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Lawrence Radiation Laboratory
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THE TORY II-C PROGRAM: INTRODUCTION AND GENERAL DESCRIPTION

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FOREWORD

This is Part 1, "Introduction and General Description," of the ten-part report UCRL-7036. A list of all ten parts, including titles and major subheadings, appears on the following two pages.

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INTRODUCTION

The Lawrence Radiation Laboratory plans to operate its second reactor of the Pluto Program, Tory II-C, during the late summer of 1963. To make the Tory II-C program available in report form, there will be a series of 10 reports issued as separate parts under the same UCRL number. These various reports have each been assigned a part number and will be on specific topics as indicated in the preceding list, pages iv and v.

This report, UCRL-7036 (Part 1), serves as an introduction to the series of reports and gives some general description of the Tory II-C program. The parts to follow will not be issued in chronological order but rather as they are made ready by the various authors. This will insure that the information is made available as soon as possible and also permit those parts which are unclassified to be so published. Once this series of documents has been completed, a more concise one-volume report on Tory II-C will be prepared under a separate UCRL number.

GENERAL DESCRIPTION

In 1957, the Lawrence Radiation Laboratory (LRL) was requested by the U. S. Atomic Energy Commission to undertake a program to develop a nuclear reactor capable of propelling a ramjet vehicle. After lengthy considerations, attention was directed to a vehicle which would travel at supersonic speeds over long distances and at very low altitudes. Ambient air would enter at the intake end and pass through the reactor, where it would be heated to high temperatures and forcibly discharged rearward through the nozzle, thus imparting thrust to the vehicle. Thrust values sufficient to permit transportation of large thermonuclear warheads were desired.

To meet these ends, a program was established at LRL to design, develop, and test a series of high-power, high-temperature nuclear reactors. The first of these, Tory II-A, was successfully tested a number of times during 1961 at the Nevada Test Site (NTS). This reactor was designed with facility limitations in mind, but nevertheless provided very pertinent information on fuel element integrity under realistic operating conditions. The engineering feasibility of the engine concept was thereby established. Invaluable design and operational experience was acquired. Not only were the desired operating conditions attained, but the reactor itself withstood extreme temperature and power levels for the desired period of time.

Tory II-C is the second reactor of the Pluto Program. It is, in fact, meant to be adequate as an engine for a ramjet vehicle. Problems such as control element operation within the reactor environment, which were avoided in the Tory II-A design, are inherent in Tory II-C. Its design is essentially complete, and many components are fabricated. Full power operation is expected to occur in the late summer of 1963. The reactor is expected to operate at a power level of 500 MW and at peak fuel element temperatures of 2500°F during a 5-minute run.

The reactor is essentially a right circular cylinder about 7 feet long and 4.75 feet in diameter. The core, which is 51.0 in. long and 47.25 in. in diameter, is composed of about 300,000 fueled and unfueled BeO tubes. The mass of OyO_2 (i.e., 93.2% U^{235}) is about 52 kg. Each fuel tube is hexagonal in cross section, with a coolant hole passing down the 3.925-in. length. The outer flat-to-flat dimension is 0.297 in. and the hole diameter is 0.227 in., giving a fuel element porosity of 53%. Fuel loading is varied throughout the core to achieve a particular power profile. Approximately 25 classes will be spanned, where successive classes differ in fuel content by 8.0 wt %.

The core is reflected on all sides. The upstream end reflector is 9.7 in. thick, while the downstream reflector is slightly more than 2 in. thick. Both are essentially of BeO. The side reflector is more complex, especially when one recognizes that the support structure influences the neutronic design significantly. A layer of low-porosity BeO approximately 2 in. thick and also composed of hexagonal tubes is in immediate contact with the core. In turn, a layer of nickel peripheral shims, nominally 1 in. thick, surrounds the BeO.

Corrugated springs apply a uniform radial compressive force on the entire tube array through the nickel shims. These are meant to provide system stability and contend not only with normal vibrations and expansion, but also loads induced by missile maneuvers.

The springs are coupled to the pressure duct through rails, which provide only lateral support of the reflected core. Axial support is provided by 121 superalloy tie rods which pass axially through the entire reactor and are firmly anchored to a front support structure. The downstream ends of the tie rods support the base plates against which the reactor presses.

During normal operation, an average core power density of 10.0 MW/ft^3 will be realized. Peak power densities within fueled tubes will be as high as 27 MW/ft^3. Temperatures in the fueled tubes will range up to 2500°F. The tie rods, which are of René 41 and Hastelloy R-235, will be cooled so that temperatures do not exceed 1400°F.

Before entering the reactor, the coolant air is throttled down by an aerodynamic grid which is situated several feet forward of the reactor. The grid serves to decouple the tank farm air supply from reactor transients, and also makes possible the reliable determination of the flow rate through measurement of temperature and pressure immediately upstream of the grid. After passing through the reactor, the air enters a convergent nozzle and then leaves the system. The air is allowed to expand freely after passing through the nozzle throat. The design employed does not adversely affect the pressure profile across the reactor, but does bypass the need for cooling a nozzle bell.

Nuclear control is achieved through the movement of 14 hafnium control rods within the core. Twelve of these, called "shim" rods, are situated approximately 9 in. off axis, while the remaining two are closer to the side reflector. One serves as a vernier rod, the other as a safety rod. All move axially within tie rods, through the front reflector, and may penetrate at most 40 in. into the reactor. The tie rods which accommodate these are oversized since the control rods, which have an asterisklike cross section, have a 1.0-inch span.

Normal shim rod movement is mechanically restricted to less than 3 inches per second. Scram time, however, is approximately 1.5 seconds. Four actuators located within the duct move the shim rods; each actuator handles a set of three shim rods. The safety and vernier rods have separate actuators. These actuators are pneumatically powered from external sources and are designed to operate over the very large temperature and pressure ranges expected within the forward duct.

An independent safety system composed of six poison rods is also mounted within the ducting. This system is designed to yield a standby shutdown capability. It may be used only when the reactor is at zero or low power, for entry of these rods into the corresponding centrally located tie rods restricts coolant flow in the tie rods. The system is mechanically actuated from outside the duct to provide a high degree of reliability.

The reactor is mounted on a railroad flatcar to permit movement between the test point and disassembly building. The car is specially designed to accommodate the massive body throughout the entire operating phase. A battery-powered prime mover is available to move the flatcar and reactor about through remote control. The flatcar itself is provided with a fail-safe breaking system to prevent any but deliberate car movement.

The basic requirement of the test facility is to deliver 1900 pounds of air per second to the reactor at 1060°F for 300 seconds. The flow rate and temperature correspond to a flight condition of Mach 3 at 1000 feet elevation. These conditions are met through provision of 1.2 million pounds of air stored in a tank farm. The air is heated by passage through a pebble-bed heat mass composed of 2 million pounds of large stainless steel ball bearings, preheated to a temperature somewhat above 1060°F. The flow rate and temperature may be continuously adjusted during operation by valve manipulation. Flow meters and pressure and temperature transducers permit determination of the flow rates.

The major features of the test facility at NTS have been described elsewhere. At Site 401, the reactor will be operated remotely from a control building 8200 feet from the test point. A disassembly building equally distant from the test point is connected by a railroad track to it. The concrete bunker at the test point accommodates air supply ducting and bunker control equipment, and is designed to allow entry of personnel shortly after a high-power run. The disassembly building is specially designed to handle the kilocurie activities which result from the high-power nuclear operations.

High-power operation of Tory II-C is expected in the latter portion of 1963. Initial runs will be at one-third of full power to check out the facility as well as reactor aerodynamic heat transfer and neutronic design predictions. No more than 10 high-power runs are anticipated. Automated data reduction techniques will permit rapid assessment of field data and so reduce usual programmatic delays.

The hazardous aspects of field operation are also reviewed in this series of reports. It is implicit in the basic philosophy of the program that since Pluto reactors, by their nature, operate at extreme temperatures and pressures, and since only now is operational experience being acquired, experiments should be carried on at a remote site. This should be, if no other reason than the reactors are operated in open cycle and so release radioactivity and beryllium to the atmosphere. Hazards of normal operation are therefore evaluated. Credible accidents as well as an extreme accident situation are also studied.