Advanced Oxygen-Hydrocarbon Rocket Engine Study

Contract NAS 8-33452
Bi-Monthly Progress Report 33452M-1
December 1979

Prepared For:
National Aeronatuics And Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

By:
C. J. O'Brien

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FOREWORD

This is the first bi-monthly progress report submitted for the Advanced Oxygen - Hydrocarbon Rocket Engine Study per the requirements of Contract NAS 8-33452. The work is being performed by the Aerojet Liquid Rocket Company for the NASA-Marshall Space Flight Center. The contract was issued on 15 October 1979. The program inclusive dates for period of performance are 15 October 1979 through 15 February 1981. This report covers the period from 15 October to 30 November 1979.

The program consists of parametric analysis and design to provide a consistent engine system data base for defining advantages and disadvantages, system performance and operating limits, engine parametric data, and technology requirements for candidate high pressure LO_2/Hydrocarbon engine systems.

The NASA-MSFC Project Manager is Mr. E. J. Paff. The ALRC Program Manager is Mr. J. W. Salmon and the Project Engineer is Mr. C. J. O'Brien.

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TABLE OF CONTENTS

FIGURE LIST

FIGURE LIST (CONTD.)

I. INTRODUCTION

In the decade of the 1980's and beyond, the nation's expanding space operations may require an improved surface-to-orbit transportation system using advanced booster vehicles which have increased performance and capability compared to the current space shuttle concept. The mixed-mode propulsion principle clearly indicates the potential performance advantages of using high density-impulse rocket propellants in such large ΔV applications. For this reason, hydrocarbon fuels exhibiting increased density relative to liquid hydrogen (LH_2), at the penalty of lower specific impulse, are being considered for the booster propulsion system of space shuttle improvements and derivatives as well as for single-stage-to-orbit and two-stage-to-orbit heavy-payload vehicles.

Preliminary identification and evaluation of promising liquid oxygen/hydrocarbon (LO_2/HC) rocket engine cycles is desirable to produce a consistent and reliable data base for vehicle optimization and design studies, to demonstrate the significance of propulsion system improvements, and to select the critical technology areas necessary to realize such advances.

It is the purpose of this study to generate a consistent engine system data base for defining advantages and disadvantages, system performance and operating limits, engine parametric data, and technology requirements for candidate high pressure LO_2/HC engine systems. The study will also synthesize optimum LO_2/HC engine power cycles and generate representative conceptual engine designs for a specified advanced surface-to-orbit transportation system.

To accomplish the program objectives, the study is composed of four major technical tasks and a reporting task. These tasks and summarized objectives are:

I, Introduction (cont.)

A. TASK I - ENGINE CYCLE CONFIGURATION DEFINITION

Formulate and assess families of high chamber pressure LO_2/HC engine cycles.

B. TASK II - ENGINE PARAMETRIC ANALYSIS

Generate performance, weight, and envelope parametric data for viable concepts based upon historical data and conceptual evaluations.

C. TASK III - ENGINE/VEHICLE TRAJECTORY PERFORMANCE ASSESSMENT (ENGINE SCREENING)

Conduct a preliminary comparison of selected engine cycles utilizing a simplified vehicle trajectory performance model.

D. TASK IV - BASELINE ENGINE SYSTEMS DEFINITION

Prepare preliminary designs of two baseline engine configurations. Conduct heat transfer, turbomachinery, combustion stability, structural, and controls analysis of the baseline engines and components. Conduct a parametric sensitivity analysis including the effects of turbine temperature and number of usable life cycles. Provide the appropriate data in a format suitable for use in vehicle application analyses.

E. TASK V - REPORTING

Provide informal bi-monthly technical and fiscal progress reports, hold program reviews at NASA/MSFC and prepare a final report.

II. TECHNICAL PROGRESS SUMMARY

The overall progress on the program is indicated in Figure 1.

II, Technical Progress Summary (cont.)

A. TASK I - ENGINE CYCLE CONFIGURATION DEFINITION

Preliminary engine specifications are being prepared for the families of candidate cycles selected from the general conceptual matrix of potential cycle choices shown in Figures 2 and 3. Cycle schematics for some of these cycles and for additional promising cycles are given in Figures 4 through 21.

B. TASKS II - IV

No activity scheduled.

C. TASK V - REPORTING

The study program plan defining the methods and technical approach to be used in achieving the objectives and requirements set forth in the Statement of Work was submitted to NASA-MSFC on 20 October 1979.

III. CURRENT PROBLEMS

The heat transfer effort will not be initiated until January. This will not cause a slip in the overall schedule.

IV. WORK PLANNED

A. TASK I

Complete the power cycle matrix and preliminary engine specifications. Initiate the engine performance analysis effort.

IV, Work Planned (cont.)

B. TASK II

Initiate the engine weight and envelope parametric analysis subtasks.

C. TASK III

Define the mission characteristics and select a two-stage heavy lift vehicle for approval by the NASA/MSFC Project Manager.

D. TASK IV

No scheduled activity.

E. TASK V

Conduct a program review with NASA/MSFC personnel at ALRC on 11 December 1979.

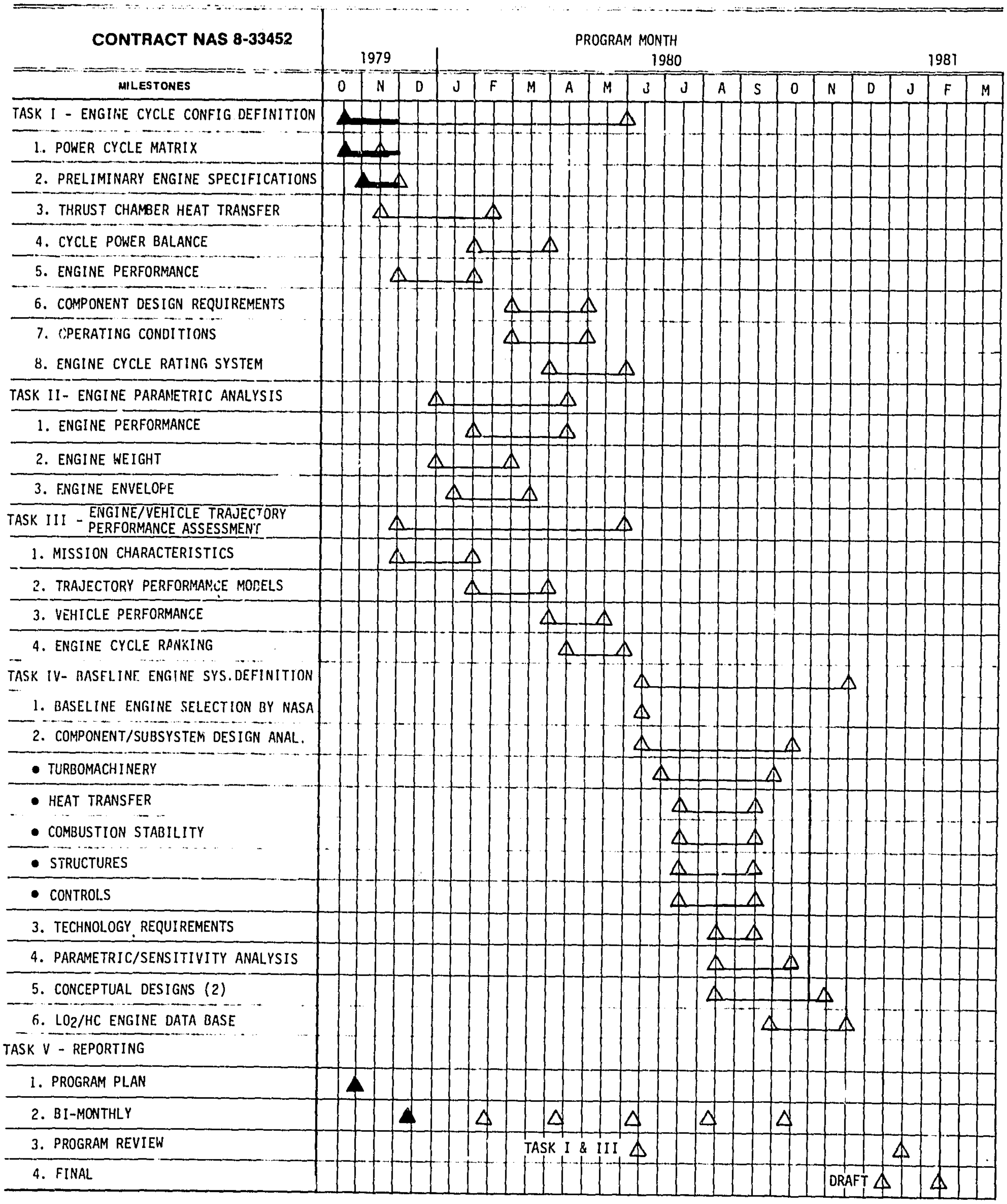

Figure 1. Major Milestone Schedule

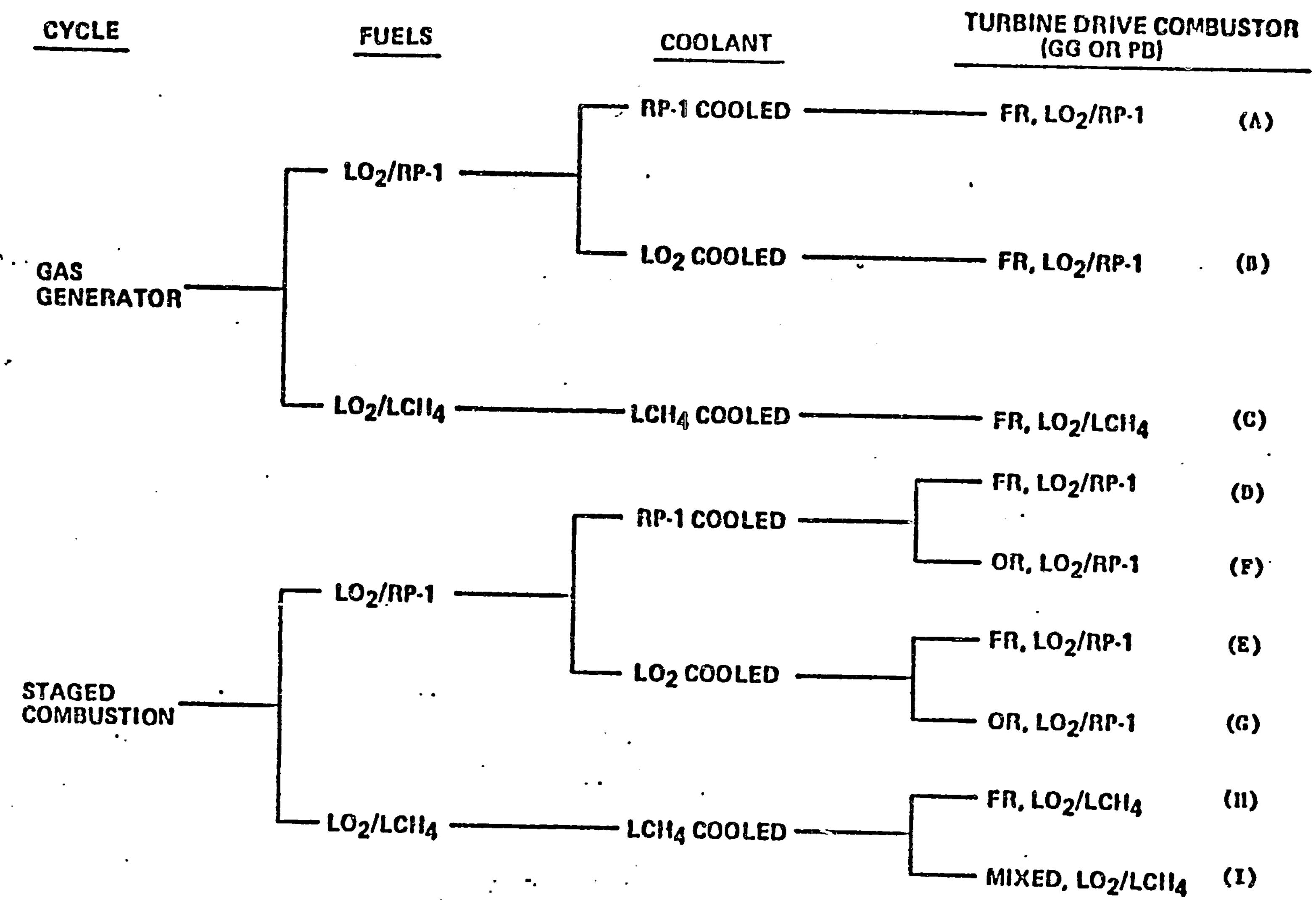

Figure 2. Candidate Cycles for Advanced LO_2/HC Engines

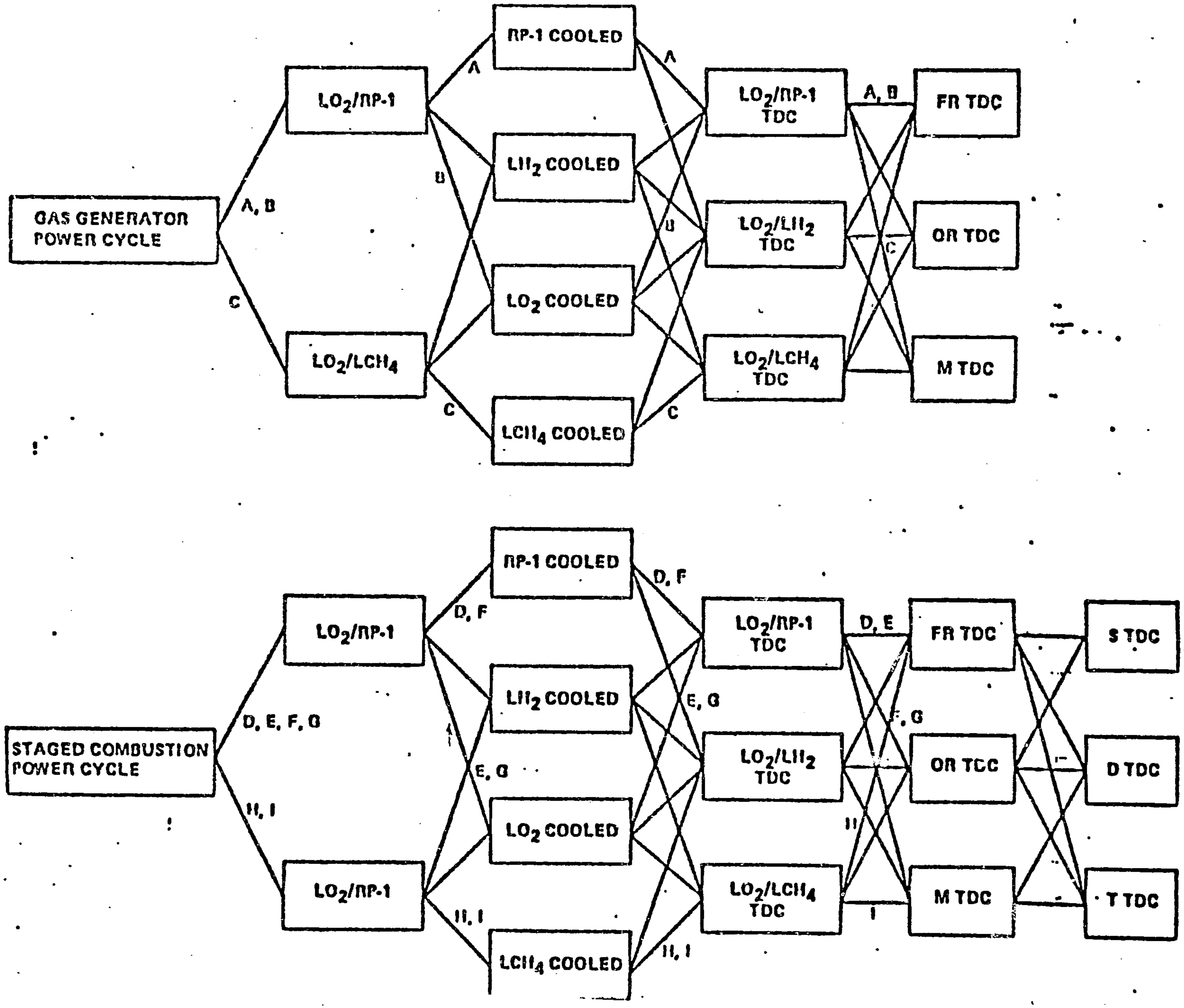

Figure 3. Concept Array of Potential Cycle Choices for Advanced LO_2/HC Engines

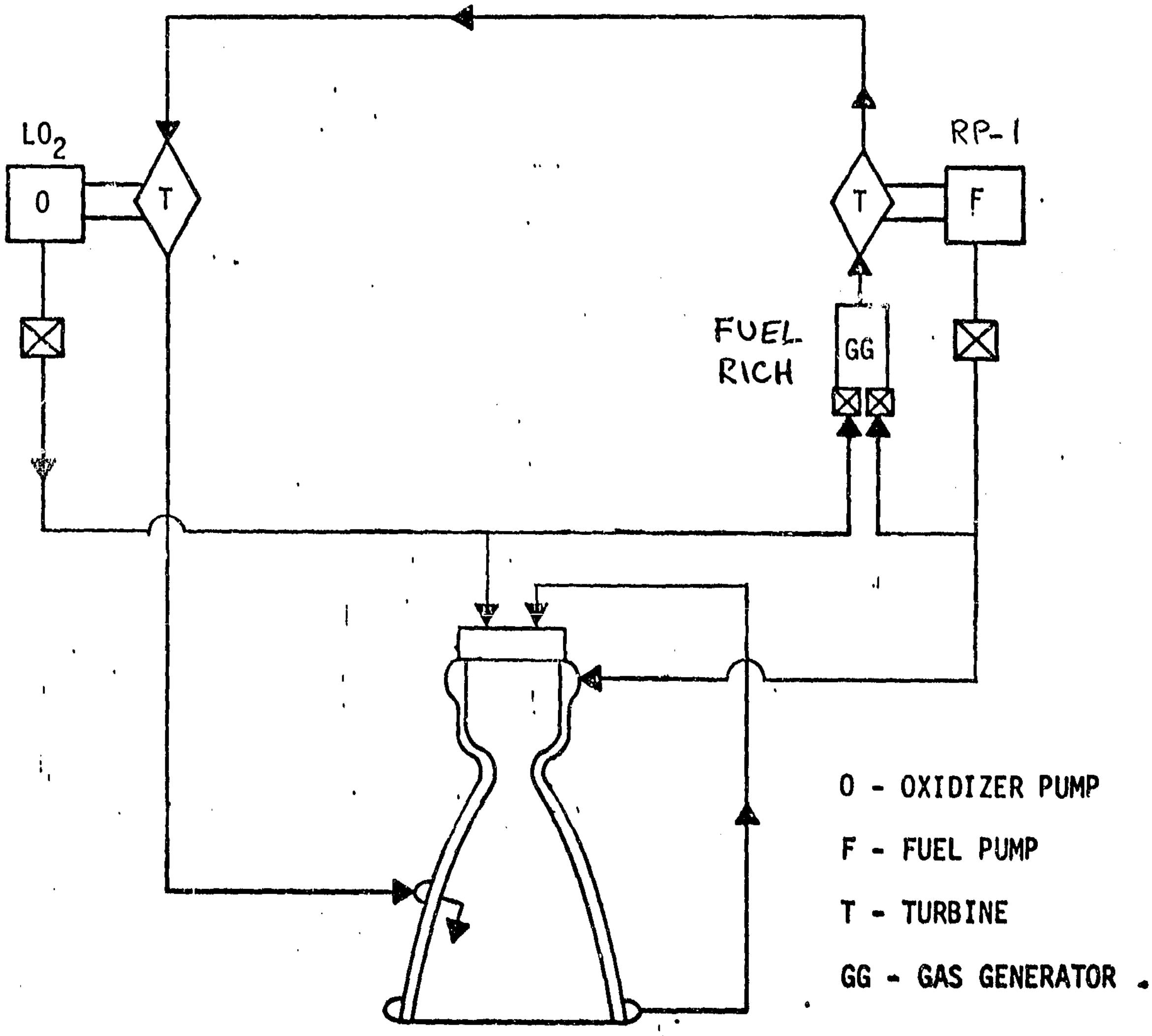

Figure 4. RP-1 Fuel-Rich Gas Generator Cycle (a) RP-1 Cooled

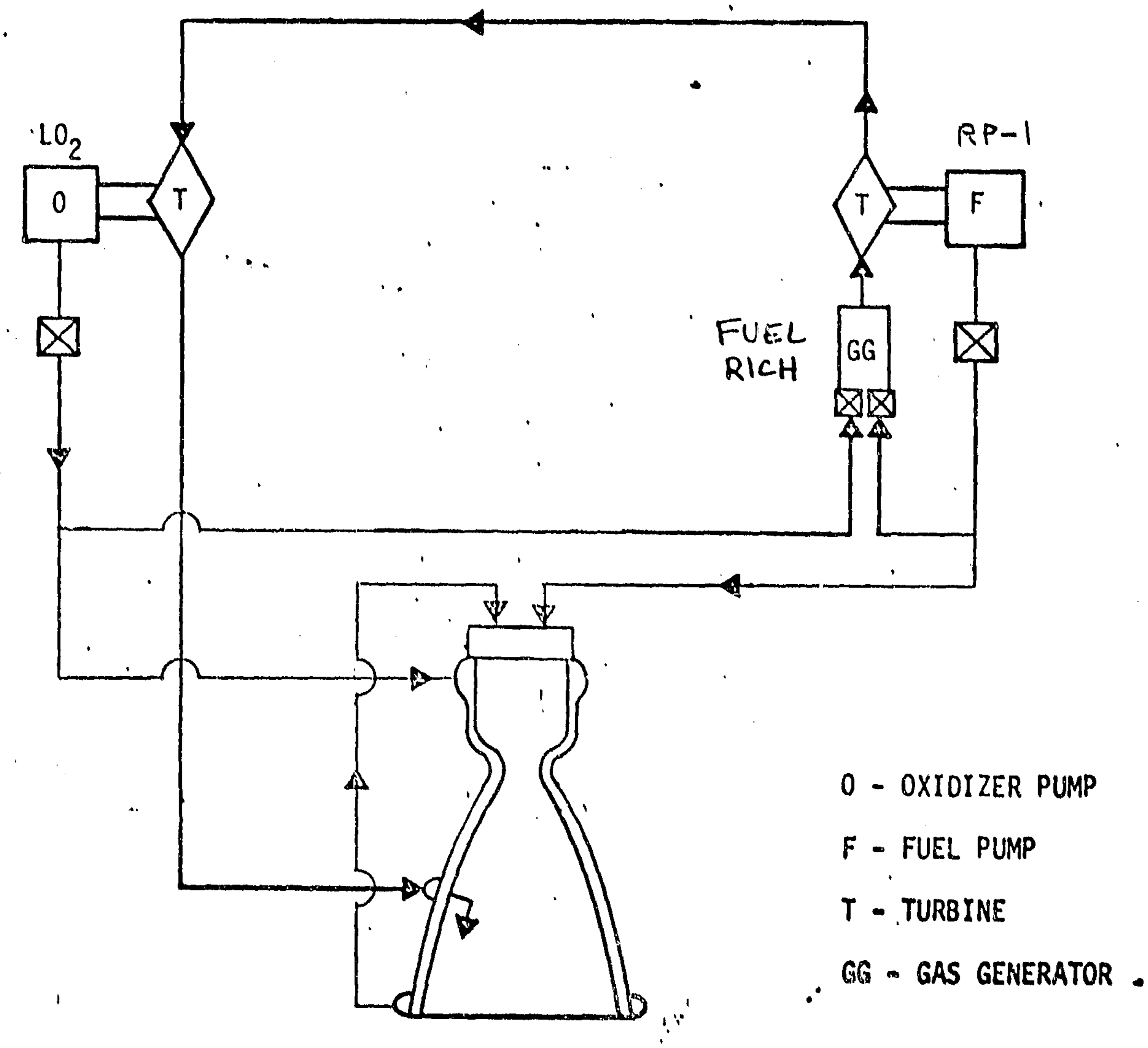

Figure 5. RP-1 Fuel-Rich Gas Generator Cycle (b) LO_2 Cooled

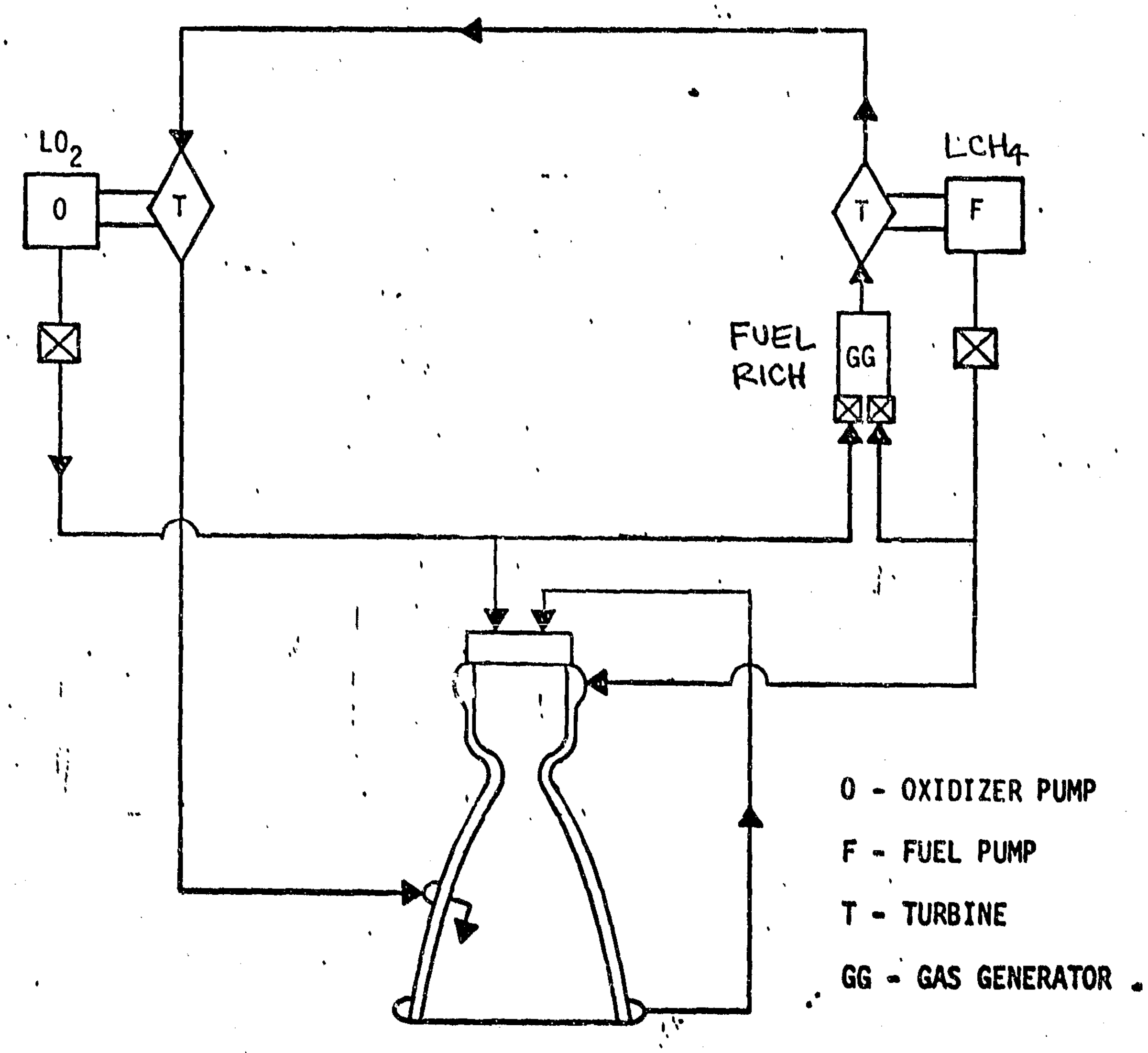

Figure 6. RP-1 Fuel-Rich Gas Generator Cycle (c) LCH_4 Cooled

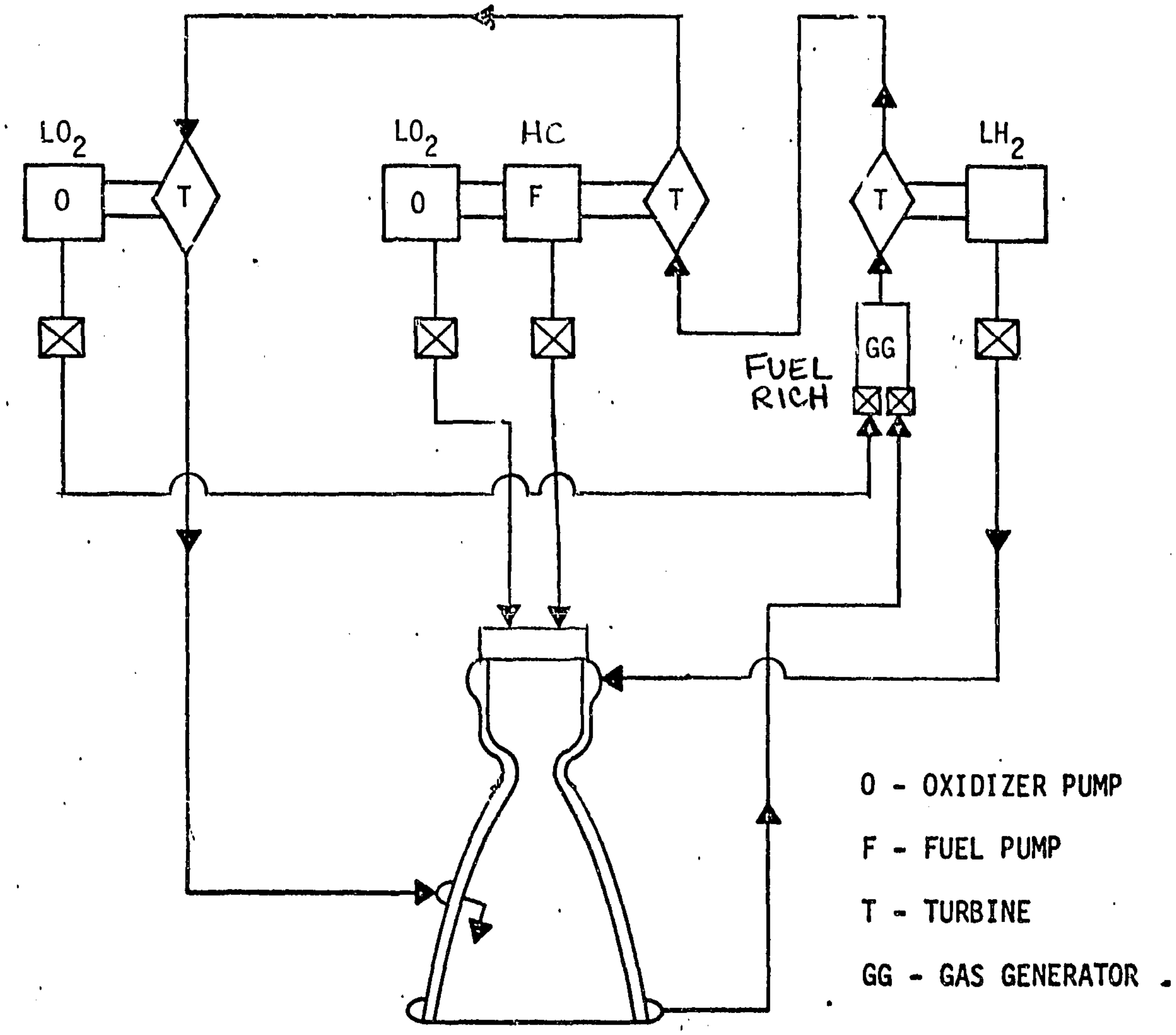

Figure 7. LO_2/HC Engine Fuel-Rich LH_2 Gas Generator Cycle (j) LH_2 Cooled

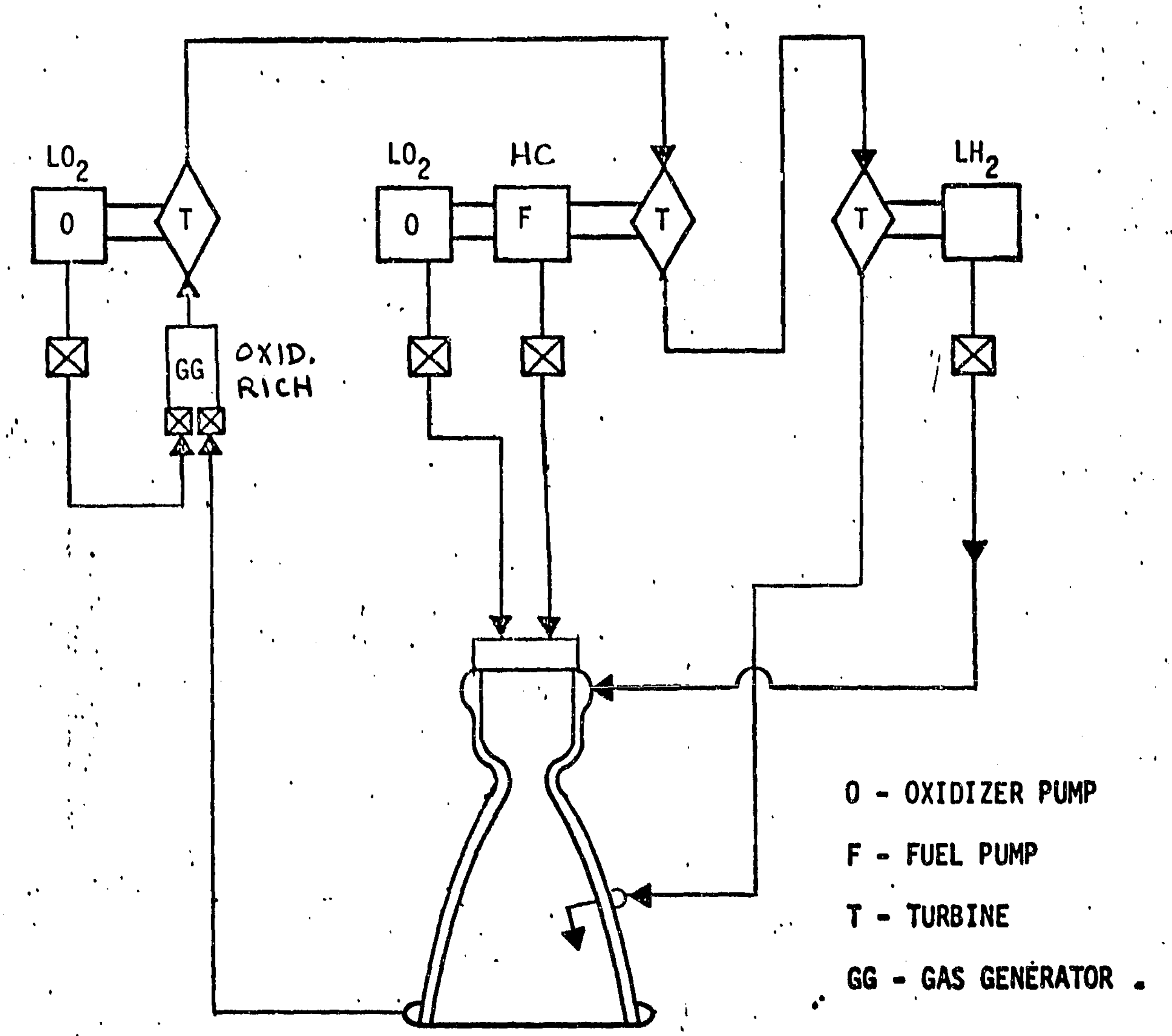

Figure 8. LO_2/HC Engine Oxidizer-Rich LH_2 Gas Generator Cycle (k) LH_2 Cooled

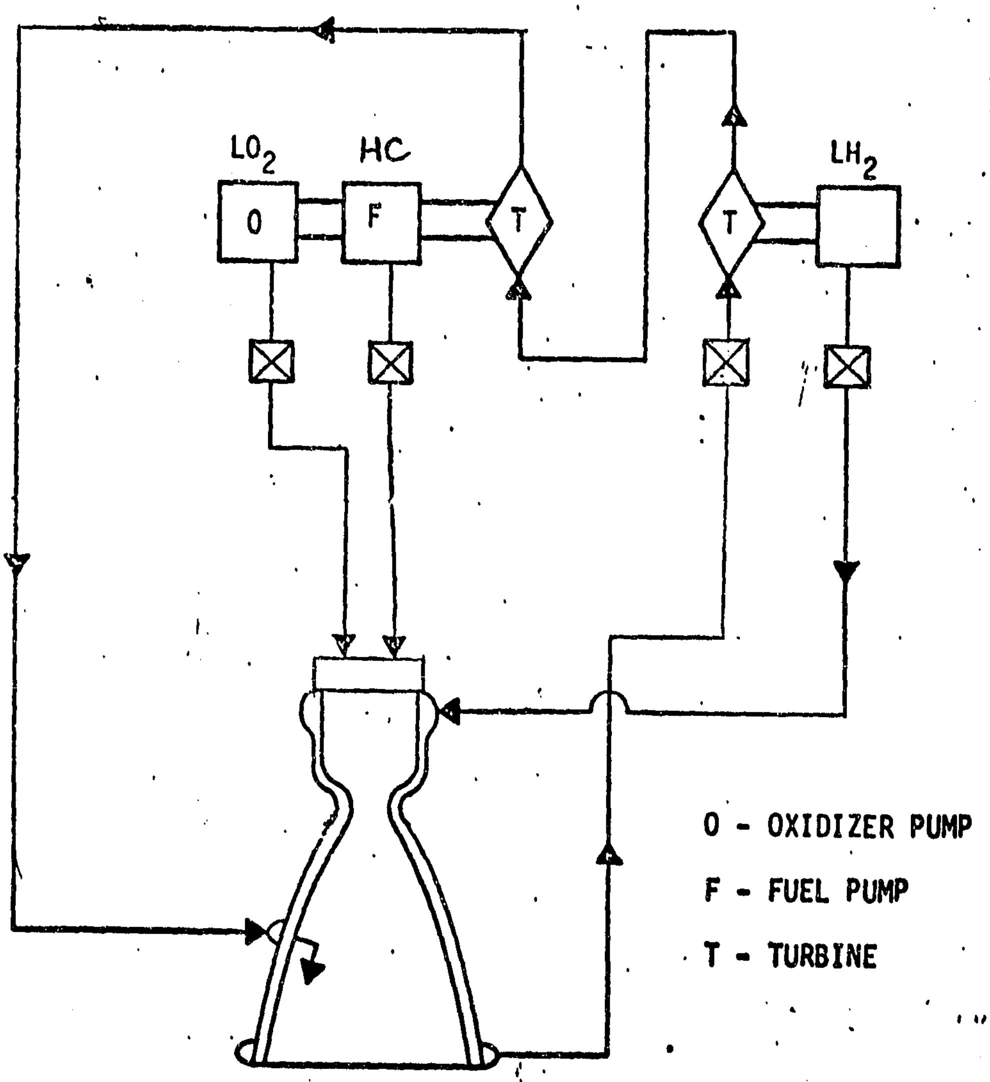

Figure 9. LO_2/HC Engine LH_2 Expander Bleed Cycle (1) LH_2 Cooled

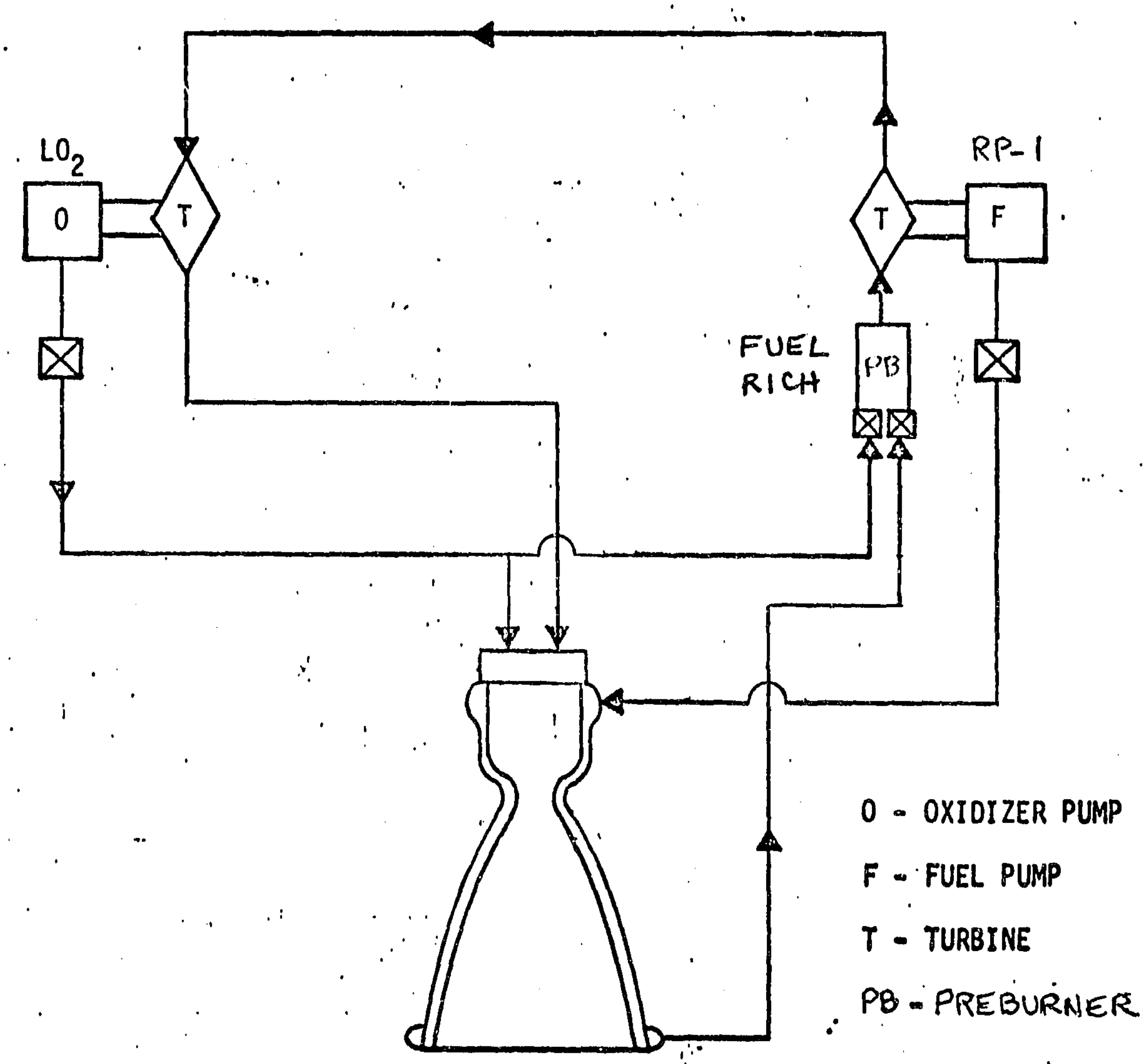

Figure 10. RP-1 Fuel-Rich Preburner Staged Combustion Cycle (d) RP-1 Cooled

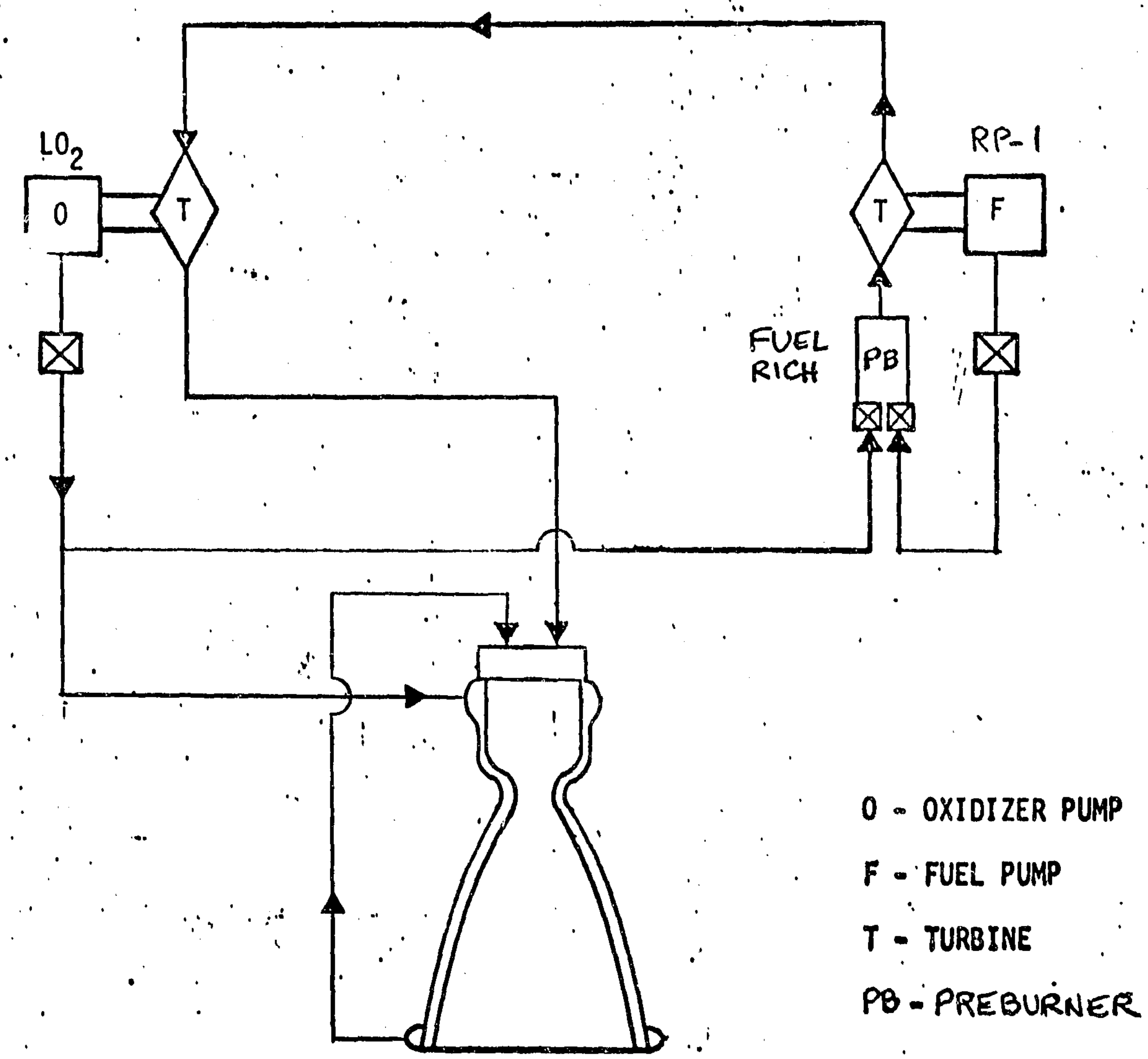

Figure 11. RP-1 Fuel-Rich Preburner Staged Combustion Cycle (e) LO_2 Cooled

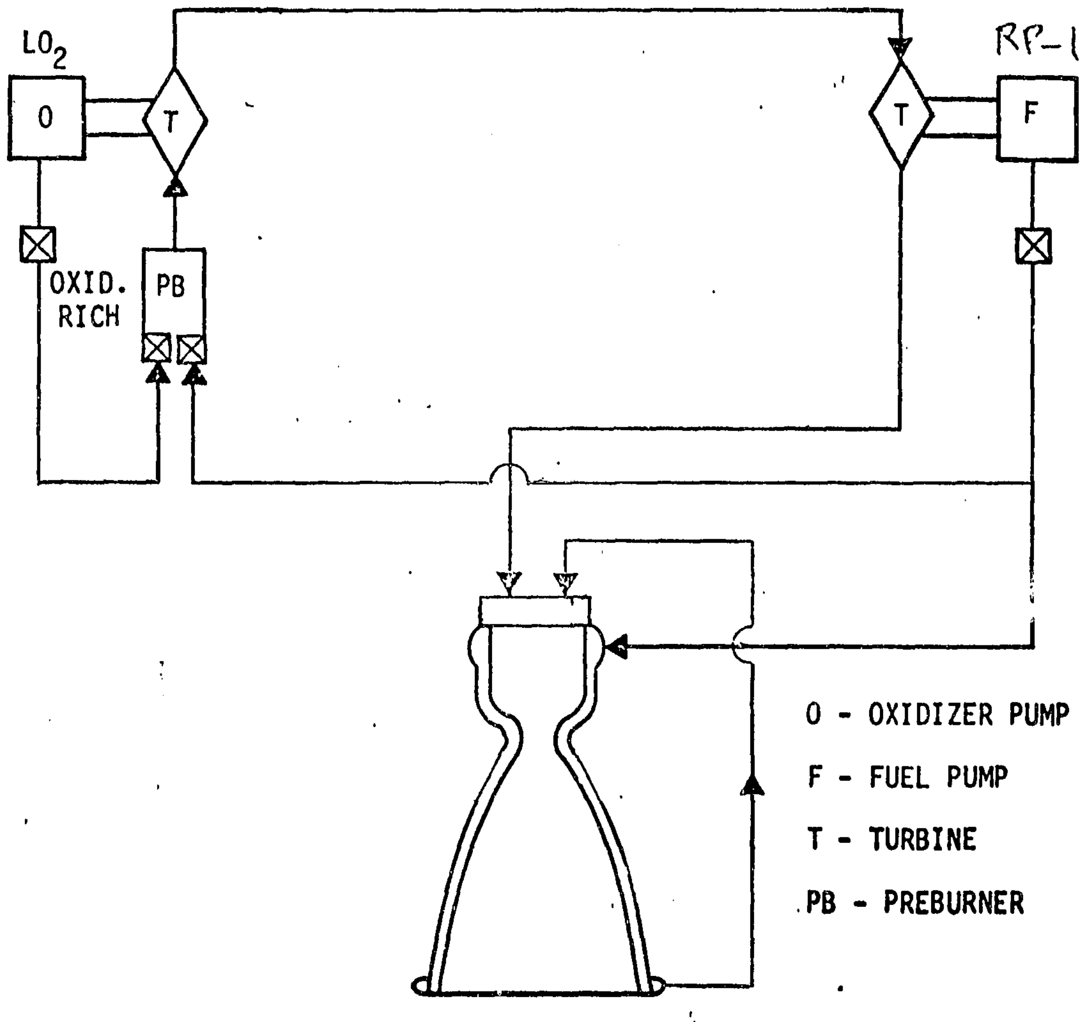

Figure 12. RP-1 Oxidizer-Rich Preburner Staged Combustion Cycle (f)
RP-1 Cooled

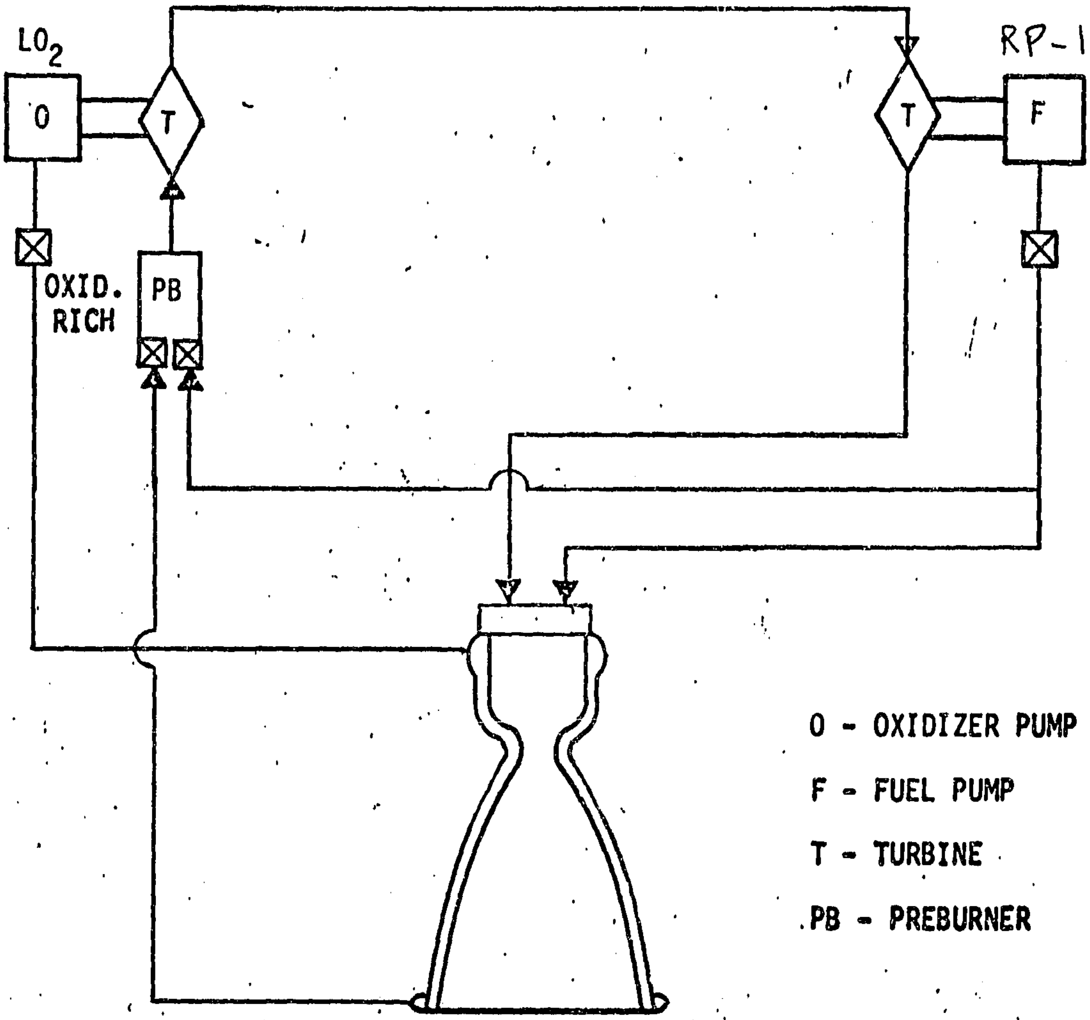

Figure 13. RP-1 Oxidizer-Rich Preburner Staged Combustion Cycle (g) LO_2 Cooled

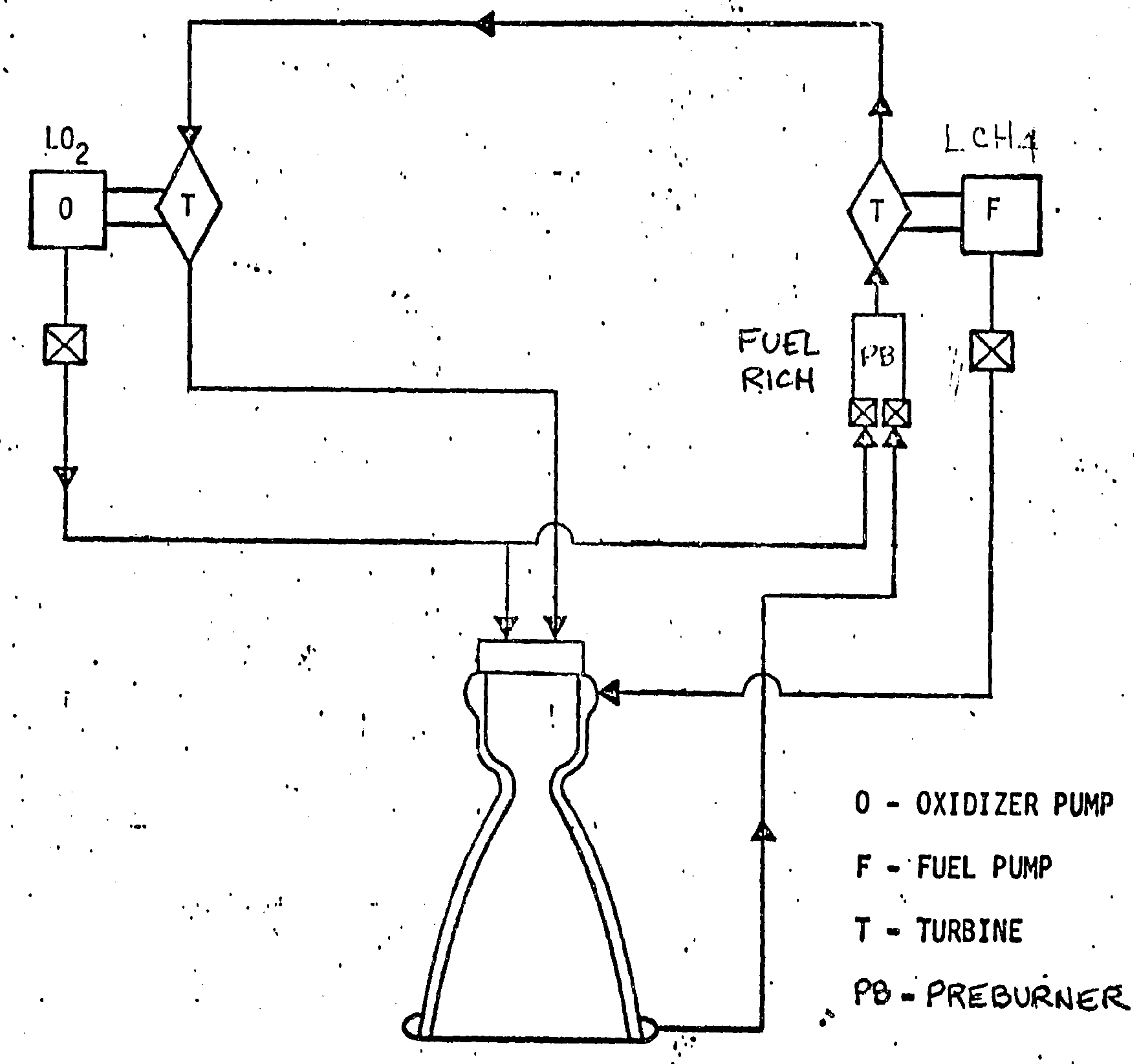

Figure 14. LCH_4 Fuel-Rich Preburner Staged Combustion Cycle (h) LCH_4 Cooled

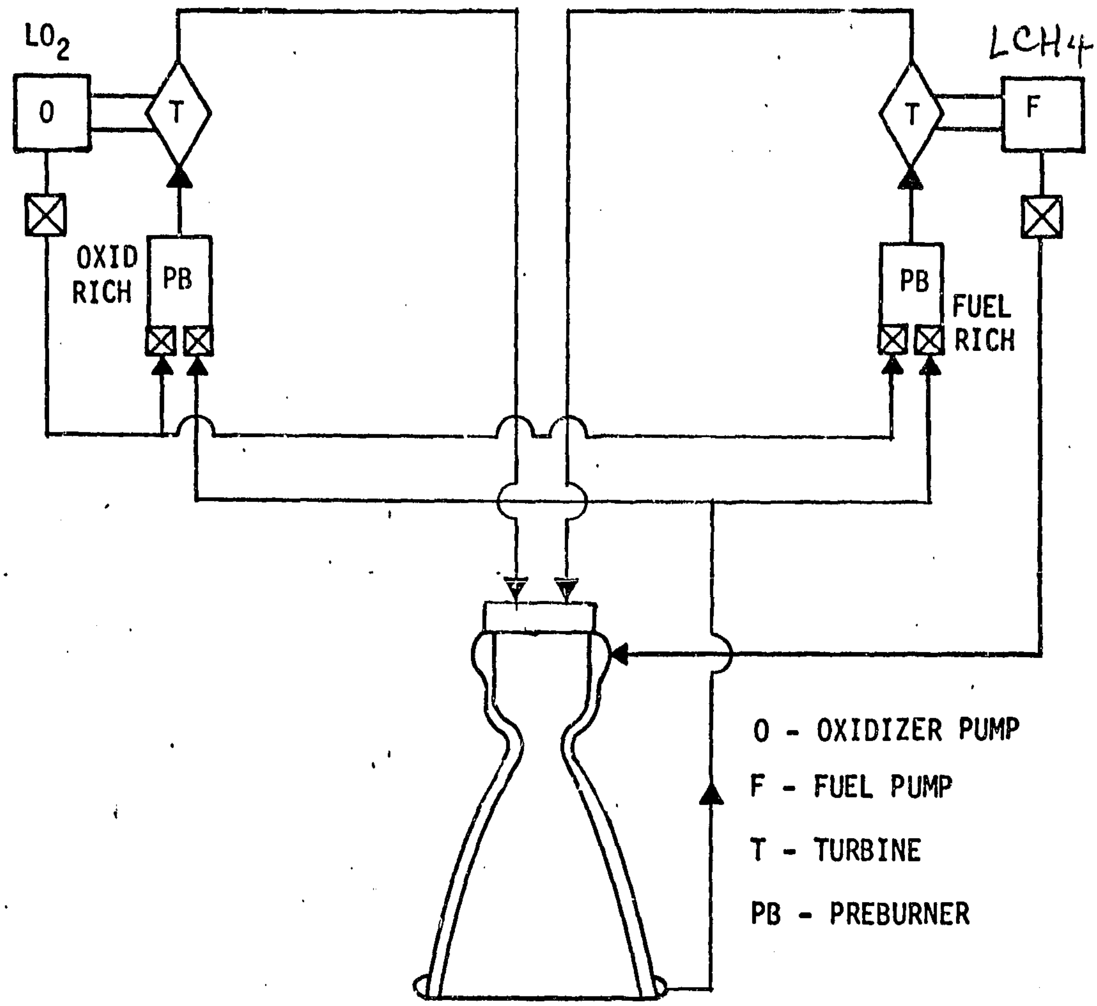

Figure 15. LCH_4 Mixed Preburner Staged Combustion Cycle (i) LCH_4 Cooled

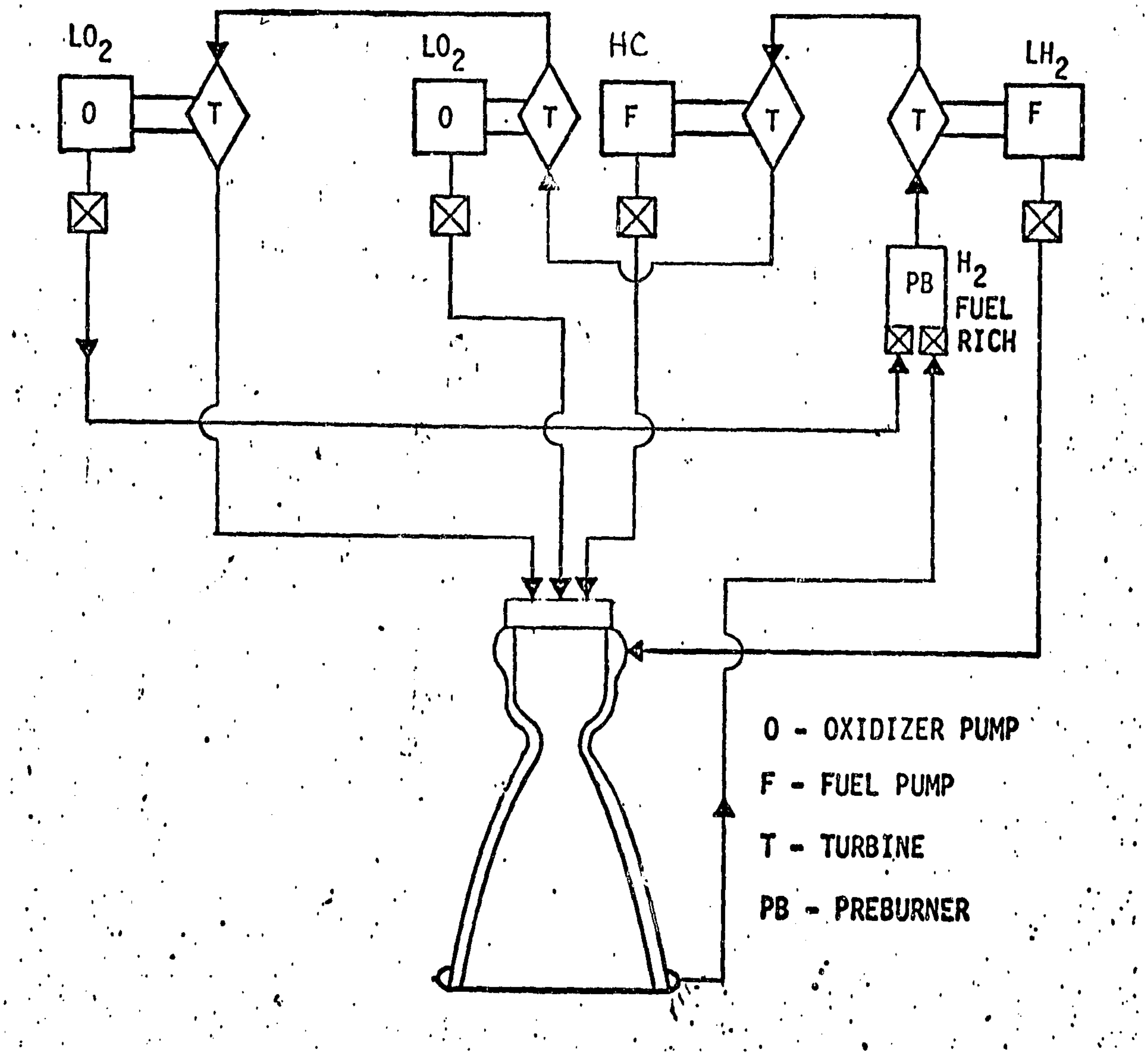

Figure 16. LO_2/HC Engine Staged Combustion Cycle (1 Preburner) LH_2 Cooled

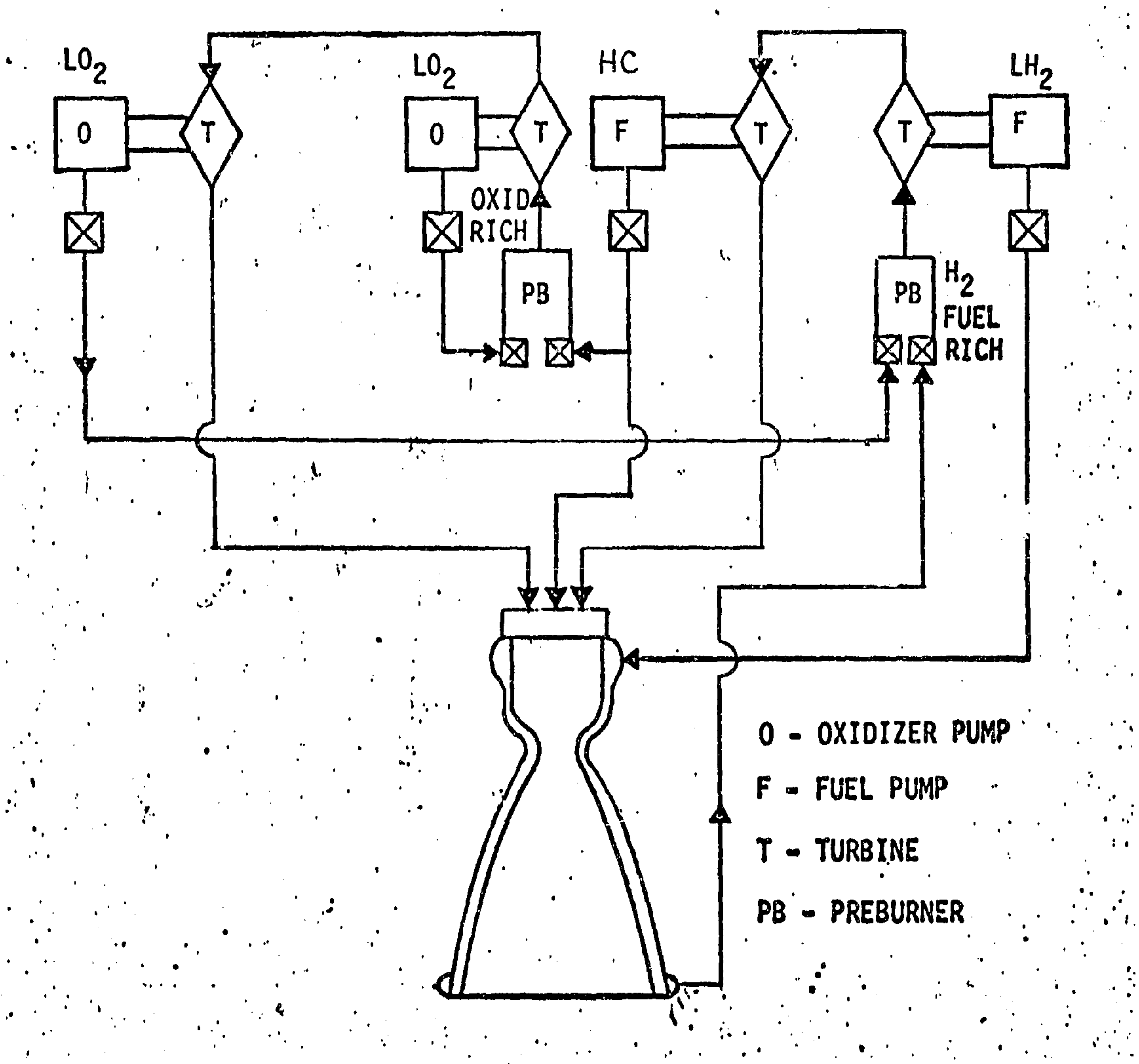

Figure 17. LO_2/HC Engine Staged Combustion Cycle (2 Preburner) LH_2 Cooled

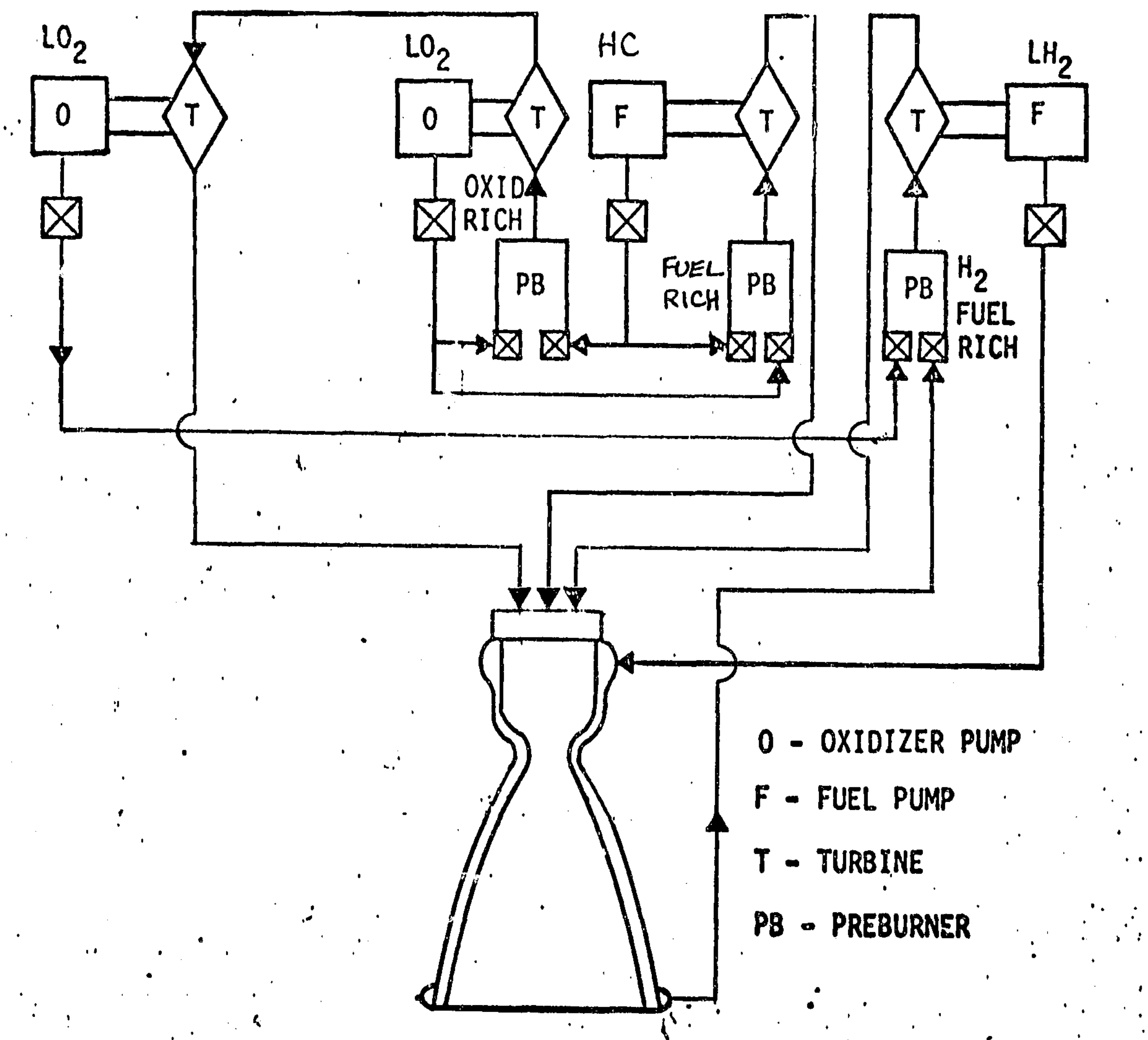

Figure 18. LO_2/HC Engine Staged Combustion Cycle (3 Preburner) LH_2 Cooled

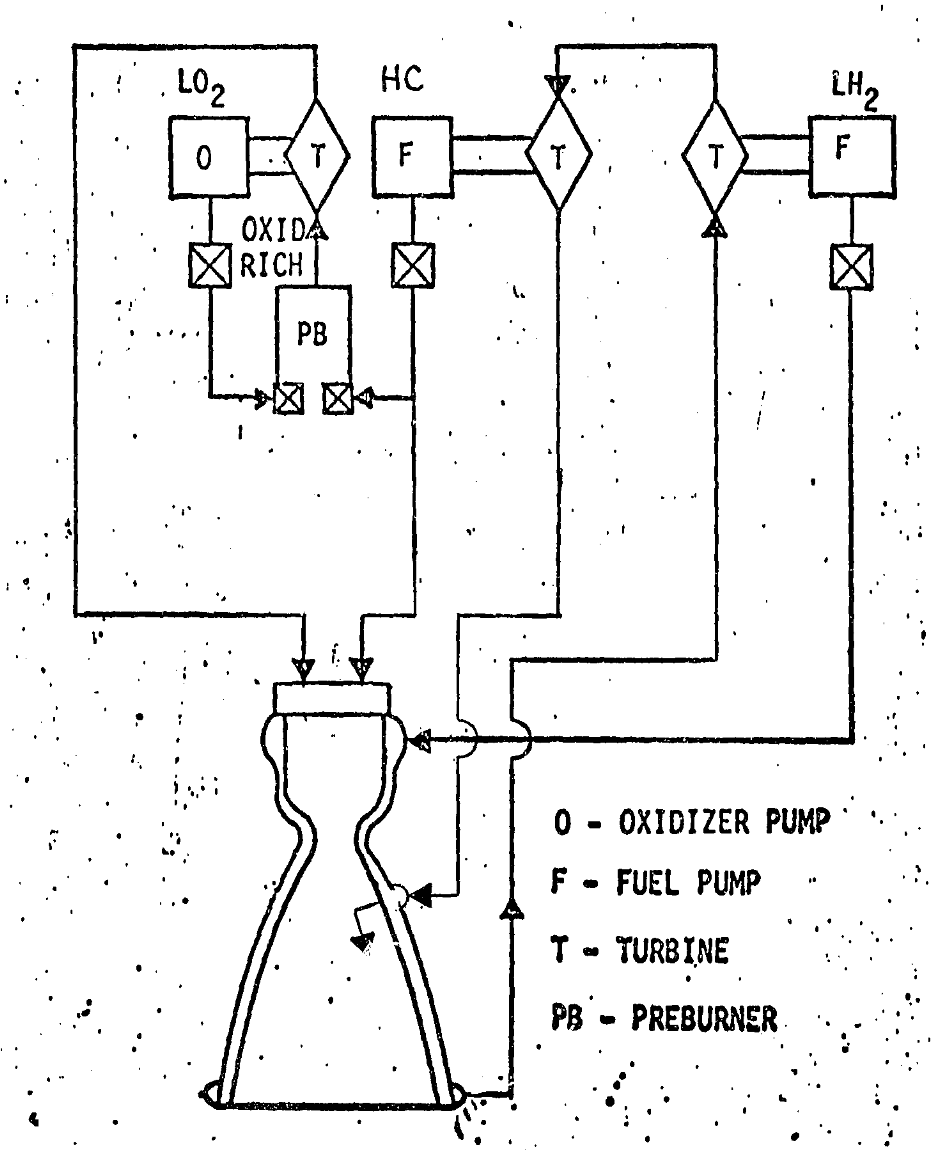

Figure 19. LO_2/HC Engine Staged Combustion/Expander Bleed Mixed Cycle - LH_2 Cooled

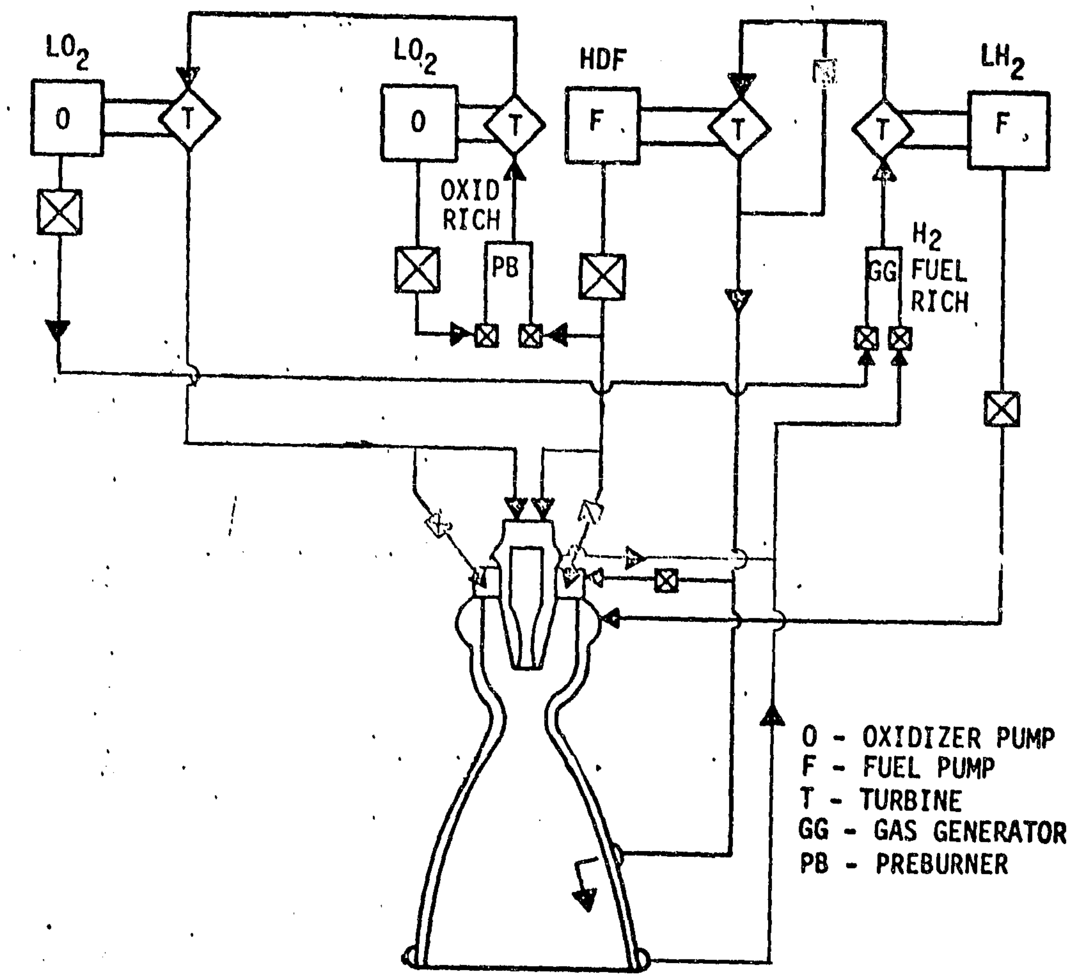

Figure 20. LO_2/HC Dual-Throat Engine Mixed Gas Generator/Staged Combustion Cycle - LH_2 Cooled

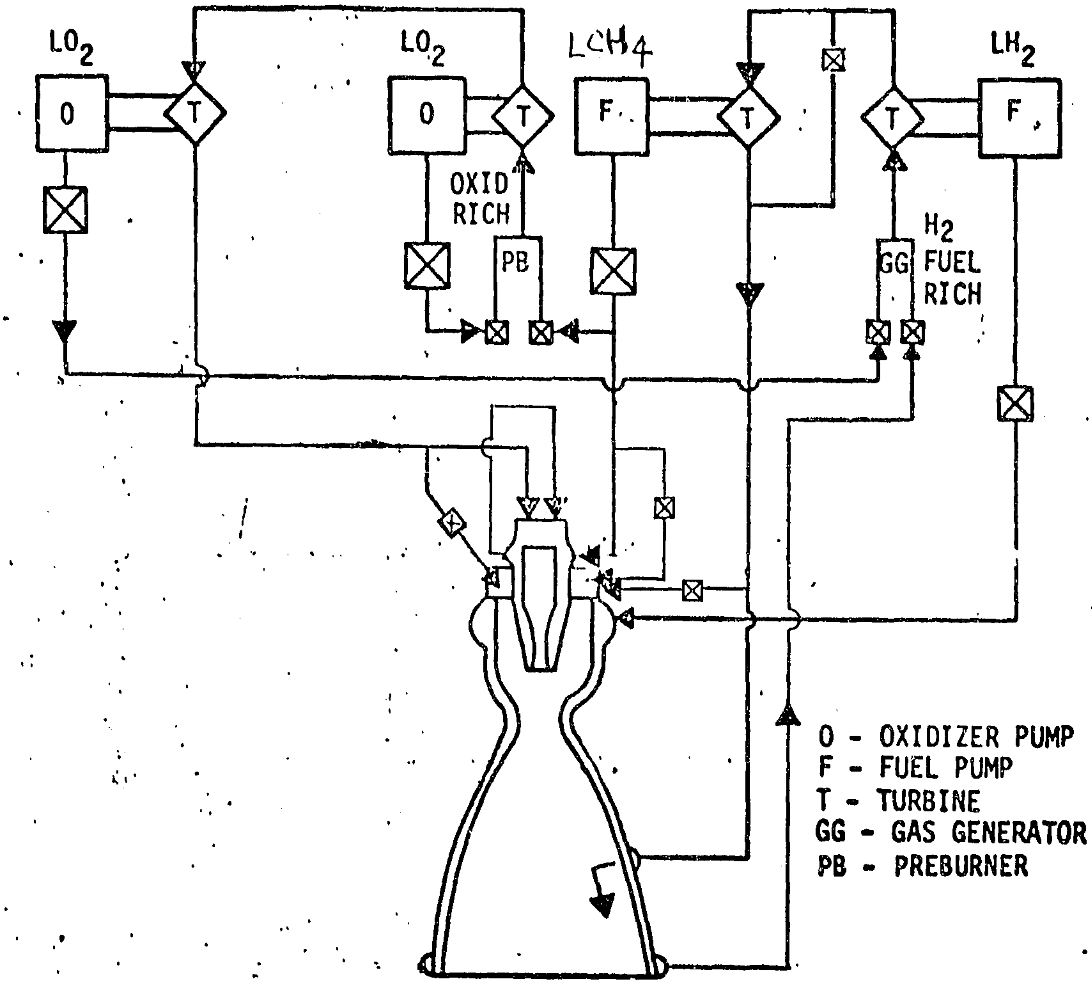

Figure 21. LO_2/LCH_4 Dual-Throat Engine Mixed Gas Generator/Staged Combustion Cycle - LCH_4 and LH_2 Cooled