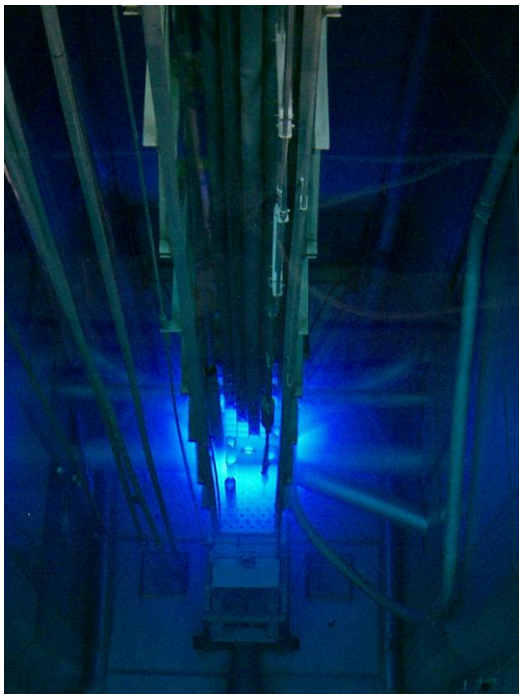
Reactors and Nuclear Safety Unit



Reactors and Nuclear Safety Unit

José Gonçalves Marques

The Research Unit on Reactors and Nuclear Safety includes the ***Portuguese Research Reactor*** (RPI), a unique infrastructure in the Iberian Peninsula, as well the ***Neutron Activation in Environment, Nutrition and Epidemiology*** and ***Applied Dynamics*** groups. The RPI also supports activities for groups in the Research Unit of Chemical and Radiopharmaceutical Sciences and in the Research Unit of Radiological Protection and Safety. The year 2008 was remarkable in human resources terms, as four new auxiliary researchers were hired under the *Ciência 2007* program and two more were selected to start in 2009.

The staff involved in all aspects of the operation and use of the RPI presents its activities under the common headline of ***Operation and Exploitation of the Reactor.*** The activities for this group were dominated by the return to the USA of the highly enriched fuel previously used by the reactor, thus closing a cycle started in 1974. A new researcher brought support in dosimetry to enhance the capacity to respond to new users and new demands.

The ***Neutron Activation in Environment, Nutrition and Epidemiology*** group uses the k_0 INAA technique in the RPI and was again the main Portuguese user of the reactor in 2008, accounting for 20% of the total irradiation time. The group is dedicated to cycling and impact of trace elements in the atmosphere. It addresses, specifically, the development and application of nuclear techniques, source apportionment and tracking in the atmosphere, chemical speciation, uptake and release of chemical elements in biomonitoring and monitoring, as well as health linkage through epidemiology and nutrition studies. These objectives are approached through research, included mostly in PhD theses. The activities are essentially financed by the Foundation for Science and Technology (FCT). The group had a much needed influx of young researchers in 2008, with two Auxiliary Researchers hired under the *Ciência 2007* program and one post-doc with a FCT grant.

The research performed by the ***Applied Dynamics*** group is mostly concerned by vibration and acoustic problems displayed by components of nuclear and conventional power plants. As such, a significant part of their research results has been motivated and funded by the French *Commissariat à l'Energie Atomique (CEA)* and the Portuguese *Electricidade de Portugal (EDP).* However, the techniques developed by this group can and have been used to solve problems, both of industrial and fundamental nature, outside the realm of power generation. This group also had a new researcher this year. In spite of continuing to be one of the smallest groups in terms of ITN staff, this fact is compensated by an active collaboration with Universities and Research Laboratories, both in Portugal and abroad. The vitality of this group is well demonstrated by their research contracts and publications

Reactors and Nuclear Safety Unit Staff

Researchers

J. G. MARQUES, Princ.
M. C. FREITAS, Princ.
A. V. ANTUNES, Princ.
A. FALCÃO, Princ.
A. KLING, Aux. (90%)
N. P. BARRADAS, Princ.(90%)
A. R. RAMOS, Aux. (90%)

Technical Personnel

J.P. SANTOS, Dosimetry
J. A. M. RIBEIRO, Reactor Operator
J. C. ROXO, Reactor Operator
N. SERROTE, Reactor Operator
R. SANTOS, Reactor Operator
R. POMBO, Radioprotection
F. B. GOMES, Radioprotection
A. RODRIGUES, Technician
I. DIONÍSIO, Laboratory Assistant

Administrative Personnel

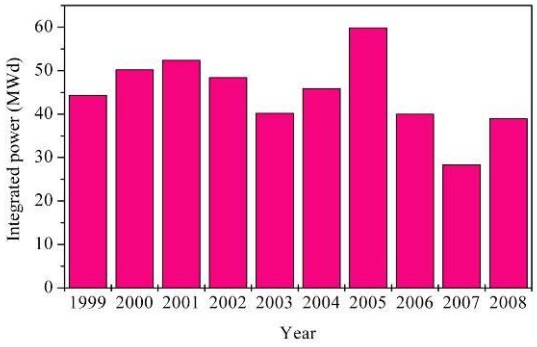
T. FERNANDES, Secretariat

OPERATION AND EXPLOITATION OF THE REACTOR, DOSIMETRY (RPI) AND REACTOR CALCULATIONS

José Gonçalves Marques

The main objective of the Operation and Exploitation of the Portuguese Research Reactor (RPI) is to be able to satisfy the users' needs while conducting all tasks with the assurance that the reactor is operated in a safe and reliable manner by a highly competent and motivated staff. The implementation of such objectives demands a variety of activities, some of which are repetitive in objective and variable in content, while others address specific aspects of the same end situation.

The activities in 2008 were clearly dominated by the return of the highly enriched uranium (HEU) fuel to the USA. This was a complex task, started in January with the evaluation of bids for the supply of a transport cask and only concluded in the late summer when the fuel arrived finally arrived in the USA. Regarding new setups, a prototype setup for neutron tomography became operational this year, once the initial problems were solved.



The main users of the reactor are described in the Table below. External users accounted for more than 50% of the use of the reactor in 2008.

User	Area	Time (%)
URSN	NAA	20.0
	Dosimetry and detector development	10.3
	Radiation effects	1.5
	Education and training	0.4
	Other	0.9
UCQR	NAA	11.5
	Isotope Production	0.6
UPSR	Isotope Production	1.8
UFA	Neutron scattering	0.4
Univ. Lisboa	Isotope Production	17.8
IVIA	Radiation Effects	0.4
Univ. Bona	Isotope Production	34.4

The figure to the left indicates the integrated power produced by the RPI in the last 10 years. The year of 2008 marked the conclusion of the "conversion and return" process, which led to significant periods without reactor operation. A recovery is already visible, in both the integrated power (39 MWd in 2008 vs. 28 MWd in 2007) and total irradiation time (1394 h in 2008 vs. 1256 h in 2007).

Research Team

Researchers

J.G. MARQUES, Princ.
N.P. BARRADAS, Princ. (90%)
A. FALCÃO, Princ.
A.P. FERNANDES, Aux
A. KLING, Aux. (90%)
A.R. WAHL, Aux. (90%)

Students

M.A.F. COSTA, PhD Student, UNL, FCT grant
M. LUBRANO, MSc Student, INSTN, France
A. RICO, MSc. Student, FCT, ITN grant
M. SOUSA, Graduation Student, FCUL, ITN grant

Reactor Operators

J.A.M. RIBEIRO
J.C. ROXO
R. SANTOS
N. SERROTE

Technical Personnel

F.B. GOMES
R. POMBO
A. RODRIGUES
J.P. SANTOS

Collaborators

T. GIRARD, CFNUL
T. MORLAT, Post-doc., CFNUL

Return of HEU fuel from the RPI to the USA

J.G. Marques, N.P.Barradas, A. Kling, A.R. Ramos

Objectives

Return to the United States in the summer of 2008 of fresh and irradiated Highly Enriched Uranium (HEU) fuel assemblies from the Portuguese Research Reactor (RPI). The shipment of the fuel assemblies was the last step within IAEA's Technical Cooperation project POR4016, which covered also the core conversion to Low Enriched Uranium (LEU) fuel in 2007.

Results

The RPI was commissioned in 1961 with LEU fuel. However, it was later converted to HEU fuel. The HEU fuel was delivered to the RPI in the summer of 1974 but only started being used in 1990, at a time when a significant number of reactors was instead being converted to LEU, for non-proliferation reasons.

Fig 1. Loading into the TN-MTR transport cask of an irradiated (top) and a fresh fuel assembly (bottom).

In 1999 Portugal declared its interest to participate in the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program of the Department of Energy (DOE) of the USA. A commitment was then made to stop using HEU fuel after May 12, 2006, convert the core of the reactor to LEU and return all HEU until May 12, 2009.

The core conversion to LEU fuel was done within IAEA's Technical Cooperation project POR4016 with financial support of the USA and Portuguese governments. An extension on the use of HEU until May 31, 2007 was granted by DOE, in order to minimize the downtime of the reactor. The actual conversion was completed in October 2007.

TN International, an AREVA NC subsidiary, was selected as supplier of the transport cask and services by the IAEA, as a result of an international call for bids within project POR4016.

TN International provided an integrated package, which included a TN-MTR transport cask, a transfer cask for transport of individual assemblies from the reactor's pool to the TN-MTR cask, and technical assistance during loading. Limitations on the floor loading of the reactor building and on the capacity of the crane prevented the placement and loading of the TN-MTR transport cask inside the containment building. The cask was thus placed outside, under permanent surveillance, in a support structure built around it. The irradiated assemblies were discharged from the transfer cask in a small water basin placed on top of the TN-MTR cask, as shown in Fig. 1 (top). Fresh, non-irradiated, assemblies were loaded by hand into the same cask, as shown in Fig. 1 (bottom). The loading of the transport cask was made within three working days; three additional days were required to complete the radiological tests, close the cask, dry its interior and place the TN-MTR inside a standard 20 feet ISO container.

The transport to the USA was done by a ship under contract with DOE.

Published work

J.G. Marques, N.P. Barradas, A. Kling, A.R. Ramos, C. Anne, V. Garcia, Return of HEU Fuel from the Portuguese Research Reactor, *Proc. Int. Meeting on Reduced Enrichment for Research and Test Reactors, Washington, USA, Argonne National Laboratory, Paper 11-2.*

New Beam Filter for the Fast Irradiation Facility of the RPI
M. Lubrano[1], A.C. Fernandes, J.G. Marques

The performance of electronic components under irradiation is a concern for the nuclear industry, and both the space and the high-energy physics communities. In many situations the use of radiation hard components is not an option due to the high costs involved and standard components are used instead. However, the use of such components complicates the radiation hardness assurance. Only testing can give an indication on the radiation tolerance of the component and indicate which malfunctions can occur in a radiation environment. A fast neutron irradiation facility was implemented in the RPI in the year 2000 and was extensively used for qualification of electronic components for the LHC facility at CERN. The same facility will be used within the MTR Integrated Infrastructure Initiative (FP6) to test components for the Jules Horowitz Reactor, to be erected in Cadarache, France. A study of the modifications to be introduced in the neutron and gamma filter to adapt it to the new needs was performed as the subject of an internship of the "Génie Atomique" course of INSTN. A MCNP model of the current facility was built and qualified with measurements. A new composition for the filter was found and will be used in an update of the safety analysis report.

[1] INSTN, Saclay, France

Implementation of ASTM Standard E1855-04 in the RPI
M. Sargedas, J.P. Santos, A.C. Fernandes, J.G. Marques

The core conversion to LEU fuel performed in late 2007 changed significantly the neutron and gamma spectra in the fast neutron gamma facility of the RPI used for the qualification of electronic components. A full characterization of the facility was done combining MCNP calculations with conventional dosimetry techniques for neutrons and photons. At the same time, a new technique for fast neutron dosimetry was implemented using the variation of the small current gain of NPN transistors (reference 2N2222) under neutron irradiation, following ASTM standard E1855-04. A correction for the effects of the simultaneous gamma irradiation was done through separate irradiations in the ^{60}Co irradiation facility of ITN. A good agreement was found between the different techniques to obtain the "1 MeV equivalent" fluence, as specified in ASTM standard E722-04, which is commonly used to compare irradiations performed in different installations. Procedures for the application of standard E1855 at fast neutron irradiation facility at the RPI were drafted.

Neutron Tomography at the RPI
A. Rico, J.G. Marques

Neutron radiography is a well established non-destructive analysis method. Compared with X-rays, neutrons have as specific advantages a high interaction probability with hydrogen and a lower attenuation in several heavy elements which are "black" for X-rays. Tomography requires a reasonably high number of 2D images in digital form of the observed object rotated over 180 degrees related to its central axis. With modern CCD cameras it is possible to obtain 2D images in less than one minute, even for modest neutron fluxes of the order of 10^5 n/cm2/s. A prototype setup for neutron tomography was implemented in the horizontal access of the thermal column of the RPI. The prototype includes a ZnS:Ag scintillator screen, a FingerLakes CCD camera with fast readout and a rotary table where the object is placed in front of the beam. Full control of the setup is done through a custom-made MATLAB application. It is expected that this setup will be transferred to a neutron beam line, using a divergent beam, which will improve the resolution and increase the imaging area.

New Acoustic Instrumentation for Superheated Droplet Detectors

M. Felizardo, R.C. Martins[1], T. A. Girard[1], A.R. Ramos, T. Morlat[1], F. Giuliani[1], J. G. Marques

The application of Superheated Droplet Detectors (SDDs) in dark matter searches by the SIMPLE project, as well as neutron dosimetry and spectrometry at the Portuguese Research Reactor, uses an acoustic instrumentation sensitive to the shock wave generated by the bubble nucleation of the refrigerant droplets. Previous instrumentation relied on the use of a low-cost piezoelectric transducer, which was generally unable to provide discrimination between true bubble nucleation events and background noise events common to SDDs, including microleaks, fractures and trapped nitrogen gas. The development of a new instrumentation (high-quality electret microphone and adaptive electronics) was shown to provide this discrimination capacity through a reduced noise level and distinct fast Fourier transforms of the event registration. The performance demonstrates a factor 10 reduction in noise compared with the previous transducer instrumentation. The spatial localization of an event through an array of sensors was also initiated. Locating an event can automatically reject those that fail to satisfy prescribed criteria related to their nature or origin. This was accomplished in a two step procedure: event validation and localization. Results yielded resolutions of ~1.21 mm^2 with a 90% confidence level.

[1] CFN da Univ. Lisboa, Av. Prof. Gama Pinto 2, 1649-003 Lisboa, Portugal

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The SIMPLE Dark Matter Search Project

T.A. Girard[1], M. Felizardo, T. Morlat[1], A.R. Ramos, Fernandes, J.G. Marques, F. Giuliani[1] and R.C. Martins[2]

With a new 30 kg exposure measurement finally approved in April, the remainder of 2008 has been spent in preparations and acquisitions necessary to the measurement, which involves 15x 2% superheated droplet detectors (SDDs) equipped with new acoustic-background discriminating instrumentation, to be installed in a 700 liter temperature-regulating water bath, surrounded by 25 tons of water shielding, sited 500 m below ground for background suppression. Dr. Morlat returned to SIMPLE from PICASSO with a 5 year research position under the FCT "Ciência 2007" program; now temporarily located at the project site at "Laboratoire Souterrain Bas Bruit" (LSBB) near Apt (France), she oversaw the safety recertification of the hyperbaric chamber, extensive cleanroom cleaning, temperature controller testing, and input of a new high capacity bi-distiller.

Locally, apart from the R&D of new instrumentation (reported elsewhere), construction of the required 15 channel DAQ, and preliminary R&D of a new "big droplet detector" which remains in progress, the results of a preliminary CF3I SDD measurement were finalized, again indicating a significantly increased sensitivity of the superheated liquid technique over the more traditional (cryogenic, noble liquid, scintillator) in such searches. In December, an LSBB mission was effected to assess the experiment development and readiness for the initiation of the 200 day measurement which is now scheduled for January 2009.

[1] Centro de Física Nuclear, Univ. de Lisboa, 1649-003 Lisbon, Portugal
[2] Inst. Telecomunicações, IST, Av. Rovisco Pais 1, 1049-001 Lisbon, Portugal

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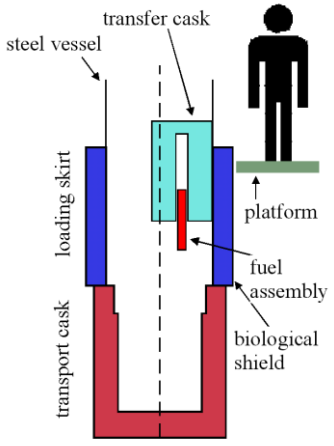
Radiological Shielding Calculations for the Optimization of Spent Fuel Loading

A. Kling, J. G. Marques

For the shipment of the spent fuel of the Portuguese Research Reactor (RPI) the fuel assemblies had to be transferred from the reactor pool to the transport cask using a transfer cask. Since some of them had a significantly shorter cooling time than in the last shipment new calculations for the determination of the expected dose rates at the transfer cask and the transport cask surface were necessary to minimize radiation exposure of the staff. The radionuclide inventory of each fuel assembly was estimated using the ORIGEN code which served as input for the shielding calculations. Since Monte Carlo calculations for photon shielding calculations with thick lead shielding are very time consuming the MicroShield code, which uses analytical methods, was employed. The results showed that the highest dose rates to be expected at the side walls of the transfer cask were in the order of 2 mSv/h in good agreement with the maximum measured value of 1.2 mSv/h. Due to the short exposure time and the distance kept to the side walls of the transfer cask these values were considered as acceptable. The maximum photon dose rate at the fully loaded transport cask at contact was calculated to be 2.8 μSv/h (measured 3.0 μSv/h), which was far below the permitted dose rate of 2 mSv/h.



Applied Dynamics

José Antunes

The activities at Applied Dynamics Laboratory (ADL) are devoted to research in nuclear engineering, with an emphasis on the vibratory and acoustic behaviour of mechanical components. Our group started in 1986, with the following objectives: (1) Develop theoretical methods, computer tools and experimental techniques, to solve structural problems in nuclear power station components; (2) Use this state-of-the-art know-how, in order to solve structural problems arising in Portuguese power plants and other industrial facilities.

The first objective has been pursued through extensive international collaboration with our main scientific partner - the French Commissariat à l'Energie Atomique (CEA) / Département de Mécanique et Technologie (DMT). More than one decade of fruitful collaboration is attested by a significant number of published results. Important problems have been solved, such as nonlinear vibrations in steam-generators, flow-induced vibrations of nuclear fuel and stability problems in rotating machinery. Furthermore, new identification techniques have been developed and applied with success to nonlinear dynamical systems.

The second objective has been pursued by starting in 1990 a series of projects with (and for) the Portuguese power supplier Electricidade de Portugal / Companhia Portuguesa de Produção de Electricidade (EDP/CPPE), stemming from actual structural problems in power plants (Sines, Setúbal): These projects enabled us to model and solve vibratory problems arising in rotating machinery, vibro-acoustical problems in boilers and heat-exchangers, as well as structural identification problems. Several computer codes have been developed in connection with these projects.

In recent years we also developed research projects of more fundamental nature, mainly funded through the Portuguese Science Foundation (FCT) research programmes. These projects have been developed in partnership with several Portuguese institutions (Faculdade de Ciências de Lisboa, Instituto Politécnico do Porto, Instituto Politécnico de Setúbal, Instituto Superior Técnico, Universidade Nova de Lisboa), as well as the Université de Paris, Trinity College Dublin and Southampton University. This work, developed in the context of fundamental physics – in particular addressing problems in music acoustics, optimization and structural geology – is centred in modelling nonlinear dynamics and flow-structure phenomena. The methods developed transcend the context of these projects and may be adapted to solve several aspects of industrial problems.

The Applied Dynamics team is mainly concerned with the following scientific fields: structural dynamics, flow-induced vibrations, nonlinear dynamics, vibro-acoustics, experimental methods, signal processing, system identification, structural and acoustical optimization. As a spin-off from our research activities, teaching has been actively pursued on structural dynamics and acoustics - ranging from university level courses in Portugal (Coimbra, Lisbon) to several post-graduation short courses abroad (Paris, Dublin, Cargèse). Also, student and post-doc training, as well as several university thesis (MSc and PhD) have been successfully supervised, for both Portuguese and foreign students. An extensive book on fluid-structure dynamics and acoustics, co-authored by two researchers from CEA and ITN/ADL was internationally published during 2006 and another volume on flow-induced vibrations is currently under completion, to be released in 2009.

Among the above-mentioned scientific fields one should stress those features which give this small group a distinct profile from others working in structural dynamics in Portugal. Those features are: (1) a proven expertise and output in flow-excited systems and nonlinear vibrations; (2) a complementary theoretical/experimental approach for every problem.

Most of the research projects pursued at ADL have been based on both industry and academic research contracts. Research activities at ADL were internationally recognized by two prizes from the American Association of Mechanical Engineers (ASME).

In 2008, the Applied Dynamics group was blessed by welcoming a new researcher as permanent staff.

Research Team

Researchers

J. ANTUNES, Princ.
V. DEBUT, Aux. (contract since Feb.)

Collaborators

L. HENRIQUE (10%), Ph.D., Adj. Professor , IPP Porto

Students

O. INÁCIO (25%) Ph.D. Inv. Professor

Optimization of multimodal acoustic control resonators

J. Antunes, F. Axisa, V. Debut,O. Inácio[1]

Objectives

This project aims at the development of optimized resonating devices, for passive control of the frequency-dependent amplitude responses of the main acoustical systems to which they are attached. Achievement of this objective is connected with the development of analytical and numerical techniques for modeling and optimization of the resonators shape and location.

Results

The significance of this project lays in the fact that the dynamical behavior of many components in industrial plants and acoustic volumes can benefit from resonating auxiliary resonating devices, in order to avoid the effects of over-enhanced resonances. The number of controlled acoustic modes depends on the central frequency and damping of resonators, as well as on the modal density of the controlled system within the resonators frequency range. The original and powerful idea of this project is to improve the efficiency of such devices by – instead of using basic single degree of freedom Helmholtz resonators – develop shape-optimized and optimally located multimodal resonators, in order to cope with a large number of intrusive modes of the main system.

Results obtained in 2008 built on the previous development of a modal-based sub-structure theoretical approach to compute the coupled acoustical modes of volumes fitted with several multi-mode resonators (Figure 1). The theoretical model was further extended to include viscous boundary layer absorption effects at the acoustical volume/resonator interfaces. Such approach proved to be computationally very efficient, being therefore well suited for optimization purposes. Numerical results obtained showed the feasibility of this multimodal coupled resonator concept.

Most recent developments concern the resonators optimization, performed by iteratively adapting their shape and location in order to minimize a target error-measure, within imposed physical and/or geometrical constraints. As a specific illustrative application, using a global optimization technique – simulated annealing – we optimized two auxiliary resonators in order to level, within a given frequency range (20~100Hz), the acoustical frequency response function between a loudspeaker and a listening location in a given control room (Figures 2 and 3).

Such problem encapsulates most of the difficulties encountered in other fields, and we obtained truly representative results for the optimized complex acoustical problem. The results obtained so far suggest that very significant response improvements can be achieved, see Figure 2. This work highlights the potential of the proposed corrective methodology.

Published work

O. Inácio, J. Antunes, Shape-optimization of several multi-modal resonators accounting for room-resonator acoustical coupling (2008), *Acoustics* 2008, 29 June – 4 July 2008, Paris, France, abstract in *Journal of the Acoustical Society of America*, Vol. 123, p. 2983.

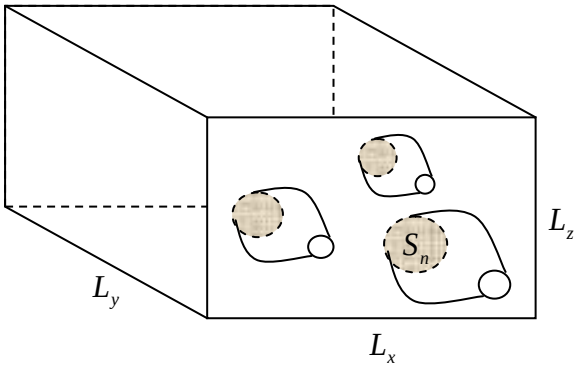


Figure 1: Room fitted with multi-mode resonators.

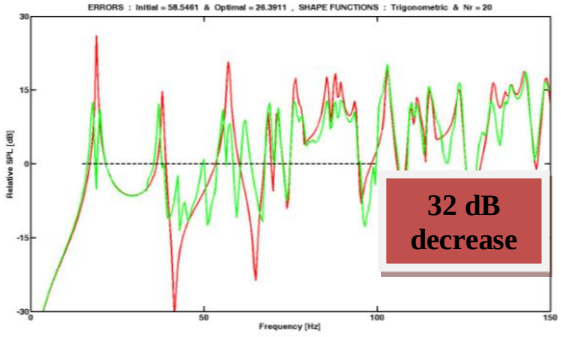


Figure 2: FRFs of the original (red) and corrected (green) room using optimal resonators.

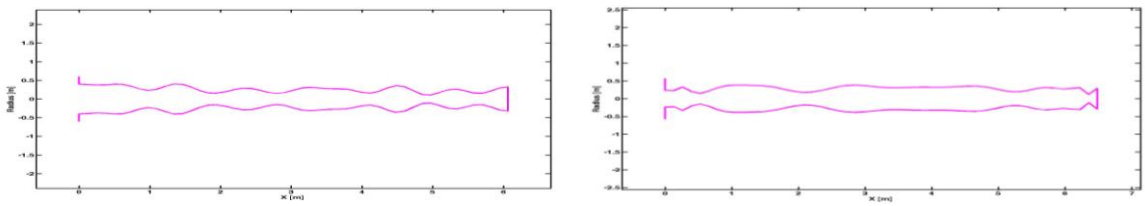


Figure 3: Examples of optimal resonators, with shapes described respectively using sets of trigonometric functions and of Chebyshev polynomials.

[1] Inst. Politécnico do Porto, ESMAE, Lab. of Music Acoustics

Flow-induced vibrations of tubular nuclear components
J. Antunes, X. Delaun[1], P. Piteau[1],L. Borsoi[1]

Flow turbulence excitation is a common source of structural vibrations, leading to fatigue failures and wear. For nuclear facilities, such problem must be addressed with particular care, for obvious safety reasons. At ITN/ADL, under contract with CEA-Saclay, we gained significant expertise in this area. This project, now third year, is aimed at the development of up-to-date software to compute the flow-induced vibrations of nuclear components such as fuel rods or steam-generator tubes. Nonlinear vibro-impact phenomena between the tubes and their supports are incorporated in the nonlinear time-domain computational models. During 2008 a new version of our computer program was developed, incorporating a "direct" method for the time-domain generation of partially space-correlated turbulence excitations. Such technique is based on a Proper Orthogonal Decomposition (POD) of the cross-spectral complex matrix of the random field, followed by inverse FFTs of the frequency-domain signals. This excitation method proved well suited for both axial and transverse flows. We are currently comparing the linear and nonlinear system responses obtained using this turbulence simulation technique with those stemming from an original simplified method developed in 2007.

[1] Commissariat à l'Energie Atomique, Lab. of Dynamical Studies, Saclay, France

Modeling and reduction of aeroacoustic noise in flow-conveying systems
M. Moreira[1], V. Debut, J. Antunes, H. Pina[2], J. Paulino[3]

The interaction between a gaseous flow and the tube banks of heat exchangers often leads to self-excitation of acoustic resonances which can seriously affect the system integrity. Similar problems also arise in pipe-systems. In spite of the industry concern, the physical mechanisms of sound excitation are still far from understood and current stability criteria are not trustful. This three years project, funded by a FCT grant, aims at increasing our understanding of the relevant physical mechanisms of aero-acoustic instabilities, and also developing techniques for optimizing the acoustical devices used to inhibit them. Following our theoretical work previously developed, we performed new wind tunnel experiments to validate a simplified numerical model of the vortex-excited acoustic field, coupled with global optimization methods for the optimal configuration of acoustical baffles. Concerning a closely related problem of industrial interest, the acoustic self-excitation of corrugated pipes under axial flow, a conceptual phenomenological model was developed to reproduce the qualitative trends observed in experiments with corrugated pipes. Such model involves coupling an acoustic pipe with a line of self-excited oscillators which stand for the corrugations vortex excitation. This model was explored through extensive time-domain simulations and complex modal computations.

[1] Instituto Politécnico de Setúbal, Escola Superior de Tecnologia, Department of Mathematics
[2] Instituto Superior Técnico de Lisboa, Department of Mechanical Engineering
[3] Instituto Superior de Engenharia de Lisboa, Department of Mechanical Engineering

Vibro-acoustical modelling of structures coupled with two-phase fluid mixtures
V. Debut, J. Antunes

Energy dissipation in bubbly mixtures is an important issue, as many industrial components operating in two-phase fluids are prone to flow-induced vibrations, nuclear steam generators for instance. Understanding such dissipative phenomena is required to avoid excessive vibrations, which depend on the mixture void fraction and flow regime. A significant increase of damping is observed in two-phase flow, however the nature of the dissipation mechanisms remains an open issue. As a step toward fundamental understanding, we performed preliminary experiments on a cylindrical shell filled with a bubbly liquid. Modal identification was achieved by implementing the Eigen-Realization Algorithm (ERA). These tests demonstrated the strong attenuation due to two-phase damping. A theoretical model involving piston oscillators coupled by a bubbly liquid was developed, using a fourth-order linearized model for the wave propagation in two-phase mixtures. The set of modal ODEs obtained after modal projection provided numerical time-domain simulations, as well as frequency-domain computation of the coupled modes as a function of the mixture void fraction. Preliminary results show that our theoretical model encapsulates the qualitative trends of real systems.

Dynamical modelling of nonlinear vibratory and acoustical systems
J. Antunes, O. Inácio[1], M. Wright[2]

This research started some years ago as a FCT funded project, an international cooperative effort to develop theoretical methods and numerical techniques for dealing with strongly non-linear dynamical problems, such as involving impacts and friction phenomena. The main objective was the development of modeling techniques for nonlinear multi-modal structures. In previous years we developed efficient numerical techniques to predict the nonlinear dynamics and interaction forces of friction self-excited systems, including strings, bars and shells, as well as complex coupled sub-systems. During 2008 we have extended our computational methods in order to model the controlling effect on self-excited vibratory responses of secondary coupled oscillators. The theoretical results thus obtained were validated by experiments. A PhD thesis was presented at Southampton University, examination being scheduled for February 2009.

[1] Instituto Politécnico do Porto, ESMAE, Laboratory of Music Acoustics
[2] University of Southampton, Institute of Sound and Vibration Research, UK

Neutron Activation in Environment, Nutrition and Epidemiology

Maria do Carmo Freitas

The research is focused on development of methodologies in neutron activation analysis and their application to studies of atmospheric environment, nutrition and health. The investigation appeared as a natural application of the potentialities of k_0-INAA (instrumental neutron activation analysis using the k_0-method). The unit activities include six main lines:

Development of Methodologies, Quality Control, Automatization, Data Handling aim to optimize the technique in order to enable the measurement of numerous samples measured and to speed the calculation and handling of the data. Also it aims to extend to other methodologies in order to improve the detection limits for important chemical elements as cadmium, arsenic, nickel as well as to turn possible to determine lead and the light elements. Steps are being given towards ISO 17025 to establish protocols and standard procedures. Exercises of interlaboratory data comparison are targets.

Monitoring, Biomonitoring aims to characterise areas of Portugal using lichen transplants, air particulate matter collection, and (wet+dry) deposition. The data are analysed for factors aiming at identifying emission sources and the spread of elements through the atmosphere, both locally and by long-range transport. Data analysis methods and their development are very important due to the multielement nature of the analytical technique used. To assure the quality of the data, accuracy and precision studies are being performed, both in biomonitoring and monitoring fields, aiming at better understanding differences found in the results for the same element and sample. Air particulate matter obtained by different air samplers is compared. So-called conventional analytical techniques are applied to complement the research unit's results. New biomarkers are suggested and studied. Pb-210 is being determined to confirm terrestrial origin of aerosols. Within this activity line, the following is being done: services to industry/Universities, FCT funded project research and Ph.D. theses in collaboration with Universities.

Epidemiological studies include health related problems. The objective is to link biomonitoring and monitoring to epidemiological studies, at local, regional and European scale. Currently, one PhD is dedicated to this subject and two projects on this subject are running, financed by FCT.

Element Uptake Processes. The group also studies the plant physiology looking for effects on plants due to atmospheric chemical components. The underlying questions are related to the extent in which lichens may reflect the element contents of particulate matter, which may possibly be dominated by its soluble element concentration fractions. This is the subject of one Ph.D. thesis and one project funded by FCT. Lichen dynamics, this is, accumulation and release are being deeply studied.

Nutrition. Selenium has been the target. A PhD thesis was finished and aimed to conclude on selenium in Portuguese diets. A project was now accepted for FCT financial support aiming to continue the study in cereals, supported by supplementation of the element and study of its absorption (how, how much) in the cereal pant and the cereal grains.

Training. The research unit has a strong component in post graduation training. An intensive workshop will take place at ITN on 2009, on the different expertises of the group. It will be available to any interested attendee from ITN and other Institutes/Universities. The group organizes international conferences.

Participation in intercomparison exercises
Whenever offered, the group collaborates in data intercomparison, to improve data quality.

Services. Analytical services are also provided under request.

Research Team

Researchers

M. CARMO FREITAS, Princ. Res., Group Leader
S.M. ALMEIDA, Ciência 2007, FCT
H.M. DUNG, Post-doc., FCT grant; Ciência 2007, FCT
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Collaborators

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H.TH. WOLTERBEEK, Sen. Res., TUDelft, The Netherlands
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A.P. MARQUES (PhD student, finished October)

Characterising Air Particulate Matter Composition and Sources for an Epidemiological Study

M.C. Freitas, S.M. Almeida, C.S. Repolho, I. Dionísio, H.M. Dung, D. Beasley, C.A. Pio[1], C. Alves[1], A. Caseiro[1], A.M.G. Pacheco[2]

Objectives

The project "Impact of Atmospheric Aerosol on Human Health" focuses on the chemical characterization of $PM_{2.5}$ aerosols aiming to analyze the health risks associated with exposure to aerosols. It also aims to understand how their chemical composition contributes to the toxicity and the human health problems, usually associated with fine particles. The study of the associations between the sources contribution and the health impact aims to introduce focused abatement strategies in industrial processes, automobile circulation and city planning; they might contribute to the decrease of particulate levels and, consequently, the decrease of impact on human health.

Results

Thirty seven basic schools of Lisbon city followed a questionnaire about respiratory diseases, nutrition habits, ingested medication and environmental aspects, among others. The questioned children were 5 to 10 years old, and the answers were collected from June to December 2006. Results showed that from 1175 children inquired 25.9% had asthma and 27.7% had rhinitis.

Students from four schools around the air sampler (São José, São João de Brito, nº 183 and Actor do Vale) were selected and rhinitis and asthmatic symptoms were daily registered from May 2007 to April 2008.

In 2007, $PM_{2.5}$ was collected in a daily basis in the centre of Lisbon. Sampling was done with a Partisol sampler using Teflon® filters. The filter loads were measured by gravimetry using a Mettler Toledo balance with 0.1 µg sensitivity. The exposed filters were cut into two parts controlled by weight: one was analyzed by Neutron Activation Analysis and the other was analyzed by Ion Exchange Chromatography. The irradiation was performed in the Portuguese Nuclear Reactor for 5-7 h, and measurements of 4-7 h after 3-7 days and 4 weeks of decay were made with high purity high resolution germanium detectors, with automatic sample changers. A comparator – 0.1% Au-Al disc – was irradiated and measured for application of the k_0 standardized neutron activation analysis.

$PM_{2.5}$ annual average mass concentration was 19 µg/m^3. Therefore, results show that the studied children, living and studying in Lisbon, are breathing an atmosphere with fine particles concentrations higher than advised by World Health Organization and U.S. Environmental Protection Agency, although below the proposed European Union value.

$PM_{2.5}$ levels are mainly due to anthropogenic particles, being the ions SO_4^{2-}, NH_4^+ and NO_3^- the most abundant species in $PM_{2.5}$ (Fig. 1). These ions derive from gas to particle conversion processes and are associated with anthropogenic sources such as traffic and industry. The concentration variability along the day and the ratio between weekdays and Sundays show, as expected, that traffic is an important source of particles in Lisbon.

Higher number of rhinitis episodes were observed in April (123 children) and lower number in August (27 cases) in the Lisbon basic school inquired population. The questionnaires revealed that 56 of the children reporting rhinitis in April and August live in streets where trucks are passing frequently or the whole day. The children inhale higher concentrations of zinc and antimony in April than in August, mainly due to the high traffic reduction in August. Furthermore in April the studied anthropogenic elements are more concentrated in finer particles (PM_1 or lower) than in $PM_{2.5}$. Such small particles enter easily the lungs. Pollens were guessed not to interfere with the rhinitis cases found because in April only 18 children out of 123 showed hay fever and rhinitis together. The traffic by itself, with all its pollutant (inorganic+organic) charges, may then be the main cause for the higher number of rhinitis complains in April than in August.

Back trajectory analysis showed that ocean contribution is very significant for $PM_{2.5}$ collected in the centre of Lisbon. Maritime samples presented the lowest concentrations for SO_4^{2-}, NH_4^+ and NO_3^-. This fact could be attributed to the transport of cleaner air masses from the sea and to the existence of better vertical dispersion conditions during these events.

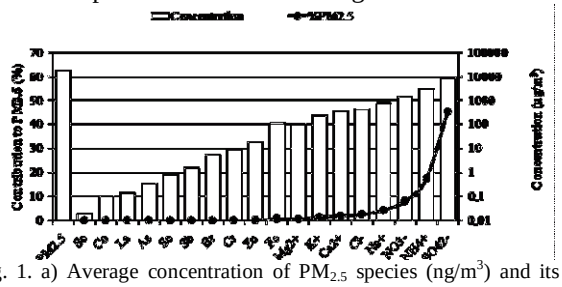

Fig. 1. a) Average concentration of $PM_{2.5}$ species (ng/m^3) and its contribution for total mass of $PM_{2.5}$ (%). b) Average contribution of the aerosol species to $PM_{2.5}$ mass.

Published work

M.C. Freitas, S.M. Almeida, A.M.G. Pacheco, I. Dionísio, C. Repolho, A. Caseiro, C.A. Pio, C. Alves (2008) Seasonal exposure to air pollutants characterisation for a respiratory epidemiological study, Journal of Radioanalytical and Nuclear Chemistry (accepted).

S.M. Almeida, M.C. Freitas, C. Repolho, I. Dionísio, H.M. Dung, C.A. Pio, A. Caseiro, A.M.G. Pacheco (2008) Characterizing air particulate matter composition and sources for an epidemiological study, Journal of Radioanalytical and Nuclear Chemistry (accepted).

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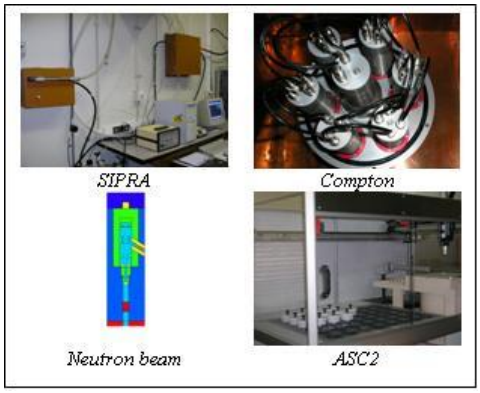
Neutron Activation Analysis at ITN

H.M. Dung, D. Beasley, I. Dionísio, M.C. Freitas



The irradiation and count techniques of neutron activation analysis (NAA) includes 1) fast pneumatic irradiation facility (SIPRA) with epithermal or/and thermal neutrons upgraded; 2) Compton suppression system (CSS) with and without anti-Compton mode enabled and automatic sample changers (ASC2). The systems have been optimized and combined to determine multi-element in quartz and Teflon aerosol filters. The elemental concentrations resulted from the optimized and combined techniques of NAA for the elements: Al, As, Br, Ca, Cl, Co, Cr, Cu, Fe, Hf, I, K, La, Mg, Mo, Na, Sb, Sc, Si, Sm, Th, Ti, U, V, W and Zn. These elements have been used in source receptor modeling at sampling sites such as Azores, Aveiro and Lisbon. The k_0-standardized method of NAA has been used for the calculation of elemental concentrations in samples. The calibration of all gamma-ray spectrometers have been done each six months. The neutron spectrum parameters at irradiation facilities used for k_0-NAA on the Portuguese research reactor have been re-characterized after changing fuels from HEU to LEU. Facilities for Prompt Gamma Neutron Activation Analysis (PGNAA) are being installed at the reactor. PGNAA permits the quantification of some elements undetectable by traditional NAA. At this stage we have planned the new facilities using the Monte Carlo code MCNPX to build a model of the proposed PGNAA facilities. These included thermalising the current epithermal beam by the introduction of a sapphire crystal into the beam line. The intercomparison runs by NAA with three "coffee" samples (Brazil), three tobacco samples (Poland) and two mussel samples (Brazil) have been completed. Several protocols and equipment have been documented and the non-conformance has also been managed following the ISO-17025 guidelines.

Exhaled Breath Condensate: a tool for noninvasive evaluation of pollutant exposition?

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The aim of the present study is to investigate whether Exhaled Breath Condensate (EBC) can be employed for a better risk assessment among humans exposed to toxic pollutants, in lead processing industries. The project is a joint initiative of ITN units UFA and URSN, together with the Instituto de Soldadura e Qualidade and the Hospital de Santa Maria. The primary objective is to develop a new non-invasive human bioindicator that could be applicable for professional exposition. During 2008 industries were selected and EBC sampling was tested in voluntaries to establish the better methodology to sample, store and analyse the EBC. Preliminary tests were also made in workers along the working shift to define the most representative sampling time. EBC chemical characterization are being performed by TXRF in INETI and by ICP-MS in ITN, the latter recently installed under the Programa Nacional de Re-Equipamento. This collaborative work with the Environmental and Analytical Chemistry Group of ITN and LAAQ/INETI will enable methodology validation and perform inter-laboratory exercise for analytical performance comparison.

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Different aspects of biomonitoring, epidemiology and data handling

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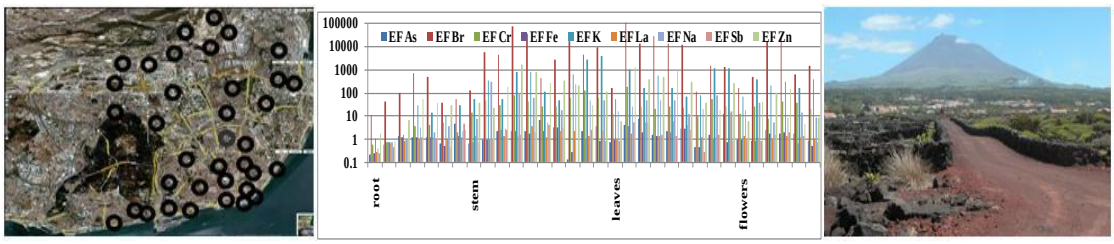

This study is the subject of 4 Ph.D. grants and 2 projects funded by FCT. It aims to map air pollution in Lisbon city by exposure of lichen and bark transplanted from clean areas to 22 school courtyards, and measurement of conductivity and determination of chemical element contents after being exposed. Also it aims to infer the remote air pollution in altitude by exposing lichens every 150 m starting at sea level to the summit of Pico Mountain, Azores, and analysing them for element contents. At São Domingos mine, vascular plants and soil were collected and analysed after separation of the plant in root, stem, leaves and flowers. Enrichment factors were determined showing higher enrichments in stems and leaves mainly for arsenic, bromine and antimony.

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