DETERMINATION OF CORE THERMAL SAFETY LIMITS FOR THE ETRR-2

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Safety of a research reactor emphasizes the fact that thermal rather than neutron power is the more limiting term during the design and operation of a reactor. Besides, the determination of the core thermal safety limits is a significant part of the reactor safety system setpoint calculations. In general, the established design bases for core are related to the safety criteria for fission product barrier integrity and, consequently to prevent fuel clad damage and undesired release of radioactive products into the environment. Therefore, the present work was performed in order to determine the safety limits in both the natural and forced convection regimes for the Egypt's second research reactor (ETRR-2). The ETRR-2 is a 22 MW (thermal) pool-type multipurpose reactor with an open water surface and variable core arrangement with MTR-fuel elements, cooled by light water, moderated by water and with beryllium reflectors. Fuel elements are square shaped with an active length of 0.8 m. Each fuel element is composed of 19 plates with a 19.7% enriched uranium load and aluminum cladding.

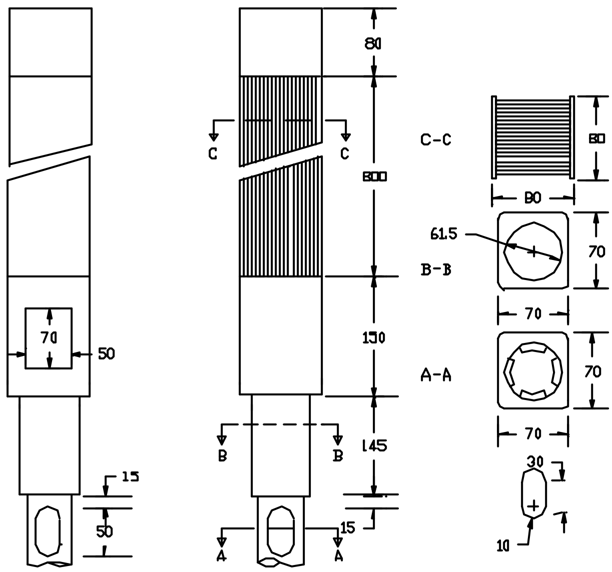
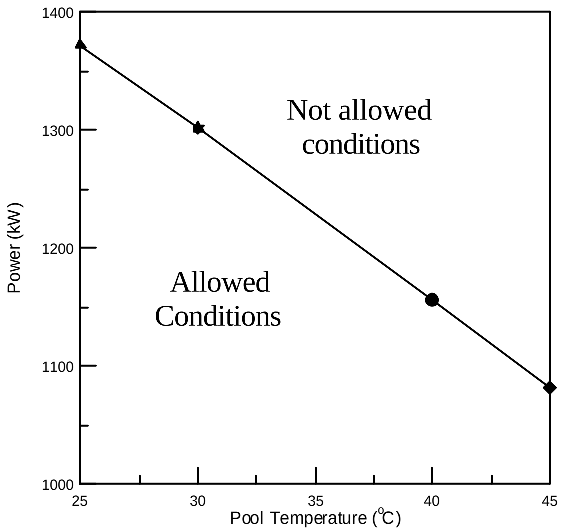


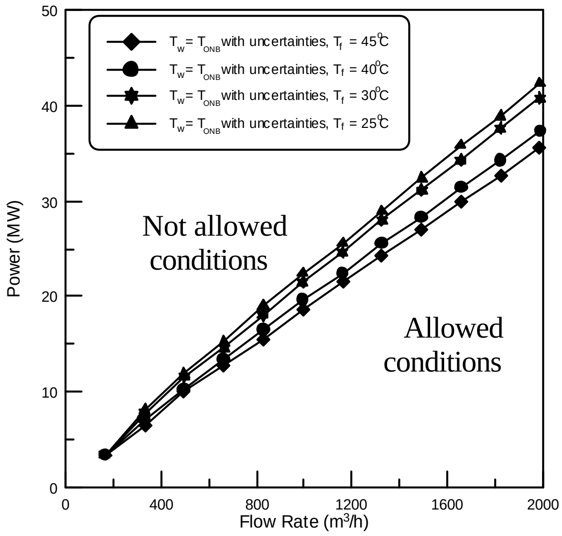
Fig. 1. ETRR-2 fuel element (dimensions in mm).

Calculations have been made under the more restrictive conditions: 24 fuel elements in the core, 9.29 meter height of water over the top of the core (one meter below the normal level), clad temperature lower than the onset of nucleate boiling, and inlet water temperatures of 45, 40, 30, and 25ºC.

The most important core thermal limit for research reactors is the onset of nucleate boiling. Therefore, CONVEC code [1] was run in the natural convection regime for a maximum hot channel heat flux lower than the onset of nucleate boiling heat flux using the fuel element geometric data shown in Fig.1. The maximum reactor power under the more restrictive conditions was calculated from the maximum hot channel heat flux of CONVEC output. In the forced convection regime, TERMIC 1H [2] code was run for a clad temperature lower than the onset of nucleate boiling temperature with statistical uncertainties treatment for different flow rates ranges between 200 and 2000 m^3/h. The maximum power and flow rate were calculated from the corresponding maximum admissible heat flux and coolant velocity of TERMIC 1H output respectively. The results of the core thermal limits calculations for both the natural and forced convection regimes were depicted in Fig. 2 for a pool temperature of 45, 40, 30, and 25ºC. The range contained under the core thermal limits in Fig. 2 presents allowable reactor conditions which is the safe operating range. As long as the reactor operating point remains inside the operating range, adequate heat transfer from fuel cladding to coolant will be ensured. Table 1 summarizes the determined thermal safety limits for each operation regime of the ETRR-2.



(a) Natural convection regime



(b) Forced convection regime

Fig. 2. ETRR-2 safety limits under the more restrictive conditions.

TABLE 1. THERMAL SAFETY LIMITS OF THE ETRR-2 OPERATION REGIMES

Operation regime	Maximum power [MW]			
	T_p = 45ºC	T_p = 40ºC	T_p = 30ºC	T_p = 25ºC
Regime (0) Natural convection No pumps	1.0812	1.1554	1.3018	1.3716
Regime (I) Forced convection One pump, 1000 m^3/h	18.785	19.715	21.597	22.527
Regime (II) Forced convection Two pumps, 2000 m^3/h	35.49	37.35	40.78	42.34

Where T_p is the pool temperature.

REFERENCES

[1] CONVEC Program: for thermal-hydraulic calculus of MTR reactors in natural convection mode, INVAP S. E., Argentina.
[2] TERMIC 1H mode 3.00: A program for the calculus and thermal-hydraulic design of reactor cores, INVAP S. E., Argentina.
[3] Code on the safety of nuclear research reactors: design safety series-Nº35-S1-IAEA.