

POWER UPGRADING OF THE TEHRAN RESEARCH REACTOR

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Facts In Brief:

- Most pool type research reactors with nominal power in the range of ~MW are potentially upgradeable to higher powers
- TRR is a 5 MW pool type research reactor & from long ago considered for upgrading
- The underlying factor is to enhance heat removal system (increasing water flow)
- Various options are considered & compared for optimum solution
- Easiest, & most suitable way is chosen regarding;

Cost

Operability

Safety

Ease of execution

Minimum down time period

...

- The best choice for the present TRR considering minimal modifications is:

Orifice plate removal + fully opening butterfly valve —————> 8 MW

OR

plate in place + fully opening butterfly valve —————> 7.5 MW

- The last option is checked & exercised in a temporary manner (up to 20 minutes) & to be advised for steady state operation in future. Minimum changes in pump room are required to be done in order steady state operation is feasible

<u>Reactor type</u>	Pool type	Void fraction (%)	10
<u>Steady state power (MW)</u>	5	Enrichment (%)	20
<u>Core</u>		Fuel element dimensions (mm)	80.1x76.9x750
Number of standard fuel elements in EQ. Core	22	Lattice pitch (mm)	81.0x77.1
Number and shape of control rods	5, fork type	<u>Reactor pool</u>	
Number of active plates per fuel elements:		Pool surface area (m ²)	57.24
Standard fuel elements	19	Pool depth over core (m)	7.4
Control fuel elements	14	Volume (m ³)	477.8
Water channel thickness (mm)	2.7	Primary pump mass flow rate (m ³ /h)	500
Loading of U ₂₃₅ (gm):		Maximum design pool temperature (°C)	38
Standard fuel elements	290.7	<u>Hold up tank</u>	
Control fuel elements	214.2	Height (m)	4.54
Fuel meat density (gm/cm ³)	4.760	Wet X-sectional area at bottom (m ²)	89.24
Fuel meat weight percent (%):		<u>Containment</u>	
U ₂₃₅	12.44	Inside diameter (m)	30
U ₂₃₈	49.78	Building height (m)	13.7
O	11.17		
Al	26.5		

Table 1. TRR General specifications

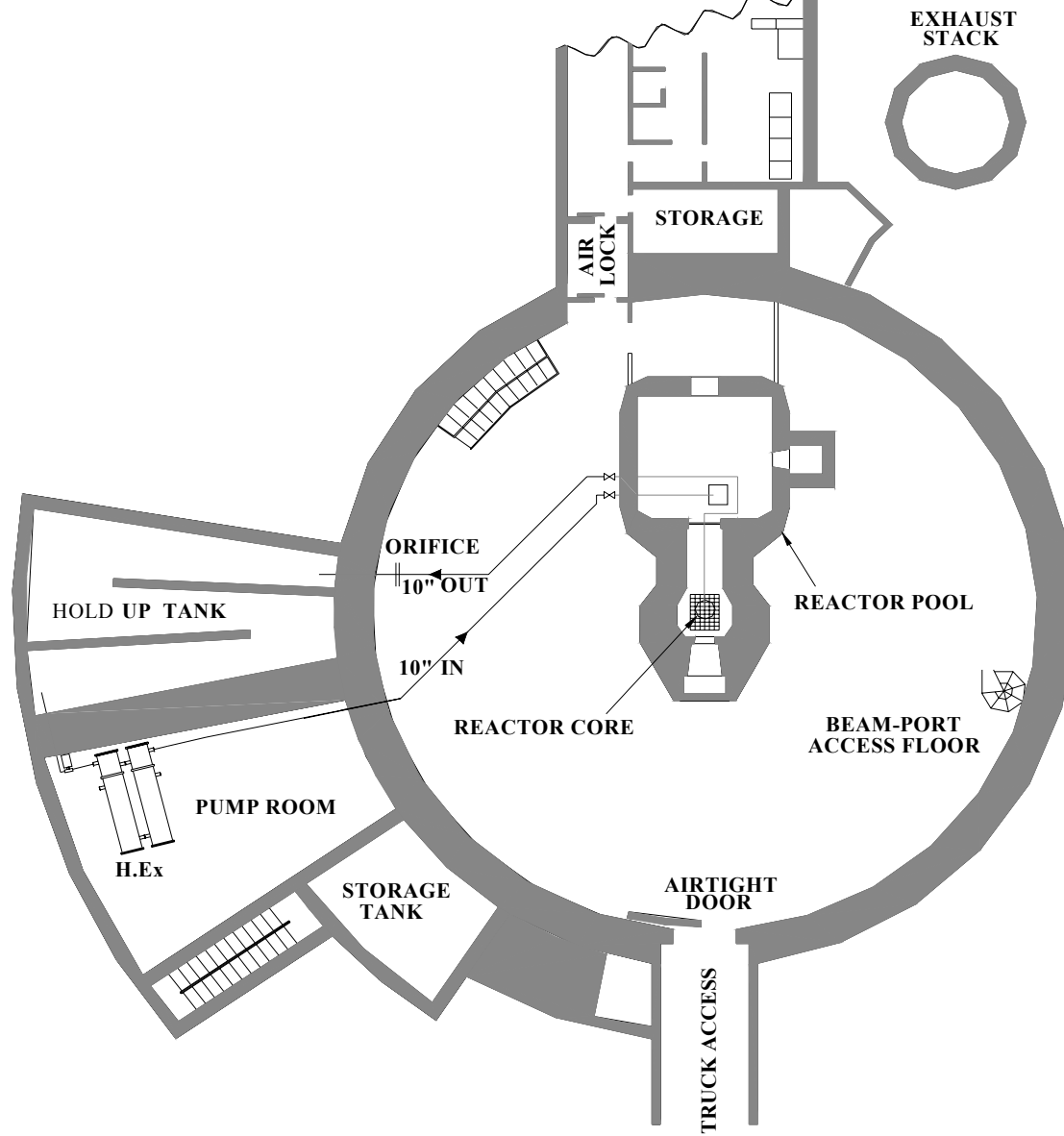
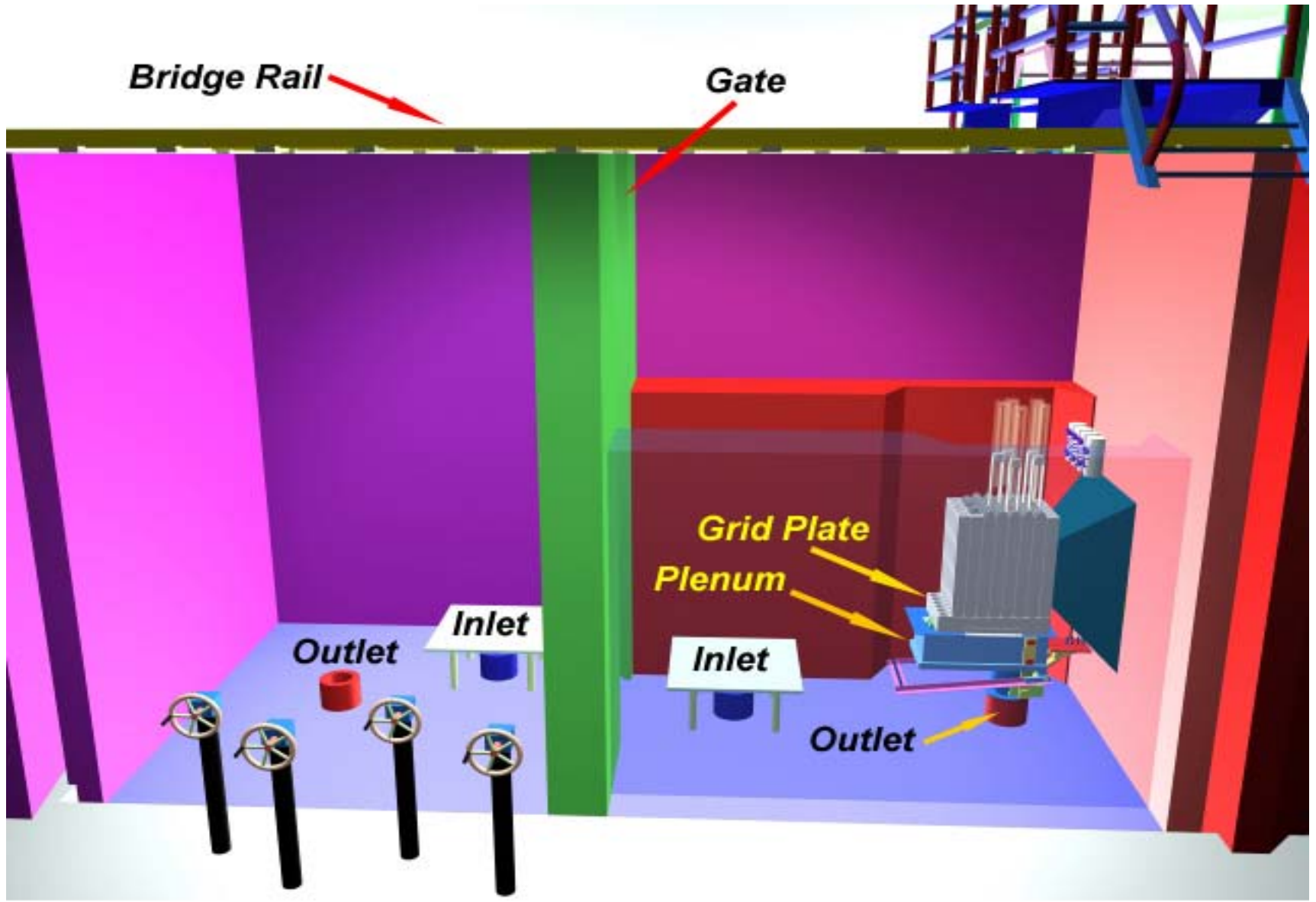
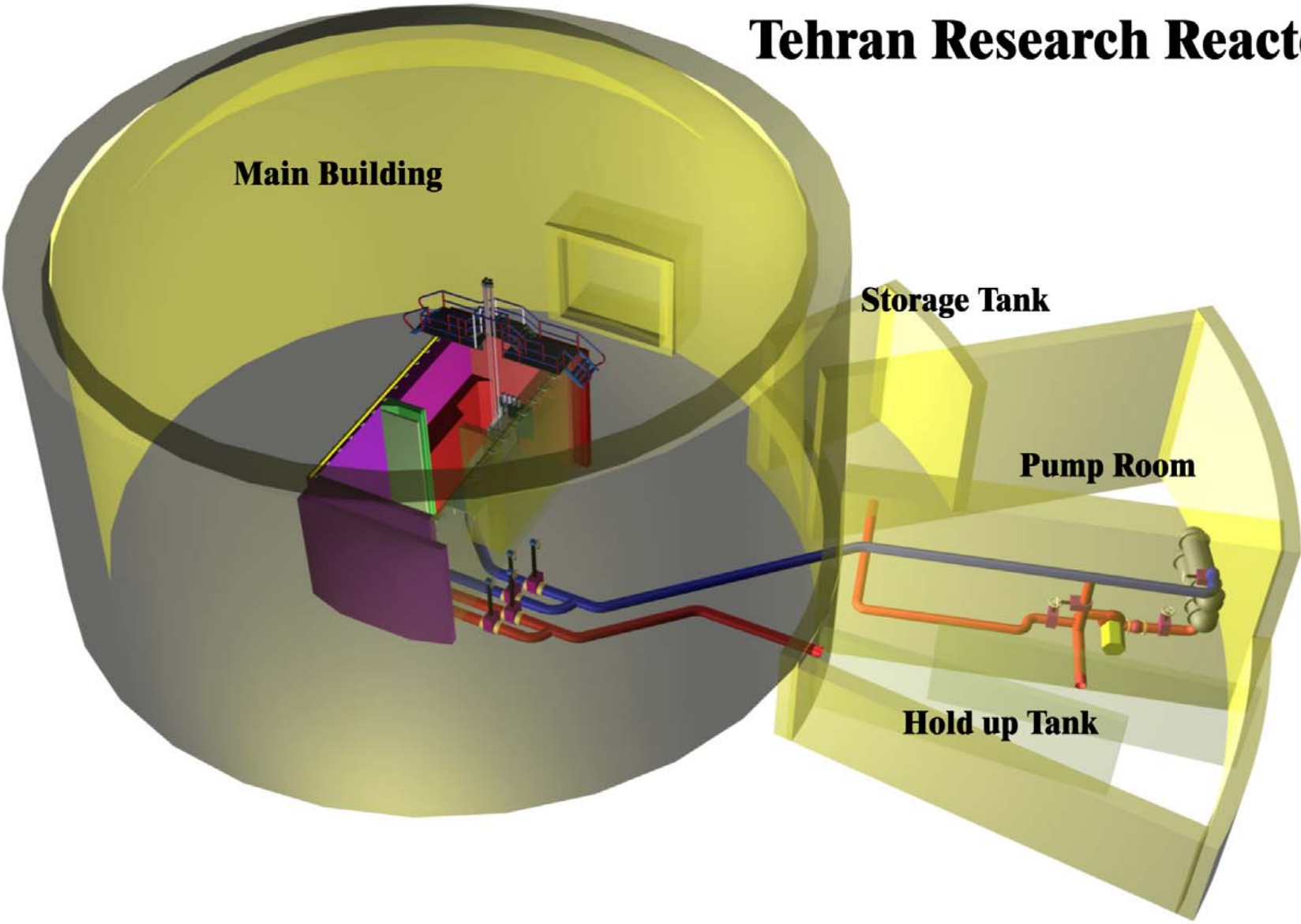


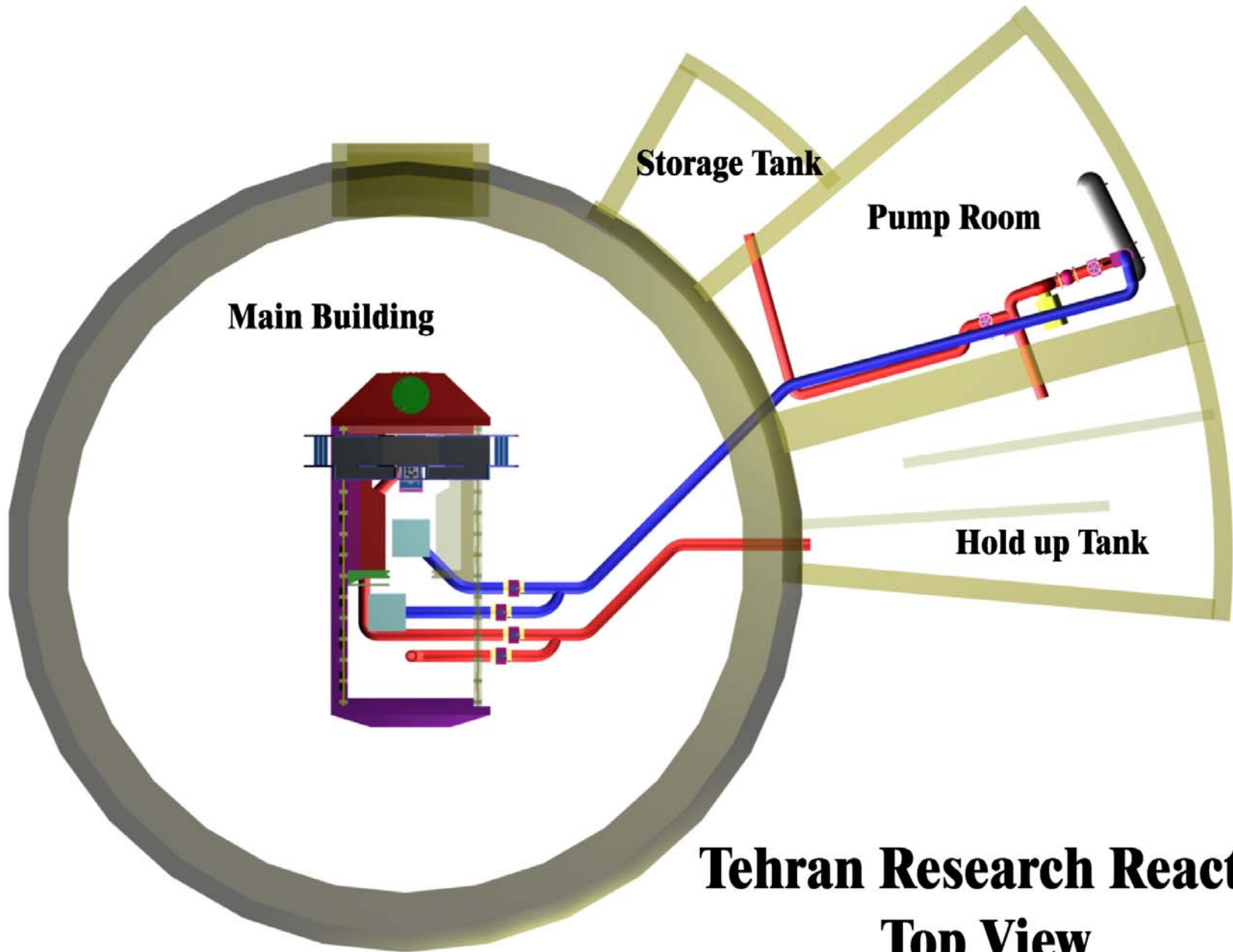
Fig. 1. Reactor Containment and peripherals with emphasis on primary cooling circuit



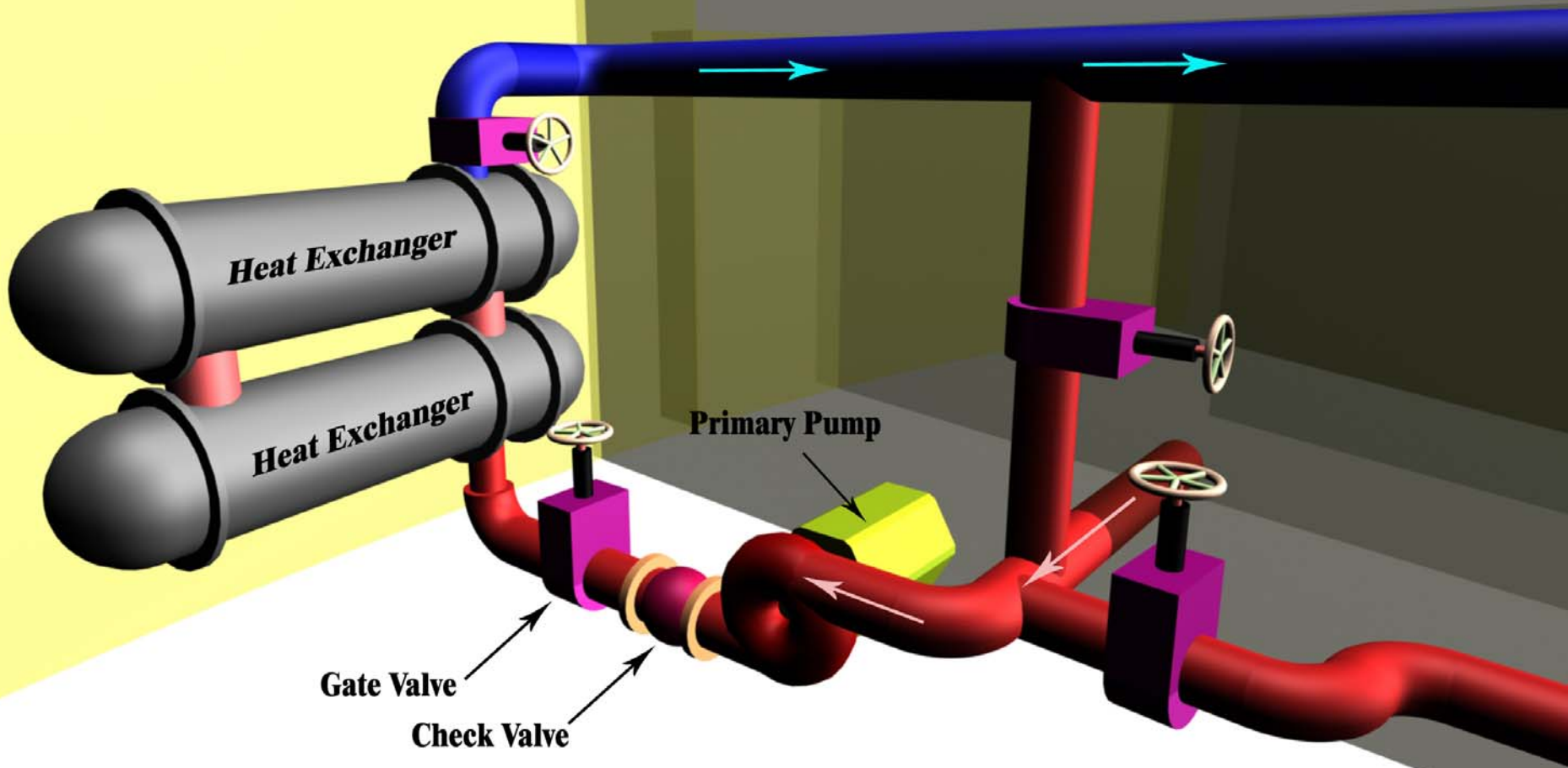
Vertical Section Through Reactor pool

Over View of Tehran Research Reactor





**Tehran Research Reactor
Top View**



Heat Exchanger

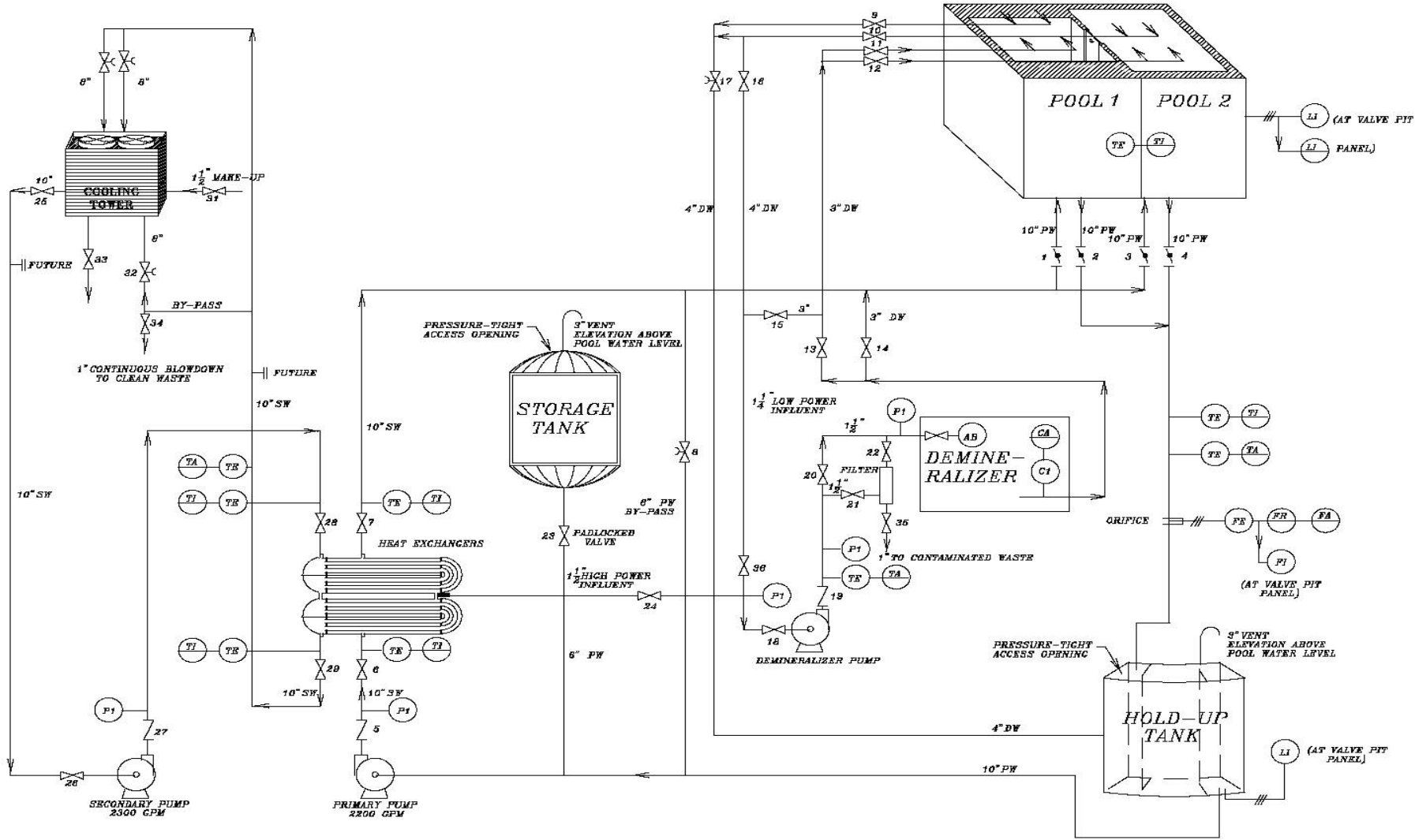
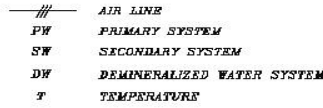
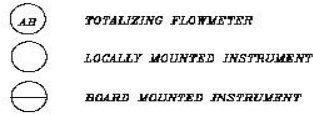
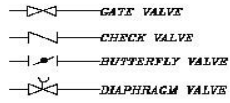
Heat Exchanger

Primary Pump

Gate Valve

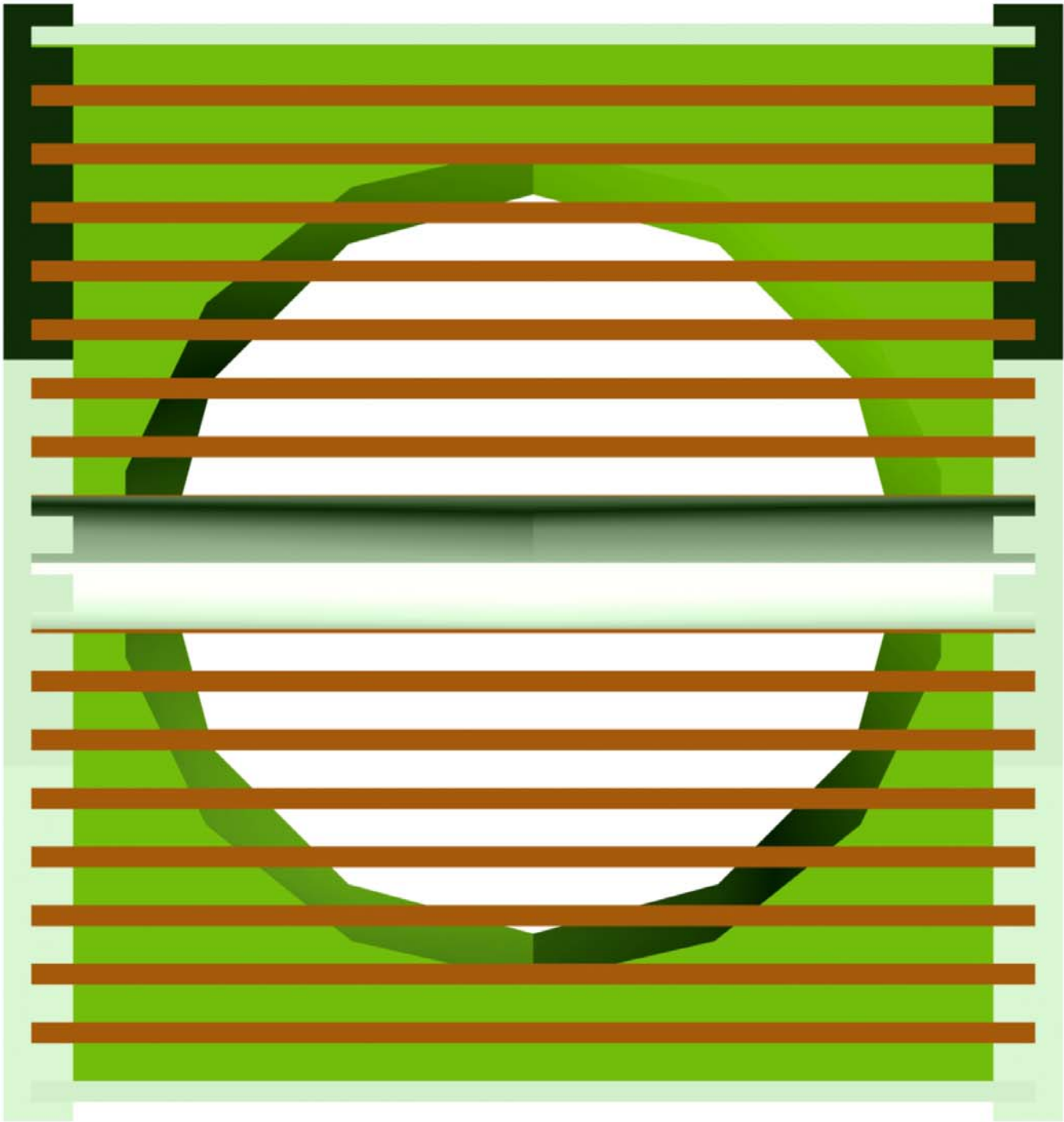
Check Valve

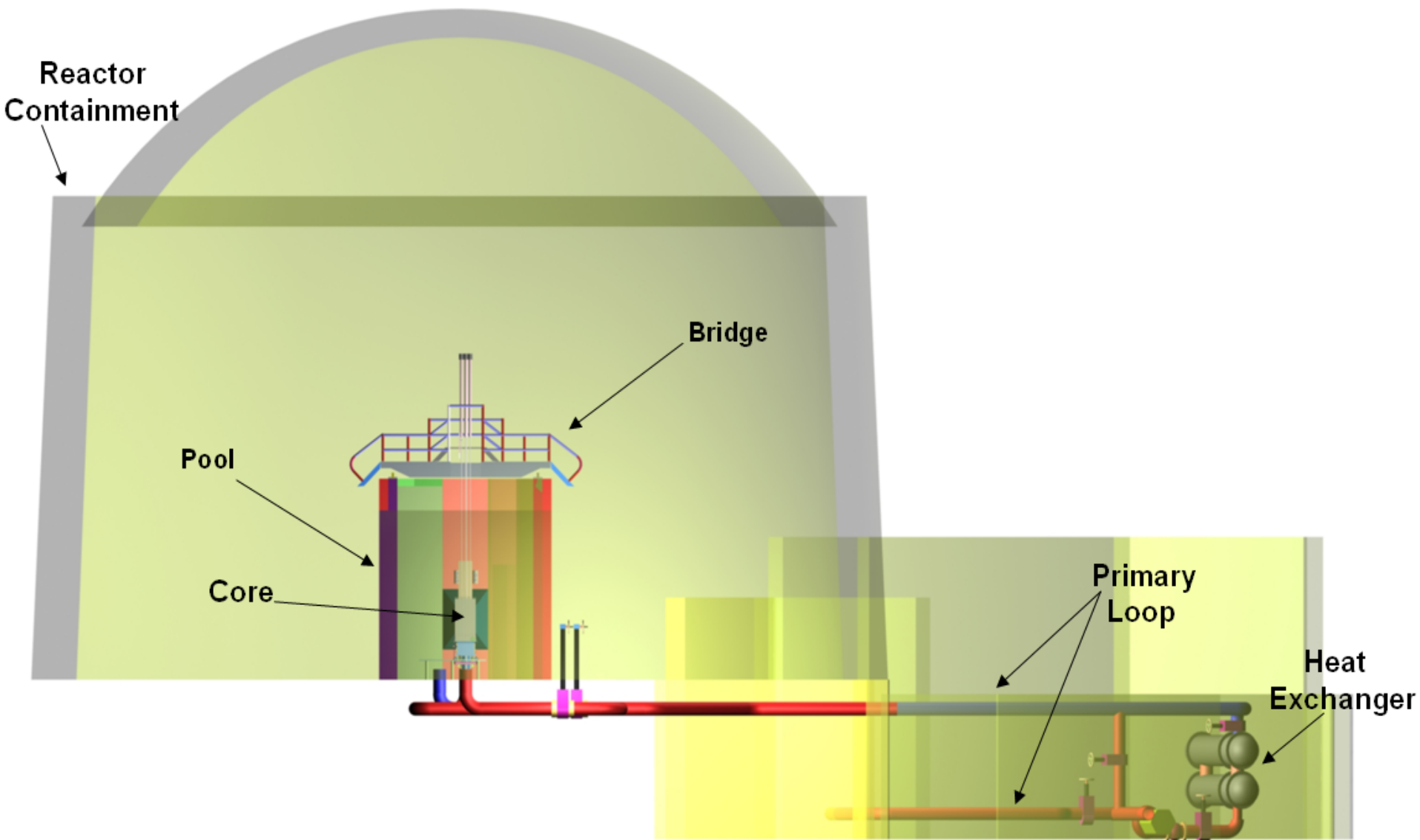
LEGEND



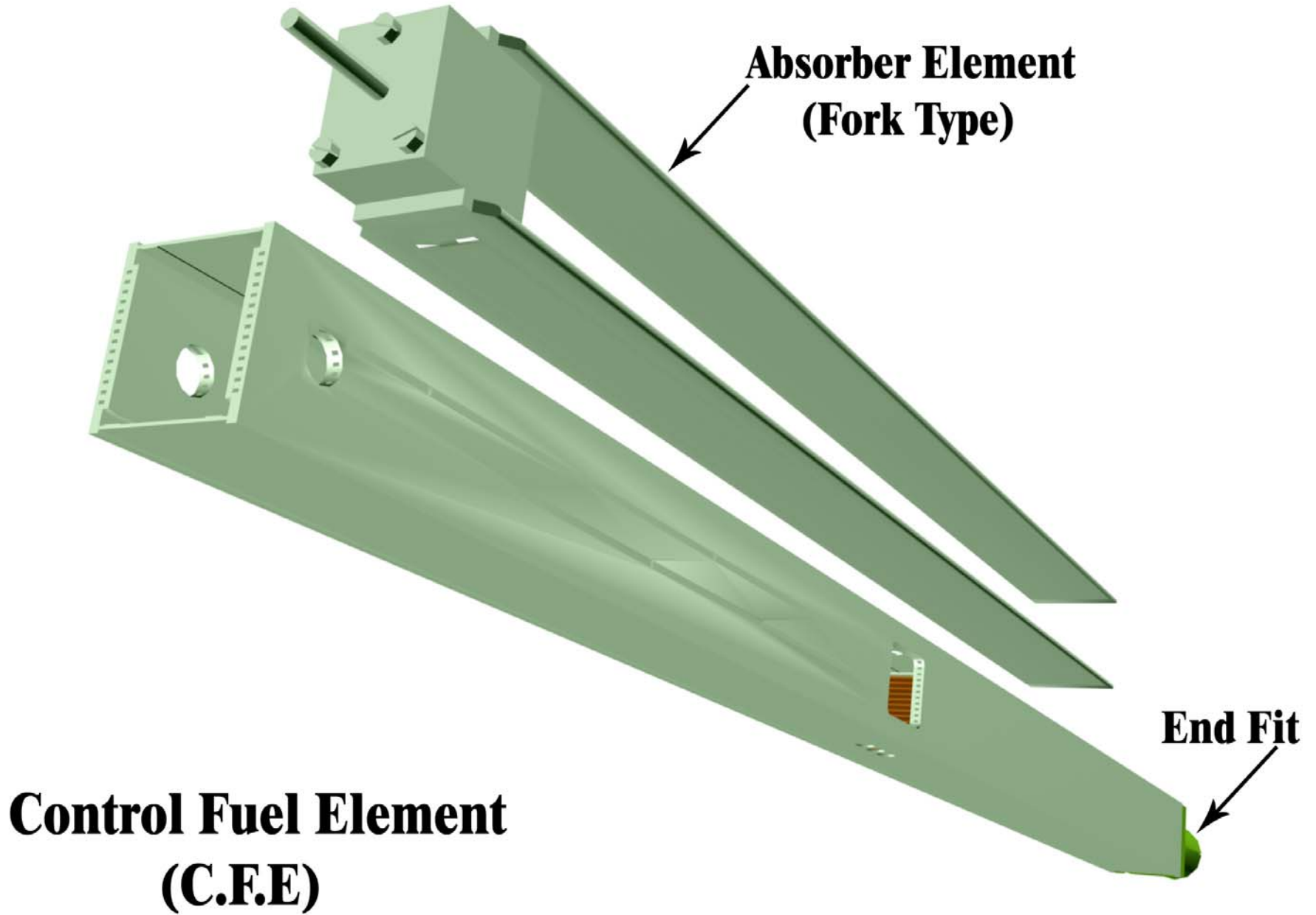
COOLING SYSTEM FLOW DIAGRAM

(S.F.E)
Top View

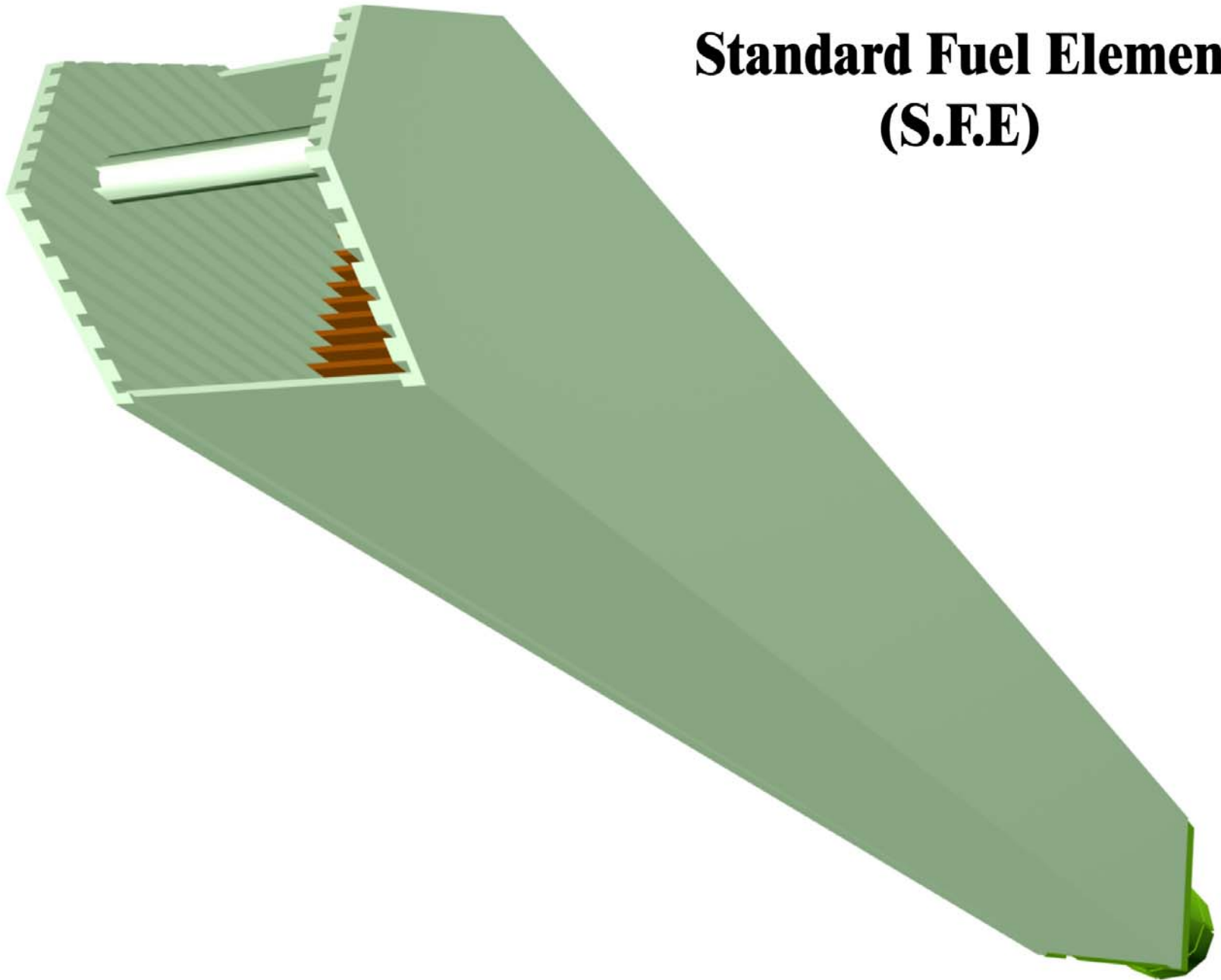


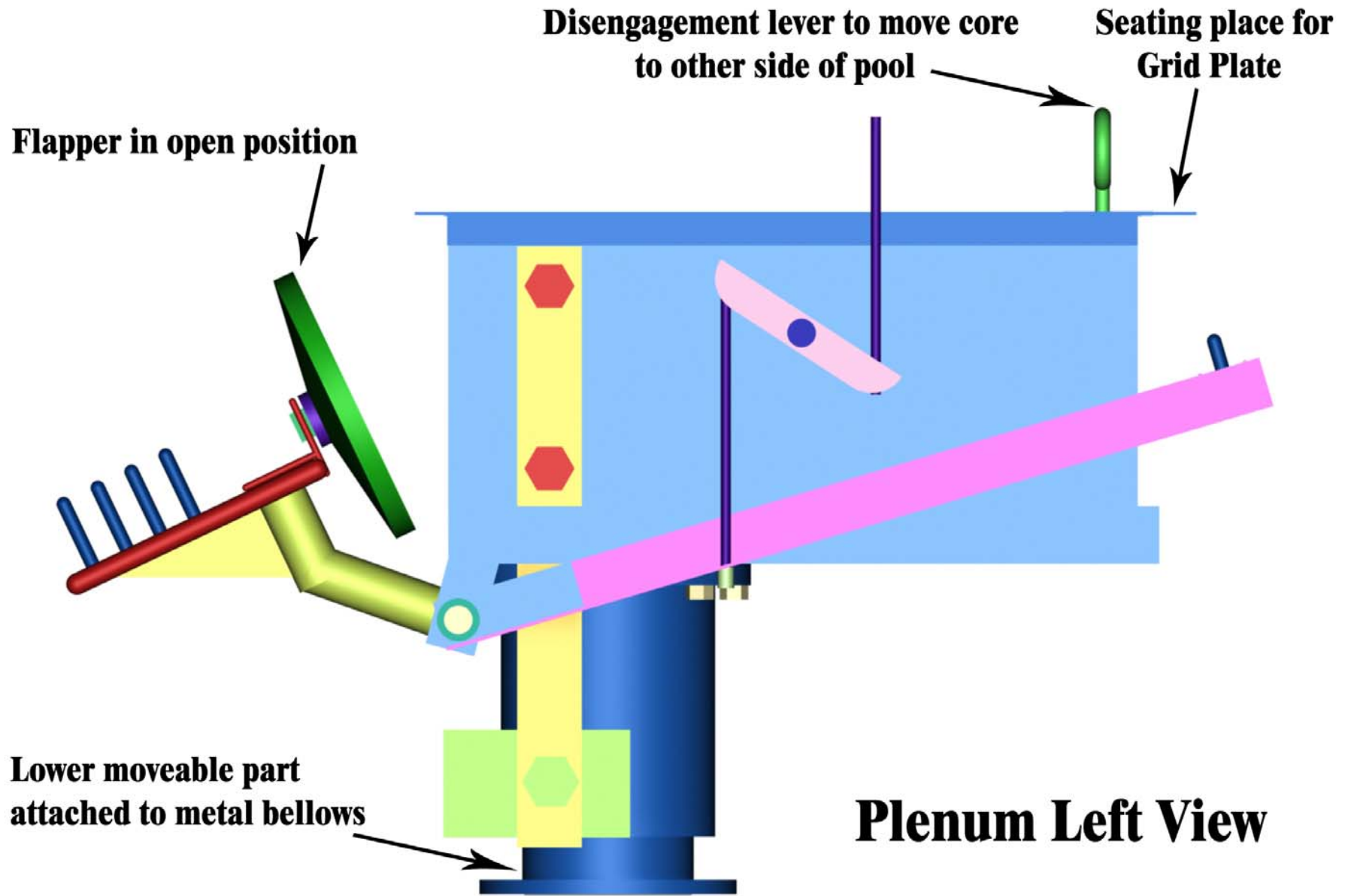


Side View Of Tehran Research Reactor With Adjacent Auxiliary Rooms



Standard Fuel Element (S.F.E)





1.Comparison of different schemes

In order to upgrade steady state power up to 10 MW, a number of choices are conceivable.

1.1 Installing a discharge pump in reactor hall:

This option is to accelerate water flow through core. In this way power level of 10 MW is achievable with a 1000 m³/h pump installed on exit pipeline between reactor pool and hold-up tank (H.U.T). Embedded piping is left intact while 10” piping between exit butterfly valve and H.U.T is replaced with 16” pipe as well as larger valve in place of existing one. An alternate to this option is to add aforementioned discharge pump but leave valve and exit pipeline from butterfly valve to H.U.T as they are. Therefore water velocity in that segment would increase to the extent that erosion and vibration may undermine its lifetime and safety. A second alternate is to place discharge 1000 m³/h pump inside existing H.U.T, instead of reactor hall, and leave everything else intact. Again, this generates a large pressure drop; too much a burden for a sound engineering project.

1.2 Replacing existing pipeline from pool to H.U.T:

One way to avoid fast water velocity within pipelines, and, at the same time maintain water flow through core by gravity is to replace all existing 10” pipelines, including those embedded within concrete, by a larger 20” piping. This requires an extensive demolition.

1.3 Removing orifice plate:

The easiest and least expensive method is to remove existing orifice plate and fully opening butterfly valve. It is expected to reach to a flow rate about 850 m³/h. This would allow operation at slightly over 8 MW power. A new transducer causing less pressure drops out to be installed.

1.4 Forced flow using sealed H.U.T:

One way to enhance flow rate through core with existing pipeline in place, is to seal H.U.T and generate a negative pressure. A 1000 m³/h flow would be achieved but withstanding existing stainless steel cladding of H.U.T against warping make this a questionable task. Problems at the end of paragraph 1.1 would still be applicable for this option.

1.5 Forced flow using new H.U.T:

Design and construction of a new sealed tank to permit forced flow may be another alternative. High cost, and long reactor shut down time are the major drawbacks, as well as sacrificing passive safety feature built in original design.

1.6 Use of parallel piping:

Parallel with existing 10” exit pipeline from reactor pool, still, another pipeline may be envisaged to connect core exit to H.U.T entrance. This new 16” pipe starts from lower plenum and reaches down to H.U.T. In order to prevent excessive demolition, one may take advantage of the second pool outlet at the open pool position (not shown in Fig1) and lay this new pipeline at pool surface floor. The only constraint that imposed is that reactor would only be operable at stall end position.

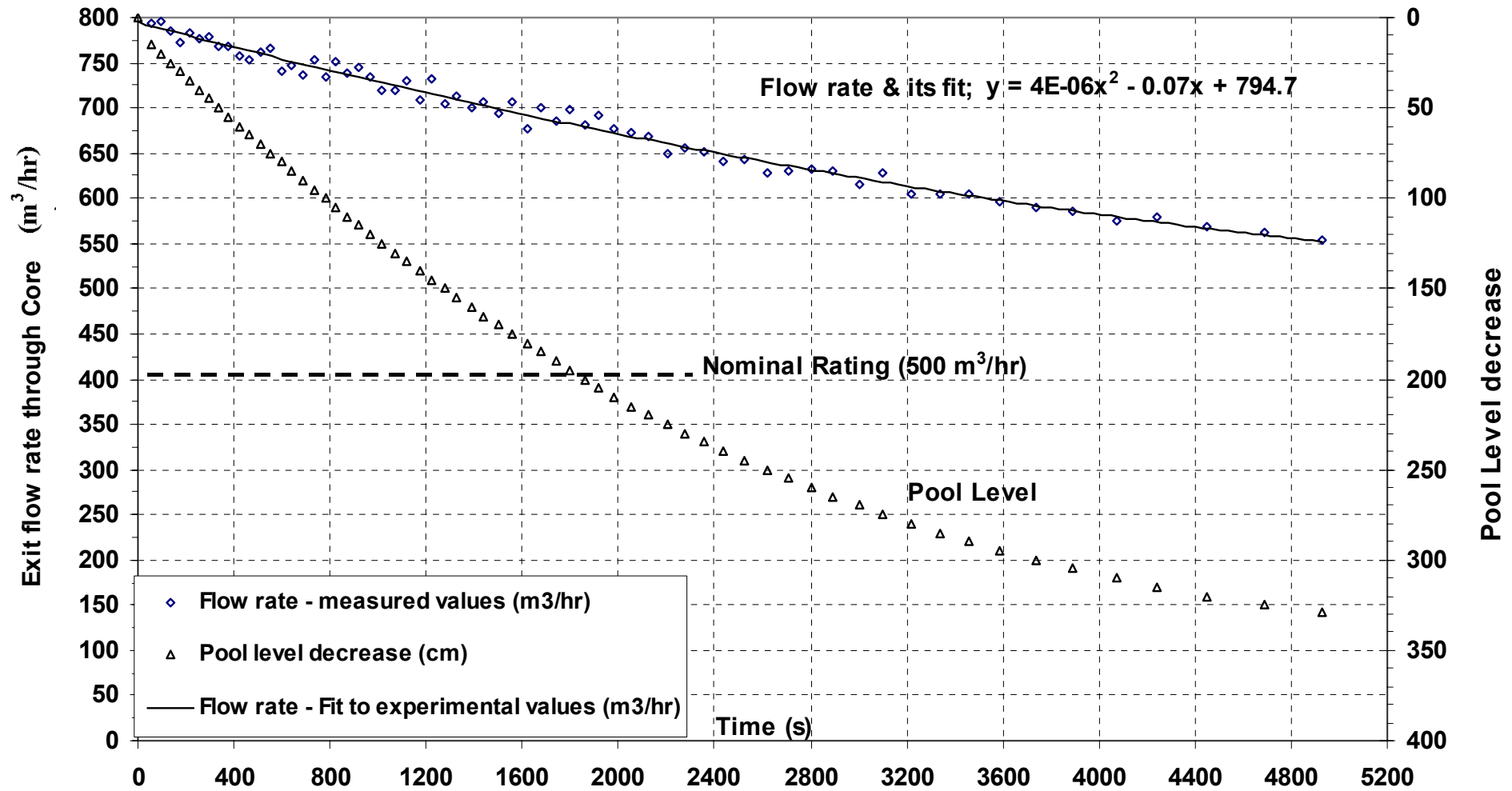


Fig.2. Measurement of flow rate through TRR core with maximum valve opening While primary pump is ON

Conduct of Tests

While Reactor is OFF

- Primary pump ON
- Butterfly valve fully opened
- Flow rate in excess of 750 m³/h maintained within 15 min at least

While Reactor is ON

- Normal operation at 5 MW
- Let it works for sometime
- Butterfly valve fully opened to its extreme
- Power raised to 7.5 MW immediately
- Let it works for 15 minutes
- Observe operational parameters & any transients

Analysis

- Within all Th. Hyd. Parameters, the most stringent one is cladding surface temperature
- Limiting value for clad. Surface temp = 105 °C
- T-clad ≤ 105 °C is due to corrosion effect (Al + H₂O)
- According to SAR, there should be
 - Redistribution ratio > 2
 - DNBR > 2
- If T-clad relaxed to some extent, a series of upgraded power is possible

Thermal hydraulic parameter	105 °C Wall temperature criteria	110 °C Wall temperature criteria	115 °C Wall temperature criteria
Maximum heat flux (W/cm ²)	53.7	58.3	63.0
Temperature rise in hot channel (°C)	20.8	22.6	24.5
Redistribution minimum ratio	2.1	2.0	1.8
Minimum DNBR	3.5	3.2	2.9
Upgraded power (MW)	6.4	7.0	7.5
Equilibrium core with 27 FE Total peaking factor: 3	Increased flow rate: 700 m ³ /h Coolant Vel. within fuel channel: 1.93 m/s		

Table 2. Comparison of TRR thermal-hydraulic parameters based on maximum cladding temperature