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**BECHTEL JOB 15340 FOR
LAWRENCE LIVERMORE NATIONAL LABORATORY**

**CONCEPTUAL CAPITAL COST ESTIMATE AND FACILITY DESIGN
OF THE MIRROR FUSION
TECHNOLOGY DEMONSTRATION FACILITY**

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This report contains contributions by Bechtel Group, Inc. to Lawrence Livermore National Laboratory (LLNL) for the final report on the conceptual design of the Mirror Fusion Technology Demonstration Facility (TDF). Included in this report are the following contributions:

- o Conceptual Capital Cost Estimate
- o Structural Design
- o Plot Plan and Plant Arrangement Drawings

The conceptual capital cost estimate is prepared in a format suitable for inclusion as a section in the TDF final report. The structural design and drawings are prepared as partial inputs to the TDF final report section on facilities design, which is being prepared by the FEDC.

CONTENTS

	<u>Page</u>
Conceptual Capital Cost Estimate	1
Appendix A: Structural Design	A-1
Appendix B: TDF Plot Plan and Plant Arrangement Drawings	B-1

CONCEPTUAL CAPITAL COST ESTIMATE

TOTAL CAPITAL COSTS

The total capital costs estimated for the Technology Demonstration Facility (TDF) are shown in Table 1. This estimate is in millions of mid-1982 dollars and has the following qualifications:

- o The estimate was prepared assuming that the scope of services will be that of a prime contractor responsible to the owner for engineering, procurement, and construction.
- o Equipment and materials will be procured from U.S. sources, and lead times will be able to support the project schedule without cost penalties.
- o Sufficient manual and nonmanual personnel to complete the project within the construction schedule is assumed to be available in the project vicinity.
- o Existing water sources and power will be adequate for the requirements of this project.

Direct Costs

The direct costs shown in Table 2 include the plant equipment, materials and subcontracts, and installation labor associated with the permanent facilities, systems, and equipment.

The costs of the TDF equipment were estimated by the engineers and organizations responsible for the design and specification of that equipment (Table 3). A cost data collection methodology was developed to ensure that all components and systems were included in the cost estimate, and to ensure that all cost data are on a common basis.

The TDF work breakdown structure was first arranged to correspond to the standard accounts for fusion cost estimates developed by Battelle (Ref. 1). The engineer responsible for the account developed the work breakdown below the level shown on Table 2. By reviewing the detailed

Table 1

TDF CAPITAL COST SUMMARY
(Mid-1982 \$ x 10⁶)

<u>Description</u>	<u>Cost</u>
Direct cost	653
Indirect cost	<u>110</u>
Total field cost	763
Home office cost	191
Owner's cost (operating entity)	38
Contingency	<u>298</u>
Total capital cost	<u>1,290</u>

Table 2

TDF DIRECT COST SUMMARY
(Mid-1982 \$1000)

<u>Account</u>	<u>Description</u>	<u>Component Engineering</u>	<u>Plant Equipment</u>	<u>Material and Subcontract</u>	<u>Instal- lation Labor</u>	<u>Total</u>
21	Structures and site facilities			80,640	53,760	134,400
22.01.01	Vacuum vessel and beam dumps	877	13,336		1,825	16,038
22.01.02	Shield		5,568		1,634	7,202
22.01.03	Magnets	7,394	41,334		1,958	50,686
22.01.04	Heating and fueling	27,133	125,888		10,834	163,855
22.01.05	Primary structure	146	1,775		374	2,295
22.01.06	Reactor vacuum systems	2,370	11,847		2,370	16,587
22.01.07	Power supply switching and energy storage	700	4,667		537	5,904
22.02	Heat transport system		10,500		3,500	14,000
22.03	Cryogenic system		12,420		6,650	19,070
22.04	Radioactive waste treatment and disposal		2,250		750	3,000
22.05	Fuel handling and storage		46,990		7,670	54,660
22.06	Other reactor plant equipment		58,950		3,100	62,050
22.07	Instrumentation and controls			26,645		26,645
24	Electric plant equipment		12,650		2,530	15,180
25	Miscellaneous plant equipment		4,500		500	5,000
BOP	Equipment		8,000			8,000
BOP	Piping			13,000	7,000	20,000
BOP	Instrumentation			1,300	700	2,000
BOP	Electrical			10,000	16,000	26,000
Total direct cost		38,620	360,675	131,585	121,692	652,572

Table 3

TDF CAPITAL COST ACCOUNTS

<u>Account</u>	<u>Description</u>	<u>Responsible Organization</u>
21	Structures and site facilities	Fusion Engineering Design Center (FEDC)
22	Reactor plant equipment	
22.01.01	Vacuum vessel	General Dynamics (GD), LLNL
22.01.02	Shield	TRW
22.01.03	Magnets	GD, FEDC
22.01.04.01	Beam heating	TRW, FEDC
22.01.04.02	RF heating	FEDC
22.01.04.03	Fueling	FEDC
22.01.05	Primary structure and support	GD
22.01.06	Reactor vacuum system	LLNL
22.01.07	Power supply switching and energy storage	FEDC
22.02	Heat transport system	FEDC
22.03	Cryogenic system	GD
22.04	Radioactive waste treatment and disposal	FEDC
22.05	Fuel handling and storage Systems	Science Applications, Inc. (SAI)
22.06	Other reactor plant equipment	FEDC
22.07	Instrumentation and control	TRW
24	Electric plant equipment	FEDC
25	Miscellaneous plant equipment	FEDC

account breakdown before actual cost estimating began, the cost estimating group was able to resolve omissions and redundancies early in the project.

The responsible engineers were then provided with equipment cost forms, which were used to transmit cost data on equipment, component engineering and installation. The equipment cost was defined to include the base mechanical equipment plus all required drives, piping, instrumentation, and electrical materials that are furnished with the equipment before delivery to the jobsite. It excludes installation, freight, vendor representatives, contingency, and component engineering. The component engineering cost, which was included as a separate item, is the cost associated with the design of a first-of-a-kind component. Installation costs were reported as direct installation hours excluding nonmanual supervision. Allowances for vendor representatives, freight, and installation materials were developed by the cost estimating group.

Materials include all permanent plant materials usually purchased in bulk quantities, such as the following items:

- o Earthwork
- o Formwork
- o Rebar and embedded metal
- o Concrete
- o Steel
- o Pipe
- o Valves and connectors
- o Electrical equipment
- o Wire and cable
- o Conduit and cable tray
- o Computers and control modules
- o Field instruments and bulks

To simplify preparation of the estimate and accurately account for all field labor, subcontracts are generally not included as such in the estimate. This method in effect assumes that all field labor is performed by the prime contractor's work forces and results in essentially the same total estimated construction cost as that based on some subcontractor work. The instrumentation and control (I&C) system is the only exception to this approach. The I&C package was estimated by TRW on a subcontract basis; this convention made it easier to integrate the I&C estimate into the total plant estimate.

The materials estimate was prepared by Bechtel personnel based on scope definition developed at the FEDC.

Installation labor includes all manual labor involved directly in the erection of the permanent plant facilities, systems, and equipment. Typically, installation manhours were provided by the study participants and reviewed by Bechtel. Where the manhour estimates were omitted or appeared to be inconsistent with general construction experience, appropriate allowances were developed by Bechtel. An average U.S. labor rate of \$22.00 per hour including all applicable premiums, fringes, taxes, and insurance additives was assumed for this study, based on a review of current U.S. craft labor agreements.

Indirect Costs

Indirect costs are those costs that cannot be directly identified with specific permanent plant facilities, systems, and equipment; this includes the following:

- o Temporary construction facilities: temporary buildings, working areas, roads, parking areas, utility system, and general purpose scaffolding
- o Miscellaneous construction services: general job cleanup, maintenance of construction equipment and tools, material handling, surveying, and watchmen and guards

- o Construction equipment and supplies: construction equipment, small tools, consumable supplies, and purchased utilities
- o Field office: craft supervision, engineering, procurement, scheduling, personnel administration, warehousing, first aid, and the costs of operating the field office
- o Preliminary checkout and acceptance testing: testing of materials and equipment to ensure that components and systems are operable
- o Project insurance: public liability, property damage, and builder's risk insurances

The costs of the facilities, supplies, and services were estimated as a percent of direct labor costs based on an evaluation of Bechtel experience on nuclear facilities and other projects of a similar magnitude and nature. This analysis resulted in an allowance for indirect costs equal to 90 percent of direct labor.

Home Office Costs

Home office costs include preliminary, definitive, and detail design engineering, cost engineering, scheduling, procurement, and project and construction management services.

The estimate of home office costs was developed based on an analysis of experience on nuclear facilities and other projects of a similar nature. This resulted in an allowance for home office costs equal to 25 percent of total field cost.

Owner's Costs

Owner's costs are those incurred by the project during engineering and construction that are not directly attributable to the prime contractor. They include such items as:

- o Program administration and management
- o Preliminary engineering
- o Site investigation

- o Research and development
- o Initial charges, inventory, and spares
- o Startup and training

Because TDF would be a government-owned and -operated facility, a relatively small allowance of 4 percent of the total field and home office cost has been included.

Contingency

Contingency is an allowance for the uncertainty that exists within the conceptual design in quantity, pricing, or productivity and that is under the control of the engineer/constructor and within the defined scope of the project. Implicitly, the allowance will be expended during design and construction of the project and it cannot be considered as a source of funds for overruns or additions to the project scope.

Contingency excludes factors outside the control of the engineer/constructor, such as scope changes; force majeure; regulatory, operating, safety, and environmental standards; site selection; and political and financial market conditions. Contingency has been included in the estimate at 30 percent of the total of field, home office, and owner's costs.

DISCUSSION OF COST ESTIMATE

Cost Comparisons

The total capital cost summary developed in Table 1 assumes that the TDF will be constructed at an undeveloped site with engineer/constructor as the prime contractor. It is also possible that the TDF will be constructed at an existing national laboratory, with the laboratory as prime contractor, and that existing facilities may be used during the construction. To estimate the indirect costs associated with this type of project, the factors developed at the Fusion Engineering Design Center (FEDC) are employed (Ref. 2).

The total direct cost as defined by the FEDC excludes component engineering and installation labor for the reactor plant equipment. However, labor costs for facilities that would normally be subcontracted to industry are included as direct costs in the FEDC cost algorithms. These include:

<u>Account</u>	<u>Description</u>
21	Structures and site facilities
22.02	Heat transport system
22.04	Radioactive waste treatment and disposal
(22.06)	Other reactor plant equipment except remote maintenance equipment
25	Miscellaneous plant equipment

The total direct cost of the TDF defined to be compatible with FEDC is then:

<u>Cost Item</u>	<u>Cost, \$ x 10⁶</u>
Equipment cost	360.7
Material and subcontract	131.6
Subcontract labor	<u>58.8</u>
Total direct cost	551.1

This is the cost that should be used in comparing TDF to the FED designs developed by the FEDC.

The total cost is then developed by the FEDC method as:

<u>Cost Item</u>	<u>Cost, \$ x 10⁶</u>
Total direct cost	551
Engineering and management (45%)	248
Installation (15% of TDC)	<u>83</u>
Subtotal	882
Contingency (30%)	<u>265</u>
Total cost	1147

The factors are comparable to the costs developed in Tables 1 and 2 if engineering and management is identified as the component engineering, home office and owner's cost, and if installation is defined as the labor not included in the FEDC direct cost. The difference between the two total cost estimates is the indirect (field) cost. The indirect field costs will vary depending on the applicability and availability of existing facilities to support the TDF construction.

The capital cost of TDF was also estimated by LLNL, based on construction at LLNL and using existing facilities and services. Using the direct cost developed in Table 2, LLNL experience would apply the following factors:

o Construction equipment and services	10%
o LLNL project engineering	5%
o Systems checkout and acceptance	5%
o Project management	2.5%

At this stage in the TDF study, an uncertainty in direct cost of ± 20 percent is applied to account for design and scope changes before a commitment to construct. The contingency is estimated to be 20 percent, based on LLNL project experience.

The capital cost is then estimated as:

<u>Cost Item</u>	<u>Cost, \$ x 10⁶</u>	
Direct cost	653	<u>+131</u>
Indirect cost (22.5%)	147	<u>+ 29</u>
Total field cost	<u>800</u>	<u>+160</u>
Contingency (20%)	<u>160</u>	<u>+ 32</u>
Total capital cost	960	<u>+192</u>

Direct Cost Elements

To display the major cost elements, and to provide a basis for scaling the TDF component costs, a further breakdown of the cost accounts is shown in Table 4. The direct costs developed in Table 2 were used for this breakdown, and they include equipment, material, component engineering, and labor.

Table 4

DIRECT COST ELEMENTS
(Mid-1982 \$ x 1000)

<u>Cost Item</u>	<u>Cost</u>	
1. Reactor vessel		23,417
Central cell vessel	210	
Anchor/end cell vessel	13,944	
Central cell shield	6,202	
Anchor/end shield	1,000	
Support structure	2,061	
2. Magnets		50,920
Central cell coils	32,995	
Anchor/transition coils	8,001	
Choke coils	2,265	
Anchor vacuum vessel	7,425	
Central intercoil support	234	
3. Heating		162,372
Central cell NBI	121,758	
Anchor/transition NBI	24,980	
RF	13,750	
Beam dumps	1,884	
4. Fuel system		58,027
Fuel injection	3,367	
Purification and preparation	14,153	
Water cleanup systems	19,868	
Air cleanup systems	11,978	
Other tritium processing	8,661	
5. Maintenance equipment		59,045
Reactor cell	22,637	
Hot cell	24,551	
Special purpose	11,857	
6. Reactor services		49,657
Vacuum system	16,587	
LHe system	11,470	
LN2 system	7,600	
Reactor cooling	6,200	
Facility cooling	1,300	
Heat rejection	6,500	

Table 4 (cont'd)

<u>Cost Item</u>	<u>Cost</u>	
7. Electrical systems		21,089
Magnet power supplies	4,391	
Magnet control systems	1,518	
Pulsed power substation	11,508	
Facility power substation	2,040	
Emergency power	1,632	
8. Instrumentation and control		26,645
Supervisory control/data system	13,055	
Local control instrumentation	10,601	
Personnel safety/interlocks	2,989	
9. Facilities		201,400
Reactor building	40,000	
Hot cell	24,200	
Reactor auxiliary building	17,200	
Power supply building	6,000	
Other buildings	30,000	
Site improvements	14,400	
Cooling system structures	2,600	
Radioactive waste treatment system	3,000	
Miscellaneous plant equipment	8,000	
Bulk materials	56,000	
Total direct cost		652,572

REFERENCES

1. S.C. Schulte, T.L. Willke, and S.R. Young, Fusion Reactor Design Studies - Standard Accounts for Cost Estimates, Battelle-Pacific Northwest Laboratory, PNL-2648, May 1978.
2. Fusion Engineering Design Center, Fusion Engineering Device Design Description, ORNL/TM-7948, December 1981.

Appendix A
STRUCTURAL DESIGN

STRUCTURAL DESIGN CRITERIA

These criteria govern the design of the buildings and structures of the TDF plant. In general, the design requirements comply with all appropriate Federal Regulations, and industry codes and standards. State and local government regulations, codes and standards must be added to these criteria after a site is selected.

The criteria specified herein are based largely on criteria established for the breeder Large Developmental Plant study. It is implicitly assumed that most of the structural design criteria applicable to breeder and light water reactor plants are also applicable to fusion plants.

Codes, Standards, and Regulations

Unless specifically stated otherwise, the design of all buildings and structures is tentatively based on applicable portions of the following codes, specifications, industry standards, regulations, and other reference documents. Where conflict occurs between criteria, the more restrictive will apply. Where no date is shown, the latest issue will apply:

Governing Codes, Specifications, and Industry Standards

- o International Conference of Building Officials,
"Uniform Building Code" (UBC).
- o American Institute of Steel Construction (AISC).
"Specification for the Design, Fabrication, and
Erection of Structural Steel for Buildings," 8th
Edition 1978.
- o American Welding Society (AWS)
 - "Structural Welding Code" - AWS D1.1
 - "Reinforcing Steel Welding Code" - AWS D12.1

- o American Concrete Institute (ACI)
 - "Building Code Requirements for Reinforced Concrete" - ACI 318 - 77 and Commentary
 - "Code Requirements for Nuclear Safety Related Concrete Structures" - ACI 349 - 76
- o "Building Code Requirements for Minimum Design Loads in Buildings and other Structures" - American National Standards Institute (ANSI) - ANSI A58.1
- o American Society for Testing and Materials (ASTM). Applicable Standards of ASTM specifications are referred to in Section A.7, Construction Materials.

United States Nuclear Regulatory Commission (USNRC) Regulations and Standard Review Plans

- o Code of Federal Regulations (CFR), Title 10 - Atomic Energy, Part 50, "Licensing of Production and Utilization Facilities," (10 CFR 50), including applicable Appendices A through M.
- o Code of Federal Regulations (CFR), Title 10 - Atomic Energy, Part 100, "Reactor Site Criteria," (10 CFR 100), including Appendix A thereto, "Seismic and Geologic Criteria for Nuclear Power Plants," adopted November 27, 1973.
- o USNRC - Regulatory Guides as follows:
 - 1.59 Design basis floods for nuclear plants
 - 1.60 Design response spectra for seismic design of nuclear power plants
 - 1.61 Damping values for seismic design of nuclear power plants
 - 1.76 Design basis tornados for nuclear power plants
 - 1.92 Combination of modes and spatial components in seismic response analysis
- o USNRC - Standard Review Plans
 - 3.8.4 Other seismic Category I structures

Site Characteristics

A hypothetical site for the TDF was selected for the purposes of this study. This hypothetical site is generally compatible with installation at an established government nuclear reservation, such as the Idaho National Engineering Laboratory (INEL). This hypothetical site is also compatible with a significant number of potential U.S. sites. General information about the site is given below:

Geology and Seismology

Maximum MIE* ground acceleration	0.25g
Maximum MPE+ ground acceleration	0.13g
Ground response spectra	Use Regulatory Guide 1.60 assumptions
UBC seismic	Zone 2

Foundation material

Net allowable bearing capacity	
Static	500 kPa
Dynamic	700 kPa
Damping	Use Regulatory Guide 1.61 assumptions
"S" Wave velocity	1200 m/s
Depth to bedrock	At surface
Location of the nearest surface capable of faulting	The site is located more than 8 km from a surface that is capable of faulting greater than 300 m in length.
Snow and ice load	1 kPa

*MIE - Maximum intensity earthquake

+MPE - Most probable earthquake

Wind load and height for safety-related structures

Velocity 145 km/h
At a height above ground 9 m

Tornado loading

Region Use Regulatory Guide
1.76, Region III, Design
Basis Tornado

Characteristics:

Maximum wind speed 386 km/h
Rotational speed 306 km/h
Maximum translational speed 80 km/h
Minimum translational speed 8 km/h
Radius of maximum rotational speed 46 m
Pressure drop 10 kPa
Rate of pressure drop 4.1 kPa per second

Tornado missile characteristics

<u>Missile</u>	<u>Mass (kg)</u>	<u>Dimensions (m)</u>	<u>Horizontal impact velocity (m/sec)</u>
A. Wood plank	52	0.092 x 0.289 x 3.66	58
B. 152 mm pipe (6-in. schedule 40)	130	0.168d x 4.58	10
C. 25 mm steel rod	4	0.0245d x 0.915	8
D. Utility pole	510	0.343d x 4.58	26
E. 305 mm pipe (12 in. schedule 40)	340	0.32 x 4.58	7
F. Automobile	1,810	5 x 2 x 1.3	41

Vertical velocities of 70% of the postulated horizontal velocities are acceptable on an interim basis, except for the small missiles, or missile

C in Spectrum 1, used to test barrier openings, which should be assumed at the same speed in all directions.

The impact velocities of the tornado-generated missiles are selected for tornado intensity Region III, consistent with the design basis tornado criteria. Tornado intensity regions are defined in Regulatory Guide 1.76.

Seismic Design Classification of Structures

The plant structures, systems, and components are classified into three categories from the standpoint of their importance to safety.

Seismic Category I Structures. Seismic Category I structures, systems and components are those necessary to ensure the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of DOE. These structures shall be designed to remain functional in the event of an MIE. Furthermore, stresses in Seismic Category I structures shall be well within the elastic limits under the effects of an MPE.

The following are Seismic Category I structures:

- o Reactor building
- o Hot cell, radwaste, and reactor auxiliary building
- o Tritium, heat transport and HVAC building
- o Power supply, cryogenics, and diesel generator building
- o Control building
- o Control tunnel

Non-Seismic Category I Safety Related Structures. Non-Seismic Category I structures are those whose failure could affect the integrity of adjacent safety related systems, structures, and equipment. The vent stack is a Non-Seismic Category I safety related structure.

Non-Seismic Category I Non-Safety Related Structures. These are structures whose failure could not affect the integrity of safety related systems, structures, and equipment.

All plant structures not listed in the previous two categories are classed as Non-Seismic Category I Non-Safety related structures. This includes but is not limited to the following:

- o Administration building
- o Plant services building
- o Cooling tower
- o Demineralized water storage tank
- o Air compressor station
- o Water treatment plant
- o Pump house
- o Raw water storage tank
- o Fire water storage tank
- o Off-site raw water supply line
- o Off-site power supply
- o Guard house

Plant Internal Loads

Dead Loads. The dead loads include the weight of all permanent structural elements and the weight of all permanently attached equipment, piping, etc.

Live loads. The live loads include floor area loads (occupancy and laydown) and loads from movable equipment or structures.

Design Basis Accident Internal Pressure Load. The reactor building design basis accident internal pressure load is approximately 120 kPa. The positive accident pressure is caused by a cryogen release and helium pressurization accident.

Accident Thermal Loads. Accident temperatures are unspecified at this time.

Loads Not Included. For simplicity, the following loads have not been included in the preconceptual structural design criteria:

- o Missiles (other than tornado)
- o Normal and accident pipe loads
- o Dynamic earth pressures
- o Compartment pressurization

Design Bases

The following sections establish factors of safety, codes, and loading combinations to be used for all structures:

Factors of Safety. A minimum factor of safety shall be provided for all structures as shown below.

Minimum Factors of Safety

<u>Loading Conditions</u>	<u>Overturning</u>	<u>Sliding</u>	<u>Flotation</u>
a) MPE	1.5	1.5	-
b) Wind	1.5	1.5	-
c) MIE	1.1	1.1	-
d) Tornado	1.1	1.1	-
e) Probable Maximum Flood	-	-	1.1
f) UBC Earthquake	1.5	1.5	-

Loading combinations (a), (c), and (d) do not apply to Non-Category I Non-Safety related structures. Load combination (a) does not apply to Non-Category I safety related structures.

Seismic Category I Structures. Seismic Category I concrete structures are designed in accordance with ACI-349 supplemented by ACI 318. Seismic

Category I steel structures will be designed in accordance with the AISC Code. The applicable loading combinations will be as specified in the NRC Standard Review Plan 3.8.4.

Non-Seismic Category I Safety Related Structures. Non-Seismic Category I Safety Related reinforced concrete structures are designed in accordance with ACI-318 for concrete structures. These structures will be designed in accordance with the loading combinations in Chapter 9 of ACI-318.

Non-Seismic Category I Safety Related steel structures are designed in accordance with the AISC code. Wind and seismic loadings are in accordance with ANSI A-58.1 and the UBC respectively.

In addition to the above loading combinations, Non-Seismic Category I Safety Related structures are checked and strengthened as required to assure that they do not impose loads on a Category I structure or system during the design basis tornado or MIE event. For concrete structures under these conditions, the load factor for all loads shall be 1.0. The allowable stresses for steel structures shall be increased by 60 percent and the plastic section modulus of steel shapes shall be used. Only the main structural members are considered for these load combinations. These structures are allowed to be damaged during these events; for example, the structures can be permanently deformed as a result of these extreme loadings.

Non-Seismic Category I Non-Safety Related Structures. Non-Seismic Category I Non-Safety Related Structures will be designed in accordance with ACI-318 for concrete structures. Steel structures shall be designed in accordance with the AISC code. Wind and seismic loadings shall be in accordance with ANSI A-58.1 and the UBC, respectively.

Construction Materials

The principal construction materials for Seismic Category I and Non-Seismic Category I structures are concrete, reinforcing steel, structural steel, masonry, and metal decking and are noted below:

- o Concrete design compressive strengths are:

<u>Item</u>	<u>fc'</u>
All plant structures	27 MPa
Lean concrete backfill and electrical duct encasement	17 MPa

Note: Compressive strength (fc') refers to compressive strength at 28 days if only cement is used and to compressive strength at 90 days when pozzolan replaces part of the cement.

- o Reinforcing steel shall be deformed billet steel, conforming to ASTM Designation A-615 grade 60
- o Welded steel wire fabric shall conform to ASTM A-185 (plain wire) or A-497 (deformed wire)
- o All structural steel shall be ASTM A-36
- o Fasteners shall conform to ASTM A-307. High-strength bolts shall conform to ASTM A-325 or A-490
- o Anchor bolts shall conform to ASTM A-307, A-36 or A-449
- o Unless otherwise required by special conditions such as the control room penetration areas, metal decking shall be used for forming concrete slabs

STRUCTURAL DESIGN DESCRIPTION

A preconceptual structural design is presented here on the most important TDF buildings and structures. A very limited structural analysis is performed in a few key areas of the TDF structures. This analysis is performed in accordance with the structural criteria discussed above. Possible alternate designs for some key areas and recommended future studies are also discussed.

Reactor Building Complex

This complex consists of the reactor building (including heat exchanger and radwaste areas) hot cell building and tritium building. These buildings have been combined into one large complex sharing a common

basemat. For the most part, these buildings are massive reinforced concrete structures which use structural steel members only to support concrete weight during forming and thereby eliminate expensive and time consuming shoring and form removal operations. The most significant exceptions to this are the roofs of the reactor and hot cell buildings which use steel trusses to carry both dead weight and seismic loads. Concrete roof and floor slabs are designed to act as diaphragms to transfer lateral loads to the concrete walls which are designed as shear resisting elements. The foundation mat is designed as a slab on an elastic foundation. The thickness of walls and slabs surrounding radioactive areas is generally governed by shielding requirements.

The most significant structural feature of the reactor building complex are the 2m thick walls, floors, and roofs required for shielding in the reactor building and hot cell. This, combined with the large distances over which these structural elements must span, constitute a very significant cost factor. The large thickness required for shielding increases structural mass which results in high gravity and seismic loads.

Two areas of high sensitivity to these loads are the roofs of the reactor building and hot cell which have large clear spans. The design selected is a deep steel truss system with rolled beams acting as purlins to support a steel deck. This design is selected because of its relative ease of construction: First, the trusses are placed on the walls and then the secondary framing and steel decking is erected on the trusses. Next, the reinforced concrete roof slab is placed.

The steel truss concept is selected over the following two alternate methods:

- o Barrel Vault (Arch shaped roof) - Since the large concrete thickness is required for shielding, not strength, its thickness must be held constant and so the usual economy of a barrel vault cannot be utilized. Also, due to curvature of the vault, more concrete is required, compared to the flat roof system. Moreover, the barrel vault requires a steel truss for form support.

- o Post-tensioned T-beams with a reinforced concrete slab placed on top. The main disadvantage of this concept is the large crane capacity and time required to lift the heavy T-beams into position. This lifting problem is most critical on the high reactor building as opposed to the hot cell roof. Even with this disadvantage, the post-tensioned T-beam concept is the more attractive of the two alternate concepts considered due to its low fabrication cost. A future cost comparison study (T-beam versus steel truss) is recommended.

Another area of high sensitivity to the high building weight caused by the large shielding thickness is the limited span that can be tolerated by the basemat due to the soil pressure. This requires that the basemat be stiffened by walls (and the first floor, where possible) to keep basemat thickness and reinforcement at reasonable levels. Future studies should investigate the tradeoff between incorporating such walls into the building layout vs. eliminating some of them and providing more basemat thickness and reinforcement.

Another area of high sensitivity to the required shielding thickness is the induced seismic load on the walls of the reactor building, particularly the east wall. Most of these heavy walls span large distances without stiffening from adjacent floors or walls. This configuration appears feasible, but the reinforcement levels required for seismic will be very high in the east wall. Future studies should consider alternative designs that stiffen this wall with pilasters.

Tritium, Heat Transport, and HVAC Building Complex

The tritium, heat transport, and HVAC building does not have the high shielding requirements required by the reactor and hot cell buildings. However, since this building forms one corner of the reactor building complex, its structure is heavier than what would be required if it were allowed to stand alone. It is recommended, therefore, that future studies investigate the feasibility of extending the length of the hot cell to equal the length of the reactor building. This would allow the expensive, long, clear, east-west span of the hot cell building roof to

be reduced. The tritium heat transport and HVAC building could then be a separate structure or placed over the extended hot cell building adjacent to the reactor.

Another recommendation for future study would be to lower the extended hot cell building such that the hot cell basemat is at the same elevation as the reactor building basemat. This would put the entire basemat at one elevation and place the floor of the local control and viewing corridor approximately at grade.

Power Supply, Cryogenics, and Diesel Generator Building (Power Supply Complex)

This is a Category I structure that is a completely separate structure from the reactor building complex. The power supply complex has no radiation shielding requirements, and tornado shielding will require much thinner walls than the adjacent reactor building complex (2 m walls). If the two structures were joined into one large structure, the power supply complex would have required significant strengthening to take the large soil pressure reaction that would be induced in the power supply complex basemat. As a separate building it can be an economical light steel structure with relatively thin reinforced concrete floors and walls and a reduced basemat thickness. The piping and electrical connections between the two complexes, however, must be able to withstand relative seismic and differential settlement displacements.

Reactor Support

The reactor has three support regions:

- o North end cell support
- o Anchor cells and center cell support
- o South end cell support

The north and south end cell supports are attached directly to the operating floor (El. 100 m) of the reactor building which has been reinforced with walls directly below the supports. Horizontal loads are taken by the operating floor acting as a diaphragm. The center cell support is attached directly to the basemat as shown.

For the purposes of this study, it has been assumed that the south end cell provides north-south, east-west, and vertical restraint. The north end cell support provides only east-west and vertical restraint and the center cell support provides only vertical restraint. This arrangement allows machine thermal movement.

The center cell support is the most critical from a structural viewpoint, since it is required to be small in plan to permit maintenance of the neutral beam injectors and yet it must be 13 meters high. This design concept relies on the structural strength of the reactor so that the center cell and anchor cells transmit their east-west seismic loads to the north and south end cells. Note that since the south end cell support is assumed fixed, the center and anchor cells must also transmit the north-south seismic load of the north end cell to the south end cell support. It is not known at this time if this is feasible. If the center cell support also requires east-west restraint, then the single cantilevered column support will most likely not be acceptable since it probably lacks the necessary horizontal stiffness compared to the stiffness of the center cell and anchor cell structures. In this case, future studies should investigate the following two alternate concepts:

- o A concrete column with a horizontal reinforced concrete, east-west, strut to the west wall at the 100 meter elevation and an optional similar strut in the north-south direction to the floor at elevation 100 m. This will horizontally stiffen the center anchor support significantly.
- o The same structural configuration described above except that the column and strut(s) are each made of four wide-flange steel members laced together to form box sections.

Appendix B

TDF PLOT PLAN AND PLANT ARRANGEMENT DRAWINGS

The drawings for the plant arrangement are as follows:

<u>Drawing No.</u>	<u>Title</u>
SK-C-1000	Plot Plan General Arrangement Reactor and Support Buildings
SK-P-1001	Plan Below El. 130.0 m
SK-P-1002	Plan Below El. 113.0 m
SK-P-1003	Plan Below El. 106.0 m
SK-P-1004	Plan Below El. 98.0 m
SK-P-1011	Section A-A
SK-P-1012	Section B-B
SK-P-1013	Section C-C
SK-P-1014	Section D-D

SCALE: 1:1000

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24.5

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C

STAIR
WELL

ROOF OVER "STAIR WING" (PENDING)
ELL 110 CM

AU
MA

STAIR
WELL

ROOF OVER

ST
WELL

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REQUIRED FOR FINAL REPORT					DATE <u>11/11/81</u> BY <u>WJ</u>				
IN	NO	DATE	BY	NO	DATE	BY	NO	DATE	BY
NO	200								
BECHTEL GROUP, INC. SAN FRANCISCO									
MIRACOR FUSION		TIDF GENERAL ARRANGEMENT REACTOR & SUPPORT BLDGS PLAN BELOW EL 330.0M
JOB NO.		DRAWING NO.		REV.			
		15340		SK-P-1001		0

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DATE	10/1/80	PROJECT	10/1/80	PAGE	1	OF	1		
BECHTEL GROUP, INC. SAN FRANCISCO									
REACTOR FUSION TID#									
GENERAL ARRANGEMENT REACTOR & SUPPORT BLOCS PLANT/MWEL 1050M
REV NO.	DESCRIPTION					REV		
	15340	SK-P-1003					0		

Graphic scale bar showing distances in miles and kilometers. The bar is marked from 0 to 100 miles and 0 to 160 kilometers.

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(3)

SECTION

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SECTION A-A

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SEE DRG SK-P-1062

SEE DRG SK-P-1011

SEE DRG SK-P-1011

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ISSUED FOR FINAL REPORT					
BECHTEL GROUP, INC. SAN FRANCISCO					
MIRROR FUSION		TDR GENERAL ARRANGEMENT REACTOR & SUPPORT BLOCS SECTION A-A			
	15340	SK-P-1011	101	0	

READING RAILS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

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SECTION

SECTION D-D

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SAN FRANCISCO		DATE	BY
MIRROR FUSION		DATE	BY
GENERAL ARRANGEMENT		DATE	BY
REACTOR & SUPPORT BLDGS		DATE	BY
SECTION D-D		DATE	BY
JOB NO.	DRAWING NO.	REV.	
15340	SK-P-1014	0