Nuclear energy related researches at the University of Pisa

Nuclear Reactor Thermal-Hydraulics

Contacts: Proff. W. Ambrosini and N. Forgione
Activities in the field of nuclear reactor thermal-hydraulics

General capabilities (Prof. N. Forgione)
• Application of system thermal hydraulics codes (e.g. RELAP5/Mod3.3 modified) to reactor system problems

Activities in the field of nuclear reactor thermal-hydraulics
• Application of CFD codes with RANS models (e.g., STAR-CCM+ or FLUENT) for detailed analysis of component behaviour and heat transfer in challenging conditions
Activities in the field of nuclear reactor thermal-hydraulics

**General capabilities**
- Use of codes for the interaction between water and molten metals in Gen IV and fusion reactors postulated accident conditions (SIMMER code)

Activities in the field of nuclear reactor thermal-hydraulics

**Specific**
- Coupled code technique developed at UniPi using RELAP5 and ANSYS Fluent codes.
- Applications are on-going for the analysis of loop-type and pool-type experimental apparatus (inside SESAME and MYRTE EU-Projects).
Activities in the field of nuclear reactor thermal-hydraulics

General capabilities (cont’d)
(Proff. W. Ambrosini and N. Forgione)

• Past experimental activities on:
  ✓ **Steam condensation** in the presence of noncondensable gases with validation of CFD codes (two international Benchmarks)
  ✓ **Natural circulation** with different fluids and gas injection enhanced circulation
  ✓ **Statistical characteristics** of falling water films for cooling heated surfaces in Gen.III reactors
  ✓ **Evaporation of falling water films**
  ✓ **Model development and application** for all the above considered phenomena
Past Activities in the field of nuclear reactor thermal-hydraulics

**CONDENSATION**

**NATURAL CIRCULATION**

Past Activities in the field of nuclear reactor thermal-hydraulics

**EVAPORATION OF FALLING FILMS**

**FILM THICKNESS BY CAPACITANCE TRANSDUCERS**
Activities in the field of nuclear reactor thermal-hydraulics

General capabilities (cont’d)
(Proff. W. Ambrosini and N. Forgione)

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  ✓ Steam condensation in the presence of noncondensable gases with validation of CFD codes (two international Benchmarks)
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Activities in the field of nuclear reactor thermal-hydraulics

Specific ongoing studies
(Prof. W. Ambrosini)

• Heat transfer to supercritical pressure fluids in deteriorated and enhanced conditions
  ✓ application of CFD and system codes (RELAP5)
  ✓ advanced modelling with four-equation turbulence models
  ✓ proposal of new similarity principles for scaling heat transfer phenomena
  ✓ introduction of the effect of wall roughness in low-Re turbulence models
  ✓ LES analyses for supporting similarity principles

• The above activities are performed in cooperation with different EU and non-EU institutions and in the frame of IAEA Coordinated Research Projects
Activities in the field of nuclear reactor thermal-hydraulics

Specific ongoing studies

- Studies of flow stability with supercritical pressure fluids in channels and natural circulation systems
  - application of CFD and system codes
  - in-house models
  - similarity theories with high degree of universality (different fluids and supercritical pressures)

- Development of mechanistic models for predicting boiling heat transfer by CFD codes (in cooperation with MIT)

- Coupled code technique developed at UniPi using RELAP5 and ANSYS Fluent codes. Applications are ongoing for the analysis of loop and pool type experimental apparatus (SESAME and MYRTE EU Projects, Prof. Forgione)
Activities in the field of nuclear reactor thermal-hydraulics

STABILITY ANALYSES OF A NUCLEAR FUEL SUBCHANNEL WITH SC FLUIDS BY CFD AND SYSTEM CODES

NUGENIA is mandated by SNETP to coordinate nuclear Generation II & III R&D

Trends in severe accident research at UNIPI the SARNET network from Euratom to NUGENIA

Sandro Paci (Source Term, Codes and Knowledge spreading)
Walter Ambrosini, Nicola Forgione (thermal-hydraulic aspects)
Bruno Gonflotti (ASTEC and MELCOR during PhD & post PhD)
**Euratom Context**

- SARNET (Severe Accident NETwork of excellence) was co-funded from 2004 to 2013 in EU FP6-FP7 and then integrated in NUGENIA
  - All previous scientific domains are now in NUGENIA Technical Area TA2 “severe accidents” with extension to:
    - Emergency preparedness and response
    - Severe accident impact on environment
- The main network activities continuing:
  - Technical workshops by sub-domains
  - ERMSAR conferences
  - Education & Training courses
  - Ranking of R&D needs
  - And elaboration of new R&D projects

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**UNIPI in Euratom SARNET**

**Working Packages WP**

- Dissemination of knowledge (UNIPI was WP leader)
  - 8 ERMSAR periodic conferences (100 to 150 participants)
  - 7 Education & Training one-week courses (40 to 100 participants)
  - Publication of a reference textbook on severe accident phenomenology (free for Italian Universities as pdf)
  - Mobility programme for young researchers & students (52 delegations)
- Containment WP (experimental and numerical activities)
- ASTEC Code Users WP
- Source Term WP
and now SARNET in NUGENIA

- Coordination: IRSN
- Sub-TA and leaders (in bold UNIPI involvements)
  - 2.1 In-vessel corium/debris coolability (KIT)
  - 2.2 Ex-vessel corium interactions-coolability (CEA)
  - 2.3 Containment behaviour, incl. $H_2$ risk (JSI)
  - 2.4 Source term released to environment (CIEMAT)
  - 2.5 Impact of severe accidents on environment and emergency management (IRSN)
- 2.6 Severe accident scenarios (ENEA)
- Coordination of dissemination of knowledge: UNIPI

R&D SA main goal

*Scenario simulation with the ASTEC code*

ASTEC simulation of SA Management (SAM) for the NPP types operating in Europe

UNIPISA goal: ASTEC and MELCOR codes adaptation & validation for the safety analysis of future fusion plants (in collaboration with IRSN, ENEA Frascati and KIT)
14 years after its start, SARNET networking continues efficiently in NUGENIA frame

- **Technical workshops:** essential “bricks” for the share of R&D progress and brain-storming for new projects...
- **Recent events:**
  - 8th ERMSAR Conference in Warsaw May 2017
  - 5th Education Course in October 2017 at JSI (Ljubljana)
- **SARP (SA Research Priorities):** starting in 2018 for update of priorities
- **Main challenges:**
  - keeping still active the SA Community (workshops, new projects, publications) despite possible cuts of R&D funding
  - increase links with OECD/NEA, very active on SA

**Perspectives**

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**UNIVERSITÀ DI PISA**

**DIPARTIMENTO DI INGEGNERIA CIVILE E INDUSTRIALE (DICI)**

**Nuclear Measurement Laboratory (NML)**

Contact persons:
Prof. Francesco d’Errico (francesco.derrico@ing.unipi.it)
Dr. Riccardo Ciolini (r.ciolini@ing.unipi.it)
Research activities

- Development of techniques for neutron detection, spectrometry and dosimetry in medical, nuclear and industrial applications
  - Superheated drop detectors
  - Activation threshold and resonance detectors
  - Track etch detectors (CR-39 and LR-115)
  - ThermoLuminescent Detectors (TLD)
  - BF$_3$ and $^3$He proportional counters and proton recoil counters
  - Bonner spheres
  - Semiconductor dosimeters and SiC neutron spectrometer
  - Ion chambers
  - Radioinduced polymerization gel dosimeters
  - In-core (SPND) detectors

- Gamma, alpha and beta radiation measurements
  - Low background system for gamma activity measurements
  - Silicon detectors for alpha spectrometry

- Personal dosimetry
  - Neutron personal dosimetry in nuclear reactors with track etch detectors
  - Criticality accident dosimetry
  - Radon concentration measurements in schools and workplaces
  - BNCT dosimetry
  - TLD measurement of the dose delivered to pediatric patients during a CT scanning
  - Dosimetry measurements and quality image assessment during CT and echo graphic scanning

- Simulation of radiation transport and detector response with deterministic and stochastic methods
- SNM detectors (nuclear security): development of antiterrorism systems for detection of dirty and nuclear bombs

- Activated charcoal characterization to be used as radioactive noble gases filters in nuclear power plants

- Radon concentration measurements in deep waters for earthquakes forecast

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**Structural mechanics**

Contact Persons:
Prof. Donato Aquaro (donato.aquaro@unipi.it)
Dr. Rosa Lo Frano (rosa.lofrano@ing.unipi.it)
Activity on decommissioning and RW cask/packaging licensing

Licensing of cask and packaging for RWs transport and storage (Lab. B. Guerrini certified IAEA)

- Fire test
- Drop test

Cask licensing: experiment & simulation

Activity on fission technology

Investigation of NPP (existing or Gen IV systems) and RWs repository performance in design and beyond design condition (aircraft impact, seismic analysis with sloshing, core compaction, pipe whipping, steam generator tube rupture, etc.)

- Missile impact on metallic structures

Simulation of core compaction in LFR
Activities on fusion technology

- Evaluation of the thermal conductivity of ceramic pebble beds for breeder in fusion nuclear reactors
- Thermo-mechanical analyses of HCPB box components
- Pipes Stress of ITER Reactor & THs of the primary heat transfer system
- Experimental and numerical evaluation of dust re-suspension in ITER Vacuum Vessel
- Experimental study of steam pressure suppression by condensation in a water tank at sub-atmospheric pressure

Instron device for the compression tests on pebbles

Condensation test facility

condensation regime map at sub-atmospheric pressure

\( \text{Li}_4\text{SiO}_4 \quad d = 0.57 \text{ mm} \quad \text{- Collapse load} \quad P = 11.6 \text{ N} \quad \text{Test n.4F} \)

Reactor Physics Group Activities

Valerio Giusti

Università di Pisa
Dipartimento di Ingegneria Civile ed Industriale