NASA - Lewis

December 6, 1962

MEMORANDUM For Deputy Director - E. J. Manganiello

Subject: Proposed contract study, "Preliminary Design of Turbopump for Advanced Nuclear Rockets"

1. The subject proposal is very complete and covers the design study of the turbopump very well. It may indicate too much detail encouraging the contractor to expend effort on details which will not be beneficial to the government. (For example, I-C-6, required torque on all fasteners).

2. Two study programs that have already produced a great deal of similar information should be pointed out.

(a) For nearly a year, Lewis, Marshall, and Aerojet have been carrying on an intensive design study of the hydrogen turbopump for the M-1 engine. The present pump design conditions result in a flow of 640 lb/sec. and discharge pressure of 1800 lb/in^2. Most of the fundamental problem areas that determine the choice of configuration between centrifugal, multistage centrifugal, and multistage axial flow, were considered in this design study.

(b) An Advanced Technology contract has been underway at Rocketdyne to study high pressure and high flow pumping. The proposals and definition of this project have been a joint result of Marshall and Lewis with Marshall managing the contract. Turbopump design configurations have been studied up to 6,000,000 lbs. thrust level (2500 lbs/sec., LH_2) and chamber pressure from 1000 to 5000 psi. Lewis has been invited to suggest items for study in the follow-on program in high pressure pump technology.

3. Even though the above hydrogen turbopump studies are for chemical rocket they cover a large portion of the turbopump problems in the nuclear rocket. The effect of the radiation field on choice of materials and problems specifically associated with the nuclear rocket start and shutdown procedures are still being defined and studied under the Nerva development and it is doubtful that new information can be obtained in a study program.

4. Considering items 2 and 3 above, it is suggested that those areas which seem to be duplication not be considered in the subject program. (Such as axial vs. centrifugal - thrust balance - critical speed - etc.).

5. On the other hand the previous studies have not particularly considered boost pumps except to admit the desirability and necessity of a boost pump. No boost pumps of the range of sizes required have been involved in a development program. High suction performance data has recently become available from the Lewis research program and other studies which are applicable to boost pumps.

6. From the above it is suggested that the subject study be directed primarily at boost pump design studies. Specific problems to be suggested for investigation in the High Pressure Pumping Technology Contract (Rocketdyne) follow-on program (paragraph 2-B above) should be directed to the Turbopump Branch, Fluid System Components Division.

Melvin J. Hartmann
Head, Pump Section
FSCD

Enclosure:
Contract Study Proposal

MJH:slp
AG
IIP

Copies to: Files
Deputy Director
I. I. Pinkel
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PRELIMINARY DESIGN OF TURBOPUMPS

FOR

ADVANCED NUCLEAR ROCKETS

The turbopump unit required for a possible future nuclear rocket system is currently envisioned as having a capacity of 1000 lb/sec of liquid hydrogen at a discharge pressure of 2000 psia. To facilitate the development of such a unit, a series of preliminary designs is required to judge the merits of several types of pumps and power cycles and to gain an insight into possible mechanical restrictions and problem areas which may evolve. Furthermore, the use of existing technology, i.e., proven levels of blade, bearing and seal loading, bearing DN values, seal rubbing surface speeds, rotor tip speeds, etc., is required to demonstrate the adaptability of this technology to future system and/or to determine areas which may demand advanced technology. The requirements set forth in the following items are designed to produce four preliminary designs of turbopump units that will provide the basis for future development programs of turbopumps for advanced nuclear rocket engines.

STATEMENT OF WORK

Item I: Preliminary Designs of a Liquid Hydrogen Turbopump

A.

A. The contractor will establish four (4) separate preliminary turbopump designs and one boost pump design with the capability of pumping 1000 lb/sec of liquid hydrogen and which fulfill the general requirements set forth in Item II. The individual designs will be based on the specific design requirements set forth in Item III. The final configuration of each design will be coordinated with and approved by Lewis Research Center's project engineers.

B. The contractor will analyze each design on an overall and component basis and report the results. The analysis will include but not be restricted to the following:

1. Selection of blade shape and blading arrangement, to include comparisons of various blade types and reasons for choosing a particular configuration.

2. Determination of hydrodynamic and aerodynamic dimensional and non-dimensional performance parameters, and design criteria for all blading, e.g. blade loading, solidity, head rise and flow coefficients, velocity vector diagrams, blade-jet speed ratio, etc.

3. Determination of estimated performance maps of the pump and turbine, including pump suction performance.

4. Comparison of bearing and seal materials, lubrication methods, and designs including an estimate of the expected life under load and radiation environments.

5. Calculation of axial thrust balancing system performance and characteristics.

6. Evaluation of all materials and expected radiation, thermal shock and thermal expansion effects.

7. Evaluation of critical speed and an estimate of vibratory and g-load effects that will result from a given degree of unbalance. Choose several values of unbalance (within current balance limitations) for analysis.

8. Evaluation of varying component arrangement on critical speed, bearing loads, seal loads, etc., and selection of optimum.

9. Breakdown of estimated weight by individual components.

10. Effects of varying g-loading on all components for both operational and shut-down conditions.

11. Effects of continuous and intermittant operation on bearing and seal life.

6. The contractor will develop complete assembly and detail drawings of each design. These drawings will include but not be restricted to the following:

1. Physical dimensions of entire unit and all components.

2. Complete list of materials.

3. Assembly, alignment, and balancing procedures and degree of accuracy required.

4. Required balance of rotating parts.

5. Required clearances on rotor blades, seals, bearings, assembly of parts, etc.

6. Required torques on all fasteners.

Item II: General Requirements for All Designs

A. System Configuration

1. Boost pump (geared or turbine powered)

2. Inducer (intregal with main pump)

3. Main Pump (consider both single and multiple outlets for discharge flow)

4. Turbine (bolted coupling with pump shaft)

5. Vertical installation

B. Materials

1. Lightweight

2. High strength

3. Radiation resistant (see "J")

C. Bearings

1. Anti-friction type (DN values within proven load limitations and proven lifetime performance)

2. Liquid and/or gaseous hydrogen lubricated and/or cooled

3. Radiation resistant (see "J")

D. Seals

1. Rubbing surface and labyrinth types.

2. Rubbing speeds within proven limitations.

3. Radiation resistant (see "J")

E. Weight of Entire Unit

1. As light as possible for flight application.

F. Size Envelope

1. Minimum possible for flight application.

G. Critical speed (either of following)

1. First mode 10 percent higher than operating speed.

2. First mode as low as possible with the second mode 10 percent higher than operating speed.

H. Axial Thrust Balance System

1. Pressure compensating type

I. Component Arrangement

1. Dual shaft design with direct coupling

2. Bearing and seal locations optional

3. Mounting attachments suitable for flight installation

J. Flight and Operating Data

1. Sea level to deep space

2. 0 to 10 g's acceleration load

3. 10 minute continuous operation or 5 - 2 minute intermittant periods with restart and shutdown

4. Thermal shock and distortions in pump up to a ΔT of $\sim 500^{\circ}$

5. Radiation field:

a. 10^8 rad/hr gamma dose rate

b. 5×10^{12} n/cm^2-sec fast neutron flux

Item III: Design Requirements for Individual Components

A. Boost Pump

1. Type - Mixed Flow

2. Blading - Established Technology

3. NPSH - 0 psia - TSH

4. Discharge - 20 psia

5. Flow Rate - 1000 #/sec.

B. Main Pump plus Inducer

	Design Number 1	2	3	4
1. Type	Axial	Centrif.	Axial	Centrif.
2. Blading	Established Technology ----------			
3. NPSH	As low as possible			
4. Discharge Pressure	2000 psia	2000 psia	To be determined	
5. Flow Rate	1000 #/sec ----------			

C. Turbine

	Design Number			
	1	2	3	4
1. Type	Axial ----------			
2. Blading	Established Technology ----------			
3. Cycle	Bleed	Bleed	Topping	Topping
4. Inlet Temp.	2000° R	2000° R	To be determined	
5. Inlet Pressure	1000 psia	1000 psia	To be determined	
6. Exit Pressure	To be determined		2000 psia	2000 psia

Item IV: Reports of Work

A. Monthly Progress Letters - The contractor will submit a monthly progress letter of all work accomplished during each month of contract performance. The letter shall be brief and informal in content and be in a narrative form. The letters shall include the following:

1. A quantitative description of the reporting month's progress and overall contract progress.

2. A description of any problems which could impede performance of the Statement of Work and the methods of corrective action.

3. A description of work to be performed during the next monthly reporting period.

Monthly letters will be submitted in three copies plus one reproducible copy.

B. Final Report - The contractor will submit a final report which documents and summarizes the results of the entire contract work, including recommendations and conclusions based on the analysis and results of all the designs. The final report will include tables, graphs, vector diagrams, equations and methods used for calculations, nomenclatures and sketches in sufficient detail to explain and clarify the results and detail and assembly drawings of each design.

The final report will be submitted in six copies plus a reproducible copy.