linearity of response and very precise analysis. In a simultaneous configuration, there is no need for detector gas for all elements from Na.

Each monochromator has its own temperature control system (to $\pm 0.1^\circ\text{C}$) ensuring excellent stability of analysis. For the analysis of light elements, multilayer synthetic crystals are used. Adjustment of pulse height discrimination, high voltage and deadtime correction can be programmed through the software.

Goniometers

Very precise sequential analysis

Goniometers can be programmed to analyze specific elements (quantitative analysis) or to scan the X-ray spectrum to detect elements present in a given sample (qualitative analysis). Two very fast and highly accurate gearless goniometers allowing standard-less analysis are offered for ARL 9900 series instruments.



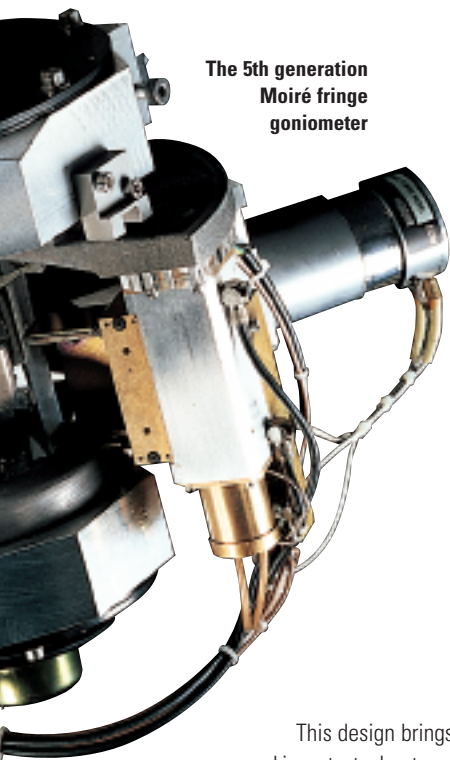
**Excellent
repeatability for
Cr and Ni over
24 hours**

The availability of the **SmartGonio™** distinguishes the ARL 9900 from its predecessors. The SmartGonio allows analysis of elements from F to U. It is a compact goniometer using three crystals and two detectors to provide a versatile and affordable detection system. Up to three SmartGonio can be fitted in the instrument.



The Thermo **F45 universal goniometer** is an alternative when additional crystals are required for specific applications. Up to two universal goniometers can be fitted.

Both goniometers provide high quality sequential X-ray spectrometry as a result of the detector and crystal being positioned rapidly with great precision by micro-processors using Moiré fringe technology.



The 5th generation Moiré fringe goniometer

This design brings several important advantages:

- *Fast positioning – a slewing speed of up to 4800° 2 θ /min is five times faster than a conventional goniometer and between ten and twenty times faster than a scanner.*
- *Automatic alignment of the θ /2 θ angular relationship between crystal and detector – the alignment is performed electronically by the microprocessor and no mechanical adjustments are needed.*

- *Rapid qualitative analysis – continuous digital scanning allows fast acquisition of spectra at speeds up to 320°/minute. Peak identification is automatic.*
- *No wear, no performance degradation – the absence of gears, hence of friction, makes them 'no wear' systems assuring excellent angular reproducibility ($\pm 0.0002^\circ$) and precision (0.001°).*
- *High accuracy of peak positions (eg 0.01° with LiF crystal) – analytical peaks are found exactly in their theoretical positions, a performance up to ten times better than conventional systems.*
- *Independent rotation of crystal and detectors allows two detectors to be mounted side by side. Secondary collimators in front of each detector optimize count-rate or resolution.*
- *When specialized applications require specific crystals, up to nine of them can be fitted on the universal goniometer allowing the analyst to choose the best crystal for each region of the X-ray spectrum. Up to four primary collimators (fine, medium, coarse, extra coarse) are available in order to optimize resolution or intensity.*

Both goniometers offer full capability for the analysis of non-routine elements. They can back up any of the fixed channels and provide semi-quantitative analysis when coupled to appropriate software packages (e.g. QuantAS™ and Uniquant® with the universal goniometer or OptiQuant™ with the SmartGonio).

Power supply

A choice to suit the application

ARL 9900 series instruments can be specified with integrated high frequency solid-state generator of various powers to best suit each application.

- ARL 9900 Oasis – 1200 W power supply cooled with its own independent circuit, thus avoiding the need of external water cooling.
- ARL 9900 XP – 3.6 kW power supply which will suit most applications where low limits of detection and high performance is required. The maximum output for this generator is 60 kV (70 kV optional), maximum current is 120 mA.
- ARL 9900 XP+ – up to 4.2 kW for those applications requiring ultimate performance. Two types of power supply can be chosen
 - 60 kV, current up to 120 mA (standard)
 - 70 kV, current up to 140 mA (optional).

Full microprocessor control

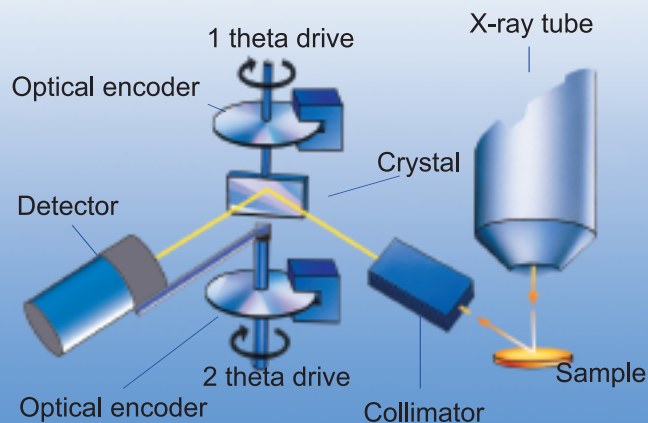
Putting the emphasis on reliability and ease of use

Full digital control makes the ARL 9900 series easy to use. It also ensures consistent results over many operations.

The microprocessor architecture comprises clusters of microprocessors, microcontrollers and digital signal processors connected by full duplex links. They control the overall operation of the instrument, monitor several hundred status points every few seconds and direct the goniometer(s), diffraction system and monochromator functions.

The analyst's instructions are processed in the master microprocessor and sent to the appropriate cluster. The resulting analytical data is displayed on the video screen. For convenience, current operations can be followed on a synoptic panel.

Goniometer principle of operation



Software

Reliable analysis made easy

Operating the ARL 9900 and the rapid processing of data to deliver highly accurate analytical reports is achieved through state-of-the-art software. It is being constantly developed to enable operators of the ARL 9900 to take full advantage of their instrument's capabilities.

WinXRF is the analytical software governing the operation of the ARL 9900 and the processing of data. It uses the Windows® XP Professional operating system.

More details can be found in a separate Product Specification but its principal features are:

- *Analytical Assistant helping the operator to define analytical programmes, undertake calibrations and basic operations of the instrument.*
- *Simple routine analysis mode.*
- *Unattended use through batch commands and sequences*
- *Fast and accurate calibration curve determination through multi-variable regression (MVR) facility*
- *Post-processing functions performed while the instrument is analysing, e.g. results storage and retrieval or export of statistics to Excel spreadsheet*
- *SPC-Basic: instrument control with online integrated SPC (Statistical Process Control) package*
- *Remote diagnostics through modem connection*
- *Support of XRF and XRD analysis allowing use of the same routines of calibration and analysis for both techniques.*

When the F45 universal goniometer is specified, there is a choice of standard-less analytical packages on option:

QuantAS™ automatically processes a wide scan covering up to 70 elements from F to U

- Semi-quantitative analysis produced within three minutes.
- Automatic smoothing, background subtraction, peak identification, overlap and matrix corrections, calculation of semi-quantitative concentrations and normalization to give a fast and easy semi-quantitative analysis of unknown samples.

UniQuant® provides standard-less results in 14 minutes or less depending on the number of elements analysed. The extended counting time per element makes it the first choice if the application puts emphasis on great accuracy and the detection of low concentration levels.

- Standard-less analysis of up to 79 elements when specific standards are not available. Ideal when samples can be obtained only
 - in small quantities
 - in irregular shapes
 - as coatings.
- Calculation of the balance of unanalysed elements present in the sample (eg organic and ultralight elements) – is a valuable feature.

The SmartGonio™ comes with **OptiQuant™** software, an option which is a version of UniQuant® optimized for use with the SmartGonio™.

- Standard-less analysis of up to 75 elements.

The QuantAS, UniQuant and OptiQuant packages are fully calibrated and installed in the factory. They are therefore ready to use immediately after the instrument is commissioned. Stable samples for setting-up and maintenance over time are included.

Other software options

Programmes to make the most of the ARL 9900

- ARLnet: results transmission via Local Area Network to up to 18 destinations
- Compac: transmission of results to up to five computers via serial lines
- Remote: remote display of results to up to eight remote printers or terminals via serial lines
- NBSGSC: programme for theoretical alphas generation
- Charge correction: calculation of furnace charge additions
- SPC-Full: Integrated Statistical Process Control software for instrument quality assurance and production process control. Fully on-line (bi-directional) with automatic evaluation and SPC test result feedback to the operator.
- Remote Sample Definition: reception of sample identification and analysis parameters from third party application software.
- Sentry: allows a simplified sample registration including bar code support and powerful sample batch entry capabilities.
- OEM mode: connection to an external process computer for automation purposes.
- Translation of WinXRF texts into any language supported by Windows® XP Professional.



Analytical Assistant helps definition of analytical programs, calibrations and instrument use

Sample introduction

Degrees of automation to free staff for other work

- Fast, simple and highly reliable sample introduction system using a 12-position sample changer.
- Large X-Y magazine allows automatic handling of larger series of samples.



Small and large cassettes can accommodate samples of various sizes



Full automation through ARL SMS-2000



Large XY sample changer

The X-Y magazine has 98 coded positions for samples in cassettes or on specific supports. The coding of each position allows unattended operation and saves time and effort in determining which sample belongs to a particular analysis. This larger magazine can easily replace the basic system if the need arises.

A version of the X-Y sample changer allows connection to transport belts suitable for one sample form e.g. pressed powders in steel rings. This simple automation is named ARL SMS-XY.

- Optional SMS-2000 and SMS-3000 robotic systems offer fully automatic sample preparation and introduction. With either of these options, the instrument can automatically conduct continuous process monitoring unattended and raise an alarm if any anomaly is detected. The SMS-2000 is a flexible and very powerful system which links the whole sample preparation and analysis process. The SMS-3000 is a larger robot which serves both an OES and an XRF instrument.

Quantitative analysis

Accuracy made easy

Analytical programmes and calibration are defined with the help of the on-line Analytical Assistant. Calibration curves are built using the multi-variable regression (MVR) programme.

Correction models are used to minimize the influence of interfering elements in multi-component matrices and achieve better accuracy of analysis. These models are:

- Line overlap correction
- Additive correction on intensities
- Additive correction on concentrations
- Multiplicative correction on intensities
- Multiplicative correction on concentrations
- Multiplicative and additive corrections on concentrations

- Comprehensive LAchance (COLA) with 3 term alphas to be used with the optional NBSGSC fundamental parameters programme, which can simulate analytical calibrations for homogeneous materials. Inter-element correction factors (theoretical alphas) are calculated and used as known coefficients in the MVR. This minimizes the number of standards necessary to produce calibrations and improves the accuracy of analysis.

In addition, ex-works calibrations can be delivered for various materials such as;

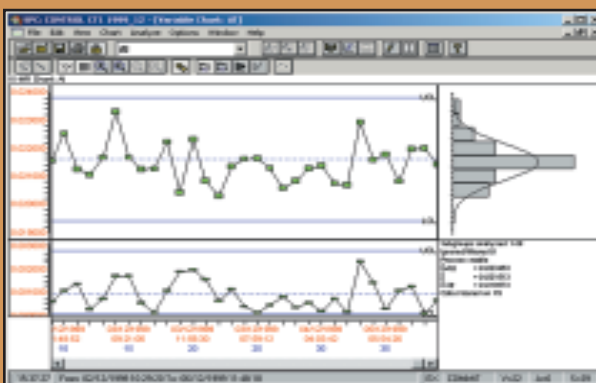
- iron and steel
- copper, bronze and brass
- aluminum and alloys
- nickel, stellite and super-alloys
- various oxides through the General Oxide calibration
- traces in soils and sediments
- ferro-alloys and others for which analytical specifications are available on request.

Customer support

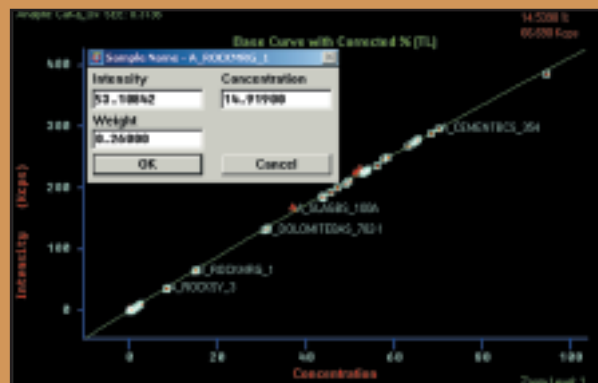
The backing of a major international corporation

The Thermo Electron Corporation offers you worldwide support.

- Application product teams can advise on the most suitable ARL 9900 for a given application and help to draw up specifications.
- Dedicated training allows operators to exploit to the full the capabilities of their ARL 9900.
- A comprehensive worldwide after-sales service network assists with the resolution of day to day queries and ensures that the ARL 9900 achieves the very high standard of reliability and durability it is designed to give.



Statistical Process Control - Typical screen



MVR calibration curve: real concentrations vs. intensities

Specifications

ARL 9900 XP and XP+ (for ARL 9900 OASIS, see separate brochure)

Element range	Boron (Nr. 5) to >Uranium(Nr. 92) providing all necessary crystals are fitted.
Spectrometer environment	Stabilized vacuum using molecular pump.
Spectrometer design	Analysis devices contained in a vacuum chamber made of grey cast iron and temperature controlled at $\pm 0.3^{\circ}\text{C}$. Temperature control by a differential heating and cooling system. Crystals regulated to $\pm 0.1^{\circ}\text{C}$.
Spectrometer arrangement	X-ray tube mounted vertically at 90° above sample surface. Analytical devices positioned on a 360° ring looking down at the sample surface.
Spectrometer capacity	32 fixed channels or 1 goniometer and 24 fixed channels or 1 goniometer, 1 XRD system and 14 fixed channels. Up to three goniometer configurations also available.
X-ray tube	High performance Rh anode end window tube with thin Be window (0.075mm). Extra thin (0.05mm) window option further increases sensitivity for light elements. Optional Mo anode with 0.125 mm Be window.
X-ray generator	ARL 9900 XP: Solid state 3.6 kW high frequency generator (max. settings: 60kV-60mA or 30kV- 120mA). 70 kV option (max. settings: 70kV-51mA or 30kV-120mA). ARL 9900 XP+: Optional 4.2 kW high frequency generator (max. settings: 60kV-70mA or 35kV-120mA). Optional 4.2 kW top performance generator (max. settings: 70kV-60mA or 30kV-140mA). Max. line voltage variation -15% to +10%. Stability $\pm 0.0001\%$ per 1% variation. Optional OASIS version: 1200W (no external water cooling - see separate specification sheet for more details).
Monochromators	Fixed mechanical systems using curved crystal optics (flat optics for light elements) and flow proportional, sealed or scintillation detectors. Each monochromator has its individual temperature control to $\pm 0.1^{\circ}\text{C}$. For ultra-high countrates, absorbing filters can be fitted. Dual Pulse height integration to discriminate and correct for 2nd order peaks.
Universal Goniometer	Gearless, microprocessor controlled goniometer using optical encoders. Fully automatic programming of: <ul style="list-style-type: none">• Up to 9 flat crystals• Up to 4 primary collimators: fine, medium, coarse, extra-coarse• 2 detectors: scintillation and flow proportional (Ar/CH4 10%: flow 5 to 10 ml/min) Independent rotation of crystals and detectors Maximum slewing speed: 4800° 2 theta/min Accuracy of peak positions vs. ASTM table on LiF crystals: $<0.015^{\circ}$ Angular reproducibility $< \pm 0.0002^{\circ}$ Angular resolution 0.001° Total angle range: 0° - 153° 2 theta (Flow proportional counter: 17° - 153° . Scintillation counter: 0° - 115°) Continuous digital scans: from $0.25^{\circ}/\text{min}$ to $327^{\circ}/\text{min}$ as function of measuring time and increment. Step scan range: Minimum step: 0.001° . Maximum practical: 1.00° Time of measurement for each step: 0.1 s. - 655 s
SmartGonio™	Gearless, microprocessor controlled compact goniometer using optical encoders. Fully automatic programming of: <ul style="list-style-type: none">• 3 flat crystals• 2 detectors: scintillation and flow proportional (Ar/CH4 10%: flow 5 to 10 ml/min) Fixed collimator selected according to customer's application Independent rotation of crystals and detectors Maximum slewing speed: 5500° 2 theta/min Accuracy of peak positions vs. ASTM table on LiF crystals: $<0.015^{\circ}$ Angular reproducibility $< \pm 0.0002^{\circ}$ Angular resolution 0.001° Total angle range: 0° - 150° 2 theta (Flow proportional counter: 17° - 150° . Scintillation counter: 0° - 90°) Continuous digital scans: from $0.25^{\circ}/\text{min}$ to $320^{\circ}/\text{min}$ as function of measuring time and increment. Step scan range: Minimum step: 0.001° . Maximum practical: 1.00° Time of measurement for each step: 0.1 s. - 655 s
Patented XRD system	Microprocessor-controlled X-ray diffraction system for determination of phase content in various process monitoring.
Counting electronics	Multi-channel analyzer to discriminate peaks of higher energy. Digital Automatic Gain Control (AGC) for pulse shrinkage correction. Automatic dead time correction ensures linearity of response up to 2 Mcps on flow proportional counter, 1.5 Mcps on scintillation counter, 1 Mcps on sealed detectors.
Sample changer and cassettes	Basic magazine: 12 cassettes for samples of max. height 40 mm and diameter 60 mm. Large capacity X-Y changer: 98 cassettes for samples of max. height 30 mm and diameter 52 mm or 98 samples on supports for direct introduction. Exposed opening 29 mm diameter (basic). Rotation of cassettes in analysis position: 60 rpm. Large changer is easily retrofittable.
Primary beam filter	Up to 4 position programmable primary beam filter for modifying X-ray excitation. <ul style="list-style-type: none">• Cu: For analysis of Ru, Rh, Pd, Ag and Cd (elements that are interfered by Rh lines from the Xray tube) in light and variable matrices• Al: To improve peak to background ratio on Pb or As in light matrices• Others filters on request
Cooling system	Built-in closed circuit for deionised water flowing through liquid/liquid heat exchanger. External water needed is $<20^{\circ}\text{C}$, pressure > 2 bar, flow is regulated between 0.5 and 4.5 lt/min according to generator setting (water consumption minimization).
Dimensions and weight	H 166 cm, D 136.5 cm, W 93 cm with basic sample changer. System weight: approximately 750 kg.
Laboratory information	Optional phone service support through Modem connection. Power requirements: 7 kVA single phase (8kVA for XP+). Safety standards: Electrical and protection: IEC 1010-1, IEC 950. Radiation (fully protected system): ORap (CH)414.501 and BGB1.I norms ($< 1 \mu\text{Sv/h}$). Electromagnetic immunity: CENELEC EN 50081-2 + EN 50082-2 (industrial).

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

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