



# UNIVERSITÀ DI PISA

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## NUCLEAR THERMAL HYDRAULICS

**FRANCESCO SAVERIO D'AURIA**

Anno accademico 2023/24  
CdS INGEGNERIA NUCLEARE  
Codice 1088I  
CFU 12

Moduli	Settore/i	Tipo	Ore	Docente/i
NUCLEAR THERMAL HYDRAULICS	ING-IND/19	LEZIONI	120	FRANCESCO SAVERIO D'AURIA

### Obiettivi di apprendimento

#### *Conoscenze*

fondamenti di fisica tecnica

#### *Modalità di verifica delle conoscenze*

esame orale: tre esercizi allo studente: dopo la soluzione degli esercizi, domande sul programma

#### *Capacità*

progetto termoidraulico dei reattori nucleari ad acqua

#### *Modalità di verifica delle capacità*

come verifica delle conoscenze

#### *Comportamenti*

risposte alle domande

#### *Modalità di verifica dei comportamenti*

come da verifica di cui sopra

#### *Prerequisiti (conoscenze iniziali)*

fisica tecnica principalmente e/o fluidodinamica

#### *Indicazioni metodologiche*

fisica tecnica ==> esame attuale

#### *Programma (contenuti dell'insegnamento)*

**NUCLEAR ENGINEERING COURSE' – YEAR 2020/2021**

**Title: 'Thermal-hydraulics in Nuclear Technology'**

**Professor: F. D'Auria**

*The program includes three key topics as listed below. Integration lectures and Seminars will be held in the areas of 'CFD (Computational Fluid Dynamics)', 'Nuclear Fuel' and 'Boron-Dilution-Issue'.*

**1) THERMAL-HYDRAULICS AND NPP TECHNOLOGY.** The following sub-topics are considered: a) NPP key components and design principles; b) PWR & BWR RCS thermal-hydraulic design; c) The Safety Technology of NPP: the DBC, the DEC-A and DEC-B; d) The criteria for ECCS design from 10 CFR 50.46. Meaning and content of 'Nuclear Thermal-hydraulics (NTH)' according to recent review of NTH books (6th recommended Journal Special Issue, below).



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**2) DESIGN OF NUCLEAR FUEL PIN.** This includes the applications of the Fourier Equations and of the Fourier Law. The concepts of LHGR, MDNBR and MCHFR are introduced

**3) MODELING IN NUCLEAR THERMAL-HYDRAULICS.** The following sub-topics are considered: a) fundamentals including flow regimes, b) pressure drops, c) balance equations, d) multi-dimensional surface for HTC (the condensation, the CHF and the reflood), e) structure of a system thermal-hydraulic code for design & transient analysis of NPP performance, f) constitutive/closure equations, g) (verification) and validation (V & V) for SYS TH codes, h) scaling and uncertainty issues, i) the BEPU approach.

**4) IDENTIFICATION AND CHARACTERIZATION OF THERMAL-HYDRAULIC PHENOMENA IN LWR.** IT and SET phenomena are distinguished. Reference made to OECD/NEA/CSNI CCVM and to IAEA SRS 23. The boiling channel. The blow-down and the TPCF. The CCFL. The containment pressurization following LOCA

**5) NATURAL CIRCULATION.** NC constitutes a key IT phenomenon relevant for design and safety of NPP. Application to recent reactor technological aspects will be considered: RCS, Containment and ECCS design, SMR design. Instability in fluid-dynamics and in two-phase conditions (DWO). Reliability of NC and of passive systems.

**6) THERMAL-HYDRAULIC ASPECTS OF KEY ACCIDENTS IN NPP TECHNOLOGY:** Three Mile Island – 2 (PWR, 1979), Chernobyl – 4 (RBMK, 1986), La Salle & Oskarshamn (BWR, 1988 & 1999), Fukushima 1-4 (2011).

### SUGGESTED BOOKS (IN ADDITION TO LECTURE MATERIAL)

- Lahey-Moody “Thermal-Hydraulics of a Boiling Water Reactor” – ANS 2nd – 1993
- Todreas-Kazimi “Nuclear Systems, I & II” – CRC (Taylor & Francis Group), 2nd – 2011
- D’Auria F. (Editor) “Thermal-hydraulics in Water Cooled Nuclear Reactors”– Elsevier – 2017
- IAEA, SRS 23 Accident Analysis (available from web) – 2002
- IAEA, SRS 52 Uncertainty Analysis (available from web) – 2008
- Elsevier Journal ‘Nuclear Engineering and Design’ (J NED), Special Issue n. 354 (December, Ed. F. D’Auria, available from web) – 2019
- OECD/NEA/CSNI, A state of the art report on scaling in system thermal-hydraulics applications to nuclear reactor safety and design (Ed. F. D’Auria available from web) – 2017

### Bibliografia e materiale didattico

vedi casella sopra

### Indicazioni per non frequentanti

è suggerito frequentare - i non frequentati dovrebbero interloquire con il docente

### Modalità d'esame

indicata sopra

### Altri riferimenti web

vedi programma del corso

### Note

è suggerito frequentare le lezioni del docente

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