NILU OR: 21/97

NILU : OR 21/97
REFERENCE : O-91023
DATE : APRIL 1997
ISBN : 82-425-0868-2

WETCORR instrument used for measuring the wetness impact on stone facades

STEP-CT90-0107

Svein E. Haagenrud and Jan F. Henriksen

Contents

Summary

Inside the STEP project STEP-CT90-0107 a study of the local impact of temperature and wetness has been carried out by use of WETCORR instruments. The new developed WETCORR instruments worked as planned through the test period, and increased knowledge about the deterioration processes on Nidaros Cathedral in Trondheim, Norway, was obtained.

Based on the last years testing results, the WETCORR instrument today is sold to several countries and they are also used in a new EU project, WOOD-ASSESS.

WETCORR instrument used for measuring the wetness impact on stone facades

STEP-CT90-0107

1. Introduction

The Norwegian Institute for Air Research's (NILU) task to the STEP project STEP-CT90-0107 "Conservation of historic buildings, monuments and associated cultural property" was to provide WETCORR instruments for selected sites for measuring the wetness impact of stone facades and to make an interpretation of the results.

The WETCORR instrument was developed in an EUREKA/EUROCARE project EUROCARE WETCORR EU 615. Due to some delays in the production, the use of the WETCORR instrument in STEP-CT90-0107 was limited to Nidaros Cathedral and to a study on artificial facade at Trinity College, Dublin.

2. The WETCORR instrument concept

Deterioration of most materials is caused by the impact of the environment where the local influence of rain, dew and water absorption to hydroscopic salts play an important role. The WETCORR instrument was designed to record this local impact of the wetness and temperature parameters.

The principle of the instrument is shown in Figure 1. The instrument consists of three units:

- 1 System Controller for controlling the setting of the instrument, supporting of the current needed and data collection and storage.
- Up to 16 Sensor Adapters where each adapter controls the data from four sensors.
- Up to 64 Sensors for recording the temperature and the time of wetness.

A short presentation of the instrument with sensors is given in Annex 1, NILU information No. 2 1994.

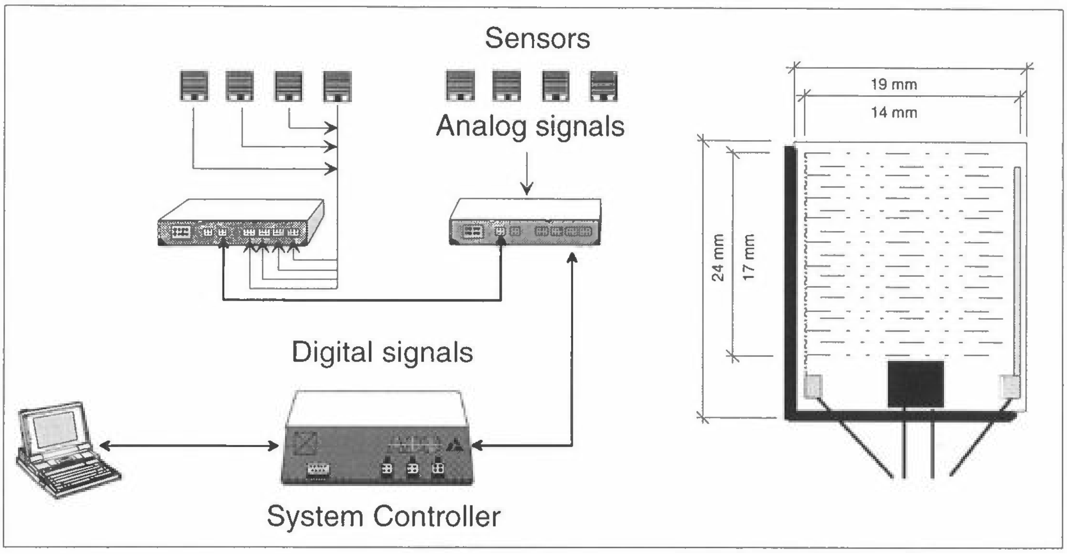


Figure 1: The principle for the WETCORR instrument.

3. Field tests

Beside the measurements carried out in STEP-CT90-0107 a Nordic field test programme has been carried out at the following institutes:

- The Swedish Corrosion Institute,
- Swedish Institute for Building Research (now Royal Institute of Technology, Material Technology Division),
- Danish Building Research Institute,
- Icelandic Building Research Institute,
- Svennerstedt Consulting, Lund, Sweden.

The main conclusions from all these field tests are given in a NILU report (Henriksen and Haagenrud, 1994).

4. Research at Nidaros Cathedral

Nidaros Cathedral in Trondheim is the most prestigious soapstone building in Norway with several deterioration problems. In STEP-CT90-0107 a study at two different facades was carried out. The two facades were:

- The octagon of the East Chapel, which is the oldest part of the church.
- The West front of the church, which is the largest and most decorated part of the church.

The measurements were carried out in the period October 1992 to April 1993. The main conclusions from the study were that the octagon was completely sheltered from driving rain, and that the main problem was the absorption of hygroscopic salts to the surface. In the polluted history of the city, sulphate was a part of the salt mixture, while today chloride as sea-salt aerosol is dominating. Fluctuation between dissolved salts and recrystallization is the dominating deterioration process.

The west facade was regularly washed with driving rain and absorption of salts was a problem only in small sheltered areas. The driving rain leaked into the facade and dissolved the calcareous mortar in the wall. Freezing and thawing cycles accelerate the deterioration process.

The complete report is only in Norwegian (Støre, 1994). However, the most important results were presented at the international RILEM/UNESCO Congress in Paris 1993 (Henriksen et al., 1993) (Annex 2).

5. Benefit of the project result

A clearer understanding of the deterioration processes at the Nidaros Cathedral is achieved. The WETCORR instrument has worked as planned at all test sites. However, the interpretation of the results needs scientific skill, and the WETCORR instrument should mainly be used by scientific groups.

Based on the test results for the different projects, the use of the WETCORR instrument has now been extended and the instrument has been sold to following countries: Sweden, Denmark, Iceland, Germany, Australia and Norway.

The WETCORR instrument plays an important part in the EU project ENV4-CT95-0110 Wood-Assess.

6. Publications

Henriksen, J.F., Haagenrud, S.E. and Støre, M.(1993) Monitoring of the wetness impact on buildings by means of a new instrument for continuous recordings. In: *Proceedings of the International RILEM/UNESCO Congress "Conservation of Stone and Other Materials"*, June 29–July 1, 1993, Paris. London, SPON, pp. 784-791.

7. Reports

Henriksen, J.F. and Haagenrud, S.E. (1994) The EUREKA project EU 615 EUROCARE WETCORR. Report from the NBS-MK seminar at ABB Conference Centre, Billingstad, 24 November 1993. Lillestrøm (NILU OR 37/94).

Støre, M. (1994) Measurements of moisture conditions on the Nidaros Cathedral with a WETCORR instrument. Lillestrøm (NILU OR 9/94) (in Norwegian).

Annex 1

NILU Information No. 2, 1994

I stedet for denne siden legges
faktablad nr. 2/94
"Wetcom in buildings"

Norwegian Institute for Air Research

No. 2 1994

NILU INFORMATION

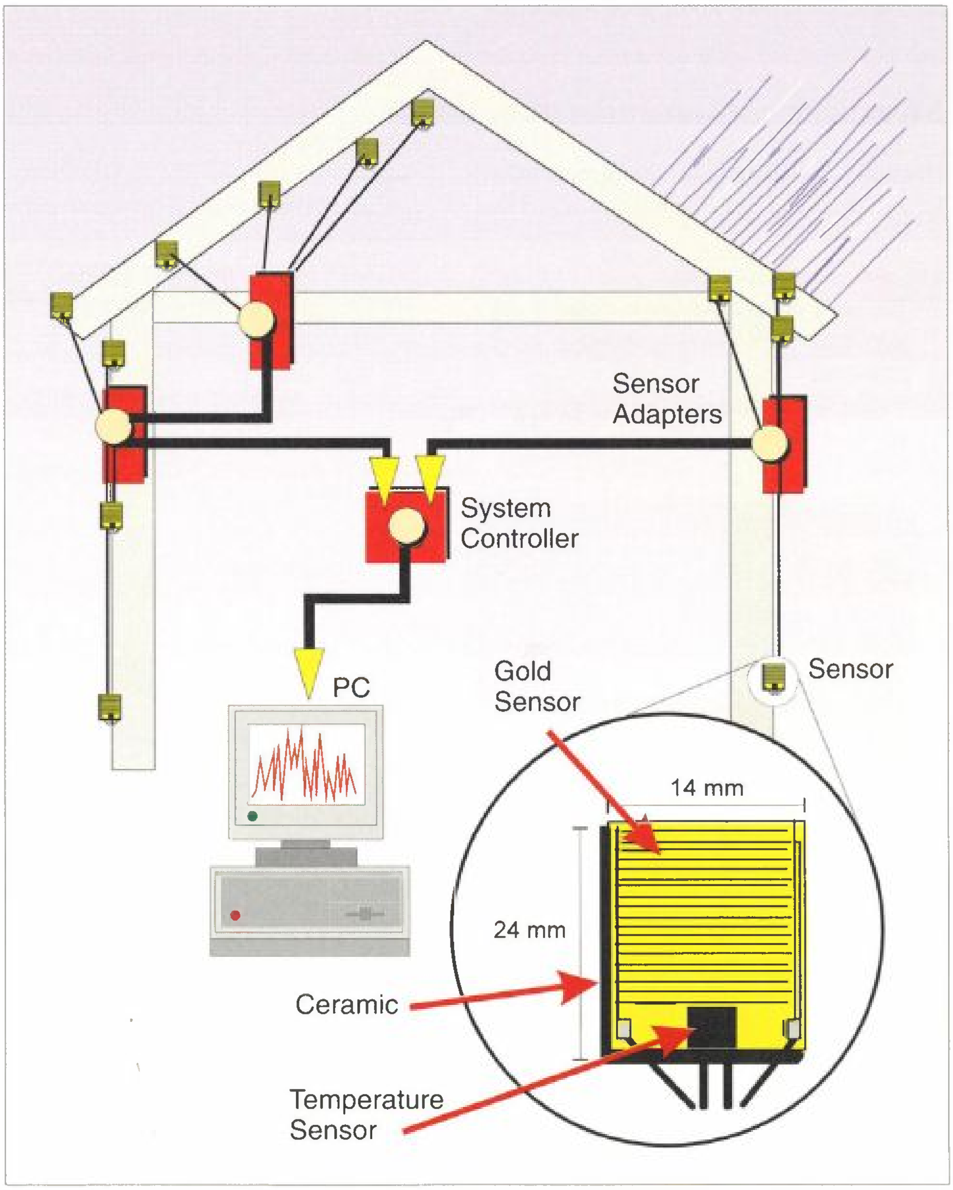
WETCORR in buildings

The WETCORR instrument has been developed by NILU to measure temperature and humidity conditions in the micro-environments on surfaces and within building materials.

Material deterioration is caused by chemical reactions where moisture humidity often plays an important role. The chemical reactions increase with increasing humidity, and for most materials a critical humidity level can be defined. Above this level the deterioration is usually substantial. The time period when the material is exposed to conditions above this critical level is defined as the time of critical humidity (TOCH).

The understanding of the deterioration processes is best known for metals, but the humidity impact has also been observed for other building materials like wood, stone, rendering and concrete.

Consequently there is a great need for mapping the humidity conditions in the micro-environment; on the surfaces and inside various building materials. The WETCORR instrument can be used for such applications.



WETCORR measurements on and within building materials

Postal address:
P.O.Box 100
N-2007 KJELLER, Norway

Office address:
Instituttveien 18
N-2007KJELLER

Telephone: +47 63 89 80 00
Telefax: +47 63 89 80 50
Telex: 74854 nilu n

Bank: 5102.05.19030
Postgiro: 3 30 83 27

Annex 2

Proceedings from the International RILEM/UNESCO Congress "Conservation of Stone and Other Materials", June 29–July 1, 1993, Paris.

96 MONITORING OF THE WETNESS IMPACT ON BUILDINGS BY MEANS OF A NEW INSTRUMENT FOR CONTINUOUS RECORDINGS (EUREKA PROJECT EU 615 EUROCARE WETCORR)

J.F. HENRIKSEN, S.E. HAAGENRUD and M. STØRE
Norwegian Institute for Air Research (NILU), Lillestrøm, Norway

Abstract
The time of wetness (TOW) is an important degradation factor for buildings and construction. At the Norwegian Institute for Air Research (NILU) different methods for recording the real time of wetness (TOW) have been studied for many years. The experience obtained has led to the development of an instrument (WETCORR) for continuous monitoring of the wet condition. The instrument has been tested in different applications in Norway and in other countries. The results will be presented together with the new instrument developed in a EUREKA/EUROCARE project between NILU, ABB Miljøkontroll, Norway, Swedish Institute for Building Research (SIB) and Swedish Corrosion Institute (SCI). The instrument has many potential applications for measurements of humidity and wetness in the micro-environment, such as mapping of humidity conditions, surveillance of humidity condition on the outside and inside of buildings and materials, studies of porous materials and paint performance influenced by moisture, etc.
Keywords: Time of Wetness, Stone Deterioration, Wetness Instrument, Water Absorption.

1 Introduction

The deterioration of materials exposed in atmospheric environments mainly occurs when the surface is wet. A sensor that records the time of wetness will therefore describe a major degradation factor for materials.

The Norwegian Institute for Air Research has studied atmospheric degradation factors for 20 years. These studies have included development of an instrument for measuring the real time of wetness. The development and measurements have been performed in close collaboration with other Nordic research institutes like SIB and SCI (Haagenrud et al., 1982 ; Haagenrud et al., 1984 ;

Conservation of Stone and Other Materials. Edited by M.-J. Thiel. © RILEM.
Published by E & FN Spon, 2–6 Boundary Row, London SE1 8HN. ISBN 0 419 18850 9 (vol. 2).

Haagenrud et al., 1985a ; Haagenrud and Henriksen, 1989).

2 The new WETCORR instrument concept

In 1989 NILU decided to industrialize their laboratory model, based on the same basic measuring principle, but taking advantage of new technology. Together with an industrial partner, ABB Miljøkontroll, an environmental group inside the ASEA Brown Boveri consolidated group, and SIB, a EUREKA/EUROCARE project was launched in 1990. From summer 1992, ten test prototypes of the new instrument have been tested out in various R&D projects in Europe.

The measuring principle of the instrument is to record the current generated in electrolytic cells during atmospheric exposure, and calculate the TOW as the time when the cell current exceeds a fixed value. The theory for interpretation of the results was published in 1985 (Haagenrud et al., 1985b).

When designing the new WETCORR instrument, it was decided to make an instrument with high flexibility adaptable for different applications. The resulting system is shown in Figure 1. It consists of three units; 1 System Controller, 1 to 16 Sensor Adapters with 4 measuring cells for each adapter. Fully equipped, the instrument is able to measure the wetness condition at 64 different points.

The System Controller is the main controlling and data storage unit with a 4 MB memory. The unit reads the selected voltage to the cells and collects the average temperatures and cell current data, which are generated in the Sensor Adapter for the selected recording periods.

The TOW sensor consists of two gold electrodes which form a finger pattern on a ceramic backing with an insulation gap between the fingers of the electrodes of 127 µm. The size of the TOW sensor is 14x17 mm. A thermistor of type AD 592 is also attached (see Fig. 1).

The temperature signal and the cell current are transferred to the Sensor Adapter as analog signals and transformed into digital signals in the adapter. The current sensitivity is 1 nA and the measuring range is 10^{-9} - 10^{-3} A.

To minimize stray current effects, the distance between the cells and the adapter is kept small, preferably below 2 metres.The Sensor Adapter therefore had to be designed as rainproof for outdoor application.

The System Controller is for indoor use only and is able to communicate with sensor adapters at distances up to 250 metres in two lines, which gives a total range of 500 metres.

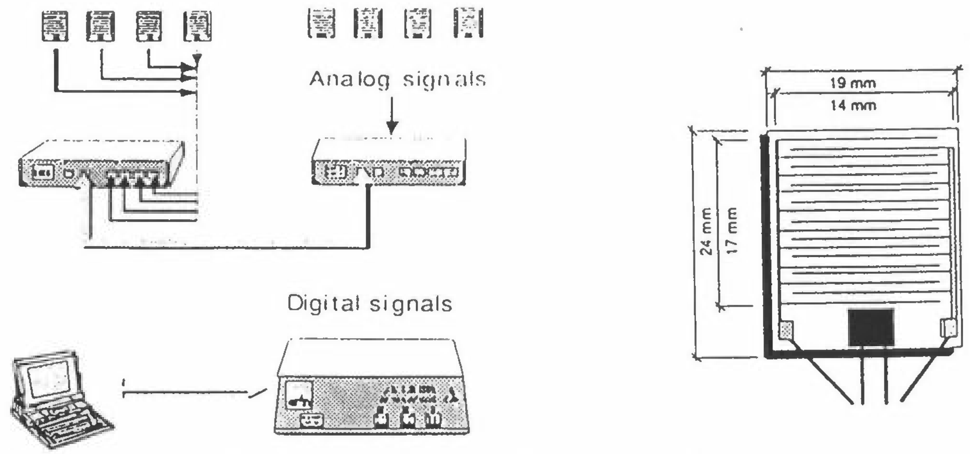


Fig.1. The principle scheme of the WETCORR monitoring system and the gold measuring cell.

The System Controller has an RS-232C serial interface and the communication is established by means of a PC, preferably a 386, and an ANSI terminal; communication can also be made through a modem.

A data processing programme "RingSys" has been developed at NILU for the processing and presentation of the data.

3 Quality control

A quality control of the stability and accuracy of the prototypes has been carried out. The results showed that the standard deviation of measurements is much lower than the specified requirements. At a current value around 10 µA, the standard deviation for all adapters was 0.3%.

The gold thickness of the sensor was 1.5 µm ± 0.25 µm, while the width of the electrode fingers and the insulation gap between them were 127 ± 2 µm. A microscope control showed that the cells followed these requirements very well.

A climate chamber test with rain pH 4.2 showed that the current response of a clean cell was low even at very high degrees of wetness. After an open air exposure which included at least two events with rain, the cell response reached the acceptable current level. The response difference between wet and dry conditions was of the order of 100 nA.

A reproducibility test with 16 measuring cells exposed on a plexiglas sheet facing south with an angle of 45° was carried out. After 42 days of testing, the conclusions drawn were that the current pattern was the same for all

16 cells and the recorded time of wetness (TOW) was 31 ± 2% of the exposure time. By calculating the TOW according to the ISO standard (TOW = the time with temperature > 0°C and relative humidity > 80%) from simultaneous thermo-hygrographic measurements, a TOW value of 37% was obtained.

4 Experiences from field tests

Two of the WETCORR instruments were used in NILU research projects. One was tested in different applications on the roof of NILU's own building, while the second was used in the EEC STEP project "Conservation of Historic Buildings, Monuments and Associated Cultural Property". The measurements are performed at Norway's most prestigious building, the Nidaros Cathedral in Trondheim.

5 Outdoor exposure of 8 cells at NILU

During 42 days in spring and summer 1992, eight measurings cells were exposed on the south facade of the building. The building material was coil coated steel. Site 1 was a freely exposed site on the top of the metal flashing and was used as a test spot for the rainy conditions that occur in an unsheltered place. Site 2 was a sheltered site between the wall and the metal flashing. Site 3 and 4 were sites on the vertical wall, freely exposed to drifting rain.

The results showed very good agreement between the parallels. At site 1 the cell response was in good agreement with the weather observations and gave TOW values for 38% of the exposure time.

Fig. 2 gives the results from site 2 and 3. At the sheltered position (site 2) condensate and slow drying up cycles gave 60% TOW at that position for both cells.

At sites 3 and 4, the vertical positions on the wall, the TOW was much lower, only 10% of the exposure time. This reflects two main characteristics. Firstly, drifting rain occurs only occasionally, particularly during the summer. Secondly, on the south face the sun heats up the wall and the cell quickly, and reduces the time with wet cells.

6 Research at Nidaros Cathedral

Nidaros Cathedral in Trondheim is the most prestigious soapstone building in Norway but has several deterioration problems. To study some of these problems, mapping

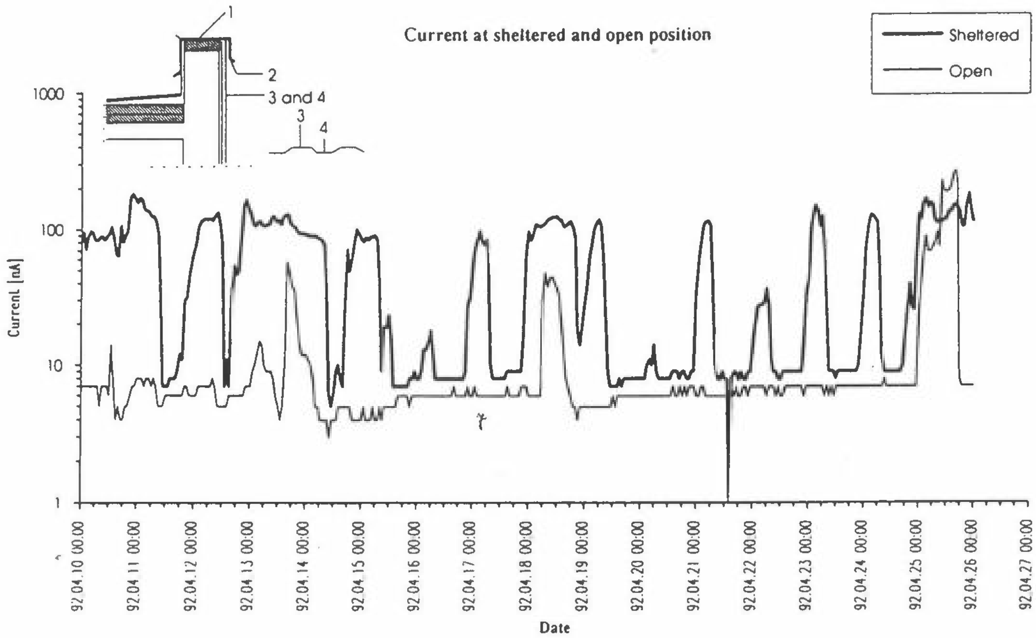


Fig.2. The results from the spring test on the wall of NILU's building, sheltered (2) and open (3) positions.

of the wetness impact on different parts of the facades was carried out.

In autumn 1992 a study at the east part of the church, the octogon of East chapel, was carried out. This part of the church is hardly ever affected by rain, nevertheless substantial stone deterioration has been observed on most of the stone facade. The basic thought has been that deterioration products absorb water during high humidity conditions and recrystallize during dry periods. To study this idea 16 cells were applied to the octogon. Two of the cells were put up out from the wall as references for detecting the main events with rain and the air temperature (Fig. 3). The 14 cells were attached on the walls, 4 on the south, 6 on the east and 4 on the north side. To study the effect of the deterioration products, 6 of the cells were treated with a slurry of water and deterioration product and then dried before the cells were attached; the other cells were kept clean. In this way a comparison can be made between the results for the reference rain cells, the same clean cell on the wall for drifting rain, and the cell contaminated with hygroscopic salts.

The results from the period 5th to 19th October 1992 are used to explain the main trends observed so far (Fig. 4 and 5). The reference cell (cell 1) recorded rain for most of the period 7th to 13th October. Actually the

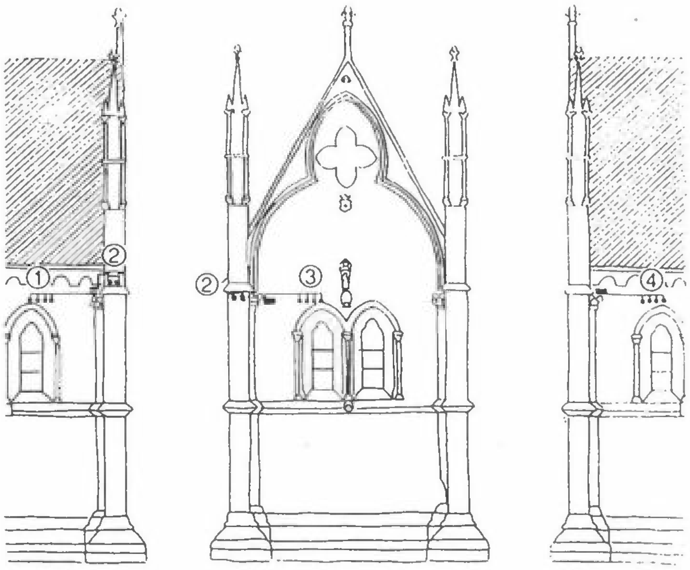


Fig.3. The monitoring set-up at the East chapel.

precipitation measured on the 8th October was the largest ever observed in Trondheim. From the 14th October the weather improved with clear sky and low temperatures for the rest of the period. The cell was facing south and the sun hits the cell in the middle of the day around 12 o'clock. This led to a sharp increase temperature on the 5th, 9th, 14th, 15th, 16th, 17th and 18th October. The measurements from the cells on the wall were quite different. Only on the rainy days, 8th and 10th October, the current of the clean cells increased for a short time to a level where we could describe the cells as wet. The clean cells gave low reaction, but the small changes in the current observed gave the same pattern as the contaminated ones. The current flow of the contaminated cells was of the same magnitude as for the reference. However, the changes with time are much smaller and the cell dried out only on the evening 15th October. The next day dew had formed on the cell and the current was high again. This took place even if the temperature of the cells was below 0°C. This indicates that the deterioration product has formed an electrolyte with lower freezing point than 0°C. The results are comparable for all three sides and showed that absorption and desorption of water took place on the stone surface. This mechanism contributes to the deterioration processes by salt crystallization on the surfaces. Washing out of the deterioration products did not take place during this period even on the extremely wet days, 8th and 10th October.

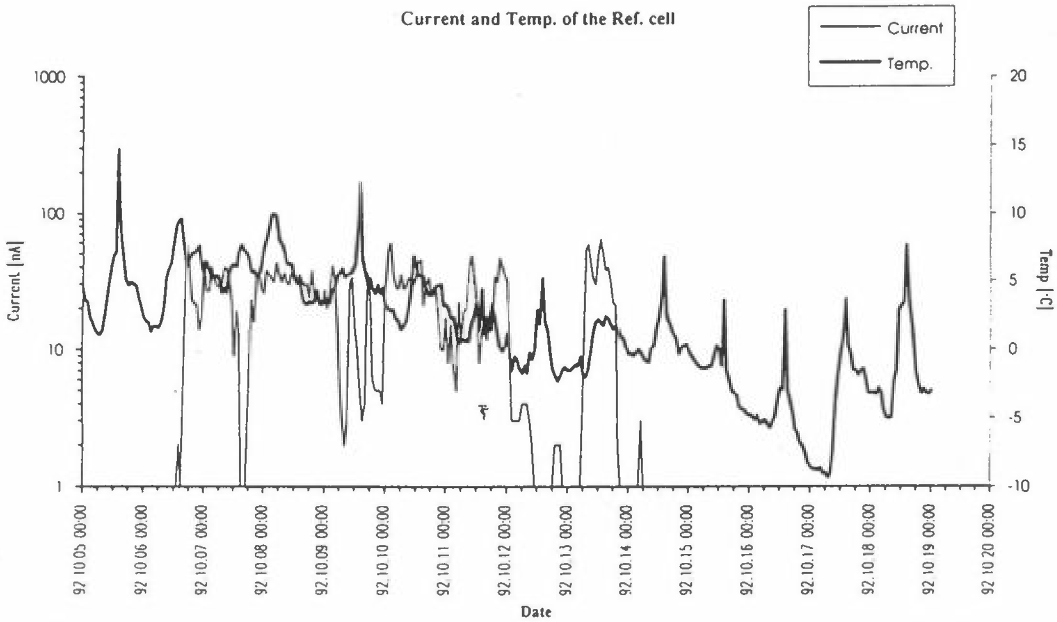


Fig.4. The wetness and temperature measurement of the reference cell in the period 5th to 19th October 1992.

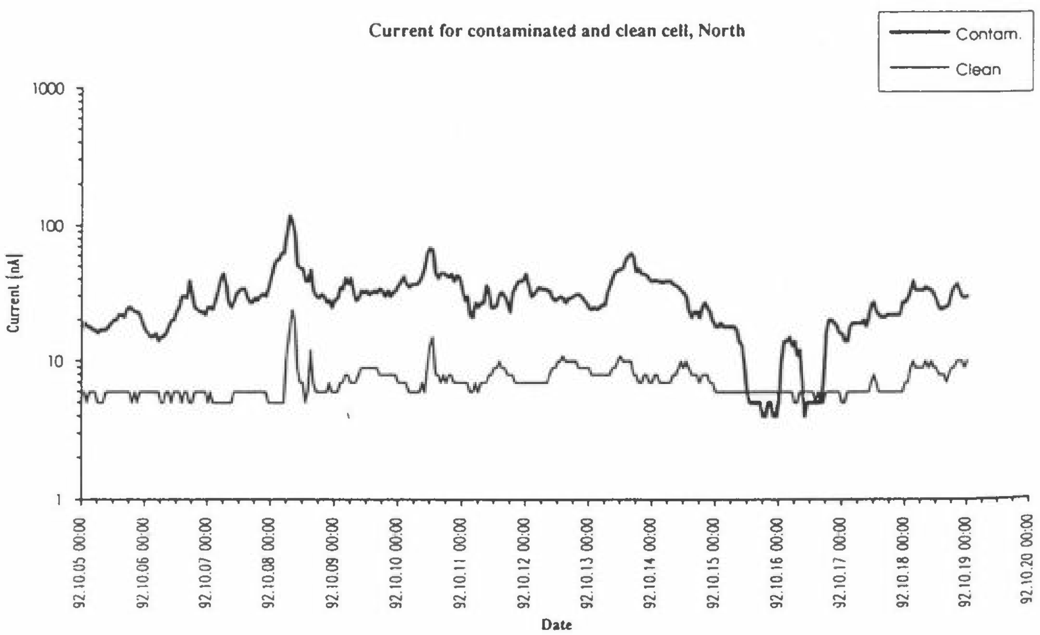


Fig.5. The wetness measurements on clean and contaminated cells on the wall of the East chapel of the Nidaros Cathedral in the period 5th to 19th October 1992.

7 Future applications

In the test programme, the 10 prototypes were tested in various applications. The WETCORR instrument has many potential applications for measurements of humidity conditions, such as:

- Recording of wetness impact (TOW) on materials for dose-response studies.
- Mapping of internal and external humidity conditions of building and constructions.
- Warning system for critical humidity loads in buildings and constructions.
- Study of the paint performance and other coatings under different wetness situations.
- Study of the water migration inside materials like wood, concrete and other porous materials.
- Study of the absorption desorption cycles of different deterioration products under different weather conditions.

8 References

Haagenrud, S.E., Kucera, V. and Gullman, J. (1982) Atmospheric corrosion testing with electrolytical cells in Norway and Sweden, in **Internat. Symp. on Atmospheric Corrosion,** Hollywood, Florida, 1980, (ed W.H. Ailor), Willey NY, pp. 669-693.

Haagenrud, S.E. Haagenrud, Henriksen, J.F., Danielsen, T. and Rode, A. (1984) An electrochemical technique for measurement of time of wetness, in **3rd int. conference on the durability of building materials and components,** Espoo, Finland, pp. 384-401.

Haagenrud, S.E., Henriksen, J.F. and Svennersted, B. (1985a) Time of wetness measurements on World-Pilot study with the NILU WETCORR method. Lillestrøm, Norway (NILU OR 17/85).

Haagenrud, S.E., Henriksen, J.F. and Wyzisk, R. (1985b) Electrochemical Characteristics of the NILU/SCI atmospheric corrosion monitor, in **"Corrosion 85"**, NACE, Boston, USA.Paper no. 83.

Haagenrud, S.E. and Henriksen, J.F. (1989) A Continuous Monitor for time of wetness (TOW) measurements in the micro-environment, in Proceedings **"Science, Technology and European Cultural Heritage"** 1989 (eds N.S. Baer, C. Sabbioni and A.I. Sors), Butterworth-Heinemann Ltd., Oxford.

Norwegian Institute for Air Research (NILU)
P.O. Box 100, N-2007 Kjeller – Norway

REPORT SERIES SCIENTIFIC REPORT	REPORT NO. OR 21/97	ISBN 82-425-0868-2 ISSN 0807-7207	
DATE 14.4.97	SIGN. Øystein Hov	NO. OF PAGES 16	PRICE NOK 30.-
TITLE WETCORR instrument used for measuring the wetness impact on stone facades STEP-CT90-0107		PROJECT LEADER S.E. Haagenrud	
		NILU PROJECT NO. O-91023	
AUTHOR(S) Svein E. Haagenrud and Jan F. Henriksen		CLASSIFICATION * A	
		CONTRACT REF. STEP-CT90-0107	

REPORT PREPARED FOR:
European Commission
Directorate General XII
Science, Research and Development
Brussels, Belgium

ABSTRACT
Inside the STEP project STEP-CT90-0107 a study of the local impact of temperature and wetness has been carried out by use of WETCORR instruments. The new developed WETCORR instruments worked as planned through the test period, and increased knowledge about the deterioration processes on Nidaros Cathedral in Trondheim, Norway, was obtained.
Based on the last years testing results, the WETCORR instrument today is sold to several countries and they are also used in a new EU project, WOOD-ASSESS.

NORWEGIAN TITLE

KEYWORDS		
Wetness	Stone deterioration	Instrument

ABSTRACT (in Norwegian)

** Classification* — *A* *Unclassified (can be ordered from NILU)*
B *Restricted distribution*
C *Classified (not to be distributed)*