SANS FACILITY AT THE PITESTI 14MW TRIGA REACTOR

I. Ionita 1), B. Grabcev 2), S. Todireanu 2), G. Popescu 5), F. Constantin 3), M. Mincu 1), E. Anghe 1), V. Shvetsov 4), A. Datcu 1)

1) Institute for Nuclear Research – Pitesti, Romania
2) National Institute of Materials Physics (NIMP) Bucharest, Romania
3) National Institute of Physics and Nuclear Engineering Bhcharest, Romania
4) Joint Institute for Nuclear Research Dubna, Russian Federation
5) National College Al. Odobescu Pitesti, Romania

E-mail address of main author: ionionita@lycos.com

At the present time, an important not yet fully exploited potentiality is represented by the SANS instruments existent at lower power reactors and reactors in developing countries even if they are, generally, endowed with a simpler equipment and are characterised by the lack of infrastructure to maintain and repair high technology accessories. The application of SANS at lower power reactors and in developing countries nevertheless is possible in well selected topics where only a restricted Q range is required, when scattering power is expected to be sufficiently high or when the sample size can be increased at the expense of resolution. Examples of this type of applications are: 1) Phase separation and precipitates in material science, 2) Ultrafine grained materials (nanocrystals, ceramics), 3) Porous materials such as concrete and filter materials, 4) Conformation and entanglements of polymer-chains, 5) Aggregates of micelles in microemulsions, gells and colloids, 6) Radiation damage in steels and alloys.

The need for the installation of a new SANS facillity at the Triga Reactor of the Institute of Nuclear Researches in Pitesti, Romania become actual especially after the shutting down of the VVRS Reactor from Bucharest.

Experimental SANS configurations suited for a stady state reactor

Any SANS configuration is formed by a monochromator unit, an analyser unit and a detecting system. In the most used instruments the analyser unit is a simple one given by the detecting system itself. The monochromator unit can by formed by one or two single crystal. For the two crystals system the spatial extension around the beam of the experimental setting is decreased significantly while the luminosity is lowered because of the second refection. A quite common configuration has a crystal monocromator and a crystal analyser the sample being positioned between monochromaror and analyser. The analyser crystal is rotated around an axis normal to the beam direction and a “rocking” curve $I(\theta)$ is recorded, representing the angular distribution os the scattered neutrons. For the case of a mechanical monochromator the monochromatic beam has the direction of the beam channel.

The selection of the optimum configuration; The selection criteria definition

For SANS the recorded curve is I(Q), Q = k_i-k_f. As the dimensions of the components are finite, a given number of counts correspond not to a certain value Q, but to $Q+\Delta Q$. The value of $\Delta\theta$ is given by the overall collimation while $\Delta\lambda$ is given only by the monochromator. We shall choose as selection criterion the value of the monochromatic beam intensity at sample corresponding to a given value of $\Delta\lambda/\lambda$. Another criterion is the instrument extension around the beam channel; the involved sum of money to realize the instrument is important as well.

For the case of crystal monocromator unit, that with one crystal is the most desirable though the instrument is somewhat extended from the beam channel axis. The SANS instrument with double crystals monochromator is significantly less extended while that with crystal monocromator and analyser allows for the very low Q values determinations. For both of them, because of the two reflections, the luminosity is rather poor. These instruments could be preferred for the case of large flux reactors as neutron source.

The SANS configuration with mechanical monochromator has significantly increased luminosity, in comparison with those having crystal monocromator units, while the spatial extension of the instrument is quite reasonable. Tacking account that TRIGA reactor existing at INR Pitesti is a medium flux reactor and that the available dimension for the SANS instrument is severely limited by the dimensions of the room where the instrument has to be installed, this experimental configuration has been chosen as the most suited for the situation existing in our institute.

For usual collimation values of about 30 minutes, and for an inclination angle of the monochromator axis of about 2-3 degrees, $\Delta\lambda/\lambda$ is about 20-30%, i.e. quite reasonable value. sample width may be fixed between 10 mm and 20 mm. The minimum value of the scattering vector is $Q_{min} = 0.005 \ \overset{o}{A}^{-1}$ while the maximal value is $Q_{max} = 0.5 \ \overset{0}{A}^{-1}$. The relative error is $\Delta Q / Q_{min} = 0.5$. In the case of our SANS instrument a monochromatic neutron beam with $1.5\overset{0}{A} \leq \lambda \leq 5\overset{0}{A}$ is produced by a mechanical velocity selector with helical slots. The distance between sample and detectors plane is (5.2 m).

Mechanical monochromator description

The monochromator length is L = 600mm, the cadmium walls defining the hellicoidal slits is Δx = 0.5 mm, the slits number is N = 180, the slits inclination angles are respectively Φ = 8^{0}, $\varphi = 2^{0}$. As the mechanical monocrhromator is practically transparent for fast neutron and for gamma radiation, this device can be used only for a thermal neutron beam. Otherwise mono or polycrystalline filters should be used to remove fast neutrons and gamma radiation. A convenient filter is the bismuth monocrystal. A DC 1kW motor to be used at a maximum angular speed of 3000 rot/min rotates the mechanical monocrhromator.

The SANS instrument (fig. 1) has the following components: The mechanical monochromator, shielding, the Bi filter, the sample table and holder, the detecting system formed by two rows of 40 He^3 detectors each, 2 flux monitors, the beam stop. Paraffine blocks and recipients with water form the shielding. The flux monitors are positioned one before the sample (in front of the monocromator window) the other in front of the beam stop. The sample can be rotated using a step by step motor. A cadmium slit system actioned by a step by step motor allows for the determination of the monochromatic beam center at the beam stop position.

The control system

The control system allows for the measure time and the monochromator angular speed setting and for record of the counts from each of the 80 He^3 detectors, given by the counters system.

The main program SANS is realised in Visual C++ for Widows. The main Dialog window is given in fig.5. At the command “start citire-start reading” the counters reading is performed and the corresponding values are displayed. This command is used just before the SANS measurement is realised, in order to verify the communication between the computer and the counters system.

In the field “parametri de achizitie” the reading time is introduced and accessing the command “Start achizitie” the measuring process is started. In the field “Salvare in” a file name is generated where the read values are saved. With the command “ Stop achizitie” the measurement can be stooped before the given measuring time is elapsed.

The read values are represented in a special field of the main window.

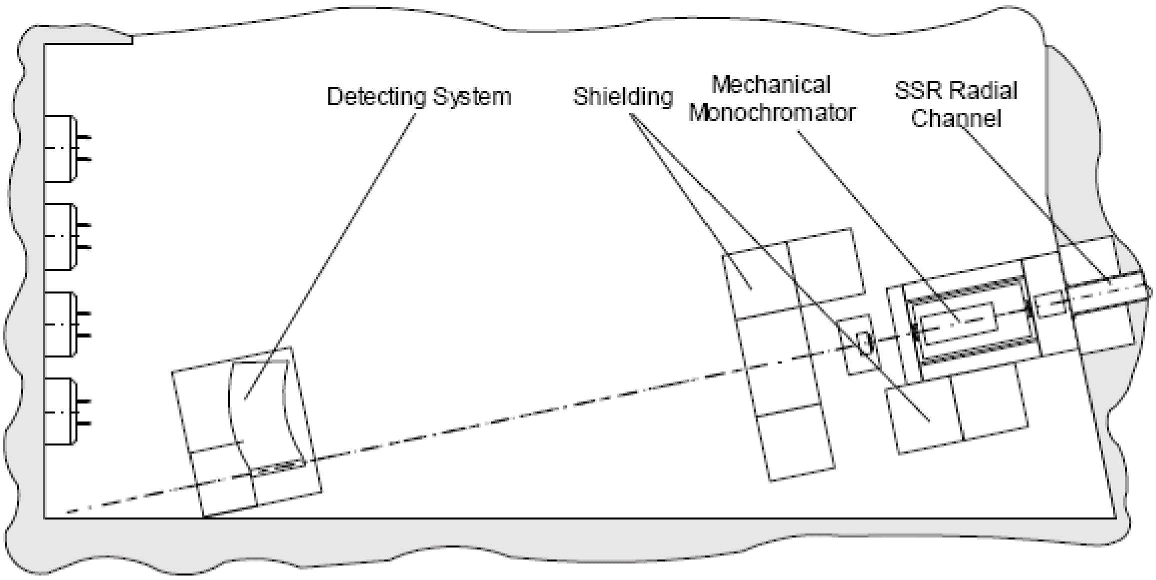


Fig.1 The instrument layout

In order to set a given angular speed for the mechanical monochromator, an inverter Allen Bradley has been used. This inverter is linked to the PC through a serial interface. The used soft has two components:

-the Allen Bradley soft allows for the command of the inverter itself involving the setting of the inverter parameters (the angular speed to be set, the maximum angular speed allowed, the acceleration/deceleration time, for example), the parameters visualisation.

-a special designed program, in Visual C^{++}, allowing the increasing or the decreasing of the monochromator angular speed by the operator, simply by pressing the taste 1 or 4.

The counting system is formed by a number of controller blocks connected each other in parallel and using a serial line; the connection to the computer is done by a pearled interface card. The counting system use the distributed control principle, each of the controller block processing the received counts, through the 8 entrance ways, from the corresponding detector output, independently. The controller blocks are connected to realize a chain; each block is connected to the main communication line where the registers content is displayed when the confirmation of the finishing transmission process from the previous block is received.

The chain- like connection allows being interconnected as many blocks as are necessary. The computer does the start of transmission process.

The transmission using a unidirectional clock and data line. The counter control is realised locally, the counts coming from the detectors are deposited in the controller registers and the serial transfer is done numerically. A suited program is realised for each controller.

The preliminary evaluation of the installation performances

The angular speed of the monochromator is given by

$$u = \omega R = 2\pi\nu = \frac{\pi R}{30n} \tag{1}$$

where ν, n is the frequency in rot/sec and rot/min respectively, R is the radius of the rotor.
The monochromator transmission is given by:

$$T(\gamma) = \exp\left[-4\ln 2\frac{\left(\gamma - \frac{u}{\nu} - \varphi\right)^2}{\alpha^2}\right] \tag{2}$$

where γ is the angle between the beam axis and the rotation axis of the rotor, α is the collimating angle,

, with l the lengths of the slits, d the slits width.

Using the first relation and putting $\nu = \frac{3958}{\lambda}$ (2) becomes:

$$T(\gamma) = \exp\left[-4\ln 2\frac{(\gamma - cn\lambda - \varphi)^2}{\alpha^2}\right] \tag{3}$$

where $c = \frac{\pi R}{30 * 3958}$. For R = 0.1 m, c has the value $c=2.6510^{-6}$

The maximum intensity is obtained for the neutron with the trajectory along the rotor axis $(\gamma=0)$ and their wave-length most probable value is:

$$\lambda_0 = \frac{\varphi}{cn} \tag{4}$$

Using (4) the monochromator transmission is:

$$T(\gamma) = \exp\left\{-4\ln 2\frac{\left[\gamma - cn(\lambda - \lambda_0)\right]^2}{\alpha^2}\right\} \tag{5}$$

The relative spread of the transmission function and therefore the relative spread of the wave-length, is:

$$\frac{\Delta\lambda}{\lambda} = \frac{\alpha}{\varphi} \tag{6}$$

Fig.2

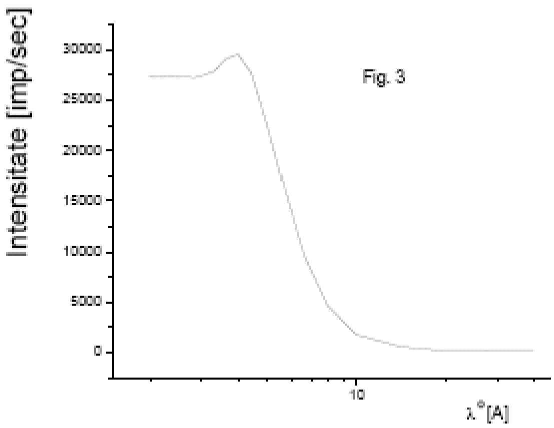
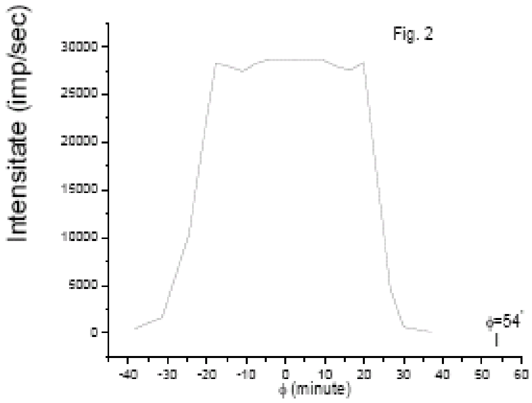


Fig.2. The intensity/wave-length

With the monochromator rotated at $\varphi = 1^0$ from the channel axis, using a BF_3 detector positioned parallel to this axis the curve giving the transmitted intensity/ monochromator angular speed has been determined (fig.2). Also was obtained the transmited intensity/ monocromator angle from the position parallel to the beam direction (fig.3).

In order to obtain the relation between the wavelength and the monochromator angular speed, at the monochromator entrance has been placed a Be polycrystalline filter, of 8 cm width. The transmitted spectrum has a discontinuity for $\lambda=3.95$ A (fig.4). The relation between λ and the monochromator angular speed is $\omega_c = \frac{C}{3.95}$. The discontinuity slope, centered at $\omega=1510$ rot/min, is given by the monochromator resolution. The experimentally determined values are:

$\varphi=54'$, C=5964.5 si $\Delta\lambda$ =1.64 A.



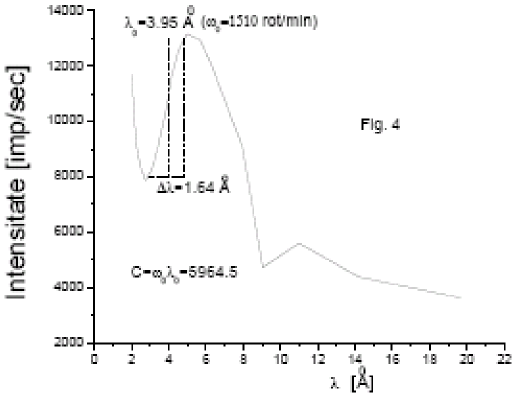


Fig.3 The intensity/monochromator angle

Fig.3 The intensity/wave-length

As operational tests of the SANS instruments experimental diagrams were realized using two stainless steal and four ZrH samples. The corresponding diagrams are given in fig 6 and 7. A partnership was established between INR Pitesti, Romania and JINR Dubna, Russia. The first step in this cooperation consists in the manufacturing at Dubna of a battery of gas filled positional detectors devoted to the SANS instrument

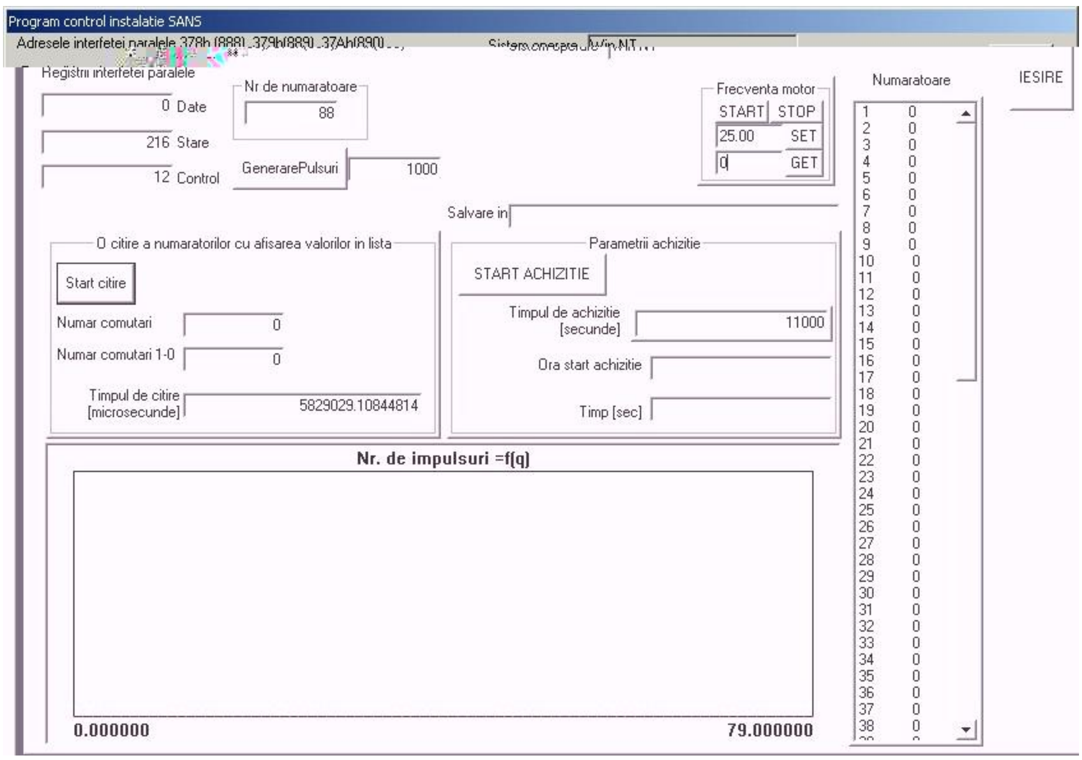


Fig.5 The main dialog window

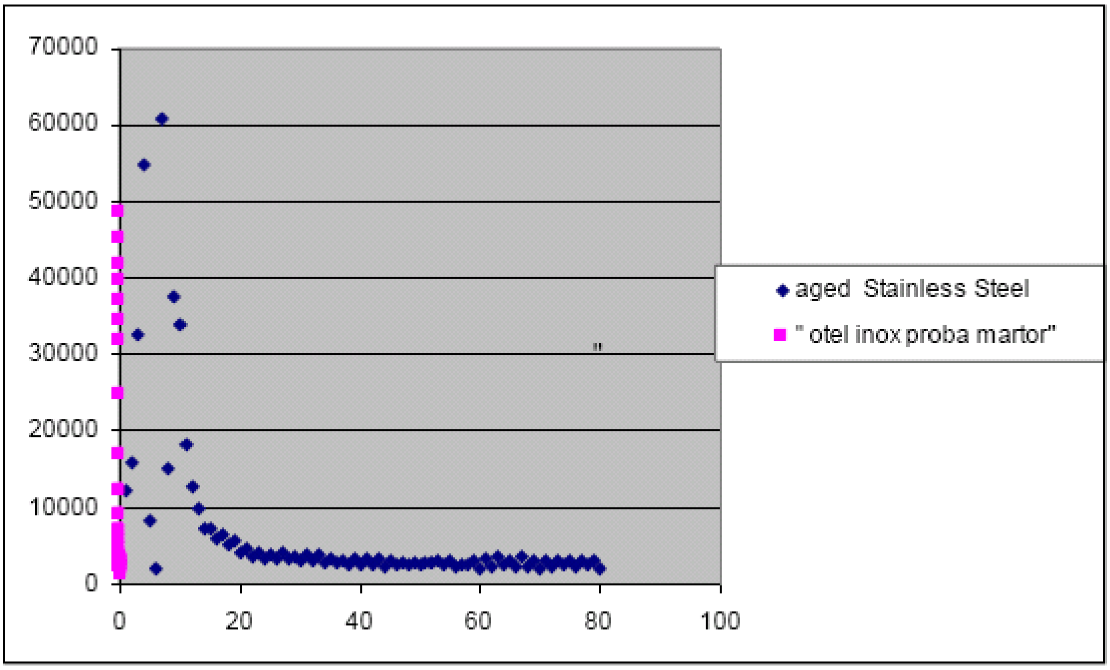


Fig. 6 Test determinations on aged stainless steel

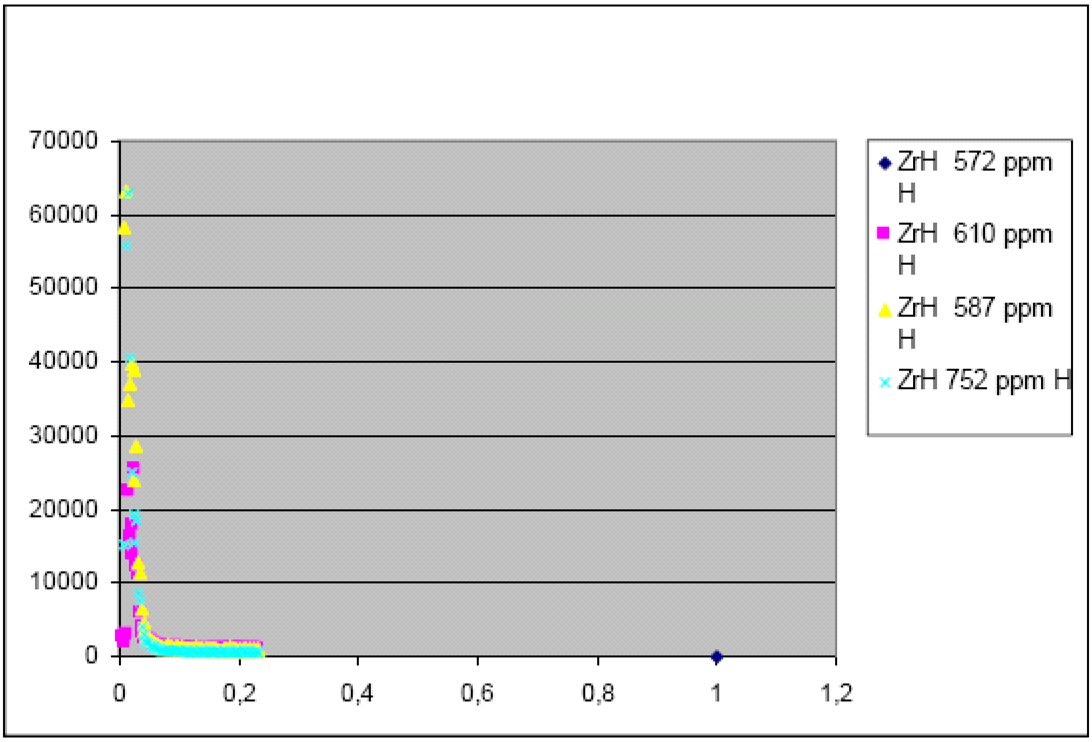


Fig.7 Test determinations on ZrH samples