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RICERCA DI SISTEMA ELETTRICO

Sistemi di monitoraggio di fenomeni di cavitazione e di impurezze non metalliche nel circuito litio liquido

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SISTEMI DI MONITORAGGIO DI FENOMENI DI CAVITAZIONE E DI IMPUREZZE NON METALLICHE NEL CIRCUITO LITIO LIQUID

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Note:

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Sommario


Presso il centro di ricerche di Oarai in Giappone è in fase di realizzazione un impianto a litio fluente avente l'obiettivo di validare sperimentalmente il progetto del circuito litio della macchina IFMIF.

Un aspetto fondamentale di tale impianto di prova sarà quello di ottenere un flusso stabile di litio sulla backplate del target. Per rimuovere l'enorme quantità di potenza (20 MW) focalizzata dal fascio deuteronico nel ristretto volume di litio investito (area esposta: 200 mm x 50 mm), il litio scorre ad una velocità pari a 15-20 m/s. Tale valore garantisce un efficiente raffreddamento della black-plate e previene fenomeni di ebollizione del metallo liquido. Al fine di mantenere delle condizioni operative che non compromettano il funzionamento dell'impianto ed evitino il danneggiamento delle sue parti costituenti, occorre dunque verificare sia la regolarità fluidodinamica del flusso del litio, sia l'assenza di impurezze di differente natura chimica in esso disciolte che possano aumentarne significativamente l'azione corrosiva nei confronti dei materiali dell'impianto.

Questo documento si articola pertanto in due sezioni. La prima si occupa della possibile insorgenza di fenomeni di cavitazione in diversi punti del circuito litio e della relativa metodica e connessa strumentazione atta a monitorarla; la seconda parte tratta invece degli aspetti teorici e del dispositivo strumentale impiegato per monitorare il quantitativo di impurezze non metalliche all'interno del litio (in special modo l'azoto).

Per quanto concerne la prima sezione, va detto che i fenomeni di cavitazione, come già confermato da precedenti analisi e studi sperimentali, sono in grado di innescarsi in zone del circuito litio caratterizzate da alte velocità e basse pressioni del metallo liquido (in particolare nella zona di aspirazione della pompa elettromagnetica). Tali fenomeni possono disturbare l'interazione nucleare nel target tra deuteroni e atomi di litio e danneggiare i materiali del circuito in seguito alla implosione delle bolle di vapore.

CASBA, sviluppato da ENEA nel corso degli anni, è un sistema utilizzato per monitorare le vibrazioni dovute all'implosione di bolle prodotte da fenomeni di cavitazione o di ebollizione. Tale sistema è costituito da un accelerometro, un amplificatore di segnale ed un oscilloscopio: è stato dimostrato sperimentalmente che esso rileva più velocemente di altri sistemi di misura l'insorgenza di tali fenomeni. Si è stabilito di installare sull'impianto a litio fluente di Oarai due unità CASBA: una in corrispondenza della backplate del target e l'altra

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all'aspirazione della pompa elettromagnetica. A questo scopo è stato progettato un apposito componente meccanico di interfaccia tra l'impianto e l'apparecchiatura. Tale componente consiste in una guida d'onda costituita da una barra di acciaio ed ha anche la funzione di disaccoppiare dal punto di vista termico l'accelerometro dall'impianto.

In questo documento vengono dunque dettagliati: il campo di applicazione e l'esperienza di ENEA nell'utilizzo del sistema CASBA; il principio di funzionamento, la descrizione dell'apparecchiatura e la procedura per un suo corretto utilizzo; la descrizione dell'interfaccia meccanica con l'impianto a litio ed il sistema di acquisizione dati.

Il controllo e la misura delle impurezze chimiche, oggetto della seconda parte del documento, viene invece gestito attraverso l'impiego di un 'resistivimetro', ossia di un misuratore in linea della resistività del litio liquido. Questo sistema si basa sulla relazione che lega la resistività di un campione reale di litio al contenuto di impurezze non metalliche presenti, in particolar modo all'azoto: tanto maggiore è il contenuto di impurezze, tanto più la resistività misurata si discosta da quella del litio puro. Lo strumento impiegato, non commerciale ma realizzato su misura per l'esigenza sperimentale, è il frutto concreto della collaborazione che ha legato per anni l'ENEA all'Università di Nottingham (UK): sarà testato e validato nella struttura di imminente realizzazione Lifus VI, per poi essere installato nell'EVEDA loop ad Oarai (JP).

Nel documento vengono quindi riportati: la rappresentazione schematica dello strumento; la teoria che sottende alla misura, la sua validità di applicazione e la metodica sperimentale; le interconnessioni meccaniche ed elettriche principali per l'installazione nell'EVEDA loop.



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1. Part I: Engineering design of the cavitation detector equipment

1.1 Introduction and background


The main objective of the EVEDA Lithium Test Loop is to validate the IFMIF design [1], in particular with respect to a fast, reliable and stable flow of lithium on the backplate of the target assembly. All characteristics of the EVEDA loop are similar to the one foreseen for the IFMIF Li target flow, except its flow width on the target backplate, reduced to about 1/3 of the full scale.

In the past, ENEA [2], in the frame of IFMIF Key Element Technology Phase, initiated a co-operation with JAERI for the monitoring of the lithium experimental facility at Osaka University against the risk of cavitation occurrence near the electromagnetic pump, the orificed multi-holes flow straighter and the nozzle of a straight mock-up. Cavitation experiments were carried out to determine the friction coefficient in the Osaka lithium loop, to validate the IFMIF loop design, and to conduct a test on the cavitation detection device developed at ENEA.

As a result of these experiments, the following conclusions were obtained. The two steps contraction nozzle can form a stable flow without violent waves and dispersion for velocities of up to 15 m/s. Surface wakes were generated from the chemical compounds attached at the nozzle outlet. The compounds were found not to be easily removed by the main stream, and created flow splashing in some cases.

As shown also in the previous ENEA theoretical study on the conditions for cavitation generation in various parts of the IFMIF Lithium Loop [3], particular attention has to be paid to the primary pump, the flow straighter, the nozzle and their interconnections where the local increases of velocity or the flow separations could promote the emission of cavitation vapour bubbles. This could produce large jet instability and disturbance of the neutron field in the D⁺ beams-lithium target zone. The successive bubble re-implosions, in the higher pressure liquid bulk, could activate material erosion and transport of activated particles. For these reasons, the cavitation risk must be avoided along the whole lithium circuit.

The risk of cavitation onset in the EVEDA loop become realistic considering the lithium height in the target loop and its static pressure, the high flow velocities and the presence of

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several devices for the flow control and the pressure reduction. In fact, to generate the lithium flow with velocities of 10–20 m/s, the flow rate of the IFMIF loop is more than 100 l/s. Since the target section is connected to the beam accelerators, the lithium flows under the vacuum condition of 10^{-3} Pa and is collected into the quench tank after irradiation of the beam. There is a free surface in the quench tank, and the lithium flows from the tank to an electromagnetic pump (EMP) driven by the head between the free surface and the EMP. Thus, one of the most critical point where the cavitation might occur is at the suction of the EMP. So, the monitoring of the insurgence of lithium cavitation in the EVEDA lithium test loop by the ENEA CASBA-2000 equipment, at least at the inlet of the EMP and on the EU backplate at the height of the nozzle, will be performed with the purpose to protect the loop from damaging conditions which could arise at high velocity/low pressure operations.

1.2 General description of the detector principle

The detector principle is based on the process of nucleation, growth and collapse of the fluid vapour bubbles, in common engineering flowing systems, when either the local pressure is below the vapour pressure or the local temperature is over the saturation temperature [4]. The former condition is called cavitation while the latter is typical of heat transfer with fluid boiling.

In these conditions, the micro-bubbles may nucleate reaching the high pressure or low temperature fluid regions where collapse occurs in the form of condensation shocks. The high velocity liquid micro-jet strikes the structural wall causing material erosion or damage associated with the undesirable fluid cavitation conditions. The high specific energy emissions are converted into very high pressure and kinetic energy of the impact liquid drops colliding on the surfaces. The transient phenomenon acts also as a water hammer on the solid surfaces in contact with the collapsing regions.

The shocks produce vibrations, exciting an accelerometer fixed to a waveguide immersed in the fluid or located on the external structure in the proximity of the flow region, as in our application. At the beginning, when the bubbles begin to grow and collapse, the noise emission is clearly evident in terms of the ratio of signals to the pedestal and for the typical range of ultrasonic frequencies involved.

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These accelerometer recordings anticipate largely other instrumental or visual detection systems giving the possibility of monitoring such flow conditions with a non-intrusive and non-location-dependent probe.

The method described here was already successfully qualified by ENEA in the field of cavitation detection, in the frame of the fast breeder reactor pump and fuel assembly development [5]. In the case of boiling, when high degrees of sub-cooling are involved, and with a relatively low vapour void fraction, the previously mentioned process of bubble nucleation and growth on the related heated surface is similar to the cavitation process.

In fact, at the onset of the phenomenon, when the heat transfer changes from a single to a two phase flow regime, the vapour bubbles are finely dispersed but attached to the heated surfaces on which they immediately collapse. This means that the two phenomena are almost indistinguishable because of the same energy levels and frequencies generated and then, from the point of view of the instrumental recording, the hypothesis foresees that the bubble signal noise detection can be treated in the same way both in the case of the cavitation and at the onset of the boiling.

ENEA, having gained expertise from cavitation prediction with the same signal treatment, planned to test whether the same approach can be extended to sub-cooled heat transfer in order to distinguish the inception of the sub-cooling phenomenon, the stabilization of the full development of the nucleate boiling regime and the prediction, in advance of the conventional instruments, of the reaching of the critical heat flux (CHF). At the onset of nucleate boiling, the bubble cavities increase with the related noise emissions and then, with increasing heat flux, the accelerometer signal reaches a maximum. This value can be quite stable during fully developed boiling (FDB), when the bubble dimensions and frequencies increase. At higher heat flux the noise emission reduces gradually because of the appearance of another phenomenon.

In fact, due to the dumping of the greater bubbles that begin to implode in the bulk of the fluid rather than on the heated surfaces, this padding effect procures a noticeable reduction of the vibrations. This trend begins to be clearly evident when, approaching the CHF, the vapour creates a film attached to the wall surface. This particular form of boiling can originate an unstable film regime that can suddenly reach tube burnout, close to this signal minimum, or can evolve to a more stable vapour film zone before the tube is completely damaged. In this case the hypothesis relies on the identification of the signal drop in comparison with other

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instrumental (i.e. thermocouples, pressure oscillation etc.) or visual (i.e. melting, tube destruction etc.) observations.

The cavitation index utilized to estimate this occurrence was defined as:

$$\sigma = (P_s - P_v) / P_d \quad (1)$$

with

P_s = static pressure in the cavitation zone of the component;

P_v = vapour tension in the fluid at operating temperature;

$P_d = 0.5 \rho V^2$ or dynamic pressure in the cavitation zone of the component;

ρ = density of the fluid at operating temperature.

When $\sigma < 1$ the probability of cavitation occurrence is high.

1.3 ENEA cavitation detector equipment

The cavitation detector equipment developed and patented by ENEA [5] is used for monitoring bubble re-implosions due to cavitation or boiling phenomena. It is based on two different quartz piezoelectric accelerometer transducers, two noise meters (CASBA-2000 units) and a digital storage oscilloscope (see figure 1).

As described in the chapter 1.2 the CASBA-2000 acoustic detection of bubble re-implosions is based on vibration frequency spectra obtained from an accelerometer operating in its non linear resonance region (see figure 2).

The various experimental studies, carried out in the past, have shown that the onset of cavitation generates a white noise (i.e., a flat power spectral density in the whole frequency range) with a possible exception for the very early onset phase when fast pulse rise fronts are emitted at a frequency of about some tens kHz.

The CASBA-2000 accelerometer has a resonant frequency of 38-40 kHz, much higher than those generated by mechanical or hydrodynamic vibrations. Therefore, it magnifies the bubble noise emissions at a frequency close to its resonance.



a)



b)



c)



d)

Figure 1: ENEA Cavitation detector equipment: a)-b) accelerometer transducer; c)-d) CASBA-2000 units and a digital oscilloscope

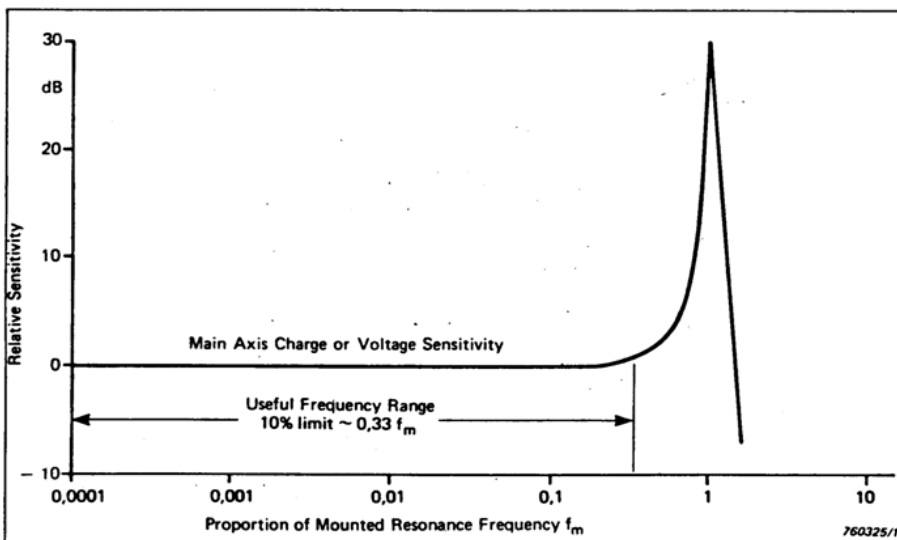


Figure 2: sensitivity vs. frequency of a piezoelectric accelerometer

The CASBA-2000 unit includes:

- a piezoelectric accelerometer transducer with a resonance frequency of 38-40 kHz;
- a fixed band pass filter (around 38-40 kHz and 50 dB/octave) on the resonance response of the transducer;

- a signal amplifier for the implosion shock pulses;
- a true-rms voltmeter;
- a time constant to set the duration signal integration;
- an adjustable amplitude threshold.

The CASBA dynamic response of the bubble implosion onset was tested to be greater than other common systems. In fact, tests on cavitation of pumps have demonstrated the CASBA greater capacity to detect the noise inception in advance of pressure head drop monitoring or visual bubble growing (see Fig. 3). Different comparison was performed in sub-cooled boiling two-phase flow between CASBA detection and thermocouple measurement with the evidence of a faster and better phenomenon monitoring (see Fig. 4).

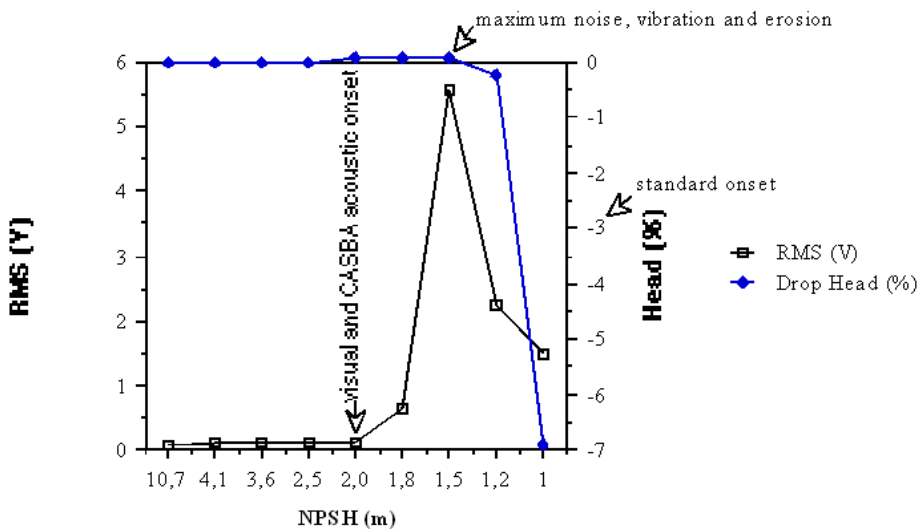


Figure 3: pump cavitation detection in "EPOCA" test

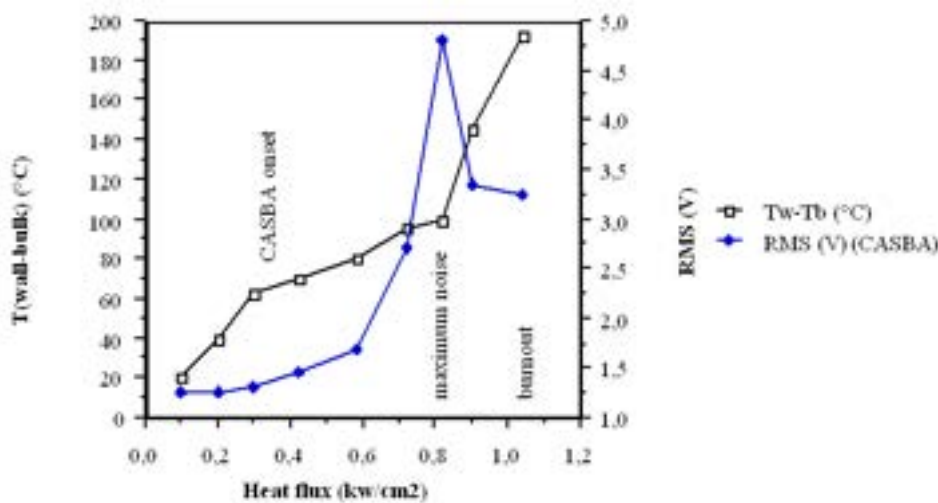


Figure 4: sub-cooled boiling detection in divertor tubes

1.4 Operation of the ENEA cavitation detector equipment

In order to correctly operate the CASBA-2000 meter the following procedure is recommended:

1. fix the transducer on the structure by a cavitation transmission bar, to maintain low temperature in the transducer. A electrically isolated stud is necessary; in any case, if the transducer ground is different from CASBA-2000 ground, work in FLOAT condition;
2. connect the transducer to CASBA-2000 INPUT, with a short length cable;
3. connect DC OUT to an external data logger. Put CASBA-2000 INTEGRATION TIME, compatible with scanner data and physical parameter change rate;
4. connect MAINS;
5. select GAIN (dB) value, to utilize a large test dB range (maximum ~ 70 dB);
6. plot the VRMS = $10^{DC\ OUT}$ values, over corresponding physical parameter values;
7. in some case is useful to see one pulse in "1pulse" selection, after RESET.

In Figs. 5-6 are reported the schemes of the CASBA 2000 to which the operative procedure refers.

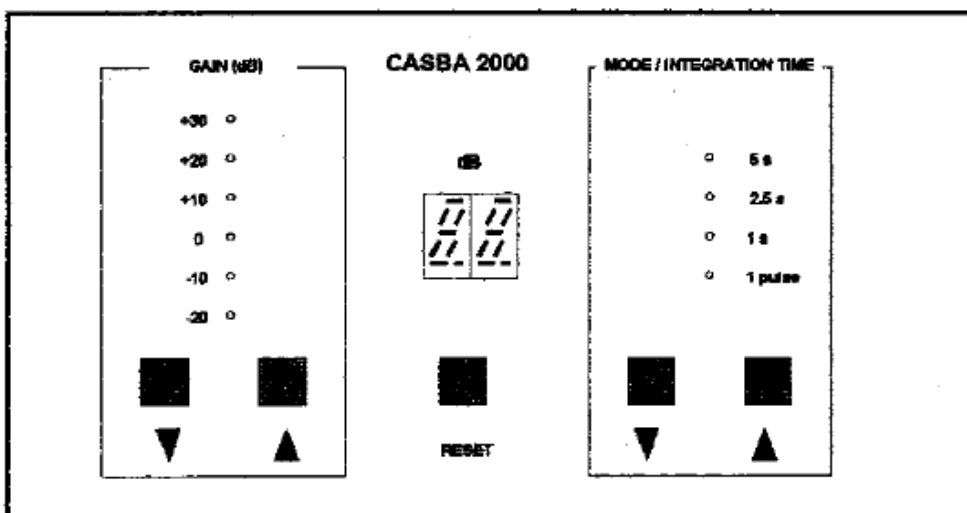



Figure 5: CASBA-2000: front panel scheme

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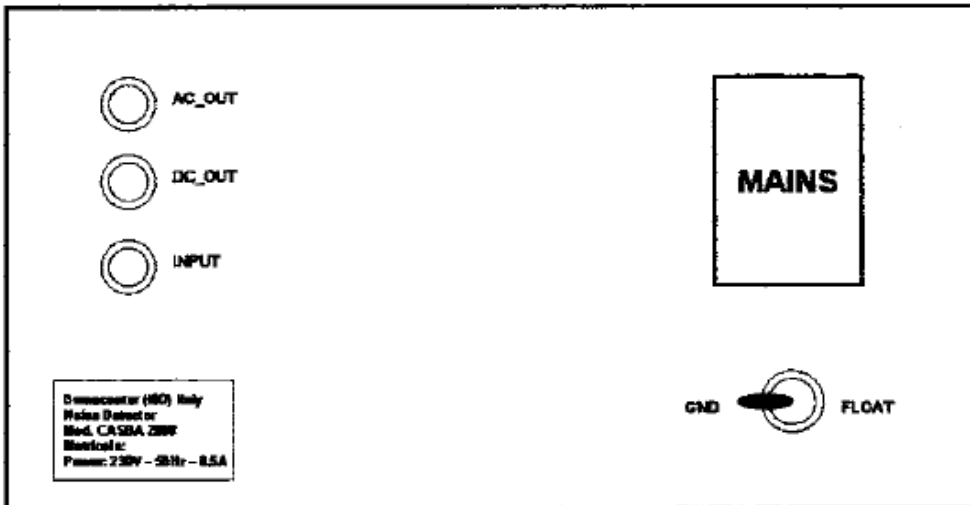


Figure 6: CASBA-2000: rear panel scheme

1.5 The mechanical interface

Concerning the installation of the cavitation detector on the EVEDA lithium loop, two installation positions have been identified: one over the bayonet backplate delivered by ENEA (in correspondence of the nozzle) and the other one at the EM pump inlet, (see Fig. 7).

In order to have a working temperature of the sensor lower than 60 °C two cavitation transmission bars will be designed, realized and installed into the EVEDA lithium loop.

The heat exchange surface and the consequent dimensions of the transmission bars are the result of the study carried out in order to reduce the contact temperature from 250 °C to 60 °C. In particular, the calculated heat exchange surface is 6600 mm². So, the length of each bar ($\phi = 15$ mm), considering a thickness of the thermal insulation of 100 mm, is 240 mm.

Both the two transmission bars, realized by ENEA, will be welded to the backplate and to the pipe of the loop, whilst the mechanical attachment with the sensors will be obtained by M3 thread. The first welding on the back-plate will be realized by ENEA in Italy, the second one, into EVEDA loop, by MHI-MS (TBC) in Oarai under support and assistance of JAEA.

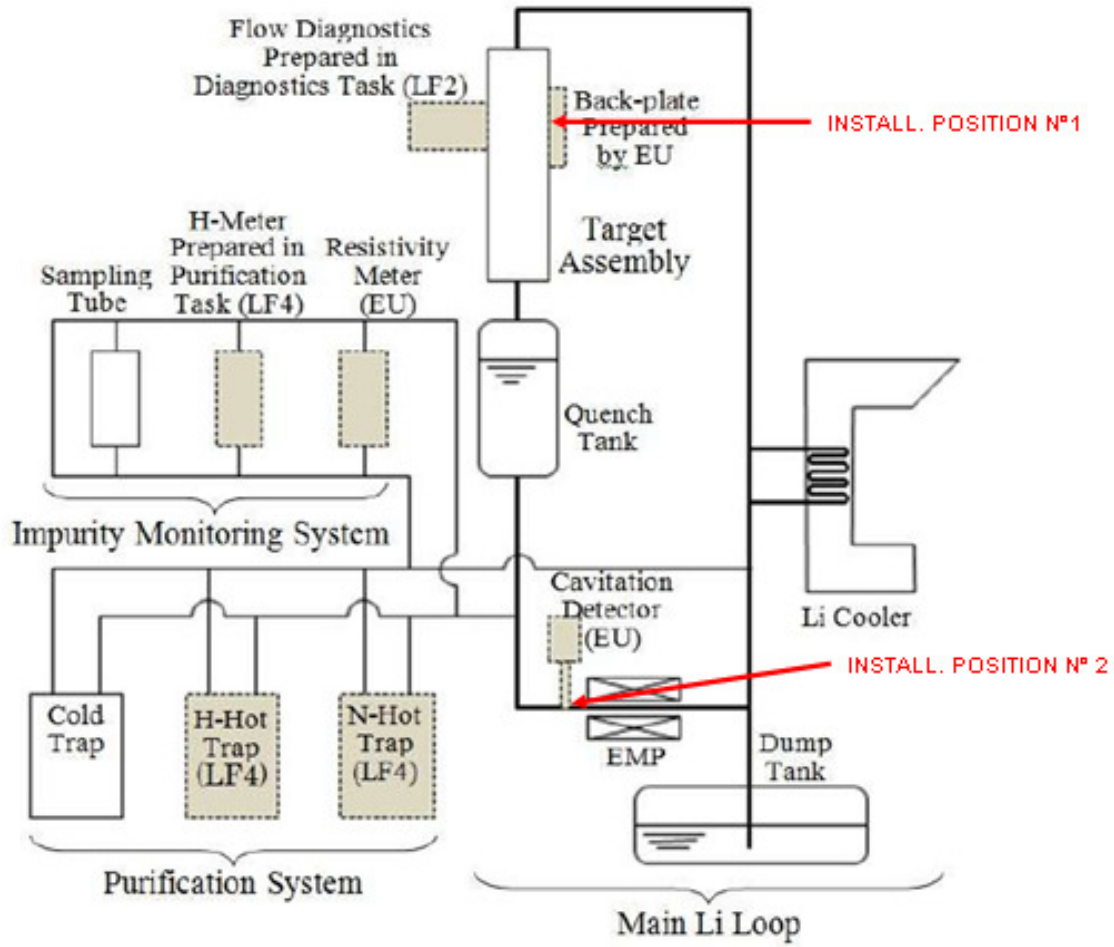



Figure 7: cavitation detector installation positions

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2. Part II: Engineering design of a monitoring system for the on-line measurement of the nitrogen concentration in liquid lithium

2.1 Introduction and background

The International Fusion Materials Irradiation Facility (IFMIF) is aimed at testing, under high neutron flux of about 10^{18} n/m²s, the candidate fusion materials up to a damage rate of 50 dpa/fpy. This neutron flux is obtained by a nuclear stripping reaction activated by 40 MeV accelerated deuterons impinging above a flowing lithium layer.

To remove the huge power deposition of 20 MW in the lithium volume corresponding to the footprint surface (200 mm x 50 mm), the lithium flows at the speed of 15÷20 m/s. This Li speed value ensures also an efficient cooling of the back plate and prevents boiling phenomena in the Li bulk. In contrast, the high lithium speed entails a significant erosion/corrosion effect on the metallic walls of the target assembly which are in contact with the flowing lithium. Since IFMIF will be designed to have a corrosion rate value < 1µm per year, a purification system will be employed, aimed at trapping all non metallic impurities, like nitrogen, which enhance the corrosive behaviour of the lithium. The control and measurements of these impurities is hence necessary; for what concerns nitrogen, it will be performed by means of the so called “resistivity meter”, which was developed at the University of Nottingham in collaboration with ENEA Brasimone. The resistivity meter is going to be tested in the Li Fus VI facility, for its validation, will be then installed in the EVEDA Li loop in Oarai(JP).

This document describes the features and the engineering design of the resistivity meter to be installed on this latter loop.

2.2 Principle of the measurement method

The proposed method for the online monitoring of nitrogen content in lithium, relies on the increase of the metal electric resistivity (ρ) produced by the dissolved nitrogen. This behaviour was shown in the 70's by Nottingham University researchers [6,7]: the higher the nitrogen concentration in lithium, the higher the resistivity of lithium. Actually, the resistivity

meter is not chemically specific to nitrogen impurities, being sensitive to any kind of impurity able to modify the total number of available valence electrons of the lithium; anyway, the reduced sensitivity to other non metals, like oxygen and hydrogen, together with the smaller expected amounts of these impurities in the analysed sample, assure the variation of resistivity can be almost entirely ascribed to nitrogen content.

Obviously, the resistivity of liquid lithium depends also on temperature, increasing with it. For what concerns pure liquid lithium, the following experimental relation has been derived [7]:

$$\rho_{\text{Li}} [\Omega\text{m}] = 16.476 \times 10^{-8} + 4.303 \times 10^{-10} (T/^{\circ}\text{C}) - 2.297 \times 10^{-13} (T/^{\circ}\text{C})^2 \quad (2)$$

dictating a nearly linear dependence in the range of investigated temperatures. Therefore, two aspects shall be considered in the measurement of the electric resistivity of lithium: temperature and nitrogen concentration. The effect of both of them emerges from figure 8 [8], in which the four different curves relate to differently treated Lithium samples, with a purification degree which decreases going from (a) to (d) sample.

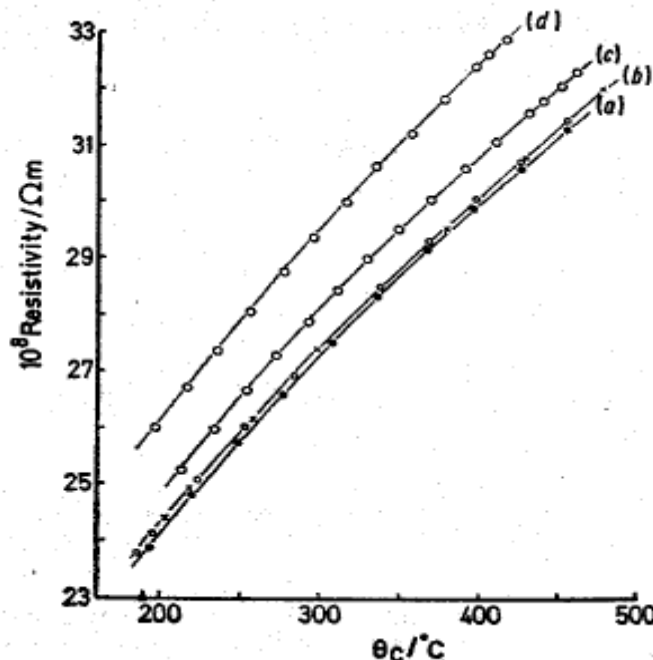


Figure 8: variation of the resistivity of liquid lithium with temperature and impurity content
 (a): Lithium filtered and treated by Titanium and Yttrium getters (b): Lithium filtered just above its melting temperature (c): Lithium having 99.98 purity before filtering (d): Lithium having 99.85 purity before filtering

To validate the results that will be obtained with the on-line monitoring approach, an off-line method will be employed, the foil equilibrium method [8]. This method is based on the

exact activity/concentration relationship for nitrogen in the foil material (AISI 304 steel). The activity/concentration relationship can be achieved by means of thermodynamic calculations using the nitrogen solubility in the foil steel and the Free Energy of formation data for the chromium nitride. The same procedure is followed for the system lithium-nitrogen using the solubility of nitrogen in lithium. Chemical analysis of the AISI 304 foil after 500h exposure to lithium at a given temperature enables to calculate nitrogen concentration in lithium through the established equations.

2.3 Overview of the experimental setup

The resistivity meter was developed at University of Nottingham in collaboration with the ENEA research centre of Brasimone for the on-line monitoring of the Nitrogen concentration in Liquid Lithium. It is made of AISI 316L and it is an all TIG welded assembly. Its main components are the capillary tube section (C), the electromagnetic pump (B) and the source lithium bulk (A) (figure 9).

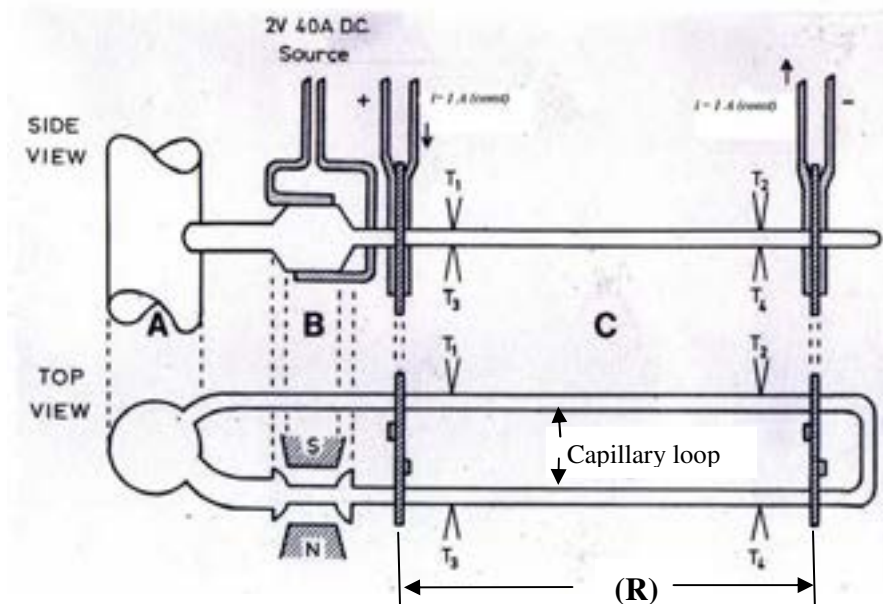



Figure 9: sketch of the resistivity meter

The capillary tube ($\varnothing_o = 4.8$ mm, $\varnothing_i = 3.0$ mm, $l = 450$ mm), within which the resistivity measurements are made, is in the form of a loop which is continuously fed with liquid lithium from the bulk source ($\varnothing_o = 25.3$ mm, $\varnothing_i = 21.3$ mm) by a miniature electromagnetic pump. The

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duct of the pump (cross section 5 x 15 mm, $l = 15\text{mm}$) is fabricated of a flattened section of tube and is located between the poles of a permanent magnet generating a field strength of 0.55 T. The duct is insulated from the magnet by means of thin mica sheets. A couple of silver leads are attached to the narrow faces of the duct for connection to a constant current source.

The duct is connected to the capillary tube directly and to the bulk source through a short section of tube ($\varnothing_o = 9\text{ mm}$, $\varnothing_i = 7\text{ mm}$, $l = 20\text{ mm}$) to provide an inlet and outlet to the meter. By passing a dc current (up to 40 A) through the duct pump, at right angles to the magnetic field, the liquid lithium is drawn down from the bulk source. In figure 10 a view of the duct pump and the permanent magnet is given.

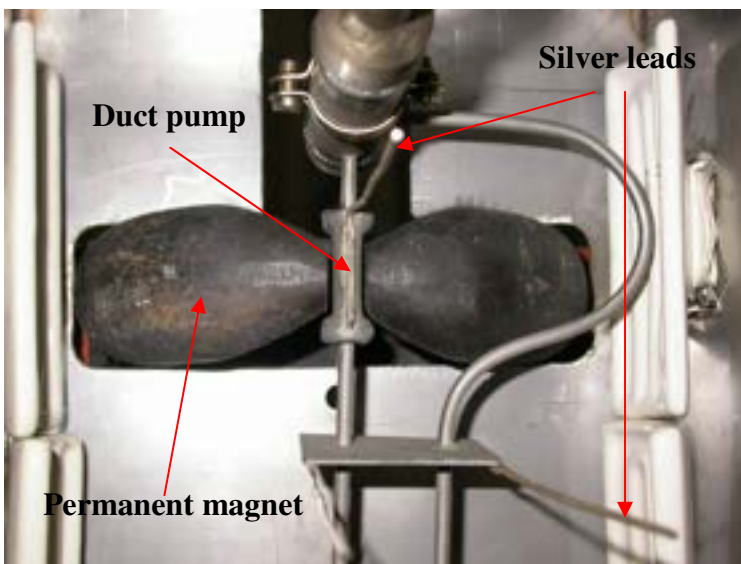


Figure 10: general view of the electromagnetic pump of the resistivity meter

The resistance (R) is measured across two plates (40 mm x 40 mm, thickness= 2 mm) welded to the capillary tube. Each plate is provided of two electrical leads ($\varnothing = 2.0\text{ mm}$). All the electrical leads of the resistivity meter are made of silver. This material was chosen for its low electrical resistivity and to prevent, due to the high working temperature, the oxidation of the electrical contacts.


A **nano ohm meter**, already used in Lifus 3 (see figure 11), is employed for the acquisition of the resistance values, through a standard four terminal method. It is connected by means of a serial port (RS232) to a data logger interfaced to a PC. The main characteristics of the instrument are summarized in table 1. It should be pointed out that the resistance values to measure are of the order of 10 m Ω .



Figure 11: general view of the measurement apparatus, with the nano ohm meter close-up

Display	2.8"
Measurement method	Four terminal
Points of measure	32000
Updating Frequency	5 Hz
Range	32.00 $\mu\Omega$ ÷ 320.00 Ω
Resolution	1n Ω ÷ 10m Ω
Accuracy	$\pm(0.05\%+2\text{digit})\div(0.07\%+5\text{digit})$
Working temperature	0.0 ÷ 50.0 °C
Max distance from the R.M.	10 m
Serial port RS232	DAQ connection

Table 1: main characteristics of the nano ohm meter

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2.4 Nitrogen content determination

Since we may only measure the total electric resistance exerted by the capillary section (R_{tot}), if we want to know the real value of resistance of the lithium flowing inside it (R_{Li}), it is necessary to already know the resistance of the capillary alone, that is the resistance of the capillary when empty (R_{cell}). Through the expression for parallel resistances:

$$R_{Li} = (R_{cell} \times R_{tot}) / (R_{cell} - R_{tot}) \quad (3)$$

is therefore possible, once measured the resistance of the empty capillary, to obtain the resistance of the only lithium.

Lithium resistance, on the other hand, is not an intrinsic properties of the metal, depending also on the geometric parameters of the capillary (cross sectional area -A- and length -l-), so, to achieve its value of resistivity, which is instead indicative of the nitrogen content, the following expression shall be used:


$$\rho_{Li} = R_{Li} \times A / l \quad (4)$$

Due to the convoluted nature of the capillary loop, the best solution to achieve an accurate value of (A/l) consists in deriving it from the measured resistance of a sample characterized by an exactly known value of resistivity. This can be done employing pure liquid lithium, for which equation (2) holds, so calibrating the resistivity meter at every desired temperature.

Resistivity-composition isotherms for solutions of nitrogen in liquid lithium, determined at various temperature in the range 200-450 °C, show that in any case for very diluted solutions resistivity increases with a slowly increasing gradient, while, for more concentrated solutions, it increases linearly, up to a saturation value, beyond which it remains constant. In the linear region, which is the dominant feature of the isotherm and where the following relation holds:

$$\rho_{Li} = A + B \times x \quad (5)$$

is hence possible to obtain the value of x (% of nitrogen content) once the value of ρ has been measured and A and B parameters have been evaluated from the fitting of

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experimental data. Both these two parameters vary with temperature, even if not to a great extent, the sensitivity of the resistivity meter increasing a little with temperature. So, while at 200 °C the composition dependence of the resistivity (B) is $5.7 \times 10^{-8} \Omega \text{ m} / (\text{mol} \% \text{ N})$, this value becomes 7.2×10^{-8} at 450 °C. Since the minimum change in the resistivity value that can be measured is about 0.5 nΩ m, as derived from the minimum actual variation of resistance that can be registered with the described instrumentation, we have that the minimum detectable nitrogen concentration is about 175 wppm at 200 °C, 139 wppm at 450 °C.

Experiments with insoluble getters confirmed the effectiveness of the meter in monitoring nitrogen concentration in liquid lithium. In all cases (both employing Cr and V as getter), the resistivity value measured by the instrument quickly decreased as soon as the introduced getter, adsorbing nitrogen, was able to lower its concentration below the saturation value; conversely, when new nitrogen was added more to the liquid metal solution, so to exceed the adsorption capacity of the already present getter, measured resistivity quickly came back to an higher value.

2.5 Description of the hardware to be delivered for the resistivity meter

Three components will be installed in the EVEDA lithium loop at Oarai research centre in Japan: the resistivity meter, the instrumentations board and a PC to display and store data. A general view of these components and their interconnection is shown in figure 12.

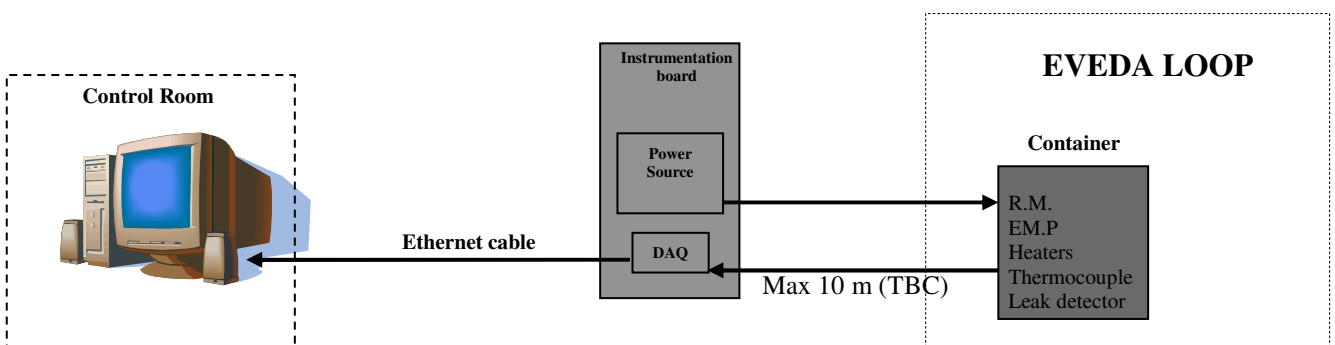


Figure 12: general view of the components to be installed in the EVEDA loop

The resistivity meter is inserted into a metallic box, together with its ancillary components. In particular the box contains: two type K thermocouples to monitor the temperature of the apparatus, four heaters to avoid the thermal stress of the components inside the container itself and a leak detector to check any loss of lithium. The container (shown in a 3D view in figure 13) is made of AISI 316L and is an all welded assembly; it will be provided with a support system for the installation in the EVEDA loop and with proper interfaces for both the mechanical and the electric connections. The instrumentation rack requires a voltage source of 100 V, 50÷ 60 Hz and 1200 W of power; the power source will be provided by JAEA. The rack should be placed on the floor or attached to the wall.

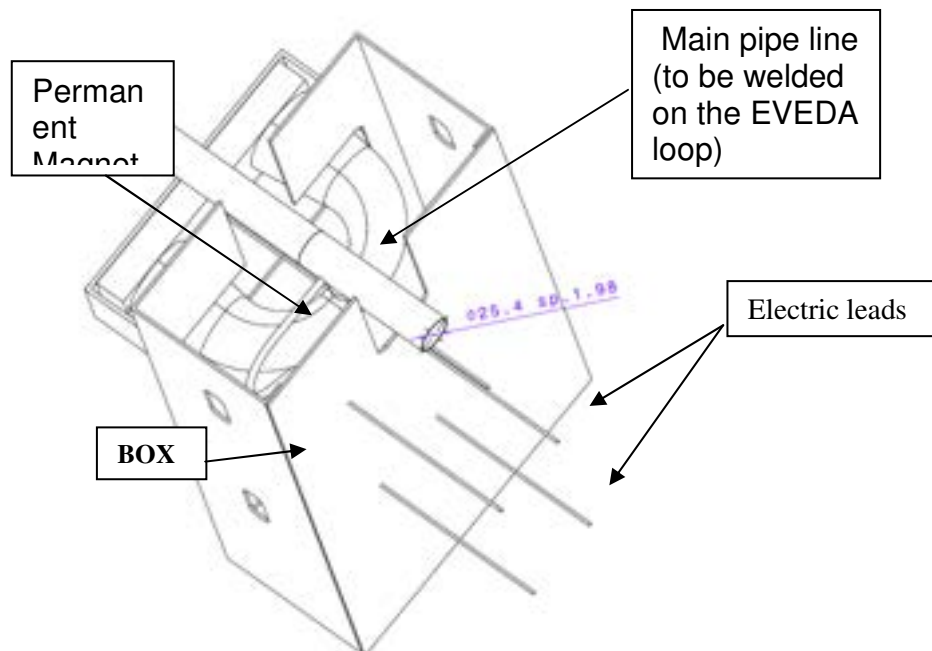



Figure 13: 3D view of the container for the resistivity meter

ENEA has realized a unique dedicate data acquisition system (DAQ) for both the cavitation detector equipment and the resistivity meter.

The DAQ system is based on the National Instrument Field point technology and consists of the following parts:

- 1) Interface Ethernet/serial for compact Field point –NI cFP- 1804
- 2) Module Field point analog input –NI – cFP-AI-110
- 3) Module Field point digital output –NI – cFP-DO-410

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In addition a signal converter Datexel mod. DAT 4532A is used for the acquisition of the two thermocouples signals. The electrical schemes of the DAQ are shown in the document reported in ref. [9].

The DAQ is connected by means of a standard Ethernet network with a PC located in the control room (figure 14). A software application VIs for the visualization and storage of data will be developed using LabView 7.1 Professional.

The electrical cabinet for the instrumentations and the DAQ (see figure 8), installed on the platform, will be connected after the completion of the mechanical installations and the signals will be transmitted to the control room of the plant.



Figure 14: electrical cabinet for the cavitation detector and the resistivity meter

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