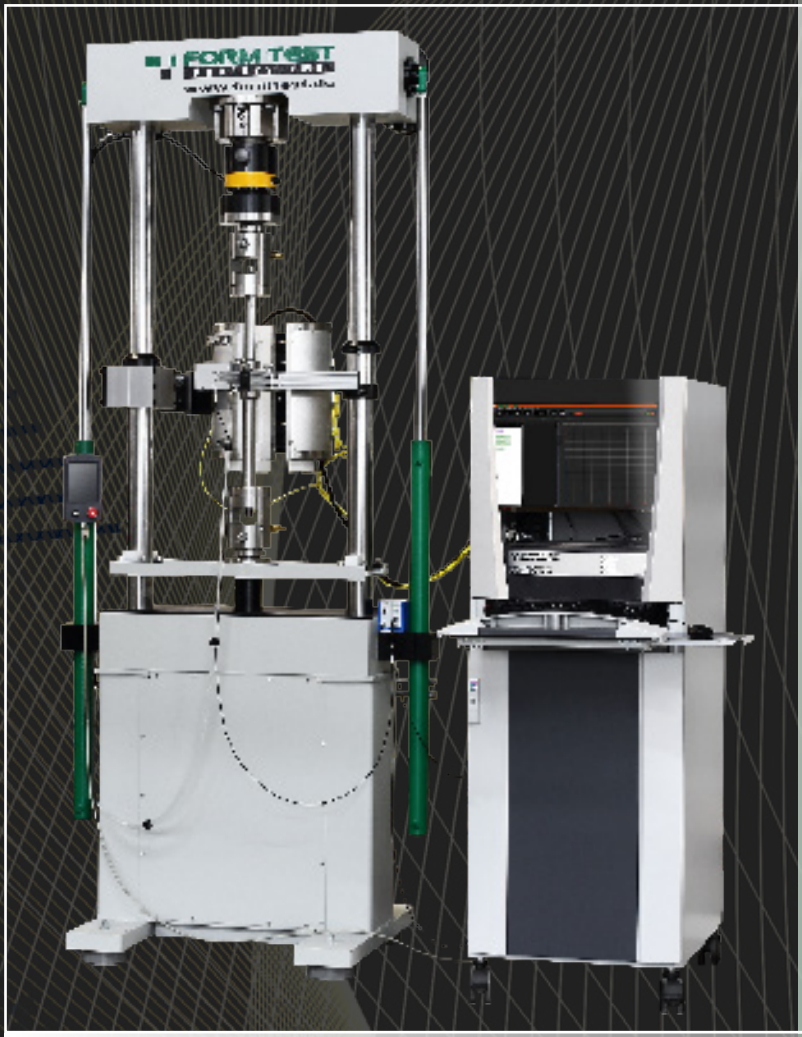
FORM+TEST PRÜFSYSTEME



High Temperature Testing

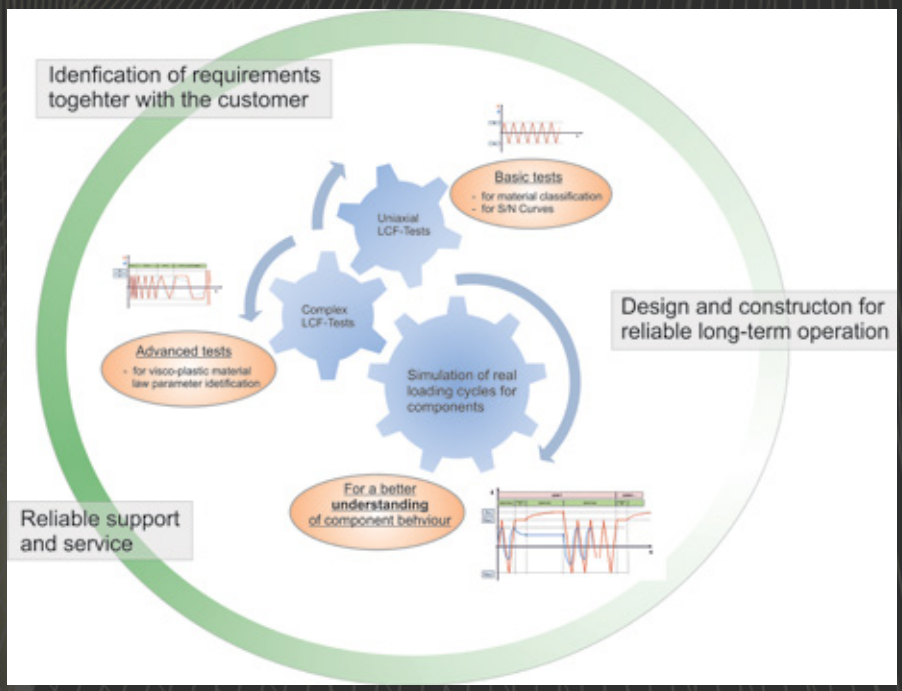
Determination of the material behaviour at operation related temperatures

ORIGINAL FORM+TEST PRÜFSYSTEME

Introduction

When it comes to operational demands at high temperatures, the material behaviour must be describable with appropriate models. This requires fundamental knowledge of the material properties – at the same time suitable tests must be defined to gain these properties correctly.

Together with the customer, FORM+TEST creates specific testing solutions for static and dynamic tests adapted to each task. Besides a testing machine, designed for long-term operation, FORM+TEST supplies reliable support and service for all relevant parts of the test system.



Assessment concept for extended material testing

Calibration

The testing machines are calibrated according to DIN EN ISO 7500-1 - valid for material testing machines - accuracy class 1 or better. The load cells as well as length and strain sensors can be calibrated separately.

All certificates comply with the guidelines of the German accreditation association DAkkS and can be issued after commissioning on site. For this purpose FORM+TEST has the appropriate manpower – in its own calibration lab but also in long-standing and proven partnerships with well-known calibration labs. This enables FORM+TEST to organise all relevant processes and to ensure optimal documentation.

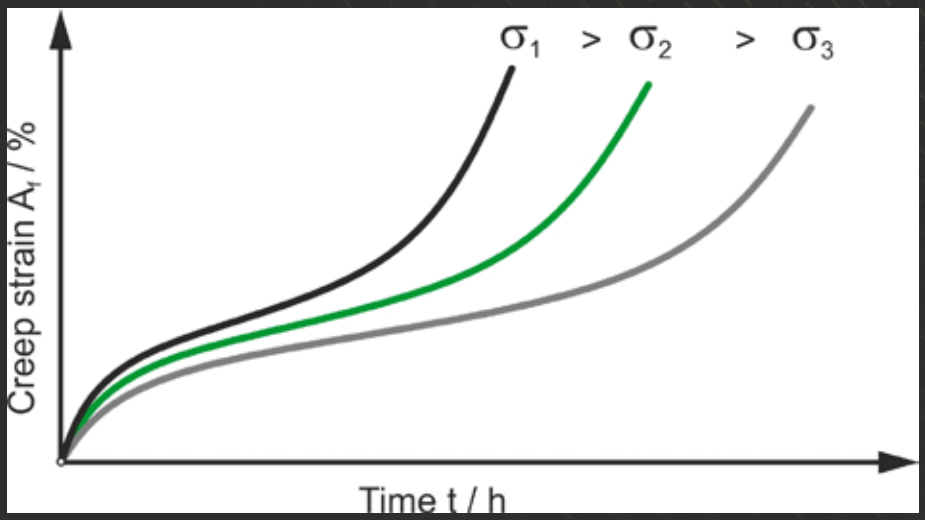
High Temperature Testing Part I

Quasistatic Creep Loading

Reliable design of high temperature components is based on resilient material properties which are determined in long-term, mostly isothermal creep tests under constant load.

The testing systems of FORM+TEST offer reliable, stable and high-precision solutions for long-term creep tests in perfect compliance with the applicable standards. These comprise e.g. DIN EN ISO 204 or ASTM E 139 or - for the evaluation of embrittlement in notched creep specimens - ASTM E 292-01 (other standards can be considered upon request). Additionally relaxation tests according to DIN EN ISO 10319 and ASTM E 328 are feasible.

In addition to various testing machine concepts, various useful accessories can be supplied for these demanding tests, equipping your test lab with the full functionality of required test procedures.



The Machine Concept

a) dead weight lever arm testing machines up to 100 kN

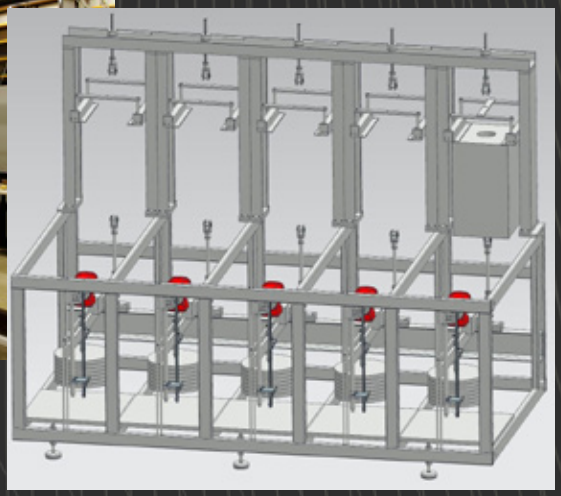
b) actively controlled single or double spindle electromechanical testing systems up to 250 kN and above

Temperature Control

In order to apply the required specimen temperature in long-term tests, reliable heating systems must be used. The guaranteed maximum operating temperature can be maintained permanently without significantly affecting the service life of the heating elements. In the unlikely event that a heating element should still fail, it can be replaced individually, which saves time and money. The same applies to the measuring and control thermocouples of the furnace. On request, FORM+TEST provides a temperature profile of the complete load train - this is created during the pre-acceptance tests. Depending on the maximum temperature different heating systems are used.

a) climatic chambers at low to medium temperatures up to 350°C

b) 3-zones radiation furnace at temperatures up to 1700°C



Example for creep test machines with integrated furnaces

Measuring and Control System with Software

A flexible data acquisition system is integrated for the safe and reliable storage of measured data of the temperature readings and other measured variables for dead weight machines that are not actively controlled. For actively controlled systems, e.g. applied in a relaxation test, the digital controller **DIGIMAXX**® from FORM+TEST is used in combination with a suitable software package.

Climatic Chamber

At medium temperatures and the combination of testing in a non-air atmosphere, FORM+TEST offers the possibility of integrating appropriate test chambers. They can be supplied with an inspection window and adequate lead-throughs for the pull rods of the load train and the measuring equipment.
The dimensions can be adapted to customer-specific and application-specific requirements.

Example photo:
climatic chamber

Key Facts

- dimensions (WxDxH): customised
- max. operating temperature: 350°C
- max. operating pressure: 1,5 MPa
- lead-throughs for pull rods and measurement channels

Continuous Strain Measurement

Current investigations of new concepts for the evaluation of the creep strength, mainly carried out by be ECCC (European-Collaborative-Creep- Committee), show the importance of continuous strain measurement for the extrapolation of the creep strength.

FORM+TEST offers suitable contacting extensometers with ceramic components for use at highest temperatures and a reliable strain measurement.

Extensometer for continuous strain measurement

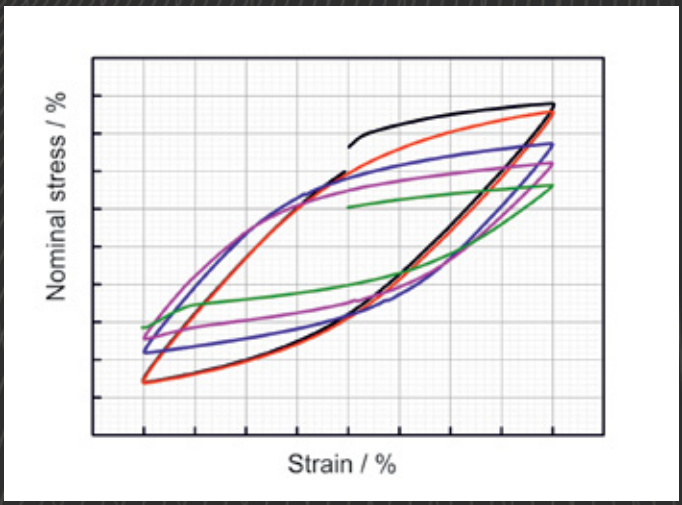
Key Facts

- max. operating temperature (currently): 1100°C
- max. operating temperature (after clarification): 1700°C
- long-term experience in operation

High Temperature Testing Part II

Fatigue Tests (LCF / HCF)

Due to the flexible operation of power plants, the limits for fatigue loading must be known for safe operation. Material effects under elastic-plastic cyclic stress are of outstanding importance in the formulation of modern and precise material models. FORM+TEST offers suitable testing equipment to reliably carry out standard tests, such as ASTM E 606 or ASMT E 2714.



The Machine Concept

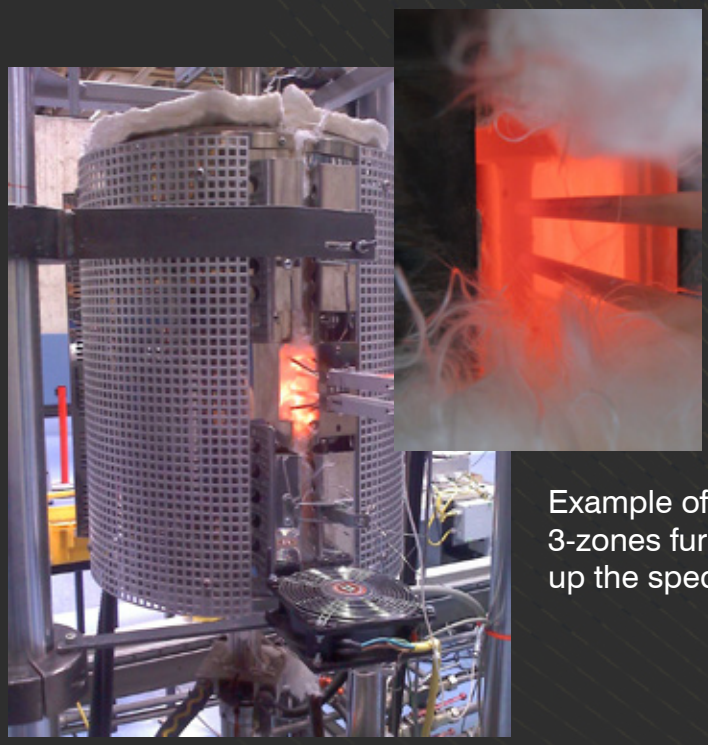
a) electromechanical drives for low test frequencies
b) hydraulic test systems for highest test frequencies

Example for electromechanical test machine

Temperature Control

In principal, the same systems are suitable as for quasi-static tests already described in part I.:

a) climatic chambers at low to medium temperatures up to 350°C
b) 3-zones radiation furnace at temperatures up to 1700°C
b) vacuum heating systems up to 2000°C



Example of usage of a 3-zones furnace for heating up the specimen (*)

Measuring and Control System with Software

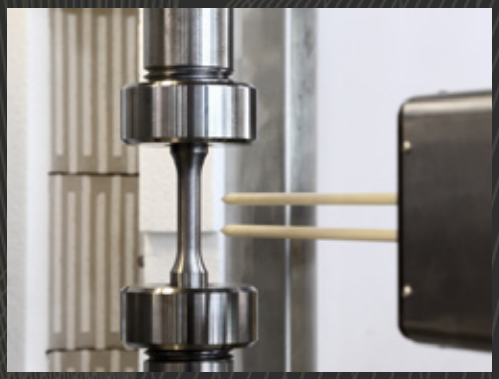
For measurement and control of any requirement, high-resolution 64-bit **DIGIMAXX**® digital controllers are available which can be extended for multi-channel testing acc. to requirements (e.g. for combined tension and torsion testing). The data recording is synchronous in all available measuring channels.
All connected measuring instruments can be used for both measurement and control of the system.
With the PROTEUS$^{PRO\ A}$ software used, completely flexible test sequences can be created – from simple fatigue tests to complex loading sequences similar to those of components.

See leaflet DC 100.01

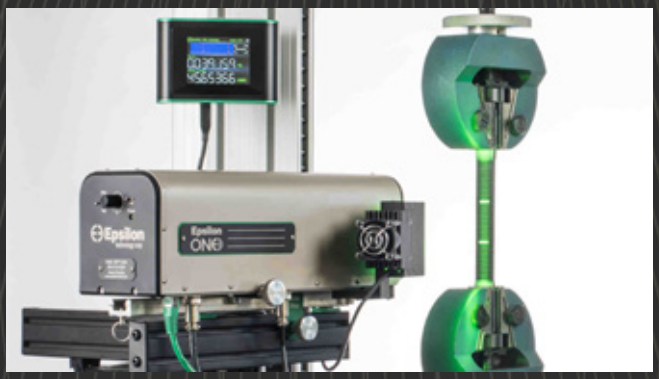
(*) Pictures by courtesy of MPA Stuttgart

Determination of Deformation and Strain

For the determination of material behaviour in the viscoplastic range, reliable strain measurements even with smallest deformations are of central importance. For this purpose the furnaces and climatic chambers are equipped with the adequate accessibility, for contacting and non-contacting extensometer.



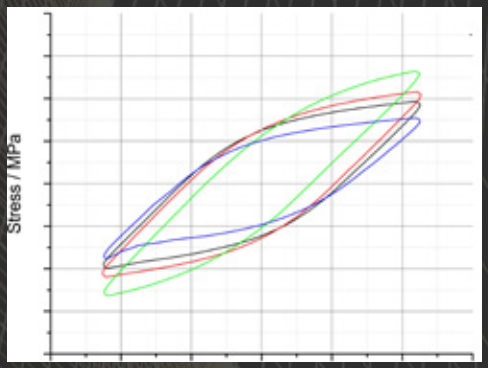
Contacting measurement



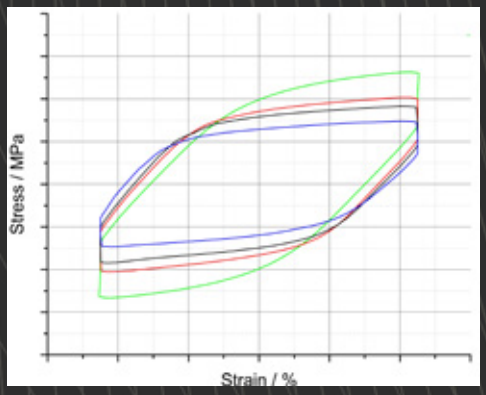
Non-contacting measurement (*)

In long-term LCF or relaxation tests as well as in tests with long initial gauge lengths, the FORM+TEST test system has great advantages in terms of reliability. Since the extensometer encloses the specimen, slipping of the extensometer rods is prevented. Especially in long-term tests, the combined use of inductive displacement transducers and ceramic clamping parts significantly minimizes temperature drift. This could be proven in long-term tests with running times of up to 1000 hours.

a)



b)



Real LCF test data with rod type extensometer a) without , b) with hold-time.

In addition to the rod-type extensometer developed by FORM+TEST for stable long-term tests, different solution concepts are used, depending on the requirements with the following key data:

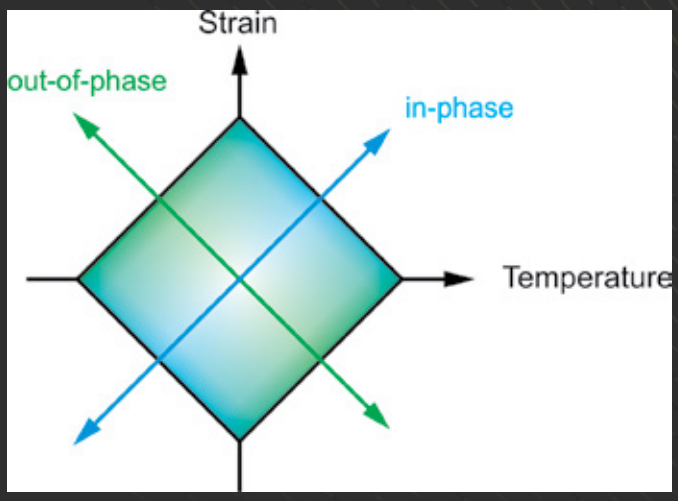
- max. temperature: 1650°C
- at test frequencies up to: 200 Hz
- for corrosive media
- for biaxial tests
- for tests of fracture mechanical specimens

(*) Pictures by courtesy of Epsilon

High Temperature Testing Part III

Thermo-Mechanical-Fatigue (TMF) Testing

During the operation of high temperature components, a transient in temperature may occur in addition to a variable mechanical load. These temperature fluctuations usually lead to additional mechanical stresses in the component. For the analysis of the interaction of combined, non-steady mechanical and thermal load, the temperature dependent material behaviour must be known for the numerical analysis of components and the assessment of the lifetime. For this purpose the test systems of FORM+TEST offer suitable possibilities, especially for carrying out thermo-mechanical fatigue tests according to ISO 12111 or ASTM E 2368.



TMF testing, schematic

The Machine Concept

a) electromechanical drives for low test frequencies
b) hydraulic test systems for highest test frequencies

Example for servo-hydraulic test machine

Temperature Control

Typically, inductive heating systems are used in TMF-tests to apply the temperature to the specimen. They offer the highest flexibility and sufficiently high temperature transients. The specimen can also be actively cooled.

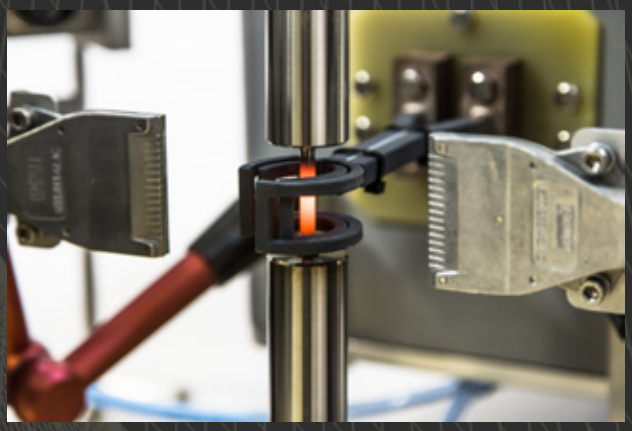
If required, FORM+TEST provides the temperature profile along the specimen, which is generated by default in pre-acceptance tests. However, this pre-acceptance test does not refer to the “0” force test in which the pure thermal strain is measured. The measurement of the (temperature-dependent) expansion coefficient is necessary to be able to distinguish between mechanical and thermal strain during the test. With the commonly used high temperature extensometers only the total strain can be measured as a sum of thermal and mechanical strain.

If only slow temperature transients are required, the TMF software can also be used in combination with common 3-zones radiation furnaces, e.g. with LCF or HCF testing machines.

Inductive Heating System

For highest temperature transients FORM+TEST offers an inductive heating system with different performance levels which is directly integrated into the test system. The system must be adapted to specimen geometry, material properties and the requirements on temperature gradients. For controlled specimen cooling, compressed air, protective gases or water mist for thermal shock tests can also be used.

The temperature can be controlled by contacting thermocouples or by non-contact pyrometers and is directly integrated in the DIGIMAXX® controller.



Specimen heating (*)

(*) Pictures by courtesy of iew

Key Facts

- adaption of inductors for special requirements on material and geometry
- variable power input
- operation only in non-conductive atmospheres

Calibration of Temperature Field

In addition to the homogeneity of the temperature field, the correct measurement of the temperature during inductive heating must be ensured. For this purpose, the test system must be validated and checked with different measuring equipment. This can be done before delivery by us or by means of advisory support.

Strain Measurement

During a TMF test, the individual thermal and mechanical portion of the total elongation must always be known to enable a correct evaluation of the material behaviour. Due to the robust and high- precision strain sensors and extensometers also used in the LCF range, this can also be made possible for TMF tests. The determination of the thermal strain components is carried out – as already described - in a preliminary test.

Measurement and Control System with Software

FORM+TEST also relies on digital controllers from the DIGIMAXX®-series for TMT-tests. With the PROTEUS$^{PRO\ A}$ software used, completely flexible test sequences can be created – from the classic in-phase and out-of-phase TMF test to complex component-like load cycles.

Additional Test Functions and Accessories

In order to extend the existing standard test procedures and to offer further possibilities, different accessories with suitable software packages and integration into the control loops are available.

a) for example crack growth measurements according to ASTM E 1457 or ASTM E 647 with application of the potential probe technique

b) equipment and adapters for different fracture mechanics tests (static and dynamic)

c) climatic chambers for different fluid atmospheres (inert gas, corrosive media)

d) strain measurement with contacting and non-contacting extensometers

Potential Probe

By measuring the electrical potential, the crack extension can be reliably measured online during the test.

For this purpose FORM+TEST can integrate a potential drop probe system that has already been tested and validated in many long-term high temperature tests. The potential drop probe is supplied with a suitable data recording software, which also allows the recording of user-defined formula calculations from the measured values. The measured values can then be fed into the **DIGIMAXX**® controllers from FORM+TEST and used to control the tests. The respective application background is considered in each case separately. For an optimal understanding of the system, a specially coordinated user training is recommended.

Example of a potential drop probe (**)

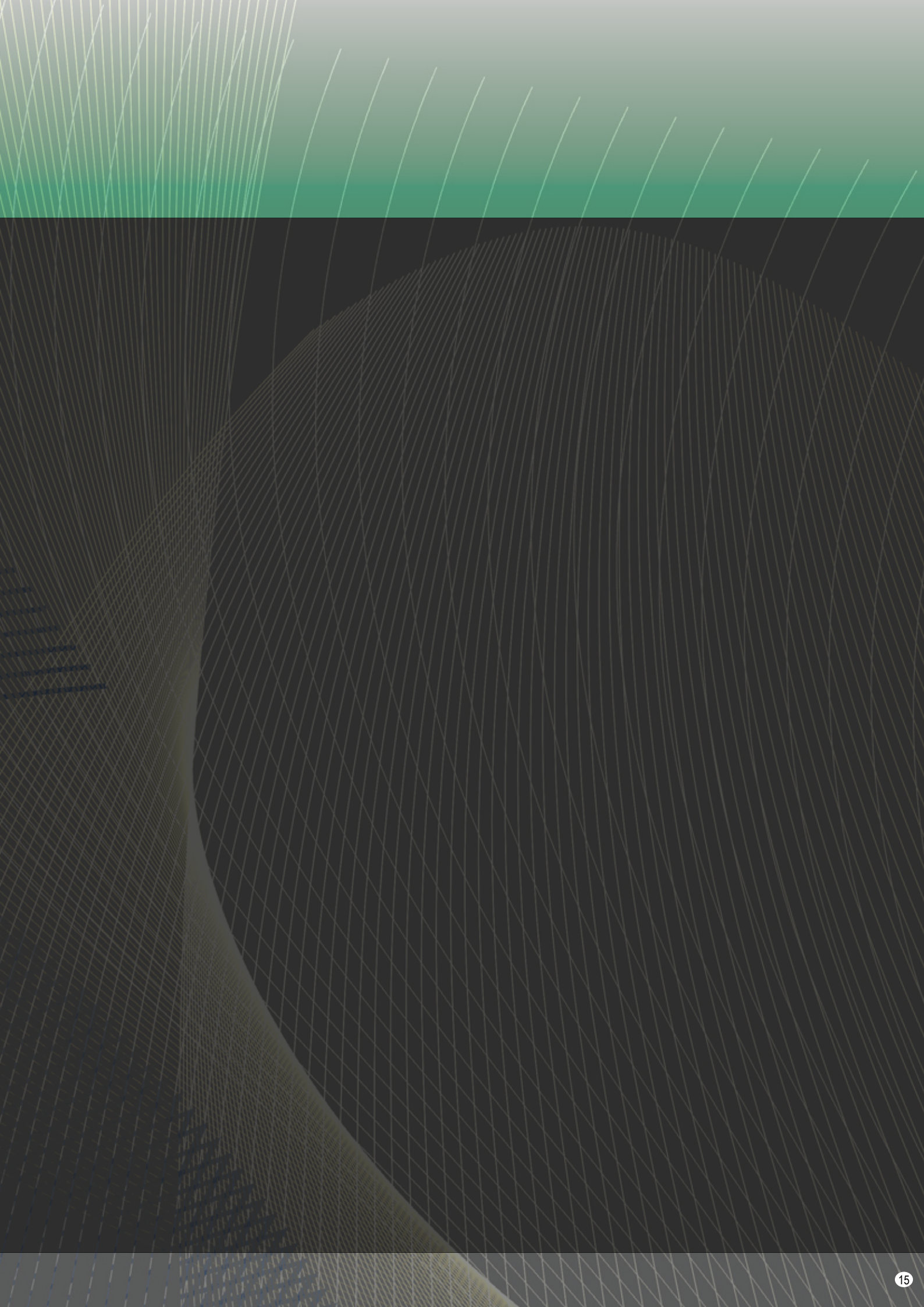
Example of the application of a potential drop probe (*)

Key Facts

- available for DC and AC current technology
- expandable via multiplexer
- digital data recording and evaluation

(*) Pictures by courtesy of MPA Stuttgart
(**) Pictures by courtesy of Matelect

Notes



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