Technical Working Group on ADSS:
INTERIM REPORT

France: H. Flocard, B. Barré, H. Sztark

Italy: G. Gherardi, G. Locatelli, M. Napolitano,

C. Rubbia (Chairman)

Spain: J. Martinez-Val, E. Gonzalez, M.A. Hidalgo

Scientific Secretary: S. Monti

Mandate of the Group of Advisors

- Potentialities of ADS for transmutation of LLW
- Construction of a DEMO plant on a 10 years time schedule
- R&D: co-ordination between governmental agencies and industrial bodies
- Regional facility. European collaboration (support within 5th-FMWP). Collaboration with USA and Russia
- Appropriate industrial platform (agreement among interested European partners)

Mandate of the Group of Advisors

10 years European programme in three time phases:

① European partnership: setting up of a Technical Working Group

② R&D programme: final design of the demonstration facility

③ Construction and operation

Mandate of the Group of Advisors

Issues to be considered:

- Accelerator technologies
- (beam) window technologies
- liquid metal technologies
- Material testing
- Fuel cycles
- Safety and site licensing

Mandate of the Group of Advisors

"The TWG should give a cost estimate for the necessary, related activities, namely the generalised R&D and the demonstrator"

"The initial expenditure rate for 1999 has been recommended to be not less than 10 MECU/country in order to keep the necessary momentum"

Modus operandi

- Primary task: demonstrator's programme for Europe
- First task: first comprehensive review of on-going activities in France, Italy and Spain
- R&D relevant to the realisation of the demonstrator --> parameters for the definition of a European ADS DEMO
- Connection with the 5th Framework Programme

Main choices

- Fast neutron spectrum: burning of MA (and, eventually, Pu) and LLFP (Tc-99, I-129)
- Spallation target: Pb or Pb-Bi
- Diffusing medium: high Z nuclei
- Maximum P_{th}: order of 100 MWatt (to be “thrown away”)
- Reasonable value for K: 0.95-0.90

Need for a Demonstrator

- Feasibility already proven in experiments such as FEAT an TARC
- Need of more experimental accuracy in nuclear physics (nuclear data) and energy technology physics (material corrosion, material endurance)
- GLOBAL DEMONSTRATION OF THE OPRATION AND SAFETY OF THE COMPLEX AS A WHOLE: ASAP_DEMO

Preliminary conclusion of the ADS_TWG

Mission of the ASAP_DEMO:

- Operability of the accelerator/spallation target/tank complex in realistic conditions and with a sufficient power (100 MWatt).
- Initial fuel: existing U-Pu oxide
- Demonstration of the capability to transmute various actinide fuels
- Assessment of the capacity to transmute long lived fission products

Complete numerical simulation studies to be carried out for some ASAP_DEMO conceptual designs (agreement with 5th FMWP)

Preliminary conclusion of the ADS_TWG

Need of large dedicated facilities:

- ENEA-Brasimone (Italy) to study molten metal performances
- CEA MASURCA (France) for neutron and reactivity experiments
- LAESA laboratory (planned in Spain) for studies requiring accelerator devoted to ADS assessment

General considerations

Critical safety functions:

- *Safe shutdown*: operation in a sub-critical mode at all times. Control by the accelerator. Shut-down rods to be considered
- *Decay heat removal*: redundant and diversified means. Decay heat cooling with natural circulation
- *Radioactivity confinement*: Containment barrier to be guaranteed in all plant conditions

Design criteria and requirements mainly to be derived from EUR

Degrees of freedom and interconnection among variables

- K_{max} = 0.98 (to be explored) --> licensing procedure similar to the one for a critical reactor
- K_{min} for 100 Mwatt = 0.80
- Proton kinetic energy of the order of 1 GeV: ($0.6 < T_p < 1.5$ GeV)
- Accelerator current: determined by the triplet (P_{th}, K_0, T_p)

Accelerator

Two alternatives:

- Super-conducting cavity LINAC: experience at CERN, DESY, Italy, France)
- Isochronous cyclotron (either by ordinary magnets or SC coils): experience at PSI, GANIL, CAL and LNS)

Two possible schemes:

- Option for a high energy facility: LINAC
- Option for a low energy facility: PSI-like cyclotron or H_2^+

Preliminary conclusion of the ADS_TWG: Accelerator

- An accelerator with the characteristics required by the ASAP_DEMO could be built in Europe on a relatively rapid time scale
- Vigorous effort on the development of superconducting cavities, RFQ front end and cyclotrons (final choice in a near future)

The Spallation Source

- Performances within the ones of other accelerator driven neutron sources
- Most suitable target material: Pb or Pb-Bi
- Two possible conceptual geometry (downward proton beam):

① spallation target ≡ coolant of sub-critical medium (only for Pb or Pb-Bi)

② separation between spallation target and sub-critical medium: either with or without window

- Required R&D: Cooling method, Thermal shocks due to beam variations, Radiation damage, Spallation product containment

The Beam Window

- Element of the boundaries to the main containment volume: major element of the R&D
- Current practise: 20 $\mu A/cm^2 \Rightarrow$ Mechanical stability and endurance to radiation damage: 1 Year
- For given P_{th} and K_0, local radiation damage rapidly decreasing with T_p

Preliminary conclusion of the ADS_TWG: Target

- Best materials for the spallation target:

  Pb or Pb-Bi
- Russian experience + additional R&D on Pb and Pb-Bi
- Test of the spallation target assembly with a suitable accelerator beam (before coupling it to the sub-critical system)
- Beam window as a major element of the R&D

The Sub-critical System

- Fast neutron spectrum to efficiently transmute MA
- Solid fuel: inclusion of MA or FP to be tested
- Initial fuel: U-Pu Oxide. Later on: Thorium based fuel
- Fuel cladding: Titanium Stabilised Austenitic Steel or 9%Cr Martensitic Steel
- Available primary coolants to obtain a fast neutron spectrum:

① Liquid metals: Pb, Pb-Bi, Na

② Gas: He or Co_2

The Sub-critical System: Primary Coolant

- Pb or Pb-Bi:

① Advantages: good neutronic and thermal proprieties; same medium as for the spallation target

② Disadvantages: opacity (ISI problems); erosion/corrosion

- Gas:

① Advantages: easy ISI and repair; no adverse reactivity feedback coefficient in case of voiding

② Disadvantages: high internal pressure (50-70 bars); problems in removing decay heat in case of LOC; physical separation between spallation medium and primary coolant; loads related to the gas

- Na (not to be included in R&D studies):

① Advantages: best known molten metal: compatible materials available

② Disadvantages: chemical reactivity with air and water; physical separation between spallation medium and primary coolant

- Molten Salt: need of very lengthy R&D effort: not suitable for DEMO

The Sub-critical System

- Power control: via beam intensity. Need of control rods to be assessed. Redundant and diverse systems
- Heat removal: forced circulation (pumps or other devices) for normal conditions. Passive heat removal for decay heat.
- Containment: three barriers

① Fuel cladding

② Reactor vessel (together with the interface with the accelerator target)

③ Reactor building (including or not the accelerator)

- Other components

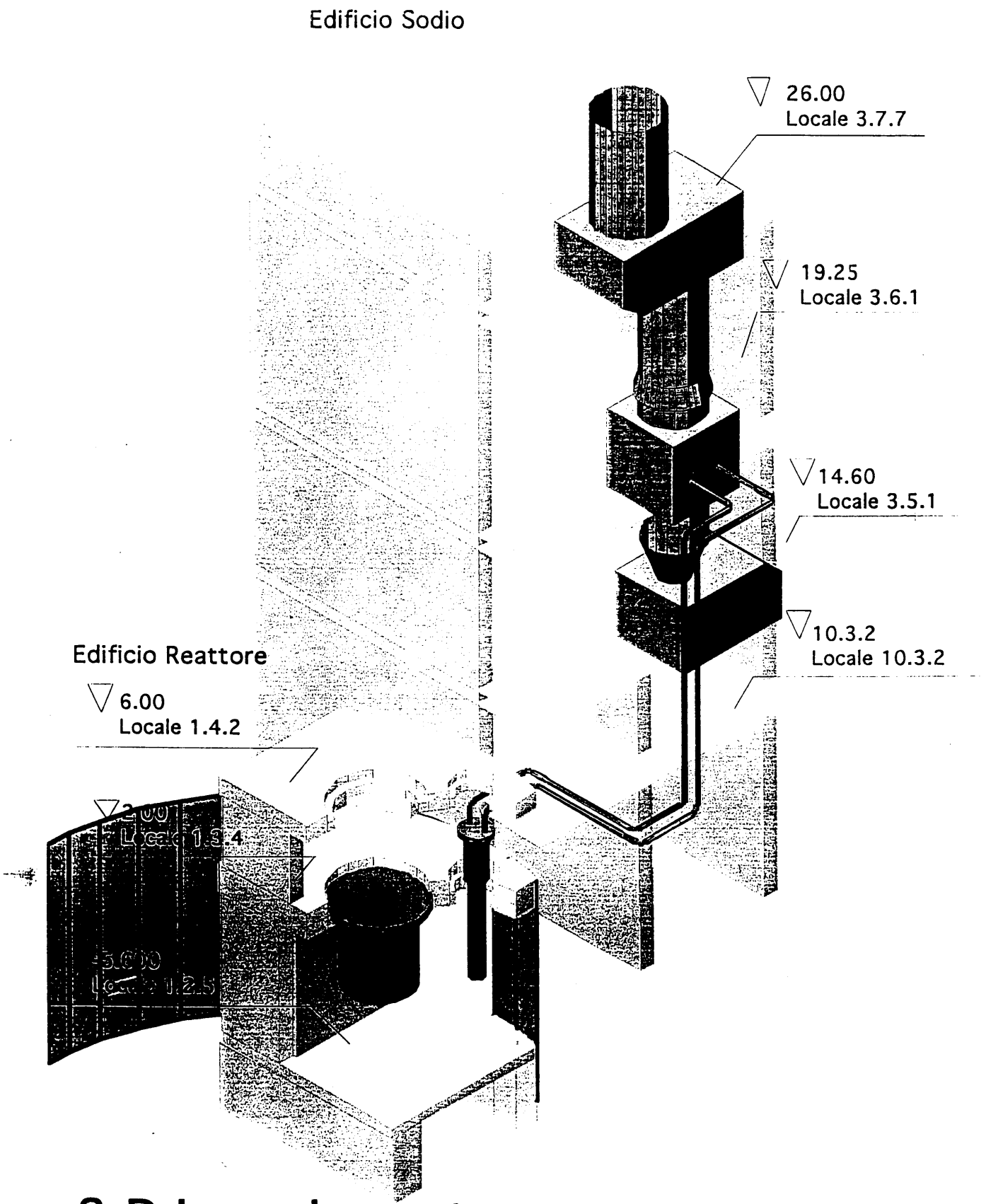
Preliminary conclusion of the ADS_TWG: sub-critical system

- Fast neutron spectrum
- R&D campaign on the use of Pb-Bi as coolant
- Limited number of experimental facilities to study separate effects (material compatibility, etc.)
- Only one large facility for the demonstration of the integrated behaviour of Pb-Bi as coolant
- Conceptual design of a DEMO cooled by gas in parallel to the Pb-Bi preliminary design

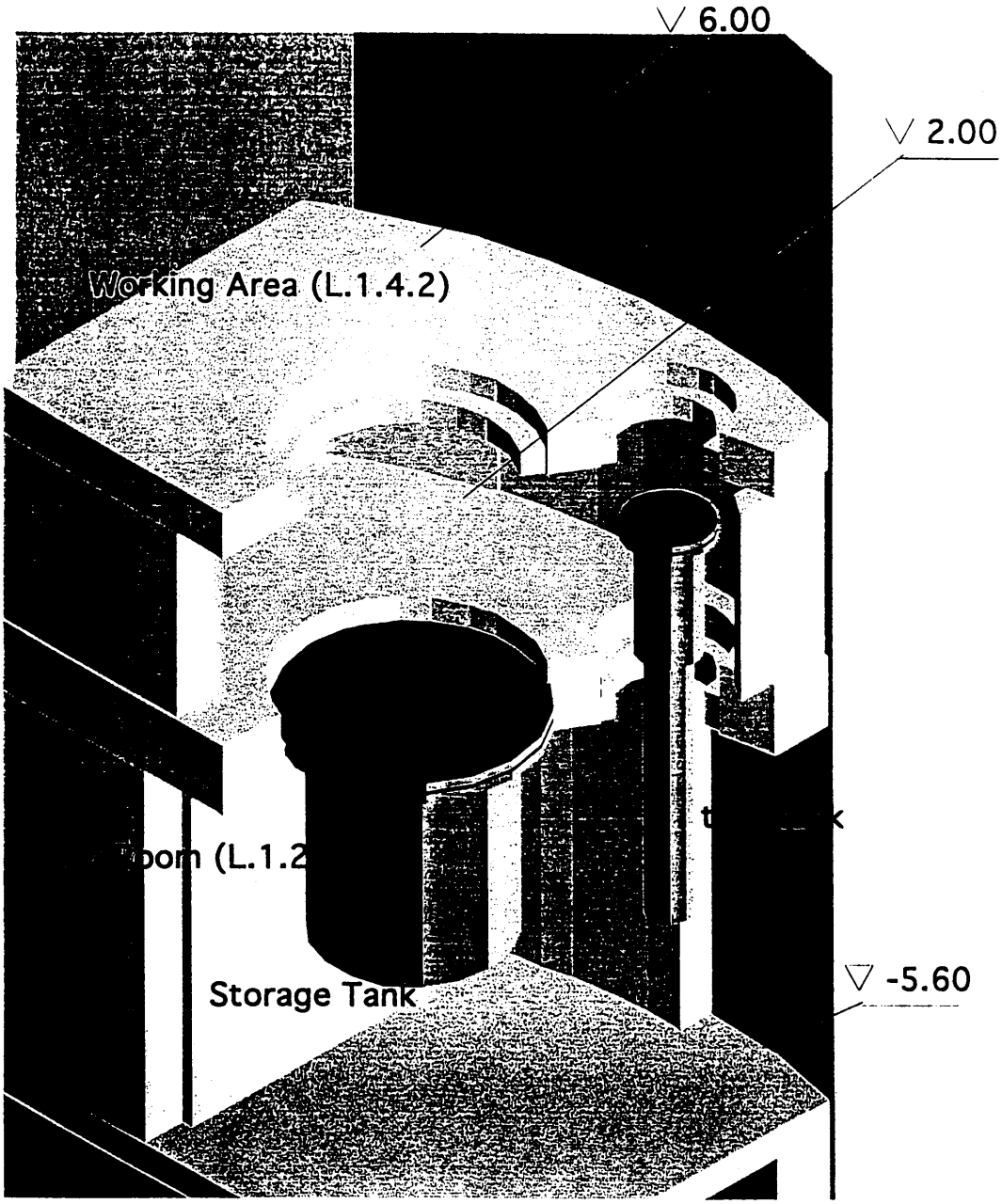
Preliminary conclusion of the ADS_TWG: other R&D activities

- Investigation of pure lead as a coolant
- Advanced fuels (metallic, nitrides)
- Development of coated particle fuels
- Preliminary research on the Thorium cycle
- Advanced reprocessing
- Preliminary investigation on molten salts

Annexe 3 2/2



3 D Loop Layout



3 D LOOP LAYOUT

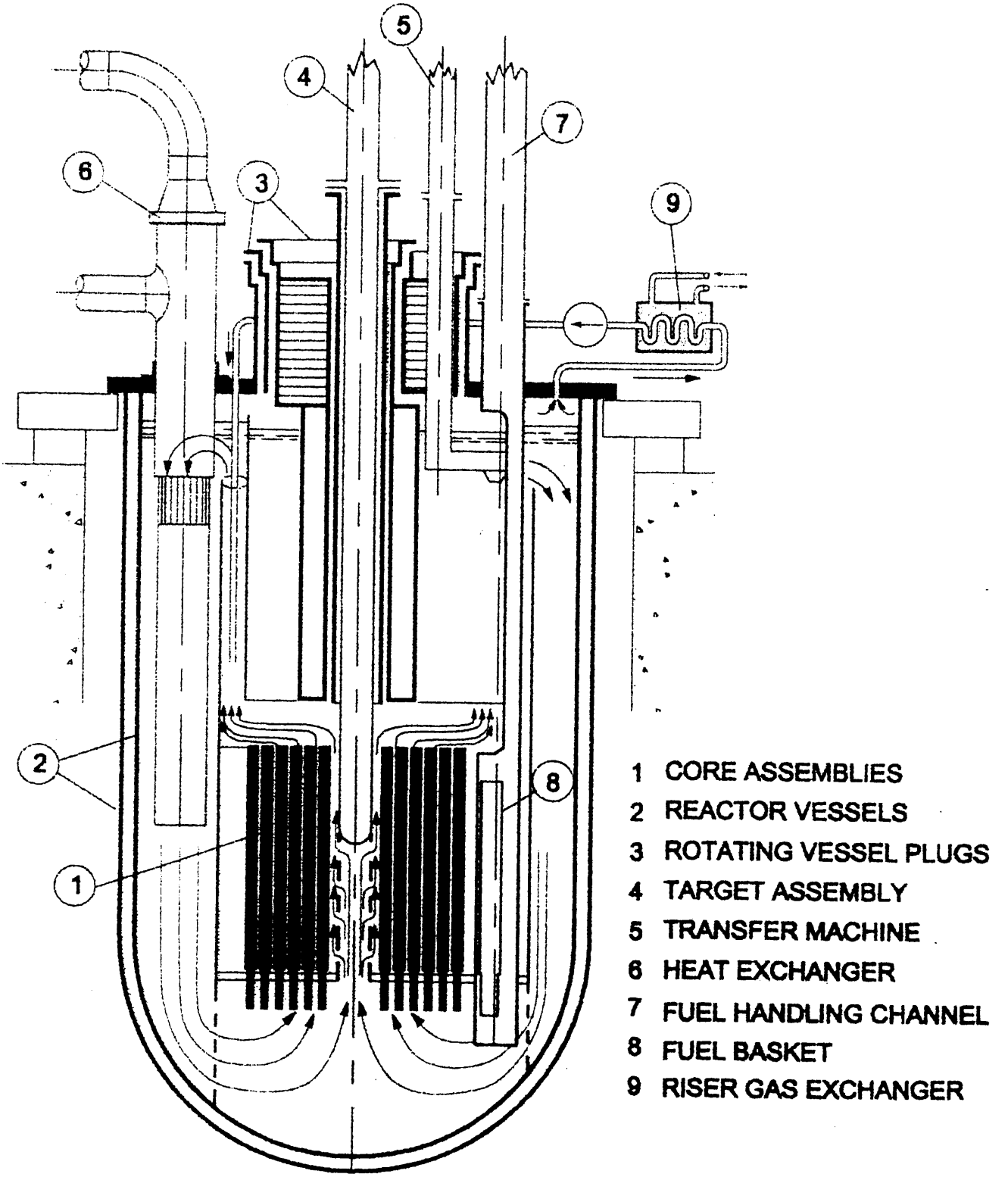


Figure 2.5-2 - Reactor System Assembly – Simplified Mechanical Scheme