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School on Physics, Technology and Applications of Accelerator Driven Systems (ADS)

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ADS Physics: Physics and Dynamics.
Part I

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ADS Physics

Lectures
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CONTENT

Set I:
SUB-CRITICAL SYSTEM NEUTRONICS

I.1. INTRODUCTION: PHYSICAL PROPERTIES

I.2. PHYSICS BACKGROUND. GENERAL FEATURES.

I.2.A.

Physics of the external neutron sources. Nuclear reactions leading to the neutron production (Y. Kadi interpretation). Spallation and Fusion neutron Yields (multiplicity of emitted neutrons).

I.2.B.

Spallation source characteristics to be used in an ADS.

Neutron Spectrum (i.e. energy distribution of emitted neutrons).

Product distributions (the radio-toxicity of the residues), Energy deposition (the thermal-hydraulic requirements). Energy consumptions. General features of accelerators and other devices.

I.2.C.

Physics of sub-critical systems: Statics.

Spatial neutron distributions, amplification of neutrons, experimental studies of spallation. Sub-critical multiplying cores in stationary regime, flux distributions, the reactivity of sub-critical cores, reactivity coefficients, the integral importance of external source neutrons.

I.3. ADS NEUTRONICS

On Principal Neutronic Features of ADS. Integral ADS parameters. Spacial neutron distribution. ADS and Safety related Physics

I.4. DIVERSITY OF HYBRID SYSTEMS

I.4.1. DEFINITIONS: ARTIFICIALLY ENHANCED NEUTRONICS AND CORE SUBCRITICALITY. ENERGY TRANSFER DIAGRAM.

I.4.2. HYBRIDS WITH AN INDEPENDENT EXTERNAL NEUTRON SOURCE: Accelerator Driven Systems (ADS)

I.4.3.HYBRIDS WITH THE COUPLED EXTERNAL NEUTRON SOURCE: Delayed Enhanced Neutronics (DEN) concept, Accelerator Coupled Systems (ACS)

I.4.4. HYBRIDS WITH AN ALTERNATIVE NEUTRON SOURCE: FUSION DRIVEN SYSTEMS (FDS). Particularity of fusion reactions. Neutron analysis. Fusion as an external neutron source.Inter-comparison: ADS versus FDS

I.5. EXPERIMENTAL VALIDATION OF SUB-CRITICAL CORE PHYSICS.

The MUSE Experimental Program - the physical principle, experimental results and techniques, further experimental validation at power.
YELINA experiments.

SET II:
ADS SAFETY PHYSICS

CONTENT

II.1. INTRODUCTION: Challenges facing Nuclear Power.

International Generation IV Forum’s criteria. Nuclear Power safety requirements and ADS. Intrinsic safety and deterministic safety principles. Simplified ADS and ASC kinetics.

II.2. ON INTRINSIC SAFETY POTENTIAL OF ADS.

Asymptotic Reactivity Balance. ADS ANALYSIS
Transients Over-Power (TOP) / Transients Over-Current (TOC).
Loss Of Flow Without Scram (LOF) - Pumps Stop. Loss Of Heat Sink Without Scram (LOHS). ACS ANALYSIS

II.3. NON-LINEAR COUPLED ADS

Non-linearAccelerator-core coupling: DENNY- mode. Y_n non-linear effect. Principle of the operation.

II.4. SUB-CRITICAL SYSTEMS VERSUS CRITICAL REACTORS DYNAMICS INTER-COMPARISON (EXAMPLE: MOLTEN SALT ADVANCED POWER PRODUCTION SYSTEM)

II.4.1. CHOICE OF THE SUBCRITICALITY LEVEL

II.4.2. ILLUSTRATION: SUBCRITICALITY AS A TOOL FOR INTRINSIC SAFETY ENHANCEMENT.

Molten Salt Reactor model. Molten salt ADS kinetics. Fast Spectrum System: Thermo-Hydraulics And Feedbacks. Subcriticality Level Aiming To Enhance Intrinsic Safety Features.Unprotected Anticipated Transients. Reference Cores For Transient Simulation: Fast-Spectrum Molten Salt ADS. Unprotected transients in the fast-spectrum systems. Unprotected Transients Over Power/Transients Over Proton Current. Unprotected Loss Of Fuel Flow. Unprotected Loss Of Heat Sink Transients. Discussion.

Set III:
LONG-LIVED RADIO- WASTES AND TRANSMUTATION POTENTIAL of ADS

III.1. INTRODUCTION.

General characteristics of nuclear wastes and their origins: risks of the long-life wastes, activity and toxicity waste levels and their natural decays.
Quantitative Measure of Radiotoxicity (R)

III.2. PHYSICS OF THE TOXICITY REDUCTION VIA TRANSMUTATION/INCINERATION

Methods of assessments of the overall transmutation potential of NP.
The Physics Approach - The D-Method
The “Equilibrium” E-Method
Fuel Family Overall Neutron Consumption
On Irradiated Fuel Toxicity

III.3. ON LLFP TOXICITY REDUCTION.

On neutron consumption by LLFP. Conclusion.

Set IV:
EXPECTED ROLES ADS in FUTURE NUCLEAR POWER: TRU-TRANSMUTATIONS and LONG-LIVE WASTE FREE OPTIONs

GENERAL CONCLUSION:
Why Nuclear Power needs hybrids?
Motivations