Established 1955

INSTITUTE OF NUCLEAR PHYSICS
HENRYK NIEWODNICZAŃSKI
Department of Nuclear Radiospectroscopy

RESULTS

RELAXATION-TIME STUDIES OF WATER SAMPLES

In the MR Tomography Laboratory, Department of Nuclear Radiospectroscopy, of the Institute of Nuclear Physics, spin-lattice relaxation-time measurements T1 were performed on water samples supplied by FENIX of Gliwice.

Five water samples designated A1, B1 and C1 were supplied, originating from the evaporative-cooling system of the open-hearth furnaces at the Łabędy Steelworks, taken respectively before the system - raw water; after passage through the magnetic field of a RAM-type device; from steam condensate of raw water; and samples designated A and B, taken from the test system at the Silesian University of Technology in Gliwice, where A - raw water, B - water after passage through the magnetic field of the RAM-type device. The water was supplied in glass bottles of approximately 100 ml, closed with plastic caps.

- Spin-lattice relaxation-time measurements and apparatus

Measurements were made with an MR microtomograph operating in a 6.4 T magnetic field at 270 MHz for protons. The measurements used an inversion-recovery sequence consisting of a magnetization-inverting RF π pulse, a variable waiting time τ, followed by an RF π/2 pulse measuring the recovery of magnetization to equilibrium. Immediately after the π/2 pulse, the free-induction decay (FID) signal was recorded. By varying τ, a 2D matrix of signals was acquired, from which spin-lattice relaxation times T1 were determined by analysis.

Measurements used π/2 pulses 27 μs long, and π pulses 54 μs long; magnetization recovery was recorded at 32 equally spaced points up to 9 s. Between measurements, 10 s was allowed for recovery of magnetization M0. Measurements were made at room temperature, 22 °C.

Water from the transport bottles was transferred with a clean plastic syringe into clean glass sample tubes of 6 mm internal diameter, which were placed in the MR microtomograph probe head.

The measurement results were analyzed using the "MULTIFID", which fits a multi-exponential magnetization-recovery curve and determines relaxation time T1. The program printout provides fitting parameters and errors.

H. Niewodniczański Institute of Nuclear Physics, Departament of Nuclear Radiospectroscopy
Address: Radzikowskiego 152, 31-342 Kraków. Poland
tel. (012) 37-02-22, tlx. 322461 ifj pl, fax 37-54-41

- Measurement results

The measurement results obtained are shown in the printouts on pp. 3 and 4. Figures 1 and 2 show magnetization recovery on a logarithmic-linear scale. They show that magnetization recovery follows a single exponential, as expected for water samples.

The following spin-lattice relaxation-time results were obtained for the tested samples at a temperature of 22 °C:

Sample	T1 [ms]	Error [ms]
A1	2770	+/- 37
B1	3010	+/- 57
C1	2880	+/- 53
A	3010	+/- 66
B	2980	+/- 56

The results show that samples A1 and B1 have different relaxation times, by an amount well above the measurement error, whereas sample A1 - raw water - and C1 - condensate from raw water - have the same relaxation times within the measurement error. Likewise, samples A and B have the same relaxation times.

These results show that after passing through the magnetic field of the RAM device, the water changed its properties so that its relaxation time increased by nearly 10%. This change may be associated with a change in the manner in which oxygen dissolved in the water and paramagnetic ions dissolved in the water are bound; these factors determine the value of the relaxation time. These measurements cannot answer the question of which mechanism determines the changes in water properties in the RAM device. This requires further measurements.

The same relaxation-time value for samples A1 - raw water - and C1 - steam condensate from raw water indicates that, in this case, in both samples the factor determining relaxation time is oxygen dissolved from the atmosphere. Otherwise, one would expect the steam-condensate sample, which should contain no impurities other than those originating from the system, to have a significantly different relaxation time from the raw-water sample.

Samples from the test system at the Silesian University of Technology have the same relaxation times, demonstrating a complete absence of any effect of passage through the RAM system on the properties of the water.

24/06/94

KIEROWNIK
Pracowni Tomografii MRI
doc. dr hab. Andrzej Jasiński

MEASUREMENT RESULTS

```
 Filename : a1mag_1.fit
sample          a1                      298K
######             Mrq             ###### Initial Chi^2 :     0.000000

######End of Marquardt minimization######  Final  Chi^2 :      9.37153
                                          Chi^2/(N-np):     0.195240
                                          No of Iter. :           25

Covariance matrix :
  0.000  0.000  0.000                            M0   -.249E-01 +/-.476E-02
  0.000  0.000  0.000                           %T11  0.104E+01 +/-.471E-02
  0.000  0.000  0.001                            T11  0.277E+01 +/-.377E-01

Sum of residuals                :      0.326615E-05
Number of positive residuals    :             18
Number of negative residuals    :             33
Number of change of resid. sign :             21
Interval of residual values     :     -0.752893E-02    0.122317E-01
First residual                  :     -0.182271E-03

--------------------------------------------------------------------------------
 Filename : b1mag_1.fit
sample b1                               298K
######             Mrq             ###### Initial Chi^2 :      9.37153

######End of Marquardt minimization######  Final  Chi^2 :      8.35513
                                          Chi^2/(N-np):     0.288108
                                          No of Iter. :            8

Covariance matrix :
  0.000  0.000  0.000                            M0   -.338E-01 +/-.606E-02
  0.000  0.000  0.000                           %T11  0.104E+01 +/-.636E-02
  0.000  0.000  0.003                            T11  0.301E+01 +/-.568E-01

Sum of residuals                :     -0.433996E-06
Number of positive residuals    :             11
Number of negative residuals    :             21
Number of change of resid. sign :             16
Interval of residual values     :     -0.604284E-02    0.141607E-01
First residual                  :      0.486267E-02

--------------------------------------------------------------------------------
 Filename : c1mag_1.fit
sample c                                298K
######             Mrq             ###### Initial Chi^2 :      8.35513

######End of Marquardt minimization######  Final  Chi^2 :      5.34590
                                          Chi^2/(N-np):     0.184342
                                          No of Iter. :           22

Covariance matrix :
  0.000  0.000  0.000                            M0   -.210E-01 +/-.566E-02
  0.000  0.000  0.000                           %T11  0.104E+01 +/-.634E-02
  0.000  0.000  0.003                            T11  0.288E+01 +/-.529E-01

Sum of residuals                :      0.129119E-04
Number of positive residuals    :             17
Number of negative residuals    :             15
Number of change of resid. sign :             12
Interval of residual values     :     -0.746451E-02    0.793834E-02
First residual                  :     -0.637305E-02

--------------------------------------------------------------------------------
```

MEASUREMENT RESULTS

Filename : a0mag_1.fit

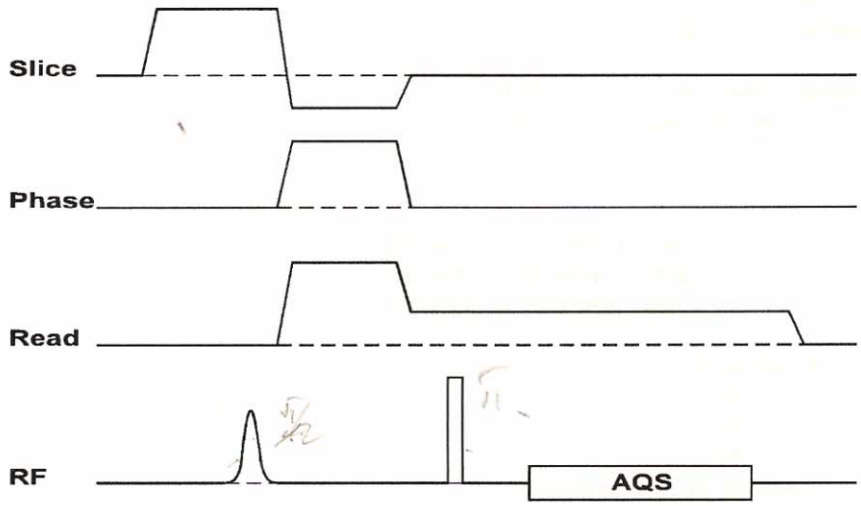
sample a 298K

```
######            Mrq            ###### Initial Chi^2 :     5.34590

######End of Marquardt minimization######  Final  Chi^2 :     3.70135
                                          Chi^2/(N-np):    0.127633
                                          No of Iter. :           4

Covariance matrix :
  0.000  0.000  0.000                              M0   0.393E-01 +/-.605E-02
  0.000  0.000  0.000                             %T11  0.900E+00 +/-.739E-02
  0.000  0.000  0.004                              T11  0.301E+01 +/-.657E-01

Sum of residuals               :      0.149012E-07
Number of positive residuals   :             10
Number of negative residuals   :             22
Number of change of resid. sign :            15
Interval of residual values    :     -0.680938E-02    0.860843E-02
First residual                 :      0.566339E-02
```

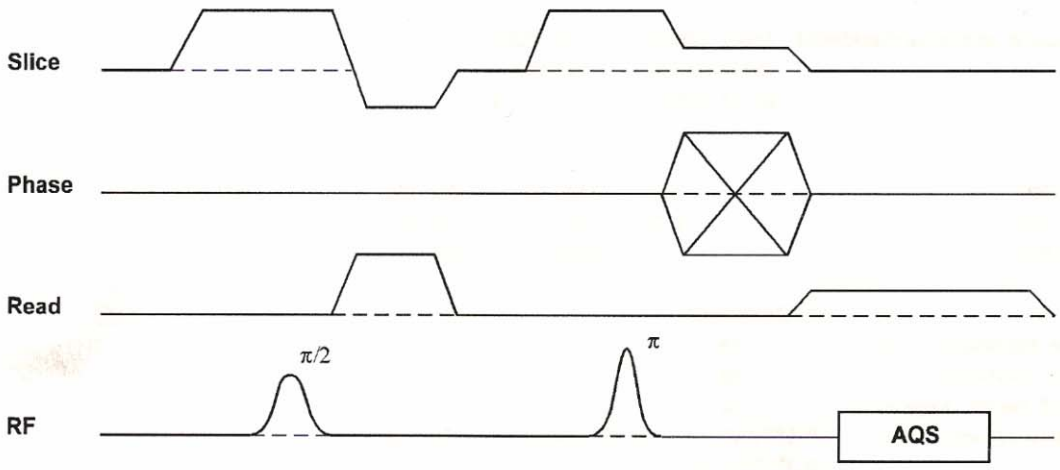
Filename : b0mag_1.fit

sample b 298K

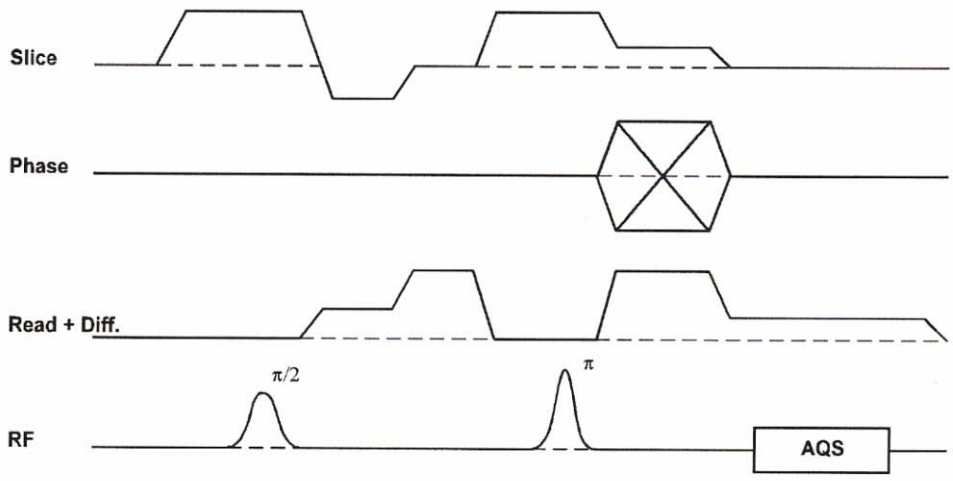
```
######            Mrq            ###### Initial Chi^2 :     3.70135

######End of Marquardt minimization######  Final  Chi^2 :     5.80084
                                          Chi^2/(N-np):    0.200029
                                          No of Iter. :           3

Covariance matrix :
  0.000  0.000  0.000                              M0   -.310E-01 +/-.598E-02
  0.000  0.000  0.000                             %T11  0.104E+01 +/-.637E-02
  0.000  0.000  0.003                              T11  0.298E+01 +/-.560E-01

Sum of residuals               :     -0.139698E-06
Number of positive residuals   :             16
Number of negative residuals   :             16
Number of change of resid. sign :            16
Interval of residual values    :     -0.587490E-02    0.975536E-02
First residual                 :     -0.359201E-02
```



12. Imaging Soft-Hard



13. SSI



14. SSDI

Figure No. 1

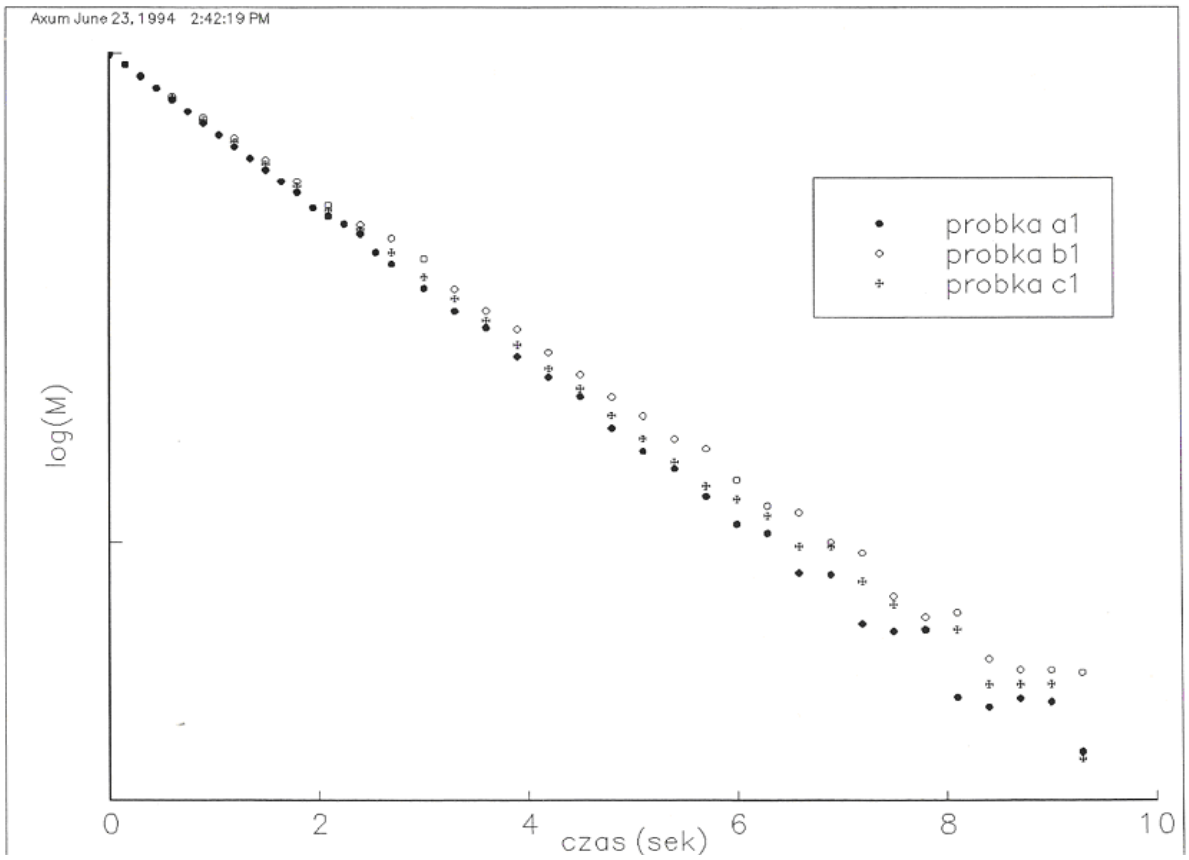
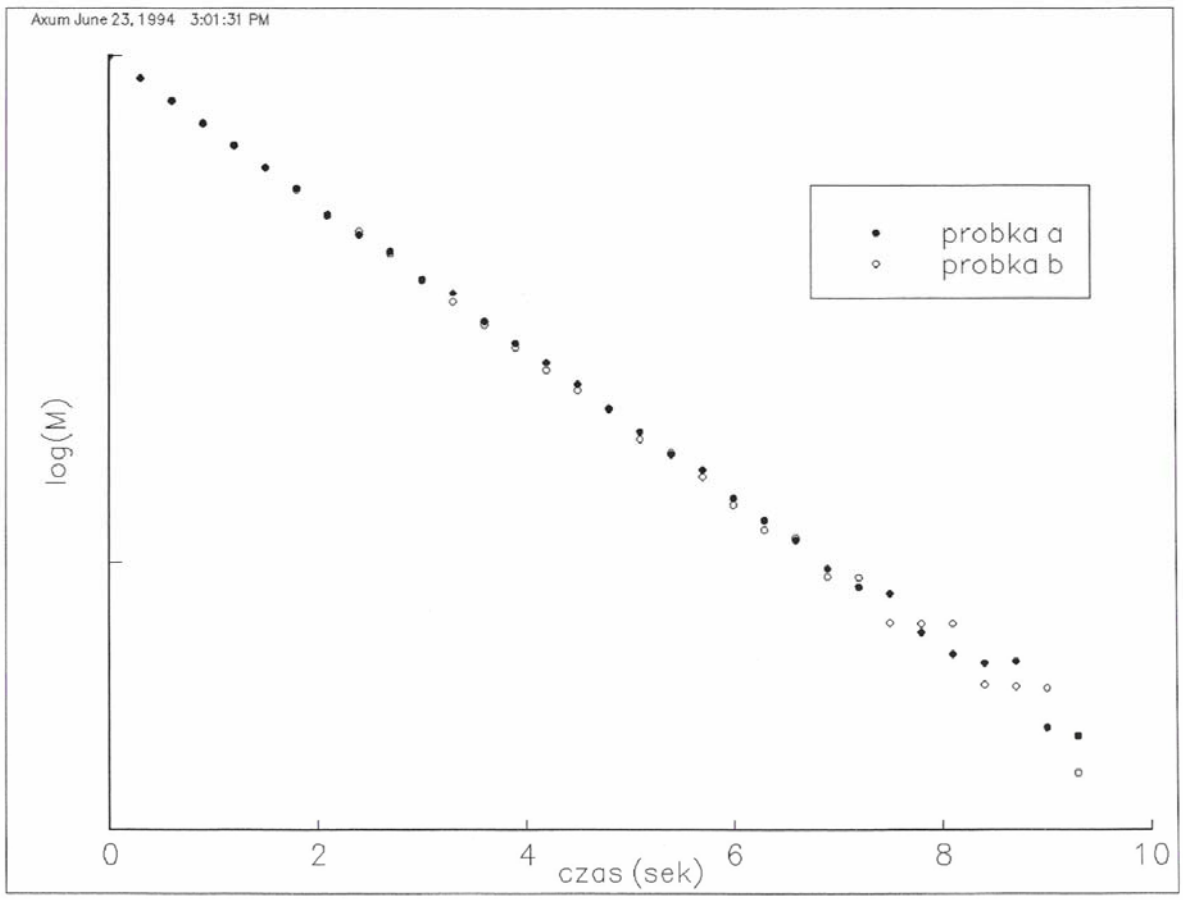
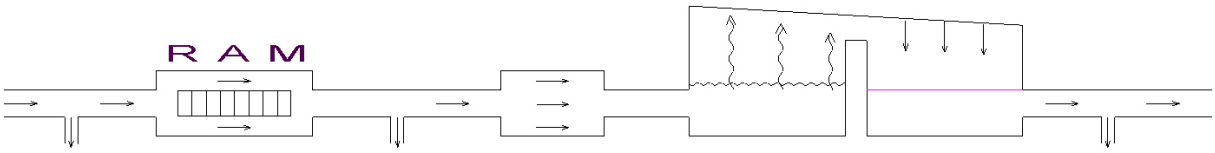


Figure No. 2

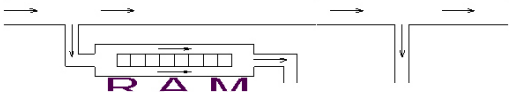


Comment
on the results of the T1 relaxation-time measurement of water carried out by the Institute of Nuclear Physics in Kraków on 24 June 1994.

The purpose of the measurements carried out by the Institute was to determine whether the relaxation time
changes in water exposed to the magnetic field of the RAM device. Samples of raw water and steam condensate from the evaporative-cooling system of open-hearth furnaces
at the Łabędy Steelworks were submitted for measurement.
The samples were designated as follows:
A1 - raw water, before passage through the magnetic field
B1 - raw water A1 after passage through the magnetic field
C1 - steam condensate from water B1



and samples of raw water from the system in the laboratory of the Silesian University of Technology:
A - raw water upstream of the RAM device
B - raw water A after passage through the magnetic field



Sample C1 was submitted for measurement despite the technical impossibility of comparing it with
steam condensate from raw water A1. The purpose was to determine the relaxation time of the condensate which, as observed, broke down deposits formed in the system during the preceding period. This was recorded in the prepared report.

The measurement carried out for samples designated A and B showed no differences within the measurement error. It is believed that this was caused by the water flow velocity through the device being too low
(below 0.5 m/s). This low velocity resulted from the presence of a large amount of deposits in a section of piping in the Silesian University of Technology laboratory.
A sufficiently high water-flow velocity in the magnetic field of the RAM device is of decisive importance for obtaining changes in its physical properties. This is confirmed by the effects
obtained in industrial installations and by research results.

Accordingly, the only comparable results that are at the same time
confirmed by the processes occurring in the evaporative-cooling systems of open-hearth furnaces
at the Łabędy Steelworks, as described in the report attached below, are the results - showing a 10% difference in relaxation time - of measurements between sample A1 and sample B1.

The relaxation-time measurement carried out by the Institute of Nuclear Physics in Kraków, the results of which are presented above (with a magnetic-field frequency of 270 MHz for protons), was preceded by a measurement not included in this report (with a magnetic field

at a frequency of 27 MHz and with the water also at 22 °C) for the same water samples, and the results were respectively:

- for raw water A1, before its passage through the magnetic field of the RAM device - 1100 µs.
- for raw water B1, after its passage through the magnetic field - 1300 µs.
- for condensate C1, steam obtained after evaporation of the demineralized water - 1500 µs.

As follows from the facts presented above, after the water passed through the magnetic field of the "RAM" device, with the appropriate flow parameters maintained, its relaxation time changed. The limited scope of the study does not yet make it possible to establish a complete theoretical basis for the mechanisms determining these changes; therefore, this research will be continued.