

Diagnostics in the OPTIFLUX

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Process instrumentation + diagnostics = higher plant availability

Sensors and actuators control production sequences and help to assure product properties ranging from the concentration of an acid to the taste of a lemonade.

The failure or drift of a sensor in complex control loops can initiate a chain of successive reactions making it difficult to locate the faulted device and get the process going again. Also, drifts in sensor characteristics, including those due to external influence, can be so gradual as to go unnoticed until the process exceeds acceptable limits. The results of such failures are reduced plant availability and loss of production; in other words, higher costs.

Integral diagnostic facilities in sensors and actuators indicate the location and type of fault and so allow rapid fault recovery. Such an internal diagnostic feature can, moreover, indicate device drifts and also any unacceptable influence by external process parameters. That allows predictive maintenance measures to be carried out and can help to avoid device failures with their negative consequences on the process.

VDI/VDE/WIB/NAMUR Guideline 2650

The VDI/VDE/WIB/NAMUR 2650 Guideline (NAMUR 2650 in short) includes a list of the most frequent failure modes of field devices, based on the experience of users and manufacturers, together with a diagnostics "wish list". Owing to their significance for process measurement technology, electromagnetic flowmeters (EMFs) are also described in the Guideline.

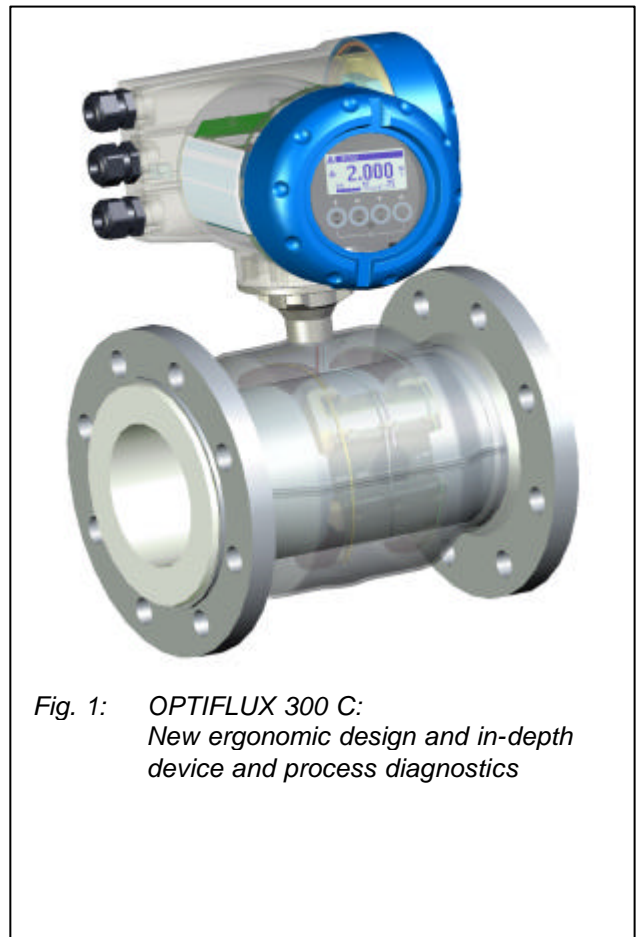
Example of internal diagnostics: OPTIFLUX

The new OPTIFLUX EMF series with specially designed sensors and μ P-EMF signal converter IFC 300 (Fig. 1) detects all the failure modes listed in the Guideline, plus a few more.

High computing power, signal analysis, new measuring and test modes, additional measuring paths and intelligent software-aided evaluation allow early detection of drifts and unacceptable process conditions right up to faulty installation.

Diagnostics in concrete terms:

Tab. 1 lists the most frequent causes as specified in NAMUR 2650 of electromagnetic flowmeter fault conditions based on user experience, together with their detectability by OPTIFLUX.



*Fig. 1: OPTIFLUX 300 C:
New ergonomic design and in-depth
device and process diagnostics*

EMF: Application-related faults or fault conditions acc. to NAMUR 2650 Sh. 3	Causes and effects Practical examples		Detected by OPTIFLUX
	Typical causes (examples):	Typical effects (examples):	
Entrained gas in liquid product	<ul style="list-style-type: none"> ▪ Cavitation ▪ Vacuum ▪ Incorrectly installed 	<ul style="list-style-type: none"> ▪ Measuring error ▪ Noisy indication 	☑
Electrode corrosion	<ul style="list-style-type: none"> ▪ Wrong material selected ▪ Change in composition of liquid product 	<ul style="list-style-type: none"> ▪ Noisy indication ▪ Corrosion, up to complete failure, and ▪ Seepage of liquid product 	☑
Conductivity too low	<ul style="list-style-type: none"> ▪ Change of liquid product ▪ Wrong meter selected 	<ul style="list-style-type: none"> ▪ Indication too low, ▪ Noisy indication 	☑
Damage to liner	<ul style="list-style-type: none"> ▪ Wrong material selected ▪ Abrasion from solid particles ▪ High temperature and vacuum ▪ Meter incorrectly installed 	<ul style="list-style-type: none"> ▪ Measuring error of some % points, up to ▪ Destruction of the EMF, ▪ Seepage of liquid product 	☑
Electrode fouling	<ul style="list-style-type: none"> ▪ Deposits of oil, grease on the electrodes ▪ Electrode passivation (wrong material selected) 	<ul style="list-style-type: none"> ▪ Measuring error ▪ Noisy indication ▪ Failure of measurement 	☑
External magnetic fields	<ul style="list-style-type: none"> ▪ Electric melting furnaces ▪ Electrolysis plants 	<ul style="list-style-type: none"> ▪ Measuring error ▪ Varying indication 	☑
Electrode short-circuit	<ul style="list-style-type: none"> ▪ Metal particles deposited in the measuring tube 	<ul style="list-style-type: none"> ▪ Indication tends towards zero 	☑
Partial filling	<ul style="list-style-type: none"> ▪ Meter incorrectly installed 	<ul style="list-style-type: none"> ▪ Measuring error ▪ Varying indication 	☑

Tab. 1: Diagnostic requirements to NAMUR 2650 and those met by the electromagnetic flowmeter OPTIFLUX 300

Diagnostic tools in OPTIFLUX in excess of NAMUR 2650 requirements:

Application-related faults or fault conditions	Causes and effects, Practical examples		Detected by OPTIFLUX
	Typical causes	Effects	
Inaccuracy of signal processing	<ul style="list-style-type: none"> Component drifts 	<ul style="list-style-type: none"> Measuring error 	☑
Coil temperature too high	<ul style="list-style-type: none"> Process temperature too high 	<ul style="list-style-type: none"> Reduced lifetime 	☑
Temperature of electronic equipment too high	<ul style="list-style-type: none"> Process temp. unacceptably high (compact EMF) Direct solar radiation Defective components 	<ul style="list-style-type: none"> Reduced lifetime Higher failure probability Drift, measuring error 	☑
Nonlinearity of magnetic circuit and signal processing	<ul style="list-style-type: none"> External magnetic fields Electronic equipment defective 	<ul style="list-style-type: none"> Measuring error 	☑
Field current value incorrect	<ul style="list-style-type: none"> Electronic equipment defective Wire break in coil 	<ul style="list-style-type: none"> Measuring error 	☑
Current output faulty	<ul style="list-style-type: none"> Load too high Wire break in coil 	<ul style="list-style-type: none"> Measuring error 	☑
Flow profile	<ul style="list-style-type: none"> Installed e.g. behind valve 	<ul style="list-style-type: none"> Measuring error 	☑

Tab. 2: Additional diagnostic tools in OPTIFLUX

Diagnostics in the OPTIFLUX:

Fig. 2 gives an overview of the most important monitoring elements in the OPTIFLUX IFC 300 signal converter.

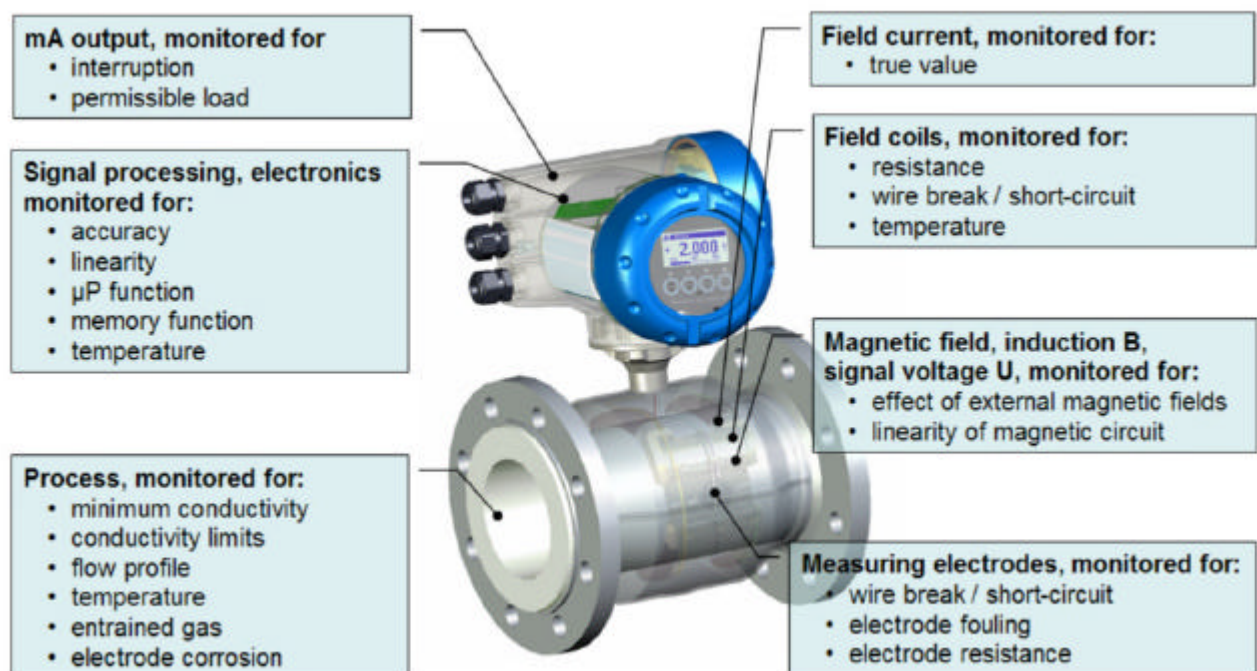


Fig. 2 Monitored process and device parameters in the OPTIFLUX

Two examples of monitoring individual failure modes:

Monitoring of the measuring electrodes

The signal converter injects an alternating current I_{EP} into the process liquid by way of the EMF electrodes. This current generates a voltage drop U_{RE} , which is dependent on resistance R_E and hence the electrical conductivity σ of the liquid product.

From this are deduced the following failure modes:

- Electrode fouling
- Short circuit, wire break in electrode line (important for EMFs with remote signal converter)

The measured resistance R_{EI} allows indication of conductivity s and enables e.g. the following statements to be made:

- Conductivity outside the acceptable limits of the EMF or the liquid product
- Change of liquid product (e.g. switch from process to cleaning liquid, or vice versa in CIP processes)
- Quality of cleaning processes (e.g. wastewater)

Status outputs with adjustable operating points or bus connections indicate over- or undershooting of the associated conductivity values.

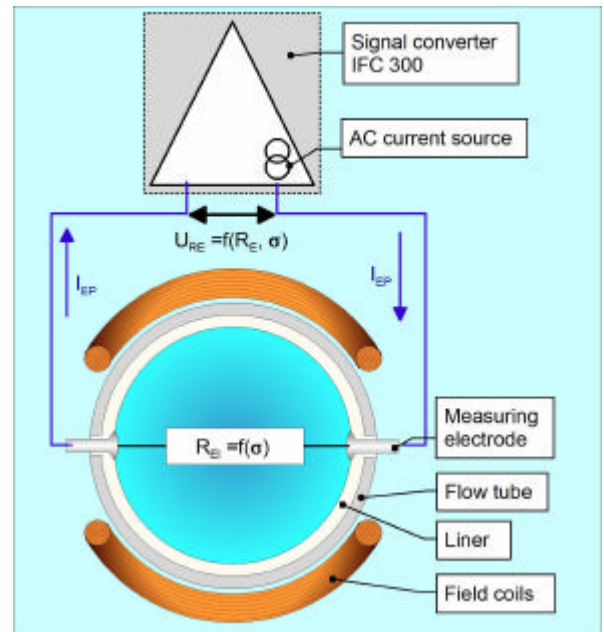


Fig. 3 Monitoring of the electrode circuit

Testing the linearity of magnetic circuit and signal processing

This patented linearity test for the EMF is based on the EMF equation

$U = v \cdot B \cdot k \cdot D$ where:

- U = induced signal voltage,
- v = mean flow velocity,
- B = induction in the measuring tube,
- k = proportionality constant,
- D = tube diameter

Normally, induction B and signal voltage U are proportional to field current I_F , which the signal converter feeds to the field coils.

For the linearity test, the amplitude of the rectangular field current I_F is switched temporarily to 50% of the nominal value. So long as everything is linear, B , U - and hence the output of the primary signal processing - must drop to 50% of the values present at full current I_F (100%).

Where there is nonlinearity of the magnetic circuit or the electronic equipment, this setpoint of 50% is not maintained. This is detected and indicated by the signal converter.

Detection of external magnetic fields

EMFs are also used in electrolysis plants and in the vicinity of electric melting furnaces in strong external magnetic fields.

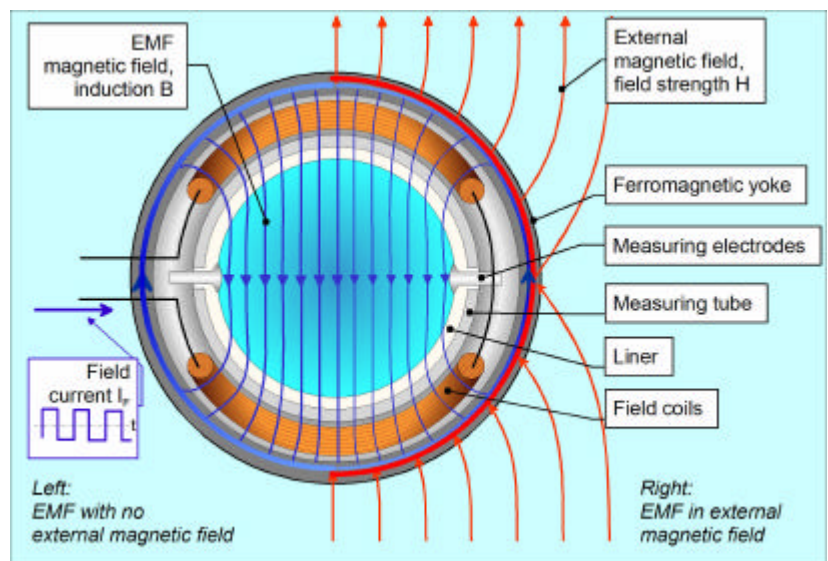


Fig. 4 External magnetic field, influence on the EMF

Such fields can saturate the ferromagnetic yoke of the EMF's magnetic circuit, which is designed to offer the useful magnetic field of the EMF a low magnetic resistance on its return path along the outside of the measuring tube (Fig. 4). In a condition of saturation, this resistance increases. Induction B in the measuring tube and signal voltage U become smaller. Thus errors can occur in flow indication.

Where there is no external field (Fig. 5, blue lines), the rectangular current I_F through the magnetic coils generates a field strength swing ΔH and an induction swing ΔB . This determines the signal voltage U . When the field current is switched to 50%, ΔB and U drop linearly to 50% of the previous values.

A strong external field with field strength H_0 will shift the working point of the magnetic circuit into the nonlinear saturation range of the magnetization curve $B = f(H)$ (Fig. 5, red lines). The ratio of induction and signal voltage values at field current 100% and 50% then deviates from the setpoint.

That is then a clear indication that the accuracy of the EMF is being influenced by the external magnetic field, and will initiate a message.

Diagnosics in field devices provide information on process and environment

The diagnostic tools of the OPTIFLUX provide information, for instance

- on the process (conductivity, coil temperature, i.e. process temperature, entrained gas in the liquid product, flow profile),
- on the process environment (signal converter temperature, external magnetic fields)
- on the proper functioning of the EMF (functionability, linearity, accuracy and any drifts, printout of verification protocols possible)

The large number of internal tests in the OPTIFLUX provides certainty that the measuring point is functioning properly in difficult applications and environmental conditions.

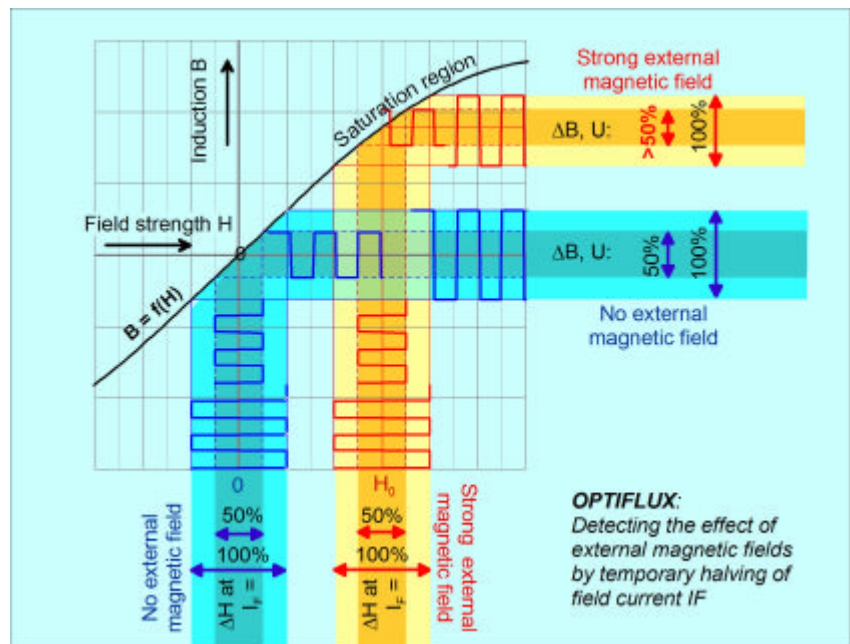


Fig. 5: Measuring errors caused by strong external magnetic field and their detection in the OPTIFLUX