CONF-8706184--1-Vugraphs

FUSION ENGINEERING DESIGN CENTER

FUELING SYSTEMS*

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TIBER II REVIEW MEETING

FUSION ENGINEERING DESIGN CENTER

OAK RIDGE, TENNESSEE

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AT ORNL/FEDC

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FUELING SYSTEMS

TIBER II FUELING SYSTEM STATUS:

FUELING SYSTEM DESIGN IS BASED ON PHYSICS DATA 2PH, 3PH AND 4PH.

REQUIREMENTS WERE ESTABLISHED THAT SATISFY THE PHYSICS DATA OF ALL THREE SCENARIOS.

DESCRIPTION OF THE FUELING SYSTEM FOR THE STARTUP, INTERMEDIATE, AND POWER RANGE OPERATIONS HAS BEEN COMPLETED.

OUTLINE OF THE RESEARCH AND DEVELOPMENT NEEDS WERE ESTABLISHED FOR THE POWER RANGE SYSTEM. DEVELOPMENT WORK NOW BEING FUNDED SHOULD MEET THE R & D NEEDS OF THE STARTUP AND INTERMEDIATE RANGE OPERATIONS.

DRAFT OF THE DOCUM ENTATION IS COMPLETED.

RESET\DWELL TIME OPERATION FOR THE 4PH SCENARIO WAS NOT ADDRESSED BECAUSE NO PHYSICS DATA ARE AVAILABLE AT THIS TIME. THE INTERMEDIATE RANGE AND POWER RANGE SYSTEM SHOULD ADEQUATELY PROVIDE FOR THIS OPERATION ALSO.

Table 3.1.9-1 Basis for the fuel injection system requirements

Parameter, Units	Options-- 2ph	3ph	4ph
Average fusion power, mw	314	314	265
Burn time, s	infinite	229	1331
Reset time, s	N.A.	20	133
Plasma volume, cu. m	96	96	96
Particle confinement time, s	5.89	11.35	8.59
Electron density, E20 / cu. m	1.06	1.78	1.28
Electron temperature, kev	19.20	10.72	15.89
Ion density, E19 / cu. m	7.96	15.62	11.22
Ion temperature, kev	19.58	10.00	13.00
Plasma radius, m	3.00	3.00	3.00
Plasma elongation	2.40	2.40	2.40
DT mass in the torus, mg	31.74	62.29	44.74
Max mass of a DT fuel pellet, mg (10 % of DT mass in the torus)	3.17	6.23	4.47
Diameter of a DT pellet, mm (Cylinder with d = h).pa	2.53	3.17	2.83
Fueling rate based upon confinement time and mass in torus, mg/s	5.39	5.49	5.21

Table 3.1.9-2 Startup fueling requirements data

Number of fuel gas injection valves	6
Location of fuel gas injection valves	Topside
Composition of the fuel gases:	
% hydrogen	0.1 - 99.9
% deuterium	0.1 - 99.9
% tritium	?
% diagnostic impurity gases	?
Max fuel gas injection rate:	
Deuterium, torr-l/s	150
Tritium, torr-l/s	?
Time duration of gas injection per cycle, s	20?
Percent availability per injector,%	95?
Number of cycles before replacement, E4	50?

Table 3.1.9-3 Other startup range fueling requirements

1. Six gas injection valves will be located by pairs at three nearly equally distributed locations around the torus.

2. Each injector control valve will have two ranges: 0.5 to 5 and 0.5 to 50 torr-l/s.

3. Vacuum isolation during maintenance or replacement of the fuel control valves is not necessary.

4. Fast control valves are neccessary if automatic plasma density control is required.

5. Minimum fuel gas transport time between the control valves and the plasma is also neccessary to enhance the use of automatic plasma density control.

6. Fuel control valves must be accessible for remote maintenance and replacement.

7. The gas supply system must have distribution valves that provide for selecting the composition of the injected gas which may be hydrogen, deuterium, tritium, or diagnostic impurity gases such as helium.

8. Depending on their location, radiation hardened control valves and isolation valves will probably be required.

9. Fuel control valves must operate satisfactorily in high steady state and pulsed magnetic fields.

10. Fuel gas control valves should be located in vertical ports so the more horizontal space is available for blanket modules and diagnostics.

Table 3.1.9-4 Intermediate range fueling requirements data (Pre-ignition)

Number of 1 to 2 km/s DT ice pellet injectors	2
Pellet composition range:	
% hydrogen	0.1 - 99
% deuterium	0.1 - 99
% tritium	0.1 - 99
% diagnostic impurity?	0.1 - 1
Pellet mass, mg	2.7
Steady state injection rate, p/s	2
Max injection rate, p/s	5
Max rate of change, p/s2	5
Max injection velocity, km/s	1.5
Cycle injection period, seconds	
3PH operation	230
4PH operation	1330
2PH operation	continuous
Permissible inventory, g	20?
Percent availability	98?
Number of pellet shots before injector replacement, E7 (1500 hrs @ 2/s)	>1.08?

Table 3.1.9-5 Other intermediate range fueling requirements

1. The fuel composition, consisting of mixtures of frozen hydrogen, deuterium, and tritium must be controllable over a wide range.

2. Pellet size will probably have to be controlled between 2 and 4 mm to cover all phases of engineering operations and experiments.

3. Pellet velocity will probably need to be controlled between 0.5 and 1.5 m/s to accomodation operations between startup and ignition.

4. The number of pellets per plasma pulse will vary widely to accomodate plasma disruptions and provide for continuous operation.

5. Pellet injection rate will probably have to be controlled between 0 and 5 p/s to accomodate startup, intermediate, and power range operations.

6. Liquid and frozen tritium holdup in the pellet former should be as low as possible to minimize the size of the tritium recovery system for the reactor vault and to diminish the extent of a worst possible accident.

7. Torus vacuum isolation valves will be provided so that a pellet injector can be serviced without breaking the torus vacuum and discontinuing operation.

8. The pellet injection tube must be electrical isolated from the torus to minimize the impact of plasma disruptions.

9. Adequate radiation shielding will be provided to permit hands on servicing of the pellet injectors when necessary.

10. Tritium containment will be provided both during normal operations and during maintenance.

11. The fuel system must be designed to accomodate thermal expansion between fixed location components.

Table 3.1.9-6 Power range fueling requirements data
(Burning plasma)

Minimum no. of high velocity injectors	1
Pellet composition range:	
% hydrogen	< 1
% deuterium	1 - 99
% tritium	1 - 99
Fuel mass to plasma, mg	2.7
Approx. pellet diameter, mm (Cylindrical, d = h, 5 mg)	3
Maximum injection rate, p/s	2
Max rate of change, p/s2	2
Injection velocity, km/s	>40
Cycle injection period, seconds	
3PH operation	230
4PH operation	1330
2PH operation	continuous
Permissible tritium inventory, g	20
Percent availability	98?
Number of pellet shots before equipment replacement, E7 (1500 hrs @ 2/s)	>1.08
Number of laser beam or plasma gun systems.	1
Electrical energy per laser pulse, MJ	1
Electrical energy per plasma gun pulse, MJ	1

Table 3.1.9-7 Other power range fueling requirements

1. The injected fuel mixture of hydrogen, deuterium, and tritium must be controlled over a wide range.
2. The fueling velocity must be controllable up to 50 km/s.
3. Because the power will be changed slowly, the high velocity fueling rate to the plasma need not be greater than 10 mg/s.
4. To minimize damage from plasma disruptions, the fueler must be electrically isolated from the torus.
5. The fuel inventory should be minimized to diminish the impact on the environment during a worst case accident.
6. *Tritium containment must be provided both during normal* operations and during maintenance.
7. The fueler should be designed so that it can accomodate thermal expansion between fixed location components.
8. Adequate radiation shielding will be provided to permit hands on maintenance when necessary.

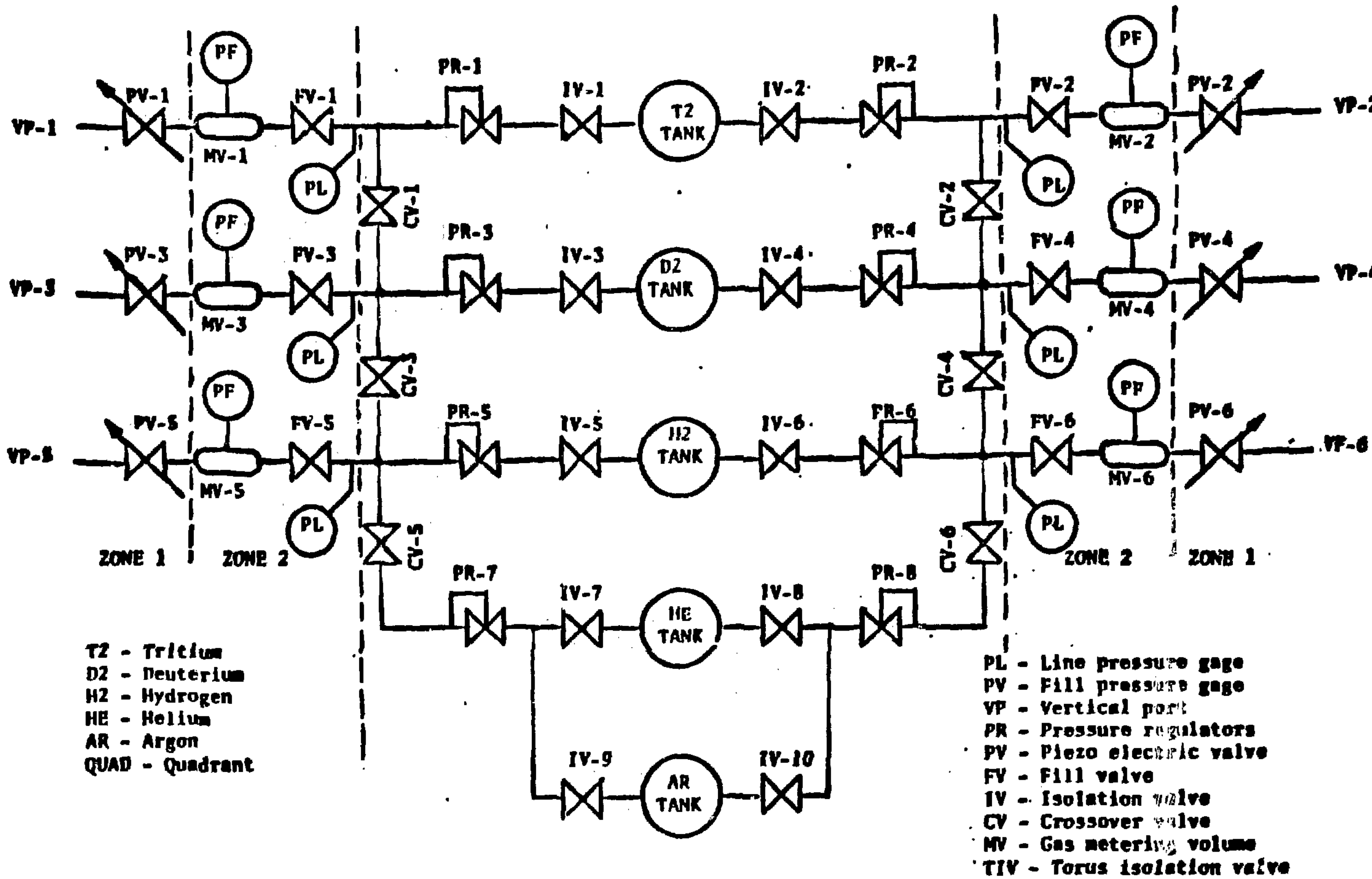


FIGURE 3.1.9-1 ONE LINE DIAGRAM OF A FUEL GAS INJECTION SYSTEM WITH PIEZO-ELECTRIC CONTROL VALVES LOCATED IN VERTICAL PENETRATION PORTS

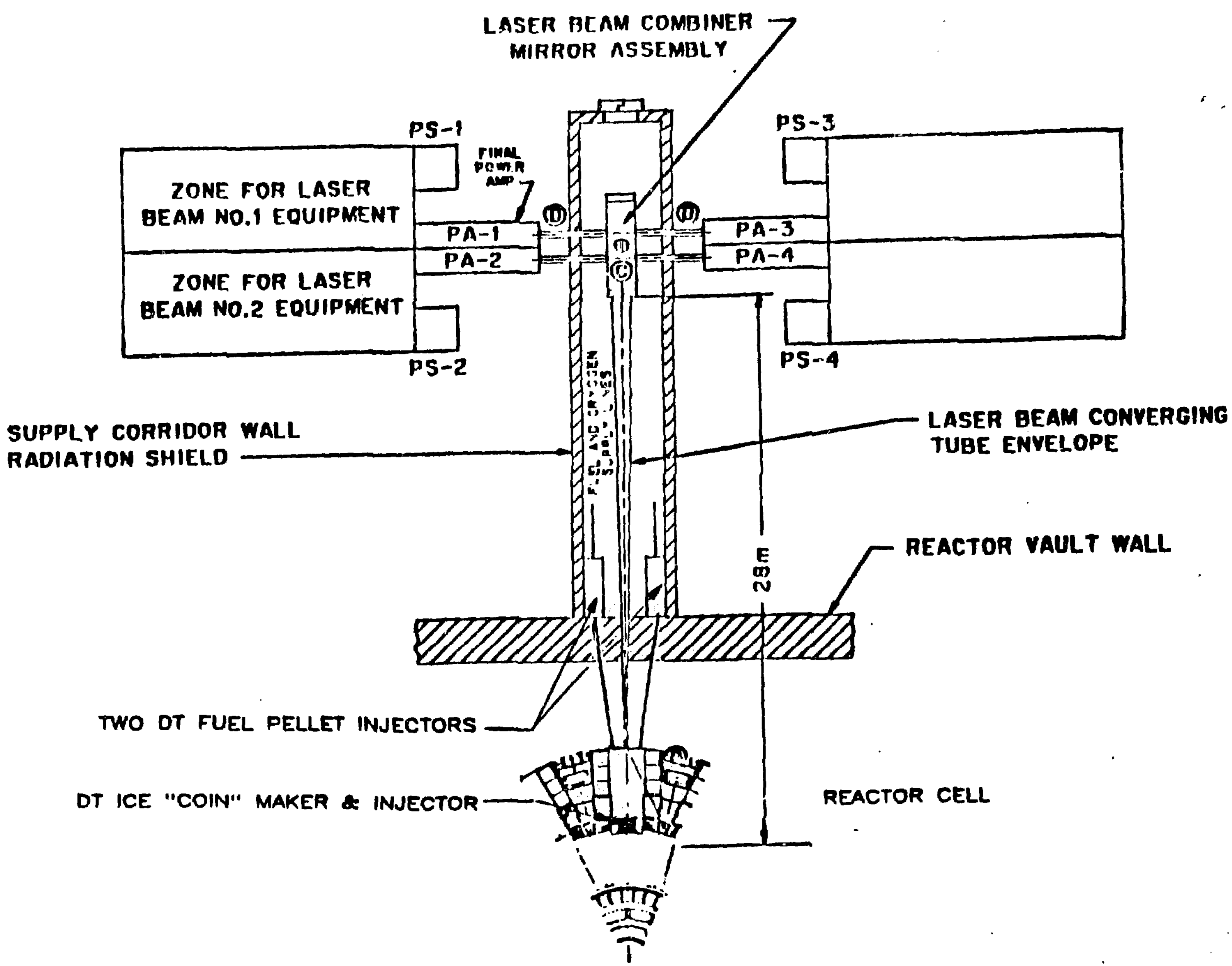


FIGURE 3.1.9-2 OVERALL PLAN VIEW OF A LASER-DRIVEN FUEL PELLET SYSTEM FOR TIBER II

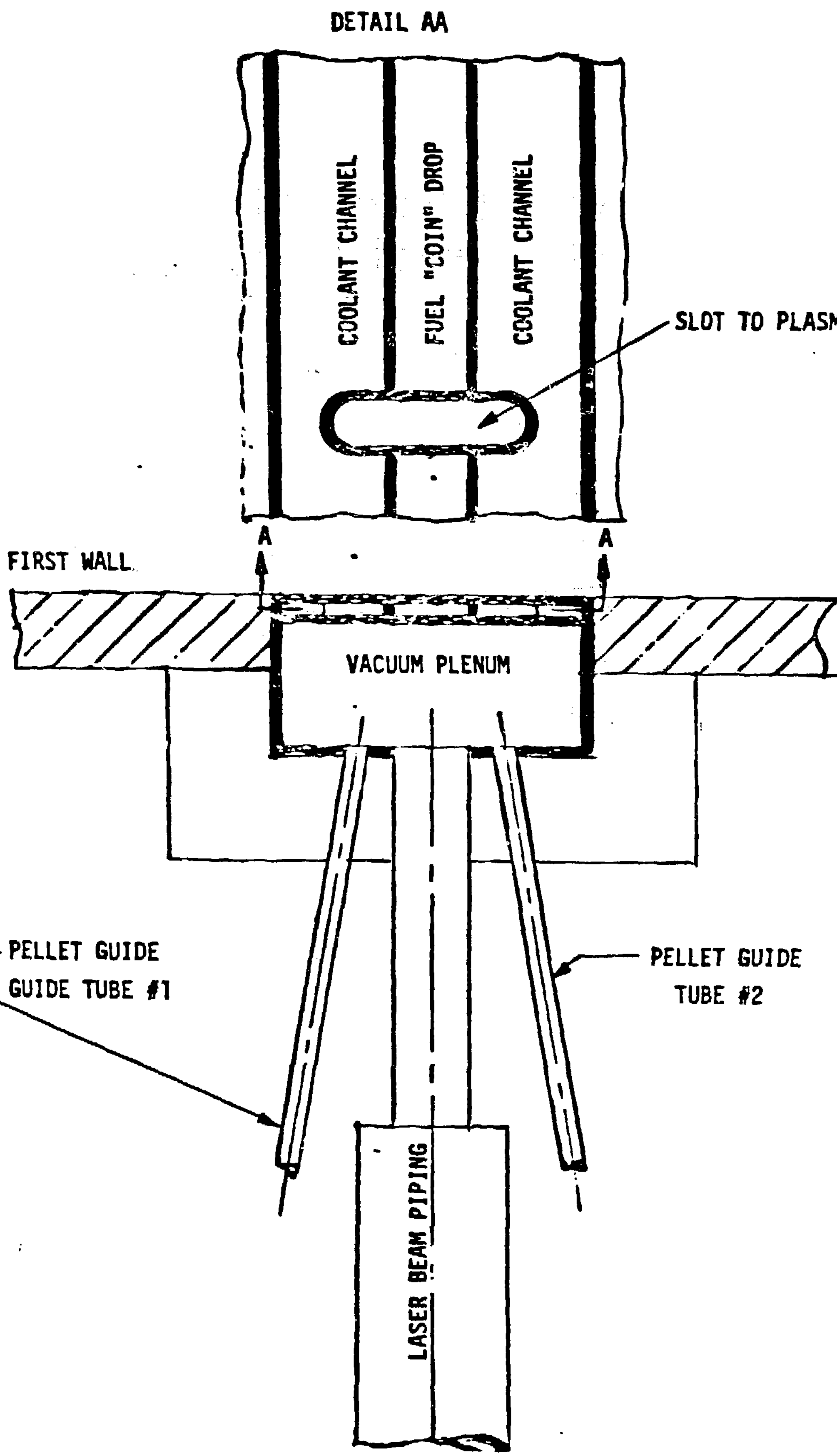
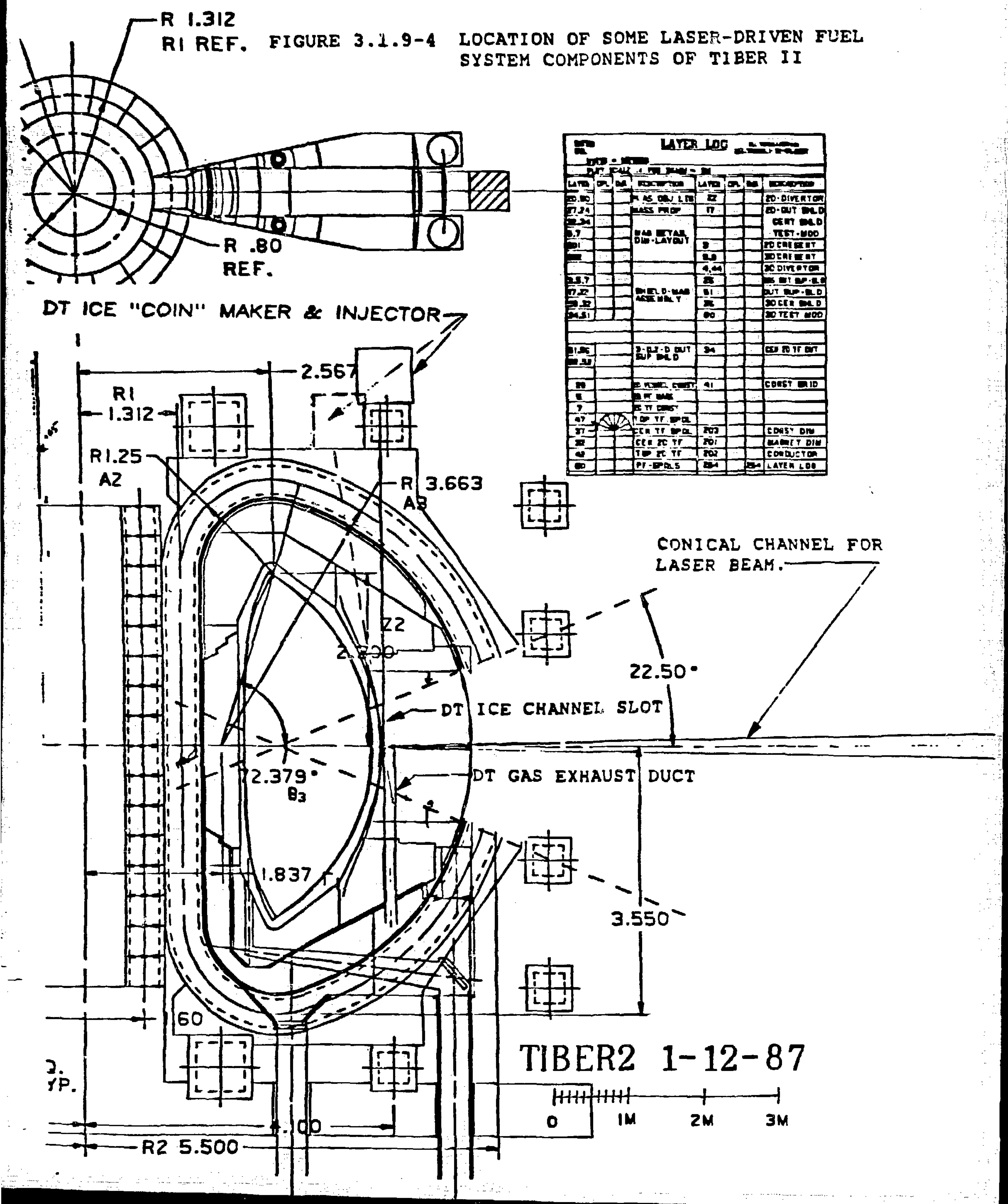


FIGURE 3.1.9-3 DETAIL SKETCH OF THE FULING AND LASER BEAM JUNCTION FOR TIBER II

FIGURE 3.1.9-4 LOCATION OF SOME LASER-DRIVEN FUEL SYSTEM COMPONENTS OF TIBER II



3.1.9.6 Research and Development. Fueling components for the startup and intermediate range operation have been developed for use with hydrogen and deuterium. Funds have also been allocated for developing these components for tritium fueling operation. An electron beam pellet accelerator is also being funded to some extent. This accelerator might be able to increase the velocity of a fuel pellet to 10 km/s. The electron beam accelerator ablates the pellet like the laser beam but on a comparatively slower time scale. If fueling velocities >40 km/s are required in the power range, considerable additional R & D funding will be needed for either the laser beam accelerator or the plasma gun alternate.

Both the laser and the plasma gun alternates require about one megajoule of energy per fueling pulse which may be obtained from a capacitor bank. Some capacitor development work is needed to meet the life time requirements. As an alternate, it may be possible to develop the rotating pulsed generator proposed by the University of Texas and LLNL about 7 years ago. The rotating inertia energy of this magneto-type of device can be converted into one milliisecond electrical pulses which may be suitable for some laser or plasma gun applications.

Some laser driven fueling R & D are needed to establish engineering feasibility in the following areas:

1. Maximum number of laser pulses before the equipment needs repair or maintenance.

2. Tracking of the pellet and synchronizing of the laser firing time.

3. The optimum laser wavelength for maximum overall efficiency of the fueling system.

4. The best fuel pellet or disc geometry and orientation for coupling to the laser beam at the crossover.

5. Radiation hardening of laser equipment to operate in direct line of sight nuclear radiation without the use of beam directing mirrors.

6. Controlling the fueling penetration by controlling the laser beam pulse width or energy.

7. Improvements that will reduce the cost of the equipment needed for fueling applications.

Similarly there is R & D needed to establish the feasibility of the plasma fueling gun alternate:

1. Maximum number for fueling pulses before the equipment needs repair or replacement.
2. Separation of the erosion products from the fueling plasma.
3. Decreasing the size of the fueling penetration through the nuclear radiation shield.
4. Radiation hardening of components exposed to the nuclear radiation emanating from the penetration through the shield.
5. Feasibility of injecting a high velocity fuel plasma across a strong magnetic field.
6. Controlling the fuel penetration into the torus plasma by controlling the velocity of the fueling plasma.
7. Improvements that will decrease the cost of the equipment needed for fueling applications.