THE DESIGN STATUS OF THE UNITED STATES DEPARTMENT OF ENERGY MODULAR HIGH TEMPERATURE GAS COOLED REACTOR

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The U.S. Department Energy's Modular High Temperature Gas Cooled Reactor (MHTGR) is being designed using a systems engineering approach referred to as the integrated approach. The top level requirement for the plant that it provide safe, reliable, economical energy. The safety requirements are established by the U.S. Licensing Authorities, principally the Nuclear Regulatory Commission. The reliability and economic requirements associated with the top level functions have been established in close coordination and cooperation with the electrical utilities and other potential users and the nuclear supply industry. The integrated approach uses functional analysis to define the functions and sub-functions for the plant and to identifiy quantitatively how the various functions must be fulfilled. The top four functions associated with the MHTGR are:

1) Maintain Safe Plant Operation

   Reliably maintain the functions necessary for normal plant operation, including the plant states of energy production,shutdown, refueling, and startup.

2) Maintain Plant Protection

   Assume that, despite the care taken to maintain plant operation failures will occur, and provide design features or systems to limit plant damage within economic and safety limits.

3) Maintain Control of Radionuclide Release

   Provide design features for systems to ensure control of radionuclides within safety limits in the event that Goal 1 and/or Goal 2 requirements are not met.

4) Maintain Emergency Preparedness

   Maintain adequate emergency preparedness to protect the health and safety of the public in the event that Goal 3 requirements are not met.

Goal 1 is to be achieved by highly reliable operation using well trained qualified personnel. Goals 2 and 3 will be achieved through using inherent characteristics and passive safety features. Goals 1, 2, and 3 are to be achieved so well that minimal reliance will need to be placed on Goal 4.

In addition to meeting all U.S. Regulatory Requirements this advanced reactor concept is being designed to meet the following requirements:

1. Do not require sheltering or evacuating of anyone outside the plant boundary of 425 meters as a result of normal or abnormal plant operation.

2. Do not require operator action in order to accomplish the above sheltering and evacuation objectives and the design must be insensitive to operator errors.

3. Utilize inherent characteristics of materials to develop passive safety features.

4. Provide very long times for corrective actions following the initiation of an abnormal event before plant damage would be incurred.

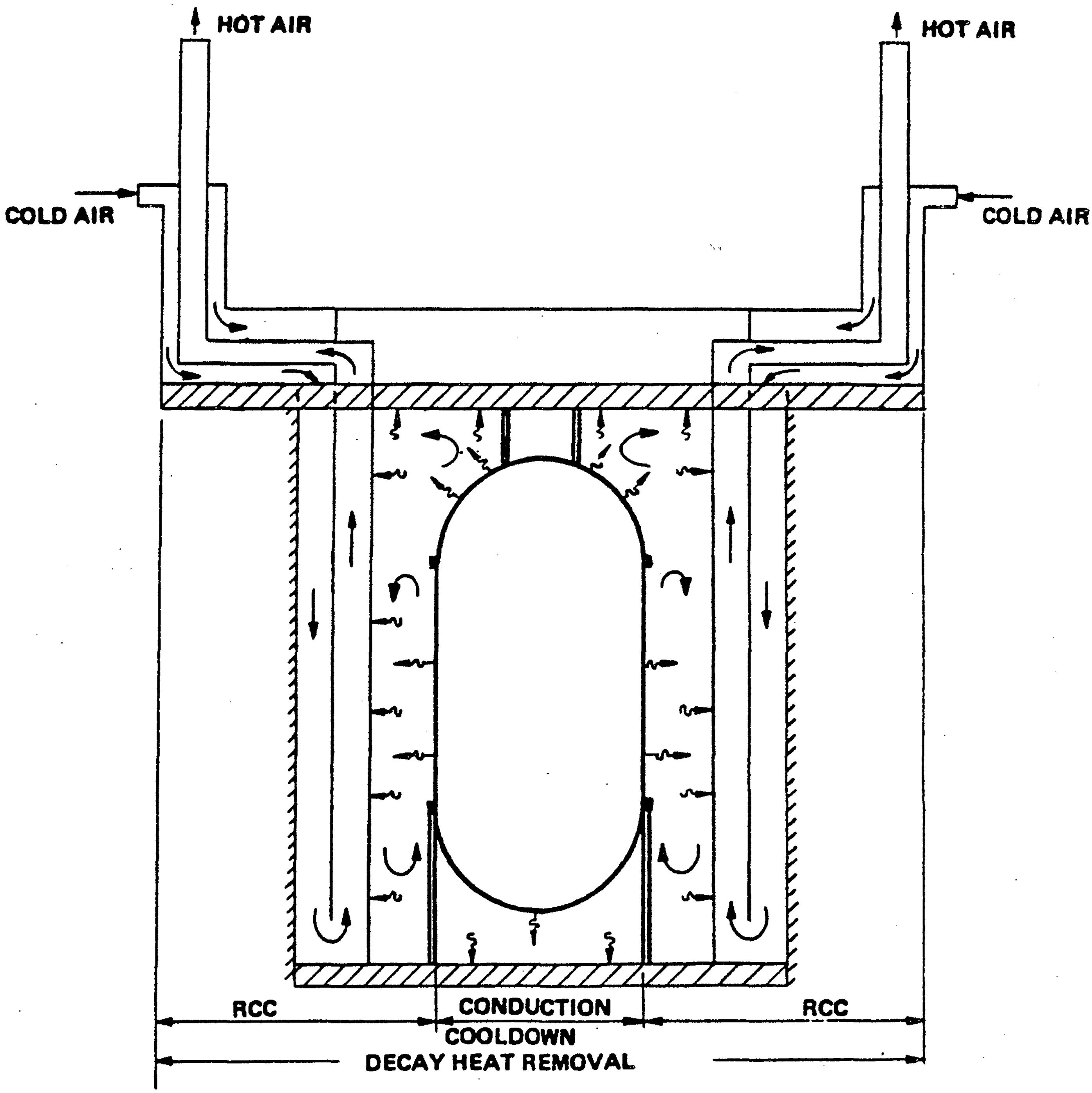
One of the important areas to the MHTGR passive safety characteristics in the event of off normal operations is the Reactor Cavity Cooling System (RCCS). The air cooled RCCS is designed to remove heat from the reactor cavity surrounding the reactor vessel in a passive manner through radiation and convection heat transfer. Figure 1 provides an illustration of the relationship between the RCCS and the reactor vessel. The uninsulated reactor vessel transfers heat by radiation to outside air through cooling panels located in the reactor cavity. The reactor vessel also transfers energy through conduction to the earth surrounding the reactor building. Cool air flows from the exterior of the reactor building as a result of natural convection through cooling panels which form a cylindrical area that is totally external to the primary coolant pressure boundary and surround the uninsulated vessel. The cooling panels and associated ducting collect the heat transferred from the vessel by radiation and natural convection and transport the heated air to the environment outside of the reactor building. In addition, the cavity cooling panels function to protect the concrete cavity wall from overheating during normal operation and provide an alternate method of decay heat removal in the event that forced cooling system functions are lost. Figure 1 shows schematically the heat transfer features which are described above. The RCCS design has no valves or active components which could malfunction to prevent achieving the design objectives. The cooling panel surfaces function as a barrier to separate the outside atmosphere from the atmosphere in the building and the reactor cavity. This separation minimizes the potential for off site radiological exposure which could occur during normal and abnormal operations.

During the present preliminary design phase of the MHTGR computer methods for analyzing the RCCS system will be evaluated and verified to assure that the computer code correctly performs the operations specified in a numerical model demonstrates substantially identical results when compared with known solutions to the problem from other sources. Subsequent to the computer methods verification, validation of the methods will be accomplished to assure that the model correctly represents the processes occurring in the RCCS and correlates with data such as experiments or reactor operation. As part of the process for the verification and validation of the computer codes and models the codes will be tested against benchmark solutions for the range of appropriate application. Some appropriate benchmark solutions being considered for use are comparison with hand calculations, comparison with other computer codes which have been verified and validated, and comparison with experimental or operational data. Part of the method verification process will include sensitivity analyses to evaluate the importance of the various physical phenomena to the method results. The sensitivity analysis will use an uncertainty band associated with the feature or parameter and a resultant uncertainty in the predicted result will be calculated by the code. Among the principal parameters which control the RCCS performance are the reactor vessel and panel emissivity, the convection coefficients in the reactor vessel cavity and in the panels, the environmental wind conditions, and the inlet and outlet structure configuration. The impact of these perimeters will be evaluated to determine the necessity of experimental testing of the reactor cavity cooling system. During the current preliminary design phase a determination will be made regarding the need for tests which may include separate effects tests, scale model tests, or full scale testing on the first MHTGR plant to be constructed.

Another area of importance to plant reliability is the performance of main circulator. The circulator is in an early stage of preliminary design and is planned to be a two stage and axial flow machine. The circulator will be of a unique design using previous efforts to the maximum extent but modified to be specific for the MHTGR. The circulator will be driven by an induction motor of variable speed approaching four megawatts in size. This unique design will be capable of operating at speeds of approximately 4500 revolutions per minute at flow rates in the range of 160 Kg/sec.

Prior experience in using water lubricated bearings in circulators has led to the design selection of magnetic bearings for the MHTGR circulator. In addition to the 5 axial magnetic journal and thrust bearings a catcher bearing is also provided. The roller type catcher bearing supports the circulator shaft assembly when it is at rest and also will provide a back-up for the magnetic bearings in the event of a magnetic bearing malfunction. An area of particular design interest is the behavior of the rotating assembly shaft following the potential failure to function of the magnetic bearings.
In conclusion, the preliminary design of the MHTGR continues to progress with many areas of great interest. Of particular interest is the area of technology development which is addressed in a separate paper. We are looking forward to finalization of the design and plant construction with optimism.

FIGURE 1: RCCS INTERFACE WITH REACTOR VESSEL



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