

# Monitoring System NDU for Determination of Corrosion Processes of Reactor Vessels and Piping in Chemical Plants

For monitoring of the corrosion activities within a chemical apparatus different methods are known, as e.g.:

- Supervision of immersed specimens at intervals
- Measurement of wall potentials and redox - potentials
- Determination of the polarisation resistance or the electrode impedance of specimens within the apparatus

Another method has been developed in the past decade, but hitherto its application was restricted to laboratorial use: The evaluation of the electric noise produced by electrochemical processes.

Electric currents produced by electrochemical processes show time - depending fluctuations, commonly called noise. This noise can be measured both as a current signal as well as a potential signal. Besides long - term fluctuations (drift), aperiodic oscillations are observed. Their frequency spectrum is determined by the chemical reaction. Theoretical works on these effects were first published by Pisarenko and Tyagai <sup>1</sup>. Technical use of this phenomenon could be achieved as soon as appropriate electronic circuits were available which had low intrinsic noise. The noise of different electrode

reactions was measured <sup>2</sup>, very sophisticated systems allowed to study the noise of metals in the passive state <sup>3, 4</sup>.

## Methods Used by the NDU System

The NDU system uses a variety of different methods in parallel:

- Measurement of the potential noise of a pair of electrodes inside the object. The electrodes may be of similar material as the walls, or one of both may be dissimilar.

- Measurement of the current noise between a pair of electrodes inside the object. Again, The electrodes may be of similar material as the walls, or one of both may be dissimilar.

- Measurement of the wall potential
- Measurement of galvanic d.c. currents (only for electrode pairs made of similar material)
- Measurement of the polarisation resistance using a pair of electrodes, of which one is of similar material as the wall.

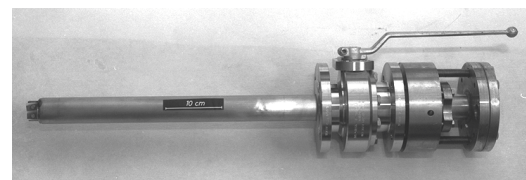
## Technical Realisation

The NDU measurement system was developed by Bank Elektronik - Intelligent Controls GmbH in Co-operation with Hoechst AG and the Institute for Materials Testing and Materials Engineering Dr. Dölling + Dr. Neubert GmbH.

The NDU bases on the combination of a low - noise potential meter, a low - noise current sink and a control unit for polarisation of the electrodes.

The analogue signals are filtered, amplified and, after A / D conversion, processed by a personal computer.

Noise signals are small. Usually the potential noise spans some few millivolts, and the current some nanoamps. Therefore, much effort was done to reduce undesired influences using e.g. battery powered analogue circuitry and optical data transfer to the PC.



Extractable sensorhead of the NDU mounted on a 2" flange with ball valve.

<sup>1</sup>V. A. Tyagai, *Electrochimica Acta* 16, (1971), S. 1647

<sup>2</sup>U. Bertocci, R.W. Shideler, Falls Meeting October 1987, Abstract 124

<sup>3</sup>R. Dölling, Dissertation, Clausthal 1984

<sup>4</sup>K. Nachstedt, Dissertation, Clausthal 1990

## Advantages

The measured signals allow the interpretation of the state of corrosion activities.

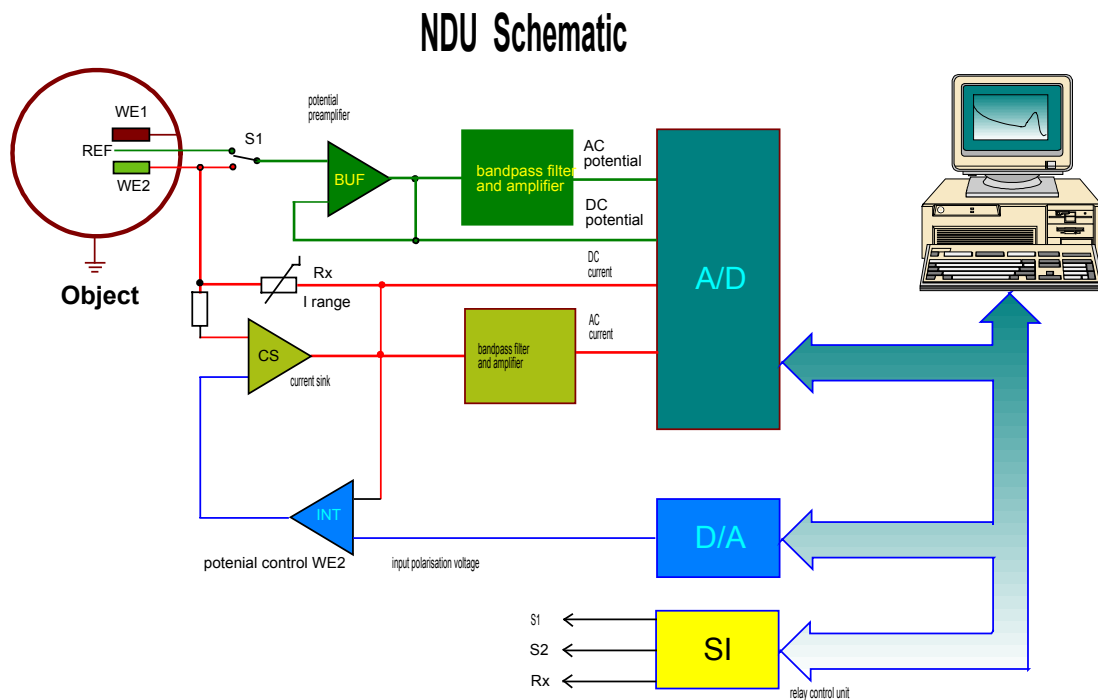
### Qualitatively:

- common corrosion (active or passive metal dissolution)
- localised corrosion (pitting, crevice corrosion, stress corrosion cracking)

### Quantitatively:

- corrosion rate

So, it is possible to detect the development of damages very soon, and to draw conclusions from the relation of actual process parameters to corrosion activities.



## System Description

### The NDU consists of:

- a set of working electrodes (WE) and inside the object. If the task is the supervision of the object, at least one WE consists of material identical to the wall material. If the task is to determine which material might be of better use, one WE is of a material similar to that of the wall, and a set of WE of dissimilar materials is used for evaluation of their properties.
- a low - noise potential preamplifier (BUF)
- a low - noise current sink (CS)
- a polarisation control unit (INT), operating on the current sink for periods when the polarisation resistance is to be measured.
- a control unit (SI)

### The Evaluation System Consists of:

- an A / D converter unit
- a personal computer
- software, based on Keithley - CEC - Testpoint™

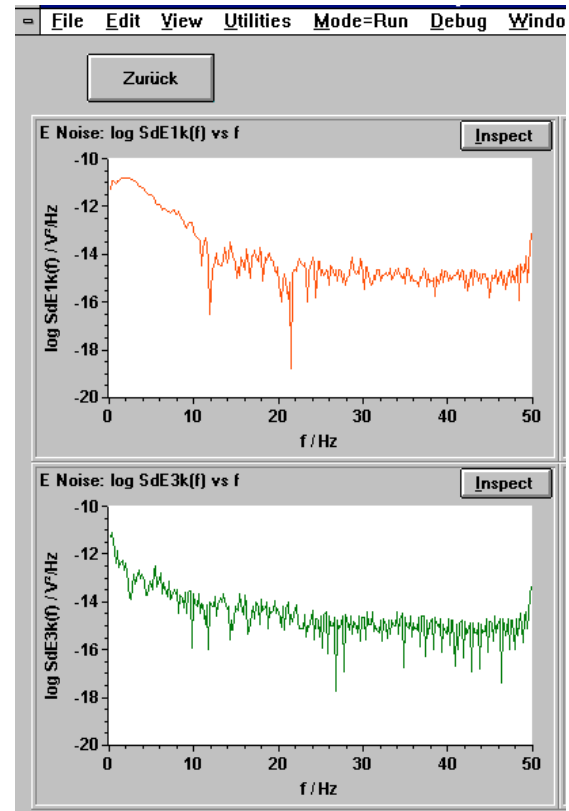
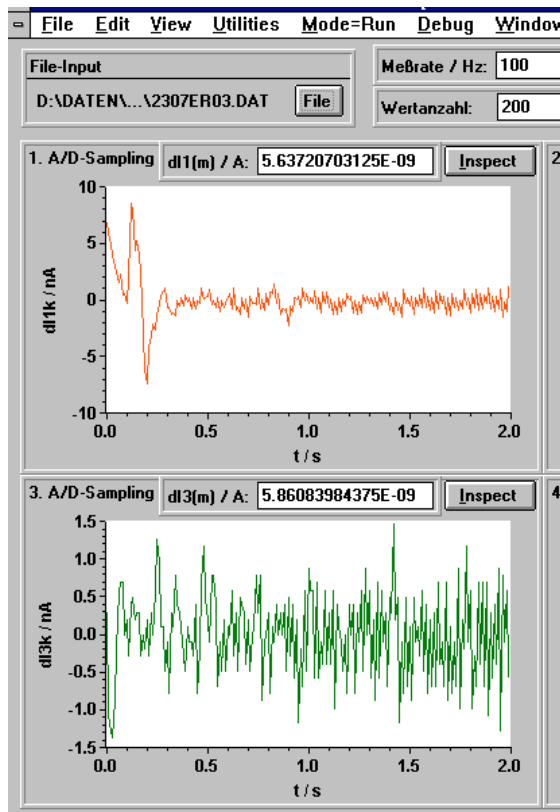
## Fundamentals of the Techniques

The measurement of polarisation resistance is known and shall not be discussed further, as well as the measurement of wall potentials with respect to a reference electrode. Both methods are so far helpful to indicate the state of a surface as „passive“ or „active“, and the overall corrosion rate can be determined.

The additional evaluation of the electrochemical noise gives some advantages: The noise spectrum is characteristically for different corrosion processes. So, the nature of the corrosion process can be determined.

Different methods are described in the literature showing how to get information from the noise spectra <sup>5</sup>. A drawback of these methods is that some additional assumptions have to be made concerning the relation of noise current density to total current density.

data recording and screening the signals for alarm states. If alarm states are detected, the complete set of data will be stored. If no alarm occurs, only once a day one set of data is stored for evaluation purpose. Part two is a capable programme which enables the engineer to interpret the data measured, if alarms occur.



To avoid these drawbacks, the NDU combines the methods of noise measurement, potential measurement, galvanic current and polarisation resistance measurement

Both alarm data and raw data can be transferred via a network for remote control.

So, four different methods allow to cross-check the respective data. Even wrong data from a drifting reference electrode now will not longer produce wrong alarms or - worse - pretend good state of the apparatus when rapid corrosion is developing.

Alarm thresholds are set according to the plant's properties. The programme is secure against unauthorised changes.

The amount of information allows a description of the state of the corroding surface. On the other hand, the operator in the plant it is essential to get information in terms of "good" or "alarm". For this purpose, the software consists of two main parts: Part one cares for

Figures above:

Potential signals of a duplex - electrode (1.4462) in chloride containing process medium in a distillation column.

Above: strong peaks indicate onset of pitting.

Below: Low noise of the passive state (note the intensity scale).

Left side: AC measurements, right side: Frequency spectra

<sup>5</sup>Patent DE 37 80 633 T2

## INTRINSIC SAFE

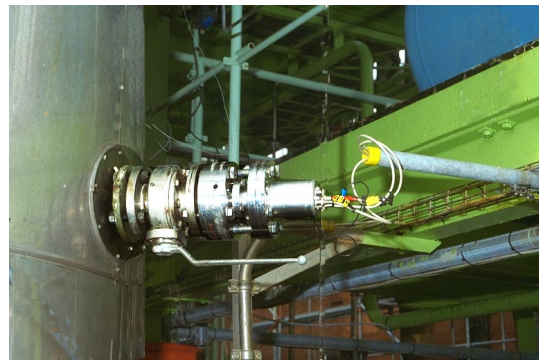
The NDU system is intrinsic safe. So, it can be operated also in potentially explosive environments. The housing is either weatherproof (IP 65) or explosion - proof. Data transfer to the computer is done by optical fibre transmission lines which allow up to 1500 m distance between sensorhead and the evaluation PC.



NDU electronics in ex - proof housing

## PRACTICAL EXPERIENCE

The first system was installed at Hoechst AG in 1995, the next were installed in 1996 / 97. They have proved their supervision capability, and in addition, some alternative materials have been screened for future plant design.



NDU sensorhead mounted on a 2" - flange of a distillation column.

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