3. THERMAL HYDRAULICS ANALYSIS

3.1 Heat Balance in the Core

The principal aim in choosing a new coolant system is to allow a power output of 500 KW while keeping the basic core conditions as similar as possible to those maintained during prior operation at 100 KW. By maintaining similar moderator/coolant temperature profiles, reactivity effects which are related to the moderator/coolant will change very little.

The thermal output of a closed loop system with a heat source and a heat sink can be expressed by the relation:

$$q = \dot{m}c\,\Delta t \qquad (3.1.1)$$

where q = thermal output (KW)

$\dot{m}$ = volumetric flow rate (gallons per minute)

c = volumetric heat capacity of the coolant; for water c = 0.1462 KW-min/gal-F°

and Δt = temperature change across either the heat sink or the heat source.

The proposed flow rate for the VPI&SU research reactor when operating at 500 KW is 90 gpm, therefore;

$$\Delta t = q/\dot{m}c = 500/\ (90)\ (0.1462)$$

$$= 38°F$$

The present temperature change across the heat exchangers with the reactor operating at 100 KW is 30°F.

In order to allow for the increase in primary flow rate, the piping size will be increased from the present 1" diameter to 2½" diameter. The relative location of all primary system components will remain unchanged. (See Fig. 2.2)

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The major changes in the system will be the replacement of the present primary coolant pump by a pump which is capable of delivering 100 gpm into a 40 ft. head and replacement of the two primary/city water heat exchangers with a U-tube type heat exchanger supplied by the Richmond Engineering Co.

The secondary cooling system will be a closed loop system utilizing water as coolant, a primary/secondary heat exchanger previously mentioned, and a cooling tower to be located on the roof of Robeson Hall. The proposed temperature drop across the cooling tower is 5°F which means that the required flow rate will be 685 gpm. The flow rate through the secondary will be controlled by a throttle valve located on the output side of the pump to allow for operation of the reactor at lower power levels where the rates of heat removal are necessarily smaller. Schematic diagrams of the existing and modified reactor coolant systems are shown in Figures 2.2 and 2.3, respectively.

In order to minimize rapid temperature changes in the primary system and to prevent the secondary coolant from freezing, the temperature in the secondary system will be controlled to stay within limits of 55° and 120° F. For this purpose a 10 KW heater will be installed in the sump of the cooling tower.

3.2 Maximum Fuel Temperature

In order to calculate the maximum fuel temperature, one must first determine the heat transfer coefficient "h". The reactor coolant flow through the core has been calculated to be within the transition flow regime. Since no directly applicable information is available pertaining to flow through a rectangular channel with a sinusoidally varying heat flux, experimentation must be conducted to determine the desired parameters. A heat transfer rig must be constructed to model the hottest coolant channel whereupon the heat transfer coefficient and maximum fuel plate temperature may be determined.

3.3 Fuel Plate Temperature After Shutdown

With thermocouples welded to a fuel plate, it has been observed that the fuel plate surface temperature does not rise after a shutdown when the reactor has been operated at 100 KW[3.1]. The maximum fuel plate temperature following a shutdown after the reactor has been operated at 500 KW has been calculated by Tuley [3.2]. He showed that the surface temperature would peak at 489°F which is well below the melting point of aluminum (1220°F). As noted by Tuley this demonstrates that a loss of coolant accident would not result in a fuel meltdown following operation at 500 KW.

3.4 References

3.1 Anon., "Thermocouple Data of VPI & SU Reactor Fuel Plate Surface Temperature", VPI & SU Report (1966)

3.2 Tuley, K. D., "Power Excursion Safety Analysis of the VPI & SU Reactor 500 kw Model", M. S. Thesis, VPI & SU (1976)