European ADS programme. Present considered designs & perspectives

OECD/NEA NSC Workshop
“R&D Needs for Current and Future Nuclear Systems”
Paris (France), November 6-8, 2002

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Summary

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Introduction (1)

• The fuel cycle strategy and the fuel cycle closure is a national policy in Europe. There are various strategies considered:
  – $\text{UO}_2$ in LWR + final disposal,
  – $\text{UO}_2$ in LWR + ADS + final disposal,
  – $\text{UO}_2$ in LWR + MOX in LWR + ADS + final disposal,
  – $\text{UO}_2$ in LWR + MOX in LWR + (durty MOX + MAs) in FbR + ADS + final disposal

• In nearly all scenarios P&T and ADS are given a consideration that leads to a need for a coordinated R&D
Both critical and sub-critical reactors are potential candidates as dedicated transmutation systems. Critical reactors, however, loaded with fuel containing large amount of minor actinides (Am and Cm) pose safety problems caused by unfavourable reactivity coefficients and small delayed neutron fraction. With regard to this latter problem, the sub-criticality is particularly favourable and allows a maximum MA load while operating in a safe manner.
Introduction (3)

• The European Technical Working Group (ETWG) on ADS under the chairmanship of Prof. Carlo Rubbia played this coordinating role at European level for P&T and ADS development as a route for Waste management. The ETWG members concluded in their report of April 2001 that:
  – P&T associated to ADS could help the waste mgt. problem
  – There is a need for a first step demo of ADS at international level
  – There is a need for a coordinated R&D effort at European level with a strong support from the EC
ADvanced Options for P&T
ADOPT Thematic Network
PARTITIONING AND TRANSMUTATION


Provide a basis for evaluating the practicability, on an industrial scale, of partitioning & transmutation for reducing the amount of long lived radionuclides to be disposed of
Projects on ADvanced Options for Partitioning and Transmutation (ADOPT)

PARTITIONING (5 MEuro)
- PYROREP
- PARTNEW
- CALIXPART

TRANSFORMATION (6 MEuro)
Basic Studies:
- MUSE
- HINDAS
- N-TOF_ND_ADS

TRANSFORMATION (6.5 MEuro)
- PYROREP
- PARTNEW
- CALIXPART

TRANSFORMATION (7.2 MEuro)
Technological Support:
- SPIRE
- TECLA
- MEGAPIE - TEST
- ASCHLIM

TRANSFORMATION (3.9 MEuro)
Fuels:
- CONFIRM
- THORIUM CYCLE
- FUTURE

Preliminary Design Studies for an Experimental ADS:
- PDS-XADS
Useful EC Cordis Websites

- http://www.cordis.lu/fp5/decisions.htm

ADOPT Them. Net. Website

PDS-XADS Objectives

- The Preliminary engineering Design Studies of the eXperimental ADS have to be performed in order:
  - to select the most promising technical concepts,
  - to address the critical points of the whole ADS system,
  - to identify the R&D in support of ADS development,
  - to define the safety and licensing issues,
  - to preliminary assess the cost of the installation,
  - to consolidate the roadmap of the XADS development
PDS-XADS Concepts

• Taking into account that fast neutron spectrum is the a priori solution for transmutation purpose, the R&D efforts are focused on liquid metal-cooled ADS and gas-cooled ADS. The preliminary design studies are concentrated mainly on three concepts of the nuclear sub-critical reactor part:
  – EA-80, Large Pb-Bi cooled XADS by ANSALDO
  – Large Gas cooled XADS by Framatome ANP
  – MYRRHA, small Pb-Bi cooled XADS by SCK•CEN
PDS-XADS Organisation

- 25 European organisations participate to the PDS·XADS project:
  - Major European nuclear plant designers (Framatome-ANP SAS, Ansaldo, Tractebel EE, Empresarios Agrupados, NNC Ltd, Framatome-ANP GmbH, BNFL)
  - European and national research centres in support of Nuc. Eng. (CEA, CIEMAT, EC-JRC-Petten, ENEA, FZK, PSI, NRG, SCK·CEN, CRS4, ITN, FZJ)
  - Industrial company (IBA) and research centres (CNRS IN2P3, INFN, CEA) for accelerator design and development
  - Universities (University of Frankfurt, University of Mining and Metallurgy of Cracow, KTH, Universita Politecnica de Madrid)
PDS-XADS Organisation

- The PDS·XADS project is split in five main work packages (WP) as indicated below, the overall co-ordination being the duty of Framatome-ANP SAS, France:
  - WP1: global coherency (objectives and the general specifications of the XADS)
  - WP2: plant performance and safety
    - WP2.1: general safety approach
    - WP2.2: modelling of the phenomena important for the safety studies
    - WP2.3: preliminary safety evaluation of the XADS concepts.
  - WP3: accelerator for XADS
  - WP4: core and spallation target
    - WP4.1: core studies of the LBE-cooled concept
    - WP4.2: core studies of the gas-cooled concept
    - WP4.3: spallation targets design studies.
  - WP5: system integration
    - WP5.1: EA-80, Large Pb-Bi cooled XADS by ANSALDO
    - WP5.2: Large Gas cooled XADS by Framatome ANP
    - WP5.3: MYRRHA, small Pb-Bi cooled XADS by SCK•CEN
PDS-XADS Illustrations

• WP3 : Accelerator for XADS
  – The ETWG has qualified the linear-type accelerator, with SCRF (super-conducting radio-frequency) cavities for the high energy part as "the solution of choice" for high-power accelerator applications, that is for a power level which exceeds, say, 2 MW
  – WP3 is presently investigating in more detail that :
    • such a linac matches perfectly the required energy regime,
    • its inherent modularity allows an easy upgrade to whatever energy finally demanded for industrial transmutation,
    • the projected beam currents of such a linac very safely fulfil the industrial request,
  – two other considerations emerge as being in particular support for a SCRF based linac:
    • reliability, availability, maintainability
    • cost-optimisation of the operation
PDS-XADS Illustrations

• Indeed, the initial studies carried out in WP3 confirm that SCRF technology has a very high reliability potential because several typical failures can be addressed by means of an adequate design philosophy:
  – implement an extremely conservative over-design approach.
  – high modularisation of all components => redundancy ("spare on-line") => reliability and maintainability
  – Adopt "fault-tolerant" design
  – high modularisation into power- and size-limited components => very active spare part policy possible + preventative maintenance measures.
  – low beam losses, in order to avoid activation of the structure and to permit easy human access ("hands-on maintenance").
SCRF Linac sketch for XADS

The PROTON linac driver

- **Injector**
  - Source
  - RFQ
  - DTL
  - 100 keV, 5 MeV, 10 MeV

- **Intermediate section**
  - DTL, SC cavities...

- **Low Energy section**

- **SCRF cavities**
  - \(\beta = 0.5\)
  - \(\beta = 0.65\)
  - \(\beta = 0.85\)
  - 100 MeV, 200 MeV, 500 MeV

- **High Energy section**
  - \(\sim 1-2\)GeV possible
PDS-XADS Designs

• Illustrations of the 3 XADS designs presently studied under PDS-XADS are:
  – EA-80, Large Pb-Bi cooled XADS by ANSALDO
  – Large Gas cooled XADS by Framatome ANP
  – MYRRHA, small Pb-Bi cooled XADS by SCK•CEN
XADS Configuration
Hot Window Target Unit
Windowless Target Unit
1 – Axial end Radial Reflector
2 – Active Zone

Schematic Core Configuration - Axial Section
Core Configuration with Target Unit
PDS-XADS Gas Cooled System
Reactor vessel       (Status 11/2001)
PDS-XADS Gas Cooled System
Design evolution with a thick RV closure stab
PDS-XADS Gas Cooled System
Spallation target preliminary design
MYRRHA Radial layout
MYRRHA Diaphragm top view
MYRRHA Diaphragm bottom view
MYRRHA View 2
IP-ADOPT Perspectives (1)

• In the FP6, the EC created 2 new instruments for favouring the integration and re-enforcement of the European R&D at large scale, namely:
  – Integrated Project (IP):
  – Network of Excellence (NoE):
Integrated Project
IP-ADOPT

EoI for an IP in the FP6
prepared by ADOPT members
Aim of the Proposed IP

- The aim of this proposal is to mobilise the European scientific and industrial expertise in nuclear fuel reprocessing, nuclear fuel development, nuclear reactor research and engineering design, and high power proton accelerator research and development to provide advanced options for high level waste management leading to the relaxation of the conditions of the waste geological disposal.

- The high level waste management is clearly indicated as a society problem to be solved in the Framework programme 6.
Contribution to the European Research Area

The IP-ADOPT project will allow the structuring and the integration of the European activities related to P&T and ADS development as it will:

- avoid the fragmentation of the present P&T and ADS community by focusing the objectives towards a mid-term objective of realising an ADS demo facility and testing at large scale the economical feasibility of the transmutation of MA in a dedicated core within this test facility;
- offer a stable research environment for this community;
- serve as a trigger for maintaining the national funding in this field at a reasonable level;
- encourage the realisation of the objective of exploring new technologies that contribute to solving the society problems of waste management and looking to technologies that can be of use for next generation reactors.
IP-ADOPT is proposed by:

- Belgium: SCK•CEN, UCL,
- Europe: JRC-ITU,
- France: CEA, CNRS, Framatome ANP,
- Germany: FZK, FZJ,
- Greece: APC,
- Italy: ENEA, ANSALDO,
- Spain: CIEMAT,
- The Netherlands: NRG,
- Portugal: ITN,
- Sweden: KTH,
- Switzerland: PSI,
- United Kingdom: BNFL
LOGIC of the IP-ADOPT

- After 10 years of exploratory research in the field of P&T and ADS development,
  - it is time to put research in the position of being able to quantify indicators for decision-making,
  - keep the logic of the final aim of building an ADS in Europe within a reasonable time scale,
  - justification of building the meaningful R&D support programme and first-of-kinds experiments,
  - ADOPT members suggested to keep a reasonable activities,
  - as concluded in Santa Fe NEA HPPA Workshop to start working seriously on the licensing & siting of ADS.
- Therefore ADOPT members proposed to organise the IP-ADOPT into 4 sub-areas each one with well identified leading organisation or consortium of organisations.
IP-ADOPT Components (1)

• **Partitioning**
  – Development of hydrometallurgical partitioning process,
    • Possibly adapted to innovative fuels,
  – Demonstration of the feasibility of a quantitative recovery of actinides by pyrochemical process;
    • Possibly, recycling of all actinides together
IP-ADOPT Components (2)

• Advanced Fuels
  – Development of fuels and targets specifically devoted to transmutation
  – Better understanding of their behaviour (experimental irradiation and modelling)
  – Including fuel safety, licensing and reprocessing aspects;
IP-ADOPT Components (3)

• ADS Design
  – Accelerator development, in particular the qualification of reliability of the prototypical components,
  – Proof of feasibility of both window and windowless spallation targets,
  – LBE and/or gas cooled sub-critical core design with testing of key components,
  – Establishment of the safety referential for ADS,
  – Siting and licensing approach for ADS,
  – Complementary nuclear data for achieving a reliable design;
IP-ADOPT Components (4)

- **Materials & Coolant Technology**
  - Promising structural materials qualification under proton and neutron irradiation,
  - Exposure to Pb-Bi through the use of the MEGAPIE-Test, KALLA and CIRCE facilities,
  - Key issues to be addressed are:
    - corrosion due HLM
    - liquid metal embrittlement due to Pb-Bi,
    - embrittlement due to irradiation in a mixed radiation (n,p) field,
    - coating for corrosion or LME mitigation,
    - establishing of engineering characterisation DB
  - Pb-Bi technology as core coolant or target material
    - Thermal-hydraulics data,
    - Modelling and instrumentation of HLM.
Integrated Project on ADvanced Options for Partitioning and Transmutation (IP-ADOPT)

IP-ADOPT Steering Committee
Present members of ADOPT + Major Contributors

PARTITIONING

ADVANCED FUEL

ADS Design, Sitting & Licensing,
Safety & Nuclear Data

MEGAPIE-Test, Structural
Material & HLM Tech.
Conclusions

• The European Program is a rationale approach allowing to select, then develop an European XADS.
• The PDS-XADS project involves the major nuclear and accelerator design organisations in Europe.
• The studies are starting now and no critical point has been identified up to now. In particular, the first results on the accelerator part are very promising.
• Focusing towards one design is expected to happen at fall 2003.