GA-A--20958

DE92 015374

MHTGR THERMAL PERFORMANCE ENVELOPES – RELIABILITY BY DESIGN

by

K.T. ETZEL, W.W. HOWARD and J.B. ZGLICZYNSKI

Paper to be presented at the ANS Annual Meeting on "The Atom & Human Values," June 7-11, 1992, Boston, Massachusetts

Work Supported by
Department of Energy
Contract No. DE-AC03-89SF17885

GENERAL ATOMICS PROJECT 7600
MAY 1992

GENERAL ATOMICS

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MHTGR THERMAL PERFORMANCE ENVELOPES - RELIABILITY BY DESIGN

by
K.T. Etzel, W.W. Howard and J. Zgliczynski

ABSTRACT

Thermal performance envelopes are used to specify steady-state design requirements for the systems of the Modular High Temperature Gas-Cooled Reactor to maximize plant performance reliability with optimized design. The thermal performance envelopes are constructed around the expected operating point accounting for uncertainties in actual plant as-built parameters and plant operation. The components are then designed to perform successfully at all points within the envelope. As a result, plant reliability is maximized by accounting for component thermal performance variation in the design. The design is optimized by providing a means to determine required margins in a disciplined and visible fashion. This is accomplished by coordinating these requirements with the various system and component designers in the early stages of the design, applying the principles of Total Quality Management (TQM). The design is challenged by the more complex requirements associated with a range of operating conditions, but in return high probability of delivering reliable performance throughout the plant life is assured.

INTRODUCTION

The MHTGR is an advanced reactor concept being developed as a cooperative program between the U.S Department of Energy (DOE), the nuclear industry represented by General Atomics, ABB-Combustion Engineering, Stone & Webster Engineering Corp., Bechtel National, Inc., Oak Ridge National Laboratory and the utilities represented by Gas-Cooled Reactor Associates.

The reference MHTGR plant design consists of four reactor modules, each module rated at 350 MW(t) which produces superheated steam at 540.6°C (1005°F) and 17.34 MPa (2515 psia). The four reactor modules are coupled to two turbine generators to produce a net electrical power output of approximately 544 MW(e). The four-module plant is divided into two major areas; the Nuclear Island (NI) which contains the reactor, steam generator, helium circulator, vessels, enclosures and supporting systems; and the energy conversion area (ECA) which contains the turbine generator and the feedwater systems equivalent to a similar sized fossil generating unit. Each reactor module is housed in a vertical cylindrical concrete enclosure which is fully embedded in the earth.

MHTGR APPROACH TO RELIABLE PLANT PERFORMANCE

Traditionally power generating plants are designed to point design requirements. Component designers add margins in an unintegrated fashion. The adequacy of the margins of the integrated plant components in achieving plant performance is only realized after operational testing is performed. This can result in carrying the cost of excess margins or in poor plant performance or expensive rework due to inadequate operating margins. An MHTGR component which can be used as an example to explain this relation is the helium circulator. By circulating the primary coolant, this component transports the core generated heat to the steam generator. The circulator design is crucial for sucessfull MHTGR operation. If sized for point design requirements, the integrated plant has to perform as expected or otherwise the circulator is either undersized or oversized. If undersized, the circulator is incapable of providing the required heat removal rate to achieve rated power output. As a result, the plant may have to be derated or a properly sized circulator be refitted, measures which in any case result in economic loss. If the circulator is oversized, then the module will operate successfully but eventual cost of excess margin may also result in economic penalty. Also, adding margins to other components as well will almost certainly result in unexpected module performance, unless these margins are integrated on a systems level.

For the MHTGR, design requirements for all systems and components are specified by thermal performance envelopes. These envelopes specify a performance range, and the component designers select the condition which sets the sizing point for their components. The thermal performance envelope encompasses overall module performance uncertainty and allocates design margins to components in an integrated fashion. An individual envelope or set of envelopes is specified for each key component. The consideration and incorporation of module performance uncertainty early in the design phase significantly reduces the risk of disrupted plant operation due to unexpected performance characteristics. To assure maximum process efficiency in developing thermal performance envelopes, design and performance analysis are performed early in the design effort which is based on effective teamwork. The cooperative initiative to incorporate reliability in the design of systems and components is one of the key foundations which make the MHTGR design outstanding.

THERMAL PERFORMANCE ENVELOPES

A cartesian coordinate system is used to visualize the range of thermal performance due to uncertainties. The axes represent a selected set of plant parameters with significance for the design of a system or component. If the design is affected by more than two parameters, a set of envelopes is provided for the design.

Thermal performance envelopes are developed using the following process: The parameters with significant effect on the steady-state performance of a particular component are identified in a sensitivity study. High and low values are established for each parameter based on calculational uncertainty of thermal characteristics or achievable measurement accuracies. A typical example for a thermal characteristic is heat transfer effectiveness. The resulting uncertainties are combined in an additive fashion and steady-state heat balances for all possible combinations are generated based on these uncertainties and the expected module performance. These resulting heat balances provide the data which form the thermal performance envelopes. Fig.1 depicts an example of a thermal performance envelope developed for the helium circulator. Shown is the system helium pressure drop as a function of circulator helium flow. The solid dot located within the envelope represents the expected operating point. The area contained within the envelope boundaries specifies the range of potential module performance when accounting for the performance uncertainties in primary coolant loop pressure drop and steam generator heat transfer effectiveness, and the measurement uncertainty in feedwater flow rate.

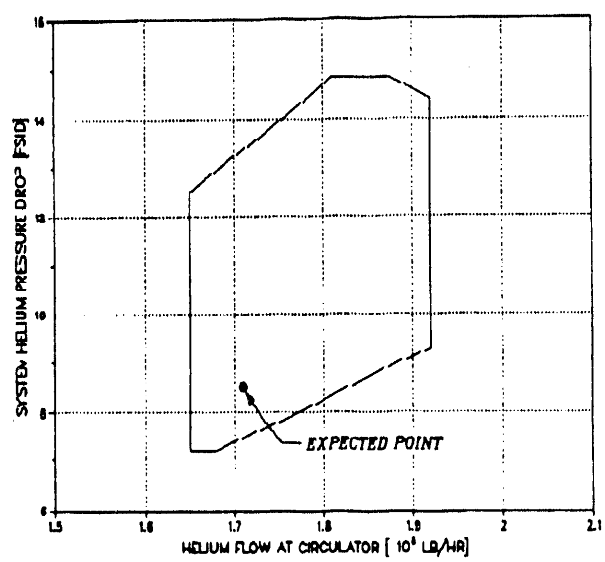

Fig. 1: Helium Circulator Envelope at Rated Power

SUMMARY

Thermal performance envelopes specify the design requirements for the systems and components of the MHTGR. Because they incorporate thermal performance uncertainty in the design, the resulting product is more robust and hence more reliable. Statistical thermal performance analysis of the MHTGR concluded that the confidence level of achieving full power without violating limits is extremely high. In addition to greatly improving plant reliability, performance envelopes help to optimize the design by specifying and controlling expensive design margin. Thermal performance envelopes effectively embody the ideas of Total Quality Management (TQM): They assure reliability by design, and are made possible by teamwork early in the design effort.

ACKNOWLEDGMENTS

The authors would like to thank the U.S. Department of Energy for approval to publish this work, which was supported by the San Francisco Operations Office Contract DE-AC03-89SF17885.

DATE
FILMED
8 / 14 / 92