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EVALUATION OF THE IMPACT OF A COMMITTED SITE ON FUSION REACTOR DEVELOPMENT*

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Summary

In this study,[1] the technical and economic merits of a committed fusion site for development of tokamak, mirror, and EBT reactor from ignition through Demo phases were evaluated. Schedule compression resulting from evolving several reactor concepts and/or phases on a committed site as opposed to sequential use of independent sites was estimated. Land, water, and electrical power requirements for a committed fusion site were determined. A conceptual plot plan for siting three fusion reactors on a committed site was configured. Reactor support equipment common to the various concepts was identified as candidates for sharing. Licensing issues for fusion plants were briefly addressed.

Introduction

The committed site concept for fusion power development emerged from FY76-77 studies conducted by the Advanced Systems Program of the Fusion Energy Division of Oak Ridge National Laboratory. The Committed Fusion Site Project for FY78/79 was conducted by Bechtel under guidance from Oak Ridge National Laboratory and with input from the fusion community at large.

In many cases, the committed or centralized site for the development and commercialization of a new or advancing technology has been highly successful. The committed site helps reduce development time, centralizes and focuses development effort, and promotes maximum economy of resources. Examples of such committed sites are Houston and Cape Kennedy for the United States Space Program, Dounrey for the British Fast Breeder Reactor Program, and Karlsruhe for German physics and nuclear research.

There are many potential advantages for a commited fusion site. A committed site could provide a strong focus for the basic fusion power research and development program that is presently being conducted at many locations throughout the United States. A committed site can maximize the utilization of common facilities. A major potential advantage is a reduction in the overall time and cost for fusion development by eliminating the need to repeatedly select and develop sites for each step in a fusion power reactor development program; a program that may require as many as four development stages (TNS, Engineering Power Reactor, Demonstration Plant, and a Commercial Plant).

Possible disadvantages of the committed site approach are that it may require near term fusion program budget increases to cover the development of the site and its administrative maintenance. Also, it may prematurely subject fusion development to the restrictions of licensing and regulatory considerations. Further, under closer examination, the expected technical, programmatic, and cost advantages of a committed site may turn out to be illusory.

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Economic Ramifications

The economics of a committed site with shared facilities were determined for the development of a single fusion reactor concept, i.e., tokamak, tandem mirror, or EBT, and for the development of combinations of these reactors at the committed site. A typical scenario for the development of a candidate reactor consists of three phases: ignition demonstration, power technology demonstration, and commercial prototype demonstration. Since several tokamak designs exist from ORNL, GA, PPPL, and MIT, no single design was chosen, but a typical tokamak was configured for this comparison. The typical tokamak will produce 1000 MW_t in the TNS phase; be upgradable to the EPR phase by adding a 300 MW_e turbine generator; be matched with a similar 300 MW_e turbine in the Demo phase to establish the merits of sharing pulsed power. The EBT will similarly produce 1000 MW_t during TNS; be upgradable to EPR by adding 300 MW_e turbine; operate at 2000 MW_t (600 MW_e) in the Demo phase by operating at higher plasma power density. The tandem mirror will produce 300 MW_t during TNS; be upgradable to 100 MW_e during EPR. The Demo phase of a mirror reactor was not adequately defined by reactor studies; therefore, it was not included in this analysis.

The major cost advantage of the committed site was found to lie in its implementation in the development of a single fusion device as opposed to the development of multiple fusion devices on the same site. The cost saving associated with site preparation, structures, and reactor support equipment for tokamak development on a committed site is 610 M$ (TNS-EPR-Demo), and the cost saving for EBT on a committed site is 576 M$, as shown in Table 1. These savings represent a reduction in cost of about 50% compared to three separate sites for tokamak and three separate sites for EBT. However, combining the development of the tokamak and EBT on a single site results in much less cost advantage ~80 M$ compared to the combined cost of the development of the tokamak on a separate dedicated site and the development of EBT on a separate dedicated site (see Table 2). Grouping the tokamak with the tandem mirror reactor leads to the same general conclusion.

The cost advantage of the committed site for single fusion concept development over that for multiple concept development results because there is little equipment which can be shared among upgrades of the different fusion reactor plants. The tokamak needs large quantities of pulsed electrical power for current initiation and heating. Power supplies which are needed on a tokamak TNS for electrical power conditioning can be used on the EPR upgrade and shared between multiple tokamak units in a demonstration phase. However, EBT and tandem mirror reactors are steady state machines and do not need the large banks of stored electrical energy required for pulsed operation. The mirror needs large amounts of high energy neutral beams to drive the reactor, but this power is assumed to be drawn off the utility grid in a continuous fashion.

The primary cost elements which can be shared among different fusion concepts at a committed site are the costs associated with site selection and development and the cost advantage of high capacity process equipment, such as heat rejection systems and tritium handling systems, sized to meet the combined needs of the candidate fusion reactors.

Table 1. Cost Comparison of Fusion Devices Constructed on Individual Sites and on a Common Committed Site

SINGLE OR MULTIPLE FUSION CONCEPTS		COST, MILLION $ TNS	EPR	DEMO/PROTO	TOTAL
GENERIC TOKAMAK	ON INDIVIDUAL SITE	225.1	385.5	583.4	1,194.0
	ON COMMITTED SITE	225.1	160.4	197.9	583.4
	SAVINGS	0	225.1	385.5	610.6
TANDEM MIRROR	ON INDIVIDUAL SITE	104.8	168.9		273.7
	ON COMMITTED SITE	104.8	64.1		168.9
	SAVINGS	0	104.8		104.8
ELMO BUMPY TORUS	ON INDIVIDUAL SITE	210.4	365.7	514.4	1,090.5
	ON COMMITTED SITE	210.4	155.3	148.7	514.4
	SAVINGS	0	210.4	365.7	576.1

NOTES: 1. For devices on individual sites it is assumed that each development phase of each device is constructed on an individual site.

2. For devices on the committed site it is assumed that all development phases of all considered devices are constructed on a committed site.

3. Costs shown are not total plant costs, but only the sums of site selection and preparation and major elements of supporting reactor system costs.

Table 2. Cost Comparison of Multiple Fusion Devices Constructed on Individual Sites and on a Common Committed Site

MULTIPLE FUSION CONCEPTS		COST, MILLION $ TNS	EPR	DEMO/PROTO	TOTAL
GENERIC TOKAMAK AND TANDEM MIRROR	ON INDIVIDUAL SITE	329.9	224.5	197.9	752.3
	ON COMMITTED SITE	292.7	222.5	197.9	713.1
	SAVINGS	37.2	2.0	-	39.2
GENERIC TOKAMAK AND ELMO BUMPY TORUS	ON INDIVIDUAL SITE	435.5	315.7	346.6	1,097.8
	ON COMMITTED SITE	378.9	310.6	328.0	1,017.5
	SAVINGS	56.6	5.1	18.6	80.3
GENERIC TOKAMAK, TANDEM MIRROR AND ELMO BUMPY TORUS	ON INDIVIDUAL SITE	540.3	379.8	346.6	1,266.7
	ON COMMITTED SITE	460.3	378.9	328.0	1,167.2
	SAVINGS	80.0	0.9	18.6	99.5

NOTES: 1. For multiple devices on individual sites, it is assumed that each device is constructed on an individual site, but all three (TNS, EPR, and demonstration/prototype) development phases will be operated on the same site.

2. For devices on the committed site, it is assumed that all development phases of all considered devices are constructed on a common, committed site.

3. Costs shown are not total plant costs, but only the sums of site selection and preparation and major elements of supporting reactor system costs.

Schedular Effects

The selection and certification of a grass-root site for the construction and operation of a nuclear power generating facility involves a lengthy and expensive procedure. If a committed site is dedicated for the construction and operation of several fusion devices, the time involved and the expenditures incurred in this procedure occur once. Assuming the construction of three different fusion concepts and their operation in each of the TNS, EPR, and prototype/demonstration phases on the committed site, the cost of site selection and certification, and the time required to obtain the construction permit, could approach one third of that required to place the same three concepts at three different locations.

Typically, time required to obtain a construction permit for a grass-root light water reactor power plant is four to six years. For a grass-root coal-fired fossil power plant, it is two to four years. Based on this experience, a time span of five years has been assumed for the activities required to obtain the construction permit for a fusion reactor from the Nuclear Regulatory Commission. The activities and their duration necessary for site selection and improvement is shown in Figure 1. The cost of these activities is estimated to be 25 M$. It is further estimated that the completion of EPR experiments for the three different fusion concepts can be accomplished five to ten years sooner on the committed site, than on individual sites.

Site Requirements

The requirements of the site location itself are land, electric power, and process water. Based upon the requirements developed for the TNS, EPR, and demonstration development phases of the tokamak, tandem mirror, and EBT concepts the following maximum requirements were established for the simultaneous operation of the three reactor types:

Land

400 hectares of land is required for the committed site, selected and certified for the construction and operation of multiple fusion facilities. It must be technically (soil and geologic characteristics, seismic characteristics, meteorology, hydrology, aircraft flight patterns, transportation facilities) and environmentally acceptable. For the tokamak alone, an exclusion area of 250 hectors (∿617 acres) is estimated.

Electric Power

Electric power requirements can be fulfilled by two 230 kV transmission liners from a utility. To supply simultaneous operation of three concepts (tokamak, mirror, EBT), 600 MVA of power will be required (assuming all neutral beam power is extracted from the utility grid). For the tokamak alone, 325 MVA will be required assuming beam power is drawn from the grid; 200 MVA of continuous power will be required assuming the beams are supplied power from an energy storage source such as MGF sets.

Process Water

800 liters per second capacity process water system will be provided to supply the circulating water, makeup, demineralized water, fire water and domestic water needs necessary for the operation of up to three fusion concepts in all their development phases.

Conceptual Plot Plan

A conceptual plot plan has been developed for the sequential operation of three (tokamak, tandem mirror, and EBT) fusion reactors in the EPR phase.

The arrangement of all major facilities is shown in Fig. 2. The three reactors are closely clustered

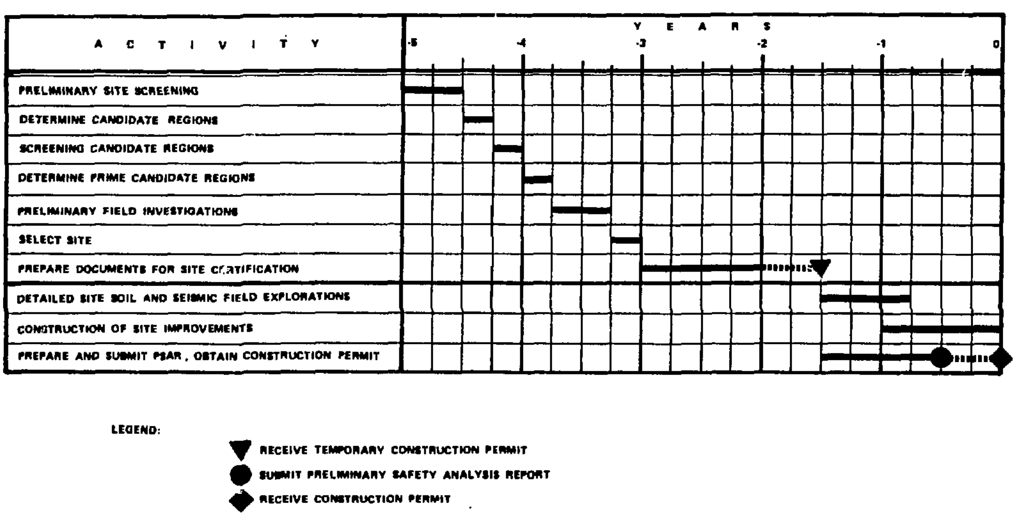

Figure 1
Schedule for Site Selection/Certification and Site Selection

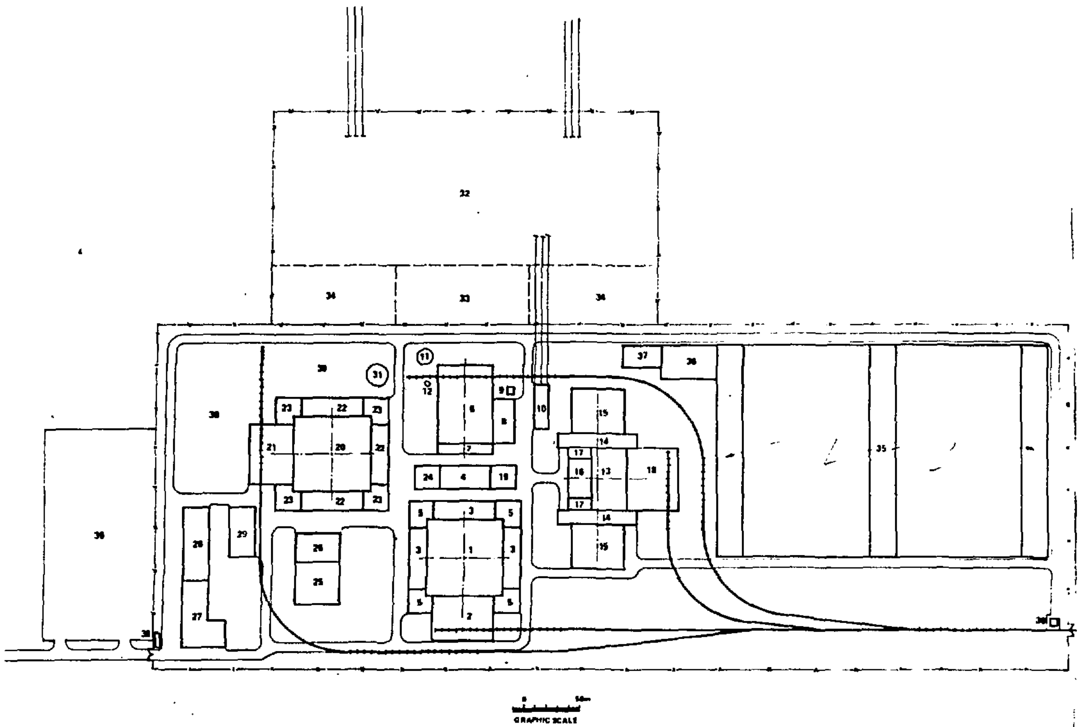

Figure 2

CONCEPTUAL SITE PLAN
OPERATION OF THREE DEVICES IN EPR PHASE

LEGEND:

1 TOKAMAK REACTOR BUILDING
2 REACTOR MAINTENANCE BUILDING AND HOT SHOP
3 PROCESS SUPPORT SYSTEMS BUILDING
4 CONTROL BUILDING
5 STEAM GENERATOR BUILDING
6 TURBINE GENERATOR BUILDING
7 STEAM HEADER AND VALVE GALLERY
8 SWITCHGEAR BUILDING
9 AUXILIARY TRANSFORMER
10 MAIN TRANSFORMER
11 CONDENSATE TANK
12 OIL TANK
13 TANDEM MIRROR REACTOR BUILDING
14 NEUTRAL BEAM INJECTORS
15 DIRECT CONVERTERS
16 STEAM GENERATOR BUILDING
17 PROCESS SUPPORT SYSTEMS BUILDING
18 REACTOR MAINTENANCE BUILDING AND HOT SHOP
19 CONTROL BUILDING EXTENSION FOR TMR
20 EBT REACTOR BUILDING
21 REACTOR MAINTENANCE AND HOT SHOP
22 PROCESS SUPPORT SYSTEMS BUILDING
23 STEAM GENERATOR BUILDING
24 CONTROL BUILDING EXTENSION FOR EBT
25 MAGNET FABRICATION BUILDING
26 MOCK-UP BUILDING
27 ADMINISTRATION AND ENGINEERING BUILDING
28 LABORATORIES AND MAINTENANCE SHOPS
29 WAREHOUSE
30 AREA RESERVED FOR CONSTRUCTION OFFICES, SHOPS AND STORAGE
31 FIRE WATER STORAGE TANK
32 UTILITY SUBSTATION AND PLANT SWITCH YARD
33 PULSED POWER SUPPLY AREA
34 DC POWER SUPPLY SYSTEM AREA
35 COOLING TOWERS
36 CIRC. WATER PUMPHOUSE
37 CIRC. WATER INTAKE BASIN
38 GATE HOUSES
39 PARKING AREA

around the control building and its extensions and the turbine generator building. This arrangement results in relatively short cable runs between the reactors, the turbine building and the control building. The length of steam lines from the steam generator buildings to the steam header and valve gallery also are reasonably short. The steam header, through proper valving and controls, can feed the turbine from any of the three reactors.

The magnet power supply and NBI/RF heater power supply equipment are located next to the utility substation and plant switchyard and at a reasonable distance from the reactors they serve.

The reactor maintenance and hot shop buildings have railroad spur access for all three reactors. The turbine building is also provided with a railroad spur access. The process support systems buildings are closely coupled to the reactor buildings they serve, to minimize piping and control cable runs. The facilities for general service, magnet fabrication building, mock-up building, administration and engineering building, laboratories and maintenance shops, warehouse, gate houses, and parking area are functionally located.

Licensing

There are currently no established regulations addressing the nuclear safety aspects of a fusion plant. Although many of the basic concepts of nuclear safety applicable to light water fission power plants are also applicable to fusion plants, it may not be possible to extrapolate current fission-plant-oriented regulations to fusion reactors. There are significant safety and environmental advantages for fusion power plants over fission plants. It is anticipated that a fresh approach to fusion plant licensing will result in more consistent and effective regulation and a shorter licensing schedule.

Future regulations may also address hazards unique to fusion reactors such as the release of liquid metal coolants (lithium), the effects of strong magnetic fields, or the possibility of magnetic interference with local electronic and communication systems.

Although there does not appear to be any specific fusion regulatory consideration related to the siting of a facility of this nature, the licensing process has become progressively more subject to public opinion, and environmental litigations could delay or complicate licensing of a particular site. For this reason, it would be prudent to select a site at which potential delays can be minimized. Consideration might be given to use of a government reservation for siting the first fusion demonstration plant.

Conclusions

1. Approximately fifty percent reduction in the cost of site preparation, structures, and reactor support equipment for the development of a fusion concept (such as the tokamak) through three phases (TNS-EPR-Demo) can be achieved by the utilization of a committed site relative to the use of three individual sites.

2. Marginal economic benefits are derived from the combined development of different fusion reactor types at a committed site.

3. It is estimated that the completion of EPR experiments for three different fusion concepts (tokamak, EBT, Mirror) can be accomplished 5-10 years sooner on a committed site than on individual sites.

4. Approximately five years and 25 million dollars are required for site selection, certification, and improvements.

Reference

1. Bechtel National, Inc., "Final Report, Evaluation of a Committed Fusion Site," ORNL/SUB-7503/1, San Francisco, California (July 1979).