19890005474

N89-14845

S3-75

175149

27P

STATUS OF FUSION RESEARCH AND IMPLICATIONS FOR D-^{3}He SYSTEMS

George H. Miley
Fusion Studies Laboratory
University of Illinois
103 South Goodwin Avenue
Urbana, IL 61801

World-wide programs in both *magnetic* confinement and *inertial* confinement fusion research have made steady progress towards the experimental demonstration of energy breakeven.[1-4] Both approaches are now in reach of this goal within the next few years using a D-T equivalent plasma. For magnetic confinement, this step is expected in one of the large tokamak experimental devices such as TFTR (USA), JET (EC), JT-60 (Japan), or T-15 (USSR). Upgraded versions of the Nova glass laser (USA) and GEKKO (Japan) also appear to have a good chance at this goal. The light-ion beam facility "PBFA-II" is viewed as a "dark horse" candidate. Recent physics parameters obtained in these various experiments will be briefly reviewed in this presentation.

However, after breakeven is achieved, considerable time and effort must still be expended to develop a usable power plant. The time schedules envisioned by workers in the various countries involved are fairly similar.[1-3] For example, the European Community (EC) proposes to go from the physics studies in JET to an engineering test reactor (NET) which has a construction decision in 1991. This is projected to result in a demonstration reactor after 2015. Plans for inertial confinement are currently centered on the development of a "next-step" target facility based on an advanced 5-megajoule laser on roughly the same time scale as NET.[5] The facilities required for both magnetic and inertial confinement will be large and expensive. Consequently, international cooperation is receiving strong consideration for the next magnetic façility, namely ITER (International Thermonuclear Experimental Reactor). This project would be shared by the USA, EC, USSR, and JAPAN.

The main program described above is focused on D-T devices. For burning advanced fuels such as D-^{3}He however, alternate confinement concepts with high ($>$ 30%) plasma beta (magnetic confinement)[6] or a D-T seed ignited burn[7] (inertial confinement) appear necessary. These alternatives have less of a physics data base than the tokamak and conventional inertial targets. Thus, the possibility of success is less certain and the best approach not so clear.

In magnetic confinement, three of the most promising high beta approaches with a reasonable experimental data base are the Field Reversed Configuration (FRC), the high field tokamak, and the dense Z-pinch. The best experimental data from an FRC is roughly an order of magnitude lower in temperature and 2 orders of magnitude less in Lawson $n\tau_E$ than the best tokamak results.[8] However, these results were achieved with a much smaller, less costly experimental device. Also a number of key issues such as control of certain instabilities and the establishment of methods for adiabatic compression and translation have been resolved.[7] A high-field tokamak has just become operational in the USSR while the Ignitor Apparatus is being designed in Italy. A related device, CIT, is proposed as a "next-step" ignition experiment in the U. S. Z-pinch studies in both the U. S. and Europe have made rapid strides with the discovery that a relatively stable pinch can be formed by passing a high current discharge through a thin deuterium fiber. Consequently, there appears to be a solid physics data base to build on in these areas if a development plan to burn D-^{3}He is desired.

The situation is less clear in inertial confinement where the first step requires an experimental demonstration of D-T spark ignition. It appears that this must wait for the next generation of high-powered laser drivers combined with advanced target designs.

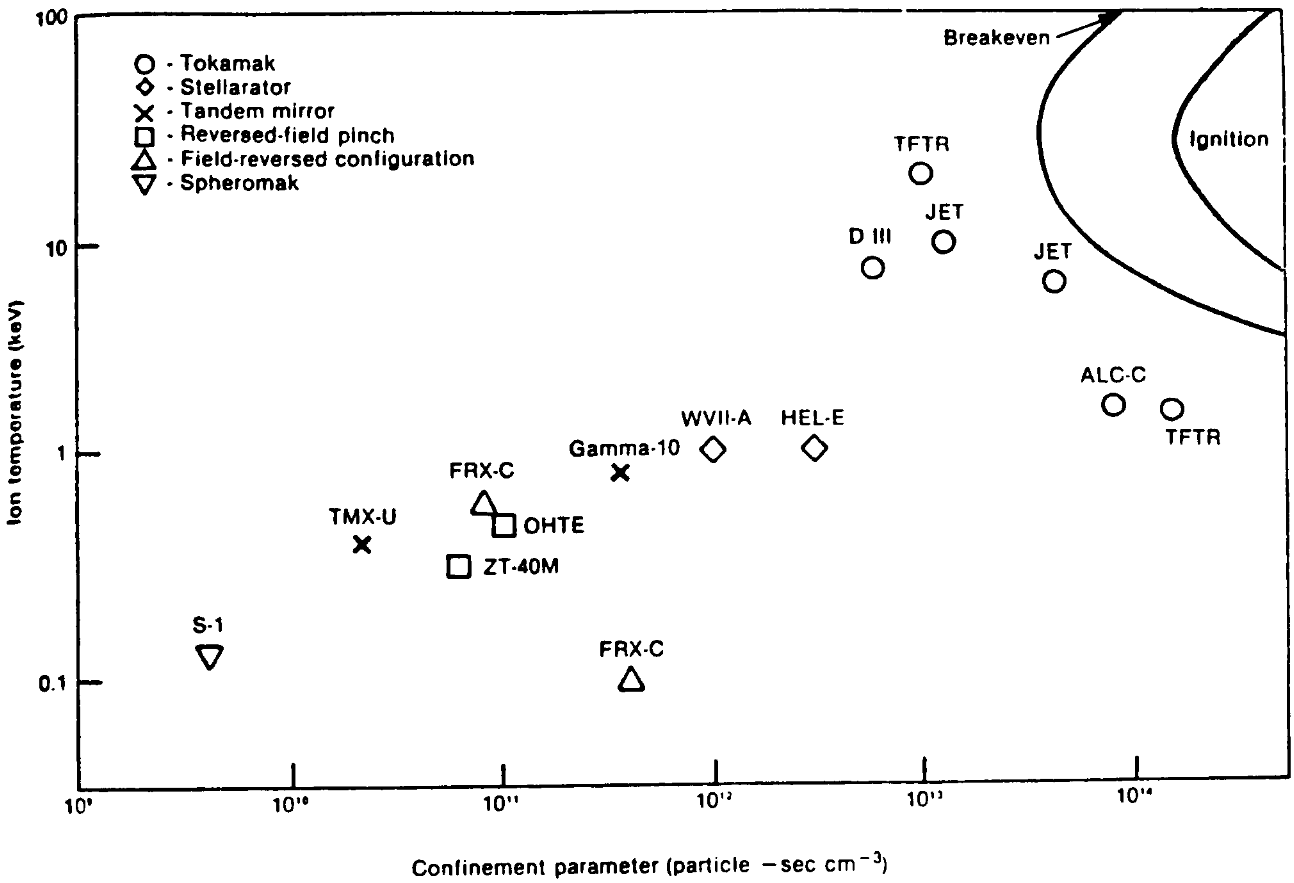
In conclusion, it appears that fusion research has reached a point in time where an R&D plan to develop a D-^{3}He fusion reactor can be laid out with some confidence of success. Such a plan could build on the continuing progress in D-T studies, but the development of an alternate confinement concept(s) would be essential. Because engineering problems (e.g., tritium breeding and neutron damage to materials) are reduced and an approach such as the FRC involves relatively small experimental devices, the D-^{3}He development program appears to be much less expensive than the D-T tokamak program. Also, as shown by several reactor studies (e.g., see Ref. 10), the resulting reactor is thought to boast important benefits with improved environmental compatibility, small size, higher efficiency, and favorable economics.

1. TPA Plasma Science Final Report, U. of Wisconsin, December 1986.
2. Technical Planning Activity Final Report, ANL/FPP-87-1, Argonne National Laboratory, January 1987.
3. Starpower: The U. S. and the International Quest for Fusion Energy, OTA-E-338, U. S. Government Printing Office, Oct. 1987.
4. Review of the Department of Energy's Inertial Confinement Fusion Program, National Academy of Sciences, March 1986.
5. D. Bixler, "On Achieving a Laboratory Microfusion Capability," Proceedings, Workshop on Laser Interaction and Related Plasma Phenomena (H. Hora and G. Miley, eds.) Monterey, CA (1988).
6. G. H. Miley, "Potential and Status of Alternate-Fuel Fusion," *4th ANS Topical Mtg. on the Technology of Controlled Nucl. Fusion, Vol. I*, p. 905, King of Prussia, PA, 1980.
7. G. H. Miley, "Advanced-Fuel Targets for Beam Fusion," Proceedings of the 6th International Conference on High-Power Particle Beams (BEAMS '86), p. 309, Kobe, Japan, 1986..
8. M. G. Tuszewski, "Field-Reversed Configurations without Toroidal Field," Los Alamos National Lab. Report LA-UR-88-945 (1988).
9. B. Coppi, "Ignition Experiments and Physics: Ten Years Later," Intern. School of Plasma Phys. Workshop on Basic Phys. Processes of Toroidal Fusion Plasmas, Vol. II, 713, Varenna, Italy, 1985.
10. G. H. Miley, J. G. Gilligan and D. Driemeyer, "Preliminary Design of a Self-Sustained, Advanced-Fuel Field Reversed Mirror Reactor-SAFFIRE," *Trans. Am. Nucl. Soc., 30*, 47 (1978).

Large Tokamak Facilities

Characteristic	TFTR	JET	JT-60	T-15
Location	USA	EC/UK	Japan	USSR
Experimental Start	1982	1983	1985	1987
Major Radius (m)	2.5	3.0	3.0	2.4
Minor Radius (m)	0.85	1.25	0.95	0.70
Elongation	1.0	1.6	1.0	1.0
Toroidal Field (T)	5.2	3.5	4.5	5.0
Plasma Current (MA)	3.0	5.0	2.7	2.3
Auxiliary Heating (MW)	30	40	30	30
Heating Pulse (s)	2	10	5	>1
Heating Methods	Neutral Beam (NB) ICRH	ICRH NB	NB LHH ICRH	ECH NB
Working Gas	H,D,DT	H,D,DT	H,D	H
Special Features	Adiabatic compression Tangential NB	D-Shape	Outer divertor	Super-con-ducting coils
Program Emphasis	Confinement at high nT DT breakeven	Confinement at high β High-power rf Plasma shaping Alpha physics	Confinement at high nT High-power rf Divertor	ECH Plasma control

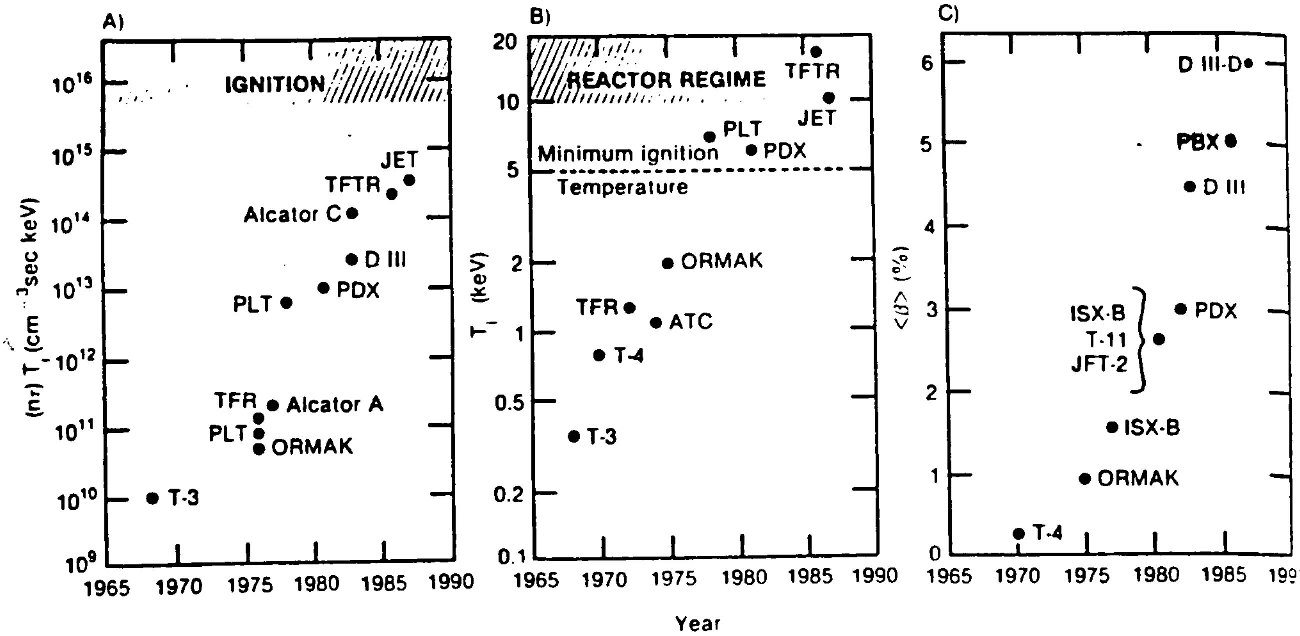
Plasma Parameters Achieved by Various Confinement Concepts



KEY: S-1: Spheromak-1; Princeton Plasma Physics Laboratory, Princeton, NJ.
TMX-U: Tandem Mirror Experiment Upgrade; Lawrence Livermore National Laboratory, Livermore, CA.
ZT-40M: Toroidal Z-pinch, -40, Modified; Los Alamos National Laboratory, Los Alamos, NM
FRX-C: Field-Reversed Experiment C; Los Alamos National Laboratory, Los Alamos, NM
OHTE: Ohmically Heated Toroidal Experiment; GA Technologies, Inc., San Diego, CA.
Gamma-10: University of Tsukuba, Ibaraki, Japan
WVII-A: Wendelstein VII-A; Institute for Plasma Physics, Garching, Federal Republic of Germany
HEL-E: Heliotron-E; Kyoto University, Kyoto, Japan.
D III: Doublet III; GA Technologies, Inc., San Diego, CA.
JET: Joint European Torus; JET Joint Undertaking, Abingdon, United Kingdom.
TFTR: Tokamak Fusion Test Reactor; Princeton Plasma Physics Laboratory, Princeton, NJ
ALC-C: Alcator C; Massachusetts Institute of Technology, Cambridge, MA.

SOURCE: Office of Technology Assessment, 1987.

Figure 4-14.—Progress in Tokamak Parameters

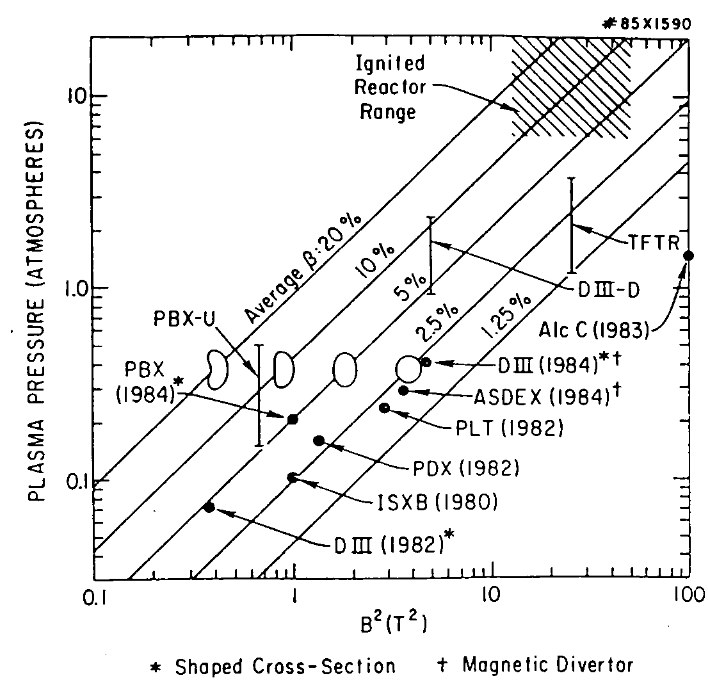


(A) $n\tau T_i$, representing the simultaneous achievement of the three parameters—density, ion temperature, and confinement time—needed to produce fusion power

(B) T_i = ion temperature

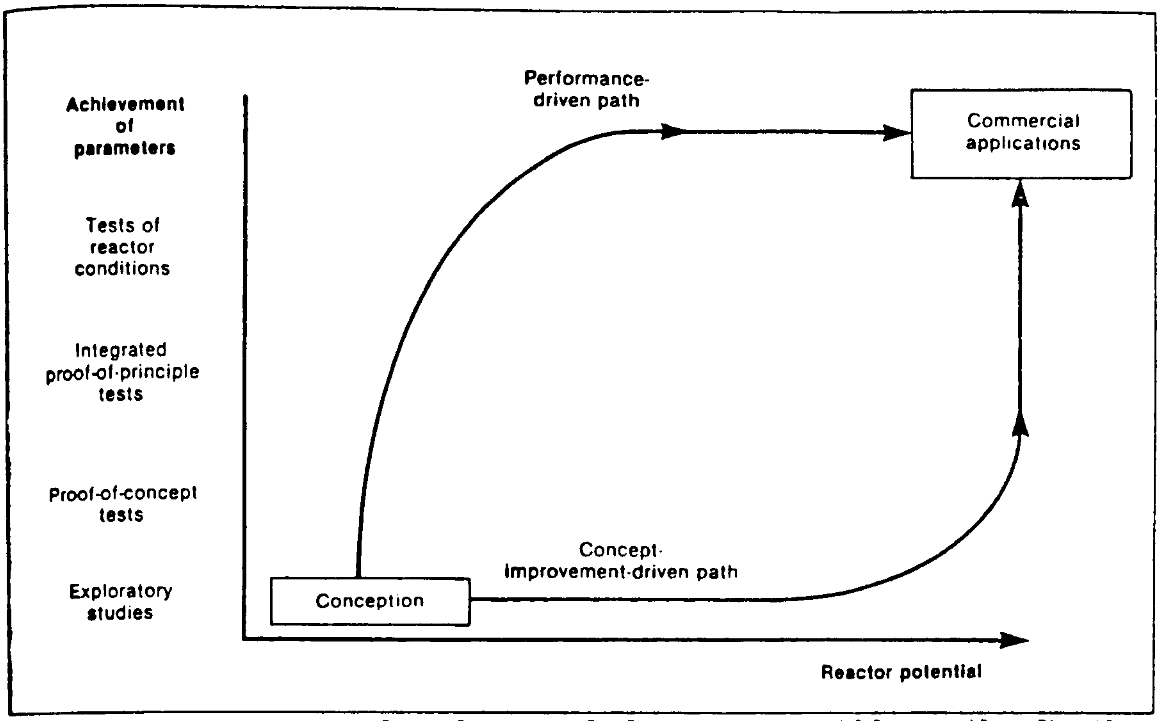
(C) <β> = beta = ratio of plasma pressure to magnetic field pressure; provides a measure of the efficiency with which the magnetic fields are used

SOURCE: Updated from National Research Council, *Physics Through the 1990s: Plasmas and Fluids* (Washington, DC: National Academy Press, 1986), figure 4.6 : 18.



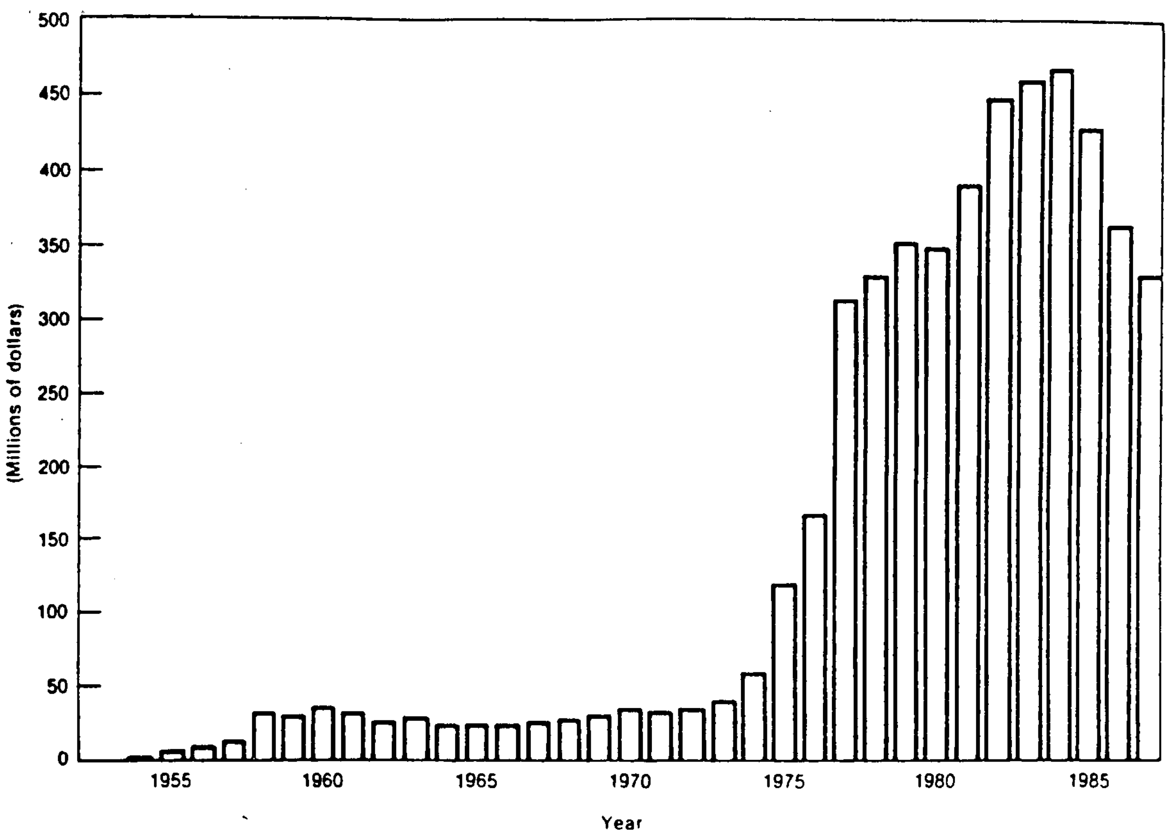
Recent progress of toroidal experiments towards the beta regime of an ignited reactor. The illustrative cross-section shapes indicate theoretical beta-limits for aspect ratios of about 3. Experimental results are mainly for near-circular cross-section tokamaks, except for DIII-D (D-shaped) and PBX (bean).

Alternate Paths for Concept Development

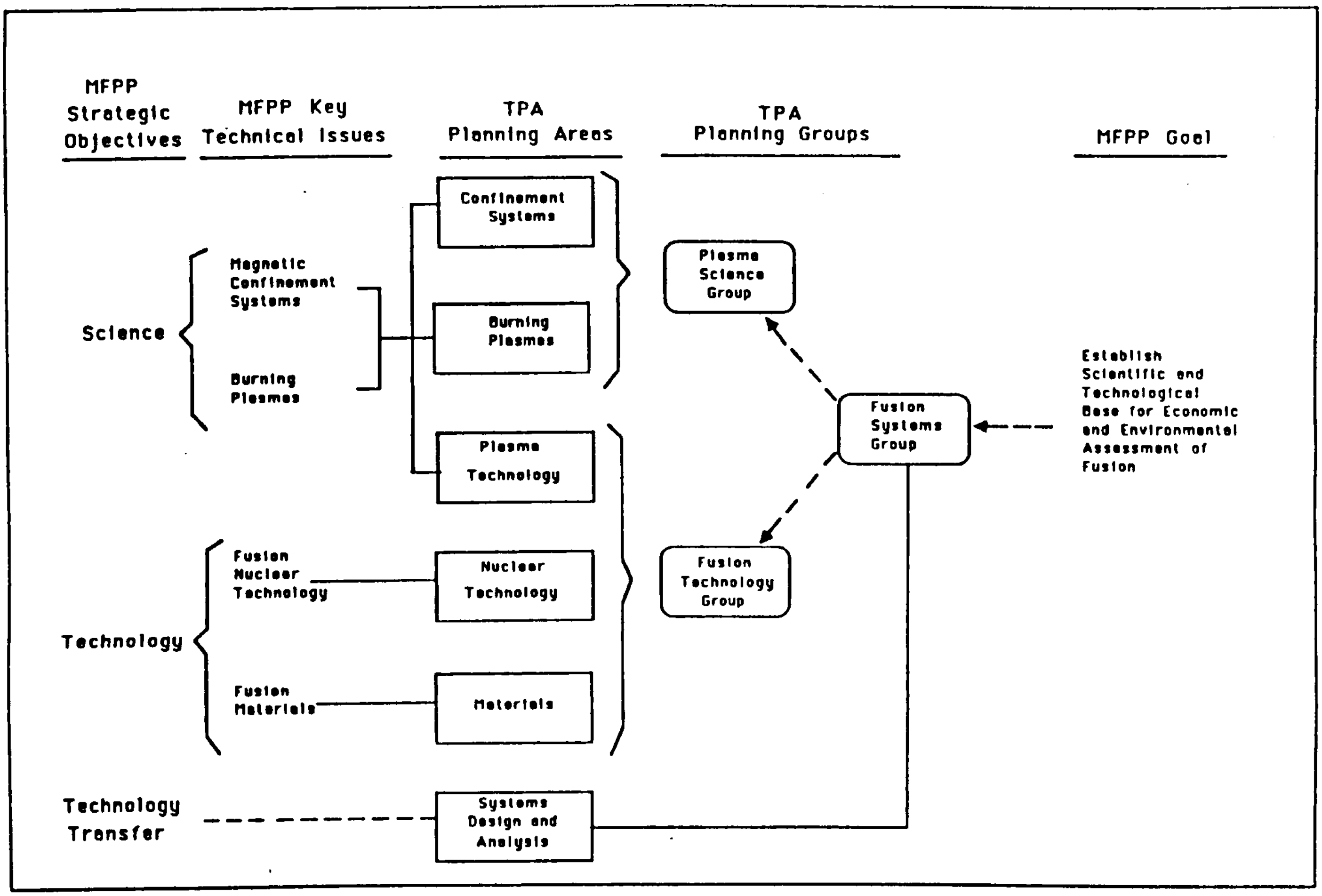


SOURCE: Adapted from Argonne National Laboratory, *Technical Planning Activity, Final Report*, commissioned by the U.S. Department of Energy, Office of Energy Research, ANL/FPP-87-1, January 1987, figure 1.5, p. 56.

Historical Magnetic Fusion R&D Funding, 1951-87 (in current dollars)

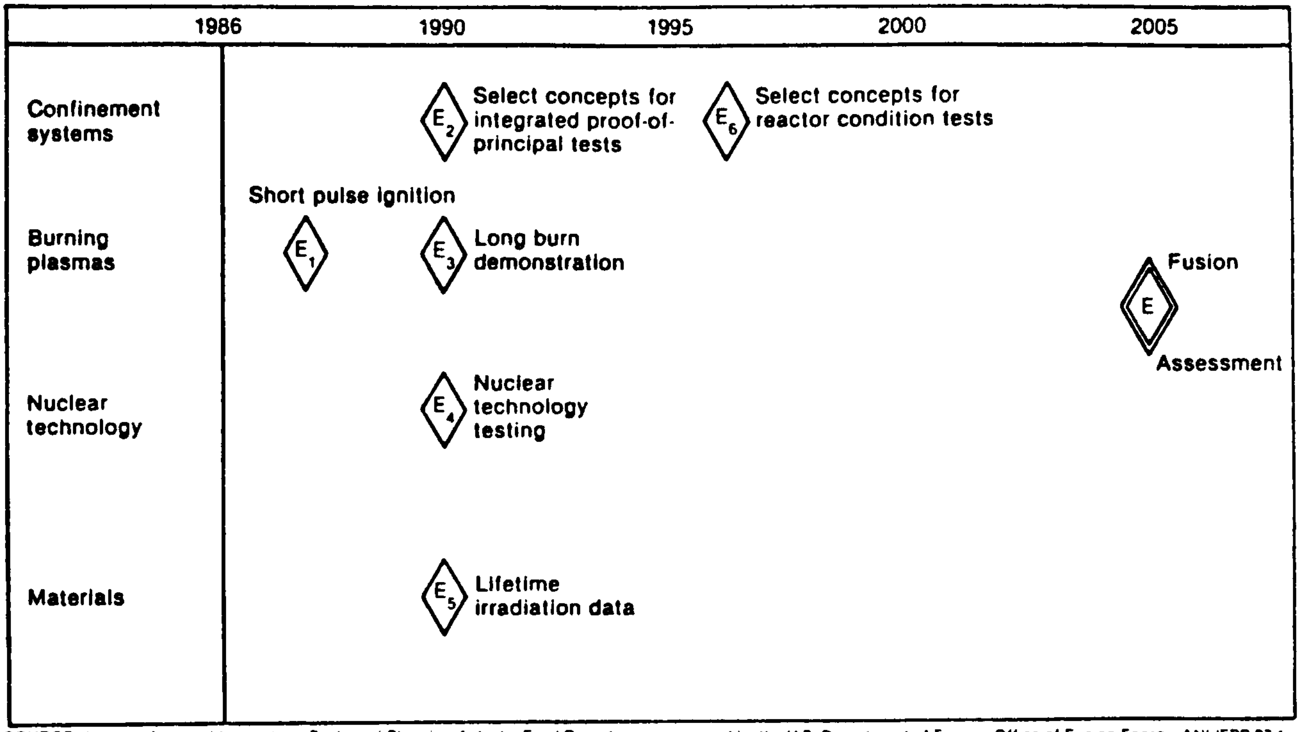


SOURCE: U.S. Department of Energy, Office of Energy Research, letter to OTA project staff, Aug. 15, 1986



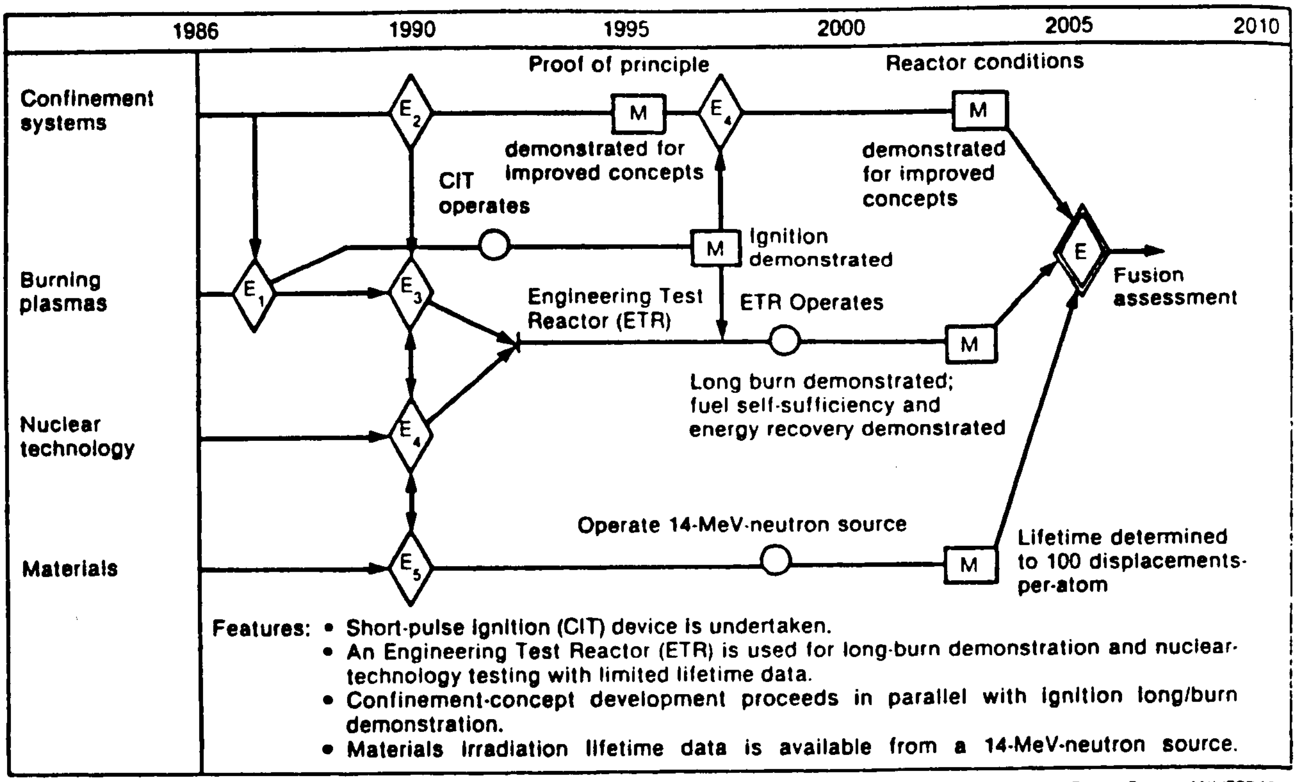
Structure of Technical Planning Activity and Its Relationship to Magnetic Fusion Program Plan

Top Level Decision Points in the Magnetic Fusion Program



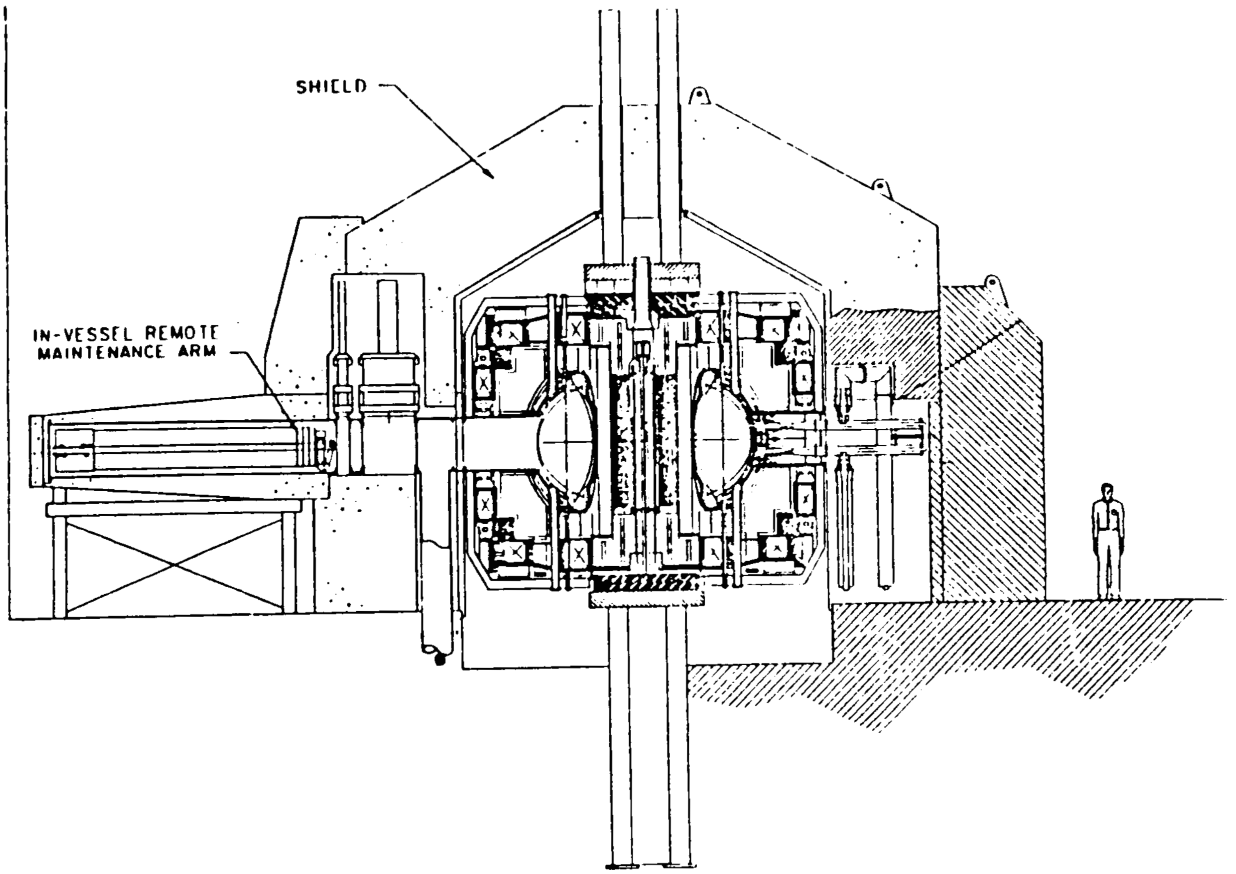
SOURCE: Argonne National Laboratory, *Technical Planning Activity: Final Report*, commissioned by the U.S. Department of Energy, Office of Fusion Energy, ANL/FPP-87-1, January 1987, figure S.8, p. 23.

Reference Scenario for the Magnetic Fusion Program



SOURCE: Argonne National Laboratory, *Technical Planning Activity: Final Report*, commissioned by the U.S. Department of Energy, Office of Fusion Energy, ANL/FPP-8-, January 1987, figure S.10, p. 27.

Preliminary CIT Design



SOURCE: Princeton Plasma Physics Laboratory, 1987.

Fusion Fuel Cycles[a]

Cycle	Primary reaction	Percent of energy carried by charged particles
D-T cycle	$D + T \rightarrow {}^4He + n + 17.59$ million electron volts (MeV) [D = deuterium; T = tritium; ^4He = alpha particle, or helium nucleus]	20%
D-D cycle	$D + D \rightarrow p + T + 4.03$ MeV $D + D \rightarrow {}^3He + n + 3.27$ MeV [p = proton; ^3He = helium isotope with one less neutron than ^4He]	62%[b]
D-^{3}He cycle	$D + {}^3He \rightarrow {}^4He + p + 18.34$ MeV	up to 98%[c]
D-^{6}Li cycle	$D + {}^6Li \rightarrow 5$ different reactions [^6Li = isotope of lithium]	over 65%
p-^{11}B cycle	$p + {}^{11}B \rightarrow {}^4He + {}^4He + {}^4He + 8.66$ MeV [^{11}B = isotope of boron]	almost 100%[d]

[a] Presented in order of increasing difficulty; the last reaction is from 100 to 10,000 times harder to ignite than the first one, depending on temperature.

[b] Sixty-two percent is the fraction of the energy carried off by charged particles, assuming that the intermediate reaction products (T and ^3He) react further via D-T and D-^{3}He reactions. With these additional reactions, the full reaction is

$$6D \rightarrow p + p + n + n + {}^4He + {}^4He + 43.23 \text{ MeV}$$

[c] Ninety-eight percent can be attained for mixtures lean in D and rich in ^3He (see footnote 21 in main text, above).

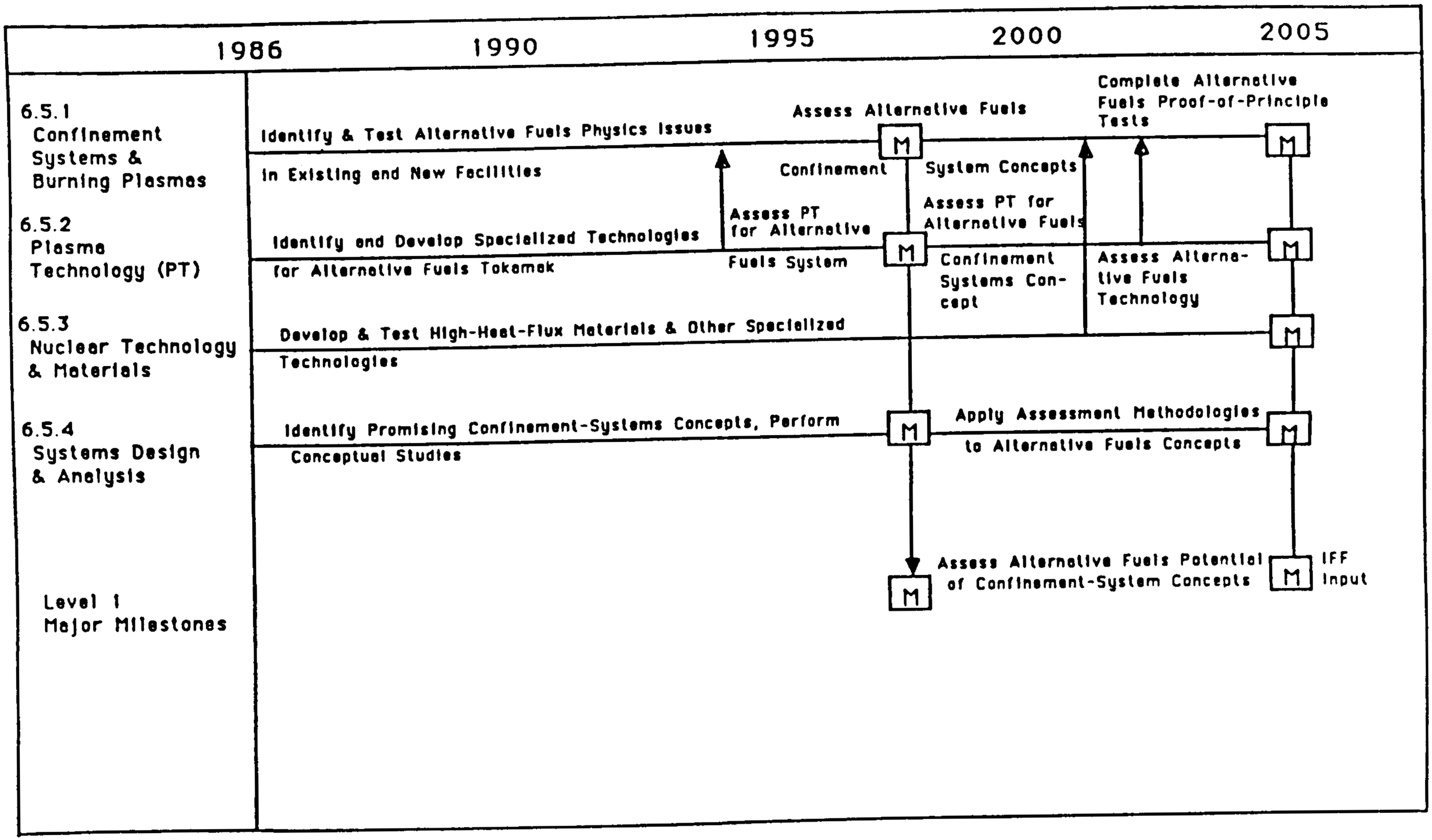
[d] A low energy (0.15 MeV) neutron is produced in the secondary reaction $^4He + {}^{11}B \rightarrow n + {}^{14}N + 0.158$ MeV [^{14}N = isotope of nitrogen].

SOURCE: U.S. Department of Energy, *Background Information and Technical Basis for Assessment of Environmental Implications of Magnetic Fusion Energy*, DOE/ER-0179, August 1983, p. 2-3 (table 2.1) and pp. 2-24 to 2-27, including table 2.2.

Objectives and Attributes for Alternative Fuels Program Element

Objectives	Attributes
Minimize production and handling of tritium.	Cost of tritium-handling subsystem, expressed as percent of total plant cost
Minimize production of neutrons.	Fraction of total fusion energy carried by neutrons, expressed as percent
Maximize potential for nonthermal energy conversion.	Overall plant efficiency, in percent
Maximize capability to achieve the higher beta and confinement times necessary for alternative-fuel systems.	Predictive capability of plasma theory to verify experiment

ORIGINAL PAGE IS OF POOR QUALITY



Level 2 Logic Diagram for Alternative Fuels

ORIGINAL PAGE IS
OF POOR QUALITY

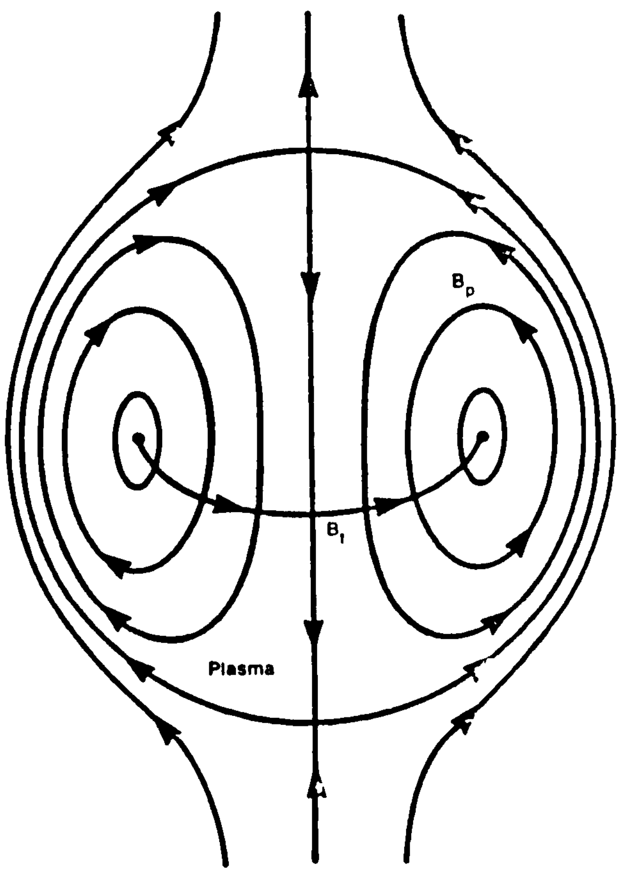
COMMENTS ABOUT ALTERNATIVE CONFINEMENT CONCEPTS WELL SUITED FOR D/^{3}He OPERATION AND DEVELOPMENT PLANS FROM U.S. MAGNETIC FUSION PROGRAM PLAN

Classification of Confinement Concepts

Well-developed knowledge base	Moderately developed knowledge base	Developing knowledge base
Conventional Tokamak	Advanced Tokamak	Spheromak
	Tandem Mirror	Field-Reversed Configuration
	Stellarator	Dense Z-Pinch
	Reversed-Field Pinch	

SOURCE: Adapted from Argonne National Laboratory, Fusion Power Program, *Technical Planning Activity: Final Report*, commissioned by the U.S. Department of Energy, Office of Fusion Energy, ANL/FPP-87-1, 1987, p. 15

Spheromak



B_p = Poloidal magnetic field

B_t = Toroidal magnetic field

SOURCE: M.N. Rosenbluth and M.N. Bussac, "MHD Stability of Spheromak," *Nuclear Fusion* 19(4):489-498 (Vienna, Austria: International Atomic Energy Agency, 1979).

Major World Spheromaks[a]

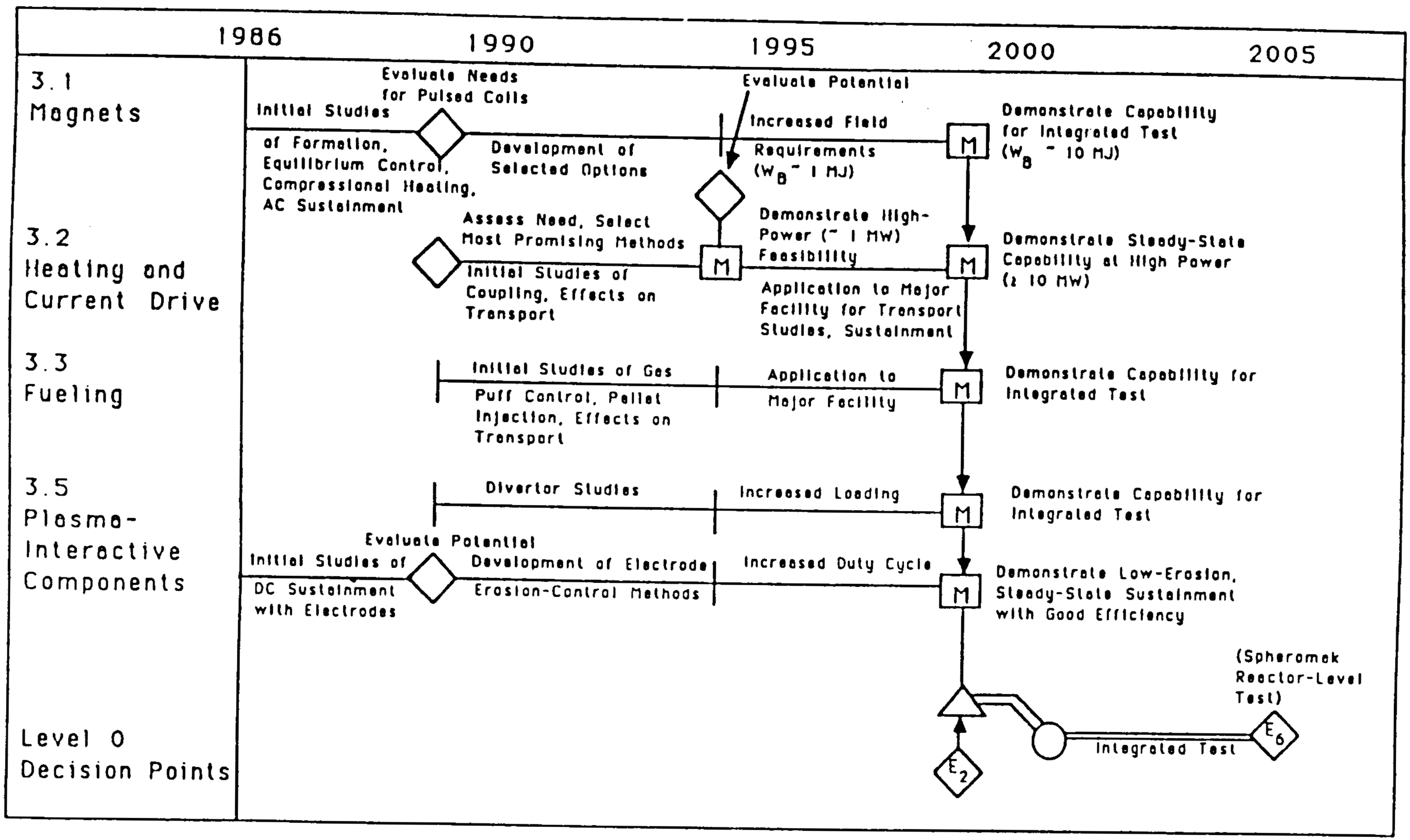
Device	Location	Status
S-1	United States (PPPL)	To be terminated, fiscal year 1988
CTX	United States (LANL)	Terminated, fiscal year 1987
MS	United States (University of Maryland)	Under construction
CTCC	Japan	Operating
Manchester U.	United Kingdom (University of Manchester)	Operating
TS-3	Japan	Operating

[a]Listed approximately by decreasing order of the size of the spheromak research effort at each site. It is difficult to specify any single physical parameter as a rough measure of spheromak capability.

SOURCE: Office of Technology Assessment, 1987.

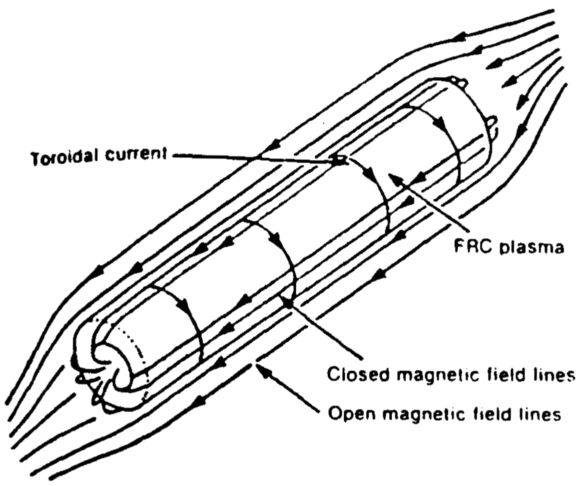
Spheromak Program Elements, Subelements, Objectives, and Attributes

Program Elements and Subelements	Objectives	Attributes
Macroscopic Equilibrium and Dynamics		
Macroscopic Stability	Minimize the amount and complexity of external structures (both driven and passive) required to control equilibrium and gross tilt and shift instabilities.	Field-line symmetry and closure
Current- and Pressure-Driven Effects	Obtain q-profiles that reduce kink- and ballooning-mode effects.	$q(\psi)$, $<\beta>$
Transport		
Energy Confinement	Control the processes that determine spheromak energy loss.	$n\tau_E$
Wave-Plasma Interactions		
Wave Heating	Apply auxiliary heating or current drive by efficient rf techniques, as required.	Source-to-spheromak efficiency
Particle-Plasma Interactions		
Impurity Control	Reduce impurity effects through combined ohmic-heating, burn-through and divertor action of open magnetic flux.	Z_{eff}
Composite		
Pulse-Length Optimization	Develop methods for sustainment against resistive decay, based on helicity injection or current drive.	Efficiency, τ_{pulse}/τ_R



Level 3 Logic Diagram for Spheromak Plasma Technology

Field-Reversed Configuration



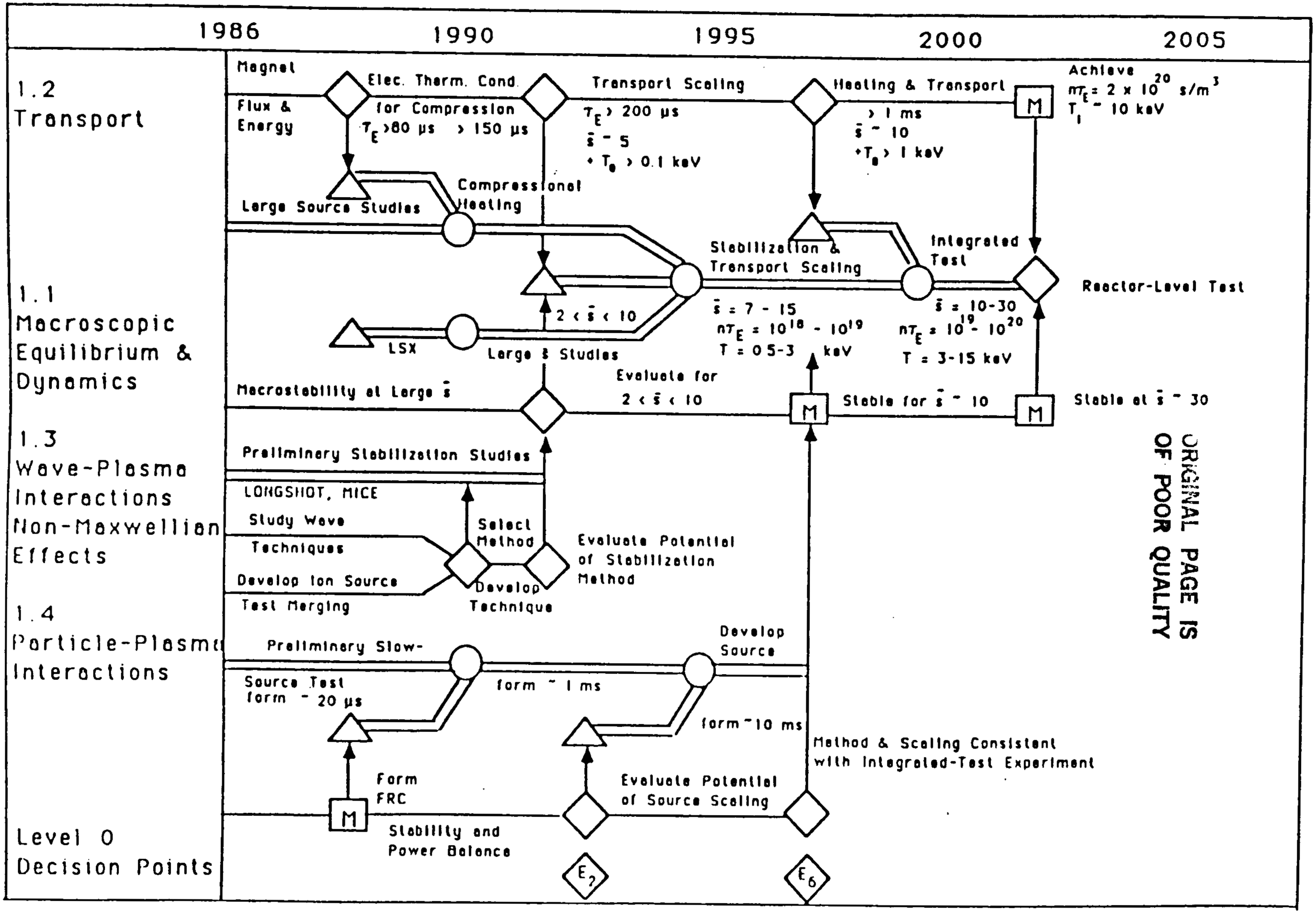
SOURCE National Research Council *Physics Through the 1990s Plasmas and Fluids* (Washington, DC National Academy Press, 1986)

Major World Field-Reversed Configurations[a]

Device	Location	Status
LSX	United States (Spectra Technologies)	Under construction
FRX-C	United States (LANL)	Operating
BN. TOR	U.S.S.R. (Kurchatov)	Operating
TRX-2	United States (Spectra Technologies)	Operating
OCT. PIACE	Japan (Osaka University)	Operating
NUCTE	Japan (Nihon University)	Operating

[a]Listed approximately by decreasing order of size, similarly sized devices at the same institution are listed together

SOURCE Office of Technology Assessment, 1987; from information supplied by the Los Alamos National Laboratory

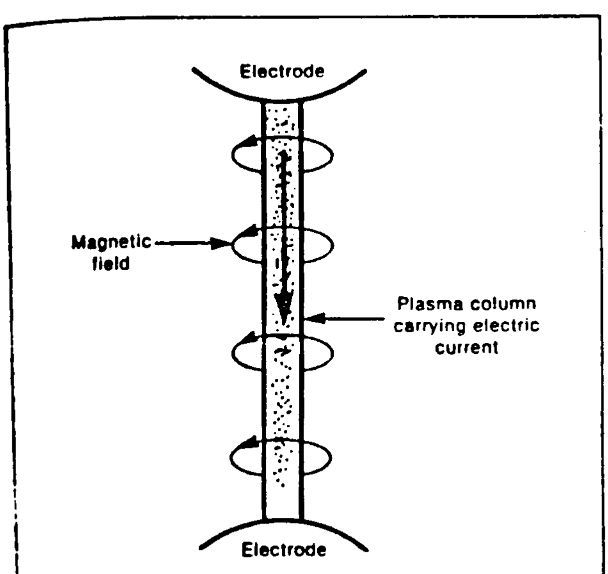


Level 2 Logic Diagram for the Field-Reversed Configuration

Field-Reversed Configuration Program Elements, Subelements, Objectives, and Attributes

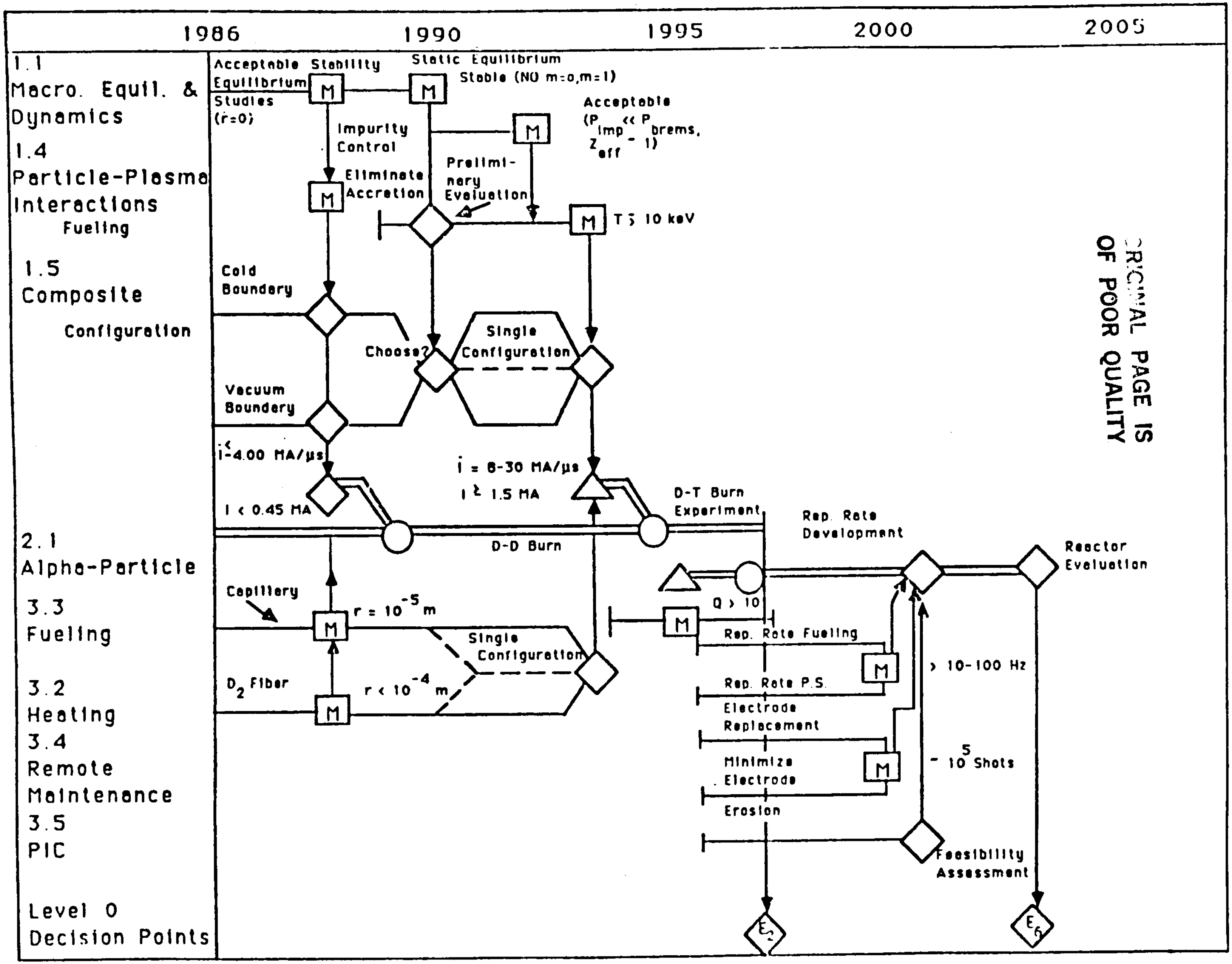
Program Elements and Subelements	Objectives	Attributes
Macroscopic Equilibrium and Dynamics		
MHD Equilibrium and Stability	Maintain stability with increased $\bar{s}$.	Value of $\bar{s}$
Transport		
Energy Confinement	Demonstrate favorable scaling of energy confinement with $\bar{s}$.	$\tau_E(\bar{s})$
Heating	Establish adiabatic compression as viable method.	τ_E(Temp.)
Composite		
Formation	Develop lower-voltage formation method.	τ_f, formation timescale

Dense Z-Pinch



SOURCE: Office of Technology Assessment, 1987

ORIGINAL PAGE IS OF POOR QUALITY



Level 2 Logic Diagram for Dense Z Pinch

ORIGINAL PAGE IS
OF POOR QUALITY

C-2

Program Elements, Subelements, Objectives, and Attributes for the Dense Z-Pinch

Program Elements and Subelements	Objectives	Attributes
Macroscopic Equilibrium and Dynamics		
Magnetic Transients	Demonstrate stable equilibrium at $I \geq 1.4$ MA.	No gross instability during current rise
Transport		
Energy Confinement	Demonstrate reactor-level confinement.	$n\tau_E$
Particle-Plasma Interactions		
Fueling	Eliminate accretion.	$\dot{N} = 0$ rep rate in Hz
	Reactor-relevant repetition rate.	Repetition rate in Hz
Alpha-Particle Effects	Minimize core plasma heating; minimize exo-column ionization and current diversion; and understand alpha-particle/electrode interaction.	Frequency/mass/cost of electrode replacement
Radiative Collapse of Pinch	Understand dynamics Enhance fuel burning.	DT burnup
Composite	Choose configuration (cold boundary vs. vacuum boundary).	Z_{eff}, τ_E

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

Dense Z-Pinch Decision on Proceeding with DD Burn Experiment

Statement of Decision

To proceed with the DD burn experiment, in which the primary objective is to obtain equivalent DT $Q > 1$.

Decision Criteria

Obtain stable, static equilibria at the 1.5-MA current level.
Explore confinement scaling for $n\tau_E \sim 10^{17}$–10^{18} s/m^3.
Choose between cold-boundary and vacuum-boundary approaches on the basis of preliminary transport, stability, and impurity-level assessments.

Sources of Information

Results from existing dense Z-pinch experiments.
Preliminary results from dense Z-pinch DD burn experiments.
Plasma supporting activities (principally in Europe).

Outcomes and Consequences of Decision

Favorable assessment and achievement of the objectives of the DD burn experiments would lead to a DT burn experiment and an assessment of the technological possibilities of developing the concept towards a reactor (particularly with respect to the repetition-rate problem).
Undertake further research to resolve the remaining issues.
Terminate the dense Z-pinch program.

Cost of Representative Fusion Experiments

Experiment	Location	Type	Construction cost (millions of 1987 dollars)
Tokamak Facility Test Reactor	PPPL	Tokamak	$562
Mirror Fusion Test Facility-B	LLNL	Tandem Mirror	$330
Doublet III	GA	Tokamak	$ 56[a]
Doublet III-D (Upgrade)	GA	Tokamak	$ 36[a]
International Fusion Superconducting Magnet Test Facility	ORNL	Magnet Test[b]	$ 36[c]
Poloidal Divertor Experiment	PPPL	Tokamak	$ 54
Princeton Large Torus	PPPL	Tokamak	$ 43
Tritium Systems Test Assembly	LANL	Tritium Test[b]	$ 26
Tandem Mirror Experiment	LLNL	Tandem Mirror	$ 24
Tandem Mirror Experiment Upgrade	LLNL	Tandem Mirror	$ 23
Texas Experimental Tokamak	UT	Tokamak	$ 21
Advanced Toroidal Facility	ORNL	Stellarator	$ 21
TARA	MIT	Tandem Mirror	$ 19
ZT-40	LANL	Reversed-Field Pinch	$ 17
Alcator C	MIT	Tokamak	$ 15
Rotating Target Neutron Source	LLNL	Materials Test[b]	$ 11
Impurity Studies Experiment-B	ORNL	Tokamak	$ 5
Field Reversed Experiment-C	LANL	Field-Reversed Configuration	$ 3
Phaedrus	UW	Tandem Mirror	$ 1.8
Macrotor	UCLA	Tokamak	$ 1.5
IMS	UW	Stellarator	$ 1.4
Tokapole	UW	Tokamak	$ 0.6

KEY: PPPL—Princeton Plasma Physics Laboratory, Princeton, New Jersey
LLNL—Lawrence Livermore National Laboratory, Livermore, California
ORNL—Oak Ridge National Laboratory, Oak Ridge, Tennessee
GA—GA Technologies, Inc., San Diego, California
LANL—Los Alamos National Laboratory, Los Alamos, New Mexico
UT—University of Texas, Austin, Texas
MIT—Massachusetts Institute of Technology, Cambridge, Massachusetts
UW—University of Wisconsin, Madison, Wisconsin
UCLA—University of California, Los Angeles, California

[a] Values shown for the combined Doublet III facility and upgrade do not include an additional $54 million (in current dollars) of hardware provided by the government of Japan or $36 million (in 1987 dollars) for a neutral beam addition.
[b] These facilities are fusion technology facilities, all others on the table are confinement physics experiments.
[c] The cost of this facility does not include the cost of the six magnet coils that are being tested there. It is estimated that the magnet coils cost between $12 million and $15 million each (in current dollars).

SOURCE: U.S. Department of Energy, Office of Fusion Energy, 1987.

EXAMPLE OF HIGH TEMPERATURE $D/^3He$ BURN EXPERIMENT

OBJECTIVES OF HI-T EXPERIMENT

- OBTAIN PLASMA SCALING DATA AT 30 TO 40 keV OF INTEREST TO D-BASED ADVANCED FUELS
- DEMONSTRATE ADVANCED FUEL BURN BY REFUELING TO CONVERT FROM D-T TO $D/^3He$

APPROACH

- USE D-T THERMAL RUN-AWAY IN HIGH-β RFTP

RF⊙P BURN DYNAMIC EXPERIMENT

NEUTRAL BEAM/PELLET INJECTION INTO FRTP

- PROVIDES AUXILIARY HEATING BEYOND COMPRESSION/SHOCK
- PROVIDES FUELING SO $\tau_{BURN} \sim 5\tau_{PARTICLE}$
- COUNTER-DIRECTED BEAM SUPPRESSES ROTATION
- DENSITY PROFILE CONTROL SUPPRESSES LOWER HYBRID DRIFT

WHY RFTP?

- HIGH β
- EXPERIMENTAL DATA PROMISING
- LSST SCALING SUPPORTS FEASIBILITY OF HIGH-T OPERATION
- COMPACT SIZE ALLOWS RAPID CONSTRUCTION AT MODEST COST
- ALLOWS ADVANCED FUELS

KEY PROBLEMS

- SUPPRESS PLASMA SPIN-UP
- SUPPRESS STEP DENSITY GRADIENTS CAUSING LOW HYBRID DRIFT INSTABILITY

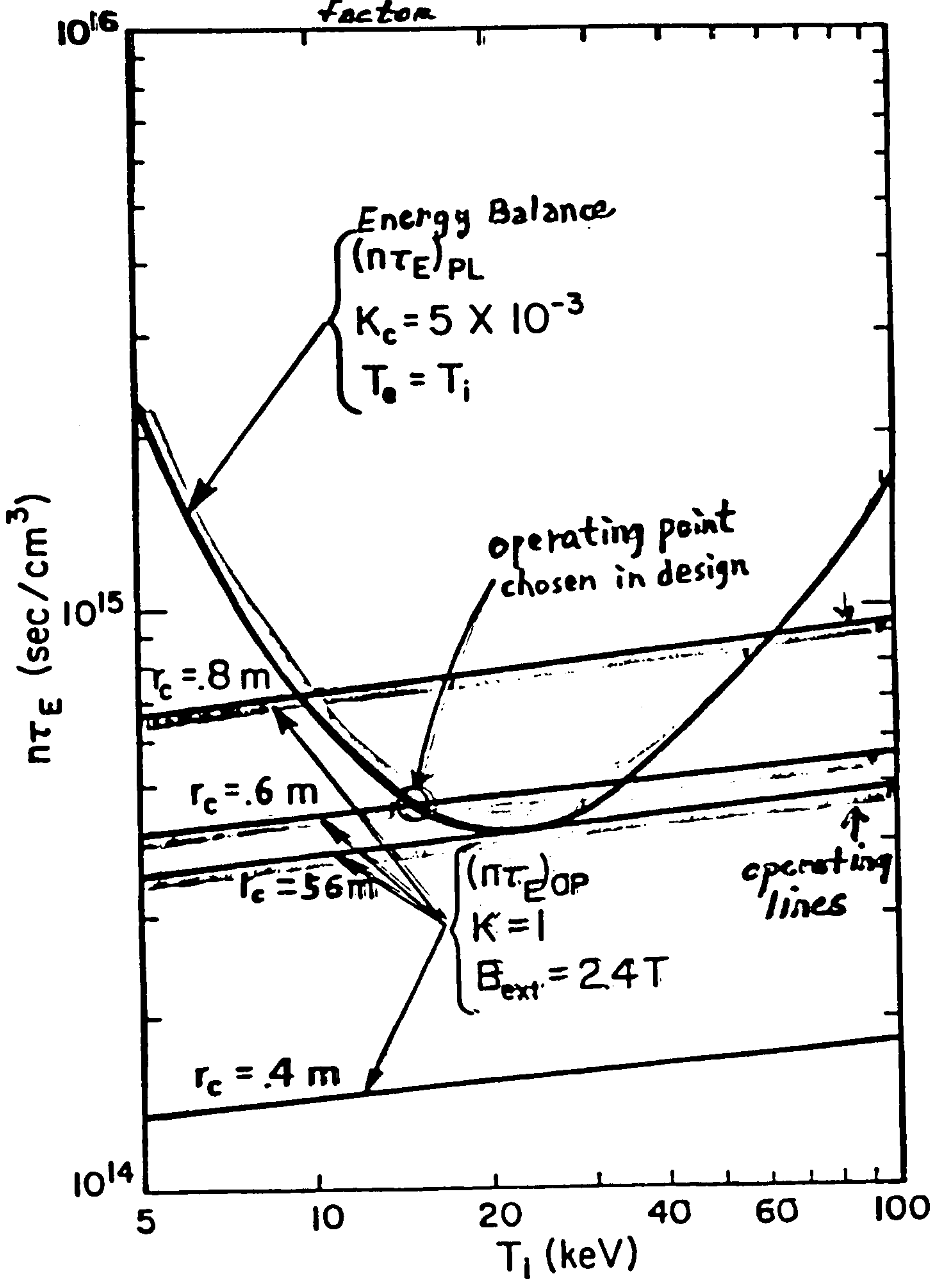
$$\tau_p^{LCST} \sim T_i^{0.2}\, K^{2.7}\, r_c^{1.8}\, M_R^{1.3}\, B^{2.5}\, n^{-1}$$

reversal factor

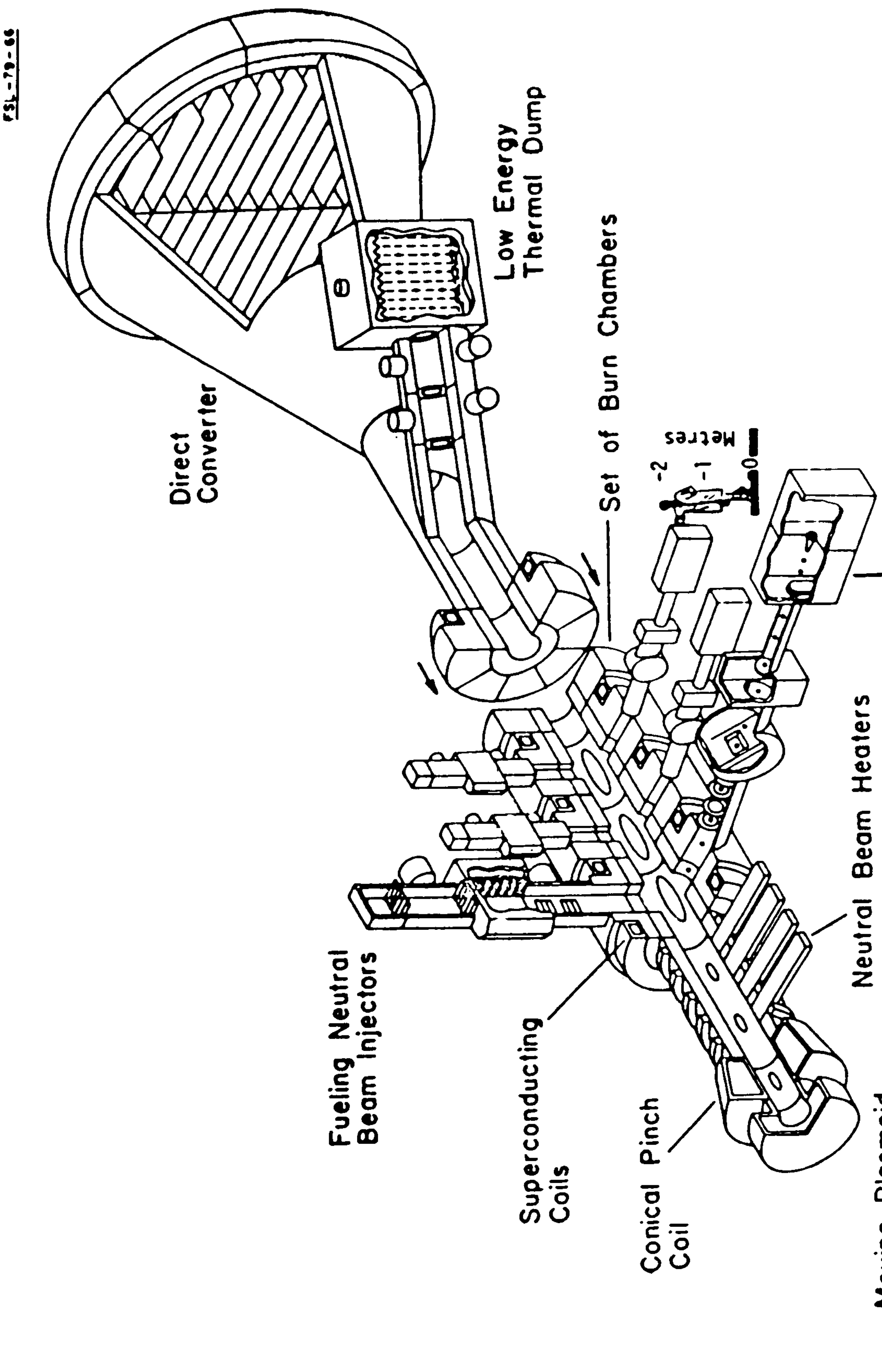
coil radius

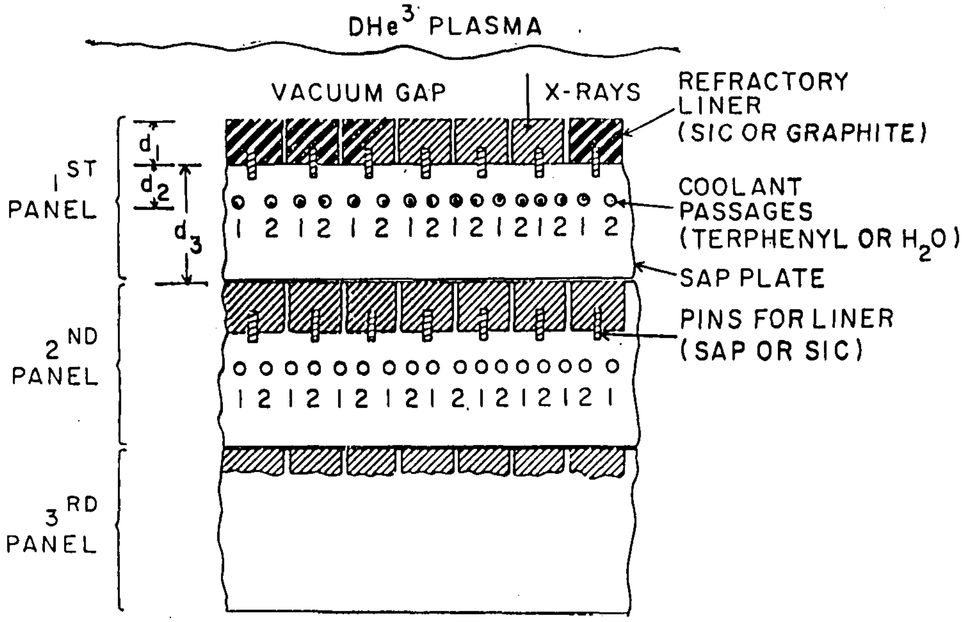
mirror ratio

field at coil



$(n\tau_E)_{OP}$ and $(n\tau_E)_{PL}$ versus T_i for a D-T system. Here $(n\tau_E)_{OP}$ is based on the "loss-cone-like" scattering transport model (see reference), where K is the field reversal factor.


FSL-79-66
Direct Converter
Low Energy Thermal Dump
Set of Burn Chambers
Metres
-2
-1
0
Pellet Injectors
Neutral Beam Heaters
Fueling Neutral Beam Injectors
Superconducting Coils
Conical Pinch Coil
Moving Plasmoid Heater Startup



ALUMINUM BLANKETS FOR DHe^3 REACTORS CROSS SECTION

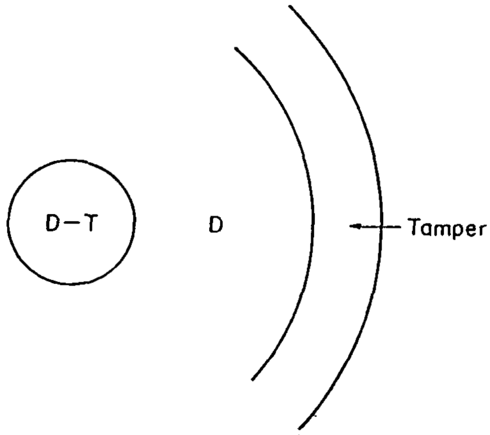
SAFFIRE

Power Split, %

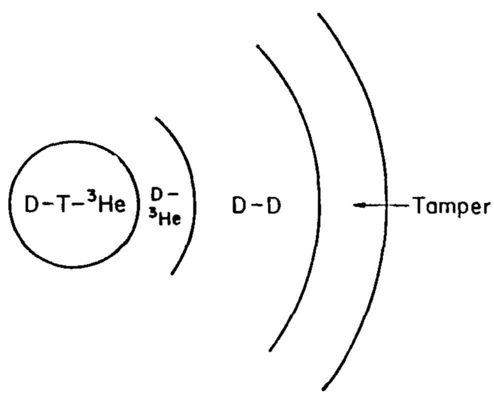
plasma	0.39	0.76
fp	0.37	
radiation	0.22	
neutrons	0.02	

CONCEPTS FOR BURNING ADVANCED FUELS WITH INERTIAL CONFINEMENT USING A-FLINT CONCEPT

[Burn propagation ignited by a D-T central spark.]

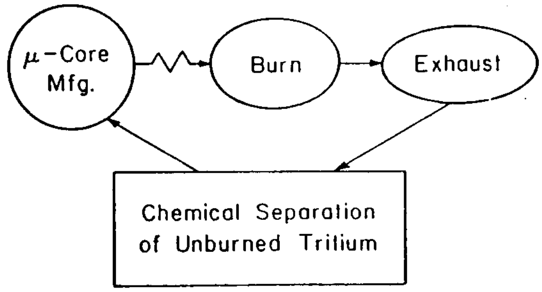


THE AFLINT TARGET CONCEPT USES BURN PROPAGATION TO IGNITE AN OUTER DEUTERIUM LAYER. A MAIN OBJECTIVE IS TO PROVIDE TRITIUM BREEDING IN THE TARGET (VIA D-D REACTIONS) SO THAT THE BLANKET NEED NOT BREED.



THE BURN PROPAGATION IS IMPROVED BY USE OF ^{3}He (BREED INTERNALLY BY D-D ALSO). IN THIS FIGURE AN OPTIMUM ARRANGEMENT IS SHOWN.

TRITIUM SELF SUFFICIENCY



FLOW DIAGRAM FOR TRITIUM WHEREBY TRITIUM PRODUCED BY D-D REACTIONS IN THE BURN IS USED TO MANUFACTURE SUBSEQUENT D-T MICRO-CORES. A TARGET TRITIUM BREEDING RATIO (TBR) SLIGHTLY GREATER THAN 1.0 IS REQUIRED FOR SELF SUFFICIENCY, i.e., ELIMINATE THE NEED FOR A LITHIUM BREEDING BLANKET.

Prior D-Based Pellet Studies

REFERENCE	TYPE	E_I (MJ)	ϵ (J/gm)	ρr (gm-cm^{-2})	TBR	G
WOOD, Ref. 8	Cat.D Burner (T;^{3}He Seed)	3xDT	?	?	> 1.0	1/2xDT
NUCKOLLS, Ref. 9	Cat.D Burner (T;^{3}He Seed)	10	3×10^7	?	> 1.0	?
MOSES, Ref. 7	Pure D Spark	> 100	1.5×10^9	40-80	·	200-300
SKUPSKY, Ref. 10	50/50 D-T Spark; 90/10 Outside	0.16 abs.	1.6×10^8	25	0.4	580
1978 A-FLINT, Refs. 12-14	50/50 D-T Spark; Pure D Outside	1.8 abs.	9.7×10^7	13	1.1	1700
1980 A-FLINT Ref. 1	"	0.1 abs.	5.87×10^7	6.8	1.0	700

E_I = input energy
ϵ = specific absorbed energy
TBR = tritium breeding ratio
G = gain on absorbed energy