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University of California
Radiation Laboratory
Livermore, California

353.4 Rover — 4/30/57

May 1, 1956

Brigadier General Alfred D. Starbird
Director of Military Application
U. S. Atomic Energy Commission
1901 Constitution Avenue, N. W.
Washington 25, D. C.

SUBJECT: OUTLINE OF UCRL-LIVERMORE ROVER PROGRAM

Dear General Starbird:

This report describes the method of the attack UCRL proposes to make in developing a nuclear rocket engine. The program is broken down into several phases which follow each other in time, and into several problem areas which are to be attacked concurrently as indicated.

I. PHASE I

Phase I will occupy, roughly, most of the next two years, and may be characterized as the "Core Feasibility Phase". For this phase we have separated the development program into three separate problem areas, namely, Hot Critical Experiments, Erosion and Corrosion Problems, and Engine Auxiliary Problems.

1. Hot Critical Experiments

We propose to design and build a series of reactors, called the Tory series, consisting of a cylindrical graphite core impregnated with uranium having a C to U ratio in the range of 500 to 1000:1, a diameter of about 24 inches, a length of about 60 inches. It will have end reflectors of graphite and be surrounded by an annular D_2O reflector. It will be controlled by vanes in the D_2O, it will be cooled by passing nitrogen gas through axial holes having diameters within the range of 1/8 to 1/4 inch, and occupying in all some 30%-40% of the volume. It is hoped to operate at temperatures in the low 2000's of degrees Kelvin, and to build the power up from perhaps 0-30 mw at the start to perhaps 300 mw at the end of a year of operation. We presently plan to begin low power operation in mid-1957.

In designing and building this reactor, we will be attacking the following problems:

a. Preparation of impregnated graphite, including problems of uniformity, concentration, and stabilization of U, and uniformity of the graphite itself.

b. Experimental and theoretical analysis of the neutronics problem, including power distribution, reactivity control, and reactivity variation with temperature. (A cold critical experiment is now in progress using a new assembly known as Puppy.)

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c. Analysis of the heat transfer and flow stability problem.

d. Analysis of the thermal stress problem.

e. Analysis of the site safety and contamination problem.

In operating the reactor we expect to obtain experimental data relevant to the following problems, either by prompt diagnostic methods, or by post mortems on the disassembled reactor:

a. Mobility of U in the core and loss of U from the core at various temperatures.

b. Neutronic behavior, including temperature coefficients and effectiveness of various control systems. This problem is complicated by the fact that the core and reflector are at quite different temperatures.

c. Flow stability, heat transfer, power and temperature distribution.

d. Temperature distribution, thermal stresses, and the response of the structure thereto.

e. Neutron and gamma fluxes external to the reactor proper.

In building and operating the Tory Reactors, we deliberately avoid the following problems:

a. Attack of surfaces by the propellants we eventually expect to use, namely H_2, NH_3, hydrocarbons, etc. This is done because we believe the use of the relatively non-corrosive N_2 as a coolant (or substitute propellant) will allow us to begin high temperature moderate power experiments about a year earlier than if we waited for a successful solution to the corrosion problem.

b. Development of pumps, and other auxiliary gear, suitable for rocket engine use. We will use whatever method appears simplest for forcing the N_2 thru the reactor without reference to weight or any other parameter. That is, we will use either high pressure gas or liquid N_2 pumps.

c. Development of cryogenic systems suitable for producing and handling liquid H_2 in large amounts.

In addition, the use of D_2O as the moderator rather than some presumably more suitable material such as Be, enables us to have great flexibility in the design of our reactivity control system.

2. <u>Erosion and Corrosion Problems</u>

The second major problem area in which we propose to work concurrently during Phase I is that of developing suitable methods for protecting graphite surfaces against high temperature corrosion by the interesting propellants, H_2, NH_3, hydrocarbons, etc. This work will consist primarily of finding methods of producing protective coatings of various metal carbides or nitrides in holes (or other shapes such as flat plates if holes are unfeasible) and then testing their corrosion resistivity and mechanical stability by experiments in our blowpipes. These blowpipes consist of electrically heated graphite elements thru which the propellants are passed under temperature and power conditions similar to those expected in a rocket reactor. The coating work will be done both at UCRL and by contract with such institutions as Battelle Memorial Institute, Stanford Research Institute, and Horizons, Inc.

In addition, we will also look into the use of mixed propellants, at least one of which is initially carboniferous, in order to examine the possibility that in this way corrosion can be reduced, and the build-up of carbon deposits which accompanies the use of pure hydrocarbons can be reduced.

3. Engine Auxiliary Problems

During Phase I we plan to make in conjunction with chemical rocket groups some preliminary designs of the entire engine end of a nuclear rocket. This will be done in order to determine the environment in which various components (pumps, turbines, controls, etc.) must live, to establish design and performance requirements for such auxiliary gear, and to establish approximate rocket engine parameters, such as total gross weight. Detailed design of suitable components and cooling systems should begin during this phase, probably largely by subcontract to firms familiar with the large rocket motors. This work would proceed at a relatively low level compared with that required at a later date.

II. PHASE II

Phase II begins, by definition, when sufficient progress has been made in problem areas 1 and 2 of Phase I so that these can be brought together and a nuclear rocket reactor capable of using the interesting propellants and operating at full power and temperature can be designed. Hopefully, this Phase may begin in mid-1958. Work during this period would proceed in three basic problem areas, as well as we can predict at this point.

1. The Reactor

Investigations of the reactor and various neutronic, heat transfer, and materials problems as listed under 1 and 2 in Phase I would continue. While they cannot, of course, be described in any detail at this time, they would be designed to give data necessary to prepare a flyable reactor by the end of Phase II.

2. Engine Auxiliaries

Work in this area would be stepped up greatly in this time period, and, as components and parts become available, these would be operated in the environment produced by the reactor. Development of these engine components would presumably be a joint enterprise between ourselves and others expert in the field of pumps, turbines, valves, control systems, cryogenics, etc.

3. Complete Rocket and Missile Systems Studies

During this phase, work on the design of the entire missile system should begin, so that the overall environmental problem can be studied with a view to determining the influence of the nuclear energy source on all other missile system components (guidance system, launch site, etc.) and vice versa. The role of UCRL in this area would probably be relatively small but important.

III. PHASE III

Phase III would begin, again by definition, when sufficient progress has been made on the full scale reactor and on the other engine components so that these can be combined into a true prototype nuclear rocket engine. Hopefully, this Phase might begin in 1960 or 1961 and would consist of static test of complete nuclear rocket engines. Design of the rest of a nuclear rocket would proceed during this period. Phase III would end when there existed a complete flyable nuclear rocket engine, perhaps in 1962 or thereabouts.

Very truly yours,

Herbert York

HERBERT F. YORK
Director
UCRL, Livermore

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