Technical Opportunities Subgroup Emerging Concepts

Snowmass 1999 Fusion Summer Study

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INTRODUCTION: TECHNICAL OPPORTUNITIES FOR EMERGING CONCEPTS (Ecs)

The objectives for discussions in this EC subgroup was to:

- Identify near-term applications for fusion plasmas which
  - Add to fusion power program both via expanded technology development and generating expanded interest in fusion
  - Provide "intermediate" payback to public "investors"
  - Are well suited to special features of ECs

The primary objective was to consider uses involving fusing plasmas, although other applications such as plasma processing and a wide variety of non-plasma fusion-related technologies represent very important spin-offs also. However, the latter were topics for discussion in other Snowmass groups, so the use of fusing plasmas was the primary focus of this subgroup. Further, the prime focus was on use of various ECs for this purpose.
Fusing plasma applications are of special interest to "emerging concepts" ("ECs") because these concepts often offer unique

features which can make near-tem development and corresponding commercial applications possible. For example, as discussed later, Inertial Electrostatic Confinement (IEC) is being employed in an early commercial neutron source for neutron activation analysis (NAA). This is a natural fit because the IEC functions like an accelerator-plasma target neutron source and can achieve competitive D-D neutron rates in a small size device. The simplicity of the device coupled with the durability of the plasma target greatly reduces maintenance requirements. Further, the unit is relatively simple to construct and operate, making it quite cost competitive. Many of the other ECs considered in these Snowmass discussions also offer various interesting features that might be exploited to develop near-term fusing plasma applications. Unique features that are particularly relevant, which are offered in varying degrees by various ECs include:

- Small, compact fusion sources capable of operation with D-T, D-D or D-He3
- Simple construction, relatively low cost
- Variety of geometries, modularity, ease of coupling out fusion product fluxes
- High beta, high power/weight ratio
- Potential for rapid development

BENEFITS OF NEAR-TERM APPLICATIONS

Recent advances in development of Emerging Concepts (ECs) have opened the door to possible new near-term applications of fusing plasmas. Fusion sources (well below breakeven but driven by electrical input) that serve as low level neutron sources for neutron activation analysis are an example.The opportunity to develop such near-term applications of fusion plasmas can bring a number of important benefits to the fusion, program, including:

- Provide near-term “repayment” to public
- Acquaint public with fusion prior to power units - improve fusion’s image, generate enthusiasm about fusion.
- Bring in new industry early.
- “Shared” funding opportunities help fusion power development of emerging concepts.

POTENTIAL APPLICATIONS

A number of possible fusion plasma applications can be envisioned. Some examples, ranging from neutron activation applications (now being done), to other relatively near-term uses, and on to future possibilities include:

- ----------------------------- present units------------------------------
- Neutron activation analysis, non-destructive testing and inspection
- Scientific studies, e.g. solar and magnetosphere physics
- ------------ other applications requiring higher yield units---------
- Neutron tomography
- Medical isotopes & radiation therapy
- Materials, chemical waste processing and chemical manufacture
- Compact neutron source for driven fission reactors with improved safety
- Compact neutron source for materials testing, nuclear waste transmutation
- High specific power space power and propulsion units

In order to compete in the market place, however, each application must be identified with a "market niche" where it's specific characteristics are especially well suited. For example, near-term fusion neutron sources offer key advantages for several applications:

- IEC portable neutron source with plasma target and star mode offers long life (10,000 hour guarantee), minimum licensing, low cost.
- Isotope production potentially done "in-house" e.g. in a medical facility rather than using central facility.

Some major markets appear to be accessible with near-term fusion neutron/proton sources. A prime example involves medical isotopes. This is illustrated by the following:

- World demand for radioisotopes = 100 $M in 94 ($59M, medical; $41M Indus &Res.)
- Mo-99, Tc-99m used in over 10^7 procedures annually.
- 40% hospitalized patients undergo nuclear medicine; increasing aging population will expand use.
- Small fusion source appears competitive for production vs. centralized accelerators/ reactors

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The first commercialization of a confined fusing plasma uses it for Neutron Activation Analysis (NAA) , and this represents a first step towards isotope production and other applications requiring higher fluxes. As summarized below, the present NAA device has yields of ~ 10*7 D-D neutrons/second steady state, while devices with source strengths several orders of magnitude higher are under development. This unit uses inertial electrostatic confinement (IEC) to achieve a small device which competes favorably with Cf-252 for various NAA applications. Other higher flux devices using pulsed power techniques are under development.

- Commercial portable fusion neutron source based on IEC (Daimler-Chrysler Aerospace) for NAA. Uses D-D reaction at 10^7 n/sec.
- Higher flux level fusion sources under study, using pulsed IEC

An example of one NAA application is detection of impurity elements in ores being removed from a mine. The IEC neutron source is placed below the ore conveyor belt while appropriate detection equipment for capture gamma rays is located above the belt. This approach provides an on-line measure of important impurity levels so that corrective action can be taken if specified limits are exceeded. Such analyses have previously used other neutron sources such as Cf-252 or small accelerator solid-target neutron generators. The IEC appears to be very competitive with these alternatives due to it relatively low cost, long lifetime (the plasma target does not suffer damage like solid targets do), and ease of licensing.

BENEFIT/RISK RATIO FOR NEAR-TERM DEVICES

The ability to fit into these market niches provides a high benefit/risk ratio, thus favors development of near-term fusion devices. The reasons for this are outlined next.

- Low-Q fusion device development involves less risky physics than power reactor
- Relatively quick return on investment
- Careful selection of market considering competition & unique characteristics minimize risk
- Significant benefit to "customer" and to the fusion program

OTHER NON-ELECTRICAL, SCIENTIFIC APPLICATIONS

In addition to traditional market applications, various opportunities to develop non-electrical uses for fusion plasmas may provide early uses for fusion devices. Examples include:

- Fusion space propulsion
- Hybrid systems
- Materials, waste, chemical processing

In addition, a variety of applications to scientific reasearch can be envisioned. Some are already beginning. Examples include:

- Simulation of solar physics
- Simulation of astrophysics
- Basic plasma physics in unique conditons

FUNDING OF APPLICATION DEVELOPMENT

Since the basic fusion device employed in these applications is generally also of eventual interest for a fusion power plant, DOE plays an important role in the initial development of the basic confinement physics and technology. However, special features needed to adapt the device to a specific application must remain the responsibility of the commercial developer. Thus a shared funding role of the following type is envisioned:

- DOE supports research to improve fusion yield to achieve "readiness" for applications while progressing towards energy science goal.
- Industry supports development of special features required for specific application
- Mutual funding for "overlap" areas

The shared funding maximizes utilization of funds and is of mutual benefit to both DOE and the industrial partner.
An example of how funding has been handled on the current commercial IEC neutron source is as follows:

- DOE supports IEC research to point 10^7 DD n/s achieved
- Industry supports development of:
  - commercial grid suitable for mass production
  - star mode for long life grid
  - sealed unit using getters
  - packaging and control/data collection system

CONCLUSION

In conclusion, there has been rapid progress in getting fusion devices to the point where various emerging concepts appear to have the capability of being used for a variety of near term applications. The practicality of this approach has already been demonstrated with a commercial portable neutron source for NAA applications. In view of the potential benefits to the fusion program, continued emphasis on such developments appears warranted.

Thus, based on the foregoing discussion, we conclude that:

Conclusion, EC Tech Opps

- Development of near-term applications could provide a significant benefit to the fusion program, increasing both the public's image and the fusion budget.
- ECs appear well suited to provide key features such as small size, low costs and unique geometries needed to compete in the markets identified
- DOE must support development of improved EC performan to level where industry assumes responsibility for R&D of special features.
- New industrial involvement could be a significant benefit to DOE