APEX
Status and Issues

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APEX

Ultimate Goal

Make significant contributions to making (the long-term) fusion energy system more competitive through exploring and developing more attractive concepts for Fusion Power Technology (FPT)

FPT: Region from the edge of the plasma to the inner surface of the magnets

Near-Term Objective

Explore new (and possibly revolutionary) concepts that can provide the capability to efficiently extract heat from systems with high neutron and surface heat loads while satisfying all FPT functional requirements and maximizing reliability, maintainability, safety and environmental attractiveness

APEX Phases

1. Planning Phase
   - Duration: Several months
   - Start: October 15, 1997
   - Report Due: February 15, 1998 (?)

2. Design Conceptualization and Evaluation plus supporting R & D
   - Duration: 3 Years
   - Start: October 15, 1997
   - Interim Report Due: March, 1999
   - Final Report Due: September 30, 2000

3. R & D Phase
   - Starts after the Evaluation Phase, i.e., beginning FY 2001

Notes:
APEX is trying to "invent new concepts," prediction capabilities often do not exist, and key issues are difficult to anticipate. Therefore, the Design Conceptualization phase must start prior to planning. Learning about the range of concepts and issues will make planning more realistic.

Specific Focus

- The Initial Driver for APEX is High Power Density

- Initial Goals

  Minimum Neutron Wall Load* > 7 MW/m^2

  Minimum Surface Heat Flux+ > 1.5 MW/m^2

Note:

*Assuming a peak factor of 1.4, the average neutron wall load is 5 MW/m^2

+Assuming 85% of alpha power radiated to the first wall and a peaking factor of 1.4

- Existing Design Concepts do not meet the APEX Goals.

  New (revolutionary) concepts are needed.

- Design Concepts must satisfy functional requirements

  - Vacuum
  - Plasma exhaust
  - Power extraction from plasma particles and radiation
  - Power extraction from bulk heatings
  - Tritium breeding
  - Tritium extraction

- A key driver for APEX is HIGH Power Density

  but strive to meet other attractiveness criteria based on trade-offs

Design Concepts

- Current Concepts for First Wall/Blanket can not meet the APEX Goals

- Therefore, the APEX Project is providing an environment to

  "Invent New Concepts"

* Challenge

  - Stimulating new concepts that did not occur to researchers
    over the past twenty years.

  - Fusion has too many constraints

  - Prediction Capabilities to analyze proposed new concepts often do not exist

How Design Concepts Will Be Introduced, Continued or Terminated

Initial Proposal

A concept is proposed by an individual or organization

- All proposals are listened to even if they are sketchy
- Any proposed concept can be pursued if someone is interested in pursuing
  (If the promise is high, the project will make resources available)

Stages of Design/Concept Evaluation

Stage 1: Exploration (Scientific Evaluation)

- Explore and evolve the basic elements
- Analyze and evaluate the scientific foundation of the concept
- ◊ Decision to proceed to stage 2 (pre-conceptual design) will be based more on the potential of the concept and less on how it compares to other concepts

Stage 2: Pre-Conceptual Design

- Develop a preliminary conceptual design that meets all FPT functional requirements and maximizes attractiveness features
- Analysis
- ◊ Decision to proceed to stage 3 will be based on Comparative Evaluation to other concepts

Stage 3: Conceptual Design

- Detailed engineering features
- Identify key issues and R & D
- Detailed Analysis

This January APEX Meeting should decide on a number of concepts to proceed to Stage 1 (Exploration / Scientific Evaluation)

Candidate Concepts to Start Stage 1

1) Convective Liquid Wall
   - External liquid a few - cm - thick (< 5 cm)
   - Interested Organization: UCLA
   - Nominated Leader: Neil Morley

2) Liquid - Filled Porous Wall
   - Porous wall filled with liquid seeping through a porous wall and forming thin liquid layer on the plasma side
   - Interested Organization: UCLA
   - Nominated Leader: Anter El-Azab

3) Thick Liquid "Wall / Partial Blanket"
   - Same as concept 1 but the liquid is thick, tens of cm (20-50 cm)
   - In addition to the advantages of concept 1, this concept can a) reduce activation, b) reduce damage, and c) increase tritium breeding, and d) possibly simplify maintainability
   - Proposed by Ralph Moir (for others to work on)
   - Nominated Leader: Alice Ying

cont'd: This January APEX Meeting

4) Magnetically Restrained Thick Lithium Blanket
   - Interested Organization: PPPL
   - Nominated Leader: Robert Woolley

5) Free Falling Li_2O Particulates with No Structural First Wall
   - Interested Organization: ANL?
   - Nominated Leader: Dai-kai Sze

6) Others to be presented?
   - UW?
   - GA?
   - UCLA (Ghoniem)?
   - UCLA (Gulek)?

Note: Proposals for New Concepts will always be welcome throughout the project

Concepts To Be Put on Hold or Abandoned

- Heat Pipe
- Mist Flow

Organizational Aspects

- During Stage 1, each concepts will have a leader and an interested organization willing to allocate the resources

- Support to all concepts will be provided by groups
  e.g. Mechanical Design
  Material Data Base
  Plasma Interface (Plasma B.C.)
  Safety

- UCLA is willing to provide support to all concepts in specific technical areas (with some priorities because of limited resources)

APEX Project Groups
(Revised 1/5/98)

(1) Design Conceptualization and Analysis

1. This is the core of the project
2. We encourage all individuals and organizations to contribute to this effort
3. Subgroups around design concepts will be formed in the January 98 meeting

(2) Mechanical Design and Availability Group

This group will be responsible for assisting all design conceptualization groups in developing mechanical design and integration. The group has responsibility for:

1. Vacuum boundary concept
   (separate vacuum vessel, resistive shield, or other approaches)
2. Mechanical configuration
3. Maintenance approach (innovative ideas to enhance maintainability)
4. Reliability (suggestions for reducing failure rates and for fault-tolerant designs)
5. Minimum wall thickness
6. Fabrication techniques

Chair: Brad Nelson, ORNL
Others from ORNL? (Brad to provide names)
Alice Ying, UCLA
Mark Tillack, UCSD
Siegfried Malang, FZK
Igor Sviatoslavsky, UW
M. Dagher, UCLA
Don Clemens, Rocketdyne
Other Volunteers?

(3) Materials Group

1. Suggest Materials for High Power Density Applications
2. Provide Basic Material Properties for Design,
   Assemble Database
3. Suggest Operating Limits
   - Minimum and maximum temperature limits; also coolant/material interface temperature (with justification)
   - Stress limits
4. Suggest Design Criteria

5. (Later) Evaluate compatibility of proposed combinations of materials

Chair: Steve Zinkle, ORNL
Members: N. Ghoniem, A. El-Azab, Zi Lu, Mike Billone,
Rich Mattas, M. Ulrickson, S. Majumdar, Bob Johnson

(4) Power Conversion

1. Evaluate/suggest advanced energy conversion cycles suitable for proposed high power density concepts
2. Delineate operating temperature, materials, and technology requirements and issues. Also estimate efficiency as a function of blanket/first wall outlet coolant temperature
3. Needed soon: recommendations on
   a) outlet and inlet temperatures for various coolants, and
   b) thermal efficiency as a function of T(out)

Chair: D. Sze, ANL
Members: M. Tillack, C. Wong.
Others?

(5) Physics Interface Group

Provide physics boundary conditions for FPT designs:

1) Operating temperature limits for liquids on the plasma-side of the first wall for lithium, 83 Pb-17Li, and flibe. (We are concerned about the vapor pressure. Also, it is not clear whether the vapor will go to the divertor or to the plasma).

2) What is reasonable to assume about the fraction of the alpha power radiated to the first wall? (One view in APEX is that one of the best methods to solve the divertor problem is to radiate 85% or more of the alpha power to the first wall).

3) Spatial distribution of the surface heat flux on the first wall. The parameter of most interest is the peak-to-average ratio for the surface heat flux.

4) What is a representative spectrum of plasma radiation to the first wall? (The heat removal requirements are affected by the range of bremsstrahlung radiation in a flowing liquid. The requirements can be relaxed if absorption occurs within tens of microns inside the liquid rather than a delta function at the surface).

5) What are the plasma transient conditions to be assumed for long-term power reactors under the best and under less-than-optimistic scenarios?

6) Evaluate dependence of plasma physics boundary conditions on reactor confinement scheme (limited to magnetic confinement).

7) Other issues as they arise

Chair: Dale Meade (PPPL)
Members: Robert Woolley, Mike Ulrickson, Lee Berry, Ralph Moir, Neil Morley, Rich Mattas, physicists from GA (Clement Wong is contact person).
Expert physicists in appropriate areas.

(6) Safety Group

a) Summarize and provide "fresh" guidance on how to improve safety (cover all key issues: chemical reactivity, toxicity, tritium, dose, etc.)
b) What are the real limits on decay heat (keeping in mind recent lessons from ITER)?
c) If there is a trade off between passive safety and low long-term activation, which direction is preferred?
d) Reevaluate low activation requirements considering recycling and also for the small volume of the first wall

Chair: Kathy McCarthy, INEL
Others from INEL?
M. Youssef (UCLA), M. Sawan (UW)

(7) Alternate Confinement Concepts

a) Summarize the main configuration features and general range of parameters (wall load, surface heat flux, etc.) for alternate confinement concepts and contrast them to tokamaks
b) Plan a workshop with alternate confinement concepts to promote understanding of their main features and agree on general requirements for FPT design (Plan for April or May)

Chair: Dale Meade Co-chair: Ralph Moir
Members: Lee Berry, others

(8) Expert Judgement and Selection Panel (TBD)

Date for Next APEX Meeting

Suggested:

- APEX: April 29 - May 1
  (Wednesday - Friday)

- Alternate Magnetic Confinement APEX Workshop
  April 27 - 28
  (To be coordinated by Dale Meade and Ralph Moir)

Alternate Confinement Concepts

Workshop with developers of alternate magnetic confinement concepts to:

1) Brief them on APEX
2) Learn of their ideas for fusion power technology, FPT, (first wall/blanket/divertor/vacuum vessel) for their concepts
3) discuss and agree on an approach of a) how APEX will address alternate confinement FPT, and b) support to be expected from the alternate confinement community