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Memo No. 8000R:71-006

BRIEF DESCRIPTION OF DATA PACKAGE

Summary of Propulsion/Electric Power Status at termination plus backup data issued during contract year. A more detailed report summarizing all activities in Project 395 is being made.

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395-f-2-a thru i
16 March 1972

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395-f-2-a thru i
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PROJECT 395 - PROPULSION/ELECTRIC POWER

Following is a summary of the status of each item in Project 395.

PROJECT 395-f-1

1. Introduction

Project activity for period 10 October 1970 through 28 February 1971 was a liaison and sales period to provide continuous support for the dual mode concept.

2. Conclusions

The project was continued, thus it was successful to some extent.

3. Recommendations

None.

PROJECT 395-f-2(a) - INTEGRATION, ENGINE & NSS

1. Introduction

a. Purpose

The WANL Project 395 output was directed at providing a heat source for the electric power system. This power system had to fit with the engine and vehicle for an overall useful system.

2. Conclusions

The gross conclusion is that heat can be extracted from a nuclear rocket engine for a long period of time.

3. Recommendations

None insofar as NERVA is concerned. For the LASL small nuclear rocket engine the concept is vital. Without this concept the nuclear engine will not

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be carried forward.

4. References

None.

PROJECT 395-f-2(b) and 2(c) - SENSITIVITY & FLEXIBILITY STUDY

1. Introduction

The purpose of this study was to find a method of using the radiative heat retention capability of the electric power system to greatest advantage during cooldown and to estimate the most desirable size system based on lunar mission profile.

2. Conclusions

The 25 KW(e) system originally studied in detail was too big for optimum lunar payloads. A 10 KW(e) system was best for NERVA size engine.

3. Recommendations

The small nuclear rocket engine should have a 2 - 5 KW(e) system for best payload. This size system should be used for initial parametric study.

4. References

Memorandum 8000R:71-006, dated 12 October 1971.

PROEJCT 395-f-2(d) - EVAULATE STARTUP - SHUTDOWN

(To be included in Final Report item 2(g).)

PROJECT 395-f-2(e) - ELECTRICAL REQUIREMENTS

No work done - not scheduled.

PROJECT 395-f-2(f) - PLAN FOR DEPLOYMENT

(To be included in Final Report Item 2(g).)

PROJECT 395-f-2(g)

Final report in preparation.

PROJECT 395-f-2(h) - STATUS REVIEW

This informal review was conducted with W. H. Robbins and LASL personnel with the objective of interesting LASL in the concept of dual mode NERVA for the new small nuclear rocket engine. The review covered ANSC Report ANWA-PEP-13-W-395-(N-2360) and the report N8000R:71-006. The discussion was directed at how the current NERVA concepts could be included in the LASL design. This meeting is to be followed by a visit to LASL by J. H. Beveridge on March 16, 1972, for the purpose of more discussions toward this objective.

PROJECT 395-f-2(i) - ENGINE IMPLICATIONS FOR 1000 KW THERMAL SYSTEM

Was not worked upon. It was not scheduled in this period.

PROJECT 395-f-2(j) - RADIATIVE COOLDOWN

The use of the radiation of the dual mode electrical system for saving cooldown propellants is a concept which grew with the original studies. This same concept was studied by North American Rockwell and by TRW Systems. Aerojet supplied ideas and support to these studies to insure their compatibility with the dual mode NERVA system.

The conclusion reached is that this concept is feasible and desirable. The size of the system radiation is a major problem. The selection of a particular mission, hence tank size, and detail engine design limitations will be important factors in the selection of a particular radiative cooldown system. This subject is to be discussed in the Final Report.

ENGINEERING OPERATIONS REPORT

EFFECT OF SIZE OF DUAL MODE SYSTEM
ON COOLDOWN SAVINGS

12 October 1971

J. H. Beveridge

A handwritten signature in cursive script, appearing to read "J. H. Beveridge", is written over a horizontal line.

U : Project 395
Work Statement
Paragraphs f2b and f2c

Approved:

A handwritten signature in cursive script, appearing to read "W. E. Campbell", is written over a horizontal line.

W. E. Campbell, Manager
Engineering Operations

INTRODUCTION

The following discussion presents the results of Project 395 dual mode NERVA sensitivity (f2b) and flexibility (f2c) studies. These studies have been directed to increase the effectiveness of the dual mode electrical system during the cooldown mode of engine operation and thereby increase the payload capability of a lunar shuttle stage. In other words, the dual mode electrical system functions as a radiative residual heat rejection system, thereby reducing the amount of cooldown hydrogen required. The cooldown hydrogen savings offsets the additional hardware weight of the dual mode system. Selection of the optimum size dual mode system and operating the system in the off-design condition enhances the cooldown hydrogen savings.

SUMMARY

The dual mode electric power generation system weight increases with increased power generation capability. The amount of cooldown fluid saved also increases with increased size of the dual mode system. The 25 Kw(e) system is larger than optimum for lunar missions which do not need the 25 Kw(e) power. A 10 Kw(e) system is more nearly optimum from a cooldown-payload standpoint. Payload increases to lunar orbit of 2000 to 7000 lb can be obtained based upon the assumption that cooldown impulse is not utilized. If the cooldown impulse can be utilized, the payload gain ranges from 0 to 4000 lb.

TECHNICAL DISCUSSION

The results, summarized in Figure 1, show that 3 Kw(e) and 25 Kw(e) systems are less optimum systems in comparison with the 10 Kw(e) system. The 3 Kw(e) system does not save enough cooldown hydrogen to be as effective as the larger 10 Kw(e) system. The cooldown fluid savings are shown in Figure 2. In contrast, the 25 Kw(e) system is too heavy

in comparison with its larger cooldown savings. The weights for the three systems are shown in Figure 3. The magnitude of the payload gain from a 3 Kw(e) system to a 10 Kw(e) system is relatively small. (If the additional electric power were useful, the overall situation could be quite different.) These results do not make any allowance for the electric power capability of the dual mode system.

The electric power mode is based upon a 520°R radiator. Increased payloads resulting from cooldown savings can be obtained by operating a given system at higher heat rate during the early portion of cooldown, when the decay power is much greater than the conventional temperature radiator capacity. The approximate residual power level vs. time for a leave Earth orbit burn is shown in Figure 4.

At higher heat rates, the radiator temperature increases and the electric power generation capability decreases. At 600°R radiator temperature, the output electric power is less than half of the normal rating. Increased radiator temperature to 660°R results in zero net electric power capability.

The cooldown hydrogen savings afforded by the radiative residual heat rejection system may reduce the velocity increment of the nuclear stage. The magnitude of this velocity increment, shown in Figure 1, significantly reduces the payload advantage of the dual mode system for a 520°R radiator. Off-design operation during the early phase of cooldown provides a payload gain for the hot radiator dual mode system. The reduced electric power capability is not believed to be a large penalty, because it is of relatively short duration. Also, the effectiveness of the cooldown thrust is very questionable because it occurs long after the main thrusting period when zero thrust may be desired.

Radiator area requirements are shown in Figure 5 as a function of radiated thermal energy for the 3, 10 and 25 Kw(e) systems. These areas are compatible with NERVA stages.

CONCLUSIONS

The best dual mode system size is in the 10 Kw(e) range, based upon the lunar shuttle mission. This size does not create difficulties in the design of the reactor (100 Kw(t)) and the system can be operated off-design for a short period during the early phase of cooldown to enhance cooldown fluid savings.

RADIATIVE COOLDOWN DUAL MODE SYSTEM PAYLOAD GAIN

2.7 LB PAYLOAD (LUNAR) = 1.0 LB HARDWARE

1.5 LB PAYLOAD = 1.0 LB COOLDOWN PROPELLANT

(120,000 LB NOMINAL PAYLOAD TO LUNAR ORBIT)

FIGURE 1

COOLDOWN HYDROGEN SAVING AS A FUNCTION OF RADIATIVE HEAT REJECTION CAPABILITY

FIGURE 2

SYSTEM WEIGHT AS A FUNCTION OF RADIATIVE HEAT REJECTION RATE

FIGURE 3

TYPICAL ENGINE OPERATION THROUGH COOLDOWN PERIOD WITH RADIATIVE DUAL MODE SYSTEM

FIGURE 4

RADIATOR SIZE AS A FUNCTION OF HEAT REJECTION RATE

FIGURE 5