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LOW COST TURBOPUMP STUDY

by

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Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA George C. Marshall Space Flight Center Contract NAS 8-24859 Lee Jones, Project Manager NOTICE

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FINAL REPORT

LOW COST TURBOPUMP STUDY

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

The study described herein, which was conducted by the Aerojet Liquid Rocket Company, Sacramento, California, was performed under Contract NAS 8-24859. It covers the period 30 June 1969 through 13 February 1970. The contract was sponsored by the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. It was administered under the technical direction of the Propulsion and Thermodynamics Division with Mr. Lee Jones as Project Manager.

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ABSTRACT

A Low Cost Turbopumps Study was accomplished. It was aimed at developing a methodology for synthesizing lowest over-all cost turbopumps, which means that turbopump resulting in the lowest cost for a particular mission. This was done by examining the extent as well as manner that turbopump requirements affect over-all costs, investigating the technological level of cost-contributing operations, and evaluating the effect of this technological level upon over-all costs. The results then were utilized to evolve an optimal conceptual design of a selected turbopump configuration, along with preliminary planning for the development, production, and acceptance of the turbopump. The overwhelming conclusion from the study results is that a relaxation in requirements to reduce turbopump costs is not a fruitful way to decrease program costs. In effect, the potential exists for reducing turbopump program costs by as much as 40% (or 200-million dollars) through the appropriate tightening of design requirements to a degree that would permit acceptance test operations to be eliminated. Additionally large over-all program cost reductions could be accrued through this approach because of the cost sensitivity to engine performance (I sp).

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I. SUMMARY

The Low Cost Turbopumps Study was aimed at developing a methodology for synthesizing lowest over-all cost turbopumps, which means that turbopump resulting in the lowest cost for a particular mission. This was accomplished by examining the extent as well as manner that turbopump requirements affect over-all costs, investigating the technological level of cost-contributing operations, and evaluating the effect of this technological level upon over-all costs. These results then were utilized to evolve an optimal conceptual design of a selected turbopump configuration, along with preliminary planning for the development, production, and acceptance of the turbopump. More specifically, the study was divided into the following three contractual tasks:

- Relationship of Turbopump Design Requirements to Over-All Costs
- Examinations of Cost-Contributing Operations
- Conceptual Design

Integral considerations for this study were the mission/vehicle/ engine trade-offs, detailed subcomponent analyses, and subcomponent optimizations. The representative design case selected was a half-size version of an Advanced Multipurpose Large Launch Vehicle (AMLLV) with a 500,000 lb payload capability to low earth orbit. The contract imposed study constraints of a LOX/LH₂ propellant combination and a conventional packaging arrangement with a bell nozzle, gas generator, and gimbal mount. Chamber pressure and altitude thrust also were fixed at 1200 psia and 300,000 lb, respectively. This resulted in the following design characteristics being defined as those applicable to the base turbopump design:

		TURBOPUMP VALUES	
SYMBOL	CHARACTERISTIC	LH ₂	LOX
ΔP	Pump Pressure Rise	1900 psi	1700 psi
W p	Pump Flow Rate	125 1b/sec	585 lb/sec
Ρ _{τi}	Turbine Inlet Pressure	1 190 ps ia	135 psia
PR	Turbine Pressure Ratio	7.5	3.4
T _{TI}	Turbine Inlet Temperature	1660°R	1250°R
₩ _T	Turbine Flow Rate	20 lb/sec	20 lb/sec
NPSH	Pump Net Positive Suction Head	130 ft	25 ft

These basic requirements were used to generate reference conceptual designs for fuel and oxidizer turbopumps. Then, the operational costs for producing these turbopumps were determined. Next, the requirements were altered and changes in the cost-contributing operations and performance were noted. Following this, the changes in requirements and performance were related to the mission level costs. The methodology developed was tested by utilizing the study results as a basis for final conceptual designs as well as the formulation of development, production, and acceptance plans for these designs. It was shown that a turbopump program cost savings of 3% (or 10-million dollars) is available for a 17-million pound-to-orbit program. However, when the sensitivity of over-all program costs to performance is considered, these savings are nullified and, actually, increased costs could result.

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Consequently, the overwhelming conclusion from this study is that the relaxation of requirements to reduce turbopump costs is not a fruitful way to decrease program costs. In effect, the potential exists for reducing turbopump program costs by as much as 40% (or 200-million dollars) through the appropriate tightening of design requirements to a degree that would permit acceptance test operations to be eliminated. Additionally large over-all program cost reductions could be accrued through this approach because of the cost sensitivity to engine performance (I_{sp}) . This can best be visualized from the following qualitative curves:



In the above curve, the general trend of the effect of turbopump requirements upon the cost of the turbopump components is illustrated. Most experienced engineering personnel will select a requirement that falls near the "knee" of the curve even when data is unavailable.



It can be seen from the above curve that turbopump performance is rather gradually affected by requirements in the reasonably attainable range.

When the above two trends are combined and superimposed, the following curve is evolved:



Note that a broad optimum results in terms of turbopump requirements. In highly performance-sensitive vehicles, such as the existing Space Shuttle concepts, the total program curve could become steeper than that for the highly performance-sensitive, single-stage to orbit MLLV. This would tend to drive the cost optimum turbopump toward even more rigid requirements.

The detailed supporting data for the above summarized trends is delineated in Section III of this report, along with other study results. The following is a brief index of the categorical study results and is provided for reader convenience.

RESULTS CATEGORY:

LOCATION IN TEXT:

Section of

Categorized Cost-Contributing Operations.....Section III,A,1. Categorized Design Requirements.....Section III, A, 2 and Appendix C. Relationship Between Variations in Requirements and Cost-Contributing Operations......Sections III, A, 2 and 3, Appendix C, and Figures No. 5, No. 6, and No. 11 through No. 66. Description of Alternative Methods for Performing Cost-Contributing Operations and Recommendations for Additional Technology......Sections III,B and IV,C, and Table XI Relationship Between Turbopump Requirements and Cost.....Section III,A,4, Table X, and Appendixes K and L. Optimal Turbopump Requirements and Design Criteria.....Section III,A,4 and Appendix L. Low Over-All Cost Turbopump Conceptual Designs

and Associated Development, Production, and Acceptance Plans.....Sections III,C,1 and 2, Table XII, and Appendix L.

II. INTRODUCTION

As the NASA proceeds into the post-Apollo era, costs are emerging as a dominant factor in selecting and promulgating alternative space goals. Consequently, the orientation of the technology planners has become the evolvement of a body of knowledge as well as a technical capability which will permit the attainment of meaningful goals at the lowest over-all costs. The subject Low Cost Turbopump Study is part of this new approach.

The traditional methodology applied to obtain the lowest over-all costs has been to generate a number of systems, all of which satisfy the specific technical requirements, and to select the lowest cost system or component from those generated. In the subject study, the objective was to develop a new or modified methodology which would permit synthesis of the lowest over-all

cost system by including cost as a parameter at the outset. In this way, costs are considered as one of the elements of the system during the earliest apportionment of performance requirements. Additionally, any methodology developed for the turbopump portion of a system offers a high potential for applicability to the other elements of the engine/vehicle system.

The accomplishment of study objectives within contractual schedule and budgetary constraints necessitated that the scope of the effort be limited to a single representative application. Consequently, the following guidelines were mutually established.

CHARACTERISTIC	CONSTRAINT/VALUE	BASIS
Propellant Combination	lox/lh ₂	Contract
Engine Type	Conventional: Bell Nozzle, Gas Generator, and Gimbal Mount	Contract
Chamber Pressure	1200 psia	Contract
Altitude Thrust	300,000 lb	Contract
Application	Half-Size AMLLV; 500,000 lb Payload	Contract
Fuel Turbopump Base Configuration	Single-Stage Centrifugal Pump, Two-Stage Axial Turbine, Central-Propellant-Cooled Bearings	Contract Proposal
Oxidizer Turbopump Base Configuration	Single-Stage Centrifugal Pump, Single-Stage Axial Turbine, Central-Propellant-Cooled Bearings	Contract Proposal

The Multipurpose Large Launch Vehicle (MLLV) is similar in design to the Advanced Multipurpose Large Launch Vehicle (AMLLV) as defined by NASA Contract NAS2-4079. The MLLV was sized to provide a single-stage-to-orbit (100 nautical mile circular earth orbit) payload of approximately 500,000 lb. Greater payload capability (approaching 2-million lb) could be achieved by using injection stage modules and/or strap-on solid propulsion stages.

Only the core vehicle is utilized in the mission selected for this study, which is to place approximately 20-million 1b of payload into orbit.

Recurring costs are most realistically expressed in terms of cost-perunit while the maintenance of capability costs are best denoted in terms of

cost-per-unit-of-time. Consequently, a program life and procurement rate were needed to permit an adjustment between the two and provide a basis for consistency. Two combinations of rate and life had to be investigated, but the individual values were left to the discretion of the Project Engineer (see Section III).

The results of Task I (Relationship of Turbopump Design Requirements to Over-All Costs) in this three-task study provided the basic data for synthesizing the lowest over-all cost design. These data included cost and performance information in terms of identical variable requirements as well as turbopump performance information in relationship to vehicle and mission costs.

Task II (Examination of Changes in Cost-Contributing Operations) provided cost data similar to that of task I but in terms of variable requirements for different technological levels of performing the significant (high cost) operations. These data showed at what level of requirements significant savings could be achieved by altering the method of designing, fabricating, or testing a component of the system.

Task III (Conceptual Design) served to demonstrate that the design methodology formulated from Tasks I and II actually could be applied to a realistic program while resulting in a turbopump cost savings reaching as high as 10-million dollars over the life of the program, but with negligible over-all program cost savings. However, the same methodology can be applied in a less conventional manner to provide a substantial reduction in over-all program costs by tightening rather than relaxing requirements.

III. TECHNICAL DISCUSSION

A. TASK I - RELATIONSHIP OF TURBOPUMP DESIGN REQUIREMENTS TO OVER-ALL COSTS

Task I was divided into the following four subtasks:

- Ia Identification and categorization of the costcontributing operations
- Ib Identification and categorization of design
 requirements
- Ic Relationship of variations in design requirements to cost-contributing operations, turbopump/vehicle costs, and over-all costs

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Id - Synthesis of design requirements to yield minimum over-all costs

The above subtask results, the basis of these results, the methodology applied to obtain them, and the limitations of these results are detailed in the ensuing discussions.

1. Subtask Ia - Cost-Contributing Operations

To obtain the necessary data for this subtask, a realistic conceptual design was essential to serve as the basis for selecting the operations and requirements. It was originally conceived that this would be an extensive conceptual design effort to generate configurations for both 1,000,000 lb and 300,000 lb thrust engines. However, budgetary and schedule limitations caused the higher thrust level design to be eliminated during contract negotiations and significantly reduced the effort devoted to generating the base designs at the 300,000 lbf level. Consequently, the configurations selected (see Figures No. 1 and No. 2) are non-optimum and result from a morphological evaluation as well as the necessary preliminary design calculations.

Many configurations were eliminated during the morphological evaluation based upon an objective consideration of fundamental turbopump characteristics. As an example, previous studies have shown the single turbopump to be unattractive because of the large difference in desired speeds for LOX and LH₂ pumps. The single geared oxidizer unit is unattractive at higher thrust levels because of its high development cost as well as the risk associated with gear drive systems. The twin-spool coaxial unit has an increased mechanical complexity which makes sealing more difficult and has a potential for causing a dramatic increase in development costs as well as risk.

Previous studies also have indicated that separate fuel and oxidizer turbopumps are desirable, particularly at the high thrust levels, because this arrangement permits independent optimum speed operation of the individual pumps to produce the required pressure rise. Normally, the LH₂ pump operates at approximately four to five times the speed of the LOX pumps (in units without a boost pump) because of NPSH requirements and propellant density differences. The best oxidizer pump selection generally has been a single-stage centrifugal pump with either a single or dual inlet, with the single inlet being the most common.

Fuel and oxidizer turbines can be arranged for either parallel or series flow. Studies have indicated that the parallel turbine arrangement is easier to control than the series system during engine throttling; however, throttling could be achieved with the series arrangement by utilizing proper by-pass valve sizing and control. The series turbine arrangement offers a significant reduction in turbine gas flow over the parallel system, but the ducting system is somewhat more complicated. Consequently, the candidate configurations shown on Figures No. 1 and No. 2 were selected as the bases for the Task I effort.

Having defined the basic configuration, it then was decided to concentrate the effort upon the 300,000 lbf case because maximum cost and design data were available for that class of machinery from previous development and operational programs. The resultant requirements for the base case turbopump designs are listed on Table I.





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TABLE I. - BASE CASE REQUIREMENTS

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	Requirement		
Parameter	Engine	Fuel Turbopump	Oxidizer Turbopump
Propellants	LOX/LH2	LH ₂	LOX
Application	MLLV (1/2 Size AMLLV)	-	-
Throttling	None	None	None
Startup	3 sec + Prechill	3 sec + Prechill	3 sec + Prechill
Duty Cycle	1 Start 300 sec	10 Starts/10 Hours	10 Starts/10 Hours
Reliability	0.97	0.998	0.998
Thrust	300,000 1Ъ	-	-
Thrust Tolerance	<u>+</u> 3%	-	-
Ch a mber Pressure	1200 psia	-	-
Chamber Pressure Tolerance	+ 1.5% (Control Value)	-	_
Specific Impulse	433 вес	-	-
Specific Impulse Tolerance	<u>+</u> 3 sec	-	-
Mixture R a tio	5:1	-	-
Mixture Ratio Tolerance	<u>+</u> 2.5%	-	-
Pump Pressure Rise	-	1900 psi	1700 psi
Pump Pressure Rise Tolerance	-	<u>+</u> 3%	<u>+</u> 3%
Pump Flow Rate	-	125 lb/sec	585 lb/sec
Pump Flow Rate Tolerance	-	Control Value	Control Value
NPSH	-	130 ft	25 ft
NPSH Tolerance	-	Minimum Value	Minimum Value
Turbine Inlet Pressure	-	1190 p sia	135 psia
Turbine Pressure Ratio Tolerance	-	7.5	3.4
Turbine Pressure Ratio Tolerance	-	<u>+</u> 2%	+ 2%
Turbine Flow Rate	-	20 1b/sec	20 1b/sec -
Turbine Flow Rate Tolerance	-	<u>+</u> 5%	<u>+</u> 5%
Turbine Inlet Temperature	-	1 6 60 °R	1250°R
Turbine Inlet Temperature Tolerance	-	<u>+</u> 250°	<u>+</u> 180°
Static Seal Leakage	-	None	None
Dynamic Seal Le akage	-	0.05 1b/sec	0.05 lb/sec

Appendix A contains typical fuel turbopump preliminary design calculations and assumptions which illustrate the method utilized to size the components of the base case fuel turbopump shown on Figure No. 1. Similar simplified calculations were applied in sizing the base case oxidizer turbopump shown on Figure No. 2. The preliminary characteristic dimensions generated for both base cases are listed on Table II.

Next, the cost-contributing operations were identified and categorized in a number of variations. The final listing of these operations is included as Appendix B. This listing, as presented, represents a realistic level for investigating the cost of operations as they are influenced by changes in requirements. It is recognized that other categorical breakdowns are possible, but the listing offered is based upon the commonality of the same requirements variations affecting the cost of both design operations, primarily at the functional assembly level (i.e., pump, turbine, or power transmission), and fabrication operations at the subcomponent level (i.e., impeller and pump volute).

The general categorized listing of Appendix B does not have particular significance when viewed alone, but is highly useful as a checklist or guide in gathering data to be applied in relating the costs of performing operations for various requirements levels. However, this resultant listing reveals a significant weakness in the original proposed program. Each of the operations costs could be explicitly described and quantified in terms of man and machine hours based upon the particular set of detailed requirements assumed for the base case designs, but this would result in single point data not useful by itself in performing optimizations or tradeoff studies. Determination of the relationship between variations in requirements and costcontributing operations required that the operations costs be quantified over a range of requirements. Identical techniques and manpower would be used for quantifying the base case operations costs and alternative requirements operations costs, but the original plan necessitated a redundant performance. This would have resulted in accomplishing the same effort twice as well as two separate tabulations of the data. Therefore, it was decided to defer quantification of the base case operations costs until quantified ranges of design requirements were available. Accordingly, this quantification was performed as part of Subtask Ic, where it is described.

2. <u>Subtask Ib - Identification/Categorization of</u> Design Requirements

Design requirements at the vehicle, engine, and turbopump levels generally can be segregated into the two broad categories of performance requirements and operational/mechanical requirements. At the subcomponent or part level, where the design requirements can be manipulated to affect design, fabrication, and test operations costs, virtually all design requirements must ultimately be mechanical or dimensional even though they can stem from performance requirements. Early recognition of this led to the

	Value	
Characteristic Dimension	Fuel Turbopump	LOX Turbopump
Impeller Inlet Diameter (Tip)	8.40	8.14
Impeller Inlet Diameter (Hub)	3.20	2.03
Impeller Discharge Diameter	14.75	12.90
Impeller Port Height	0.58	0.81
Base Circle Diameter	15.50	14.00
Diffuser Height	0.62	-
Diffuser Width	1.40	-
Volute Size (max section equiv dia)	2.37	3.50
Turbine Inlet Size (max section equiv dia)	3.65	9.94
Rotor Mean Diameter	9.95	17.20
lst Rotor Blade Height	0.92	. 2.48
2nd Rotor Blade Height	1.05	-
1st Rotor Chord	0.86	0.96
2nd Rotor Chord	0.78	-
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TABLE II. - PRELIMINARY CHARACTERISTIC DIMENSIONS

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realization that vehicle, engine, and turbopump level variations in design requirements would result in an overwhelming number of subcomponent alternatives because of the many possible ways of meeting a given set of the higher order design requirements. Therefore, it was decided to select only a base case set of vehicle, engine, and turbopump requirements from which to generate base case turbopump subcomponent requirements. Variations in subcomponent design requirements then could be selected and their impact upon both performance and cost parameters assessed. Next, the effects of the subcomponent requirements changes could be iterated at that level to synthesize realistic designs and an optimum set of turbopump level design requirements.

The following discussions describe the results of the effort to identify and categorize the design requirements and the variations selected for investigation.

a. Vehicle/Engine/Turbopump

The extensive categorized base case vehicle, engine, and turbopump design requirements selected are presented in Appendix C along with the basis for such selection. Requirements are segregated by the categories of performance, operational, and mechanical as well as by source (vehicle/engine or turbopump).

b. Turbopump Subcomponents

All of the turbopump subcomponent requirements are included under the mechanical category of Appendix C for the previously cited reasons. Although the alternative ranges of subcomponent requirements shown tend to reduce both the cost of manufacture and the hydraulic/aerodynamic performance, the size variations presented provide data at higher as well as lower NPSH, which reflects the higher and lower performance levels.

3. <u>Subtask Ic - Design Requirement Relationship to</u> <u>Cost Parameters, Turbopump/Vehicle Costs, and</u> <u>Over-All Costs</u>

a. Data

The following three major segments of information were needed to relate design requirement variations to over-all costs:

- How design requirements influence component costs
- How design requirements influence component performance
- How component performance influences over-all costs

Information concerning how design requirements influence component costs and performance was generated as part of the subject study program. The influence of component performance upon over-all costs was extracted from existing data developed by the Boeing Company under Contract NAS 2-5056 (Ref. 1). The ensuing discussions deal with the methodology utilized to generate or extract appropriate data, summarize the results, and describe the techniques used to relate the data. These data are presented by operation and requirement categories to facilitate comparison with the previously discussed operation and requirements listings.

- (1) Cost versus Design Requirements
 - (a) Development Phase Design Operations

Aside from reliability and schedule requirements, the cost of design operations are relatively unaffected by design requirements. Additionally, no reasonable alternatives to the existing design methodology have presented themselves which will satisfy the mechanical reliability levels now needed to assure that essentially no flight or mission failures can occur during the life of the program. It is simply not possible to attain and demonstrate the required engine reliability by a test-fail-fix design/development philosophy within a reasonable (10 years or less) schedule. The implicit series flow of such a program, along with the known lead times for turbopump major subcomponents, makes it largely unfeasible to test even two alternative subcomponents to failure within the schedular restraint.

The failure mode analyses performed for the base case fuel and oxidizer turbopumps are summarized in Appendix D. They show that when part total duty cycle reliabilities are estimated and apportioned according to the method described below, the mean time to failure for many subcomponents is on the order of 100 hours to 1000 hours.

- Step 1: All major turbopump subcomponents are listed.
- <u>Step 2</u>: All modes wherein each subcomponent could fail are listed by part (a mode is defined as the part or assembly feature describing the failure).
- <u>Step 3</u>: All mechanisms of failure are listed for each mode (a mechanism is defined as the property exhibiting the defect which precipitates the failure).
- Step 4: All mechanisms of failure are rated by experienced turbopump specialists using scales ranging from A through D for design difficulty (A is well understood while D is poorly understood) and 1 through 4 for degree of control (1 is for easily controlled while 4 is difficult to control). The results then are averaged.

<u>Step 5</u>: The ratings are converted to a weighted rating defined as "relative" failure potential" (RFP) based upon the matrix:

Rating		RFP
A-1	=	0.1
A-2, B-1	=	1.0
A-3, C-1	=	10.0
A-4, B-2, D-1	=	100.0
B-3, C-2	=	1000.0
B-4, D-2, C-3	=	10,000.0
C-4, D-3	=	100,000.0
D-4	=	1,000,000.0

Step 6:

The relative failure potential is assumed equal to the number of failures per mission.

<u>Step 7</u>:

The potential reliability of the subcomponents are calculated using the failure rate.

It is obviously that the turbopump reliability calculated by the above method can be biased by the amount of weight given the relative failure potential, but comparisons using the above scale factors have shown good agreement with historical Titan data.

Current space goals require that all design techniques be utilized in conjunction with one another rather than selecting one which appears to offer the lowest cost of executing the design at a possibly lower turbopump reliability. In view of these factors and because the NASA interest does not extend to totally redundant and expendable weapons systems, no further attempt to relate requirements variations, other than schedular, to the cost of performing design operations was made.

The schedular variations investigated included the currently used "semiparallel" design and development effort as well as a proposed "full series" approach. The over-all schedular impact of these variations upon the base case and alternative program schedules are shown on Figures No. 3 and No. 4, respectively. Further amplification of the "full series" program follows.

Six subcategories make up the design task and each must be accomplished either during the proposal effort or in the contractual program.

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Figure 3. - Current Operating Plan, Semiparallel Approach (Sheet 1 of 2)

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Figure 3. - Current Operating Plan, Semiparallel Approach (Sheet 2 of 2)

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Figure 4. - Current Operating Plan, Full Series Approach (Sheet 1 of 2)

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Figure 4. - Current Operating Plan, Full Series Approach (Sheet 2 of 2)

<u>Subcategory 1</u>: Recognized existing technology design limits are established for pumps, seals, turbines, bearings, and structural materials.

<u>Subcategory 2</u>: Parametric analysis of individual subcomponent characteristics is made based upon the design limits established.

<u>Subcategory 3</u>: Design point is selected based upon a combination of the parametric analysis and the cost-contributing operations. This gives specifications for turbopump, engine, and vehicle performance levels and tolerances.

<u>Subcategory 4</u>: Conceptual and final design layouts along with supporting stress and performance calculations.

Subcategory 5: Detailed drafting (turbopump).

<u>Subcategory 6</u>: Subcomponent test article design and turbopump development fabrication release.

Although the above subcategories in themselves are similar to those of the "standard" design phase, they are accomplished sequentially and to a different degree of completion.

In practice, it is found that the establishment of the design limits sets the "ground rules" for the entire task. Government/Contractor technical specialists review these limits before actual design activity is started. Necessary modifications are made at the outset of the program to preclude the unproductive design activity associated with controversial design limits. Once established, these design limits become the basis for the parametric analysis, which serves to provide parametric limits as well as the rate of change for the various dependent parameters as a function of the variables (i.e., speed and NPSH). Thus, the design point can be selected with a full awareness of the effects that small errors will have in the assumed design limits or the cost-contributing operations. Again, the technical specialists review the parametric trends as well as their effects upon cost and performance before the actual design begins.

Next, conceptual design is initiated and preliminary stress as well as performance characteristics are established. This allows analytical determination of the transient and steady-state operation with the interfacing engine/vehicle components. It also permits confirmation of the selection of the parametrically-defined configuration. Fabrication and assembly costs as well as quality control and maintainability are value engineered. The conceptual design and the preliminary operating characteristics are Government/Contractor reviewed for appropriate modification or

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final design approval. Upon approval, the design layout is completed in detail (i.e., fluid passage shapes and coordinates, all tolerances, and specifications for material procurement, processing, quality control, and instrumentation fittings). The final stress and materials engineering is accomplished during this last half of the layout subtask using existing Government or Industry specifications defining material properties. The final layout itself includes all pertinent dimensions, clearances, and tolerances as well as material, key fabrication/inspection processes along with the handling, marking, and shipping specifications. It is sufficiently comprehensive to permit detailed drafting to be accomplished without need of any further engineering activity. This completeness allows an in-depth final design review, which includes the quality control and manufacturing requirements. After the final design is approved, most of the design engineering personnel are reassigned in support of other programs. (In a turbopump design activity for the Titan-MOL, the manloading started at five, rose to 24, and returned to five over a 10-month period.) A minimal cadre of design project personnel accomplishes the manufacturing liaison and defines the testing requirements. These personnel are included in estimates of the cost of design operations.

The detailed drawings are completed and verified against the master layout. None of these drawings is released and no fabrication is initiated until the entire set is completed as an additional means for uncovering errors. Experience to date with the "full series" approach shows a 40% reduction in drafting time over the previously-used "standard" system. Also, the number of combined engineering-drafting errors subsequently discovered during manufacturing has been significantly reduced (approximately 1 error per 10 drawings). Further, there is a considerable reduction in release time because all of the detailed design material is available before this effort starts which permits maximum utilization of drafting personnel without regard for the availability of engineering guidance. In addition, the master layout has already been appropriately certified (i.e., manufacturing, stress, quality control, and design); therefore, individual detailed drawing certifications can await the drawing release. Recently, the "full series" approach was utilized in the "Full-Flow Inducer" effort (Contract NAS 3-7977) to produce some 60 drawings defining all of a two-speed inducer system components. These drawings were completed and released within three weeks.

As can be seen on Figures No. 3 and No. 4, the only schedule changes attributable to the "full series" approach occur in the development phase operations and result in an apparent delay of the turbopump qualification program of approximately three to six months. The design costs shown on Tables III and IV and Figures No. 5 and No. 6 reveal that the "full series" approach offers a potential design cost saving of 8.7% or 340,000 for the reference program design phase costs. These savings are probably conservative for an actual program because of the greatly reduced likelihood of committing design errors, especially in the detail drafting operations.

TABLE III. - DESIGN PHASE, DESIGN AND DEVELOPMENT ENGINEERING STANDARD PROGRAM MANPOWER SUMMARY

DISCIPLINE/ACTIVITY										PF	MANE	OWER I QUAF	TER	<u> </u>						<u> </u>	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
STANDARD PROGRAM																					
Pump Hydraulics	4	6	8	16	16	8	4	2	2	0	2	1	1	l	1	1	1	0	0	0	
Turbine Aerodynamics	4	6	8	16	16	8	4	2	2	0	2	1	l	1	l	1	1	0	0	0	
Concept Layout	2	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Thermal Analysis	2	3	4	6	6	6	3	2	2	2	l	l	1	0	0	1	1	0	0	0	
Critical Speed Analysis	1	ľ	1	l	2	1	0	0	0	0	0	1	l	0	0	0	0	0	0	0	
Structural Analysis	2	5	6	8	10	10	8	4	2	2	2	2	2	1	l	l	2	0	0	0	
Turbopump Layout & Mech Design	0	0	2	4	6	6	6	0	2	0	1	l	0	0	Ô	0	0	0	0	0	
Fabrication Drawings	0	0	0	4	6	12	12	0	0	2	l	l	0	1	0	0	0	0	0	0	
Tester Design	0	0	0	0	2	7	3	l	0	0	0	0	0	1	0	0	0	0	0	0	
Fabrication Liaison	.0	0	0	0	2	3	4	6	6	6	8	6	6	6	4	4	3	2	2	0	
Test Planning & Liaison	0	0	0	0	3	3	4	4	4	5	8	10	10	14	14	9	7	2	2	0	
TOTAL	15	25	32	55	62	64	48	21	20	17	25	24	24	25	21	17	15	4	4	0	

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Tester Design	0	0	0	0	0	0	m	ω	N	0	0	0	0	0	0	Ч	0	0	0	0	0
Fabrication Liaison	0	0	0	0	0	0	CJ	9	9	9	8	9	9	9	. ‡	†	ε	CI	QI	Q	0
Test Planning & Liaison	0	0	0	0	0	0	0	0	4	5 1	0	t 1	[]	0	2		6	4	CI	ณ	0
TOTAL	15	55	ł ¹ 3	58	64	56	53	24 1	-7 I	7	0 8		9	0	61	20	16	10	4	4	0



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PROGRAM QUARTER Figure 6. - Cumulative Design Costs

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(b) Development Phase Fabrication Operations

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Development fabrication operations costs are strongly dependent upon design requirements at the part or subcomponent level. The methodology followed in generating the data used in relating the costs to the requirements was as follows.

The conceptual sketches (Figures No. 1 and No. 2), similar sketches (Figures No. 1 through 10) prepared for higher and lower NPSH requirements, the base case and alternative part level mechanical requirements listing (Appendix C), and actual part fabrication drawings of representative components selected from the Titan, NERVA, and M-1 programs were furnished to several typical aerospace and commercial subcomponent fabricators, including Aerojet-General's own shops. Cost estimates and manufacturing plans were requested at the cost-contributing operation level (see Section III,A,1) for virtually all turbopump subcomponents. All costs werrequested in terms of both manhours and dollars for production quantities of one (pilot model), 10 (typical R&D order), 40 (initial production quantity), and more than 40 (production runs).

While the response to the requests for cost information was generally quite good, there were several notable exceptions. All of the commercial pump manufactures contacted declined to quote anything other than over-all costs of producing the assembly, implying that their production methods are proprietary information. Also, several vendors declined to quote at any level below that of casting, machining, or welding. The extensiviness of detail in the estimates received precludes their reproduction in this report. However, three sample estimates are included as Appendices E, F, and G. These sample estimates are for the base case fuel turbopump subcomponents as received from two typical aerospace vendors and one commercial job shop. These same data for the base case fuel turbopump reduced composite form with appropriate support and overhead charges applied are presented as Appendix H. Similar data for the base case oxidizer turbopump is included as Appendix I.

Although data in the form of Appendices H and I would provide a solid over-all turbopump fabrication base cost for a contractual program, it is too unwieldly for performing a cost optimization because each requirement variation would result in a separate sheet as well as a separate part cost. Accordingly, the data were interpreted and plotted at the manhour and net dollars level for only those operations that were significantly cost-affected by the requirements variations. The strong production quantity price dependency shown in Appendices H and I further reinforced the conclusion discussed in Section III,A,1 that a test-fail-fix design/development philosophy is not practical and data interpretation was generally limited to the higher quantity production lots. Figure 7. - LH₂ Turbopump Assembly Concept









A review of the raw (as received) data yielded one overwhelmingly significant fact along with several lesser conclusions. The commercial jobber's prices were significantly lower than the aerospace vendors as expected, but the apparent reason for the price differences was surprising. The hourly dollar rate charged for performing a given operation was for all practical purposes a constant for all vendors contacted, both aerospace and commercial, but the hours estimated to be required to complete an operation varied widely in direct contradiction to the expected result. Extensive discussions with the various estimators provided the following probable reasons for the surprising nature of the results:

- Machinists base hourly pay rates are relatively consistent from shop-toshop and industry-to-industry.
- The major overhead factor affecting all fabrication specialty shops is the cost of their production machinery. Hence, burdened rates at the various suppliers do not vary significantly.
- The commercial vendors do not fully understand the lost time implications of the quality control requirements usually imposed upon aerospace hardware as evidenced by their price insensitivity to variations in the QC requirements. All aerospace vendors recall similar naivete during their growth period, which results in their listing the quality control requirements as the factor most affecting their higher time estimates.

The commercial vendors are largely unfamiliar with the difficulties associated with machining the higher strength materials typically used in rocket engine turbopumps. The time estimated by the commercial vendors to complete a given operation is, therefore, significantly in error and they would be unable to produce the components for the prices or on the schedules quoted. The overwhelming conclusion from the above discussions is that a large body of the data collected during the course of this study is not useful in determining cost optimum requirements. Further, data interpretation was necessarily limited, for the most part, to that obtained from the typical aerospace vendors. Limited use of the commercial vendor data was made where subcomponents could be fabricated from conventional strength materials and quality was easily controlled to the level required by reliability considerations.

As a consequence the requirements versus cost data in the ensuing discussions are almost exclusively derived from estimates supplied by accredited aerospace vendors as well as Aerojet historical records. Significant fabrication operations are discussed and plotted by fuel and oxidizer subcomponent in the same order they are shown in Appendices H and I. Cost versus NPSH/size data are shown for several representative fuel and oxidizer subcomponents. Turbopump unit cost versus NPSH/size data also are included.

> <u>1</u> Fuel Turbopump Item 1 - Fuel Pump Backplate/Bearing Housing

a Casting Tolerance

Figure No. 11 shows the cost effect of casting tolerance. The cost of the parts is almost entirely a function of scrap rate. A typical tolerance of \pm 0.030 on flow passage and structural features results in a scrap rate of approximately 12%; split one-third for dimensional defects and two-thirds for casting flaws such as porosity and inclusions. Only the dimensional defect rate is affected by the casting tolerance, with the rate increasing four times at a tolerance of \pm 0.020 and decreasing to zero at approximately \pm 0.050. It is possible that the scrap rate curve knee could be moved to lower tolerance levels by investment casting but at a sharply increased cost because of the technique development required for such large sized components.

b Surface Finish

Figures No. 12 and No. 13 show the cost effect of surface finish requirements for general machining and handfinishing operations. The reduction in costs shown would flatten dramatically if extended to higher roughness values. At a roughness of approximately 250, general machining time is dictated by dimensional tolerance and hand-finishing becomes a simple deburring operation to remove sharp edges.

c Critical Dimension Tolerance

Figures No. 14 and No. 15 give the cost effect of critical dimensional tolerances such as the tolerances on pilot diameters, axial stacking planes, and bearing bores. Machining time Figure 11. - Cost Effect of Casting Tolerance, Fuel Pump Item 1





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Figure 13. - Cost Effect of Surface Finish (Hand-Finish), Fuel Turbopump Item 1

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reduces rapidly by approximately 20% from \pm 0.0005 to \pm 0.003 tolerance but little effect is noted at higher tolerances. Inspection time decreases linearly by 25% over the range from \pm 0.0005 to \pm 0.010 tolerance but the plots are terminated at approximately \pm 0.005 where interference loads in the pilot flanges become excessive.

d Size Effect

Figure No. 16 shows the cost effects of over-all size for the casting and lumped machining operations at the base case tolerances. Combinations at different tolerances can be scaled directly using these data.

> <u>2</u> Fuel Turbopump Items 18 and 19 -Fuel Turbine Rotors, Stages 1 and 2

> > <u>a</u> General Dimensional Tolerance

The cost effect of general dimensional tolerances (i.e., outside diameter and axial length) is shown on Figure No. 17. The rather small (4% to 5%) cost reduction shown occurs in the range from \pm 0.001 to \pm 0.003 with no significant improvement from \pm 0.003 out to \pm 0.005.

b Surface Finish

Figure No. 18 displays a significant (8% to 10%) cost effect of surface finish over the range from 32 microin. to 250 microin. roughness. For the pump backplate/bearing housing, the effect would flatten at approximately 250 microin. when dimensional variations limit machining time. Significant further improvement could be obtained if as-forged or as-forged and sandblasted dimensional variations could be tolerated on the disc surfaces.

c Blade Profile Tolerance

A very strong (20% to 25%) cost effect of rotor blade profile tolerance is shown on Figure No. 19. Primary reasons for the reduction is the reduced cutter replacement/sharpening time and the increased depth of cuts possible at the higher tolerances.

d Size Effect

Cost effects of general size for lumped forging and machining operations at the base case tolerance level are shown on Figure No. 20. Figure 16. - Cost Effect of Size, Fuel Turbopump Item 1

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Figure 18. - Cost Effect of Surface Finish, Fuel Turbopump Items 18 and 19







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Figure 20. - Cost Effect of Size, Fuel Turbopump Items 18 and 19

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<u>3</u> Fuel Turbopump Item 21 - Fuel Turbine Stator

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a Vane Profile Tolerance

Figure No. 21 gives the cost effect of stator vane profile tolerance for vane generating operations. The cost trend line flattens at a tolerance of approximately ± 0.005 when surface finish considerations limit the required machining time.

b Surface Finish Vanes

Figure No. 22 shows a significant cost effect of vane surface finish over the 32 microin. to 250 microin. range. Extrapolated reductions in cost below the level shown at 250 microin. where hand finishing costs are eliminated would not be valid. Some additional cost reduction could be obtained at higher roughness values but the rate of improvement is sharply reduced.

c General Surface Finish

Similar reductions in the general machining costs are shown on Figure No. 23. Again, significant further improvement could be obtained if as-forged dimensional variations could be tolerated.

d Size Effect

Figure No. 24 displays the effect of over-all size upon lumped forging and machining operations at the base case tolerances.

<u>4</u> Fuel Turbopump Item 29 - Fuel Pump Diffuser

a Vane Profile Tolerance

The effect of pump diffuser vane profile tolerance upon vane generating operations costs is shown on Figure No. 25. The upper curves are for a fully-machined version using a typical CRES material. The lower curves represent a combination die cast and machined version using a tens-50 type aluminum alloy. Both sets of curves show significant increases in cost at tolerances tighter than approximately ± 0.005 . It is significant to note that the die cast model would incur no vane generating costs if tolerances on the order of ± 0.010 can be tolerated.

b Surface Finish

Figure No. 26 gives similar handfinishing cost effects of surface finish for the two diffuser models. The cast



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Figure 21. - Cost Effect of Vane Profile Tolerance, Fuel Turbopump Item 21

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Figure 22. - Cost Effect of Surface Finish (Vanes), Fuel Turbopump Item 21



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Figure 23. - Cost Effect of Surface Finish, Fuel Turbopump Item 21



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Figure 26. - Cost Effect of Vane Surface Finish, Fuel Turbopump Item 29

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version again exhibits the zero cost property at the relatively high roughness value of 125 microin. The machined version would presumably exhibit the same effect if as-machined finishes are acceptable.

<u>c</u> Size Effect

The effect of over-all size upon machining or lumped casting and machining costs are shown on Figure No. 27 for the two diffuser models. Part/feature tolerances are constant at the base case values.

> 5 Fuel Turbopump Item 30 - Fuel Pump Impeller

> > a Vane Outside Diameter Tolerance

The effect of vane outside diameter tolerance upon cost of finish turning operations is displayed on Figure No. 28. The primary reason for the lost reduction shown is the reduced tracer lathe set-up time required at the larger tolerance. Quantitative lost data was not obtained at tolerances larger than ± 0.010 but discussions with suppliers indicate that no additional reduction could be obtained at tolerances greater than approximately ± 0.015 . Finish-turning might be eliminated entirely if part-topart blade height and outside diameter contour tolerances of approximately ± 0.03 could be accomplished.

b Vane Profile Tolerance

Figure No. 29 shows the effect of vane profile tolerance, including hub contour tolerance, upon vane generating costs. The very strong (20%) variation in cost is almost entirely a function of the number of cutter replacement/sharpening operations.

<u>c</u> Surface Finish

Figure No. 30 shows the very significant effect of surface finish upon hand-finishing cost for two technological levels of performing the operation. The cost of performance and the finishes obtainable from the sandblast method are both somewhat speculative because none of the suppliers contacted had actually used this method for finishing a machined impeller. It is probable that the vane profile tolerance also would have to be relaxed from the base case value to utilize the sandblast alternative.

> 6 Fuel Turbopump Item 31 - Fuel Pump Inducer

The cost effects of vane profile tolerance, outside diameter contour tolerance, and surface finish are shown on Figures No. 31 through No. 33. The data are subject to the same limitations and uncertainties described for the fuel pump impeller (Item 30).



Figure 27. - Cost Effect of Size, Fuel Turbopump Item 29

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Figure 28. - Cost Effect of Vane Outside Diameter Tolerance, Fuel Turbopump

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Figure 29. - Cost Effect of Vane Profile Tolerance, Fuel Turbopump Item 30



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- Figure 30. - Cost Effect of Surface Finish, Fuel Turbopump Item 30



Figure 31. - Cost Effect of Vane Profile Tolerance, Fuel Turbopump Item 31



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Figure 32. - Cost Effect of Vane Outside Diameter Tolerance, Fuel Turbopump Item 31

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Figure 33. - Cost Effect of Surface Finish, Fuel Turbopump Item 31

7 Fuel Turbopump Item 33 - Fuel Turbine Manifold

a Critical Dimension Tolerance

Figure No. 34 gives the cost effect of critical dimensional tolerance (i.e., tolerances on pilot diameters and axial stacking planes). Machining time reduces rapidly by approximately 12% from ± 0.002 to ± 0.005 tolerance but little effect is noted at higher tolerances. Inspection time does not vary significantly over the ± 0.002 to ± 0.005 tolerance range.

b Vane Profile Tolerance

The effect of vane profile tolerance upon cost of generating the vanes is shown on Figure No. 35 for two technological levels of performing the operation. The upper curves are for a fullymachined forged ring with integral machined vanes while the lower curves represent a model where integral vanes are first cast to some intermediate tolerance and then machined to final tolerance. A third (as-cast) version is implied but requires that vane profile tolerance be approximately ± 0.010 . A fixed casting prime cost of \$1,700 or ring forging prime cost of \$400 must be added to the appropriate curve value to compare alternative part production costs.

8 Fuel Turbopump Item 34 - Fuel Pump Housing

<u>a</u> Casting Tolerance

Figure No. 36 shows that the cost effect of casting tolerance is almost entirely dependent upon scrap rate. The base case tolerance of ± 0.030 on flow passage and critical structural features results in a dimensional defect scrap rate of approximately 4% which increases to approximately 15% at ± 0.020 tolerance and approaches zero at ± 0.050 tolerance.

b Critical Dimension Tolerance

The effect of critical dimensional tolerances upon final turning costs is given on Figure No. 37. Pilot diameter and inside diameter contour tolerances were varied together in the ratio shown to obtain the data and the effects are therefore inseparable.

9 Fuel Turbopump Assembly

a Stacking Dimension Tolerance

Assembly costs in terms of assembly labor manhours and total assembly net dollars versus critical axial stacking







Figure 35. - Cost Effect of Vane Profile Tolerance, Fuel Turbopump Item 33



Figure 36. - Cost Effect of Casting Tolerance, Fuel Turbopump Item 34



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dimension tolerance are shown on Figure No. 38. Tolerances are assumed to be distributed equally for the several parts affecting pump and turbine vane and thrust balancer clearances. Assembly cost differences are totally attributable to the additional assembly operations required to custom-fit spacers/shims for larger tolerance parts.

b Size Effect

The cost versus size data shown on Figures No. 16, No. 20, No. 24 and No. 27, along with similar data for all other major turbopump subcomponents were utilized to produce the turbopump level size effect data for the over-all machine. These data are displayed on Figure No. 39 directly as a function of required NPSH. Only net costs in dollars are shown because no single hourly rate is applicable to all subcomponents.

10 LOX Turbopump Item 17 - LOX Pump Housing

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a Casting Tolerance

Figure No. 40 shows the cost effect of casting tolerance. The cost of the parts is almost entirely a function of scrap rate. The typical tolerance of ± 0.030 on flow passage and structural features results in a scrap rate of approximately 12%; split one-third for dimensional defects and two-thirds for casting flaws such as porosity and inclusions. Only the dimensional defect rate is affected by the casting tolerance, with the rate increasing four times at a tolerance of ± 0.020 and decreasing to zero at approximately ± 0.050 . It is possible that the scrap rate curve knee could be moved to lower tolerance levels by investment casting techniques but at a sharply increased cost because the technique would require considerable development for this size machinery.

b Surface Finish

Figures No. 41 and No. 42 show the cost effect of surface finish requirements for general machining and hand finishing operations. The reduction in costs shown would flatten dramatically if extended to higher roughness values. At a roughness of approximately 250, general machining time is dictated by dimensional tolerance and hand-finishing becomes a simple deburring operation to remove sharp edges.

<u>c</u> Critical Dimension Tolerance

Figure No. 43 and 44 gives the cost effect of critical dimensional tolerances such as the tolerances on pilot diameters, axial stacking planes, and bearing bores. Machining time reduces rapidly by approximately 20% from ± 0.0005 to ± 0.003 tolerance, but little effect is noted at higher tolerances. Inspection time decreases linearly by



Figure 38. - Cost Effect of Stacking Dimension Tolerance, Fuel Turbopump Assembly



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Figure 39. - Cost Effect of NPSH/Size, Fuel Turbopump Assembly



Figure 40. - Cost Effect of Casting Tolerance, LOX Turbopump Item 17



Figure 41. - Cost Effect of Surface Finish (General Machining), LOX Turbopump Item 17

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Figure 42. - Cost Effect of Surface Finish (Hand-Finish), LOX Turbopump Item 17



Figure 43. - Cost Effect of Critical Dimension/Tolerance, LOX Turbopump Item 17

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Figure 44. - Cost Effect of Critical Dimension Tolerance, LOX Turbopump Item 17



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25% over the range from ± 0.0005 to ± 0.010 tolerance, but the plots are terminated at approximately ± 0.005 to ± 0.006 where interference loads in the pilot flanges become excessive.

d Size Effect

Figure No. 45 shows the cost effects of over-all size for the casting and lumped machining operations at the base case tolerances. Combinations at different tolerances can be scaled directly using these data.

11 LOX Turbopump Item 19 - LOX Pump Impeller

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a Vane Profile Tolerance

Figure No. 46 shows the effect of vane profile tolerance upon casting costs for two technological levels. Both methods are subject to rejection rate effects similar to those previously discussed for the pump housings.

b Seal Diameter Tolerance

The effect of seal diameter tolerance upon final turning costs is displayed on Figure No. 47. The effect of the alternative technology (investment casting) would far overshadow the cost reductions because of tolerance relaxation, but at a prohibitively large tolerance from a performance standpoint.

c Surface Finish

Figure No. 48 shows the very significant effect of surface finish upon hand-finishing cost for two technological levels of performing the operation. As was the case with the fully-machined fuel impeller, the cost of performance and the finishes obtainable from the sandblast method are both somewhat speculative because none of the suppliers contacted had actually used this method of finishing a high performance impeller. It is probable that the vane profile tolerance also would have to be relaxed from the base case value to utilize the sandblast alternative.

d Size Effect

The effect of over-all size upon lumped casting and machining operations is shown on Figure No. 49. All other requirements are constant at the base case values.

12 LOX Turbopump Item 20 - LOX Pump Inducer

The cost effects of vane profile tolerance, outside diameter contour tolerance, surface finish and size are shown on



Figure 45. - Cost Effect of Size, LOX Turbopump Item 17


Figure 46. - Cost Effect of Vane Profile Tolerance, LOX Turbopump Item 19

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Figure 47. - Cost Effect of Seal Outside Diameter Tolerance, LOX Turbopump Item 19



Figure 48. - Cost Effect of Surface Finish, LOX Turbopump Item 19



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Figure 49. - Cost Effect of Size, LOX Turbopump Item 19

Figures No. 50 through No. 53 for fully-machined, cast and cast and machined inducers. The data for the machined version are subject to the same limitations and uncertainties described for the fuel pump impeller and inducer. The casting costs are relatively invariant over the range of tolerances investigated because of the simple helicoidal shape assumed. More complex (cambered) vane shapes would probably result in a variable rejection rate as a function of tolerance but no quantitative data were obtained.

a Casting Tolerance

Figure No. 54 shows the cost effect of casting tolerance. The change in cost is totally a function of dimensional rejection rate for this part because material strength is not critical and casting flaws can be tolerated.

> <u>b</u> Critical Bore and Pilot Diameter Tolerance

The effect of critical dimensional tolerances upon final turning costs is given on Figure No. 55. Pilot diameter and bore tolerances were varied together in the ratio shown to obtain the data and the effects are therefore inseparable.

c Surface Finish

No appreciable cost differences were noted over the 63 microin. to 250 microin. roughness range investigated.

14 LOX Turbopump Item 26 - LOX Turbine Rotor

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a General Dimensional Tolerance

The cost effect of general dimensional tolerances (i.e., outside diameter and axial length) is displayed on Figure No. 56. The rather small (4% to 5%) cost reduction shown occurs in the range from ± 0.001 to ± 0.003 with no significant improvement from ± 0.003 out to ± 0.005 .

b Surface Finish

Figure No. 57 shows a significant (8% to 10%) cost effect of surface finish over the range from 32 microin. to 250 microin. roughness, but the effect would flatten at approximately 250 250 microin. when dimensional requirements limit machining time and hand work in the blading is eliminated. Significant further improvement could be obtained if as-forged/cast or as-forged/cast and sandblasted dimensional variations could be tolerated on the disc surfaces.

¹³ LOX Turbopump Item 25 - LOX Pump Inlet Adapter





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Figure 51. - Cost Effect of Vane Outside Diameter Tolerance, LOX Turbopump Item 20



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Figure 52. - Cost Effect of Surface Finish, LOX Turbopump Item 20



Figure 53. - Cost Effect of Size, LOX Turbopump Item 20

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Figure 56. - Cost Effect of General Dimensional Tolerance, LOX Turbopump Item 26



Figure 57. - Cost Effect of Surface Finish, LOX Turbopump Item 26

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<u>c</u> Blade Profile Tolerance

A very strong 20% and 50% cost effect of rotor blade profile tolerance is shown on Figure No. 58 for two technological levels of obtaining the desired blade profile. Primary reasons for the reduction in both cast/machined and forged/machined versions is the reduced cutter replacement/sharpening time and the increased depth of cuts possible at the higher tolerances. A cast only version is not shown but would display no vane generating costs.

d Size Effect

Cost effects of general size for lumped forging and machining operations at the base case tolerance level are the same as those shown in Figure No. 17 for fuel turbine rotors.

> 15 LOX Turbopump Item 28 - LOX Turbine Manifold

> > a Critical Dimension Tolerance

Figure No. 59 gives the cost effect of critical dimensional tolerance such as the tolerances on pilot diameters and axial stacking planes. Machining time reduces rapidly by approximately 12% from ± 0.002 to ± 0.005 tolerance, but little effect is noted at higher tolerances. Inspection time does not vary significantly over the ± 0.005 tolerance range.

b Vane Profile Tolerance

The effect of vane profile tolerance upon the cost of generating the vanes is shown on Figure No. 60 for two technological levels of performing the operation. The upper curves are for a fully-machined forged ring with integral machined vanes while the lower curves represent a model where integral vanes are first cast to some intermediate tolerance and then machined to final tolerance. A third (as-cast) version is implied but requires that vane profile tolerance be approximately ± 0.010 . A fixed casting prime cost of \$900 or ring forging prime cost of \$400 must be added to the appropriate curve value to compare alternative part production costs.

16 LOX Turbopump Assembly

a Stacking Dimension Tolerance

Assembly costs in terms of assembly labor manhours and total assembly net dollars versus critical axial stacking dimension tolerance are shown on Figure No. 61. Tolerances are assumed to be



Figure 58. - Cost Effect of Blade Profile Tolerance, LOX Turbopump Item 26



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Figure 61. - Cost Effect of Stacking Dimension Tolerance, LOX Turbopump Assembly

distributed equally for the several parts affecting pump, seal, and turbine clearances. Assembly cost differences are totally attributable to the additional assembly operations required to custom-fit spacers/shims for larger tolerance parts.

b Size Effect

Figure No. 62 shows turbopump level size effect data for the total machine. These data were derived from the cost versus size data of Figures No. 45, No. 49 and No. 53, along with similar data for all major turbopumps subcomponents. Only net costs in dollars are shown as a function of required NPSH because no single hourly rate is applicable to all subcomponents.

(c) Development Phase Test Operations

Development test operations costs are not strongly dependent upon any other requirements than schedule and reliability for the class of machinery investigated in this study where the technology to execute a successful design clearly exists. As in the case of the design operations, the reliability levels required to assure that essentially no flight or mission failures can occur dictates that only the most rigorous development philosophy be used. It is not possible, within a reasonable schedular restraint of 10 years or less, to attain or demonstrate the required reliability without utilizing the full depth of every known turbopump development technique.

Accordingly, only one development test plan was formulated and costed as an implement for determining over-all program cost. Figure No. 3 is an outline of the development program thus formulated and forms the basis for the development test costs shown on Figure 63 and Table V. The following discussion outlines the philosophy and ground rules assumed in developing the costs.

To accomplish the development testing, it was assumed that existing Government or contractor-owned facilities would be used. Because all of these facilities currently exist at Aerojet, facilities cost estimates were limited to the following facility activation operations.

- Loading of propellants into storage and run tank systems.
- Dehydration and purging of facility system.

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- Instrumentation of facility systems.
- Installation of flowmeters.
- Installation of flow spool.



Figure 62. - Cost Effect of NPSH/Size, LOX Turbopump Assembly

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DEVELOPMENT TEST OPERATION		MANQUARTERS	DOLLARS
1. Subcomponent test (part or feature level)			
	a. Subcomponent proof tests		
	(1) Rotor proof spin tests	11	132,000
	(2) Housing pressure tests	11	132,000
	b. Subcomponent Integrity Evaluation		
	(1) Vibration Characteristics Definition (Blading)	6	72,000
	(2) Housing Burst Pressure	8	96,000
	(3) Rotor Burst Speed	8	96,000
	(4) Bearing Life Tests	70	840,000
2.	Component Tests (Sub-Assy Level)		
	a. Pump Performance Evaluation	120	1,440,000
	b. Power Transmission Performance Evaluation	0	0
	c. Turbine Performance Evaluation	0	· 0
3.	Turbopump Development Tests	835	9,900,000
4.	Turbopump Acceptance Tests (Checkout for R&D Engines)	140	1,680,000
	Total	1211	14,378,000

TABLE V. - DEVELOPMENT TEST COST SUMMARY

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- Conducting facility leakage checks at ambient and cryogenic conditions.
- Functional sequencing of interacting systems.
- System cryogenic flow testing, both oxidizer and fuel.
- Installation of gas generator assembly and turbopump assembly.
- Gas generator assembly system functional and leakage checking at ambient and cryogenic conditions.
- Flow spool removal.
- Gas generator assembly checkout firing.
- Turbopump assembly mock-up installation for fit-up of gas generator assembly, suction line, discharge line, and exhaust line.
- Mock-up removal.
- Data review.

Development test manpower to support the program outlined on Figure No. 3 including the above facility activation report is shown by program quarter on Figure No. 63. The man loading displayed does not include the design engineering manpower required to plan the tests and interpret the results, because the engineering effort was included in the design costs shown on Tables III and IV and Figures No. 5 and No. 6.

Propellants were assumed to be Governmentfurnished and no consideration was given to the impact upon production capability or availability (see Production Phase Test Operations for quantities).

1 Turbopump Test Capabilities

A two-position turbopump test complex would be required to meet the R&D test rate. Each of the two turbopump stands would be capable of accommodating a gas generator, a single liquid oxygen pump, or a single liquid hydrogen pump. Pump backpressure as well as transient and steady-state characteristics would be controlled by programming high response flow control valves. On-stand tankage for short duration start transient testing would be necessary for both the oxygen and fuel pumps during the development program. A set of high pressure run vessels would be required to supply propellant to the gas generators. The two test stands could be controlled and instrumented from a common control room.

Basic test stand and propellant vessel capability requirements would be as follows.

a Base Structure

The base concrete structure must be capable of withstanding the forces generated by the gas generator and pump as well as the loading of a stand tank and propellant flow transients.

b Superstructure

Superstructures must be capable of carrying the full transient load condition which is expected to occur during any test contemplated. This includes ramping of suction and discharge pressures to simulate acceleration characteristics in the propellants.

> <u>c</u> On-Stand Turbopump Assembly Transient Vessels

> > LH_2 - One 5,000 gal, 100 psi vacuum jacketed

 LO_2 - One 22,000 gal, 100 psi; insulated

d On-Stand Gas Generator Assembly Vessels

 LH_2 - One 7,000 gal, 2,000 psi, vacuum jacketed

LO₂ - One 400 gal, 2,000 psi, non-insulated

e Off-Stand Run and Catch Vessels

LH₂ Run and Catch - Two 75,000 gal, 100 psi, vacuum jacketed, 10 in. outlet

LO₂ Catch - One 22,000 gal, 100 psi vacuum jacketed

f Propellant and Pressurant Storage

LH₂ - One 100,000 gal, 100 psi vacuum jacketed and one 13,000 gal, 100 psi for GH₂ conversion

LO₂ - One 28,000 gal, 100 psi vacuum jacketed

 LN_2 - One 13,000 gal, 100 psi vacuum jacketed

The LH₂ and LO₂ catch vessels listed above also serve as storage vessels.

 GN_2 Cascade - Two 1,300 ft³, 5,000 psi vessels GN_2 Cascade - Two 1,300 ft³.

5,000 psi vessels

Gas Conversion Systems

GN₂ - One 74,000 SCFH, 5,000 psi GH₂ - Two 74,000 SCFH, 5,000 psi

h Instrumentation

The following minimum instrumenta-

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tion capability should be provided and would be switched between the two stands from a common control room:

Input: 72 pressure measurements

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- 84 temperature measurements
- 24 special wide band measurements
- 84 miscellaneous traces and flow

Recording: 138 digital channels

- 40 visual displays
- 32 wide band channels
- 5 oscillographs

Servo Control Systems for Valves:

Tank pressurization, liquid flow control, and pump backpressure control.

i Test Duration

With the above capability a 300 sec run duration is available. 2 Turbopump Subcomponent Test Facilities

Turbopump subcomponent development testing would require the following specialized facilities as well as universal vibration, spin, and thermal shock test facilities.

a LH2 Bearings and Seals Test Bays

With the criteria established for a maximum test rate of 12 tests per week, it is necessary that two test positions be provided. Each test position would be supplied with all necessary working fluids from a common source (i.e., LH₂ run tanks). However, each position should be equipped with an electrically-driven bearing tester which is capable of variable speed control from 0 to 40,000 rpm.

Because the bearing tests are of long duration, one centrally located, vacuum jacketed run tank of 8,650 gal capacity with a preferred design pressure of 1,800 psi would be needed to provide high pressure liquid hydrogen to each test bay through 2.0-in.-vacuum insulated piping.

b LO2 Bearings and Seals Test Bays

Two positions similar to those for the above LH2 testing would be required for LO2 to accommodate the same rate.

One centrally located, single-walled vessel of 8,650 gal and 1,800 psi design pressure would be required.

<u>c</u> LH₂ Storage

Two 14,000 gal, 100 psi vacuumjacketed storage vessels should be provided with one truck/trailer unloading station in support. Two vessels are desirable to provide system flexibility during concurrent LH₂ off-loading and transfer and LH₂ converter operation.

d LO₂ Storage

Storage similar to that described

for the LH2 would be required for LO2.

LN₂ Storage

One 13,000 gal, 100 psi vacuumjacketed storage vessel is needed to supply the LN_2 converters. This vessel should be supported by a single trailer unloading station.

e

f LH₂ Converter

One 74,000 SCFH or two, 36,000 SCFH

each, 5,000 psi converters are needed.

g LN₂ Converter

Two 74,000 SCFH, 5,000 psi converters are required. Both LN₂ and LH₂ high pressure pumps should be electric-motordriven. All vaporizers should be of a steam or hot water heat exchanger type. Liquid supply for each system should be provided from the test facility LN₂ or LH₂ storage tank. No separate tank is needed for the converter supply.

h Support Facilities

In addition to the major facilities described above, the following support facilities are needed at a readily accessible location to the turbopump assembly and component test complexes.

- Instrumentation Repair and Calibration Shop
- Flowmeter Calibration Facility
- Valve Repair Shop
- Mechanical Machine Shop
- Clean Room Facilities
- Vibration Facilities
- Data Processing Equipment
- Office and Engineering Buildings

(d) Production Phase Design Operations

Design operations during the production phase of a high reliability rocket engine turbopump must be limited to those required for performance-oriented modifications (to satisfy changing engine requirements) and to mechanical feature modifications (to satisfy life/reliability requirements under unanticipated flight environments). Any redesign for ease of production would invalidate the results of the development/qualification program. Therefore, production phase design operations are not a definable function of design requirements and cost studies were limited to definition of the design manpower required to make the types of modifications indicated. The manpower requirements thus defined are summarized on Table VI and are invariant with design requirements.

TABLE	VI

PRODUCTION PHASE - DESIGN OPERATIONS COST SUMMARY

Activity/Discipline	Manpowe	r (Manyears)	
Performance Modifications Pump Hydraulics Turbine Aerodynamics Mechanical Modifications Design Engineering Structural Analysis Drafting		18 18 9 12 <u>18</u>	
	Total	75	

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(e) Production Phase Fabrication Operations

In keeping with the philosophy that the production turbopumps must be identical to those qualified, production phase fabrication operations are related to design requirements in exactly the same manner as previously discussed for development fabrication operations.

The cost estimates were all prepared under the assumption of high volume production and the tooling costs shown in Appendices H and I reflect that assumption. Production lot sizes larger than 40 to 50 were not specifically investigated but discussions with contributing suppliers indicate no significant change in cost would occur within the range from 50 to 100 units. Some significant additional reduction might occur in the range from 100 to 1000 units, but it did not appear that the reference application program would approach this number at the time the estimates were prepared.

(f) Production Phase Test Operations

Production Phase Test Operations can be divided into the following five subcategories and operations:

- 1 Subcomponent Level Tests
 - a Rotor Proof Spin Tests
 - b Housing Proof Pressure Tests
- 2 Component Level Tests
 - a Pump Calibration
 - b Turbine Calibration
- 3 Turbopump Level Tests
 - a Acceptance Tests
 - b Post-Test Checkout and Inspections
- 4 Engine Level Tests
 - a Engine Acceptance Tests
 - b Post-Test Checkout and Inspections
 - 5 Stage Level Tests
 - a Flight Readiness Tests
 - b Post-Test Checkout and Inspections

The MLLV Program ground rule requirements of engine acceptance test and stage static test firing (Ref. 1) eliminated the last two subcategories from consideration. Therefore, the optimum method for performing the production phase test operations is that combination of the first three subcategories which will sustain the performance and reliability requirements at the lowest cost.

Past programs have generally utilized elements of all three levels of tests to assure that the requirements were met. Consequently, little data exists to support the elimination of entire subcategories. However, the bulk of the test cost is incurred during the turbopump level acceptance tests and checkout. Therefore, programs including as well as omitting these tests were studied.

The program plan includes the turbopump acceptance plans and was prepared for three production rates. Figure No. 3 shows the minimum production rate of 60 units per year (Ref. 1). Alternative programs at double and quadruple that rate were postulated. The three rates result in production test program lengths of 18, 9 and 4-1/2 years, respectively.

The previously described development test facility capability would be adequate for the base 60 unit per year production rate but to effectively double the test rate, a second complex of two test stands would be required. These stands would be physically identical to the first complex stands. If possible, the second complex should be located near the first one to permit the common utilization of the off-stand run vessels, catch vessels, and storage capabilities by both complexes. However, no such facility exists and a utilization of existing contractor or Government-owned facilities would require a completely separate facility at some other location. The quadrupled test rate would again double the number of test positions required and result in additional test planning as well as follow-up manpower because of the separate geographical locations required to utilize existing facilities. The manpower estimates for the high production rate (240 unit/year) include these additional test planning and follow-up personnel. Production test manpower is shown by program year on Figures No. 64, No. 65 and No. 66 for 60, 120, and 240 unit/year test rates, respectively. Total costs for each alternative (excluding propellants) are shown on Table VII.

TABLE VII. - PRODUCTION PHASE - TEST OPERATIONS COST SUMMARY

Production Rate	Test Operations Costs
60 Units/Year	\$44,200,000
120 Units/Year	\$45,200,000
240 Units/Year	\$46,200,000

Propellants were assumed to be Governmentfurnished and no consideration was given to the impact upon propellant production, capability or availability for the various program alternatives. However, propellant usage for the three alternatives is shown on Table VIII.



Figure 64. - Manpower Chart, 60 Units/Year for 18 Years



Figure 65. - Manpower Chart, 120 Units/Year for Nine Years



Figure 66. - Manpower Chart, 240 Units/Year for Four and One-Half Years

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ALTERNATIVE I (60 UNITS/YEAR)					
Production	LH2 1b	LO2 Tons	LN ₂ Tons	GHe - MSCF	
1	2.552.000	5,500	7,600	577	
2	2,552,000	5,500	7,600	577	
3	2,552,000	5,500	7,600	577	
4	2,552,000	5,500	7,600	577	
5	2,552,000	5,500	7,600	577	
6	2,552,000	5,500	7,600	577	
7	2,552,000	5,500	7,600	577	
8	2,552,000	5,500	7,600	577	
9	2,552,000	5,500	7,600	577	
10	2,552,000	5,500	7,600	577	
11	2,552,000	5,500	7,600	577	
12	2,552,000	5,500	7,600	577	
13	2,552,000	5,500	7,600	577	
14	2,552,000	5,500	7,600	577	
15	2,552,000	5,500	7,600	577	
16	2,552,000	5,500	7,600	577	
17	2,552,000	5,500	7,600	577	
18	2,552,000	5,500	7,600	577	
	45,963,000	99,000	136,800	10,386	
ALTERNATIVE II (120 UNITS/YEAR)					
	5 104 000	11.000	15,200	1,154	
	5 104 000	11,000	15,200	1,154	
2	5 104 000	11.000	15,200	1,154	
3	5,104,000	11,000	15,200	1,154	
4	5 104 000	11,000	15,200	1,154	
5	5 104 000	11.000	15,200	1,154	
0	5 104 000	11.000	15,200	1,154	
/	5 104 000	11,000	15,200	1,154	
0	5,104,000	11,000	15,200	1,154	
7	45,936,000	99,000	136,800	10,386	
ALTERNATIVE III (240 UNITS/YEAR)					
	10 000 000	22 000	30-400	2,308	
	10,208,000	22,000	30,400	2,308	
2	10,208,000	22,000	30,400	2,308	
3	10,208,000	22,000	30,400	2,308	
4	TO,208,000	11 000	15,200	1,154	
5	5,104,000	11,000	10(000	10 206	
	45,936,000	99,000	136,800	10,300	

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The program plan wherein the formal turbopump acceptance tests are eliminated actually defers the mechanical and performance checkout of the turbomachinery until the engine level acceptance tests. Titan and Gemini engine production test program results offer some evidence that such an approach is feasible. The negligibly low assembly error incidence achieved in those programs virtually eliminated the necessity to verify the turbopump mechanical integrity by a hot firing test of the turbopump alone.

However, the hydraulic and aerodynamic performance data obtained during a turbopump acceptance test serves as prime input for the initial engine trim or calibration. Attempts to trim the engine based upon nominal turbopump performance levels often resulted in unacceptable thrust or mixture ratio conditions. The variations in turbopump hydraulic and aerodynamic performance which must be accounted for in the engine trim are related to the subcomponent design requirements previously discussed. However, this dependency of acceptance test and engine trim requirements upon subcomponent design requirements was not recognized early enough in the study. Only minimal useful data was obtained at the more stringent requirements that are necessary to reduce component performance scatter to a level which would allow initial engine trim to be made accurately without first calibrating (acceptance test firing) the turbopump. The subcomponent cost data generated can be extrapolated to more stringent requirement levels but the subsequently discussed performance analysis was not extended over a sufficient range to allow definition of requirements levels where calibration would not be needed. For the purposes of developing the study objective of cost optimization methodology, it was assumed that the most stringent requirement/performance levels studied corresponded to the level where calibration can be eliminated. This approach merely serves to illustrate the technique which would be used in an actual production program.

The cost of the production phase test operations for the program alternative described above would be reduced from the base case program by the entire turbopump acceptance test manpower costs as well as the propellant costs for the .60 unit-per-year production rate. The higher production rate alternatives would result in those same savings plus the additional facility activation cost savings.

(g) Production Phase Field Maintenance Operations

The Field Maintenance Operations performed on turbopumps normally are limited to periodic seal checks, periodic rotor torque checks, interface static seal replacement, and turbopump removal as well as replacement in the engine. These operations are performed to assess and provide any necessary remedies for the mechanical integrity or the performance (in terms of lost propellant) of the system. In the subject study, no way was found by which the cost of the mechanical integrity (torque) checks or resulting replacement operations could be traded with design requirement variations. However, the seal checking costs can be weighed against leakage requirements variations at two technological levels; all seals can be checked or those which are actually controlled leakage devices (i.e., labyrinths) can be excluded from the check. Seals are subject to handling/shipping damage while labyrinths are not. There is an obvious cost difference for field servicing the two types of machines. Titan/Gemini records show that 93 manhours-per-seal-per-check were expended, upon apportioned historical field service costs, and only two hours-per-seal were required, based upon apportioned historical post-fire inspection costs at the engine contractor's facility. The large discrepancy between the two can be partially attributed to the increased complexity of performing the check in the engine and stage, but the major difference appears to result from the need to maintain the checking capability during periods of inactivity.

(2) Design Requirements versus Component Performance

The base case component arrangement of series flow turbines and the turbopump configurations of single-stage centrifugal pumps. two-stage axial flow turbine, and single-stage axial flow LOX turbine strongly influence the relative worth of fuel turbopump versus LOX turbopump subcomponent performance in terms of engine specific impulse degradation through their effect upon gas generator or turbine flow rate. Ideally, the minimum turbine flow rate would occur when fuel and LOX turbopump component performance are balanced in a way that the required fuel and LOX turbine flow rates are exactly equal at the optimum turbine pressure ratio division. In practice, component performance variations from the nominal require that one turbopump performance be biased such that the turbine pressure ratio split can be varied to adjust the input power balance. Usually, this is accomplished by either by-passing some of the turbine flow around the highest performance system or by adding a control pressure drop between the turbines. The base case designs are such that the fuel turbopump establishes the turbine flow rate requirement at a value 5% to 10% higher than that required by the LOX turbine to allow for the control pressure drop.

The relative engine performance (I_{sp}) degradation contribution of fuel and oxidizer turbopumps is, therefore, a complex function of turbine pressure ratio and flow rate. The problem can be simplified to a manageable level by using the following assumptions:

- Similar performance changes can be made simultaneously in both fuel and LOX turbopumps.
- Such changes will always be made in the same (either improving or degrading performance) direction.
- Performance improvements or degradations of fuel and LOX turbopump alternatives are equal in terms of the turbine flow rate effect upon specific impulse.

It is recognized that these assumptions are not necessarily valid, but a comprehensive systems analysis defining the actual relative weighting factors was beyond the scope of the study. Thus, these assumptions allowed definition of the cost optimization methodology to proceed. A more rigorous systems analysis would be required for any future program using the methodology developed here.

The above reasoning allowed determination of the effect of design requirements variations upon component performance to proceed almost independently for the fuel and LOX turbopump subcomponents. It was not necessary to select complete propellant feed system level alternatives for study. The ensuing subsections describe this determination.

(a) Pumps

Dimensional variations up to and in excess of commonly specified tolerance bands were investigated to determine the resulting effects upon over-all pump efficiency and head rise. The surface quality or surface finish of important flow passages was varied over a wide range to assess friction losses and resulting effects upon pump performance. These effects were investigated for both the oxidizer and fuel pump, because of the characteristically different concept and method of fabrication between these pumps. Each investigation is reported separately.

1 Oxidizer Pump

Basically, this pump consists of a shrouded impeller and a volute type housing. Leakage is controlled by labyrinths on both impeller shrouds. The effects of the following parameters were investigated.

<u>a</u> Impeller Discharge Diameter

Variation of discharge diameter mainly affects pump head rise. In practice, this diameter is machined a few per cent larger to assure that the head requirement can be met without increasing speed. If necessary, the blades can be trimmed back to reduce head. In general, no matching or impeller-to-housing interaction problems will occur with a volute type housing at impeller discharge diameter variations of approximately 10%.

b Impeller Discharge Blade Height

The discharge blade height or port width mainly affects the discharge flow coefficient. Investigation of this effect was conducted using the pump design and loss isolation program developed for the NERVA turbopump project. Results indicate fairly flat efficiency versus flow coefficient curves for shrouded impellers. Performance is plotted as a function of blade height on Figure No. 67.

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Figure 67. - Effect of Impeller Discharge Blade Height upon Pump Performance, LOX Pump

<u>c</u> Impeller Discharge Blade Angle

Impeller discharge angle variations as big as + 5-degrees were considered. Inlet blade angle and discharge flow coefficient were assumed as constant. Thus, the configuration with the lowest discharge blade angle yielded the longest flow path and, therefore, friction loss. The configuration with the highest discharge angle had the lowest friction loss, but incurred a higher diffusion loss because of increased retardation of the relative flow. As a result, efficiency at both limits of vane angle is lower than at the nominal value. The head coefficient increases with increasing blade angle. Figure No. 68 depicts pump efficiency and head coefficient plotted as a function of the discharge blade angle.

d Effect of Surface Roughness

Surface roughness or surface quality effects were analyzed for impeller blade passages, the impeller disk and the volute housing. At high Reynolds numbers (RE > 10^6), skin friction essentially becomes a function of the relative surface roughness rather than that of the Reynolds number. Friction factors (f) for various surface qualities were determined with an expression recommended by the Gottingen Institute for granular surfaces:

$$f = \frac{1}{(2 \log (d/k) + 1.138)^2}$$

where (d/k) denotes the relative surface roughness defined as the hydraulic diameter of the flow passage divided by the surface finish. The range of relative surface roughness investigated extends from that of polished channels to that of corroded pipes. Figures No. 69 and No. 70 depict pump efficiency and head coefficient as a function of surface finish for the impeller and volute housing. Disc friction only affects the input head or pump efficiency. The friction factor used in the disc friction equation was varied from its nominal value according to the relative surface roughness analogous to the friction coefficient for channel flow. Results of this effect upon pump performance are shown on Figure No. 71.

e Labyrinth Dimensions

The leakage flow rate across the labyrinth determines the volumetric efficiency of the pump. The effect of radial clearance, tooth thickness, and tooth spacing upon the leakage flow was analyzed with the use of a computer program based upon G. Vermes Fluid Mechanics Approach complemented by annular orifice data from K. J. Bell and O. P. Bergelin. Leakage flow and efficiency are plotted versus the aforementioned parameters on Figures No. 72, No. 73 and No. 74. The radial clearance predominantly exerts the strongest effect, while tooth thickness and spacing have only little influence upon efficiency.



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Figure 70. - Effect of Volute Surface Roughness upon Pump Performance, LOX



Figure 71. - Effect of Disk Surface Finish upon Pump Performance, LOX Pump



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<u>f</u> Pumps at Constant Suction Specific Speed

A family of impellers of constant suction specific speed (43,000 rpm x $gpm^{0.5}/ft^{0.75}$) was sized to compare impeller discharge geometry and rotational speed for various inlet diameters. The Net Positive Suction Head (NPSH) was established at three times the inlet axial velocity head and the inlet blade angle at 1.74 times the fluid angle (incidence to blade angle ratio = 0.425) for all cases investigated. The pertinent parameters of these pumps are plotted versus the inlet diameter on Figures No. 75 and No. 76.

2 Fuel Pump

This pump is composed of an unshrouded impeller and a diffusion type housing with rolled-over volute. The following parameters were investigated.

a Impeller Discharge Diameter

Because of the vaned diffuser, the off-design performance of this pump will be more sensitive to diameter changes $(e.g., \pm 5\%)$ than the oxidizer pump which is fitted with a volute housing. However, within reasonable limits, the technique of diameter trim discussed for the oxidizer pump can be applied to this pump as well.

b Impeller Discharge Blade Height

At a constant axial clearance, tip

clearance losses will increase with decreasing blade height. Thus, the unshrouded impeller will be more sensitive to blade height variations than the shrouded impeller of the oxidizer pump. Efficiency and head coefficient are plotted versus impeller discharge blade height on Figure No. 77. Impellerhousing interactions for the $\pm 10\%$ dimensional variation were neglected.

c Impeller Discharge Blade Angle

Considerations and results of this investigation are similar to that of the oxidizer pump. Because this impeller has machined blades, the range of blade angle variation was reduced to + 2-degrees from the nominal value. Figure No. 78 presents the pump performance as a function of blade angle.

d Diffuser Blade Inlet Angle

The diffuser blade was assembled to retain its general shape and orientation while the inlet angle was varied. In this way, changes in blade inlet angle only affect blade camber in the inlet region. Fluid turning and diffusion within the blade passage increase



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Figure 78. - Effect of Impeller Discharge Blade Angle upon Pump Performance, Fuel Pump

as the blade angle, the diffusion losses diminish considerably but incidence losses result in slightly increasing total blade losses. Friction losses are constant over the entire range of inlet angles investigated. The effects upon pump efficiency and head coefficient are shown on Figure No. 79.

e Blade Tip Clearance

Performance of an unshrouded impeller is quite sensitive to the blade tip clearance. An approximate method, based upon experimental data, to assess tip clearance losses was used in the analysis. The impeller blade height was kept constant for the entire range of tip clearances investigated. Results are presented in terms of efficiency and head coefficient on Figure No. 80. Headrise and efficiency generally are subject to the same percentage variations, from zero to clearance to blade height ratios (s/b) of approximately 0.08. At greater values of s/b, Titan pump tests indicated that the head coefficient drops off more rapidly.

f Impeller Blade Surface Finish

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Head coefficient and efficiency are plotted as a function of surface finish on Figure No. 81. This effect is similar to that investigated for the oxidizer pump. Because the impeller blades are machined, the upper limit of surface roughness investigated was established at 1000 microin.

> <u>g</u> Pumps at Constant Suction Specific Speeds

Based upon the ground rules selected for the analysis of the oxidizer pump, a family of impellers of constant suction specific speed was sized to relate pump geometry and rotational speed to the inlet diameter. Parameters of interest are plotted as a function of impeller inlet diameter on Figure No. 82.

(b) Turbines

The LOX and fuel turbine designs were evaluated to determine the effects of mechanical design requirements upon the gas flow rate needed. Surface finish and dimensional control of the flow passages were varied over a wide range to obtain performance effects. The design speed of the turbines was varied by a ratio exceeding 2 to accommodate a constant pump suction specific speed. The resulting changes in tip diameter, blade height, and gas flow rate are noteworthy.

Effects were investigated for both LOX and fuel turbines because they are characteristically different in concept. Each investigation is reported separately.



Figure 79. - Effect of Diffuser Inlet Blade Angle upon Pump Performance, Fuel Pump





Figure 81. - Effect of Impeller Blade Surface Finish upon Pump Performance, Fuel Pump

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<u>1</u> Oxidizer Turbine

The turbine is a large ($D_m = 17.2$ -in.) single-stage, impulse type, propelled by the combustion products of LO₂ and LH₂. The turbine is downstream and operates in series with the fuel turbine.

<u>a</u> Nozzle Vane Angle

The nozzle exit angle was deviated up to 9-degrees from the design point giving a maximum variation of 16% to propellant flow. Turbine flowrate versus nozzle angle deviation is shown on Figure No. 83. The speed, temperature, and power were assumed constant.

b Rotor Blade Angle

An incidence loss is incurred for deviations in the inlet angle of a rotor blade. Exit angle deviations cause a similar performance loss. Combined inlet and exit angle variations of up to 10-degrees were investigated. The maximum variation caused an increase in propellant flow of 12.5%. The losses incurred by rotor blade angle deviations are shown as flow-rate increases on Figure No. 83, along with the nozzle losses.

c Flow Passage Surface Finish

Performance losses caused by flow passage roughness were approximated by use of a technique based upon Moody's friction loss formula for pipes.

The friction losses from rough surfaces are minimal giving a flow increase of 2% for a nozzle surface roughness of 2000 microin. Plots of surface finish versus increased flow-rate for the nozzle and rotor are shown on Figure No. 84.

d Rotor Blade Tip Clearances

Turbine rotor blade tip clearance losses vary directly with the radial gap controlled by fabrication and assembly tolerances. The following additional parameters must be considered when comparing different types of turbines.

High hub-to-tip ratio rotors have greater losses than low hub-to-tip ratio rotors. The higher efficiency turbines are more sensitive to increased tip clearances. Honeycomb and spongedmetal perimeter inserts allow smaller clearances without the risk of rubbing failures. Shrouded rotors have smaller losses than open ended blades.

Turbine efficiency loss and turbine flow increase as a function of blade radial gap, for the plain unshrouded blades of the base case machine, are shown on Figure No. 85.



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Figure 83. - Effect of Nozzle and Rotor Angle upon Flow Rate, LOX Turbine



Figure 84. - Effect of Surface Finish upon Flow Rate, LOX Turbine





Figure 85. - Effect of Tip Clearance upon Efficiency and Flow Rate, LOX Turbine

e Rotational Speed Variation

Turbine rotor tip diameter, blade height and propellant flow-rate were investigated to determine how they varied with design point speed changes. This investigation was carried out in conjunction with the pump NPSH-size evaluation. The results were obtained by designing a turbine to satisfy each of the pump speed and power requirements.

Turbine flow rate, turbine rotor tip diameter, and rotor blade height are plotted versus pump NPSH on Figure No. 86.

2 Fuel Turbine

The fuel turbine is a two-row, Curtis staged, overhung system operating in series with the oxidizer turbine. In addition to the parameters investigated for the oxidizer turbine, the fuel turbine was optimized with respect to gas temperature versus blade root stress.

<u>a</u> Turbine Gas Temperature

The turbine gas temperature was varied over the range from 1200°F to 1500°F in increments of 100°. The blade height was varied to maintain the root stress at a constant safety margin with the temperature degraded material properties by increasing the turbine gas density. Shaft horsepower, rotational speed, and blade speed were assumed constant. Turbine flow requirements could be reduced by approximately 4% at the maximum gas temperature investigated using Inconel 718 material properties. A plot of turbine gas temperature versus flow rate improvement is shown on Figure No. 87. Effects of disc stress margin were not quantitatively investigated, but constant shaft critical speed margin (constant overhung mass) would require that blade speed be reduced. Extensive studies conducted for NERVA (Contract SNP-1) of very similar machines have indicated that minimum turbine flow rate occurs at 1200° to 1300°F.

b Nozzle Vane Angle

The first nozzle and second row turning vane exit angle deviation were evaluated based upon the changes in tangential velocity, Vu. The maximum angle deviation of 8-degrees at the firststage nozzle caused an increased turbine flow rate of 17%. The same deviation of the second row turning vane only increased the flow rate by 4%. Turbine flow rate versus nozzle angle deviation is shown on Figures No. 88 and No. 89.

<u>c</u> Rotor Blade Angle

The rotor blade angle deviation causes a loss similar to the nozzle angle deviation. This loss was estimated by assuming that the velocity components, which are normal to the blade velocity, are completely lost. The inlet and exit blade deviations were



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Figure 88. - Effect of First Nozzle Vane Angle Deviation upon Flow Rate, Fuel Turbine

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combined for each stage and are shown on Figures No. 88 and No. 89 as a function of flow-rate change. The first rotor shows the greatest effect upon flow-rate because of the work-split effect. At 9-degrees inlet and exit angle deviation, the flow-rate increased by 7.5%. The second rotor deviation of 9-degrees would increase flow rate by only 4.2%.

d Flow Passage Surface Finish

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The roughness of the flow passages causes friction losses which reduce the available enthalpy of the propellant. Friction loss is determined by using a technique based upon Moody's friction loss formula for pipes. The friction loss then is applied to the velocity head in the flow passages to determine the performance loss. The first-stage nozzle has the most significant loss because of the high velocity. For a surface roughness of 2000 microin., the nozzle loss amounts to an increased propellant flow of 6.5%. Flow-rate as a function of surface finish is shown on Figure No. 90.

Losses in the first-stage rotor and second-stage nozzle and rotor are much less than the first nozzle. The first rotor loss amounts to a 2% flow increase and the second rotor loss is only 0.15%. The surface finish versus flow-rate for these passages is shown on Figure No. 91.

e Rotor Tip Clearances

The effect of rotor blade radial clearance upon turbine performance was evaluated using an empirical method whereby the leakage area to the blade axial flow area is proportioned. The first-stage rotor accounts for 80% of the total turbine power; therefore, the first-stage tip clearance has a predominate effect upon the total leakage losses. The tip clearance effect for plain, unshrouded blades of the base case machine is shown on Figure No. 92.

f Rotational Speed Variation

The turbine design speed variation investigation again was carried out in conjunction with the investigation of pump NPSH effects with a varying inlet diameter. The turbine rotor tip diameters, blade heights, and the propellant flow rates were compared with turbine design speeds corresponding various pump NPSH levels. They are plotted versus the pump NPSH on Figure No. 93.

(c) Turbopumps

The LOX and fuel turbopump designs were evaluated to determine the effect of NPSH upon turbopump weight. The design sketches shown on Figures No. 1, No. 2 and No. 7 through No. 10 were utilized Figure 90. - Effect of First Stator Surface Finish upon Flow Rate, Fuel Turbine

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Figure 91. - Effect of Surface Finish upon Flow Rate, Fuel Turbine



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in preparing the detailed weight estimated included as Appendix J for three levels of required NPSH for both the LOX and fuel turbopumps. These data are plotted in terms of dry weight versus required NPSH on Figures No. 94 and No. 95.

(3) Component Performance versus Engine Performance

While all of the preceding data can be readily used to relate mechanical design requirements and cost variations to performance in terms of turbine flow rate or bleed ratio, it was still necessary to relate turbine flow rate to engine performance. The following describes the method used to evaluate that relationship and summarizes its results.

The basic engine data used in the study were:

Engine Vacuum Thrust - 300,000 ib Thrust Chamber Pressure - 1200 psia Engine Mixture Ratio - 5.0 Nozzle Area Ratio - 50

For series flow turbines with the fuel turbine preceding the oxidizer turbine, the following nominal data were used:

Parameter	Fuel Turbine	Oxidizer Turbine
Inlet Pressure, psia	1190	135
Exit Pressure, psia	152	40
Inlet Temperature, °R	1660	1250
Efficiency, %	53	28
Flow Rate, lb/sec	20	20

In addition to the nominal point investigation, the turbine flow rate was varied arbitrarily to determine the effect upon engine performance. The result of this analysis is depicted on Figure No. 96 which shows that the reduction in engine specific impulse with increasing turbine flow rate is caused by two major factors. Increasing the turbine flow rate causes increases in the thrust chamber mixture ratio which result in reduced theoretical specific impulse. This loss is in addition to the loss associated with dumping a higher percentage of the engine flow inefficiently overboard through a turbine exhaust nozzle.

Fuel turbine inlet temperatures of 1960°F and 2460°R also were investigated. Oxidizer turbine inlet temperatures were calculated assuming a constant fuel turbine pressure ratio. The nominal turbine flow requirement for the increased inlet temperatures was adjusted accordingly for the higher energy drive fluid. Also, the effect of variations in this turbine flow rate upon nominal engine performance was determined. The results of the turbine inlet temperature investigation are shown on Figure No. 97. For fixed





Figure 94. - Weight Effect of NPSH, LOX Turbopump

Figure 95. - Weight Effect of NPSH, Fuel Turbopump



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- (1) GAS GENERATOR CYCLE LO2/LH2 ENGINE, THRUST CHAMBER NOTES: PRESSURE = 1200 PSIA, ENGINE MIXTURE RATIO = 5.0, IIOZZLE AREA RATIO = 50

 - (2) 95% OF THEORETICAL THRUST CHAMBER IS
 (3) BASED UPON SERIES FLOW TURBINES, FUEL TURBINE INLET TEMP. = 1660°R, FUEL TURBINE PRESSURE RATIO = 7.83, △P LINE FUEL TURBINE EXIT TO OX. TURBINE INLET = 17 PSI, OX. TURBINE PRESSURE RATIO = 3.375, FUEL TURBINE EFFICIENCY = 53%, OX TURBINE EFF. = 28%
 - (4) THREE SECS LESS THAN IS NOMINAL DUE TO 3 SIGMA COMPONENT VARIATIONS AND INSTRUMENTATION ACCURACY.







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to Engine Flow for Various Fuel Turbine Inlet Temperatures

pressure ratio turbines with constant efficiencies, increasing the turbine inlet temperature results in reduced turbine weight flow requirements and hence, higher engine specific impulse as shown by the nominal points on Figure No. 97. The higher inlet temperatures also result in higher turbine exhaust temperatures and turbine exhaust specific impulse values which contribute to the increased engine specific impulse.

The data and assumptions used to construct Figures No. 96 and No. 97 are discussed in the paragraphs which follow.

Theoretical shifting equilibrium vacuum specific impulse is shown as a function of mixture ratio on Figure No. 98 for a thrust chamber pressure of 1200 psia and a nozzle area ratio of 50. It was used in conjunction with Figure No. 99 to construct the theoretical thrust chamber specific impulse curve shown on Figure No. 96. Figure No. 99 gives the effect of the thrust chamber flow requirement and gas generator mixture ratio (fuel turbine inlet temperature) upon the thrust chamber mixture ratio and shows that for a given turbine flow requirement, increasing the fuel turbine inlet temperature reduces the thrust chamber mixture ratio shift and hence, performance loss.

The nominal thrust chamber specific impulse shown on Figure No. 96 is based upon 95% of the theoretical value. This percent of theoretical is representative of those obtained with the J-2, RL-10 and the M-1 target values. Based upon the existing data (Refs. 2, 3 and 4), the percentages of theoretical thrust chamber specific impulse for the M-1, J-2, and RL-10 engines were determined to be 95.1%, 95.3%, and 94%, respectively.

To establish the nominal engine performance, it was necessary to determine the turbine exhaust specific impulse values. This data is presented on Figure No. 100 for a turbine exhaust nozzle area ratio of 5. The data points used in the analysis are based upon the turbine efficiency and inlet and exit pressures discussed previously. The following relationship then was used to calculate the nominal engine specific impulse from the nominal thrust chamber and turbine exhaust specific impulses.

$$I_{SP}_{VE} = \frac{W_{TC}}{W_E} I_{SP}_{V_{TC}} + \frac{W_{gg}}{W_E} I_{SP}_{V_{TE}}$$

$$I_{SP}_{VE} = Nominal engine vacuum specific impulse$$

$$I_{SP}_{V_{TE}} = Nominal thrust chamber specific impulse$$

$$I_{SP}_{V_{TE}} = Turbine exhaust specific impulse$$

VACUUM SPECIFIC IMPULSE, SEC 465 460 455 450 445 440 \sim Figure 98. ω T Theoretical Vacuum Specific Impulse versus Mixture Ratio 4 MIXTURE RATIO ப σ 7 ω Q

THRUST CHAMBER PRESSURE = 1200 PSIA NOZZLE AREA RATIO = 50

100% OF THEORETICAL SHIFTING EQUILIBRIUM SPECIFIC IMPULSE

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TURBINE EXHAUST VACUUM SPECIFIC IMPULSE, SEC 360 300 320 340 280 260 200 220 240 800 1000 97% OF NOZZLE 1200 AREA RATIO = TOTAL TEMPERATURE, 1400 DATA POINTS 1600 СЛ °R USED 1800 IN ANALYSIS 2000 MIXTURE RATIO 1.085 0.90 Temperature 2200 .39

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Figure 100. T Turbine Exhaust Vacuum Specific Impulse versus Total

 \dot{W}_{TC} = Thrust chamber flow rate \dot{W}_{E} = Engine flow rate \dot{W}_{gg} = Gas generator or turbine flow rate

To obtain the minimum engine vacuum specific impulse shown on Figure No. 96, the nominal was adjusted by three seconds to account for three sigma component variations and instrumentation accuracy. The differences between the nominal and minimum specific impulse values for the M-1, J-2 and RL-10 are 2.0, 4.0 and 5.0 sec per References 2 through 4, respectively.

The above data were utilized in conjunction with turbopump performance calculations to generate the engine specific impulse influence coefficients shown on Table IX. It should be noted that only the turbine flow rate and turbine inlet temperature coefficients are independent partial derivities. Also, the pump and turbine efficiency coefficients are derived from the flow rate coefficient and linearized base case turbopump performance curves.

TABLE IX. - INFLUENCE COEFFICIENTS ENGINE SPECIFIC IMPULSE

Coefficient	Value
Turbine Flow Rate	0.296 sec/lb/sec
Turbine Inlet Temperature	0.003 sec/°F
Pump Efficiency	0.086 sec/Point
Turbine Efficiency	0.114 sec/Point

(4) Component Performance versus Over-All Cost

The third and final major segment required in developing the cost optimization methodology was the relationship between component performance and over-all costs. The Boeing Company had recently completed a major cost versus performance study (Contract NAS 2-5056) for the referenced MMLV missions and the published data (Ref. 1) were utilized in the Low Cost Turbopump Study because of the applicability of the MMLV mission requirements. However, in any future program wherein the optimization methodology developed herein is used for a different mission, it will be necessary to conduct mission level studies to define the cost versus performance relationships in a manner similar to that shown for the mission considered in this study. While it is recognized that extensive over-all cost studies of this type represent significant expenditures in both time and money, no reasonable alternative to this procedure now exists.

In its simplest form, the data required for the cost optimization methodology consist of the two basic curves shown on

Figures No. 101 and No. 102. These curves were derived from the Boeing data and represent changes in program costs in terms of changes in engine weight or stage mass fraction and engine (trajectory averaged) specific impulse. The most rigorous analysis would call for significantly more data in connection with the stage burnout equation, but for the purposes of illustrating the cost optimization methodology, the linearizations shown on Figures No. 101 and No. 102 are adequate and provide a data accuracy of within 5% over the ranges shown.

In view of the over-all cost versus performance data being derived directly from Reference 1, it is subject to the assumptions and limitations described therein.

b. Fixed Costs

(1) Design

All development and production phase design costs can be considered to be fixed for any particular schedule requirement because of their insensitivity to design requirements at the performance and reliability levels of interest. However, for the purposes of this study, they were considered a variable function of the turbopump qualification schedule.

(2) Fabrication

All fabrication and assembly facilities costs (i.e., machine tools, assembly clean room, part storage, part cleaning, part balancing, and proof test) as well as facilities and maintenance costs are considered to be fixed. They are not included in the data shown in this report, except as they influence applicable overhead rates. Special fabrication tool costs are considered to be variable functions of the requirements, but generally, no variation in cost was noted over the range of requirements investigated.

(3) Test

Test facilities construction costs are considered to be fixed and are not included in this report. Facilities activation costs are variable functions of schedular requirements in that they are dependent upon the number of facilities requiring activation.

4. <u>Synthesis of Design Requirements to Yield Minimum Over-All</u> Costs

The technique used in Task I to quantify the relationship of requirements to turbopump cost parameters, vehicle cost parameters, turbopump cost, vehicle cost, and over-all nonrecurring cost is outlined below:

Step 1: Establish vehicle/engine design requirements "base values (Appendix C).



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Figure 102. - Sensitivity of Over-All Cost to Engine Weight

- Step 2: Select turbopump "base" configuration (Table II and Figures No. 1 and No. 2).
- Step 3: Categorize turbopump design requirements (Appendix C).
- Step 4: Establish turbopump "base" value design requirements (Appendix C).

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- Step 5: Establish the variation of turbopump design requirements (Appendix C).
- Step 6: Determine turbopump cost parameters (i.e., manhours) as a function of design requirements including all turbopump cost-contributing operations (i.e., part fabrication, assembly, and inspection) (Tables III and IV, Appendices H and I, Figures No. 5, No. 6 and and No. 11 through No. 66).
- <u>Step 7</u>: Prepare graphical displays of each major turbopump cost parameter for each turbopump design requirement influencing the cost (Figures No. 5, No. 6 and No. 11 through 66).
- Step 8: Determine the linear cost function of cost versus hourly manhours and salary manhours for various turbopump operations activities.
- Step 9: Determine turbopump operation cost for each turbopump design requirement by applying the linear cost function to cost parameters (Figures No. 5, No. 6 and No. 11 through No. 66).
- Step 10: Prepare graphical displays illustrating the influence of design requirements upon subcomponent and component performance (Figures No. 67 through No. 95).
- Step 11: Determine the effect of component performance upon engine performance (Figures No. 96 through No. 100 and Table VI).
- Step 12: Define the linear effect of engine weight and performance upon over-all program costs (Figures No. 101 and No. 102).
- Step 13: Establish turbopump functional assembly level alternative requirements groups and tabulate cost and performance in terms of engine I_{sp} variation (Table XI and Appendix K).
- Step 14: Tabulate over-all cost versus requirements groups (Table X).
- Step 15: Select cost optimum requirements group (Table X).
- Step 16: Select cost optimum subcomponent requirements from functional assembly level grouping (Appendix L).

Steps 1 through 12 were adequately explained in the previous section devoted to Design Requirements versus Cost Data. However, Steps 13

Turbopump Alternative	Turbopump Unit Cost (Dollars)	Turbopump Performance (∆ ŴT-lb/sec)	Engine Weight (∆ Pounds/Module)	Engine Performance (∆ Isp-sec)	∆ Stage Mass Fraction (Turbopump Defect)	Program Turbopump Costs (∆ Dollars)	Program Performance Cost Changes (∆ Dollars)	Net Program Cost Changes (∆ Dollars)
Fuel								
Base	54,800	-	-	· · · · -		-	-	-
Alt No. 1	52,400	+0.8	NC	-	NC	_	-	-
Alt No. 2	50,100	+1.7	NC	-	NC		-	-
Alt No. 3	69,500	+2.0	+571	-	See Total		-	-
Alt No. 4	52,200	-0.3	-103	-	See Total	-	-	-
Oxidizer								
Base	42,300	- 1	-	-			_	-
Alt No. 1	40,500	+0.8*	NC	-	NC	-	-	-
Alt No. 2	39,700	+1.7*	NC	-	NC	-	-	-
Alt No. 3	62,500	+2.0*	+281	-	See Total	-	-	-
Alt No. 4	39,300	-0.3*	-66		See Total	-	-	-
Total								
Base	97,100	. –	-	-	-	·_ ·	-	-
Alt No. 1	92,900	+0.8*	NC	-0.24	0	-6,000,000	+5,500,000	-500,000
Alt No. 2	89,800	+1.7*	NC	-0.51	0	-10,000,000	+11,000,000	+1,000,000
Alt No. 3	132,000	+2.0*	+852	-0.60	-0.0032	+49,000,000	+13,200,000	+62,200,000
Alt No. 4	91,500	-0.3*	-167	+0.10	+0.0007	-8,000,000	-2,200,000	-12,200,000

TABLE X. - TURBOPUMP FUNCTIONAL ALTERNATIVE COST OPTIMIZATION SUMMARY

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*Fuel Turbopump Controls

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through 16 require additional clarification, which is provided in the ensuing discussion.

In some unique instances, individual subcomponent mechanical design requirements can be modified independently to obtain sensible changes in both cost and performance variations. However, in most cases, the subcomponent interaction effects are of a nature that an arbitrary requirement variation in a single component results in a performance change is strongly additive in a complex manner to a similar variation resulting from some other component requirement change. Rotor/impeller outside diameter and concentricity tolerance variations as well as the housing inside diameter and concentricity tolerance variations are particularly sensitive to the interaction effects. As a simple example, if the fuel turbine rotor outside diameter tolerance is varied from +0.001 to +0.005, the nominal rotor tip clearance must increase by 0.002 with a resultant turbine flow rate increase of approximately 1/2%. A like variation in the nozzle shroud inside diameter tolerance will have a similar directly additive effect while a backplate/bearing housing concentricity allowance increase of 0.004 causes a performance degradation effect that adds at double the indicated rate because the nominal rotor tip clearance must be increased directly with the concentricity allowance.

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In view of the interaction sensitivities indicated above, it was necessary to devise an optimization method which would combine the requirement alternatives in such a way that would assure all performance variations are properly accounted for. The most reasonable and attractive method that appears to exist is the consistent, albeit arbitrary, selection of mechanical subcomponent requirements followed by a tabulation of performance and cost for all parts of the turbopump. The selection of arbitrary requirements largely rests upon the application of engineering judgement to assure that reasonable turbopump level combinations result.

The turbopump functional level alternatives shown in Appendix K were prepared utilizing the above basis. Resultant subcomponent requirements were kept at maximum consistency as regards the degree of refinement throughout the turbopumps. Although only four alternatives are shown, any number of combinations could have been defined. The alternatives designated as No. 1 and No. 2 in Appendix K are for the base case level NPSH/size requirement. The separately shown alternatives No. 3 and No. 4 are for variations in NPSH with all other requirements being held constant at the base case values. The optimization process summarized in Appendix K was performed as follows:

Step 1: Utilizing the alternative part level mechanical requirements from Appendix K and the performance effects figures, turbopump level performance is calculated in terms of turbine flow rate increase (or decrease) and/or turbopump weight increase from the base. Care must be taken to assure that all interaction effects are considered.

- <u>Step 2</u>: Turbopump level performance changes are converted to engine/stage performance changes in terms of specific impulse and/or mass fraction changes using the influence coefficients of Table IX.
- Step 3: Utilizing the alternative part level mechanical requirements from Appendix K and the cost effect figures in context with Tables III and IV and Appendix H, part and turbopump unit cost is calculated. The unit costs can be developed in terms of manhours or prime dollars so as to be independent of overhead structure, but for the examples shown, a sample overhead rate was applied.
- <u>Step 4</u>: Using the turbopump unit costs, the program plan (in terms of the number of units), and the appropriate fixed costs, the program turbopump costs are determined in terms of decreases (or increases) in cost to the program for all of the turbopump related operations.
- Step 5: Using the performance changes calculated in Step 2 and the over-all program cost sensitivity to performance curves (Figures No. 101 and No. 102), program performance cost changes are calculated in terms of increases (or decreases) in cost to the program for all operations.
- Step 6: The results of Steps 4 and 5 are added to obtain the total program cost changes as a function of turbopump functional alternatives. The assumptions used in developing the engine performance influence coefficients prevent valid mixed alternatives such as the "Fuel Base" and "Oxidizer Alternative No. 2" because the power balance changes in such a manner that turbine flow rate control switches from fuel to oxidizer turbopumps. Direct combinations of the NPSH requirement alternatives (No. 3 or No. 4) with either alternative No. 1 or No. 2 are valid and were utilized, although not shown, in selecting the optimal requirements and criteria shown in Appendix L.
- Step 7: The optimum alternative is selected and the resulting design requirements and criteria are tabulated as shown in Appendix L.
 - B. TASK II EXAMINATION OF COST-CONTRIBUTING OPERATIONS

Task II was divided into the following four subtasks:

- IIa Examination of technological level of costcontributing operations
- IIb Examination of the types of operations
- IIc Selection of the most significant operations in terms
 of program costs and evaluating alternative operations
- IId Selection of operations for technology development

Subtasks IIa, IIb, and IIc were conducted in conjunction with Subtasks Ia and Ic, thereby forming an integral part of those studies. The methodology applied to obtain the results achieved was fully described in Section III,A of this report. However, the results of these subtask efforts are summarized on Table XI, which provides a clear picture of what costcontributing operations categories are responsible for the major turbopump costs. As would be expected in any high production program, the production phase fabrication and turbopump level test operations costs completely overshadow all others. In research and development type programs with relatively few launches or vehicles with a minimal number of engine modules, increased importance is placed upon the development phase operations.

Consequently, the Task II effort was directed toward investigating alternative fabrication and test technological levels as well as types that would be applicable to either development or production phase operations. 6 / N

As explained earlier in the Task I discussion, little reduction in fabrication costs is available from changes in the technological level because "commercial" technology either is not able to sustain even the minimum requirements postulated or the "commercial" costs are identical to the "aerospace" costs. However, the types of operations offer significant potential for fabrication cost savings as discussed in Section III,A. The technology needed to obtain these savings currently is available and should be utilized in future programs.

The investigators were unable to define alternative test operations technologies which would permit turbopump calibration to satisfy engine balance requirements. This resulted largely because of the extensive facilities required merely to operate a large turbopump. If engine balance requirements can be relaxed sufficiently or if the turbopump performance variations from unit to unit can be minimized, the type of testing can be changed from hot firings to either air flow tests or even be completely eliminated.

Thus, the sole result of the Task IId effort is the recommendation that the possibility of eliminating the turbopump calibration/acceptance tests be eliminated, especially for production phase operations. A technology program for accomplishing this is outlined in Section IV of this report.

		Technological Level		Туре	Significance (% Turbopump	Requires Technology	
	Operations	Base	Alternative	Base	Alternative	Program Cost)	Development
DE	VELOPMENT PHASE						
	DESIGN OPERATIONS						
	1. <u>Analysis</u>	Aerospace	None	Manual and Computerized	Manual Only	1.23	No
	a. Hydraulic/Aerodynamic Performance						
	b. Hydraulic/Aerodynamic Loads						
	c. Thermal Conditions						
	2. <u>Mechanical Design</u>						
	a. Critical Speed Determination	Aerospace	None	Manual and Computerized	Manual Only		
	b. Structural Analysis						
	(1) Static Stress/Deflection Analysis						
	(2) Inertia Stress/Deflection Analysis						
	(3) Dynamic Stress/Deflection Analysis						
	(4) Thermal Stress/Deflection Analysis						
	c. Drafting						
	(1) Layouts						
	(2) Part Fabrication Drawings						
	(3) Assembly Processing Drawings						
	d. Checking						
	3. Fabrication Follow-Up	Aerospace	None	Manual and Computerized	Manual Only	te.	
	4. Test Planning and Follow-Up	Aerospace	None	Manual	None		

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	Technolog	ical Level	Туре		Significance (% Turbopump	Requires Technology
Operations	Base	Alternative	Base	Alternative	Program Cost)	Development
DEVELOPMENT FABRICATION OPERATIONS	Aerospace	Commercial			0.58	Yes Selected Part
1. Advance Vendor Quotes/Consulting						Operations
2. Procurement Processing/Planning						
3. Tooling Fabrication				-		
4. Rawstock Procurement						
5. Casting or Forging	See Detaile Figures No.	ed Part by Par 11 through N	t Discussion in Section o. 62.	III,A, Appendices	s H and I, and 1	
6. Machining						
7. Welding						
8. Subassembly						
9. Assembly						
10. Inspection		-				
11. Shipping				x .		
DEVELOPMENT TEST OPERATIONS						
1. Subcomponent Test (Part or Feature Level)					0.25	No
a. Subcomponent Proof Tests						
(1) Rotor Proof Tests	Aerospace	None	Spin Tests	Eliminate		
(2) Housing Proof Tests	Aerospace	Commercial	Pressure Tests	Eliminate		
b. Subcomponent Integrity Evaluation						
(1) Vibration Characteristics Definition	Aerospace	Commercial	Vibration Tests	Eliminate		No
(2) Housing Burst Pressure	Aerospace	Commercial	Pressure Tests	Eliminate		
(3) Rotor Burst Speed	Aerospace	Commercial	Spin Tests	Eliminate		
(4) Bearing Life Tests	Aerospace	Commercial	Rotating-Loaded	None	_	No

	Technologi	ical Level	Туре		Significance (% Turbopump	Requires Technology
Operations	Base	Alternative	Base	Alternative	Program Cost)	Development
DEVELOPMENT TEST OPERATIONS (cont.)						
2. Component Tests (Subassembly Level)					0.28	No
a. Pump Performance Evaluation	Aerospace	Commercial	Simulant Pumping Tests	Eliminate		
b. Power Transmission Performance Evaluation	Aerospace	Commercial	Rotating Propellant	Eliminate		
c. Turbine Performance Evaluation	Aerospace	Commercial	Dynamometer	Eliminate		
3. Turbopump Development Tests					1.95	No
a. Performance Evaluation	Aerospace	None	Hot Firings	None		
b. Life/Reliability Evaluation	Aerospace	None	Hot Firings	None		
c. Malfunction Survival Evaluation	Aerospace	None	Hot Firings	None		
4. Turbopump Acceptance Tests (For R&D Engines)	Aerospace	Commercial	Hot Firings	Eliminate	0.32	Yes
PRODUCTION PHASE						
DESIGN OPERATIONS					0.74	No
1. Performance Modifications	Aerospace	None	Not Applicable	Not Applicable	-	
2. Mechanical Modifications	Aerospace	None	Not Applicable	Not Applicable		
PRODUCTION FABRICATION OPERATIONS	Aerospace	Commercial			42.4	Yes Selected Part
1. Procurement Processing/Planning						Operations
2. Tooling Fabrication						•
3. Rawstock Procurement						
4. Casting or Forging	See Detail Figures No	ed Part by Par	t Discussion in Section I o. 62.	II,A, Appendices	s H and I, and	
5. Machining	Tigutes no					
6. Welding						
7. Subassembly				· ·		
8. Assembly						

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9. Final Assembly (Engine)

	Technologi	cal Level	Туре		Significance	Requires Technology
Operations	Base	Alternative	Base	Alternative	Program Cost)	Development
PRODUCTION FABRICATION OPERATIONS (cont.)						
10. Inspection						
11. Storage						
12. Shipping						
PRODUCTION TEST OPERATIONS					39.50	
1. Subcomponent Level Tests					0.12	
a. Rotor Proof Tests	Aerospace	None	Spin Tests	Eliminate		
b. Housing Proof Tests	Aerospace	Commercial	Pressure Tests	Eliminate		
2. Component Level Tests						
a. Pump Calibration	None	Aerospace	None	Analytical	0.0	Yes
b. Turbine Calibration	None	Aerospace	None	Analytical		
3. Turbopump Level Tests					39.50	Yes
a. Acceptance Tests	Aerospace	None	Hot Firing	Eliminate		
b. Post-Test Checkout and Inspections	Aerospace	None	Leak and Torque Checks	Eliminate		
4. Engine Level Tests					Excluded	-
a. Engine Acceptance Tests	Aerospace	None	Hot Firing	None		
b. Post-Test Checkout and Inspections	Aerospace	None	Leak and Torque Checks	None		
5. Stage Level Tests					Excluded	-
a. Flight Readiness Tests	Aerospace	None	Leak and Torque Checks	None		
b. Post-Test Checkout and Inspections	Aerospace	None	Leak and Torque Checks	None		

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		 Technolog	ical Level	Туре	2	· · · · · · · · · · · · · · · · · · ·	Significance (% Turbopump	Requires Technology
	Operations	 Base	Alternative	Base		Alternative	Program Cost)	Development
FIEL	D MAINTENANCE AND REPAIR OPERATIONS						1,235	No
1.	Seal Checks	Aerospace	None	Pressure Test		Eliminate		
2.	Seal Replacement (Interfaces)	Aerospace	None	Manual		Eliminate		
3.	Torque Checks	Aerospace	None	Manual		Eliminate		
4.	Removal and Replacement	Aerospace	None	Manual		None		
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C. TASK III - CONCEPTUAL DESIGN

1. <u>Turbopump Pre-Design and Mission, Vehicle, and Engine</u> Trade-Offs

The mission, vehicle, and engine trade-off studies, together with the detailed subcomponent analyses and optimizations form integral parts of the conceptual design. A half-size version of an Advanced Multipurpose Large Launch Vehicle (AMLLV) with a payload capability to low earth orbit of 500,000 lb was selected as a representative reference design case to serve as the basis for optimization. This resulted in the following definition of design characteristics:

		Value		
Symbol	Characteristic	Fuel Turbopump	LOX Turbopump	
ΔP	Pump Pressure Rise	1900 psi	1700 psi	
ŵ	Pump Flow Rate	125 lb/sec	585 lb/sec	
P P _T	Turbine Inlet Pressure	1190 psia	135 ps ia	
T _{TT}	Turbine Inlet Temperature	1660°R	1250°R	

Qualitative consideration of the mission/vehicle interactions revealed a strong dependency upon aerodynamic and hydraulic performance of both the turbine and pump. The weight and length of the turbopump became somewhat secondary effects. It was found that the basic, separate turbopump configurations which best served as a basis for generating performance characteristics and investigating mechanical design constraints while offering a reasonable compromise between performance and weight effects incorporated overhung centrifugal pumps. The fuel pump would be driven by a two-row, Curtis, staged, overhung turbine operating in series with a single-stage oxidizer impulse turbine.

The conceptual designs of machines of this type were completed in sufficient depth to demonstrate the cost optimization methodology. Additionally, supporting optimization studies were completed which served to either confirm the basic configuration tentatively selected or permitted modification of the initial configuration to evolve an optimum turbopump for the reference engine.

a. Results

The above indicated performance requirements were utilized along with the Task I results in a brief optimization study to evolve the final selection of the basic turbopump configurations shown on Figures No. 1 and No. 2. Conceptual design was limited to selecting the design requirements and predicting the performance shown in Appendix L and on Table XII.

NAME OF

Oxidizer Fue1 Parameter 30,000 8,000 Shaft Speed (rpm) 585 Pump Flow Rate (1b/sec) 125 1700 Pump Pressure Rise (psi) 1900 69.4 69.5 Pump Efficiency (%) 3.4* 7.5 Turbine Pressure Ratio 28.0 Turbine Efficiency (%) 52.9 20.8 20.8* Turbine Flow Rate (1b/sec)

TABLE XII. - LOST OPTIMUM TURBOPUMP PERFORMANCE SUMMARY

Value

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* Fuel Turbopump Controls to Higher Flow Rate

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b. Basis of Predictions

The predicted turbine performances result from a method of loss analyses based upon the following assumptions as modified by the data presented on Figures No. 83 through No. 93 for the selected design requirements.

(1) The inlet manifold loss level can be predicted from experimental cold flow test data.

(2) Blade row losses are a function of:

(a) Reynolds Number

(b) Nozzle Exit Angle

(c) Average Kinetic Energy

(d) Loss Coefficient

(3) Loss distribution between rotor and stator is a

function of:

- (a) Stage Loading
- (b) Mean Blade Speed

Data were obtained from extensive cold flow testing of the NERVA Technology turbine inlet manifold as well as the experimental test results for the M-1 oxidizer turbine inlet manifold loss level. The common boundary layer assumption of loss variation in proportion to the one-fifth power was made for each blade row.

The nozzle exit angle was used to reflect the variation in the ratio of flow area to surface area. Its effect upon blade row loss is detailed in Reference 50.

The correlation of loss coefficient and statorrotor loss distribution with experimental turbine test data for several turbine configurations is available in References 5 and 6.

The predicted centrifugal pump performances are based upon data demonstrated by Aerojet and modified by the data shown on Figures No. 67 through No. 82. In general, the difference in efficiency between low speed commercial pumps and high speed rocket engine pumps can be attributed to suction eye (inlet) size, inducer vane wrap, running clearances, and the hydraulic design of the impeller and collector flow passage.

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The eye size is directly dictated by the suction performance requirements of the pump. High suction specific speeds require higher relative velocities and result in increased diffusion and friction losses.

Higher dynamic loads and less conservatively stressed components require high speed rocket pumps to operate with larger running clearances. These larger clearances result in lower performance and increased leakage rates which penalize efficiency.

At Aerojet, centrifugal pump efficiency is expressed as a function of pump specific speed, impeller discharge diameter, and pump suction specific speed. The discharge diameter, rather than the flow rate, is used to correlate efficiencies with specific speed because pump efficiency is more directly influenced by size for pumps of varying stage head rise and varying speed. Such influencing factors as clearance leakage, passage surface roughness, and fabrication accuracy are all directly dependent upon size.

Weights and lengths were estimated by calculations from the detailed layouts and account for selected materials, flanges out of plane, mounting provisions, bolts, and parts not shown. Although the layouts are fairly consistent for stress levels, none have been trimmed to the lowest possible weight. This is a function to be accomplished during final design.

2. Turbopump Optimization and Mechanical Design

Contractually negotiated funding restraints precluded the accomplishment of detailed turbopump optimizations and mechanical design. However, plans detailing such optimization were completed and the ensuing discussion of the fuel turbopump design serves to illustrate the method that would be applied.

a. Turbine Optimization

The turbine optimization study is divided into the following distinct activities:

(1) Turbine Parametric Analysis

Turbine parametric analysis consists of determining the relationship between the several turbine variables at the design point. The most significant of these variables are flow rate, pressure, shaft horsepower, and mean blade speed.

The method of analysis consists of determining losses for a given selection of operating conditions. The major assumptions for the analysis are as follows:

- (a) One-dimensional flow at the mean radius.
- (b) Adiabatic flow through static parts (i.e., manifold and nozzles).
- (c) Losses can be grouped into three categories(i.e., inlet manifold loss, blading loss, and bearing loss).
- (d) Blading losses are a function only of Reynolds Number, nozzle exit angles, and average kinetic energy level of the stage.

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This method of analysis was programmed for the IBM 1130 computer and briefly, is as follows:

Step 1: Select the operating requirements for the turbine to establish inlet temperature, inlet pressure, power, and pressure ratio.

Step 2: Consider the mechanical properties of materials to be used to determine at least an approximate value for the mean blade speed.

Step 3: Select load distribution. Usually this selection is equal work per stage until the final turbine configuration is determined approximately.

Step 4: Select nozzle exit angles compatible with loading, desired blade geometry, and stage number.

Step 5: The type of velocity diagram for each stage is fixed by the degree of reaction selected for the stage.

Steps 1 through 5 provide the basic input for calculating mean blade velocity diagrams, blading losses, turbine flow rate, and performance. To obtain the optimum or near-optimum turbine for a given application, many of the above independent parameters are varied to permit study of their effect upon turbine performance.

The parameters which are interrelated to both turbine and engine performance are turbine inlet temperature, turbine inlet pressure, pressure ratio, mean blade speed, and rotational speed. Parameters which affect turbine performance as a component only are stage load distribution, nozzle angles, and degree of reaction.

The first group of parameters was studied as described in Task I with the intention of optimizing engine performance and cost whereas the second group would be studied to optimize turbine component performance. In addition to performance analysis, the indicated computer program would be utilized to determine radial distributions in flow properties for the purpose of providing a basis for improved blade as well as nominal values for axial thrust.

The quantities determined at the blade hub and tip, in addition to the mean radius, are velocities, gas angles, pressures, temperatures, degree of reaction, and mach number. Blade heights and annulus areas also are determined.

The above parametric turbine analysis would provide the basis for selecting the detailed turbine configuration.

(2) Blade Stress and Weight Analysis

To provide consistency in the blade weight and the parametric stress analysis, a series of first and last stage blades would be designed using a technique similar to that discussed in Reference 7.

The weight of the blades in a turbine rotor determines the geometry and, hence, the weight of the turbine disc. Thus, blade weight dictates the weight of the entire turbine rotating assembly. The following sequential procedures are used to determine the total blade weight:

Step 1: The blade cross-sectional area is determined. This is coupled with the material density, blade height, and quantity of blades to obtain the weight for a "full weight" blade.

Step 2: The "full weight" blade weight then is reduced by 25% to obtain the value used for sizing the turbine discs. A 25% blade weight reduction can be accomplished by internal tapering.

The stresses exerted upon turbine blades can be

categorized as:

- Centrifugal stress attributable to wheel rotation,
- Circumferential gas bending stress resulting from the circumferential momentum change,
- Axial gas bending resulting from the axial momentum change,
- Centrifugal bending stress caused by centroids not being located on a radial line,
- Secondary stresses attributable to vibration.

For the parametric study, only the centrifugal stress and circumferential gas bending stress are considered. In the analysis, the following assumptions would be made.

(a) The blade weight is 75% of the "full blade"

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weight.

(b) The height of the blade is divided up into four equal lengths, each length (commencing with the section at the blade root and proceeding to blade tip) having 10% less area than the preceding length. The resulting volume then is 75% of full volume.

(c) Centrifugal stress is maximum at blade root where the cross-sectional area is equal to 90% of the full vane area.

(d) Circumferential gas bending stress will be obtained from the speed, horsepower, work per stage, and the force being applied at one-half of the blade height.

(e) Gas bending stress is assumed to be maximum at the blade root trailing edge.

From the cross-section of each turbine blade, geometric properties are obtained by using a computer program. The summation of centrifugal and gas bending stress then can be obtained.

(3) Disc Stress and Weight Analysis

The disc configuration is simplified by using a section for preliminary analysis that consists of two isosceles trapezoids with sides that taper from the neck to the hub.

The nominal blade speed is varied between 1200 ft/ sec and 1600 ft/sec. The rotational speed also is varied with a constant blade speed. The average gas temperature is varied between 1400°R and 1800°R.

The most attractive material appears to be Inconel 718, up to 1660°R. Above this, the stress rupture limitations of Inconel 718 indicate Rene' 41 could be best because its higher strength results in lighter discs.

The allowable average tangential disc stress is determined by fixing the burst speed at 1.44 times the nominal operating speed. The average tangential stress is a direct function of the blade radius and blade centrifugal force; the disc taper and minimum thickness have a small additional effect.

For Inconel 718, at a temperature of 1660° R, the allowable average tangential stress is 84,000 lb/in.².

Blade weight, blade speed, and material temperature directly affect the disc thickness. The tangential stress at the neck is limited to 45% of the design yield strength at the local temperature.

From the information obtained previously, the blade profile, weight, temperature, blade speed and blade mean diameter can be determined. The disc weight then can be determined as follows:

Step 1: From blade weight, mean diameter and speed, find the centrifugal blade force.

<u>Step 2</u>: Determine the centrifugal force of the blade platform and transition section to the neck.

<u>Step 3</u>: Knowing the allowable neck stress and combined force of blades and transition section, compute the neck thickness.

<u>Step 4</u>: With the known neck thickness, disc taper angle, and allowable average tangential disc stress, compute the disc volume and weight.

b. Pump Optimization

Three key pump parameters (i.e., shaft speed, pump suction specific speed, and impeller discharge angle) are evaluated in the pump optimization study for the selected engine. The three parameters are varied over representative ranges while the performance and weight are evaluated in terms of engine performance. Axial thrust is calculated for each case to allow those variations causing unacceptable bearing loads to be eliminated.

<u>Step 1</u>: Shaft speed is varied to investigate the performance advantage of increased specific speed and the weight advantage of decreased size.

Step 2: The suction specific speed of the impeller is varied over a wide range to evaluate the effect of impeller discharge to eye diameter proportions upon efficiency and weight.

<u>Step 3</u>: The impeller discharge angle of the main impeller is varied to determine the weight advantage of increased head coefficient (and smaller size). Efficiency remains fairly constant because the improved diameter ratio of the lower vane angle designs is offset by the higher friction losses of the longer blade passages. In evaluating this parameter, pump thrust becomes particularly significant.

The final selection of speed, specific speed, and discharge angle are based upon iterations of performance, weight, and length within allowable limits of stress, thrust (bearing load), bearing speed, and critical speed margin.

Complete summaries showing all parameters for all cases then are available to aid in refining the prediction of characteristics for various engine operating conditions as well as the selection of final design conditions once an engine operating point is fixed.

c. Supporting Mechanical Systems

The bearing analysis and design activity determines a thrust and radial bearing system with the optimum balance between severity of operation (speed and load) and reliability. A performance maximized, weight minimized turbopump requires high speed at high capacity and high radial stiffness. Reliability at acceptable life indicates the opposite. The optimum design balances these two criteria. The bearing design that results then is developed and improved until it meets the required load-life relationship. The design procedure includes the analytical approaches discussed below.

(1) Roller Bearings

The roller bearing parameters of primary interest for the design of a bearing system can be listed as follows:

- Spring Constant
- Hertz Stresses
- Basic Dynamic Load Rating

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- Roller Centrifugal Force
- DN Value
- MRC Severity Factor K
- Hysteresis Heating

Spring constant of the roller bearing is an important consideration relative to rotor critical speed. For a given size turbopump with a given nominal speed and critical speed requirement, bearing spring constants determine bearing minimum size. The spring constant of a bearing is defined as the reciprocal of the bearing radial deflection under a given radial load. A computer program developed by New Departure solves for this variable. The equations solved are those developed by Hertz with modifications to account for the effect of bearing internal clearance. A possible mode of failure with the rolling contact bearing is metal fatigue at the contacting surfaces. Early fatigue failures can be caused by the repeated overstressing at the roller-to-raceway contacts. To evaluate the possibility of early fatigue failure caused by overstressing, Hertz contact stresses are computed using a computer program which solves the Hertzian equations for stress (both mean and maximum) and includes the effects of internal radial clearance.

Another parameter used to evaluate a potential fatigue problem is the specific dynamic capacity. The parameter also gives an estimate of bearing life (relative to fatigue failure) at speeds of interest. The calculations are based upon AFBMA formulae for basic load rating and life. Hertz stresses of inner and outer raceways and dynamic load carrying capacity are affected by roller centrifugal force which is a function of roller size (bearing series) and bearing speed. As this parameter increases, outer race Hertz stresses increase, inner race stresses decrease, and bearing dynamic load capacity for a given bearing life (based upon fatigue) decreases. The indicated computer program calculates this parameter.

An indication of the severity of operation of a rolling element bearing is provided by the product of bearing bore in millimeters and shaft speed in revolution-per-minute (generally referred to as "DN Value"). This parameter does not differentiate between bearings of different series (proportions) where geometrical differences can significantly affect the effect of speed. DN values below 1.0×10^6 are not considered severe, values between 1.0×10^6 and 1.5×10^6 are moderate, while values of 2.0×10^6 are on the threshold of existing technology.

Perhaps a more realistic evaluation of the effect of speed as well as bearing size and geometry (especially relative to thrust bearings) is a parameter developed empirically by MRC. This severity factor, K, is expressed as follows:

$$K = P.D. x (RPS)^3 x d^3 / (\cos \alpha)^3 \ge 31 x 10^8$$

P.D. = Pitch dia in mm

RPS = Revolution per sec

d = Ball or roller dia., in.

 α = Dynamic contact angle, degrees

For roller bearings, $\alpha = 0$, therefore

 $\cos \alpha = 1.0$

 $K = 31 \times 10^8$ appears to be too high for roller bearings, but discussions with MRC indicate it is a good upper limit.

(2) Ball Bearings

Ball bearings in tandem duplex or triplex sets can be used to support the net thrust load of the turbopump. The various design parameters for this bearing arrangement include those already discussed under roller bearings, except for spring constant, as well as the following:

- Dynamic Contact Angles (Inner and Outer Race)
- Inner and Outer Race Ratio of Shoulder Height to Ball Diameter

- Relative Spin Angular Velocity Between Ball and Inner and Outer Raceway Contacts
- Heat Generated Due to Ball Spin and Cage Friction
- Total Heat Generated by Bearing
- Bearing Life for 90% Probability of Survival

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All of the above parameters, including those which pertain to ball bearings but already discussed under the roller bearing section, are calculated using an Aerojet Computer Program. A most important parameter of an angular contact high speed ball bearing is the dynamic contact angle at the inner and outer race. The dynamic contact angle is different at the two raceways because of ball centrifugal force and affects Hertz stresses, bearing load capacity, the MRC severity factor, K, and ball contact zone spin velocities.

The ball bearing must be capable of supporting high axial thrust loads. A limiting load is reached when the ball-to-raceway contact ellipse extends beyond the raceway shoulder height. Calculation of this parameter provides the limiting load for a particular bearing geometry.

An angular contact ball bearing operating at high speed has considerable spinning action at the ball-to-raceway contacts. The spinning velocity is a function of the dynamic contact angle which is dependent upon bearing geometry load and speed. The computer provides a calculation of the relative spin angular velocity between ball and raceway contacts (inner and outer). This velocity can be converted into the heat generated by ball spin, an important design factor. The combination of heat generated by ball spin, cage friction, and hysteresis (relatively small) provides the total heat generated by the bearing. This latter value is required to estimate the amount of LH₂ required to cool the bearing.

The computer program is set up to provide an estimate of bearing life for 90% probability of survival. It gives a rough indication of the life expectancy of the bearing under the severe conditions imposed because the life calculated is with respect to metal fatigue in a lubricated environment and, therefore, is not of real significance for this application.

- d. Structural Dynamic Considerations
 - (1) Turbopump Critical Whirling Speeds and Bearing Loads

When a turbopump with rolling contact bearings is operated at or near a whirl critical speed, the bearing reactions and shaft bending stresses can become excessive. In addition, the shaft whirl deflections can be larger than the rotor-stator running clearances resulting in rotor rub problems. Should the bearing loads, shaft loads, or deflections become too large, the results could be catastrophic. Therefore, the importance of computing the whirl critical speeds and analyzing their influence upon turbopump operation is an area of major concern.

The analytical techniques used at Aerojet for predicting whirl critical speeds are rigorous, with proven reliability. Less rigorous techniques tend to overestimate the critical speeds resulting in higher bearing loads, reduced bearing life, and larger shaft deflections than predicted.

Over the past few years, several special shake and spin tests have been performed at Aerojet to permit analytical-experimental correlations. These correlations are:

		NATURAL FREQUENCIES, CP		
SYSTEM	TYPE OF TEST	TEST	ANALYTICAL	
Titan Turbine Shaft	Shake Test	340	330	
NERVA Technology Turbopump (Three-Stage Turbine)	Shake Test	1st -295 2nd -520	1st -305 2nd -522	
Titan Task III High Speed Shaft	Shake Test	540	517	
Titan Task III High Speed Shaft	Spin Test	550 + ⁽¹⁾	615	
M-1 Fuel Turbopump	TPA Performance Test	258 + ⁽²⁾	266	

LATERAL VIBRATION AND SPIN TEST CORRELATIONS

- (1) This shaft was spin tested to 33,000 rpm (550 rps) and the shaft displacement instrumentation indicated the first critical to be above the maximum test speed. The whirl critical frequency is expected to be above the lateral natural frequency because of the "Gyroscopic Stiffening" effects.
- (2) There were no special shake or spin tests performed with the M-1 Turbopump; however, on one occasion, during the TPA performance tests, the shaft speed reached 15,500 rpm (258 rps) where the accelerometer data indicated an increase in vibration level.

Whirl critical speed effects can be alleviated by one or a combination of the following techniques:

- Operation above the first or second critical speed (super-critical operation).
- Operation below the first critical speed (subcritical operation).
- Sufficient damping to the system to limit the shaft amplitude and bearing response.

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Supercritical operation has an inherent problem known as shaft instability. That is, even though the shaft speed is well above the first critical and not near another critical, it has been found that the shaft could start to whirl and cause rubbing, bearing failures, and fatigue failures in the casings. Moreover, stability problems are difficult to analyze and do not lend themselves to good prediction. To attain supercritical operation, the turbopump system must pass through the critical speed or speeds. The start transient of this turbopump is relatively slow and, therefore, severe damage could occur before the system could be accelerated through the critical speeds.

The shaft deflections and bearing response increase exponentially as the first whirl critical speed is approached. To ensure smooth subcritical operation, the turbopump speed must be sufficiently below the first whirl critical so that the bearing capacities are not exceeded and the shaft deflections are tolerable. Experience has shown that whirl instabilities do not occur when the shaft speed is maintained below the first critical speed. Experience also has shown that for safe operation, the first critical speed should be at least 1.15 times the maximum shaft speed.

The primary factors to be considered to maximize the first whirl critical speed are:

- Rotating system should be light weight.
- Rotating system should have high flexural stiffness.
- Bearing supports should be stiff.
- Bearing housing should be stiff.
- Distance from bearing to center of gravity of overhung components should be minimized.

Damping will not significantly change the whirl critical speeds, but it can limit the shaft deflections and bearing response for subcritical operation. Conversely, if the system is operated supercritical, the shaft deflections and bearing loads will be smaller without damping. With rolling contact bearings and a very low viscosity fluid (i.e., liquid hydrogen), damping is very small and cannot be expected to limit whirl amplitudes or bearing loads.

The method that is used to analyze the lateral vibration characteristics of the turbopump is a modified Myklestad-Thompson solution facilitated by a matrix formulation and programmed for digital computer application. The program has the capability of analyzing the free or forced-undamped, lateral vibration of two, elastically-coupled, lumped parameter beams. Natural frequencies, mode shapes, as well as associated shear and moment distributions can be computed. The program can compute the amplitudes of the shears, moments, slopes, and deflections attributable to harmonic forcing functions. Shear deflections, rotary inertia, and gyroscopic effects for rotating shaft analyses also are included in the program capability.

Subcritical operation is the most desirable for this turbopump. Cursory critical speed studies performed to date show that subcritical operation is possible.

The whirl critical speeds are sensitive to the nonlinear stiffness of the roller bearings and the bearing housing stiffness. Static roller bearing load-deflection tests are in progress to substantiate the predicted bearing stiffness.

(2) Turbine Rotor Stress

In the analysis of turbine rotors, the four main areas of concern are: stress profile in the discs; disc average tangential stress and burst speed; disc axial vibration and the corresponding axial critical speeds, and rotor blade stresses and vibrations. In addition to these four areas, its fatigue life is of interest, if the turbine rotor is highly stressed.

(a) Disc Stress Profile

One of the available proven techniques for determining the stress profile in a disc is a computer program for the finite element analysis of axisymmetric solids with nonlinear material properties. The finite element approach also has been found capable of predicting stress concentrations identical to those given by the mathematical theory of elasticity. The stress profile is influenced by the geometry of the wheel, bore, blades, drum, thermal gradient, centrifugal forces, differential pressure loads and overspeed prestressing.

(b) Average Tangential Stress and Burst Speed

As set forth in the literature, the following major factors influence the burst speed of a rotor:

- Material tensile strength
- Material ductility
- Uniformity of mechanical properties through the rotor
- Evenness of the stress distribution across the diametral section

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These factors should be accounted for in predicting the burst speed. Usually, the burst speed is predicted by the following formula:

σ Ult. x K Burst Speed, $rpm = \Omega rpm \times \frac{1}{Average Tangential Stress at \Omega rpm}$

= Utilization Factor Dependent on the previous mentioned factors. where K

 σ_{Ult} = Appropriate value of tensile ultimate or stress rupture strengths.

The average tangential stress over the disc cross-sectional area may be obtained from the following well-known formula.

$$S_{DV} = 28.4 \quad \gamma \left(\frac{N}{1000}\right)^2 \quad \left(\frac{I}{A}\right) + \frac{P}{2\pi A}$$

= Average Tangential Stress of Disc, psi where S_{DV}

> = Specific Weight of Disc, 1b per cu in. γ

= Moment of Inertia of Disc Half-Section, About Centerline Ι

= Speed of Disc, rpm Ν

= Area of Disc Half Section, sq in. А

= Total Peripheral Load, 1b Ρ

The turbine discs are sized to produce an average tangential stress low enough to cause the burst speed of the disc to be well above the operating range.

(c) Disc Axial Vibrations and Critical Speeds

Disc vibrations that have been found to be dangerous are the so-called nodal diameter type. A critical speed is the shaft speed which is equal to the quotient of a natural frequency of a nodal diameter mode divided by the number of nodal diameters. It is recommended that the difference between the critical and running speed be at least 15% for a two nodal diameter and 10% for the three and four nodal diameter type vibration modes.

A computer program is available to determine the natural frequencies of rotor discs. The validity of the program has been proven in numerous disc type rotor shake tests.

(d) Rotor Blade Stresses and Vibration

Two row turbines are utilized for the fuel turbopump concept. Each stage has a different blade design; therefore, the blade natural frequencies, both bending and torsional, are different. The number of blades and stators also vary resulting in different natural frequencies and corresponding resonant speeds for each stage. No actual checks of blade response were conducted during this study and the following discussion is intended only to illustrate the method of analysis.

Each blade passes "K" number of upstream nozzle vanes per revolution and is subject to NXK/60 pulses per second, where N is shaft speed in rpm. If the frequency of these pulses coincide with one of the rotor blade natural frequencies, a resonant magnification of the vibratory stress occurs. The dynamic magnification factor at resonance is limited only by the damping properties of the system. The speed at which resonance can occur is given by:

$$N_{\text{Resonant}} = \frac{60 \text{ fm}}{\text{H-K}} \text{ rpm}$$

where

f_

Η

= Harmonic of Nozzle Passing Stimulus

= Natural Frequency for Mode, m, in cps

As the pulses are not purely sinusoidal, the higher harmonics can occur.

K = Number of Upstream Nozzle Vanes per Revolution

The total damping of a rotating blade consists of three components: the inherent damping in the material; the aerodynamic damping of the high velocity gas around the blade; and the root damping consisting of friction between the rotor and the blade surfaces. To evaluate the root damping, the other forms of damping must be subtracted from the total experimental determined damping measurement.

Materials vary greatly in their internal damping characteristics and even for a particular material damping depends upon the magnitude and distribution of the blade stress level.

As a result of many tests in the M-1 Program, considerable experience exists with Inconel 718 rotor blades.

Analysis of the blades consists, first, of computing the stress levels caused by centrifugal, gas bending, and thermal environment. Next, the natural frequencies (both flexural and torsional mode)
are computed utilizing either the classical hand calculations for a uniform, prismatic, unshrouded cantilevered beam or one of the numerous computer programs available for analyzing shrouded or unshrouded, uniform or non-uniform beams.

For blades having frequencies that can be excited within the operating range, a resonant stress analysis must be made.

The vibratory stress of the blades at the resonant frequencies can be determined by the following equation:

$$\sigma \text{ vib}_{(\text{resonance})} = \frac{(\text{S})}{(\text{H})} (\sigma_{\text{static}}) (\text{R}) \frac{\text{N}}{\text{N}} (\text{M.F.})$$

where S = Factor Expressing Fluctuation Amplitude (0.3)

H = Harmonic No. of Stimulus

R = Mode Receptiveness Factor (the response factor for a cantilever beam vibrating at the fundamental mode is approximately 0.87, at the second mode it is 0.066, and at the third mode it is 0.004

M.F. = Magnification Factor, at resonance with damping =
$$\frac{1}{6}$$

Static = Stress caused by gas and centrifugal loading at speed N_{o} .

The blade cross-sections and the number of upstream stator nozzles can both be varied within the limits of turbine performance to obtain the most optimum interaction of blade natural frequency and nozzle excitation stimulus frequency. If a resonance condition must exist within the operating range, it must be made to occur at a low enough speed so that the magnified vibratory stress will be within the design limits. Blade fatigue is evaluated using the modified Goodman Diagram technique.

Cursory checks of the turbine blades proposed for this conceptual design indicate that even though a resonant speed is passed before the operating speed is reached, the resonant stress levels, when evaluated on the modified Goodman Diagram, will be within the design limits.

(3) Impeller Stress Analysis

A centrifugal impeller can be divided into two geometrical sections, the disc and the blade.

The techniques used in the analysis of the disc have been proven by numerous tests. Impeller discs have been stress analyzed using a digital computer program which is capable of handling any body of revolution subjected to a symmetric loading. Experience from previous similar impeller designs indicate the most critically stressed vanes are those in the inlet section. These vanes in the critical stress region generally approach flat plate configuration.

To achieve lightweight impeller designs, it is recognized that more accurate stress predictions than those typically used based upon calculation of the blade centrifugal force/pressure load stresses formulated for constant thickness circular plates and simple load distributions are required. To meet this need, Aerojet has developed a computer program for the solution of plates of arbitrary load conditions. This technique was used to analyze significant problems, for which exact solutions were available, to verify its accuracy.

(4) Turbopump Housing Structural Analysis

Two general objectives in the design of the housing are to obtain a low cost design and to maintain the high performance of the turbopump. The housings should be as light as possible without allowing high deformations that would require large nominal clearances between the rotating and stationary parts. Housing deformations are kept to a minimum by adequate stiffening, while considering the trade-off between cost and performance. In establishing design criteria, internal pressures and thermal environment are readily predictable. The dynamic loads are generally difficult to predict. The determination of the dynamic environment for this turbopump, however, could make use of previous test data from the NERVA Technology and M-1 Test Programs.

Proven methods would be applied in the stress analysis of the housing and volutes. The intersection of a pipe or line with a shell which will join the volute tangent to the shell inner and outer diameters offers a direct and immediate load path to the stiffer supporting structure. This results in minimum deformations and existing methods of analysis can be utilized.

IV. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

A. RESULTS

1. Categorized Cost-Contributing Operations

There are seven major categories of cost-contributing operations associated with a turbopump during its usable life. These categories, which maintain strict separation between the development and production phases, are as follows:

- Development Design Operations
- Development Fabrication Operations
- Development Test Operations
- Production Design Operations
- Production Fabrication Operations
- Production Test Operations
- Production Field Maintenance Operations

Each of these broad categories consists of many detailed operations. These finer breakdowns are accomplished to the level appropriate for calculating the costs as detailed in Section III,A,1. An example of such a realistic level of listing is provided as Appendix B. 2. Categorized Design Requirements

All turbopump design requirements fall into the following three categories:

- Performance
- Operational
- Mechanical

However, all requirements must ultimately be reduced to the turbopump part level before a quantitative assessment of their influence upon costs can be accomplished. This was fully detailed in Section III,A,2 and is shown for the base case in Appendix C.

3. <u>Relationship Between Variations in Requirements and Cost-</u> Contributing Operations

Variations in the categorized requirements and costcontributing operations were investigated in great detail as described in Section III,A,3 and Figures No. 5, No. 6, and No. 11 through No. 66. The relationships invariably show that the more stringent the requirement, the higher the technological level of the operations needed to sustain the requirement. This is not meant to imply that the highest over-all cost necessarily results from stringent requirements, rather it is only the cost of the affected operations which increases.

4. <u>Description of Alternative Methods for Performing Cost-</u> <u>Contributing Operations and Recommendations for Additional</u> Technology

Because of their relative importance (in terms of percentage of program costs), the most attractive area for utilizing alternative methods of performing cost-contributing operations are the production phase as well as the fabrication and test operations. In the referenced MLLV program, these contribute in excess of 82% of the turbopump program costs as shown on Table XI.

Many alternative methods for performing fabrication operations were investigated and are detailed in Section III, A along with pertinent plots (Figures No. 5, No. 6, and No. 11 through No. 66). Two such examples of alternatives are sandblasting instead of hand polishing machined or cast impellers to obtain the necessary surface finish and the casting instead of fully machining pump diffuser vanes to obtain the required vane profiles. Substantial cost savings in fabrication can be realized by using such alternatives where the appropriate technology is generally available. However, in each instance, it is necessary to evaluate the performance (hence, over-all cost) effect that will result from relaxing the pertinent requirements as shown in Section III, B and Figures No. 67 through No. 95. Additionally, the optimum method among available alternatives must be selected.

No reasonable alternative methods for performing the turbopump test operations are apparent. However, if the engine balance requirement can be relaxed or if turbopump performance repeatability can be improved, there is a possibility that the production phase testing could be eliminated. Such an approach would require experimental verification to validate its feasibility. A program of this type is strongly recommended. It would be conducted in the following sequence:

Step 1: Select an active engine production program wherein the engine balance requirements are known.

<u>Step 2</u>: Utilizing the data shown on Figures No. 67 through No. 95 and similar data generated for the selected program, revise the turbomachinery mechanical design requirements to obtain the necessary performance repeatability.

Step 3: Adjust the turbomachinery fabrication drawing per Step 2.

Step 4: Fabricate a reasonable sample (i.e., 10) of parts in accordance with the revised drawing.

Step 5: Test the sample turbopumps in the usual manner to verify that the theoretical performance repeatability has been achieved.

Step 6: Utilize the sample turbopumps in the selected production program.

The costs involved in the above recommended program are those associated with engineering to accomplish Steps 2 and 3 as well as those involved with evaluating the results of Step 5 and the increase in fabrication costs to produce the sample machines against more stringent requirements.

5. Relationship Between Turbopump Requirements and Cost

The relationship between requirements and cost was defined in rigorous detail at the turbopump level in terms of man/machine hours and prime (supplier charged) dollars. A grosser definition was evolved for several composite turbopump level alternatives in terms of program dollars applying a sample overhead structure. The detailed relationships between requirements and part costs were shown on Figures No. 5, No. 6, and No. 11 through No. 66. This relationship between requirements and turbopump costs with that of program costs were summarized on Tables VII and VIII.

6. Optimal Turbopump Requirements and Design Criteria

Turbopump design requirements were made optimum for the reference MLLV case and are included as Appendix L.

7. Low Over-All Cost Turbopump Conceptual Designs and Associated Development, Production, and Acceptance Plans

A brief optimization study was accomplished using the reference (contract specified) performance requirements. This resulted in the selection of the basic mechanical configurations shown on Figures No. 1 and No. 2. Conceptual design was limited to selecting the design requirements listed in Appendix L and the predicted performance shown on Table XII. Although detailed optimizations and mechanical designs were not accomplished, the method for accomplishing them is detailed in Section III,C,2. The associated development, production, and acceptance plans were shown on Figure No. 4.

B. CONCLUSIONS

The most significant conclusions and implications which became apparent during the course of the program as well as from the results of the study are summarized in the ensuing discussions.

1. Requirements Influence Level

Generally, the design requirements influence upon the cost of operations is apparent at the part or feature level only.

2. Program Size Implications

In terms of over-all program cost, the relative importance of any category of operations performed in association with the turbopump is very strongly influenced by the size of the production program assumed. Any reasonably high production program (where delivered units exceed research units by at least one order of magnitude) costs are of a nature that individual costs (excluding production, phase fabrication, and test operations costs) probably are lower than the estimating tolerance for the production, fabrication, and test costs. Clearly, the elimination of all development phase costs from the reference program would result in less than a 5% reduction in the turbopump program costs and an almost indiscernible decrease in over-all program costs.

3. Individual Operations Cost Implications

A lack of visibility of costs for individual operations in any size program at the level where they are influenced by the requirements is apparent although as individual operations they might constitute a high proportion of the component costs.

4. Synthesis of Designs

Based upon the conclusions detailed, the synthesis of optimal turbopump requirements and design criteria from individual requirements versus cost of operations data is both imperative to low over-all cost and so unwieldy that it becomes virtually impossible because of the almost infinite number of microscopic effects to be considered.

C. RECOMMENDATIONS

The results of the study indicate that costs not be attacked at the individual requirement and operation level in an effort to reduce the cost of operations. Instead, it is recommended that costs be attacked at the major operations category level with the objective of eliminating the entire category. In keeping with this philosophy and based upon the results of Tasks I and II, it is further recommended that methods be investigated to eliminate production phase turbopump acceptance testing. The Rocketdyne Division of North American-Rockwell undertook an effort of this type during the latter portions of their J-2 program effort.

The requirement to perform turbopump acceptance tests results from the desire to make a mechanical check of the turbopump functional capability as well as to obtain calibration or balance data for subsequent engine checkout and calibration testing. Actually, at the reliability levels of current rocket engine turbomachinery, the only function served by the turbopump acceptance test is to provide engine balance data. Therefore, if turbopump performance repeatability (from unit to unit) can be achieved within the engine balance requirements, the turbopump acceptance tests can be eliminated with the engine calibration test serving as the turbopump functional and performance calibration checkout.

It is recognized that to accomplish what is recommended requires some technological development so as to obtain the needed performance repeatability. However, much of the technology needed to accomplish this largely is available from this Low Cost Turbopump Study. The cost of sustaining individual part level mechanical design requirements is known as well as their influence upon performance. Therefore, the only data necessary for performing the necessary trade-off is the relationship between part level mechanical design requirements and performance repeatability as such. This extension in the data provided herein, along with experimental verification of the results would constitute a relatively straightforward technology development program which could provide major reductions (up to 40%) in future program turbopump costs.

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APPENDIX A

TYPICAL FUEL TURBOPUMP PRELIMINARY DESIGN CALCULATIONS

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Pump

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Known

$$\dot{W}_{p}$$
 = 125 lb/sec - 13,000 gpm
 ΔP = 1900 psi - 64,000 ft
NPSH = 130 ft

Assume

$$8 \approx 90,000 \frac{\text{RPM (GPM)}^{1/2}}{\text{NPSH}^{3/4}}$$
 Max (From M-1 & J-2 experience)
For $\phi_{TT} = 0.08$

Then N =
$$\frac{S(NPSH)^{3/4}}{0^{1/2}}$$

= 30,800 rpm Say 30,000

$$N_{s} = \frac{N Q^{1/2}}{\Delta H^{3/4}}$$

= 855

Select $\beta 2 = 30^{\circ}$ and $\psi 2 = 0.55$ from experience Then $\eta_p = 0.70$ from empirical curves

for
$$\phi_2 = 0.10$$

 $U_{2T} = \left(\frac{g\Delta H}{\psi_2}\right)^{1/2}$

= 1935 ft/sec OK for titanium disc

The sizes are:

$$D_{\rm IT} = \left\{ \frac{93.6 \text{ Q}}{\text{N}\phi_{\rm IT}(1-\text{RH}^2)} \right\}^{1/3}$$
$$= 8.40 \text{ in.}$$

$$D_{IH} = R_{H} \times D_{IT}$$

= 3.20 in.
$$D_{2T} = \frac{229 \text{ U}}{\text{N}}$$

= 14.75 in.
$$h_{2} = \frac{Q \times 144}{449 \text{ TT } D_{2T} C_{m2} (1-\text{Blockage})}$$

= 0.58 in.

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Turbine

Known

Ti	=	1660°R
P _i	=	1140 psia
γ	=	1.363
R	=	403
Cp	,	1.95
PR	æ	7.5
P ₂	=	152 psia

Assume

$$U_{m}$$
 = 1300 FPS (reasonable for 718 @ 1660°R)
 K_{noz} = 0.94 (empirical loss coefficient)

Calculate

_

$$\frac{14Le}{c_0} = 2g K_{noz} C_p J Ti \left[1 - \left(\frac{1}{PF}\right)\right] \frac{\gamma - 1}{\gamma}$$
$$= 7940 \text{ ft/sec}$$

Then U/C = 0.164 and

η	=	0.53	
к ₁	=	0.78	from dogton ourwoo
к2	=	0.86	fill design curves
к ₃	×	0.90	

Solution of the velocity triangles and design equations then yields

 $\Delta V_{WT} = 13,980 \text{ ft/sec}$ $\dot{W}_{T} = 20 \text{ lb/sec}$ $T_{2} = 1250^{\circ}\text{F}$ $n_{t} = 53.5\%$

and sizes are

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h_1	=	0.92 in.	Rotor Blade Heights
^h 2	=	1.05 in.)	
c ₁	=	0.86 in.	Potor Chord Longths
с ₂	=	0.78 in.	KOLDI GHOIU LENgLIIS
^d 1	=	3.65 in.	Manifold inlet dia for 0.25 Mach No.
d ₂	=	2.58 in.	Split torus dia for 0.25 Mach No.

Estate Willie		85.20	(and a second	متعن	Carlo	فتتستك	and the	فأتكرك	لالانصا	Sec. Land	فتستسمه	فيتشتد		لوريف عالمة	في الكونية الكونية
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APPENDIX B

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COST-CONTRIBUTING OPERATIONS

I. DEVELOPMENT PHASE OPERATIONS

A. DESIGN OPERATIONS

- 1. <u>Analysis</u>
 - a. Hydraulic/Aerodynamic Performance
 - b. Hydraulic/Aerodynamic Loads
 - c. Thermal Conditions

2. Mechanical Design

- a. Critical Speed Determination
- b. Structural Analysis
 - (1) Static stress/deflection analysis.
 - (2) Inertia stress/deflection analysis.
 - (3) Dynamic stress/deflection analysis.
 - (4) Thermal stress/deflection analysis.

c. Drafting

- (1) Layouts
- (2) Part fabrication drawings
- (3) Assembly processing drawings
- d. Checking
- 3. Fabrication Follow-Up
- 4. Test Planning and Follow-Up
- **B.** DEVELOPMENT FABRICATION OPERATIONS
 - 1. Advance Vendor Quotes/Consulting
 - 2. Procurement Processing/Planning
 - 3. Tooling Fabrication
 - 4. Rawstock Procurement

- 5. <u>Casting or Forging</u>
- 6. <u>Machining</u>
- 7. Welding
- 8. Subassembly
- 9. Assembly
- 10. Final Assembly (Engine)
- 11. Inspection
- 12. Outside Liaison
- 13. Inside Liaison
- 14. Shipping
- C. DEVELOPMENT TEST OPERATIONS
 - 1. Subcomponent Test (Part or Feature Level)
 - a. Subcomponent Proof Tests
 - (1) Rotor Proof Spin Tests
 - (2) Housing Pressure Tests
 - b. Subcomponent Integrity Evaluation
 - (1) Vibration Characteristics Definition (Blading)
 - (2) Housing Burst Pressure
 - (3) Rotor Burst Speed
 - (4) Bearing Life Tests
 - 2. Component Tests (Subassembly Level)
 - a. Pump Performance Evaluation
 - b. Power Transmission Performance Evaluation
 - c. Turbine Performance Evaluation

- 3. Turbopump Development Tests
 - a. Performance Evaluation
 - b. Life/Reliability Evaluation
 - c. Malfunction Survival Evaluation
- 4. <u>Turbopump Acceptance Tests (Checkout for R&D Engines)</u>

II. PRODUCTION/OPERATIONAL PHASE OPERATIONS

- A. DESIGN OPERATIONS
 - 1. <u>Performance Modifications to Meet Changine Engine Requirements</u>
 - 2. <u>Mechanical Modifications to Meet Life/Reliability Under</u> Unanticipated (Field Test Results) Environments
- **B. PRODUCTION FABRICATION OPERATIONS**
 - 1. Procurement Processing/Planning
 - 2. Tooling Fabrication
 - 3. Rawstock Procurement
 - 4. Casting or Forging
 - 5. Machining
 - 6. Welding
 - 7. Subassembly
 - 8. Assembly
 - 9. Final Assembly (Engine)
 - 10. Inspection
 - 11. Outside Liaison
 - 12. Inside Liaison
 - 13. Storage
 - 14. Shipping

- C. PRODUCTION TEST OPERATIONS
 - 1. Subcomponent Level Tests
 - a. Rotor Proof Spin Tests
 - b. Housing Proof Pressure Tests
 - 2. Component Level Tests
 - a. Pump Calibration
 - b. Turbine Calibration
 - 3. Turbopump Level Tests
 - a. Acceptance Tests
 - b. Post-Test Checkout and Inspections

- 4. Engine Level Tests
 - a. Engine Acceptance Tests
 - b. Post-Test Checkout and Inspections
- 5. Stage Level Tests
 - a. Flight Readiness Tests
 - b. Post-Test Checkout and Inspections
- D. FIELD MAINTENANCE AND REPAIR OPERATIONS
 - 1. Seal Checks
 - 2. Seal Replacement (Interfaces)
 - 3. Torque Checks
 - 4. Removal and Replacement

APPENDIX C

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CATEGORIZED BASE CASE VEHICLE, ENGINE AND TURBOPUMP DESIGN REQUIREMENTS

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CATEGORY/LEVEL	PARAMETER	REQUIREMENT	BASIS
Performance/Engine & Stage	Thrust	300,000 1Ъ	Contract work statement
	Thrust Tolerance	+ 3%	M-1 Engine Value
	Thrust Chamber Pressure	1200 psia	Contract work statement
	Thrust Chamber Pressure Tolerance	<u>+</u> 1.5%	F, I, MR tolerance
	Specific Impulse	 433 sec	Assumes = 50, I _s = 95% theory, 3% turbine bleed, turbine I _s = 225 sec
	Specific Impulse Tolerance	+ 3 sec	M-1 Engine Value
	Mixture Ratio (Engine)	5:1	J-2 Engine Value
	Mixture Ratio Tolerance (Engine)	2.5%	M-1 Engine Value
	Mixture Ratio (G.G.)	•90	To give 1660°R
	Fuel Flow Rate	116 lb/sec	F, I _s , MR above
	Oxidizer Flow Rate	580 lb/sec	F, I _s , MR above
Performance/Fuel Turbopump	Pump Pressure Rise	1900 psia	Typical J-2 & M-l losses
	Pump Pressure Rise Tolerance	<u>+</u> 3%	Typical component variations
	Pump Flow Rate	125 lb/sec	F, I _s , MR above + bearing/ balancer flow
	NPSH (Minimum)	130 ft	Typical vehicle value
	Turbine Inlet Pressure	1190 psia	$P_{cos} = P_{c} = duct loss$
	Turbine Pressure Ratio	7.5	Pre-Design
	Turbine Inlet Temperature	1660°R	State-of-the-art uncooled material properties.
	Turbine Inlet Temperature Tolerance	250°R	MR operating envelope & thrust balance
20	Static Seal Leakage	"Negligible")	Typical performance values (see
7	Dynamic Seal Leakage	.05 lb/sec)	operational requirements)

DESIGN REQUIREMENTS

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CATEGORY/LEVEL	PARAMETER	REQUIREMENT	BASIS
Performance/Oxidizer Turbopump	Pump Pressure Rise	1700 psia	Typical M-1, J-2 losses
	Pump Pressure Rise Tolerance	<u>+</u> 3%	Typical 3 component variations
	Pump Flow Rate	585 lb/sec	F, I _s , MR above + bearing/ balancer flow
	NPSH (Minimum)	25 ft	Typical vehicle value
	Turbine Inlet Pressure	135 psia	Pre-Design
	Turbine Pressure Ratio	3.4	Pre-Design
	Turbine Pressure Ratio Tolerance	<u>+</u> 2%	Typical 3 component variations
	Turbine Inlet Temperature	1250°F	Pre-Design
	Turbine Inlet Temperature Tolerance	<u>+</u> 180°	MR operating envelope & thrust balance
	Static Seal Leakage	"Negligible")	Typical performance values (see
	Dynamic Seal Leakage	.05 lb/sec)	operational requirements)
Operational/Stage & Engine	Throttling	None	Typical launch vehicle requirement
	Startup Duration	3 sec	Typical launch vehicle requirement
	Duty Cycle	4 starts 300 sec	Engine acceptance & balance tests, stage FRF & launch
	In Flight Restarts	None	
	Pre Start Chilldown	-400°F fuel pump	Typical launch vehicle requirement
		-280°F Oxidizer pump	Typical launch vehicle requirement
	Static Seal Leakage	5 psi decay in 20 min from 50 psig GN ₂ leak test	Typical engine requirement
	Dynamic Seal Leakage	.05 lb/sec	Typical requirement

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CATEGORY/LEVEL	PARAMETER	REQUIREMENT	BASIS
	Environment	GN ₂ or d ry air blanket except during launch	Typical environment
	Reliability (Engine Duty Cycle)	preparation .97	Typical value
	Schedule	6 years to 1st R&D flight	Preliminary program plan
Operational/Turbopumps	Same as engine except as follows:		
	Duty Cycle	5 starts 300 sec	Engine firings + turbopump acceptance test
	Static Seal Leakage	2 psi dec ay in 20 min from 50 psig_GN ₂ leak test	Apportioned engine leak rate
	Reliability	.998	Apportioned from engine requirement Titan value
Mechanical/Turbopumps	Design Life	10 hours)	Titan values which resulted in
	Design Firings	10 starts)	above reliability for similar duty cycle
Mechanical/Turbopumps	See part by part listing on the following pages of this table.		

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Subcomponents

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE
Bearing Housing/Backplate, Fuel (1)		
Size (O.D.)	25.0 in	22-32 in
Material	Cast 347	Cast 347
Surface Finish	63	250
Tolerance		
Pilot Dia's	<u>+</u> .001	<u>+</u> .005
Bearing Dia's	<u>+</u> .0005	<u>+</u> .0005
Axial Dimensions	<u>+</u> .001	<u>+</u> •005
Quality Control	Current Aerospace *	Minimum ^{**}
Shaft, Fuel (2)		
Size (Bearing Dia.)	2.25 in	2-3.5 in
Material	Inconel X	Inconel X
Tolerance		
Diameters	<u>+</u> .0005	<u>+</u> .0005
Axial Dimensions	<u>+</u> .001	<u>+</u> .010
Surface Finish	16/63	16/63
Quality Control	Current Aerospace	Minimum
Dynamic Balance	Required	Required
•		

- * 100% Dimensional, Material Certification & Traceability
- ** Critical Dimensions only, Material Certification & Traceability

SUBCOMPONENT/REQUIREMENT	BASE VALUE		ALTERNATE RANGE	
Bearings, Fuel $(3)(4)(6)(7)$				
Size	60mm		50 - 90 min	
Number/Type	4/Preloaded Bal	11)		
Material	440C/Armalon)	- No Change	
Class	5)		
Quality Control	Current Aerospace			
Spacer, Bearing-Upper & Lower (3.5) (6.5)				
Size (0.D.)	2.750		2.5-3.5 in	
Material	Inconel X)		
Tolerance)		
Diameter	+ .0005)	- No Change	
Surface Finished	 16/63)		
Quality Control	Current Aerospa	ace)		
Turbine Shaft Coupling, Fuel (8)				
Size (0.D.)	5.5 in		5-8 in.	
Material	Inconel X		Inconel X	
Surface Finish	16/63		16/63	
Tolerance				
Diameters	<u>+</u> .0005		<u>+</u> .0005	
Axial Dimensions	<u>+</u> .001		<u>+</u> .010	
Quality Control	Current Aerospa	ace	Minimum	
Dynamic Balance	Required		Required	
	•			

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE
Bolt, Shaft Coupling (9)		
Size (Thread Diameter)	1.125 in.	1-2 in.
Material	Inconel X	
Tolerance		
Diameter	<u>+</u> .0005)	
	<u>+</u> .010)	
Thread	Class A)	No Change
Concentricity	.001)	
Surface Finish	32/63)	
Quality Control	Current Aerospace)	
$\mathbf{W}_{\mathbf{r}}$ = $\mathbf{C}_{\mathbf{r}}$		
Size (O D)	1.5 in.	1.25 - 3.0 in.
Material	A 286	A 28
Thread	.625 Class A	.5-1.0 Class A
Squareness	.001	.001
Surface Finish	63	63
Quality Control	Current Aerospace	Minimum
Labyrinth, Shaft (11)		
Size (0.D.)	4.5 in.	4-6 in.
Material	Phosphor Bronze	Phosphor Bronze
Tolerance		
Diameter	<u>+</u> .001/000	<u>+</u> .002
Squareness	.001	.005
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ALTERNATE RANGE SUBCOMPONENT/REQUIREMENT BASE VALUE 32/63 32/63 Surface Finish Minimum Current Aerospace Quality Control Carrier, Bearing - Upper (12) 4-7 in. Size (0.D.)4.25 in. Inconel X Material Tolerance + .0000 Diameter - .0005 ----- No Change .001 Concentricity 16/63 Surface Finish Current Aerospace) Quality Control Carrier, Bearing - Lower (13) 4-7 in. Size (O.D.) 4.25 in. Inconel X Material Tolerance + .0000 Diameter No Change - .0005 .001 Concentricity 16/63 Surface Finish Current Aerospace) Quality Control

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214 ALTERNATE RANGE SUBCOMPONENT/REQUIREMENT BASE VALUE Spacer, Shim-Bearing Retaining (14) 4.5 - 7.5 in. 5.0 in. Size (O.D.) Inconel X Material Tolerance .001 Diameter . ---- No Change .001 Parallelism 63 Surface Finish Current Aerospace) Quality Control Spacer, Bearing Retaining (15) 4.5 - 7.5 in. 5.0 in. Size (O.D.) Inconel X Material Tolerance .001 Diameter ---- No Change .001 (or less) Parallelism 63 Surface Finish Current Aerospace) Quality Control Labyrinth, Coupling (16) 4-5 - 7.5 in. 5.0 in. Size (0.D.) Phosphor Bronze Phosphor Bronze Material Tolerance + .002 + .0005 Diameter .005 .0005 Flatness 63 63 Surface Finish Minimum Quality Control Current Aerospace

SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE		
Turbine Seal, Fuel (17)				
Туре	Shaft Riding	Labyrinth		
Size (I.D.)	2.5 in.	a. 2.25 - 4.0 in.		
Tolerance				
Flange Dimensions	<u>+</u> .010	<u>+</u> .010		
Sealing Elements	<u>+</u> .0005	<u>+</u> .0005 <u>+</u> .001		
Quality Control				
lst Stage Turbine Rotor, Fuel (18)				
Size (0.D.)	10.8 in.	8-16 in.		
Material	Forged 718	Forged 718		
Surface Finish	63	125	ν.	
Tolerance	-			
Blade	+ .003	+ .010		
Diameters & Axial Dim's	+ .001	+ .005		
Quality Control	- Current Aerospace	— Minimum		
Dynamic Balance	Required	Required		
2nd Stage Turbine Botor, Fuel (19)				
Size $(0,D_1)$	10.8 in.	8-16 in.		
Material	Forged 718	Forged 718		
Surface Finish	63	250		
Tolerance				
Blade	+ .003	<u>+</u> .010		
Diameters	- + .001	- + .010		
2 Quality Control	- Current Aerospace	Minimum		
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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE	
Nut, Ring Orifice - Low Pressure (23)			
Size (0.D.)	6.75 in.	6 - 9 in.	
Material	3 ⁴ 7	347	
Tolerance			
Diameters	<u>+</u> .0005	<u>+</u> .010	
Squareness	.001	<u>+</u> .001	
Surface Finish	63	63	
Quality Control	Current Aerospace	Minimum	
Ring, Orifice-High Pressure (27)			
Size (0.D.)	16.0 in.	14-22 in.	
Material	Inconel 718	347/Flame Place	
Tolerance			
Diameters	<u>+</u> .003	<u>+</u> .003	
Flatness	<u>+</u> .001	<u>+</u> .001	
Surface Finish	32	63	
Quality Control	Current Aerospace	Minimum	
Nut, Ring Oridice-High Pressure (28)			
Size (0.D.)	16.0 in.	14-22 in.	
Material	347	347	
Tolerance			
Diameter (O.D.)	Class A Thread	Class A Thread	
(I.D.)	.001	<u>+</u> .010	
Squareness	.001	<u>+</u> .001	
Surface Finish	63	63	
Quality Control	Current Aerospace	Minimum	

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE				
Pump Diffuser, Fuel (29)						
Size (Base Circle Dia.)	15.5 in.	14-22 in.				
Material	347	Cast Aluminum				
Surface Finish	63	250				
Vane Tolerance	<u>+</u> .003	<u>+</u> .010				
Diameter Tolerance	<u>+</u> .003	+ .010				
Quality Control	Current Aerospace	Minimum				
Impeller, Fuel (30)						
Size (0.D.)	14.6 in.	12-21 in.				
Material	Forged Titanium	Forged Titanium				
Surface Finish	63	250				
Vane Tolerance	<u>+</u> .003	<u>+</u> .010				
Diameter Tolerance	<u>+</u> .003	<u>+</u> .010				
Quality Control	Current Aerospace	Minimum				
Dynamic Balance	Required	Required				
Inducer, Fuel (31)						
Size (O.D.)	8.4 in.	8-10 in.				
Material	Forged Titanium	Forged Titanium				
Surface Finish	63	250				
Vane Tolerance	<u>+</u> .003	<u>+</u> .010				
Diameter Tolerance	<u>+</u> .003	<u>+</u> .010				
Quality Control	Current Aerospace	Minimum				
Dynamic Balance	Required	Required				

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE	
	•		
Nut Assy, Impeller Retaining (32)			
Size (0.D.)	3.1 in.	3-4 in.	
Material	Aluminum	Aluminum	
Tolerance			
Diameter (Thread)	Class A	Class A	
(I.D.)	<u>+</u> .001	<u>+</u> .030	
Contour Thickness	+ .002	<u>+</u> .030	
Surface Finish	63	125	
Quality Control	Current Aerospace	Minimum	
Pump Housing, Fuel (34)			
Size (0.D 180° Sect)	24.0 in.	21-32 in.	
Material	Cast 347	Cast 347	
Surface Finish	63/125	125/250	
Tolerance			
Volute	<u>+</u> .03	<u>+</u> .10	
Contour	<u>+</u> .003	<u>+</u> .010	
Pilots	<u>+</u> .001	<u>+</u> .005	
Quality Control	Current Aerospace	Minimum	
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Housing, Bearing Oxid (1)			
Size (0.D.)	5.9 in	3-7 in.	
Material	347		

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE
Surface Finish	32/63*)	
Tolerance)	
Pilot Dia's	+.001)	No Change
Bearing Dia's	<u>+</u> .0005)	
Axial Dimensions	<u>+</u> .001)	
Quality Control	Current Aerospace)	
Shaft, Oxid (2)		
Size (Bearing Dia.)	2.4 in.	2-3.5 in.
Material	Inconel X)	
Tolerance)	
Diameters	<u>+</u> .0005)	No Change
Axial Dimensions	<u>+</u> .001)	
Surface Finish	16/63)	
Quality Control	Current Aerospace)	
Dynamic Balance	Required)	
Bearings, Oxid (3) (13)		
Size	60mm	50 - 90mm
Number/Type	2/Preloaded Ball)	
Material	440C/Armalon)	
Class	5)	No Change
Quality Control	Current Aerospace)	

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE	
Seal Assy. Bellows-Upper Oxid (4)			
Size (0.D.)	6.2 in.	5.5 - 8.0 in.	
Material	347)	
Tolerance)	
Diameters	<u>+</u> .001)	
Flatness (Seal Surface)	l Helium Light B	and) No Change	
Туре	Purged & Vented	Dual Seal)	
Quality Control	Current Aerospac	e)	
Axial Tolerance	<u>+</u> .001)	
Surface Finish (347 Material)	63)	
Seal Ring, Running-Upper Oxid (5)			
Size (O.D.)	3.4 in.	3-5 in.	
Material	347)	
Surface Finish	63)	
Seal Face (Flame Plated)	Ground & Lapped)	
Diameters O.D.	<u>+</u> .001)	
Diameters I.D.	<u>+</u> .0005)	
Axial Dimensions Tolerance	<u>+</u> .001)	
Quality Control	Current Aerospac	ee)	

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE	
Seal Ring, Running-Lower Oxid (6)			
Size (0.D.)	5.0 in.	4-7 in.	
Material	347)		
Surface Finish	63)		
Seal Faces (2) (Flame Plated)	Ground & Lapped)		
Tolerance)	No Change	
Diameter I.D.	<u>+</u> .0005)	-	
Axial Dimension	<u>+</u> .001)		
Squareness	.0005)		
Quality Control	Current Aerospace)		
Seal Assy, Shaft Riding Oxid (7)		0 .	
Size (O.D.)	6.6 in.	5.5 - 8 in.	
Material	347)		
Surface Finish)		
Tolerance)	No. Change	
Diameter (0.D.)	<u>+</u> .001)	No Change	
Axial Dimensions	<u>+</u> .001)		
Squareness	<u>+</u> .0005)		
Quality Control	Current Aerospace)		

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE	
Seal Assy. Bellows-Lower Oxid (8)			•
Size (0.D.)	6.6 in.	5.5 - 8 in.	
Material	347)	
Tolerance)	
Diameters	<u>+</u> .001) No Change	
Axial Dimensions	<u>+</u> .001)	
Flatness (Seal Surface)	l Helium Light	Band)	
Туре	Purged & Vente	d Dual Seal)	
Quality Control	Current Aerosp	ace)	
Surface Finish (347 Material)			
Nut, Seal Retaining, Oxid (9)			
Size (O.D.)	6.8 in.	6 - 8.5 in.	
Material	Inconel X)	
Tolerance)	
Diameters (0.D. Thread)	Class A)No Change	
(I.D.)	.003)	
Squareness	.001)	
Surface Finish	63)	
Quality Control	Current Aerosp	ace)	

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE
Filter, Oxid (10)		
Size (O.D.)	5.3 in.	4.5 - 7.5 in.
Rating	10 Micron)
Material	CRES 300)
Tolerance)
Diameter (O.D.)	.030) No Change
Diameter (I.D.)	.001)
Axial Dimensions	.010	
Surface Finish (Machined Ends)	63	
Quality Control	Current Aeros	ospace)
Spacer, Bearing, Oxid (12)		
Size (O.D.)	3.0 in.	2.5 - 4 in.
Material	Inconel X)
Tolerance)
Diameter (0.D.)	<u>+</u> .005) No Change
Diameter (I.D.) (Pilot)	<u>+</u> .0005)
Squareness	.001)
Surface Finish	32 I.D. & End	nds Only)
Quality Control	Current Aeros	ospace)

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SUBCOMPONENT/REQUIREMENT	BASE VALUE		ALTERNATE RANGE	
Nut, Bearing Retaining, Oxid (14)				
Size (0.D.)	3.3 in.		2.5 - 4.5 in.	
Material	A286)		
Tolerance)		
Diameter (0.D.)	+ .010)	- No Change	
(I.D.) Thread	Class A)	- no change	
Flatness	.001)		
Surface Finish	63)		
Quality Control	Current Aeros	pace)		
Seal, Labyrinth-Lower, Oxid (15)	10 0		10.0 16.0 4-	
Size (0.D.)	12.0		10.0 - 16.0 in.	
Material	KEL-F		KEL-F	
Tolerance				
Diameter (0.D.)	<u>+</u> .010		<u>+</u> .010	
(I.D.)	+ .002		<u>+</u> .005	
(Pilot)	<u>+</u> .002		<u>+</u> .005	
Concentricity	.002		.002	
Quality Control	Current Aeros	pace	Minimum	

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STIDGOMPONIENT / REGULTREMENT	BASE VALUE		ALTERNATE RANGE	
Retainer, Labvrinth-Lower, Oxid (16)				
Size (0.D.)	12.8 in.		11.0 - 17.0 in.	
Material	Aluminum)		
Tolerance)		
Diameter (0.D.)	<u>+</u> .003)		
(I.D. Pilot)	<u>+</u> .002)	No Change	
Squareness	.002)		
Surface Finish	63)		
Quality Control	Current Aero	space)		
Volute, Pump, Oxid. (17)				
Size (0.D.) (360° Section)	23 in.	·	21-29 in.	
Material	Cast Aluminu	ım	Cast Aluminum	
Surface Finish	63/126		63/250	
Tolerances				
Flow Passage	<u>+</u> .030		<u>+</u> .10	
Pilot Diameters	<u>+</u> .001		<u>+</u> .003	
Axial Stack Up Dimensions	<u>+</u> .003		<u>+</u> .010	
Quality Control	Current Aero	ospace	Minimum	

SUBCOMPONENT/	REQUIREMENT	BASE VALUE		ALTERNATE RANGE	
Nut, Volute Pump	Retaining, Oxid (18)				
Size (0.D.)		5.8 in.		5-8 in.	
Material		Inconel X)		
Diameters	(O.D.)	<u>+</u> .010)	•	
	(I.D. Thread)	Class A)	- No Change	
Squareness	3	<u>+</u> .001)		
Surface Finis	sh	63)		
Quality Conti	rol	Current Aerosp	pace)		
Impeller, Oxid ((19)				
Size (0.D.)		13 in.		11-19 in.	
Material		Shell Mold-Cas	st Aluminum	Investment Cast Aluminum	×
Vane Tolerand	ce	<u>+</u> .025		<u>+</u> .010	
Tip Tolerance	9	<u>+</u> .010		<u>+</u> .010	
Sealing Surfa	ace Tolerance	<u>+</u> .002		<u>+</u> .010	
Pilot Diamete	er Tolerance	<u>+</u> .0005		<u>+</u> .0005	
Axial Stacku	p Tolerance	<u>+</u> .010		<u>+</u> .010	
Squareness		.001		.001	
Dynamic Bala	nce	Required		Required	
Surface Fini	sh	63		63/250	
Quality Cont	rol	Current Aeros	pace	Minimum	

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문화 이 방법에 집에 있는 것 같아. 정말 가운 영화 가슴 가슴 가슴 가슴 가슴 가슴 가슴 가셨다.

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	(Tənom-X	TsiretsM
·ut 0.5 - 2.	•uī 8•	(.D.D) size
	C C	Bolt, Impeller Retaining, Oxid (21)
unututw	essqeored inerud	Quality Control
03/ TS2	63	Surface Finish
vedurrea	Required	Dynamic Balance
100.	τοο•	ssəuəreng
010. +	0T0• -	qU Stack Up
	5000° -	sioliq
	500. +	Diameters (0.D.)
	500° -	ansV
		Tolerance
DIG CS2 ATMITTIM	munimula begro'i	Material
	•ut T•8	(.T.O) size
		Inducer, Oxid (20)
ALTANAT ATANATLA	BARE VALUE	SUBCOMPONENT/REMENT

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Quality Control	Surrent Aerospace	(
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Solerance		(
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SUBCOMPONENT/REQUIREMENT	BASE VALUE		ALTERNATE RANGE	
Seal. Labyrinth-Upper, Oxid (22)				
Size (0.D.)	10.6 in.		10 - 12 in.	
Material	KEL-F		KEL-F	
Tolerance				
Diameter (0.D.)	<u>+</u> .010		<u>+</u> .010	
(I.D.)	<u>+</u> .002		<u>+</u> .005	
(Pilot)	<u>+</u> .002		<u>+</u> .005	
Concentricity	.002		.002	
Quality Control	Current Aero	space	Minimum	
Spacer, Seal-Labyrinth, Oxid (23)				
Size (0.D.)	11.7 in.		11 - 13 in.	
Material	Aluminum)		
Tolerance)		
Diameter (0.D.)	+ .010)	- No Change	
(Pilot)	<u>+</u> .002)		
(I.D.)	<u>+</u> .005)		
Surface Finish	63)		
Quality Control	Current Aero	ospace)		

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE
Retainer, Labyrinth-Upper, Oxid (24)		
Size (O.D.)	11.72 in.	11 - 13 in.
Material	Aluminum)	
Tolerance)	
Diameter (O.D.)	<u>+</u> .003)	
(Pilots)	<u>+</u> .002)	No Change
(I.D.)	<u>+</u> .003)	
Squareness	<u>+</u> .001)	
Surface Finish	63)	
Quality Control	Current Aerospace)	
Adapter, Pump Inlet, Oxid (25)		
Size (0.D.)	14.5 in	14 - 22 in.
Material	Cast Aluminum	Cast Aluminum
Tolerance		
Diameter (0.D. Pilots)	<u>+</u> .002	<u>+</u> .005
(O.D.)	<u>+</u> .030	<u>+</u> .100
(I.D. Bore)	<u>+</u> .002	<u>+</u> .010
(I.D. at Labyrinth)	<u>+</u> .001	<u>+</u> .001
Squareness (at Labyrinth)	.001	.003
Surface Finish	63	250
Quality Control	Current Aerospace	Minimum

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SUBCOMPONENT/REQUIREMENT	BASE VALUE	ALTERNATE RANGE
Rotor, Turbine, Oxid (26) Size (0.D.) Material (Forging) Surface Finish	19.5 in. Inconel 718 63	18 - 28 in. Cast 718 125
Tolerance Blades Diameters Quality Control Dynamic Balance	<u>+</u> .003 <u>+</u> .001 Current Aerospace Required	<u>+</u> .010 <u>+</u> .005 Minimum Required
Bolt, Rotor, Oxid (27) Quantity Size	6 ea. 3/8 dia. x 1.85 long)	6 - 10 ea.

A-286 Class A Thread <u>+</u> .001 32 Current Aerospace

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Material

Tolerance

Diameter (0.D.)

Surface Finish

Quality Control

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010° + 010° +	£00• +	Tolerance Diameic
342 55 - 35 In.	.Tanconel 718 24.7 in.	(88) bixo the Inlet, Oxid (88) Size (Torus O.D.) Material (Cast. Formed & Welded)
 ALTERNAT ET ANATTA	EASE VALUE	SUBCOMPONENT/REQUIREMENT
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Quality Control

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APPENDIX D

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FAILURE MODE ANALYSES

LOW-COST FUEL TURBOPUMP (1136900) AND LOW-COST OXIDIZER TURBOPUMP (1137000)

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FAILURE MODE ANALYSIS LOW COST FUEL TURBOPUMP (1136900)

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
INDUCER					•999694
	VANE FAILURE			204.3	
		CENTRIFUGAL STRESS	A-1	.1	
		PRESSURE STRESS	B-1	1.0	
		OSCILLATING PRESSURE STRESS	B-1	1.0	
		THERMAL LC FATIGUE	B-1	1.0	
		SHAFT DEFLECTION/RUB	B- 2	100.0	
		CENTRIFUGAL GROWTH/RUB	A-1	.1	
		HOUSING DISTORTION/RUB	B-1	1.0	
		SHAFT FIT/RUB	A-1	.1	
		MATERIAL STRENGTH	B-2	100.0	
	HUB FAILURE			101.4	
		CENTRIFUGAL STRESS	A-1	.1	
:		PRESSURE STRESS	A-1	.1	
	· · · · · · · · · · · · · · · · · · ·	OSCILLATING PRESSURE STRESS	B-1	1.0	
		SHAFT FIT	A-1	.1	
		CLUTCH SHEARING	A-1	.1	
.		MATERIAL STRENGTH	B-2	100.0	

	MODE	MECHANISM	RATING	RFP	RELATIVE <u>RELIABILITY</u>
TARL	1000				. 999995
INDUCEK RETAINER	CHANK FRACTIRE			1.2	
	SHARK FINITION	TENSILE STRESS	A-1	.1	
		TOROUE STRESS	B-1	1.0	
		MATERIAL STRENGTH	A-1	.1	
	TUPEAD ERACTURE			.4	
	TIREAD FRACTOR	SHEAR LOAD	A-1	•1	
		MATERIAL STRENGTH	A-1	.1	
		THREAD SIZE	A-1	.1	
		THREAD FORM	A-1	.1	
	LOOSE STACK-UP			3.0	
		THERMAL INCOMPATIBILITY	B-1	1.0	
		DAMAGED THREAD	A-2	1.0	
,		LOCK TANG NOT ENGAGED	A-2	1.0	
TMPFLLER					.999370
	VANE FATLURE			224.2	
		CENTRIFUGAL STRESS	A-1	.1	
		PRESSURE STRESS	C-1	10.0	
		OSCILLATING PRESSURE STRESS	B-2	100.0	

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	VANE FAILURE (Continued)				
		THERMAL LC FATIGUE	B-1	1.0 4.	
		SHAFT DEFLECTION/RUB	C-1	10.0	
		CENTRIFUGAL GROWTH/RUB	A-1	.1	·
		HOUSING DISTORTION/RUB	B-1	1.0	
		MATERIAL STRENGTH	B-2	100.0	
		HIGH THRUST/RUB	B-1	1.0	
		DISC DEFLECTION/RUB	B-1	1 .0 .	
	DISC FAILURE			101.3	
		CENTRIFUGAL STRESS	A-1	.1	
		PRESSURE STRESS	A-1	.1	
		OSCILLATING PRESSURE STRESS	B-1	1.0	
		THERMAL STRESS	A-1	.1	
		MATERIAL STRENGTH	B-2	100.0	
	BALANCER RUB			203.3	
		HOUSING DISTORTION	B-1	1.0	
:		CONTAMINATION	B-2	100.0	
		CENTRIFUGAL DISTORTION	A-1	.1	
		TURBINE THRUST	B-1	1.0	
		CRITICAL SPEED	B-1	1.0	
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	τ.	I-A	THREAD FORM		
	τ.	T-A	THREAD SIZE		
	τ.	T-A	MATERIAL STRENGTH		
	τ.	⊺-∀	SHEAR LOAD		. :
-	.			THREAD FRACTURE	
	τ.	I-A	MATERIAL STRENGTH		
	0 . 01	£-A	TORQUE STRESS		
	ī.	T-V	TENSILE STRESS		
	7.01			SHANK FRACTURE	
	6 01				IMPELLER RETAINER
887666.	100°0	2-8	NOL EULLY ENCAGED		
	0.I	Z-₩	MATERIAL STRENGTH		
	τ.	I-A	HICH LORQUE		
	τ.	T-¥	SPLINE FORM		
	τ.	⊺-∀	SPLINE SIZE		
	<u>101.3</u>	-		CLUTCH FALLURE	
	0°00T	8-2	WATING FACE RETENTION		
	τ.	T-A	AXIAL VIBRATION (ND MODES)		
	τ.	1 - A	PRESSURE DISTORTION		
				BALANCER RUB (Continued)	
RELATIVE RELABILITY	RFP	RATING	MECHANISM	WODE	TAAT

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	LOOSE STACK-UP			201.0	
		THERMAL INCOMPATIBILITY	B-1	1.0	
		DAMAGED THREAD	B-2	100.0	
		LOCK TANG NOT ENGAGED	B-2	100.0	
PUMP BEARINGS					.999670
	FATIGUE			126.0	
		SHAFT FIT/INTERFERENCE	B-1	1.0	
		CARTRIDGE FIT/INTERFERENCE	B-1	1.0	
		SHAFT FIT/UNBALANCE	B-1	1.0	
		CARTRIDGE FIT/LOOSE (CRIT SPED)	C-1	10.0	
		CRITICAL SPEED	C-1	10.0	
		MISALIGNMENT	A-2	1.0	
		MATERIAL STRENGTH	A-2	1.0	
		CLAMPING LOAD HIGH OR UNEVEN	A-2	1.0	
		CARTRIDGE BINDING	B-2	100.0	
	MECHANICAL			202.0	•
•		CAGE STRENGTH	B-1	1.0	
		CAGE WEAR	D-1	100.0	м.
		CONTAMINATION	A-4	100.0	
N		COOLANT ADEQUACY	A-2	1,0	

PART	MODE	MECHANISM	RATING	RFP	RELATIVE <u>RELIABILITY</u>
	FACE FRACTURE			2.0	
		SHAFT FIT	B-1	1.0	
		MATERIAL STRENGTH	A-2	1.0	
TURBINE 'BEARINGS					.999462
	FATIGUE			434.0	
		HIGH THRUST	B-1	1.0	
		SHAFT FIT/INTERFERENCE	B-1	1.0	
		CARTRIDGE FIT/INTERFERENCE	C-1	10.0	
		SHAFT FIT/UNBALANCE	C-1	10.0	
		CARTRIDGE FIT/LOOSE (CRIT SPD)	D-1	100.0	
		CRITICAL SPEED	C-1	10.0	
		MISALIGNMENT	A-2	1.0	
		MATERIAL STRENGTH	A-2	1.0	
		CLAMPING LOAD	B-2	100.0	
		CARTRIDGE BINDING	B-2	100.0	
		CARTRIDGE POSITION	B-2	100.0	
	MECHANICAL			102.0	,
		CAGE STRENGTH	B-1	1.0	
		CAGE WEAR	D-1	100.0	
		CONTAMINATION	A-4	100.0	
		COOLANT ADEQUACY	A- 2	1.0	

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	RACE FRACTURE			2.0	
		SHAFT FIT	B-1	1.0	
		MATERIAL STRENGTH	A-2	1.0	
TURBINE ROTOR (1)					.999072
	DISC FAILURE			3 11.2	
		CENTRIFUGAL STRESS	A-1	.1	
		PRESSURE STRESS	A-1	.1	
		OSCILLATING PRESSURE STRESS	C-1	10.0	
		AXIAL VIBRATION	D-1	100.0	
		MATERIAL STRENGTH	A-2	1:0	
		STRESS CONCENTRATION	B-2	100.0	
		LABYRINTH RUB	B-2	100.0	
	BLADE FAILURE			<u>515.5</u>	
		CENTRIFUGAL STRESS	A-1	.1	
		GAS BENDING STRESS	A-1	.1	
		OSCILLATING GAS BENDING	B-1	1.0	x
:		AMPLIFIED OSC GAS BENDING	D-1	100.0	
		MATERIAL STRENGTH	A-2	1.0	
		RUB-BLADE CREEP	A-1	.1	
		RUB-DISC CREEP	A-1	.1	
		RUB-CENTRIFUGAL GROWTH	A-1	.1	

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PART	MODE	MECHANISM	RATING	<u>RFP</u>	RELATIVE <u>RELIABILITY</u>
	BLADE FAILURE (Continued)			
		RUB-SHAFT DEFLECTION	B-1	1.0	
		RUB-HOUSING DISTORTION	C-1	10.0	
		RUB-SHAFT FIT	B-2	100.0	
		RUB-AXIAL VIBRATION >	D-1	100.0	
		RUB-THERMAL DISTORTION	D-1	100.0	
		RUB-HIGH THRUST	B-1	1.0	
		RUB-FOREIGN OBJECTS	B-2	100.0	
		RUB-CRITICAL SPEED	B-1	1.0	
	COUPLING FAILURE			101.3	
		COUPLING SIZE	A-1	.1	
		HIGH TORQUE	A-1	.1	
		COUPLING FORM	A-1	.1	
		MATERIAL STRENGTH	A-2	1.0	
	· · · ·	NOT FULLY ENGAGED	B-2	100.0	
TURBINE ROTOR (2)					.999171
	DISC FAILURE			<u>311.2</u>	
		CENTRIFUGAL STRESS	A-1	.1	
		PRESSURE STRESS	A-1	.1	
		OSCILLATING PRESSURE STRESS	C-1	10.0	

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	DISC FAILURE (Continued)				
		AXIAL VIBRATION	D-1	100.0	
		MATERIAL STRENGTH	A-2	1.0	
		STRESS CONCENTRATION	B-2	100.0	
		LABYRINTH RUB	B-2	100.0	
	BLADE FAILURE	Ÿ		416.5	
		CENTRIFUGAL STRESS	A-1	.1	
		GAS BENDING STRESS	A-1	1	
		OSCILLATING GAS BENDING	B-1	1.0	
		AMPLIFIED OSC GAS BENDING	D-1	100.0	
		MATERIAL STRENGTH	A-2	1.0	
		RUB-BLADE CREEP	A-1	.1	
		RUB-DISC CREEP	A-1	.1	,
		RUB-CENTRIFUGAL GROWTH	A-1	.1	
		RUB-SHAFT DEFLECTION	B-1	1.0	
		RUB-HOUSING DISTORTION	C-1	10.0	
		RUB-SHAFT FIT	B-2	1-0.0	
·		RUB-AXIAL VIBRATION	D-1	100.0	
		RUB- THERMAL DISTORTION	B-1	1.0	
		RUB-HIGH THRUST	B-1	1.0	

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	112.0		LEAKAGE	
	0.τ	8-2	THICKNESS VARIATIONS	
	0.01	£-A	MELD DEFECTS	
	τ.	1-A	OVERTEMPERATURE	
	τ.	T-A	OVERPRESSURE	
	0.τ	2− A	MATERIAL STRENGTH	
	12.2		TSAUE BURST	
٤٤8666.				TURBINE MANIFOLD
	0.001	8-2	NOL FULLY ENGAGED	
	0.1	8-8	MATERIAL STRENGTH	
	τ.	I-A	COUPLING FORM	
	τ.	I-A	HIGH TORQUE	
	Ţ٠	I-A	COLFING SIZE	
	<u>101.3</u>		COUPLING FAILURE	
	0.τ	1-8	RUB-CRITICAL SPEED	
	0.00τ	B-2	KUB-FOREIGN OBJECTS	
			BLADE FAILURE (Continued)	
RELIABLLIVE RELIABLLIYE	RFP	RATING	WODE WECHFMISW	PART

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE <u>RELIABILITY</u>
	LEAKAGE (Continued)				
		SEALS	B-2	100.0	
		BOLTS	B-1	1.0	
	NOZZLE FAILURE			23.0	
		THERMAL LC FATIGUE	C-1	10.0	
		HOUSING DISTORTION	C-1	10.0	
		FLUTTER	B-1	1.0	
		PRESSURE LOAD	B-1	1.0	
		MATERIAL STRENGTH	A-2	1.0	
TURBINE NOZZLE (2)					.999873
	VANE FAILURE			23.1	
		THERMAL LC FATIGUE	C-1	10.0	
		FLUTTER	B-1	1.0	
		PRESSURE LOAD	B-1	1.0	
		HOUSING DISTORTION	C-1	10.0	
		DIAPHRAGM LOAD	A-1	.1	
:		MATERIAL STRENGTH	A-2	1.0	
	INTERSTAGE LEAK			104.0	
		FLANGE DISTORTION	B-1	1.0	
		ECCENTRICITY	A-2	1.0	

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	PART	MODE	MECHANISM	RATING	<u>RFP</u>	RELATIVE <u>RELIABILITY</u>
		INTERSTAGE LEAK (Continu	ied)			
			FLANGE FIT	A-2	1.0	
			LABYRINTH FIT	A-2	1.0	
			LABYRINTH RUB	B-2	100.0	
		GAS MISDIRECTION	¥		.2	
			STATOR ROTATION	A-1	.1	
			VANE DISTORTION	A-1	.1	
	PUMP HOUSING					.999894
		HOUSING BURST			2.1	
			MATERIAL STRENGTH	A-2	1.0	
			OVERPRESSURE	A-1	.1	
			THICKNESS VARIATIONS	A-2	1.0	
		LEAKAGE			102.0	
			POROSITY	A-2	1.0	
			SEALS	B-2	100.0	
			BOLTS	B-1	1.0	
		VANE FAILURE			2.2	
			HOUSING DISTORTION	A-1	.1	
			PRESSURE LOAD	A-1	.1	
			MATERIAL STRENGTH	A- 2	1.0	

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	VANE FAILURE (Continued)				
		VANE FORM (LOCAL DEFECTS)	A-2	1.0	
BEARING HOUSING					.999898
	HOUSING BURST			1.2	
		MATERIAL STRENGTH	A-1	.1	
		OVERPRESSURE	A-1	.1	
		BEARING INTERFERENCE	A-2	1.0	
	LEAKAGE			101.0	
		POROSITY	A-2	1.0	
		SEALS	B-2	100.0	
TURBINE SEAL					.999695
	EXCESS FLOW			302.0	
		LABYRINTH CLEARANCE	A-2	1.0	
		LABYRINTH RUB	B-2	100.0	
		BLOCKED VENT	A-2	1.0	
		CARBON BREAK	B-2	100.0	
:		CARBON WEAR	B-2	100.0	
	HIGH TORQUE			<u>3.0</u>	
		LABYRINTH FIT	A-2	1.0	
		PILOT CONCENTRICITY	A-2	1.0	
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PART	MODE	MECHANISM	KAIING	<u>KFF</u>	RELIADILIII
	HIGH TORQUE (Continued)				
		THERMAL DISTORTION	B-1	1.0	
SHAFT					.999891
	SHEAR FRACTURE				
		HIGH TORQUE	A-1	.2	
		MATERIAL STRENGTH	A-1	.1	
	FATIGUE			.1	
		MISALIGNMENT LOADS	B-1	4.1	
		STRESS CONCENTRATIONS	A-2	1.0	
		MATERIAL STRENGTH	A-1	1-0	
		CRITICAL SPEED	B-1	.1	
		UNBALANCED	B-1	1.0	
	DAMAGING RUB			1.0	
		CRITICAL SPEED	B-1	4.0	
		INSUFFICIENT CLEARANCE	A-2	1.0	
		MISALIGNMENT	B-1	1.0	
		UNBALANCE	B-1	1.0	
	SPLINE SHEAR			100.4	
		HIGH TORQUE	A-1	.1	
		MATERIAL STRENGTH	A-1	.1	

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	SPLINE SHEAR (Continu	ed)			
		SPLINE FORM	A-1	.1	
		NOT FULLY ENGAGED	B-2	100.0	
		SPLINE SIZE	A-1	.1	
TURBINE COUPLING					.999899
	SPLINE SHEAR			100.4	
		HIGH TORQUE	A-1	.1	
		MATERIAL STRENGTH	A-1	.1	
		SPLINE FORM	A-1	.1	
		NOT FULLY ENGAGED	B-2	100.0	
		SPLINE SIZE	A-1	.1	
	SHEAR FRACTURE			.2	
		HIGH TORQUE	A-1	.1	
		MATERIAL STRENGTH	A-1	.1	

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τ.	I-A	TIA TAAHS	
0.1	в-т	OSCILLATING PRESSURE STREES	
τ.	L-A	PRESURE STRESS	
τ.	I-A	CENTRIFUCAL STRESS	
7.101			AUUITAA HUH
0.001	B-2	HTDNAATZ JAIRATAM	
τ.	I-A	AUR\TIA TAAHS	
0.1	B-I	HOUSING DISTORTION/RUB	
τ.	I-A	CENTRIFUGAL GROWTH/RUB	
0.001	B-2	BUA NOITDELTED TAAHS	
0'Τ	B-I	THERMAL LC FATIGUE	
0.1	Т - Е	SZIATZ ERUZZEAA DNITALIIDZO	
Ο'Τ	B-T	PRESSURE STRESS	
τ.	I-A	CENTRIFUCAL STRESS	
504.3		*	YANE FAILURE

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	0.1	S-A	LOCK TANG NOT ENGAGED		
	0.1	S-A	DAMAGED THREAD		
	0°T	Т-Я	YTIJISATASMODNI JAMSEHT		:
	3.0			TU-NDATE ISOOI	
	ī.	I-A	MACT CLARAFT		
	τ.	I-A	ALL TARANT		
	τ.	I-A	HTONEATS JAIRETAM		
	τ.	. ⊥− A	CAOI FAEHS		
	7 *			ARUTOARY CAERHY	
	τ.	I-A	MATTRIAL JAINETAM		
	0.1	в-т	SEATS AUGAOT		
-	τ.	I-A	SSEALS FIISNEL		
	1.2			SHANK FRACTURE	
S66666					INDUCER/IMPELLER REFAINER
	0.001	B-2	JHTDNAATZ JAIRETAM		
	τ.	I-A	SPLINE SHEARING		
			(IED)	TINOD) - ARUIIAN DZIC	
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PART	MODE	MECHANISM	RATING	RFP	RELATIVE <u>RELIABILIT</u> Y
					.999370
IMPELLER	VANE FAILURE			224.2	
		CENTRIFUGAL STRESS	A-l	.1	
		PRESSURE STRESS	C-1	10.0	
		OSCILLATING PRESSURE STRESS	B-2	100.0	
		THERMAL LC FATIGUE	B-1	1.0	
		SHAFT DEFLECTION/RUB	C-1	10.0	
		CENTRIFUGAL GROWTH/RUB	A-l	.1	
		HOUSING DISTORTIONS/RUB	B-1	1.0	
		MATERIAL STRENGTH	B- 2	100.0	
		HIGH THRUST/RUB	B-1	1.0	
		DISC DEFLECTION/RUB	B-1	1.0	
	DISC FAILURE			101.3	
		CENTRIFUGAL STRESS	A-l	.1	•
		PRESSURE STRESS	A-1	.1	
		OSCILLATING PRESSURE STRESS	B-1	1.0	
		THERMAL STRESS	A-l	.1	
		MATERIAL STRENGTH	B-2	100.0	

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PART	MODE	MECHANISM	RATING	RELATI RFP RELIABI	VE LITY
	LABYRINTH RUB			203.3	
	· (FORE & AFT)			1.0	
		HOUSING DISTORTION	B-1	100.0	
		CONTAMINATION	B-2	100.0	
		CENTRIFUGAL DISTORTION	A-1	.1	
		TURBINE THRUST	B-1.	1.0	
		CRITICAL SPEED	B-1	1.0	
		PRESSURE DISTORTION	A –1.	.1	
		AXIAL VIBRATION (ND MODES)	A-1	.1	
		MATING FACE RETENTION	B-2	100.0	•
	SPLINE FAILURE			101.3	
		SPLINE SIZE	A-l	.1	
		SPLINE FORM	A-l	.1	
		HIGH TORQUE	A-l	.1	
		MATERIAL STRENGTH	A- 2	1.0	
		NOT FULLY ENGAGED	B-2	100.0	
PUMP BEARING				.9997	70
	FATIGUE			26.0	
		SHAFT FIT/INTERFERENCE	B-1	1.0	
		HOUSING FIT/INTERFERENCE	B-l	1.0	
<u>:</u>		SHAFT FIT/UNBALANCE	B-1	1.0	
		HOUSING FIT/LOOSE (CRIT SPD)	C-1	10.0	
		CRITICAL SPEED	C-1	10.0	
		MISALIGNMENT	A-2	1.0	

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	0.1	ια			
	0.1	8-1	HIGH THRUST		
	0.463			FATCUE	
299666°					TURBINE BEARING
	0°T	S-A	HTDNEATZ JAIRETAM		
	0.1	B-1	TIN TAARS		
	5.0			ARCE FRACTURE	
	0°T	S-A	YOAUGAGA TNAJOOD		
	0.001	₩ −₩	NOITANIMATNOD		
	100.0	1- 0	CAGE WEAR		
	0.1	B-I	CAGE STRENGTH		
	202.0		4	MECHANICAL	
	0.1	S-A	CLAMPING LOAD HIGH OR UNEVEN		
	0'τ	S-A	HTENERIAL MATERIAL		
				FATIGUE (CONTINUED)	
RELATIVE RELATIVE	RFP	DNITAR	MECHANISM	WODE	TAAT

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	HTONEATS LAIRETAM	S-A	٥•٢
	TIA ITAHS	B-I	0.1
RACE FRACTURE			5.0
	YOAUGHIA TMAIOOD	S-A	0.1
	CONTAMINATION	I-A	τ.
	CAGE WEAR	τ-α	0.001
	HTONARTE ADAD	B-I	0.1
MECHANICAL			102.1
	CLAMPING LOAD HIGH OR UNEVEN	B-2	0.001
	HTDNEATZ LAIFFIAM	S-A	0.1
	TIBINDIIASIM	S-A	0.1
	CRITICAL SPEED	T-D	0.01
	HOUSING FIT/LOOSE (CRIT SPD)	τ-α	0.001
FATIGUE (CONTINUED)			

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
TTIBBINE ROTOR			•		.999172
	DISC FAILURE			211.2	
		CENTRIFUGAL STRESS	A-1	.1	
		PRESSURE STRESS	A-1	.1	
		OSCILLATING PRESSURE STRESS	C-1	10.0	
		AXIAL VIBRATION	D-1	100.0	
		MATERIAL STRENGTH	A-2	1.0	
		STRESS CONCENTRATION	B-2	100.0	
	BLADE FAILURE			515.5	
		CENTRIFUGAL STRESS	A-1	.1	
		GAS BENDING STRESS	A-l	.1	
•		OSCILLATING GAS BENDING	B-l	1.0	
		AMPLIFIED OSC GAS BENDING	D-1	100.0	
		MATERIAL STRENGTH	A-2	1.0	
		RUB-BLADE CREEP	A-1	.1	
		RUB-DISC CREEP	A-l	.1	
		RUB-CENTRIFUGAL GROWTH	A-1	.1	

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0.001	3-2	OFFAUR YLTUF TON
0.1	S-A	HTONAATS JAIAATAM
τ.	I-A	CONFLING FORM
τ.	T-A	AUDAOT HOIH
τ.	I-A	CONFLING SIZE
£.101		COUPLING FAILURE
0.1	B-1	RUB-CHITICAL SPEED
0.001	3- 2	RUB-FOREIGN OBJECTS
0°T	1-a	TRUAHT HOIH-BUN
0.001	τ-α	NOITHOTZIC JAMAHHT-HUH
0.00T	τ-α	NOITAAAIV JAIXA-AUH
0.001	B-2	TIA TAAHZ-AUH
0.01	נ-ד	NOITHOTZIC DNIZUOH-AUH
0.1	B-1	NOITCALTANG TAARZ-AUR
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BLADE FAILURE (CONTINUED)

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	0°T	S-A	HTDNAATS JAIAATAM		
	0.1	B-I	TADI HAUSTREE		
	0.1	B-I	RETURNE		
	0.01	τ-ວ	NOITROTZIC DNIZUOH		• •
	10.01	C-T	AUDITAT OI LAMAEHT		
	<u>53.0</u>			NOZZI, FAILURE	
	0.1	B-I	FOLTS		
	0.001	B-2	SIAIR	,	
	0.01	E-A	METD DEFECTS		
	0.1	S-A	YTI20A04		
	112.0			LEAKAGE	
	0 . 1	S-A	ZNOITAIAAV ZZANYOIHT		
	0.01	E-A	MELD DEFECTS		
	τ.	L-A	OVERTEMPERATURE		
	τ.	I-A	OVERPRESSURE		
	0.1	S-A	HTDNEATR .IAIRETAM		
	12.2			TEAUE DNIEUOH	
£\$8666°		•			TURBINE MANIFOLD
RELIABILITY	RFP	RATING	METNAHDAM	WODE	TAAT

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		AVARE FORM (LOCAL DEFECTS)	V- 5	0°T	
		HTONARTS JAIRATAM	S-A	0.1	
		TARESURE LOAD	T-A	τ.	
		NOILHOLSIG ENISOCH	T-A	τ.	
	AANG FAILURE			5.2	
		SIJIOE	B-T	0.1	
		SIVES	B- 2	0.001	
		YTISOHOT	V- 5	0°T	
	TERKAGE			102.0	
		ENOITAINAY REANYDIHT	S-A	0.1	
· · ·		OVERPRESURE	I-A	τ.	
		TTONANTS IAIRATAM	S-A	0•τ	
	TEAUH DNIEUOH			5.1	
PURP HOUSING	•				•
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	0.1	S-A	LABYRINTH CLARRANCE		
	0.001	B-2	CARBON WEAR		
	0.001	B-2	COCKED BOTATING RING		
	0.1	S-A	BROKEN CARBON		
	0.001	B-2	COCKED CARBON	MOLI SENOX	
765666°	0.504				TURBINE SEAL
	0.001	B-2	SIAIS		
	0.1	S-A	POROSITY		
	<u>0.101</u>			LEAKAGE	
	0.1	S-A	BEARING INTERFERENCE		
	τ.	L-A	THREESURE OVER		
	τ.	I-A	TTERIAL ATTENDED A		
	1.2			TZAUE BUIZUOH	
868666*					BEARING HOUSING
RELATIVE RELABILITY	RFP	DNITAA	. MECHANISM	WODE	TAAT

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PART	MODE	MECHANISM	RATING	RFP	RELATIVE RELIABILITY
	HIGH TORQUE			<u>3.0</u>	
		LABYRINTH FIT	A- 2	1.0	
		PILOT CONCENTRICITY	A-2	1.0	
		THERMAL DISTORTION	B-1	1.0	
SHAFT					. 999693
	SHEAR FRACTURE			.2	
		HIGH TORQUE	A-1	.1	
		MATERIAL STRENGTH	A-1	.1	
	FATIGUE			<u>202.1</u>	
		MISALIGNMENT LOADS	B-2	100.0	
		STRESS CONCENTRATIONS	A-2	1.0	
		MATERIAL STRENGTH	A-1	.1	
		NEAR CRITICAL SPEED	B- 2	100.0	
		UNBALANCE	B-1	1.0	
	DAMAGING RUB			4.0	
		CRITICAL SPEED	B-1	1.0	
:	,	INSUFFICIENT CLEARANCE	A-2	1.0	•
		MISALIGNMENT	B-1	1.0	
		UNBALANCE	B-1	1.0	

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	0.001	B-2	NOT FULLY ENGAGED	
	τ.	I-A	MATERIAL STRENGTH	
	τ.	I-A	SPLINE FORM	
	τ.	I-A	HIGH TORQUE	
	τ.	L-A	BLINE STILLE	
	7°00T			AAAHZ ANLIYZ
RELATIVE RELABILITY	RFP	DNITAH	MECHANISM	WODE

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APPENDIX E

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SAMPLE ESTIMATE FOR BASE CASE FUEL TURBOPUMP SUBCOMPONENTS FROM LAMCO INDUSTRIES, INC.

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PERFECTO CAST - BEARING HOUSING, FUEL

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PICCO INDUSTRIES 1729 CHICO AVENUE SOUTH EL MONTE, CALIFORNIA 91733 (213) 283-7246

INVESTMENT CASTINGS FERROUS AND NON-FERROUS

## **QUOTATION**

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311

Aerojet General	QUOTE NO _ 12152
Sacramento, California	DATE 9/16/69

ATTENTION: Mr. A. C	G. Work,	Dept. 96-74,	Bldg. 20-25
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DATED: IN REPLY TO YOUR INQUIRY:

PART NO.:	1136900 (turbine manifold)
MATERIAL:	718
CONDITION:	Sol. Anneal
GRADE:	"NASA"
TOOLING:	\$15,000.00
DUCES	QUANTITY PRICE QUANTITY PRICE QUANTITY PRICE
PRICES:	<u>1 Pc. \$6,000.00 10 Pcs. \$2,000.00 40 Pcs. \$1,700.00</u>
DELIVERY	DIMENSIONAL SAMPLE 22 WEEKS AFTER RECEIPT OF ORDER. FIRST PRODUCTION RUN 14 WEEKS AFTER APPROVAL OF DIMENSIONAL SAMPLE. REPEAT ORDER 16 WEEKS AFTER RECEIPT OF ORDER.
SPECIAL CONDITIONS:	<ol> <li>THREE (3) COPIES OF PRINTS REQUIRED WITH ORDER.</li> <li>ONE HUNDRED DOLLAR (\$100.00) MINIMUM SHIPMENT</li> <li>Subject to review upon receipt of final drawings.</li> </ol>

TOOLING: NET AND DUE PRIOR TO PRODUCTION. CASTINGS: 12% 10 DAYS: NET 30 DAYS. F. O. B.: SOUTH EL MONTE, CALIFORNIA

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## APPENDIX F

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## SAMPLE ESTIMATE FOR BASE CASE FUEL TURBOPUMP SUBCOMPONENTS FROM PARAGON TOOL, DIE, AND ENGINEERING COMPANY

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COMPANY A.G.C. SAC		<u>\$</u>	CRAP ALLON	
PART NAME: HOUSING BEARING/PIN:		<u> </u>	O. PARTS	1
BACK PLATE	HOURS	RATE	COST	TOTAL
1 MATERIAL (ITEMIZE)				
347 CASTING				4
			······	
TOTAL MATERIAL				
2. LATHE OPERATIONS (ITEMIZE)	750	1195	89629	
JURN CASING COMPLETE	/3.0	1012	0125-	
3. MILLING OPERATIONS (ITEMIZE)				
DRILL & TAP ALL HOLES-				1
POPTS & SPECIAL MILLING	2350	11.95	280825	×
		<u>↓</u>		
1 HISC OPERATIONS (ITEMIZE)				
4. 115C. UPERATIONS (1121122)				
				•
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				-
5. ASSEMBLY				-
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	40.0	915	3660	3
	750	11=0	3955	
			446600	144.66.0
8. OUTSIDE PRODUCTION (ITEMIZE)			·	-
			+	
		1		-
		<u> </u>		-h *
TOTAL OUTSIDE PRODUCTION		<u> </u>	+	
9. PACKAGING		<u> </u>	ļ	-
10. TOOLING (ITEMIZE)	· · ·	ļ		-
LATHE FIXTURE		<u> </u>	750	5
MILL FIXTURE		+	10009	5 / 3
MISC. OOLS & FORIS				-  '
TOTAL TOOLING			2500 €	
11. ENGINEERING		-		
QUOTED PRICE: TOTAL TOOLING & EN	NGR:			1
3 DUDTED TOOLING: 2500,99			I PC-	4466.0
DELIVERY:				35000

·····	HOURS RATE COST TOTAL
1. MATERIAL (ITEMIZE)	
TOTAL MATERIAL	
2. LATHE OPERATIONS (ITEMIZE)	
TURN COMELETE	250 1195 29875
3. MILLING OPERATIONS (ITEMIZE)	
······································	
4. MISC. OPERATIONS (ITEMIZE)	
NRILL HOLES	- 29 1195 95.60
5. ASSEMBLY	
·	
	20915 1020
6. BENCH	2.9 1.13 10.20
	<u> </u>
IUTAL SHOP OPERATIONS	
8. OUTSIDE PRODUCTION (ITEMIZE)	
TOTAL OUTSIDE PRODUCTION	
9. PACKAGING	
10. TOOLING (ITEMIZE) NONE	
***************************************	
TOTAL TOOLING	
11. ENGINEERING	l
QUOTED PRICE: TOTAL TOOLING &	INGR :
QUOTED TOOLING: - 0 -	1 PC-469
DELIVERY:	10FC-368

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COMPANY H.S.C. ZAC		SUMP ALLON
PART NAME: P/N:		NO. PARTS
SPACER BLARING-UPPER	HOURS RATE	COST
1. MATERIAL (ITEMIZE)		
INCO - X	<b></b>	
IOTAL MATERIAL		
2. LATHE OPERATIONS (ITEMIZE)	10110	+ 4780
IVEN COMPLETE	4.0 1.1.	
3 MILLING OPERATIONS (ITEMIZE)		
	+	
	+	
4. MISC. OPERATIONS (TIEMIZE)		
5. ASSEMBLY		
6. BENCH		0 11 20
7. INSPECTION	1.0 11.2	
TOTAL SHOP OPERATIONS		21.10
8. OUTSIDE PRODUCTION (ITEMIZE)		
TOTAL OUTSIDE PRODUCTION		
9. PACKAGING		
10. TOOLING (TIEMIZE) - NONC		
II. ENGINEERING	<u> </u>	
QUUIED PRICE: IUTAL TOOLING & ENGN	<b>``</b>	
OUDTED TOOLING:		
DELIVERY:	t	321 10

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					10. TOOLING (ITEMIZE)
					9 PACKAGING
			<u></u>	NO	TOTAL OUTSIDE PRODUCT
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•				(I)	8. OUTSIDE PRODUCTION (ITEMI)
19.198	07198				TOTAL SHOP OPERATIONS
	55.60	0211	0.2		7. INSPECTION
	0281	315	50		6. BENCH
	-			<u></u>	Y. ASSEMBLY
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	NAPII	15.211	0.01	(=	3. MILLING OPERATIONS (ITEMIZ
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	02101	11321	0.21	3.1	CHINE OPERATIONS (1.9UT
			<b> </b>		
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					(ITEMIZE)
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COMPANY ACC		5	CRAP ALLON:	
PART_NAME: P/N:		<u> </u>	O. PARTS	
SPACER, BEARING LOWER	HOURS	RATE	COST	TOTAL
1. MATERIAL (ITEMIZE)				
100 - X				
TOTAL MATERIAL				
2. LATHE OPERATIONS (ITEMIZE)				
TURN COMPLETE	AC	11.05	47 80	
3. MILLING OPERATIONS (ITEMIZE)				
		+		
		ļ		
4. MISC. OPERATIONS (ITEMIZE)				
		+		
5. ASSEMBLY				
7 INSPECTION	LC	11.30	1130	
TOTAL SHOP OPERATIONS			59.10	50
QUITE DE PRODUCTION (ITEMIZE)				
TOTAL OUTSIDE PRODUCTION				•
9. PACKAGING		×		•
10. TOOLING (ITEMIZE)		4		
DUOTED PRICE: TOTAL TOOLING & ENG				
			1 Dr -	50
DELIVERY:				Λ
	PART NAME: PIN: SPRCER, BENPING LOWER 1. MATERIAL (ITEMIZE) 1. URD CONTRUCTORS (ITEMIZE) TURD CONTRUCTORS (ITEMIZE) 3. MILLING OPERATIONS (ITEMIZE) 4. MISC. OPERATIONS (ITEMIZE) 5. ASSEMBLY 6. BENCH 7. INSPECTION TOTAL SHOP OPERATIONS 8. OUTSIDE PRODUCTION (ITEMIZE) 5. ASSEMBLY 0. TOTAL SHOP OPERATIONS 10. TOOLING (ITEMIZE) 10. TOOLING (ITEMIZE) 10. TOOLING (ITEMIZE) 11. ENGINEERING QUOTED PRICE: TOTAL TOOLING & ENG OUTED TOOLING: - C -	PART NAME:       P/N:         PART NAME:       P/N:         PART NAME:       PIN:         PART NAME:       PIN:	PART NAME:     P/N:     N       DNCER, BENDIG LOWER     HOURS PATE       1. MATERIAL (ITEMIZE)     INCO-X       TOTAL MATERIAL     INCO-X       2. LATHE OPERATIONS (ITEMIZE)     INCO       TURU COMPRATIONS (ITEMIZE)     INCO       3. MILLING OPERATIONS (ITEMIZE)     INCO       4. MISC. OPERATIONS (ITEMIZE)     INCO       5. ASSEMBLY     INSPECTION       6. BENCH     INSPECTION       7. INSPECTION     INCO       8. OUTSIDE PRODUCTION (ITEMIZE)     INCO       7. INSPECTION     INCO       9. PACKAGING     INGE       10. TOOLING (ITEMIZE)     INCO       11. ENGINEERING     INTEMIZE)       11. ENGINEERING     INTEMIZE)	PART NAME:       P/N:       NO. PARTS         SPACE K, BEARING LOWER       HOURS RATE       COST         1. MATERIAL (ITEMIZE)       1000 - X       1000 - X         TOTAL MATERIAL       1000 - X       1000 - X         JURU COLLETE       4000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 10000 - 100000 - 100000 - 10000 - 100000 - 100000 - 10000 - 10000

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		RATE		11.95		11.95		5611	11.95		n n	1130											
Ø		HOURS		40.0		2.5.0		01	<b>0</b> 0 C.			305					7						
TOOLING & MISC. QUOTATION SHEET ITEN	COMPANY AGG - AC PART NAVE: P/N:	C.OUPLINCS TUREIUE 1. MATERIAL (ITEMIZE)	TOTAL MATERIAL	2. LATHE OPERATIONS (ITEMIZE) TURN COMPLETE		3. MILLING OPERATIONS (ITEMIZE)		4. MISC. OPERATIONS (ITEMIZE) DRILL (5 40LES - ETC	GRINDING ID & OD.	5. ASSEMBLY		6. BENCH 7. INSPECTION	TOTAL SHOP OPERATIONS	8. OUTSIDE PRODUCTION (ITEMIZE)		TOTAL OUTSIDE PRODUCTION	9. PACKAGING	10. TOOLING (ITEMIZE)		TOTAL TOOLING	11. ENGINEERING MOTED PRICE	COLOTED TOOLING: - 0	324 BEN
4 6 ^{11 - 5}		•				. • -									•						•	· · ·	

COMPANY MUSIC		SCRAP ALLO
PART NAME: P/N:		NO. PARTS
DOET, SAATT COULTNE	HOURS RAT	ECOST
1. MATERIAL (ITEMIZE)		
TOTAL HATERIAL		
2. LATHE OPERATIONS (ITEMIZE)		
TURN COMPLETE	200 11	05 239.00
****		
3. MILLING OPERATIONS (ITEMIZE)		00 0010
MISC. MILLING	<u> </u>	45 45.60
4. MISC. OPERATIONS (ITEMIZE)		
RIND	5.011	95 59.75
5. ASSEMBLY		
6. BENCH	1.27	15 9.15
7. INSPECTION	12011	30 22.60
TOTAL SHOP OPERATIONS		426.10
8. OUTSIDE PRODUCTION (ITEMIZE)		
SPLINE		35.00
TOTAL OUTSIDE PRODUCTION		
9. PACKAGING		
10. TOOLING (ITEMIZE)		
e en		
TOTAL TOOLING		
11. ENGINEERING		
QUOTED PRICE: TOTAL TOOLING &	ENGR:	
QUOTED TOOLING:		1 PC -
DELIVERY:		IOPC-
	325	

CAPANY AGC	SAC.		S	CRAP ALLON:	
ART NAME:	P/N:		N	O. PARTS	1
NUT CO	IFLING	HOURS	RATE	COST	TOTAL
MATERIAL (ITEMIZE)					
A-	2.96				
TOTAL MATERIAL					
LATHE OPERATIONS (	TEMIZE)		1195	1700	
TURN COM	PLEID	A 2	11.12		
	میند. با با با این ماند و بین با				
	· · · · · · · · · · · · · · · · · · · ·				
. MILLING OPERATIONS	(ITEMIZE)				
MILL SL	075	2.5	11.95	23.90	
HATCO OPERATIONS (	ITEMIZE)				
r, hist, or liverious (					
	****		<u> </u>		
					. •
5. ASSEMBLY					
S. BENCH	a an	.5	9.15	4.57	
INSPECTION	,	1.0	11.30	11.30	
TOTAL SHOP OPE	RATIONS			87.57	87.5
S. OUTSIDE PRODUCTION					
······································					
·					,
TOTAL OUTSIDE			1		
TOJAL OUTSIDE	RODUCTION				
9. PACKAGING					
10. TOOLING (ITEMPZE)				+	
· · · · · · · · · · · · · · · · · · ·					
		å	<u> </u>		
5 				+	
TOTAL TOULING	релерия адартного на округа и на остава.		+		
DINTED PRICE	TOTAL TOOLING	S ENGR:	- <b></b>		
				1.00	- 875
DUUTED TOOLING:				11-	101
JELIVERT:		ı j	*	1040	- 60.0

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THE 10. ME: 10	- 240 -	4 0 Pc -
RATE 0 11.25 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		327
		-
TOQLING & MISC. QUOTATION SHEET ITEM COMBANY A GOC SAC PART NAVE: PANE L. A. B. V. (K. I. N. T. H., E. H. N. F. T. L. A. B. V. (K. I. N. T. H., E. H. N. F. T. 1. MATERIAL (ITEMIZE) 1. MATERIAL (ITEMIZE) 2. LATHE OPERATIONS (ITEMIZE) 3. MILLING OPERATIONS (ITEMIZE) 3. MILLING OPERATIONS (ITEMIZE) 3. MILLING OPERATIONS (ITEMIZE) 4. MISC. OPERATIONS (ITEMIZE) 4. MISC. OPERATIONS (ITEMIZE) 5. ASSEMBLY 6. BENCH 7. INSPECTION 1074L SHOP OPERATIONS 1074L SHOP OPERATIONS	8. OUTSIDE PRODUCTION (ITEMIZE) TOTAL OUTSIDE PRODUCTION 9. PACKAGING 10. TOOLING (ITEMIZE) 10. TOOLING (ITEMIZE) 10. TOOLING (ITEMIZE) 11. ENGINEERING 11. ENGINEERING 11. ENGINEERING DELIVERY: DELIVERY:	
	VIARKS	REA

والأحاج الأحاج والمحاج والأحمار بالمحتر بالمحتر والمعومية المناحيات والمحاج والمحاج والمحاج والمحتر والمحتر والمحتر والمحتر
CHPANY H.G.C.	D/NI		<u>50</u>	NAP ALLON:	
CARRIER REA	RING UPPER				
		HOURS	RATE	COST	TOTAL
MATERIAL (ITEMIZE)	- X				
///					-
TOTAL MATERIAL					
LATHE OPERATIONS (1)	EMIZE)				
TURN COM	PLETE	5.2	11.95	59.75	
	TTENT 7E)			1	
. FILLING UPERATIONS (					
	TEMI 7E)				
COULD		3.0	11.95	35.85	
				······	
5. ASSEMBLY					
5. BENCH		.5	9.15	4.57	
7. INSPECTION		20	11.30	22.60	
TOTAL SHOP OPER	TIONS			122.77	122.77
A OUTSIDE PRODUCTION	(ITEMIZE)				
S. OJIJIDE I KODOCIION					
				····	
TOTAL OUTSIDE P	RODUCTION			×.	
Y. FAURAGING			1		
TAT TOPETHA (TIPHTAE)					
			<u> </u>		
TOTAL TOOLING					
11. ENGINEERING					
QUOTED PRICE:	TOTAL TOOLING &	ENGR:			
DUOTED TOOLING:		1 I		IPC-	-122.77
DELIVERY.	- <del>1</del>			ID DC -	-96.00

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COMPANY / GC. SAC			SCRAP ALLO
PART NAME: P/N:		1	D. PARTS
CARRIER, BEARING LO	WER HOURS	RATE	COST
1. MATERIAL (ITEMIZE)		<u> </u>	
		<u></u>	
ΤΟΤΑΙ ΜΑΤΕΡΙΑΙ		<u> </u>	
		+	
TUPIL COLORIETE		1,105	50 75
			- <u>51-1</u> 5
·		<b></b>	
3. MILLING OPERATIONS (ITEMIZE)			
		<u></u>	
		+	
		<u> </u>	
GPILICY	50	1100	1200
		11.7.2	<u> </u>
5. ASSEMBLY		L	
-	·····	0.5	1 - 7
6. BENCH	5	415	4.51
7. INSPECTION		11.30	27.60
TOTAL SHOP OPERATIONS			110.82
8. OUTSIDE PRODUCTION (ITEMIZE)			
TOTAL OUTSIDE PRODUCTION			
10. TOOLING (ITEMIZE)			
TOTAL TOOLING	-		
OUDTED PRICE:	OLING & ENGD.	I	
			<u> </u>
DELIVERY			IPC-
DELIVERT		1	IMPC
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**REMARKS** 

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		»، ۲۷	RAP ALLONI	
DADT NAME P/N:		<u></u>	). PARTS	(
SPACER, BENTING FRANKING		DATE	COST	
	HUUKS	M16		
INCO-X				
ΤΩΤΑΙ ΑΔΤΕΡΙΔΙ				
TURN COMPLETE	<u> </u>	11.95	35.85	
				•
3. MILLING OPERATIONS (ITEMIZE)				
		+	· · ·	
4. MISC. OPERATIONS (TEMIZE)		11.25	23.70	
		·		
		++		
5. ASSEMBLY		<u>+</u>		
6. BENCH				
7. INSPECTION	1.0	11 20	11.30	
TOTAL SHOP OPERATIONS			71.00	-7
8. OUTSIDE PRODUCTION (ITENIZE)				
			-	
TOTAL OUTSIDE PRODUCTION		+		
9. PACKAGING				
10. TOOLING (ITEMIZE)				
		+		
		+		
TOTAL TOOLING		+		
11. ENGINEERIG	ENCD .	<u></u>		
QUOTED PRICE: TOTAL TOOLING &			1.8.0	-7
I OUDTED TOOLING:			IPC	1

<u>.</u>

•

COMPANY AGC. SAC.		S	CRAP ALLON:	
PART NAME: P/N:		N	O. PARTS	
LABYRINTH, COUPLING	HOURS	RATE	COST	TOT
1. MATERIAL (ITEMIZE)				
PIDS. PROUZE				
TOTAL MATERIAL				
2. LATHE OPERATIONS (ITEMIZE)				
TUEN COMPLETE	60	11.95	71.70	
3. MILLING OPERATIONS (ITEMIZE)				
4. MISC. OPERATIONS (ITEMIZE)				
DRILL 12 HOLLS	E.O	11.95	59.75	
<u> 111195</u>		1195	22.90	
Server				
5. ASSEMBLY				
		915	457	
0. BENCH 7 INSPECTION	$\frac{1}{10}$	11.30	1.30	
TOTAL SHOP OPERATIONS			171.22	1-
5. OUTSIDE FRODUCTION (THEMZE)		·		
			-	
TOTAL OUTSIDE PRODUCTION				
9. PACKAGING				
10. TOOLING (ITEMIZE)				
TCTAL TOOLING				
11. ENGINEERING	ENCD .	I		
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то	DLING & MISC. QUOTATION SHEET		/	D	ATE: 10	-13-6
<u></u>	IPANY A.G.C. SAC.			S	CRAP ALLON:	
PA	RT NAME:	P/N:		N	O. PARTS	
· · · · · · · · · · · · · · · · · · ·	- Na - / TOK BIDE	OUPLING	HOURS	RATE	COST	TOTAL
_1_	MATERIAL (ITEMIZE)					
	A-266					
	TOTAL MATERIAL					
2	ATHE OPERATIONS (ITEMIZE)					
<u></u>	TULU COMPLETE		12.0	1195	143.40	
3						
3.	MILLING OPERATIONS (ITEMIZE)			1100	F0 70	
	MISC. MILLING		5.0	1.45		
4.	MISC. OPERATIONS (ITEMIZE)					
	OPILE 12 HOLDS.		50	105	5975	
			-> /	Luce	25.95	
	- FIND		<u></u>	1.1.2		.,
6.	BENCH		1 1.2	9.15	9.15	
7.	INSPECTION		()	11.30	33.90	
	TOTAL SHOP OPERATIONS				341.80	341.80
9	OUTSIDE PRODUCTION (ITEMIZE)		ļ			
-					·	2
·	TOTAL OUTSIDE PRODUCTION					
	TOTAL COTSIDE PRODUCTION					
9.	PACKAGING					
10	. TOOLING (ITEMIZE)		<u> </u>			
			+	+		
	· · · · · · · · · · · · · · · · · · ·	· · ·				*
	TOTAL TOOLING	<u></u>				
11	. ENGINEERING		<u> </u>	J		
Śr	OTED PRICE: TOTA	AL TOOLING & ENGR:				7 11 1
SXI of	OTED TOOLING: - O'				IVC -	- 541.80
NAN DE	LIVERY:	I		333	101c -	-268.0
KE1				· .	4040-	-241.6

MPANY A COC SAC P/N		No.	PARIS	1
BLADES 2D X 3D	DEPTH	· · · · · · · · · · · · · · · · · · ·	MIN	PASS
ITER SIZE MACHINED BLADES	FIR TREE			
ARKS	HOURS	RATE	COST	ATOTA
MATERIAL (Itemize)				
INCO- 718				
TOTAL MATERIA!		 		• • • • • • • • • • • • • • •
LATHE CREATIONS (Itemize)				
-TUPN COMP. ROUGHAFINISI	60.0	11.95	717.00	i <del>1</del>
				-
			<b>ha</b> . <b>a</b> aaaa i	• • • •
PANTOGRAPH	125.0	915	1143.75	•
CUTTERS	0.0	915	91.50	
MILLING OTHER THAN PANTOGRAPH (Hemize)				
MILL TOUGUES A SLOTS	25.0	11.95	298.75	
				ļ
VISCELLANEOUS OPERATIONS (Itemica)				
DOLL HOLES		1100	12210	
DRILL ROLLS	<u>1 4 1 0</u> _	11.12		
	•			
NENCH	60.0	9.15	549.00	
	· 15.0	11.30	16950	0110.00
TOTAL SHOP OF RATIONS			311240	3112.40
JUISIDE PRODUCTION (Ifemize)				
· · · · · · · · · · · · · · · · · · ·				
_				1   }
TOTAL OUTSIDE IROD.				
PACKAGING	•			
TOOLING (litemize)				
20 HASTER	·		5509	
HOUDING ENTURE	il		500 ≌	
	-			· · ·
TOTAL TOOLING			10509	<b>b</b>
ENGINEERING				
OTED CRUCE DEL NON				
TED TOOLING LOSO OP		Ţ		
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	DEDTU		YTTEL T	DACC
NO. BLADES ZD 3D CUTTER SIZE MACHINED BLADES	FIR TREE	DATE	COCT I	
ANATERIAL (Asoraiza)	HOUKS	NAIL	4031	
$\frac{1000-7/8}{1000}$				
τοται Δάτερια:			<b> </b>	
LATHE CERATIONS (Item zg)				
TUPN COMP. ROUGH IT INIS H	Later CA	1195	717.00	
				-
			<b> </b> -+	
B. PANTOGRAPH	1325	19:15	1235.25	
5. MILLING OTHER THAN PANTOGRAPH (Lemize)	100	-475	1-71-24	
MILL TONGUESASLOIS	250	11.95	29875	
	+		╉ ┥	
6. MISCELLANEOUS OPERATIONS (Itemize)	1			
DRILL HOLES	12.0	11.95	43.40	
			<b> </b>	
	7 60		FORIO	
S. INSPECTION	15.0	1120	169.50	
TOTAL SHOP OPERATION	9		3251.99	325
2. OUTSIDE PRODUCTION (Itemize)				
TOTAL OUTSIDE MOD.	+		+	
1J. PACKAGING				
11. TOOLING (Itemize)				
ZD MASTER	· · · · ·		1 5 00 er	
<u>IIVLLING FILLVKL</u>				<b>1</b> . ■
		ļ		
TOTAL TOOLINIG		<b>  </b>	1050	
12. ENGINEERING		·······		
QUOTED PRICE DELIVERY:				
QUCTED TUOLING 1050 2	4		́р Д	
*		<u> </u>		

OZ FFNJL	I	67-2-01
TOOLING & MISC. QUOTATION SHEET	DATE: . SCRAP	ALDN:
PART NAME: P/N:	NO. PI	ars <b>b</b>
BOLT, TUREIDE FOTOR HOU	S RATE COS	ET TOTAL
1. MATERIAL (ITEMIZE)		
JOTAL AATERIAL		
2. LATHE OPERATIONS (ITEMIZE) TURU COUPLETE (GPCS) 15.	1158110	3.25
3. MILLING OPERATIONS (ITEMIZE)	0 1.95	1 30
4. HISC. OPERATIONS (ITEMIZE)		
		<b>#</b>
5. ASSE4BLY		
6. BENCH 7. INSPECTION	1. OEII (	021
TOTAL SHOP OPERATIONS	23	<u>8.35 238.35</u>
8. OUTSIDE PRODUCTION (ITEMIZE) THPEED SPIND 25 Et 6		op 7
TOTAL OUTSIDE PRODUCTION		1260
9. PACKAGING		
TOTAL TOOLING		
QUOTED PRICE: TOTAL TOOLING & ENGR:		
OUOTED TOOLING: - O D DELIVERY: 336	- 0 4	Pc- 250.35 Pc-198.00
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21	JTTER SIZE MACHINED BLADES	FIR TREE		17576 V	· /~~ · ·
RE	MARKS	HOURS	RATE	COST	TOT
jT.	MATERIAL (Itemize)		1		
İ	<u>- INCO - 718</u>		L		
	·*				
	TOTAL MATERIA!				t t
2	LATHE CERATIONS (100 70)		<b>*</b>		
	TUPILERIOUS	200	1195	23900	
	TURN STROP		1102	11950	
	TURN COMPLETE MART BOR	25.0	11.95	298.75	
					T
3			0.5	01250	·
4	CUTTERC		JUS U.E	7200	
5.	MILLING OTHER THAN PANTOGRAPH (Isomiz		-7.10	15,4	
	MISC. MILLING	12.0	11.95	4340	
1					
6.	MISCELLANEOUS OPERATIONS (Itemise)				
	DRILL ALL HOLDS	25.0	Mas	298.75	
l					
	DEEURRANILIN FILL ASCV	4/1	aic-	2170	
7	BENCH	50.0	915	457.50	<u>├</u> - <u>-</u>
3.	INSPECTION	120	11.30	135.60	
	TOTAL SHOP OPERAT	ONS		262580	26258
2.	OUTSIDE PRODUCTION (Itemize)				
	BRAZING	650			
		<u>_</u>			
	TOTAL OUTSIDE /ROL	·		125.00	12.5
13	. PAJKAGING				
<b>   </b> 	20 NERTER	· · · · ·		Finas	i
	HOLDING WINNEY ENTIRE			50000	
1		·			
	TOTAL TOMINIO				
12	ENGINEERING			1050	
CI	JOTED TOOLING INFO PO	.т:			
<b>—</b>					
 				100-	27506
ļ		<b>*</b>	337	OPC-	2170.0

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TOOLING & MISC. QUOTATION SHEET	DATE:	10-23-69
COMPANY A G.C. C.A.C. DIN: DADT MANE:	SCRAP AL	TS /
RING ORFICE, LOW PRESSUPE	HOURS RATE COST.	TOTAL
1. MATERIAL (ITEMIZE) INCO · 7/8		
TOTAL AATERIAL		
2. LATHE OPERATIONS (ITEMIZE) TURN COMPLETE	8.0 195 95.	0.4
3. MILLING OPERATIONS (ITEMIZE) MISS MULLING	15.0 1195 179	9
4. MISC. OPERATIONS (ITEMIZE)		
5. ASSEMBLY		
6. BENCH 7 INSPECTION	3.0 9.15 18.	000
TOTAL SHOP OPERATIONS	327	05 327.05
8. OUTSIDE PRODUCTION (ITE/11ZE)		
TOTAL OUTSIDE PRODUCTION		
9. PACKAGING		
10. TOOLING (ITEMIZE)		
TOTAL TOOLING		
11. ENGINEERING OUDTED PRICE: TOTAL TOOLING & ENGR		
g ouoted tooling: - D'	100	c - 327.05
DELIVERY:		
338 EEM	40Pc	h: -707

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*.	TOOLING & MISC. QUOTATION SHEET	3	ח	ATE: 10-	23.69
	-COMPANY A.G.C. SAC		S	CRAP ALLON:	
	PART NAME: P/N:		N	O. PARTS	
	NUT, RING DEFICE LOW FRESSORE	HOURS	PATE	COST	ΤΟΤΔΙ
	1 MATERIAL (ITEMIZE)			V!	
	TOTAL MATERIAL				
	2. LATHE OPERATIONS (ITEMIZE)		1105	112.50	
	TUEN COMPLETE	100	11.42	<u> </u>	
	3. MILLING OPERATIONS (ITEMIZE)				
	MISS. L'ILLING	15.0	11.95	179.25	
	4. MISC. OPERATIONS (TEMIZE)				
					· •
	5. ASSE4BLY				
	······································	·			
		20	air	1020	
		2.0	115	2200	
	TOTAL SHOP OPERATIONS	12.0	1130	25005	-25.005
· · · ·	TOTAL SHOP OPERATIONS				
	8. OUTSIDE PRODUCTION (ITE/IIZE)				
•					· · · · ·
	TOTAL OUTSIDE PRODUCTION	*			
	9. PACKAGING	,			
	10. TOOLING (ITEMIZE)				
	TOTAL TOOLING	•			
	11. ENGINEERING				
•	QUOTED PRICE: TOTAL TOOLING & ENGR:				
KS	OUDTED TOOLING:			IPC-	-350.95
TAR	DELIVERY:	ŕ	339	10PC-	-285.00
KEN				A DVC-	-249.00
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	SCRAP ALLON SCRAP ALLON NO. PARTS BOURSS RATE COST 150 11.95 95.40 2.0 91/5 199.25 3.0 11.30 327.05 327.05 327.05 327.05	TOTAL TOOLING       11. ENGINEERING       QUOTED PRICE:       QUOTED TOOLING:       OUOTED TOOLING:       DELIVERY:	TOTAL OUTSIDE PRODUCTION 9. PACKAGINS 10. TOOLING (ITEMIZE)	6. BENCH 7. INSPECTION TOTAL SHOP OPERATIONS 8. OUTSIDE PRODUCTION (ITEMIZE)	4. MISC. OPERATIONS (ITEMIZE) 5. ASSEMBLY	TOTAL MATERIAL	COMPANY A.C.C. SAC. PART NAME: PART NAME: PART NAME: PART NAME: PART PARTICE - HIGH PRESSURE 1. MATERIAL (ITEMIZE) 1. MATERIAL (ITEMIZE)
	SCRAP ALLO       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95       95 <td></td> <td>•</td> <td>×.0 .0 .0 .0 .0 .0 .0 .0 .0 .0</td> <td></td> <td></td> <td>HOURS</td>		•	×.0 .0 .0 .0 .0 .0 .0 .0 .0 .0			HOURS

PART NAME:     P/N:     NO. PARTS       NUT, RUNG ORFICE INGH PRESUMENTAL     INCO-72/8     INURSING     INCO-72/8       INATERIAL (ITEMIZE)     INCO-72/8     INCO-72/8     INCO-72/8       INTERIAL (ITEMIZE)     INCO-72/8     INCO-72/8     INCO-72/8       INSECTION     INSECTION     INCO-72/8     INCO-72/8       INSECTION     INSECTION     INCO-72/8     INCO-72/8       INSECTION     INCO-72/8     INCO-72/8     INCO-72/8       INSECTION     INCO-72/8     INCO-72/8     INCO-72/8       INSECTION     INCO-72/8     INCO-72/8     INCO-72/8       INSECTI	LUPANI IS S		<u>S</u>	CRAP ALLON:	, È
NOT, FUSC ORFECTION PRESIDENCES RATE       COST         1. MATERIAL (ITENIZE)       10 C 1195 119.50         TOTAL MATERIAL       10 C 1195 119.50         3. MILLING OPERATIONS (ITEMIZE)       10 C 1195 119.50         4. MISC. OPERATIONS (ITEMIZE)       10 C 1195 119.50         4. MISC. OPERATIONS (ITEMIZE)       10 C 1195 119.50         5. ASSEMBLY       10 C 1195 119.50         6. BENCH       2.0 9.15 18.30         7. INSPECTION       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       350.95         9. PACKAGINS       110 C 119.5 18.30         7. INSPECTION       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       350.95         9. PACKAGINS       10 C 119.5 18.30         10. TOTAL OUTSIDE PRODUCTION       -         7. INSPECTION       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       350.95         9. PACKAGINS       -         10. TOTAL OUTSIDE PRODUCTION       -         11. ENGINEERING       - <th>PART NAME: P/N</th> <th>11 Diffunction in the</th> <th>N</th> <th>D. PARTS</th> <th></th>	PART NAME: P/N	11 Diffunction in the	N	D. PARTS	
1. MATERIAL (ITEMIZE)       1         INCO - 7/8       1         TOTAL MATERIAL       1         2. LATHE OPERATIONS (ITEMIZE)       10 C 1195 119.50         TUP-N C & MPLETE       15 C 1195 119.50         3. MILLING OPERATIONS (ITEMIZE)       15 C 11.95 119.50         MIS.C M PLETE       15 C 11.95 119.50         4. MISC. OPERATIONS (ITEMIZE)       15 C 11.95 179.25         5. ASSEMBLY       15 C 11.95 18.30         6. BENCH       2.0 9.15 18.30         7. INSPECTION       2 C 11.30 33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       1         7. TOTAL OUTSIDE PRODUCTION       1         9. PACKAGING       10. TOOLING (ITEMIZE)         10. TOOLING (ITEMIZE)       1         11. ENGINEERING       1 <th>NUL KING ORFICE HIG</th> <th>THOUR</th> <th>S RATE</th> <th>COST</th> <th>TOTA</th>	NUL KING ORFICE HIG	THOUR	S RATE	COST	TOTA
INCOL         INCOL           TOTAL MATERIAL	1. MATERIAL (ITEMIZE)				
TOTAL MATERIAL         Image: Constraint of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the sta	NCG//B				
2. LATHE OPERATIONS (ITEMIZE)       10 C 1 195 119.50         TUPAL COMPLETE       10 C 1 195 119.50         3. MILLING OPERATIONS (ITEMIZE)       150 11.95 179.25         MISC MULLINGS       150 11.95 179.25         4. MISC. OPERATIONS (ITEMIZE)       150 11.95 179.25         5. ASSERVELY       150 11.95 18.30         6. BENCH       2.0 9.15 18.30         7. INSPECTION       2.0 11.30 23.90         TOTAL SHOP OPERATIONS       350.95         3. OUTSIDE PRODUCTION (ITEMIZE)       10 11.30 23.90         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       10 11.30 23.90         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       10 11.30 23.90         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       10 11.30 23.90         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       10 11.30 23.90         TOTAL OUTSIDE PRODUCTION       10 11.30 23.90         TOTAL OUTSIDE PRODUCTION       11 1.30 11.30         10. TOOLING (ITEMIZE)       10 11.30         11. ENGINEERING       11 1.30         11. ENGINEERING       11.30 11.30         11. ENGINEERING       11.00         11. ENGINEERING       11.00         11. ENGINEERING       11.00         11. ENGINEERING       11.00	TOTAL MATERIAL				
TUPN       COMPLETE       10 C 1195 119.50         3. MILLING OPERATIONS (ITEMIZE)       15C 11.95 179.25         MISC       MILLING       15C 11.95 179.25         4. MISC. OPERATIONS (ITEMIZE)       15C 11.95 179.25         5. ASSE/BLY       15C 11.95 18.30         6. BENCH       2.0 9.15 18.30         7. INSPECTION       3.0 11.30 33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITE/12E)       1000000000000000000000000000000000000	2. LATHE OPERATIONS (ITEMIZE)				
3. MILLING OPERATIONS (ITEMIZE)         MISC MILLINGS         MISC MILLINGS         HISC MILLINGS         ISC ILQS ITTRES         4. MISC. OPERATIONS (ITEMIZE)         5. ASSEMBLY         5. ASSEMBLY         5. ASSEMBLY         5. ASSEMBLY         6. BENCH         7. INSPECTION         8. OUTSIDE PRODUCTION (ITEMIZE)         10. TOOLING (ITEMIZE)         10. TOOLING (ITEMIZE)         11. ENGINEERING	TUPN COMPLETE	10	<u>c 1195</u>	119.50	
3. MILLING OPERATIONS (ITEMIZE)       130 1195 179.25         MISC MILLING       130 1195 179.25         4. MISC. OPERATIONS (ITEMIZE)       130 1195 179.25         5. ASSE/BLY       130 1195 179.25         6. BENCH       2.0 9.15 18.30         7. INSPECTION       32.0 11.30 33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITE/IZE)       11.30 33.90         TOTAL SHOP OPERATIONS       350.95         9. PACKAGING       10.100 (ITE/IZE)         10. TOOLING (ITE/IZE)       10.100 (ITE/IZE)         TOTAL TOOLING       10.100 (ITE/IZE)         TOTAL TOOLING       10.100 (ITE/IZE)         11. ENGINEERING       10.100 (ITE/IZE)					
3. MILLING OPERATIONS (ITEMIZE)       150 11.95 179.25         MISC       MILLINGS       150 11.95 179.25         4. MISC. OPERATIONS (ITEMIZE)       150 11.95 179.25         5. ASSEMBLY       150 11.95 18.30         6. BENCH       2.0 9.15 18.30         7. INSPECTION       3.0 11.30 33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       11.20 33.90         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       10.700LING (ITEMIZE)         10. TOOLING       10.700LING         11. ENGINEERING       10.700LING	••••••••••••••••••••••••••••••••••••••				
3. MILLING OFERATIONS (TEMIZE)       150 11.95 179.25         MISC. MILLINGS       150 11.95 179.25         4. MISC. OPERATIONS (ITEMIZE)       1         5. ASSEMBLY       1         6. BENCH       2.0 9.15 18.30         7. INSPECTION       3.0 11.30 33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       1         9. PACKAGING       1         10. TOOLING (ITEMIZE)       1         11. ENGINEERING       1         9. UTELLING       1         11. ENGINEERING       1					
4. MISC. OPERATIONS (ITEMIZE)         5. ASSEMBLY         6. BENCH         7. INSPECTION         8. OUTSIDE PRODUCTION (ITEMIZE)         9. PACKAGING         10. TOOLING (ITEMIZE)         11. ENGINEERING         YOTAL TOOLING         11. ENGINEERING         QUOTED PRICE:         TOTAL TOOLING:         10. TOOLING:	3. MILLING OPERATIONS (TEMIZE)		11105	179.75	
4. MISC. OPERATIONS (ITEMIZE) 5. ASSEMBLY 6. BENCH 7. INSPECTION TOTAL SHOP OPERATIONS 8. OUTSIDE PRODUCTION (ITEMIZE) 7. INSPECTION TOTAL SHOP OPERATIONS 8. OUTSIDE PRODUCTION (ITEMIZE) 7. TOTAL OUTSIDE PRODUCTION 9. PACKAGING 10. TOOLING (ITEMIZE) 10. TOOLING (ITEMIZE) 11. ENGINEERING QUOTED PRICE: TOTAL TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. TOOLING: 10. T					
4. MISC. OPERATIONS (ITEMIZE) 4. MISC. OPERATIONS (ITEMIZE) 5. ASSEMBLY 5. ASSEMBLY 6. BENCH 7. INSPECTION 7. INSPECTION 7. INSPECTION 7. INSPECTION 7. OUTSIDE PRODUCTION 7. INSPECTION 7. TOTAL OUTSIDE PRODUCTION 7. TOTAL TOOLING 7. TOTAL TOOLING 7. TOTAL TOOLING & ENGR: 7. OUTSIDE PRODUCTION 7. TOTAL TOOLING & ENGR: 7. OUTSIDE PRODUCTION 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR: 7. TOTAL TOOLING & ENGR & ENGR & ENGR & ENGR & ENGR & ENGR & ENGR & EN					
4. MISC. OPERATIONS (ITEMIZE)         5. ASSE48LY         6. BENCH         7. INSPECTION         7. OUTSIDE PRODUCTION (ITEMIZE)         8. OUTSIDE PRODUCTION (ITEMIZE)         7. TOTAL OUTSIDE PRODUCTION         9. PACKAGING         10. TOOLING (ITEMIZE)         7. TOTAL TOOLING         11. ENGINEERING         11. ENGINEERING         QUOTED PRICE:         TOTAL TOOLING:         7. O'-					
5. ASSEMBLY         6. BENCH       2.0 9.15 18.30         7. INSPECTION       3.0 11.30 33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITENIZE)       350.95         9. PACKAGING       11.20         10. TOOLING (ITEMIZE)       11.20         TOTAL TOOLING       11.20         11. ENGINEERING       10. TOOLING (ITEMIZE)         11. ENGINEERING       10. TOOLING (ITEMIZE)	4. MISC. OPERATIONS (ITEMIZE)			·	
5. ASSE4BLY       2.0       9.15       18.30         6. BENCH       2.0       9.15       18.30         7. INSPECTION       3.0       1.30       33.90         TOTAL SHOP OPERATIONS       350.95       350.95         8. OUTSIDE PRODUCTION (1TE/11ZE)       350.95       350.95         9. PACKAGING       350.95       350.95         10. TOOLING (ITE/11ZE)       350.95       350.95         11. ENGINEERING       350.95       350.95         9. VOTED PRICE:       107AL TOOLING & ENGR:       350.95         10. TOOLING       10.70       10.70         11. ENGINEERING       350.95       350.95         11. ENGINEERING       350.95       350.95         11. ENGINEERING       350.95       350.95         11. ENGINEERING       350.95       350.95         31. ENGINEERING       350.95       350.95	****				
5. ASSE/BLY       2.0       9.15       18.30         6. BENCH       2.0       9.15       18.30         7. INSPECTION       3.0       11.30       33.90         TOTAL SHOP OPERATIONS       350.95       350.95         8. OUTSIDE PRODUCTION (ITE/IZE)       350.95         9. PACKAGING       350.95       350.95         10. TOOLING (ITEMIZE)       350.95       350.95         11. ENGINEERING       350.95       350.95         9. VOTED PRICE:       10.100LING & ENGR:       350.95         11. ENGINEERING       350.95       350.95         9. UOTED TOOLING:       70.70       10.70		· · · · · · · · · · · · · · · · · · ·			
5. ASSEMBLY       2.0       9.15       18.30         6. BENCH       2.0       9.15       18.30         7. INSPECTION       3.0       1.30       33.90         TOTAL SHOP OPERATIONS       350.95       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       350.95         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       350.95         9. PACKAGING       350.95         10. TOOLING (ITEMIZE)       350.95         TOTAL TOOLING       350.95         11. ENGINEERING       350.95         QUOTED PRICE:       TOTAL TOOLING & ENGR:         0UOTED TOOLING:       70.70					
6. BENCH       2.0       9.15       18.30         7. INSPECTION       3.0       11.30       33.90         TOTAL SHOP OPERATIONS       350.95         8. OUTSIDE PRODUCTION (ITERIZE)       350.95         TOTAL OUTSIDE PRODUCTION       -         9. PACKAGING       -         10. TOOLING (ITEMIZE)       -         TOTAL TOOLING       -         11. ENGINEERING       -         9. UOTED PRICE:       -         TOTAL TOOLING       -         12. TOTAL TOOLING       -         13. ENGINEERING       -         9. OUTED TOOLING:       -         10. TOOLING       -         11. ENGINEERING       -         12. TOTAL TOOLING:       -         13. ENGINEERING       -         14. ENGINEERING       -         15. TOTAL TOOLING:       -         16. TOTAL TOOLING:       -         17. ENGINEERING       -         18. ENGR:       -         19. C = 3       -	5. ASSEMBLY				
6. BENCH       2.0       9.15       18.30         7. INSPECTION       3.0       1.30       33.90         TOTAL SHOP OPERATIONS       350.95       350.95         8. OUTSIDE PRODUCTION (ITE/IIZE)       350.95         9. PACKAGING       350.95         10. TOOLING (ITEMIZE)       350.95         11. ENGINEERING       350.95         9. PACKAGING       350.95         10. TOOLING (ITEMIZE)       350.95         11. ENGINEERING       350.95         9. UOTED PRICE:       TOTAL TOOLING & ENGR:         9. PACKAGING       350.95         10. TOOLING       10.10000000000000000000000000000000000		·····			
0. DENCH       2.0       11.5       10.50         7. INSPECTION       3.0       11.30       33.90         TOTAL SHOP OPERATIONS       350.95       350.95         8. OUTSIDE PRODUCTION (ITEMIZE)       350.95       350.95         TOTAL OUTSIDE PRODUCTION (ITEMIZE)       350.95       350.95         9. PACKAGING       350.95       350.95         10. TOOLING (ITEMIZE)       350.95       350.95         11. ENGINEERING       350.95       350.95         9. UOTED PRICE:       TOTAL TOOLING & 10.00       350.95         11. ENGINEERING       350.95       350.95         0UOTED PRICE:       TOTAL TOOLING & ENGR:       350.95         0UOTED TOOLING:       70.70       350.95		· 7 r	OIE	1830	
7. INSPECTION     3.00 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1			11.10	2200	
3. OUTSIDE PRODUCTION (ITE/IIZE)     3. OUTSIDE PRODUCTION (ITE/IIZE)       TOTAL OUTSIDE PRODUCTION     4       9. PACKAGING     4       10. TOOLING (ITE/IIZE)     4       10. TOOLING (ITE/IIZE)     4       11. ENGINEERING     4       9. UOTED PRICE:     10 TOTAL TOOLING & ENGR:	TOTAL SHOP OPERATIONS		1.20	35095	25
8. OUTSIDE PRODUCTION (ITERIZE)         TOTAL OUTSIDE PRODUCTION         9. PACKAGING         10. TOOLING (ITEMIZE)         TOTAL TOOLING         11. ENGINEERING         QUOTED PRICE:         TOTAL TOOLING:         10. TOOLING:					
TOTAL OUTSIDE PRODUCTION     -       9. PACKAGING     -       10. TOOLING (ITEMIZE)     -       TOTAL TOOLING     -       TOTAL TOOLING     -       11. ENGINEERING     -       QUOTED PRICE:     TOTAL TOOLING & ENGR:       QUOTED TOOLING:     -	8. OUTSIDE PRODUCTION (ITE/11ZE)				
TOTAL OUTSIDE PRODUCTION       9. PACKAGING       10. TOOLING (ITEMIZE)       10. TOOLING (ITEMIZE)       11. ENGINEERING       QUOTED PRICE:       TOTAL TOOLING:					
TOTAL OUTSIDE PRODUCTION     •       9. PACKAGING     •       10. TOOLING (ITEMIZE)     •       TOTAL TOOLING (ITEMIZE)     •       11. ENGINEERING     •       9. OUOTED PRICE:     TOTAL TOOLING & ENGR:					
Initial outside production     4       9. PACKAGING     10. TOOLING (ITEMIZE)       10. TOOLING (ITEMIZE)     10. TOOLING (ITEMIZE)       TOTAL TOOLING     11. ENGINEERING       11. ENGINEERING     11. ENGINEERING       OUOTED PRICE:     TOTAL TOOLING & ENGR:       OUOTED TOOLING:     70'-					
9. PACKAGING         10. TOOLING (ITEMIZE)         10. TOOLING (ITEMIZE)         11. ENGINEERING         11. ENGINEERING         QUOTED PRICE:         TOTAL TOOLING:         TOTAL TOOLING & ENGR:	TOTAL OUTSIDE PRODUCTION				
10. TOOLING (ITEMIZE)         III. ENGINEERING         QUOTED PRICE:         TOTAL TOOLING:         III. ENGINEERING	9. PACKAGING	·			
TOTAL TOOLING	10. TOOLING (ITEMIZE)				
TCTAL TOOLING     TCTAL TOOLING       11. ENGINEERING     III       QUOTED PRICE:     TOTAL TOOLING & ENGR:       QUOTED TOOLING:     - O'-			+		
TCTAL TOOLING					
II. ENGINEERING       11. ENGINEERING       OUOTED PRICE:       TOTAL TOOLING & ENGR:       OUOTED TOOLING:					
OUOTED PRICE:     TOTAL TOOLING & ENGR:       OUOTED TOOLING:     - O'-	TCTAL TOOLING		+		
QUOTED TOOLING: - O'-	II. ENGINEERING				
UUDTED TOOLING:		JULING & ENGR:			
3/1 / 0.0	OUOTED TOOLING:	r	241	192-	55

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PANY 7GC. SAC P/N		No.	PAKIS	
BLADES 2D X 3D	DEPTH		MIN.	PASS /
TER SIZE MACHINED BLADES	FIR TREE			
	HOURS	RATE	COST	TOTAL
ATERIAL (liemize)				
,34 /				
TOTAL NATERIA!				• • •
ATHE OPERATIONS (Item ze)				
TURN FOR PANTOGRAPH	15.7	1195	179.25	
FINKH TURN	250	1.95	29875	
				l ▲ .
ANTOCRADH	100	0.0	F-10-00	•
UTTERS	PH-	1215	1575	
ILLING OTHER THAN PANTOGRAPH (Iremize)				
MISC MILLING	80	11,95	95.60	
·				
ISCELLANEOUS OPERATIONS (Homiso)				
		1100	7170	
DULL MOLES	100	$\frac{11}{100}$	119 50	
		L'I •?.		
			-	 
	350	4.15	320.25	
TOTAL SHOP OPERATIONS	10.0	1120	13.00	1791 80
				11100
TATAL ALTRIDE DO AN				
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AUNAGING	#			
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HOLDING Y INDEX			50000	
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DELIVERY:			-	· · .
IED TUOLING 05000				
			100-	1792.80

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IMPELLER, DUMP	- ITE	MŦЗ	30	
IMPELLER OUOTATION SHEET			DATE 10-	23.69
COMPANY AGC P/N	ELIOPT D	1	NO. PARTS	
Cutter Dia Generate Duplicate		ARIL (		
	HOURS	RATE	COST	TOTAL
1 NATERIAL (Itemize)				
TOTAL WATERIAL				
2. LATHE OPERATIONS (Itemize)			1000	
TURN TOP GENERATIR	35.0	1.45	410.25	
TUPN FOR BACK F.P.S.	250	1195	200.75	
EIDISH IVEN TON OUS				
3. VANE GENERATION/DUPLICATION	200.0	9.95	2985.00	
5 AULING OTHER THAN VANE GEN (Hom	ize) 25.0	- 4.J.D	240.10	
MILL BACK VALLES	50.0	1195	597.50	
HILL CLUTCH LUGS	50	1115	179.25	
SETUP 9 CUI SMALLE. TRACK	< 1500	9.50	425.00	
6. MISC. OPERATIONS (Itemize)				
PRILE HOLES ATTOP	15.0	11.95	179.25	.,
JRIM VANS	200	11.95	239.00	
<b>1</b>		<b>  </b>		
7. BENCH	2.00,0	1715	1830.00	
8. INSPECTION	500	1.30	565.00	
TOTAL SHOP OPERATION			9145.00	9145.00
9. OUTSIDE PRODUCTION (Itemize)				
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		<b>  </b>		
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		· · · · · · · · · · · · · · · · · · ·		
TCTAL OUTSIDE PROD.				
10. PACKAGING		· ·		
2 RARDIL CAHS			3000 00	
2 SUING HEIL CAIS		1	24000	
I KNEE CAM	à - ,		600°-	
1-INDES PLATE		∦	150000	
ARBORS Y JEMPY MISC			6500	
12 ENGINEERING		<u> </u>	1-1-00-0-0-	
			100	911500
CHOTED PRICE DELL	VCKY:			7220.00
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Rev. J. Regan J-24-00			40rc-	

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TOOLING & MISC. QUOTATION SHEET DATE: COMPANY A.G.C. SAC	N:
COMPANY A.G. STIC. SCRAP ALLA DADT NAME: P/N: NO. PARTS	• •
	1
NUT ASS, Y IMPELLEP PETA WING HOURS RATE COST	TOTAL
TLOMINUM	-
TOTAL MATERIAL	
2. LATHE OPERATIONS (ITEMIZE)	
TUPN COMPLETE Y THREAL ZOD 1195 3535	0
3. MILLING OPERATIONS (ITEMIZE)	
	-
4. MISC. OPERATIONS (ITEMIZE)	-
	7
6. BENCH	4
$\frac{7. \text{ INSPECTION}}{\text{TOTAL SHOP OPERATIONS}} = \frac{1.0 \text{ II.50}}{3743}$	7 37437
	·
8. OUTSIDE PRODUCTION (TIENIZE)	
TOTAL OUTSIDE PRODUCTION	
9. PACKAGING	
10. TOOLING (ITEMIZE)	
QUOTED PRICE: TOTAL TOOLING & ENGR:	
2 OUOTED TOOLING: - O -	374.37
DELIVERY: 345 10 PC	-292.00
4.0PC	-260-90

01	11							·				1500
23.6	TOTAL					*	5783.		.4	· • •		5783.7 1540.0 1050.0
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	COMPANY A.G.C. SAC.		S	CRAP ALLON:	
	PART NAME: P/N:		N	O. PARTS	
	VOLUTE PUMP	HOURS	RATE	COST	TOTA
ſ	1. MATERIAL (ITEMIZE)				
Į.	347- CASTINO	-+			
	TOTAL MATERIAL				
ŕ					
	TURN COMPLETE	75.0	11.95	896.25	•
ľ		-			
		+			
	3. MILLING OPERATIONS (ITEMIZE)		100	5075A	
	MISCONILLING	500	11:20	571.50	
	4. MISC. OPERATIONS (ITEMIZE)	_			
	DRIVE ALL MOLES & DODT - 10	100	1195	79:50	
	DRILL INCL. HUMELS TORIS	1.191			
	5. ASSEMBLY				
		25.0	9.15	228.75	
	7. INSPECTION	20.0	11.30	226.00	
	TOTAL SHOP OPERATIONS			3741.00	37.
	8. OUTSIDE PRODUCTION (THEMIZE)		·		
	TOTAL OUTSIDE PRODUCTION				
			+		
	9. PACKAGING				•
	10. TOOLING (ITEMIZE)		+	75000	
	LATH HOLDING FIXTURE			75000	1
				15000	l
				1:00-	<del>ys yn sei 12</del>
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50				1 PC	374
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MAN WEA		**		1 0 PC	261

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# APPENDIX G

 $\left\{ \begin{array}{c} \\ \end{array} \right\}$ 

## SAMPLE ESTIMATE FOR BASE CASE FUEL TURBOPUMP SUBCOMPONENTS FROM BOBBITT & PRUETT MANUFACTURING COMPANY



ATE 26/67 DELIVERY QTY
TROUBLE AREA & REMARKS
-SYNAMIC BALANCING.
PER cut
/ FIX CUT
"C" Dia VERY Difficult
REQUIRES INTERNAL GINDING.
D HOLE PATTERN
0 .001 AXIAL DIM dissignit
thd. GAGE

BOBBITT & PRUE	TT MFG. CO.			
Ŀ	/		LUST ASSEMBLT SHELT	
PART or JOB NO.	THEM	<b>S</b> DATE	DELIVERY	QTY
PROCESS	TIME	COST	TROUBLE AREA &	REMARKS
MATERIAL				
HEAT TREAT				
PLATING				
PAINTING				
PACKAGING				
INSPECTION				
SHIPPING				
CERTIFICATIONS				
SPECIFICATIONS				
SAW	to min	2		
SAND	TO TIM	2.00		
GRINDING	210	2000		
DRILL		60.0-		
MILL	2 //3	23.00		
TAP of THREAD				
LATHE	31/2	35.00		
WELDING				
FORMING, HAND				
DRMING, PUNCH PRESS				
DEBURRING				
SAND BLAST				-
PLANNING				
ASSEMBLY				
DESIGN				
TOOLING				
MISC.				

352	TOTAL
	101/16

i		Ъ		
BOBBITT	&	PRUETT	MFG.	CO.

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#### 11351 PYRITE WAY RANCHO CORDOVA, CALIF. 635-1830

### COST ASSEMBLY SHEET

PART or JOB NO, 11619 3,546,5	DATE	DELIVERY	QTY
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	PROCESS	TIME	COST	TROUBLE AREA & REMARKS
	MATERIAL			· ·
	HEAT TREAT			
13	PLATING			
) (	PAINTING			
	PACKAGING			
[**]	INSPECTION			
	SHIPPING			
ł.	CERTIFICATIONS			
i •	SPECIFICATIONS			
	SAW			
	SAND			
E.	GRINDING		-	
	DRILL			
. т	MILL			
	TAP of THREAD			
	LATHE	/ h.a. 15 min	12.00	
Č.	WELDING			
	FORMING, HAND			
	FORMING, PUNCH PRESS			
	DEBURRING			
	SAND BLAST			
	PLANNING		<u></u>	
	ASSEMBLY			
	DESIGN		<u>.</u>	
	TOOLING		·····	
	MISC.			

	6	Б		
BOBBITT	& P	RUETT	MFG.	CO.
	_ <b>_</b>			

#### 11351 PYRITE WAY RANCHO CORDOVA, CALIF. 635–1830

### COST ASSEMBLY SHEET

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PART or JOB NO.	TEM +	Z DATE	DELIVERY QTY	
PROCESS	TIME	COST	TROUBLE AREA & REMARKS	
MATERIAL				
HEAT TREAT				
PLATING				
PAINTING		-		
PACKAGING			·	
INSPECTION			· · · · · · · · · · · · · · · · · · ·	
SHIPPING				<del></del>
CERTIFICATIONS				
SPECIFICATIONS				
SAW				
SAND		-		
GRINDING				
DRILL	<u> </u>			
MILL				
TAP of THREAD				
LATHE	460	4000		
WELDING		10		
FORMING, HAND			······································	
RMING, PUNCH PRESS				
DEBURRING				
SAND BLAST				
PLANNING				
ASSEMBLY				
DESIGN				
TOOLING				
MISC.	1 1/2	15,00	SPLINE	

		0		
BOBBITT	<u>&amp; PI</u>	RUETT	MFG.	CO.
	J	9	,	

### 11351 PYRITE WAY RANCHO CORDOVA, CALIF.

COST ASSEMBLY SHEET

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PART or JOB NO. Z	TEM \$	DATE	DELIVERY QTY
PROCESS	TIME	COST	TROUBLE AREA & REMARKS
MATERIAL			
HEAT TREAT			
PLATING			
PAINTING			
PACKAGING		-	
INSPECTION	· · · · ·		
SHIPPING			
CERTIFICATIONS			······································
SPECIFICATIONS			
SAW			
SAND		- · · · · · · · · · · · · · · · · · · ·	
GRINDING			
DRILL	<u>(</u>		
MILL	1.62.	10.00	
TAP of THREAD			
LATHE	4 h.R.	4000	
WELDING	/		
FORMING, HAND			
FORMING, PUNCH PRESS			
DEBURRING			
SAND BLAST	·		
PLANNING			
ASSEMBLY			
DESIGN			
TOOLING			
MISC.			

Ē		11351 PYRITE WA	RANCHO CORDOVA, CALIF.	635-1830
BOBBITT & PRUET	T MFG. CO.		COST ASSEMBLY SHEET	
PART or JOB NO.	ten #	/2 DATE	DELIVERY	QTY
PROCESS	TIME	COST	TROUBLE AREA & REMAR	KS
MATERIAL				
HEAT TREAT				
PLATING	<u></u>			
PAINTING				
PACKAGING				
INSPECTION			·	
SHIPPING				
CERTIFICATIONS				
SPECIFICATIONS				
SAW				
SAND				
GRINDING				
DRILL				
MILL	1/2 hr.	5.00		
TAP or THREAD				
LATHE	4.5 hr.	45.00		
WELDING				
FORMING, HAND				
FORMING, PUNCH PRESS				
DEBURRING				
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PLANNING				
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BOBBITT & PRUET	T MFG. CO.			
	7	· · · · ·	CUST ASSEMBLY SHEET	
PART or JOB NO.	TEM 7	#/5_ DATE	DELIVERY	QTY
PROCESS	TIME	СОЅТ	TROUBLE AREA & REMA	RKS
MATERIAL				
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PLATING				
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INSPECTION				
SHIPPING				
CERTIFICATIONS				
SPECIFICATIONS		-		
SAW	,			
SAND				
GRINDING				
DRILL				
MILL	1/2	15.00		
TAP or THREAD				
LATHE	71/2	75.00		
WELDING			·	
FORMING, HAND				· · · · · · · · · · · · · · · · · · ·
ORMING, PUNCH PRESS				ar da a transfer a su su su su su su su su su su su su su
DEBURRING				
SAND BLAST				
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ASSEMBLY				
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TOOLING				
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		11351 PYRITE W	AY RANCHO CORDOVA, CALIF.	635-	-1830	
	<b>7</b>		COST ASSEMBLY SHEET			
PART or JOB NO.	TEM #	<b>20</b> DATE	DELIVERY	QTY.	60	EA.
PROCESS	TIME	COST	TROUBLE AREA & REMAR	ĸs		
MATERIAL						
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PAINTING	· · · · · · · · · · · · · · · · · · ·					
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INSPECTION	-4, 4					<u> </u>
SHIPPING						
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SAW						
SAND			<u></u>			
GRINDING	9 hR.	90.00				
DRILL	-					
MILL	41R.	40.00		;;;		
TAP or THREAD		•				
LATHE	50 hr.	500,00				<b></b>
WELDING						
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FORMING, PUNCH PRESS						
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HEAT TREAT				
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DEBURRING				
SAND BLAST				
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BOBBITT & PRUET	T MFG. CO.	11351 PYR	ITE WAY	RANCHO CO	RDOVA, CA	ALIF.	635 [_] 1830
	7		COS	ST ASSEMBLY	SHEET		
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# APPENDIX H

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# BASE CASE FUEL TURBOPUMP COST ANALYSIS

ت للسلة	د. محمدیات می ایند	لمتغصبت	Land Street	( in the second	التستنط	È.	فسدرتها شبكم	( marine )	الغرياديها	فور شده فيته		ارب سیست ریا	<b>.</b>	فشتنا	(all)	tere ing
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EO OI	2001	1001	521	32/	321	<u> <del>7</del></u>	527	529	562	508	542	Ist	5.	_5`	<u>`2</u>	нвгл			
RE OOX	Tz 982	528.58	3440	32.58	77.201	1992/	96081	82-7425	72.60	0969	08805	959	02	001	OVE	JAS	י <i>פוטנ</i> יט מחצבוב	INSPECTION S	יזז
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SE ESTE	31248	50 ELH	<b>XE EKE</b>	as L C+	00815				50091Z	30005	··· <i>0</i> 075.	5021	920	.056	005	НВГА	(0746)	WACHINING (2	.9
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EILLH	a\$665/	00.58.66	EIBLI	05661	00 28 6				152000	000000	2000a	00%/	0.65	0 001	0201			SONTI AD	S 
				ļ		2						-				S∧L		KAWSTOCK	. 4
		FACAT							l	<u> </u>						НВГА			
		202 206			25956						55772.				· ·	125	050	LOOLING , SWIJOOT	٤.
I 2+		57.66 26	77.6		57/46		7-+6		1101	1.02			<u> </u>	0.5	0.00			8.1.1	
77.74	10_20		92 J		01201	T. /Y	5073	50.15	TLOU	1000		969		0.0	0.02	A DAY	PLANNING	<b>Р ROCURE MENT</b>	۲.
PACT	<u> 2638</u>	207.2.2	92.7_	1641	ZLEZ		<u>bGVy</u>	62 08	DEVI	8606	102_01			<u> </u>	000	703	() _ JJJ4JC	_ · <u>_ · _ · _ · _ · _ · _ · _ · _ · _ ·</u>	
			1													มายัน	ES/CONSULTING	ADVANCE QUOT	٦.
40	στ	τ.	40	10	τ	40	στ	τ	40	στ	τ	PER HR	40	0T	τ				
12 WAN HOURS RATE NET DOLLARS DLO AT 260% * C + A AT 14.25% * TOTAL BOLLARS									TLATA HOUSING' BEHAING RHON AWAN			7N							
		••••••	· · · · · · · · · · · · · · · · · · ·			·			ł	<u> </u>	I		l			1	7		•
		(81123	<i>•</i> ) 1	307 0	ふ フรรช3	<b>a</b> /	( 470	w c o (w	67 (364	2128 14M	1800 I II	10						2169511 N	ہے ای
								70	16 210 16 210	KBOPD%	UI 120 7303 TIM	10 M 0 1						EW NO.	11 . 7

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-10-28-69

OPERATION ITEM NO 2 PN_1136913

364

#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMOO IN DUSTRIES

. '	NAME SHAFT	٨	AN HOUS	s	RATE	· NE	T DOLLA	RS	DL	0 AT 260	17 🛠	G + /	A AT 14.	25% *	TOT	AL DOLL	ARS
		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1. ADVANCE QUOTES/CONSULTING HRLY SAL		-	—													
•	2. PROCUREMENT PLANNING SAL	9.0	1.0	.7	696	62 ££	6 96	4 <b>Z</b> Z	162 24	18.19	12 ££	32 / 3	352	2.02_	25741	28 11	20 23
•	3. TOOLING HRLY SAL		-		-	17805					—	253 <b>e</b> 5			2093 45		
•	4. RAWSTOCK HRLY SAL			-		3282	219 2	197 🥶				<b>46</b> 74	3/ 24	7 <b>8 2</b> 7	37+74	250.21	22 <b>5 2</b>
	5. CASTINGS OR FORGINGS HRLY SAL		_														
•	6. MACHINING HRLY SAL	75	50	45	12 ••	900.00	600 <u>**</u>	54092		·		/2835	85.E2	7695	1028.35	6 85.07	\$/\$ <b>9</b>
	7. WELDING HRLY SAL								·			 	 	ļ			
$\bigcirc$	8. ASSY & FAB QE HRLY SAL																
	9. CLEANING HRLY SAL											ļ	ļ		ļ		
	10. Q C PLANNING HRLY SAL															(4.43	10.0
1	11. INSPECTION (REC.) HRLY SAL	ۍ. ک،	.5 .15	ۍ. 15	4.87 6.96	2 <u>•</u> • 3 • •	2 <del>4 9</del> / <del>• 4</del>	2 44.	6 14 ¶ <u>95</u>	6 <del>34</del> 2 <u>7 9</u>	63 <del>1</del> 27 <u>0</u>	125	/2£ .53	.53	/4 22	4 81	422
	12. INSPECTION HRLY SAL														ļ		
	13. INSIDE LIAISON HRLY														ļ		
	14. SHIPPING HRLY SAL					18.00	18	12				2 <i>£I</i>	2 52	2.52	2052	ZOEZ	2051
	15. SUTTLER GC (SHR/1000 OF) SAL	4.5	30	2.7	6 96	3/ 22	2020	18 72	<b>B/ +1</b>	54 22	48.25	16 07	10 24	7.64	128 2	<b>85.88</b>	77.21
	16. HRLY SAL						•				L				 		
	TOTAL UNIT COST					1345 12	848 14	782.12		L	TOOLIN	20112	F		YA34 1	POBLEL	474.1
	* MIDPOINT CF EFFORT - JAN '71	-		NET OP D ABOVE	OLLARS >	PERCEN	TAGES OUSE)	EWSUL	LIVAN	X 7872	2	OP RAT	E AT \$12 SE RATE A SE RATE	2.00/HR NT \$4.87 AT \$6.90	* //HR (HRL 5/HR (SAL	.Y) * _) *	

				ر. در میرکور د	an ar- Chùig	ia. Vari ur			nga sa sana Nga sana Nga sana		. (h	- 17			محمد المحمد من المحمد المحمد r>المحمد المحمد	7 6		n an		
•	11 P	OPERATION TEM NO. 344 N_1/36914	647 		~			LOW C U	FUEL OST TU NIT COST	RBOPU (BASE C	MP STU ASE)	DY	5. 80 / 11	- 11-	7-69	9 (1463	/1. 64	OW17. 0	F 12 )	
$\bigcirc$			(ZEL TO MATCH	ED SE	r)			L DATE					0 AT 0/0		T		254 +	707		
	N,	AME <u>132 AR/116 , D.</u>	MIL-SET GUINN		1	1001 IN	40	PERHR	1	1 DULLA	40	<u></u> 1	10 10	40		A AI 14	40	101	10	40
_	1.	ADVANCE QUOT	ES/CONSULTING	HRLY SAL																
_	2.	PROCUREMENT	PLANNING	SAL	15D	2.0	1.0	696	10440	1392	696	27/ <del>11</del>	36 17	1812	5320	719	357	427 <u>4</u> 0	5725	2263
-	3.	TOOLING		HRLY SAL																
-	4.	RAWSTOCK		HRLY SAL					66300	51000	40800									
	5.	CASTINGS OR F	ORGINGS	HRLY SAL			 		GUAN 1	50	/80									 
	6.	MACHINING 7	URNTITIES SNOWN ICLUDE SPARES	HRLN SHE	•				397800	25502	18369				56631	36333	26/62	4541 <u>8</u> Z	291335	201762
_	7.	WELDING		HRLY SAL													ļ			
C .	8.	ASSY & FAB QE		HRLY SAL										ļ	ļ					
	9.	CLEANING		HRLY SAL																
	10.	Q C PLANNING		HRLY SAL					ļ					 			ļ			· · ·
_	11.	INSPECTION , 5	OURCE	SAL	2.0	1.5	1.0	6 <u>96</u>	13 <u>92</u>	1044	696	3619	27/ <del>4</del>	1819	7/4	536	3€Z	5785	42 81	2363
•	12.	INSPECTION,	EC	HRLY SAL	1.0 1.0	1.0 .3	1.0 \3	4 <u>87</u> 6 <u>96</u>	4 37 1392	431 1044	4 87 6 96	12 66 36 19	124 <u>6</u> 27 <u>1</u> 4	124	230 7 <u>/4</u>	526	<u>250</u> <u>957</u>	57 <b>25</b>	4224	2102
	13.	INSIDE LIAISON		HRLY SAL																
-	14.	SHIPPING		HRLY SAL					12000	8000	6000				1710	1140	855	137 <u>10</u>	9110	6855
	15.			HRLY SAL										 						
$\bigcirc$	16.			HRLY SAL									ļ							
~			TOTAL UNIT COST	T					4235	2669 67	192175							5245I	376711	ZCR
	* 1	VIDPOINT OF EFF	ORT - JAN '71				NET OP D ABOVE =	OLLARS >	PERCEN	ITAGES IOUSE)					OP RAT	IE AT \$13 Se rate /	2.00/HR NT <b>\$4.8</b> 7	* //HR (HRL	<b>.Y) *</b>	

EW SULLIVAN X7872

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그는 수도 동안 이 도로 가지 않는 것 같아요. 이 가지 않는 것 같아요. 이 가지 않는 것 같아요.

~10-29-69

FUEL

ITEM NO. PN 1136915

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OPERATION

#### LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMCO NOUSTRIES

2	NAME SPACER, BEARING	1	N	AN HOUR	s	RATE	NE	T DOLLA	RS	DL	0 AT 260	)'/. *	G + /	A AT 14.	25% *	тот	AL DOLL	ARS
			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1. ADVANCE QUOTES/CONSULTING	HRLY SAL																
	2. PROCUREMENT PLANNING	SAL	3.00	. 6	.5	6	20 73	411	343	54 <u>29</u>	10.27	9 <u>05</u>	1071	2/4	179	25 II	17_1•	/4 <u>3</u>
	3. TOOLING	HRLY SAL																
	4. RAWSTOCK	HRLY SAL					<u>54 ∞</u>	3600	32 +0	—			7 70	513	4 62	6/ 70	41_12_	37.92
	5. CASTINGS OR FORGINGS	HRLY SAL																
	6. MACHINING	HRLY	25.0	18.0	16.0	1200	300.∞	21600	192:00	•			42 <u>75</u>	3078	27 36	3 + 2 2 5	27672	2192
	7. WELDING	HRLY SAL	1															
	8. ASSY & FAB QE	HRLY							-									
	9. CLEARING	HRLY SAL	1				1											
	10. O C PLANNING	HRLY SAL																
	11. INSPECTION REC	HRLY	.5	.5	.5	4 87	2 44	244	2 ==	634	634	634	125	725	125	10 03	1000	417
	12. INSPECTION, SOURCE		1.50	1.00	.75	696	<u>3 <del>4</del></u> 10 <del>+ 4</del>	696	626	9 <u>03</u> 27 <u>(†</u>	1812	1627	5.20	352	3 2/	42 7-	1863	45 <u>¥</u>
	13. INSIDE LIAISON	HRLY									1		1					
	14. SHIPPING	HRLY			<b> </b>		600	4 <u>32</u>	384			·	86	-62	য	684	4 92	4 37
	15.	HRLY SAL																
	16.	HRLY	,		<u> </u>													
	TOTAL UNIT CO	ST	<u> </u>	<u> </u>	1	t	39724	270 74	24146			1	I			521 99	357 12	3/51

ABOVE = NET DOLLARS (INHOUSE)

INHOUSE RATE AT \$4.87/HR (HRLY) * INHOUSE RATE AT \$6.96/HR (SAL) *

EWSULLIVAN X7872



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#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMCO IN DUSTRIES

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ار در در از از میشینی در در ا /10-29-69

ی محمد بد ایک از در ا

NAME	ET BEARING -LOWER		N	MAN HOU	RS	RATE	NE	T DOLLA	RS	DL	0 AT 260	)% *	G + /	A AT 14.	25% *	TOT	AL DOLL	ARS
NOTE:T	WO CA. REQUIR		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE	QUOTES/CONSULTING	HRLY SAL												-			2	
2. PROCURE	MENT PLANNING	HRET SAL	<b>3</b> .00	. 6	.5	696	2022	4 19	3 11	5429	10 27	9 <u>05</u>	10 71	2/4	179	85 <u>74</u>	17 <u>19</u>	/4 <u>-32</u>
3. TOOLING		HRLY SAL																
4. RAWSTOC	СК	HRLY SAL					18_00	12 <u>00</u>	10.50				2 <u>5 7</u>	174	154	2057	13 7/_	12 34
5. CASTING	S OR FORGINGS	HRLY SAL																
6. MACHININ	NG	HRLY SAL	<b>B</b> .00	6.00	4.00	12 00	96.00	72 00	48 <u>00</u>				13 68	1026	634	109 68	82.26	54 74
7. WELDING		HRLY SAL																
8. ASSY & F	AB QE	HRLY SAL																
9. CLEANING	G	HRLY SAL							•									
10. QCPLAN	INING	HRLY SAL																
11. INSPECT	ION, THE SOURCE	SAL	1. D	.8	. 6	696	6 <u>96</u>	5 <u>57</u>	4 13	1810	14 43	10 87	357	257	2/+	28 63	22 62	17_19
12 INSPECT	ION SCHOOL REC	HALY MEN	15	.5	.5-	4 87	294	249	2 44	634	634	634	125	125	125	1001	1005	4 27
		SAL	.5	.15	.15	696	342	1 04	104	9 05	2 10	2 10	14	22		/+==	784	
13. INSIDE LI	IAISON	HRLY SAL																
14. SHIPPING	3	HRLY SAL					200	200	200				29	29	29	2.29	2 21	2.29
15.		HRLY SAL																
16.		HRLY																
	TOTAL UNIT	COST					14976	9923	7/94	THIS A	COST F	DR UN	TOUA	N OF	rwo-	27/40	/52 <i>1</i> /	115 82
* MIDPOINT O	OF EFFORT - JAN '71				NET OP DABOVE =	NET DOLL	PERCEN	TAGES					OP RAT	E AT \$12 E RATE A	2.00/HR	+ /HR (HRL	Y) *	

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-10-29-69

# OPERATION ITEM NO. (B) PN__//36 9/6___

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### *FUEL* Low cost turbopump study UNIT COST (BASE CASE) COST ANALYSIS LAMCO INDUST RIES

NAM	E COUPLING TUR	BINE		MAN HOUF	¥S	RATE	NE	T DOLLA	RS	. DL	0 AT 260	% *	G + A	AT 14.	25% *	TOT	AL DOLL	ARS
			1	10	40	PERHR	1	10	40	1	10	40	_1	10	40	1	10	40
1. A	DVANCE QUOTES/CON	ISULTING HRL SAL	Y															
2. P	ROCUREMENT PLANN		4.5	1.0	.7	6.96	3/32	<u> </u>	4 27	8/ <u>+</u> 1	18:00	12 🛀	1667	357	250	129 62	2863	20-2
3. T	OOLING	HRL SAL	Y				50000			·			71 25			571 <u>25</u>	· -	
4. R	AWSTOCK	HRL SAL	Y		·		1538	10200	91.80				21 30	1454	1303	174 🏊	11659	10475
5. C	ASTINGS OR FORGING	GS HRL SAL	Y															
6. M	ACHINING	HRL SAL	Y 60.00	4000	3500	12 <u>00</u>	72000	48000	42000				102 👓	63 <u>40</u>	54.85	<b>B</b> 22 60	54840	479.25
7. W	ELDING	HRL SAL	Y															
8. A	SSY & FAB QE	HRL SAL	Y															
9. C	LEANING	HRL SAL	Y															
10. Q	C PLANNING	HRL SAL	Y													10 91	10.01	77.00
11. 10	NSPECTION , PEC	HRL SAL	Y .5	.5	.5	4 37 6 96	2 44	299	244	634 905	2 70	63 <u>+</u> 1 <u>70</u>	122	51	51	10	421	4.21
12, II		HAL SAL	- 3.60	2.40	210	696	25 06	1670	14 62	6516	43 👥	<u>38 oʻ</u>	12 <u>86</u>	857	750	/03 😐	<b>68 9</b>	60.13
;13. II	NSIDE LIAISON	HRL	Y			1												
14. S	HIPPING	HRL SAL	Y				14 40	9 <u>50</u>	840				205	/ 37	120	16 45	10 17_	9 00
15.	<u> </u>	HRL	Y		1													
16.	· · ·	HRL	Y															
	TO	TAL UNIT COST			T		94970	618 74	54917			TCOLING	57125			1270.70	787.5	66822
* MIC	POINT OF EFFORT -	JAN '71			NET OP D ABOVE =	OLLARS	X PERCEN	TAGES				<u> </u>	OP RAT	E AT \$12	2.00/HR AT \$4.87	* //HR (HRL	.Y) *	

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× WID	DPOINT OF EFFORT - JAU TILOGO			<b>,</b>	VBOAE =	NET DOLL	ARS (INH	CUSE) (3200)					TAR 90 SUOHNI	E NT \$12 E NATE A	78.22 T	יאש (אשר). א	+ (A	
	TOTAL UNIT COS	1	<u> </u>				TILLE	07602	15991		SNIDUL	51748				SAW S	TERT	¥ 572
.91		אר אגרא																
·st		142																
<b>J4</b> ' 2	SNIPPING	אר זער ארא					00.9	<u>320</u>	<del>00</del> E				- <b>78</b> -	ਰਤਾ	<del>TT</del>	53.7	00+	<del></del>
NI .EL	NOSIAL LIN	SAL HRLY																
. <u>75'</u> IN	NSPECTION, SOURCE	T∀S ATUM	_57	6.	۲.	3.9	<del>33</del> 01	729	78+	FILT	2 9/	<del>3</del> 7 8/	<u>77</u> .5	TEE	ळा	<del>7</del> 5 3 <del>7</del>	37.57	1000
NI 'TT	INSPECTION, ARC	SAL HRLY	ن ن	-12 -	51.	357 784	<b>TFF F</b>	<del>3</del> 0/	<del>3</del> .	30 6	ग र	का र	321	म	73	ना म/	17+	72 +
το [,] σ	D C PLANNING	SAL HRLY						_ • • F	<u> →                                   </u>	<del>4</del> £ %	***	<u>38 7</u>	321	_3E/	<u> </u>	T3 1/	TT OF	<u> <del>T</del></u> <u></u>
ю. С	OLEANING	ראַר אשר∧																
A .8	30 843 \$ Y22	ארך אוגרא														1		
W .7	MELDING	אר אשרא																
M .ð	AMCHINING	אר אשרא	७८	ا تک	71	1500	50 Z/E	55081	oc ++1				3000	3958	2025	₩9 <u>-</u> 5E	37.502	25691
o.c	SONIDADA AO SONITZAD	אר אגרא																
<b>4.</b> R	RAWSTOCK	אר אגרא					1320	006	បាន				761	\$71	371	<del>7</del> 75	AT 01	उर ७
<b>3.</b> T	TOOLING	אר אארא					500E			<del></del>			32 24			<del>52</del> 7+5		<b></b>
2° b	PROCUREMENT PLANNING	T∀S ####	<i>_S</i> **	01	<u>.</u>	<u>95</u> 9	72 /2	75 9	ड∓ह	হৰু/৪	0181	रु ४	20 91	252	271		I9 97	I0 +/
Α.Γ	ADVANCE QUOTES/CONSULTING	רע אשרא																
			τ	0τ	40	ьев нв	τ	Οτ	40	τ	ΟΤ	40	ī	01	40	T	0T	40
NAN	BNITUTOD-LJUHS'LTOE BW	]	N	UOH NAI	ระ	<b>BTAR</b>	IN	T DOLLA	Sa	na	092 TA 0	* %	/+9	AT 14 A	* %52	101	אר מסררי	SN
- NG 111E1						n כאכ	ער דצט וד דצט דצטט	∀и∨глаі . (Вузе с Вворлі Е7	ן בא <i>חב</i> SPA UTS 9W UTS 9W	<i>πολι σ</i> λα	5318/18							

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NOITARATION

17-12-01/

110-30-64

#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMED INDUST RIES

$\circ$	N	ME NUTICOUP	LINA	<b></b>	MAN HOUT	RS	RATE	NE	T DOLLA	RS	DL	0 AT 260	<b>%</b> *	G + /	A AT 14.	25% *	TOT	AL DOLL	ARS
				1	10	40	PER HR	1	10	40	1	10	40	1	10	40	1	10	40
	1.		CONSULTING HRL	Y															
-	2.	PROCUREMENT	LANNING SAL	3.0	.6	.5	6 96	2021	413	341	5429	1011	905	107	A 14	129	ตษ	17_1	14 <u>22</u>
-	3.	TOOLING	HRL	Y	1			150=	•					2/38		·	17/ 31	. <b>—</b>	
•	4.	RAWSTOCK	HRL SAL	Y			·	4 <u>88</u>	325	293				70	46	42	551	32′	3 32
•	5.	CASTINGS OR FO	RGINGS HRL SAL	Y	-		1										ľ		
-	6.	MACHINING	HRL SAL	Y 4.0	2.0	1.0	12.00	4900	2400	12 00				684	312	1 <u>7'</u>	54 14	2742	13.71
-	7.	WELDING	HRL SAL	Y		1	1												
0	8.	ASSY & FAB QE	HRL	Y	1	1	-	1											
•	9.	CLEANING	HRL SAL	Y															
	10.	Q C PLANNING	HRL SAL	Y															10.81
	11.	INSPECTION	C HRL SAL	Y .5	.5	.5	4 <u>87</u> 6 <u>96</u>	244	104	104	634 9 <u>05</u>	6 <u>34</u> 2 <u>7</u> 0	270	125	125	/31 53	1423	421	431
	12.	INSPECTION, 50	URCE SAL	1.0	.2	.6	6 96	6 96	552	412	18:0	1411	10 37	351	252	214	2863	22.62	17_19
	13	INSIDE LIAISON	HRL	Y													ļ		
	14.	SHIPPING	HRL	Y				100	<i>75</i>	75			-	14	10	10	114	25	35
	15.		HRL	Y													<u> </u>	· · · · ·	
	16.		HRI SAI	Y											ļ				1075
$\cup$			TOTAL UNIT COST					87 <del>64</del>	4/23	2622		TOOLING	/ 7/ 표				R00 22	26.91	63/6
	* )	MIDPOINT OF EFFO	RT - JAN '71			NET OP ABOVE =	DOLLARS	X PERCEN LARS (INI	ITAGES HOUSE)	EVSA	KLIVAN	/ x78	7 <b>L</b>	op ra' Inhou	TE AT \$1: SE RATE	2.00/HR At \$4.8	+ 7/HR (HRL	.Y) *	
	6000		بغيريا خرشديك فرازمانيك		د	19 T.D	(Fran	8 V 7 7	- -				A	e#9777	A (23)	<b>a</b> 1	الحينصر	کے: میں	

···	l' P	OPERATION TEM NO. (1) N						LOW C U	FUL OST TU NIT COST	EL RBOPU (BASE C ANALYSI	MPSTU ASE)	DY CO 1110	US TRIES		-10-	30-69				
0		ANT LARVEIN	TH QUART	1				DATE	1 NG		PC		0 47 260	)•/ <b>+</b>	<u>c</u> +	A AT 14	254 +	1 707		4.95
	14	AME LADJAN			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1.	ADVANCE QUOTE	CONSULTING	HRLY Sal																
	2.	PROCUREMENT	LANNING	HRLY SAL	4.5	9	.7	696	3/ 32	627	4 <u>87</u>	8/ 43	16 22	12 🥌	16 07	320	2.50	/28 🕰	2544	2003
	3.	TOOLING		HRLY SAL					90 <u>00</u>		-				1283			1020		
	4.	RAWSTOCK	, <u>, , , , , , , , , , , , , , , , , , </u>	HRLY SAL	•				2250	15 00	1350				3 21	214	192	2571	17 (4	1542
	5.	CASTINGS OR FO	RGINGS	HRLY SAL		[														
	6.	MACHINING		HRLY	7.0	4.0	.3.0	12 00	8400	4 <u>900</u>	36.00				11 97	6 84	513	95 92	548±	4/ 13
1 1 1	7.	WELDING		HRLY SAL																
0	8.	ASSY & FAB QE		HRLY SAL		1														
	9.	CLEANING		HRLY SAL		<b> </b>														
	10.	Q C PLANNING	<u></u>	HRLY SAL		<b></b>														
1	11.		<u>с</u>	HRLY	15	.ح	.5	421	244	24	244	1 3E	639	6 3 F	125	725	125	1003	7002	1003
1			180 E	SAL	.5	. 15	.15	696	343	7 41	104	905	2 <u>70</u> 9 05	705	1 24	179	179	17 <u>2</u> 88 <u>63</u>	1432	14 33
;	12.	INSPECTION, SOL		SAL	1.0			6	6 - 12							<u> </u>				
•	13.	INSIDE LIAISON		HRLY SAL												ļ		ļ		
	14.	SHIPPING		HRLY SAL				-	2 00	150	100	<b></b>			22	21	14	223	12	119
	15.	<u> </u>		HRLY SAL																
, cs	16.			HRLY SAL																
			TOTAL UNIT COST						15270	77 <u>70</u>	6233		<u> </u>	TCOUNS	102 12			305 Z	127.96	106 2
371	*	MIDPOINT OF EFFO	RT - JAN '71				NET OP D ABOVE =	NET DOLL	PERCEN	TAGES IOUSE)		E W S	ULLIVAN	×787	OP RAT	E AT \$1	2.00/HR AT \$4.87	* //HR (HRL	Y) *	

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									· M _3	KI7703	L X NO	TLB						
			•		ABOVE =	NET DOLL	HNI) SAA	(3SNO					SNOHNI	E RATE	78. <b>P</b> \$ 11	אאצ (אצר)	* <b>(A</b>	
¥	MIDPOINT OF EFFORT - JAN '71				NET OP [	VILLARS *	PERCEN	TAGES					TA9 90	E AT 512	8H/00 (	*		<u></u>
	TOTAL UNIT COST				{		77 <b>48</b> 0	JE 821:	1289/				17 <i>7</i>	-Ð.V/	<u>ET 1// 1</u>	asht +	<b>76.57</b>	Te L'él
91	· · · ·																	
s٦	•	אר אַצרא																
14	SHIPPING	ר אצרא					<u>50</u> E	575	522				<del></del>		-72-	EF E	¥2 8	238
٤ī	NOSIDE LINIGON	ראר אנרא																
72	ואצאבנוסא ^י <i>בסחעכיב</i>	JAS	01	01	07	309	759	757	757	7781	0101	5781	73 E	73 E	<u>73</u> 8	7961	ET AY	
π	۱۰۰ INSPECTION , رواید	רצאן אארא	`گ دی	_5/ `	<u>51'</u> 0'	309	275 8	701	30/	306	528	52 8	<u>x</u> /	E.F	23	2[#/	776	12+
στ	O, Q C PLANNING	S≱L HRLY						77 4	PP K	¥C /	PE 7	26.7	521	321	521	1001	2091	<u>. .</u>
6	SULLER SULLER	ЗАГ Н8ГА																
8	3. ASSY & FAB QE	צער אנרג				-												
L	MELDING	S≱L HRLY																
9	. MACHINING	SAL HRLY	0.41	0.01	0.8	00 21	<u>55</u> 891	00021	00211				73 6 <del>4</del>	0721	75_51	<b>∓</b> ₹161	-07281	76LVI
ς	CASTINGS OR FORGINGS	SAL HRLY																
*	, RAWSTOCK	S≱L HRLY			—		<del>53</del> 85	<u>00</u> 68	<del>77</del> 5E				<del>7</del> 58	2.20	200	F2 77	95++	0100
٤	TOOLING	S≱L HRLY					<del>2</del> 051						RE IT			TEILI		
2	PROCUREMENT PLANNING	TVS	009	<del></del> /	.حـ	969	<u>9</u> 2/4	<b>9</b> 59	275	छ ८०।	0181	500	<del>7</del> 5 /8	<u>75</u> 8	321	#25/	2988	₹ <b>₹</b> #/
T	. ADVANCE QUOTES/CONSULTING	S∀F HBLY																
			Ţ	στ	40	рек нк	τ	ΟΤ	40	τ	70	40	T	10	0*	τ	στ	01
	NAME CARRIER, BEARING-UPPER		N	IUOH NAN	St	BATE	3N		รช	<b>ח</b> ם'	092 TA 0	* %	+ 9	. AI 14 A	\$%92	101	VE DOLLA	Sar
	PN 1136920					n Fom Co	COST / 12 COST / 12 COST /	109089 (BASE C 1223548)	אף גדע אף גדע אף גדע	<i>со и</i> ло Да	5.7 (41.1.50)	:						

Robert

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(Balanda)

E.S. Carlos

Sec. 23

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Sec. 15

08-011

OPERATIO
ITEM NO. (3)
PN 1136921

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#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMCO INDUSTRIES

TT TT LE TT TH ALL IN - 202 - 20

NAME CARRIER BEARIN	G-LOWER	N	MAN HOUF	¥S	RATE	NE	T DOLLA	RS	DL	0 AT 260	*/• *	<u>G + /</u>	A AT 14.	25% *	TOT	AL DOLL	ARS
		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES/CONS	ULTING HRLY SAL																
2. PROCUREMENT PLANNI	NG SAL	60	1.0	.5	696	4/76	696	348	10854	18 <u>10</u>	9 <u>05</u>	2/12	<u>35-7</u>	1 <u>79</u>	159.22	27 <u>63</u>	/4 <u>32</u>
3. TOOLING	HRLY SAL																
4. RAWSTOCK	HRLY					41 <u>00</u>	27 <u>00</u>	24 <u>30</u>	•			504	385	3 <u>46</u>	4684	30 <del>75</del>	2776
5. CASTINGS OR FORGING	S HRLY SAL																
6. MACHINING	HRLY SAL	12.0	3.5	7.0	12 <u>00</u>	144 <u>00</u>	102 <u>00</u>	<u>84°0</u>				2052	1454	11 98	16452	11654	95.2
7. WELDING	HRLY SAL																
8. ASSY & FAB QE	HRLY SAL																
9. CLEANING	HRLY SAL	· ·					1								,		
10. Q C PLANNING	HRLY SAL																7.8.7
11. INSPECTION, REC	HRLY SAL	.5	.5	.5 .15	4 <u>87</u> 6 <u>96</u>	29 <u>9</u> 3 <del>23</del>	144 1 <u>04</u>	104	634 9 <u>05</u>	6 <u>34</u> 2 <u>7°</u>	634 2 <u>70</u>	125 129	12 <u>5</u> 52	<u></u>	10 05	422	421
12. INSPECTION SOURCE	SAL	1.0	1.0	1.0	6 96	6 96	696	696	1810	1810	180	35-7	352	352	2863	2762	276
13. INSIDE LIAISON	HRLY	/	1		1												
14. SHIPPING	HRLY	í				300	240	225				43	34_	32	342	2 74	257
15.	HRLY	/	1	1													
16.	HRLY	1	1	1	1	· ,											
	AL UNIT COST	1	+	+	1	29264	14970	12447			1	TOOLING	NONE		+27/6	621 62	185 E

EW SULLIVAN X7972

10-30-69

OPERATION ITEM NO. (7) PN_//36922

FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS (FARAGON)

$\bigcirc$											<b>,</b> (									
$\smile$	N	AME STACET SAM	-BLARWO RETAIN	ING	P	NAN HOU	RS	RATE	NE	T DOLLA	RS	DL	0 AT 260	)% *	G +	A AT 14	.25% *	TOT	AL DOLL	ARS
					1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1.	ADVANCE QUOTE	S/CONSULTING	HRLY Sal																
	2.	PROCUREMENTP	LANNING	SAL	30	.5	.5	696	2033	348	3 48	5429	905	905	1021	129	129	85 M	1432	1412
	3.	TOOLING		HRLY SAL												<u> </u>				1
	4.	RAWSTOCK		HRLY SAL					3600	2400	2160	·			513	342	308	4/12	2742	2463
	5.	CASTINGS OR FO	RGINGS	HRLY SAL								i			 					<u> </u>
	6.	MACHINING	LATHE DRILL INSPECT	HRLY SAL	2.0 2.0	1.6	1.4 1.4 .7	11.95 11.95 11.30	59 <u>10</u>	46 <u>40</u>	41 <u>40</u>				842	6 <u>6</u> [	512	67 <u>52</u>	53 <u>01</u>	4730
	7.	WELDING		HRLY SAL													<u> </u>			<u> </u>
С	8.	ASSY & FAB QE		HRLY SAL													<b></b>	<u> </u>		
	9.	CLEANING		HRLY SAL				1										<b>†</b>		<u> </u>
	10.	Q C PLANNING		HRLY SAL																
	11.	INSPECTION	2	HRLY SAL	۔ ح	.5 .15	5	4 <u>87</u> 6 <u>96</u>	2 <u>4 4</u> 3 4 7	244	244	6 <u>34</u> 9 <u>05</u>	6 <u>34</u> 270	6 <b>24</b> 270	125 179	7 <u>7 5</u> 53	725 53	1001	70 <u>07</u> 4 <u>27</u>	1001 421
	12.	INSPECTION SO	VRCE	SAL	10	.7	. 6	686	696	552	4 <u>18</u>	1810	14 <b>ti</b>	10:2	<u>357</u>	252	214	27-1	1262	1712
-	13.	INSIDE LIAISON		HRLY SAL																
	14.	SHIPPING		HRLY SAL					125	100	100				_12_	14	14	143	114	119
	15.			HRLY																
<u> </u>	16.			HRLY SAL																
			TOTAL UNIT COST						13011	8373	7514							24894	132 <b>E</b> L	11893
	* N	ALDPOINT OF EFFO	RT - JAN '71		· · · ·	N	ET OP D BOVE =	OLLARS X	PERCENT ARS (INH	TAGES DUSE)	EWS			7.979	OP RAT	E AT \$12 E RATE A	.00/HR 1 T \$4.87	+ /HR (HRL)	Y) *	

11-4-69

									.,				/	10-30-6	69		ы.		•
	ITEM NO.						LOW C	<i>F DE</i> OST TU NIT COST	Z RBOPU (BASE C/	MP STU ASE)	DY								
	PN <u>//3672.</u>	<u> </u>						COST	NALYSIS	LAMO	CO IND	USTRIE	5			·	1		
$\bigcirc$	NAME SPACE	R. BEARING-RETAL	NING	N	NAN HOUR	S	RATE	NE	T DOLLA	RS	DLO	) AT 260	% *	G + /	A AT 14.	25% *	тот	AL DOLL	ARS
				1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1. ADVANCE QU	JOTES/CONSULTING	HRLY SAL																
-	2. PROCUREME		HREY SAL	6.0	1.0	.5	696	41 <u>76</u>	<u>696</u>	341	10353	1810	<u>905</u>	2/92	3.52	122	1595	140	/# 3 <u>A</u>
•	3. TOOLING		HRLY SAL					102						15 67			12562		
•	4. RAWSTOCK		HRLY SAL					18.00	12 00	10 <u>30</u>				257	171	159	2052	13 71	17.34
•	5. CASTINGS 0	R FORGINGS	HRLY SAL																<b></b>
•	6. MACHINING		HRLY SAL	6.0	4.0	3.0	12 00	.72 %	43 <u>00</u>	36.00				1026	6 84	513	82.26	5429	4113
•	7. WELDING		HRLY SAL											<b> </b>					<b></b>
C	8. ASSY & FAB	QE	HRLY SAL					·											
	9. CLEANING	······································	HRLY SAL											 					<b> </b>
:	10. QCPLANNI	NG	HRLY SAL									172	772	(A.F.	125	125	10 03	70.03	// ez
	11. INSPECTION	REC	HRLY SAL	.ج ح	.5	5 5	4 <u>71</u> 696	244	104	104	63 <u>F</u> 90 <u>5</u>	270	120	122	51	53	14 32	487	4 27
	12. INSPECTION	SOURCE	SAL	LD	1.0	1.0	696	6 96	694	696	1810	1819	18'9	352	3.52	357	1861	1963	13.63
-	13. INSIDE LIAIS	SON	HRLY											1					
	14. SHIPPING		HRLY	•				2 <u>00</u>	150	150		· · · · ·	•	29	21	21	222	171	1 <u>21</u>
	15.		HRLY												ļ				
$\sim$	16.		HRLY											ļ					
<i>۲. ب</i>		TOTAL UNIT CO	DST					146 4	7890	62 22				<u> </u>	FUCLING	V25 62	2/741	141 22	<u>/// 22</u>
	* MIDPOINT OF	EFFORT - JAN '71				NET OP I ABOVE =	NET DOLL	X PERCEN	TAGES IOUSE)	EN	(SULLI	VAN X	7 <b>37</b> 5	OP RAT	E AT \$12	2.00/HR NT \$4.87	+ 7/HR (HRL	<b>. (Y) *</b>	

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(a) A set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the se

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110-30-69

#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMCO INDUSTRIES

376

OPERATION

PN LABYRINTH COUPLING

ITEM NO. (16)

G + A AT 14.25% * TOTAL DOLLARS NAME PN 1136924 MAN HOURS RATE NET DOLLARS DLO AT 260% * 1 10 10 40 1 10 40 PERHR 1 10 40 1 10 40 40 1 HRLY 1. ADVANCE QUOTES/CONSULTING SAL 174 15434 2803 1432 905 2192 10858 1810 357 696 343 Hilling 41 76 60 1D 5 696 2. PROCUREMENT PLANNING SAL 125 63 HRLY 15 68 11000 3. TOOLING ____ SAL 30-15 2057 2054 HRLY 325 252 231 2700 1800 1620 . ____ 4. RAWSTOCK SAL HRLY 5. CASTINGS OR FORGINGS SAL 684 10968 6855 5484 HRLY 12 00 9600 6000 4800 855 1361 8.0 50 40 6. MACHINING HRLY 7. WELDING SAL HRLY 8. ASSY & FAB QE SAL HRLY 9. CLEANING SAL HRLY 10. Q C PLANNING SAL 7001 1001 7003 437 244 244 244 634 634 634 634 725 725 125 .5 5 ک ، HRLY 11. INSPECTION, REC 422 421 14 12 270 53 53 270 179 104 905 SAL 1/5 696 341 104 5 15 351 352 A 63 1263 2363 1810 1210 1810 351 696 696 HALF 696 694 1D 1.0 1.0 12. INSPECTION, SOURCE SAL HRLY 13. INSIDE LIAISON SAL 221 171 171 HRLY 27 21 21 150 150 200 14. SHIPPING SAL HRLY 15. SAL HRLY 16. SAL TOOLING NOF 67 25519 16239 1348 17964 9690 7962 TOTAL UNIT COST * MIDPOINT OF EFFORT - JAN '71 OP RATE AT \$12.00/HR * NET OP DOLLARS x PERCENTAGES ABOVE = NET DOLLARS (INHOUSE) INHOUSE RATE AT \$4.87/HR (HRLY) * E W SULLIVAN X 7872

									75 M J	V #A / 77/	ELY A	<del></del>				*****	
* MIDPOINT OF EFF	<u>17' NAL - TR</u>			1 V	1807E =	NET DOLL	NSS (INH DERCEN	OUSE) LAGES					TAA 90 2UOHNI	5 AT \$12 A 3TA9 3	ЯН\00.9	/אצ (אנר +	* (J
	TOTAL UNIT COST					_	18691	1982+	61 5+8	T						TELEIA	• C
.91		SAL HRLY								<b> </b>							
.د.		ראג אארע															
A. SHIPPING	70 1¥ 3.5 0 244 7	-345					1008	009	000				511	१ष्ठ	75	\$7 6	77
INZLECTION		אר					000	002	006	+ =			<u>Z</u> S	E Þ	[]	Z3 P	5.5
NECHTRADIONI E	(0) BONECE (TUWCO)	ARTIN	Q1	&	7`	559	339	235	TT P	0,81	11+1	1801	738	732	<b>F</b> 12	1387	22
Z" INCLIDENT "Z	- 26 UT OF	⊐vs	9.1	ε.	٤.	969	309	502	602	0781	88.8	245	725	78/			

. S	ארג אצרא																
70775 0791100 791100 791100	-Tots					1008	009	00+				<del>\$</del> ,1	<u>98</u>	75	<del></del>	38 7	13+
ואצאינדענטא די אואאינטאיאנטאי איזאינטאי איזער גערטיי: די אואאינטאיאנטאי איזאינטאיי	רע איינגע	Q'I	e.	7.	759	337	- 002. - 7 8 5	006				73	<u></u> <del>7</del> 77	<b>.</b>	73 +	TTE	TET
S' INSPECTION REC AND	ר ארג	91	ε.	٤.	369	309	202	503	0181	11 21	2801	130	236	¥16 201	E986 E986	7986	5721
J. INSPECTION	רארא ארא		07	07	TEP	1.0	TE #	TE +	15 65	79 21	<u>79</u> 2/	758	<u> </u>	225	<u> Eo o Z</u>	TOOT	2002
O. QCPLANNING	ראר אצרא																·
9. CLEANING	אר אפרא															<u> </u>	
B. ASSY & FAB QE	אר אוורא																·
KSSH 7475 UJOHS 	-745 1-1214	69814 :138/	510 700 70 7025	EI 20 01-02	( 656	372.00	<del>05</del> 981	00000				TE 9#	E9 92	5002	TE // E	5 5/2	
e. Machining	SAL HRLY	520	12:51	0.21	1500	<del></del> 00E	0081	ر <u>ح</u> وم				52 60	39.52	2222	345 22	33 50 2	57811
S. CASTINGS OR FORGINGS	אר אארא																
4. RAWSTOCK	AL ARLY					05 94	50 23	0E+8				22.5	<u>32</u> E	758	129+	JE OE	<u>77</u> 72
3. TOOLING	AL SAL					·	ON-	1001	- ฮุุ่งเ								
2. PROCUREMENT PLANNING 25/ 02	JAS Marta	5 to 0 7	6. 0.1	<u>، ک</u>	<u>95</u> 9	TE 18 51/4	+ 2 9 70 7	725	EFIE TEXOI	2271	7921	2091	028	os x	72831	57.58	EOOF
1. ADVANCE QUOTESCONSULTING	YAL HRLY							27 6	13041	0/6/	506	6716	1.56	<u> </u>	AC 6.51	6987	111/
	1	τ	10 T	07	PER HR	τ	OT	07	τ	TO	05	T		0.0	+	1 OT	0.

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UNITIOD JUBBINE CONFLING

Salar Salar

#### SISTANALTSUS LAND INDUSTRIES (INIT COST (BASE CASE) LOW COST TURBOPUMP STUDY FUEL

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NET DOLLARS

**SAUOH NAM** 

69-15-011

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11 T.A.

يتستحد وتعاريوا

OT

TOTAL DOLLARS

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ΟT

C+A AT 14.25% *

TO 554 52.52

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OPERATION
ITEM NO.
PN 1136930

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#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS PARAGON

WHE PATAR T	URRINE #1	Г		AN HOUR	<u></u>	RATE	NE	T DOLLA	RS	DLO	) AT 260	/ ₆ *	G + A	AT 14.	25% *	TOT	AL DOLL	RS
NAME ADIONIT			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES	CONSULTING	HRLY SAL																74/7
2. PROCUREMENT PL	ANNING	SAL	15.0	2.0	10	6 96	10490	1392	696	27/44	3619	1819	53 56	7/4	357	42940	5725	2893
3. TOOLING		HRLY SAL					10.575						19463	• • • • • •		1/97 <u>63</u>		
4. RAWSTOCK FO.	RBING	HRE#					750∞	.525œ	47.500				106 💵	7 <del>4<u>8</u>1</del>	6769	85628	5 79 21	5 42 69
5. CASTINGS OR FOR	RGINGS	HRLY SAL																
6. MACHINING	LATHE MILL	HRLY SAL	600 25:0	47.9	4.3.7 17.9 7.6	// <u>95</u>	115915	9/ <u>59/</u>	82652				16518	13052	//77₽	/ 324 <u>74</u>	1046+3	944 <u>20</u>
7. <b>WELLING</b>	DRILL PANTOGRAPH CUTTERS	HRLY SAL	125.0	43.6 7.9 47.3	84.1 7.1 42.8	9 <u>15</u>	178425	140919	127255	<u> </u>			25426	20090	181 34	2038至	1610 69	/45381
8. <b>ASTAN FARME</b>	VENDOR INSPECTION	HRLY SAL	15.0	11.9	10.7	11 <u>30</u>	16959	13430	12093	<u> </u>			24 <u>15</u>	1914	1722	193 • 5	/5394	13816
9. CLEANING		HRLY SAL													ļ	ļ		
10. Q C PLANNING		HRLY													ļ		<b></b>	
11. INSPECTION, SO	URCE	SAL	15.0	7.5	50	696	10400	5220	3430	27040	13572	90 <u>4.8</u>	5335	2675	1785	427 75	2/470	/43/3
12. INSPECTION, PEC		HRLY	2.0	1.0	1.0	4 <u>87</u> 696	974 2088	4 <u>87</u> 3 <b>43</b>	4 <u>87</u> 348	25 <u>34</u> 54 <u>29</u>	12 <u>66</u> 9 <u>05</u>	1266 9_05	15 71	<u> 4 28</u>	428	125-34	34-34	3434
13. INSIDE LIAISON		HRLY	1	<u> </u>	1											ļ		<b></b>
14. SHIPPING	<u> </u>	HRET SAL	†				5000	4000	4000				7/3	.5-20	570	5712	45 20	45 20
15.		HRLY	1				_								 		<b></b>	ļ
16. :		HRLY	1		1		-	1						ļ				
·.	TOTAL UNIT COST			+	1	1	4157 92	309942	2785_//	-		TCCLING	1199 63			p45392	13/62 20	.puso 🖬
* MIDPOINT OF EFFO	RT - JAN '71			- <u>4</u> -	NET OP	DOLLARS	x PERCE	NTAGES HOUSE)					OP RAT	TE AT \$1 SE RATE	.2.00/HR AT \$4.8	* 7 <i>/</i> HR (HR	LY) *	`

100 mg

Sec. 2

EWSULLIVAN X7872

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	ITEM NO. 7					LOWC	FU OST TU NIT COST	EL IRBOPU I (BASE (	MP STU	IDY						•		
~	PN //30/3/					Ū	COST	ANALYSI	s <i>PA</i>	RAGON								
ر ر	NAME ROTOR, TURBINE #2		<u> </u>	MAN HOU	RS	RATE	NE	T DOLL	ARS	DL	0 AT 260	)% *	G +	A AT 14	.25% *	TOT	TAL DOLL	ARS
			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
-	1. ADVANCE QUOTES/CONSULTING	HRLY	1				}											
-	2. PROCUREMENT PLANNING	HEL-	15.0	2.0	1.0	696	10440	1392	6 26	27/44	3619	1810	यः	7/1	357	4294.	5725	<b>Z86</b>
-	3. TOOLING	HRLY			<b>x</b>	•. • •••	1050						14963			11996]	·	
-	4. RAWSTOCK	HRLY							1		1					1		1
-	5. CHARGE FORGINGS	HREN SAL-					7.5000	.525 œ	47500	2			10673	74 81	6769	B56 #1	5-99 <u>-</u>	. 542
-	6. MACHINING MILL	HRLY SAL	25.0	47.9 20.1 8.6	43.7	11 95	115915	915 <u>91</u>	8265				165 <u>18</u>	13052	117 78	192436	104641	744
-	7. WERANC CUTTERS	HREY SAL	135.0	97.0 7.2	107.9 6.5 42.3	915	1922	1509 7	1367 55		—		27395	2/5 <u>/5</u>	194 🎫	219632	17242	156Z
$\supset$	8. SEVENDOR INSPECTION	HREY Sile	150	11.9	10.7	11 30	16950	13430	12093	<b></b>			24 <u>-15</u>	1914	1723	19365	15344	138
-	9. CLEANING	HRLY				1	-									1		1
]	10. Q C PLANNING	HRLY			1		1		1									
1	11. INSPECTION, SOURCE	SAL	150	7.5	5.0	6 96	10400	5220	3400	27040	135 72	90 <b>4 B</b>	5335	2671	1725	42725	21470	143
-	12. INSPECTION, REC	HRLY	2.0	1.0	1.0	4 87	974	4 <u>87</u> 349	437	25 ¥ 5421	1266 705	12 <u>66</u> 9 <u>05</u>	15 71	422	432	12524	3421	342
	13. INSIDE LIAISON	HRLY			1.0													
 ]	14. SHIPPING	HARDY SAL					5000	4000	4000				7/3	570	570	5712	4529	45Z
]	15.	HRLY			1				<b>†</b>									
	16.	HRLY			1	1			1									
-	TOTAL UNIT COST			1	1	1	4290	3199 47	2880 11			TOOLIN	G	1199 <u>63</u>		52/022	3876 KL	3437
	* MIDPOINT OF EFFORT - JAN '71			<b>8.</b> 200.100	NET OP D ABOVE =	OLLARS X	PERCEN	TAGES OUSE)					OP RAT	E AT \$12 E RATE A	.00/HR	AR DIRL	<b>Y) +</b>	

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10-30-69

#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (EASE CASE) COST ANALYSIS LAMCO INDUSTRIES

$\bigcirc$			ATAR	<u> </u>	MAN HOLL	25	RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	G + /	A AT 14.	25% *	тот	AL DOLLA	RS
	NAME BULT. TUT	NTITY	6 P a	·	1 10	40	PER HR	1	10	40	1	10	40	1	10	40	1	10	40
				, <del></del>			[												
	1. ADVANCE QUOTE	SCONSUL	TING SAL								ļ								
	2. PROCUREMENT F	LANNING	HRE SAL	60	1.0	.5	696	41 <u>76</u>	6.96	343	1085	1810	905	2/12	357	179	15939	2863	/4.12
-	3. TOOLING		HRL	Y	-				-NON	F									
•	4. RAWSTOCK		HRL SAL	Y				3600	2400	21 <u>60</u>		·	L	513	3 42	3 <u>08</u>	4/12	27 12	24_68
•	5. CASTINGS OR FO	RGINGS	HRL	Y															
	6. MACHINING	<u> </u>	HRL SAL	Y 15.0	8.50	7.0	1200	18000	102.00	84 <u>00</u>				25.65	14 54	1197	20560	11654	<i>45 ¥7</i>
-	7. WELDING	· *-	HRL	Y															
$\mathbb{C}$	8. ASSY & FAB QE		HRL SAL	Y											ļ	ļ	<b> </b>	 	
	9. CLEANING		HRL	Y											ļ	ļ	ļ		
	10. Q C PLANNING		HRL	Y										1,38	125	125	1003	10 03	1003
			HRL	Y .5	.5	.5	487	244	244	244	634	634	6 34	1 22	53	53	1932	421	427
	II. INSPECTIONIAL	<b>L</b> .	SAL	5	.15	.15	696	35	104	104	9 03	220	1010	7/4	x 36	357	5725	12 24	1863
	12. INSPECTION SO	URCE	SAL	¥ 2.0	1.5	1.0	6 96	/393	1344	696	36 29	2/14	18.5						
	13. INSIDE LIAISON		HRUSAL	.Y				_			<u> </u>	ļ	<b>_</b>	<u> </u>		<b>}</b>			
	14. SHIPPING		HRI	Y				- 360	2 04	168				51	29	24	4	233	122
	15.		HRI SAI	-Y											ļ		ļ	<b>_</b>	
· _	16.		HRI	Y								<u> </u>		ļ	ļ	<u> </u>	1015		178 07
		TOTAL	UNIT COST X 6	ea	-			28120	1489	2120	2				1		44/ L		
	* MIDPOINT OF EFF	ORT - JAN	'71			NET OP ABOVE	DOLLARS = NET DOL	x PERCE LARS (IN	NTAGES					OP RA	TE AT \$1 SE RATE	2.00/HR AT \$4.8	* 7 <i>/</i> HR (HR	LY) *	
									EW	SULLIV	AN X	7 <b>872</b>		÷ .	• • • • • • • • • • • • • • • • • • •	, · · <b>·</b>			

380 OPERATION ITEM NO. 20 PN_//36932

CONTRACTO

LOW C U	<i>FUE</i> VCOSTTUR UNITCOST( COSTAN	لا BOPUMP S1 BASE CASE) IALYSIS	udy ( <i>prrad</i> i	oni)	- 11-	-6-69					
RATE	TE NET	DOLLARS	DL	0 AT 260	*/. *	G + /	AT 14	25% *	тот	AL DOLL	ARS
PER HR	HR 1	10 40	1	10	40	1	10	40	1	10	40
6.96	6 104 40 1	1392 69	27/44	3619	18:0	536	7 <u>/4</u>	357	4274.0	5725	2863
<u> </u>	- 12502					:4 <u>963</u>	•		119963	·	
	— 1000 <u>∞</u> :	70000 6255	∞			14250	9 <u>975</u>	89 05	114250	79925	71406
1195	<u>5 65725</u> 5	18 <u>48</u> 464	∞			<u>9366</u>	73 <u>88</u>	6612	750 <u>91</u>	59236	53012
9 <u>15</u>	E <b>876 7</b> 0 7	07 <u>37</u> 633 <u>0</u>	5			12773	10020	90 <u>21</u>	10244	808 I I.	72320
11 <u>95</u>	<u>5</u> 442 <u>15</u> 3	48 79 3/2 1	<u>ج</u> ا			6301	49 <u>70</u>	44 18	505 10	378 <del>4</del> I	356.63
9 <u>/5</u>	5 494-103	87 <u>78</u> 3488	<u>ne</u>	·	—	70 <del>4</del> 1_	53°£	49 <u>11</u>	56451	44512	398 52
11.30	<u>10</u> 1.35 <u>60</u> 10	06 <u>97</u> 95	<u> </u>			1932	1524	1364	15492	122 21	97 <u>09</u>
696	<u>6</u> 104 <u>00</u> 1	1720 342	<u>°</u> 270 <b>* •</b>	135 72	9048	533 <u>5</u>	2673	1785	42775	2/479	M312
4 <u>81</u> 6 <u>96</u>	2 7 <u>7</u> 4 6 20 <u>33</u> -	4 <u>87</u> 4 <u>37</u> 3 <b>11</b> 3 <b>1</b> 8	25 <u>31</u> 54 <u>21</u>	12 66 9 <u>05</u>	1266 9 <u>05</u>	15-71_	429	422	12531	34.55	34.04
				ļ							
<b>—</b>	50004	7000 400	•			7/3	520	5 70	5712	4570	45 24
	65 <u>00</u> 5 60 <u>00</u> 4	7 <u>29</u> 45 8 7 <u>23</u> 42 <u>3</u>	E			17 <u>31</u>	14.55	1251	142 1	10002	8781
	+039 <u>3</u> 2	9841Z2657	"	<u> </u>	TOOLING	V199 <u>6</u> 3			<b>D.S.T.S.</b>	JAN AL	
	XOLLA NET I	4037222 XOLLARS X PERCENT	AD37322784422657. XOLLARS X PERCENTAGES NET DOLLARS (INHOUSE)	A037222994422265711	A03722 298412 265711	A03722 298412 265711 TOOLING XOLLARS X PERCENTAGES NET DOLLARS (INHOUSE)	AD3732 278412 265711 TOOLING 1199 43 XOLLARS X PERCENTAGES OP RAT NET DOLLARS (INHOUSE) INHOUSE	#03732327844Z     265711     TOOLING 1197 £3       XOLLARS × PERCENTAGES     OP RATE AT \$12       NET DOLLARS (INHOUSE)     INHOUSE RATE 1	#03732278#12         2657!!!         TOOLING /197 £1           XOLLARS x PERCENTAGES         OP RATE AT \$12.00/NR           NET DOLLARS (INHOUSE)         INHOUSE RATE AT \$4.87	#037322         2784422         265711         TOOLING /19943         532442           XOLLARS x PERCENTAGES         OP RATE AT \$12.00/MR *           NET DOLLARS (INHOUSE)         WHOUSE RATE AT \$4.87/MR (HML	403732         278412         265711         700LING /19943         53249         36821           XOLLARS × PERCENTAGES         OP RATE AT \$12.00/MR *         HHOUSE RATE AT \$4.87/MR (HMLY) *

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	C	E CASE	ISA8) 1	LSO	D TINU	
,	auts	dWNd	10891	ΠI	1500	<b>W</b> 0

AIDPOINT OF EFFORT	<u>TL, NVC - 1</u>				AD T 3N ABOVE =	NET DOL	LARS (IN	ITAGES					INHON	SE RATE	8.42 TA	า <b>8</b> н) 8н∕∠	¥ (A	
ī	TOTAL UNIT COST		1		T		52 202	TOUR	55/1				1		=====			
	7S 3H	צער אגרא							3322	ł						22 278	9209/	152.50
	۲S ۱H	SAL HRLY	1				+											
SNIGGIHS	۲ <u>۶</u>	באר <u>ארי</u>					= 7											
NOSIAL AGIENI	A2	A ION	1					1 20						72	TE	325	721	721
INSPECTION SOUNC	dh ∀S <b>3</b> 2	01 7VS	01	<u>ę</u> :	9.	309	5.9											
	A 2	אר   · <i>ב</i>	2	5/ '	- 5/.	0 0		25-	2/2	5181	800/	2891	158	<u></u> 232	<b>₹7</b> 8	E988	2986	<b>1</b> 721
NULIJEDSNI	<u>ан</u>		2	<u></u>	، ک	18+	500	+0/	40/ 55X	306	02 2	018	<u><u> </u></u>	2.2	23	28 #/	124	Tet
Q C PLANNING	А2 А2	צער אגרא								DC 1	76 /	<u>ÞE 7</u>	521	521	521	<u> 2001</u>	<u> 50 0/</u>	<u> EOQ/</u>
CLEANING	ЯН A2	SAL HRLY																
ASSY & FAB QE	A2 А2	אר אשרא	1															
METDING	AR A2	פער זארע	1															
MACHINING	IAR IAR	SAL 100	00	2.5	58	00 21		507	00 2t		· · · · ·							
CASTINGS OR FORGIN	IAH IAS 2001	פער וארא											0121	220	66_3	31221	5589	5514
RAWSTOCK	IAR IAR						0098	5400	77/2				770					
TOOLING	JA2	אר. אר							700					702	202	EITO	772	89 00
······									100-									
	SNINN	5.4.	.ي	6	<u>∠.</u>	909	<del>7</del> E /E	¥29	184	2012	2291	JJ 21	20 91	525	058	72821	39.57	EOOT
ADVANCE QUOTES/CO		ער וארא														<b> </b>	1	
		t	t	στ	40	РЕ В НВ	ī	στ	07	τ	TO	07	τ	70	40	T	οτ	10
NE BINE USHENN	JAU22-20W PRESSURE	3	IAM	NU HOURS	S	<b>BTA</b> R	. BN	VITOO J	S	DIC	092 1V	*	<del>V + 0</del>		× % 57		ור ההרדעו	

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¥	MIDPOINT OF EFFORT - JAN '71			l		× SBATIO	PERCEN	SES					TAS 90	E AT \$12	AH/00.	*		
	TOTAL UNIT COST	15					52 +20	TI 621	EE 901					9.11703.1	TE ILI	E0 886	77 56/	385/
91	•	אר אארא																
s٦	•	רצער אנגר∧																
74	SHIPPING	רצער אצר∧					5 00	051	001				15	77	<b>₽</b> 7	52 2	721	मा
٤٦	NOSIDE LINISON	אר אארא																
75	. INSPECTION , SOURCE	T∀S Man	04-	8	<b>9</b> .	30 9	369	255	37 +	5781	8841	2801	2.5 8	232	まって	E = 88	EFEE	711
τt	INSPECTION, AEC	AL SAL	ک و	<i>، ای</i>	. <i>اک</i>	55 9 784	₹≠ £ 70 Z	701 701	70/ 74%	50 6	52 2	522	52/	23	23	TE #/	77+	<b>z</b> +
στ	QCPLANNING	אר אארא															AV X ć	
6	. כרבעאואנ	ר אררא														·		
8	. ASSY & FAB QE	אר אארא																
Ľ	. WELDING	אר אוורא																
9	. WYCHINING	אר אגרא	0.21	۶Z	09	15.00	<u>.</u>	509b	50 Z L				2502	15 83	9201	23 6 9/	E820/	z 78
S	CASTINGS OR FORGINGS	אר אוורא							_									
<b>'</b> †	. RÀWSTOCK	ראג אארא					<u>05</u> +20	<u>5355</u>	<u>52</u> 02				<del>20</del> 7	278	<u>3 62</u>	<b>77</b> 62	1292	न्दर
٤	. TOOLING	אר אצרא					55051	-					25/2			TE ILI		
z	PROCUREMENT PLANNING	T∀S	_S'#	Ь.	Ľ.	70 9	TE IE	<del>7</del> 29	18 4	TI 18	न्ह <b>१</b> /	<del>3</del> 9 2/	209/	330	73 T	7887/	••5E	-08
τ	. ADVANCE QUOTES/CONSULTING	נער אוצרא																
I	NA MA THING ONNE TUN AN AN	JUNSS	T	100H NAN	40 S	ААТЕ ЯН ЯЭЧ	T ƏN	100 T	<b>4</b> 0 82	ד 10	10 0 V 1 500	0 <b>1</b>	T + 9	10 14	<b>₩</b> 0	t	01	40

OPERATION

# LOW COST TURBOPUMP STUDY

69-18-011

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10-31-69

OPERATION ITEM NO. 27 PN_//36904

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#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMOCO INDUSTRIES

. )		E-WCH PRESSIRE		AAN HOLLE		RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	G + A	AT 14.	25% * _	тот	AL DOLL	RS
	NAME THING. UNIT IL		1	10	40	PER HR	1	10	40	1	10	40	1	10	40	1	10	40
	1. ADVANCE QUOTE	SCONSULTING SAL	/															
-	2. PROCUREMENT	PLANNING SAL	4.5	.9	۰7	696	3/ <u>72</u>	624	4 <u>37</u>	8/43	1622	12 66	16 07	330	250	/28 22	2566	2093
-	3. TOOLING	HRLY SAL	/			<b>e</b>		NO T	، ۲ ت ت	NG-		->					· ·	
-	4. RAWSTOCK	HRLY	1				67 <u>50</u>	45 <u>00</u>	4050				9 62	6 41	5_77_	77_12-	5141	4621
-	5. CASTINGS OR FO	DRGINGS HRLY SAL													ļ			
-	6. MACHINING	HRL' SAL	12.0	8.0	6.0	12 00	1440	9600	72 <i>∞</i>				2052	13 67	1026	/64 <u>52</u>	102 •8	842
-	7. WELDING	HRL' SAL										[	 		<b> </b>			
<u>с</u> -	8. ASSY & FAB QE	HRL' SAL								ļ			<b> </b>					
-	9. CLEANING	HRL	Y							ļ			 		<b> </b>	<b> </b>		
-	10. QCPLANNING	HRL	Y						2.44	6.34	134	1.34	125	125	125	1003	1001	7003
•	11. INSPECTION,	EC HRL SAL	Y .5 .5	·5 ·15	.5 15	4 <u>87</u> 6 <u>96</u>	2 <del>4 4</del> .3 <del>4</del> 3	104	104	9 05	2 70	2 70	1 79	53	53	14 32	422	4 22
-	12. INSPECTION, SC	DURCE SAL	1.0	·8 ⁷	.6	696	696	552	413	1819	14 43	10 32	354	22	2.13			
	13. INSIDE LIAISON	HRL SAL	Y				_	ļ		<b>_</b>	ļ	<b> </b>						1/4
	14. SHIPPING	HRL SAL	Y				200	150	100	<u>                                     </u>	—–		21		-14		/ <u>//</u>	↓ <u>·</u>
	15.	HRL SAL	Y					·	ļ	<u> </u>	<b>_</b>		ļ			<u> </u>	<b> </b>	<b>_</b>
~	16.	HRL SAL	Y										<u> </u>			42573	2/8 31	18119
		TOTAL UNIT COST					2572	9/5729	12605	·	1	1	1	<u> </u>	<u></u>			

EW SULLIVAN X 7872

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NAME <u>NUT: RING ONFICE-HIGH PRESSURG</u> 1. ADVANCE QUOTES/CONSULTING 2. PROCUREMENT PLANNING 3. TOOLING 4. RAWSTOCK 5. CASTINGS OR FORGINGS	HRLY SAL HRLY SAL HRLY SAL HRLY SAL HRLY SAL	N	10	<u>40</u> رح	RATE PER HR		T DOLLA	RS 40	DL 	0 AT 260 10	% * 40	G + /	A AT 14.	25% *	TOT	AL DOLL	ARS
1. ADVANCE QUOTES/CONSULTING 2. PROCUREMENT PLANNING 3. TOOLING 4. RAWSTOCK 5. CASTINGS OR FORGINGS	HRLY SAL HRLY SAL HRLY SAL HRLY SAL	1 6.0	10 /. <i>O</i>	<u>40</u> رح	PER HR	1	10	40	1	10	40	1	1 10	40		1 10	I
2. PROCUREMENT PLANNING 3. TOOLING 4. RAWSTOCK 5. CASTINGS OR FORGINGS	HRLY SAL HRLY SAL HRLY SAL HRLY SAL	<b>6</b> .0	1.0	.5	696	t											40
3. TOOLING 4. RAWSTOCK 5. CASTINGS OR FORGINGS	HRLY SAL HRLY SAL HRLY SAL	·				4176	696	3 🛃	10851	1810	9 <u>05</u>	2/12	557	127	15737	219	/4 <u>32</u>
4. RAWSTOCK 5. CASTINGS OR FORGINGS	HRLY SAL HRLY SAL	<u> </u>	<b>.</b>			4505		·				6413			514.13		
5. CASTINGS OR FORGINGS	HRLY SAL					15600	10400	9360				22 22	1432	13.34	17823	//8 <b>C</b> L	106 20
		<u>.</u>															[
6. MACHINING	HRLY SAL	20.0	12.0	10.0	12.00	24000	144.00	12000		—		3420	2052	17 <u>10</u>	27420	16452	197 <u>/0</u>
7. WELDING	HRLY SAL					L											 
8. ASSY & FAB QE	HRLY SAL																. <u></u>
9. CLEANING	HRLY SAL										<u></u>						
10. Q C PLANNING	HRLY SAL								10.66			4.50		4.52		1 7 91	7003
11. INSPECTION REC	HRLY SAL	1.0 1.D	1.0 .3	1.0 .3	4 <u>87</u> 6 <u>96</u>	4 <u>1</u> 6 <u>96</u>	209	4 <u>1</u> 2 <u>01</u>	1819	543	543	35L	102	107	28 63	851	357
12. INSPECTION, SOURCE	SAL	2.0	1.5	1.0	690	13 92	10 = 1	694	36/9	27/4	1810	7/4	536	351	5725	+22±	2861
13. INSIDE LIAISON	HRLY SAL														[]		ļ
14. SHIPPING	HRLY SAL					4 <u>30</u>	2 31	2 40				62	11	.34	5-12	3 29	2 24
15. ,	HRLY SAL																
16.	HRLY SAL																
TOTAL UNIT COS	ST				<u> </u>	468.31	275 24	233 20					TOOLING	p/ <del>4</del> /3	1254	336 14	

지금 성장 성과 공부 관계 이지 않는 것을 위해 지기 있는 것을 성과 성과 성과 문화 문화 문화

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OPERATION ITEM NO. 29 PN. //36 906 10-31-69

#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS LAMCO

	NAME VANE, DIFFUSER-PUMP		N	AAN HOUF	۹S	RATE	NE	T DOLLA	RS	. DL	0 AT 260	*	G + .	A AT 14	25% *	тот	AL DOLL	ARS
			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1	. ADVANCE QUOTES/CONSULTING	HRLY SAL																
2	PROCUREMENT PLANNING	SAL	1.5.0	2.0	1.0	696	10440	13 92	6 <u>9</u> 6	27/ <del>44</del>	36 19	1810	5356	7/4	357	429 <b>4</b> 0	5725	28 6 1
3	. TOOLING	HRLY SAL						-1250	<u></u> -			<b>_</b>	17 <u>3 12</u>			142812		
4	. RAWSTOCK	HRLY SAL					276 空	13° <u>4 00</u>	165 <u>60</u>				39 <u>2 2</u>	2622	2360	3/5 32	21032	189 20
5	. CASTINGS OR FORGINGS	HRLY SAL																
6	MACHINING	HRLY SAL	100.0	7.5.0	60.0	12 00	1200⊈	90000	72000				171 <u>00</u>	12825	102 00	137100	102825	822 60
7	. WELDING	HRLY SAL																
<u> </u>	. ASSY & FAB QE	HRLY SAL																
9	. CLEANING	HRLY SAL																
10	. Q C PLANNING	HRLY																
11	. INSPECTION REC	HRLY	1.0	1.0 .3	1.0 .3	4 77 6 96	437 696	4 <u>7</u> 7 2 <u>09</u>	4 <u>8</u> 1 2 <u>09</u>	12 66 18 1 <u>0</u>	12 <u>66</u> 5 <u>4</u> 3	1266 541	250 3 <u>57</u>	250	25 <u>0</u> 1 <u>07</u>	20 <u>03</u> 28 <u>63</u>	2003	20 <u>0</u> 957
12	. INSPECTION SOURCE	SAL	6.0	50	3.5	696	41 76	34 😎	24 <u>36</u>	10858	90 42	63 34	2/42	17 <u>#5</u>	1250	171 76	/43/3	10020
;13	. INSIDE LIAISON	HRLY																
14	. SHIPPING	HRLY					30 00	1800	1400				4 23	2 5 7	2 00	34 28	2057	1600
15	· · · · · · · · · · · · · · · · · · ·	HRLY																
<u>16</u>	·	HRLY																
•. •••••	TOTAL UNIT COST			Γ			1663 1	15763	ମ୍ଫ୍ରମ ଅ					TUULING	14281	2370 2	147704	1/7522
*	MIDPOINT OF EFFORT - JAN '71			 /	NET OP D ABOVE =	OLLARS	PERCEN	TAGES OUSE)		•			OP RAT	E AT \$12 E RATE /	2.00/HR AT \$4.87	* //HR (HRL	<b>Y</b> ) *	

	* (A	אש (אשר). י	78. 22 T	512 TA 3 1 3 TAN 3	TAN 90 RUOHM					CORE)	ARS (INH PERCEN	NET DOLL	1807E = 1 1907E = 1	1			DINT OF EFFORT - INN VI	401W +
1775				785801	SNITOGI				50885Z	168055	To 81/11						TOTAL UNIT COST	
7				<u></u>												A JAS HRLY		.91
	-															ARLY SAL		٢ <b>٤</b> .
<b>T</b>	TT AL	1071	726	<b>5</b> .66	1517				<del></del>	<del></del> 01	<del>50</del> 06						DPING	IHS 'PT
																S≱ר אוגרא	NOSIAI JU	SNI 'ET
<b>114</b>	<del>4</del> 45	<b>TR 57</b>	オモタ	Te+	TI SI	<u> </u>	304 7921	5745 Fr 52	77 E 77 D	TE U	7202 526	967 [26	`ک ۷۷	. بحر 01	02 02	ארא אפרא	PECTION REC	TS' INZ
3715	72458	15881	TFIL		10091	73/98	Te 24.5	<b>ZE+18</b>	न्ह ७६/	20856	57818	<b>5</b> 59	002	300	0:54	J⊿S N	DECTION SCORECE	SNI 'TT
	E 9605	13569	FTLS	<b>3</b> 389	7302				7007	20940	00 595	JE //	32:2	_5 %E	0.05	T∀S	NOLIJJJJSNI VOLIJNA UKANOG	70° 🕶
27622	72115	5014	<del>02</del> 26	30L+	3565				<del>7</del> 8 %Z	TZCEE	52814	56 //	2.01	8:51 8:11	500 1200	THES LETTER	S JUL XUN XUNES	<b>ma</b> .6
	Fr 9862	₩881L£	TIGE	73 992	FE E9+				TZ /10/	\$3.5311	50_52+1	75 k 57 b	5.701	+ · 811	ופטים בנטים	3865 1155174	HIRE BENGH	<b>27</b> .8
AZ 429	E.OOL	++188	3584	TEL8	5011				¥2155	<b>F</b> 2 <i>č</i> /9	52922	36/1	7.01,	2.11 S.BE	اي:0 حص	TWS.	שורר כרתעבא דתפי שורר פשכע גשאב	<b>BM '</b> L
<b>3</b> 5 1293	389162	Q5 16 92	EO L CE	TEEPE	TE-09+				<del>E6</del> +622	355552	52 55 25	366	2.71	2.91 P. 22	0:5Z 0:005	ALLY HRLEY	CUTTERS	19 <b>- 1</b> 9
<b>53666</b>	596111	256651	53621	39681	<u>0</u> 364				00_518	·0086	1000ti					<b>Z₩E</b> HBFTA	SONIDA CORGINES	<b>. '</b> S
59 9ZL	77-808	732701	<del>7</del> 906	EE 001	-7121				_50 X?	551.9L	32968	5011	2.01	2.61 8.11 9.12	0:51 12:0 15:0	TTS	LINKA LOW & CONLONG LINK LOW BYCK BILL	<b>1983 - 1</b> 7
· · ·		1285801			57 8 58/	1					151.5%					ראר אצרא	FING	<b>з</b> , тос
75 24	n.58	5321.5	नाः ऽ	7201	TUIL	TT/LZ	1705	₹ <b>5</b> /9E	<del>55</del> 81	88 02	02681	957	51	0 [.] E	072	N∀S	CUREMENT PLANNING	2. Р КС
																5∀F HBLY	VNCE GUOTESCONSULTING	J. ADV
01	στ	τ	07	ΟT	t	40	ΟT	τ	40	στ	τ	РЕ В Н В	40	OT	τ			
Sal	יר מסררי	101	¥ %\$Z	.≱T TA	V + 9	¥ %	092 14 0	םרס	SE	שאררא	. IN	BATE	S	AUOH NA	W	]	สพกส ี่ ชวาาวิสพท	<b>JM AN</b>
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UNIT COST (BASE CASE) LOW COST TURBOPUMP STUDY

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# ITEM NO. 31 PN_1136908

OPERATION

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### *FUEL* Low cost turbopump study UNIT COST (BASE CASE) COST ANALYSIS (PARAGON)

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N/	AME <u>INDUCER, PUMP</u>			AN HOUR	RS	RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	G +	A AT 14	25% *	TOT	AL DOLL	ARS
1.	ADVANCE QUOTES/CONSULTING	HRLY SAL	1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
2.	PROCUREMENT PLANNING	SAL	15.D	2.0	1.0	696	104 40	1392	694	27/44	3619	1810	5356	7 <u>/4</u>	357	42900	5725	2863
3.	TOOLING	HRLY SAL	·				+2012	•					578 <u>50</u>			4798 <u>50</u>		·
4.	RAWSTOCK	HRLY SAL							1		1		<b></b>			<u> </u>		1
5.	CASTINGS OR FORGINGS	HRLY SAL					100000	70000	6250	_			14250	99 <u>75</u>	3906	114250	79975	7/4
6.	TURN FOR GEN MACHINING TURN FOR SPLINE FINISH TURN + CONTOUR	HIRLEY SAL	<b>40</b> 0 200 250	47,4 15.8 19.7	42.1 14.0 17.5	11 <u>95</u>	1254 <u>75</u>	74154	<u>880 oi</u>				17880	14243	12540	/4 <u>35-55</u>	1141 <u>97</u>	100541
7.	ROUGH GEN WELONG YANE GENERATION / DUP CUTTERS	HRLEY SAL	100.0 125.0 15.0	7£.4 9£.7 11.8	70.1 87.7 10.5	9 <u>95</u>	238899	189516	138800				340.21	263 <u>6</u> 4	197 <u>79</u>	272829	215320	1525 2
8.	KEYS & TOULING HOLE	HRLEY Sale_	570 2010	3•9 15-8	3.5	11 <u>95</u>	29875	<b>2</b> 35 ⁻ 24	209 <u>53</u>				4257	3361	29 <u>86</u>	341 32	26945	23939
9.	STEANING SET UP & CUT SAMPLE TRACK	MRUN Sail	100.0	75.9	78.1	9 <u>50</u>	75099	749 <u>96</u>	66623				13532	10637	94 <u>44</u>	108533	85323	76122
10.	GEOGRAMMIC BENCH	HRLEY Sal	80.0	63.2	56.1	9 <u>15</u>	73200	57736	5/3 <b>39</b>				10431	<del>8</del> 2 <u>35</u>	73.16	836 <u>31</u>	660 <u>21</u>	58655
11.	INSPECTION, SOURCE	SAL	30.0	10.0	7.0	696	20882	6960	<u> 1812</u>	5 <b>4</b> 2.68	180 94	126 <u>67</u> .	1071	35 ZO	24 99	8 <i>58 1</i> 1	28624	20033
12.	INSPECTION , REC	HRLY SAL	2.0 3.0	1.0 .5	1.0 .5	4 <u>87</u> 6 <u>96</u>	9 <u>74</u> 20 <u>88</u>	4 <u>87</u> 3 <u>41</u>	4 <u>11</u> 3 <u>+</u> 1	2532 5421	12 <u>66</u> 9 <u>0 5</u>	1266 7 <u>05</u>	15 71	4 <u>23</u>	428	125 🗮	34-34	3439
13.	INSIDE LIAISON VENDOR INSPECTION	HREN Sat	25.0	19.7	17.5	1130	282.50	223 <u>01</u>	196 <u>13</u>				4026	3/70	2823	822.76	254 79	226 <u>36</u>
14.	SHIPPING	HRLY SAL					5DC	4000	4000				7/3	570	5 70	5712	<del>1</del> 5 ⁻ 20	45_20
15.	DUTSIDE THREAD GRIND PRODUCTION SPLINE	HAREY SHE			·		125 25 100 00	93 <u>68</u> - 7 <u>9 44</u>	87 <u>9</u> 7 70 <u>/4</u>		_		32 06	25 <u>2</u> L	\$7.11	2570	2 02 93	120 30
16.		HRLY SAL																
	TOTAL UNIT COST						7.52432	5680 <u>86</u>	4742/3				TURING	479850		76/9 23	676321	5208/3
	N 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 15. 16.	NAME <u>INDUCER, PUMP</u> 1. ADVANCE QUOTESCONSULTING 2. PROCUREMENT PLANNING 3. TOOLING 4. RAWSTOCK 5. <u>CARETHING OF</u> FORGINGS 4. RAWSTOCK 5. <u>CARETHING OF</u> FORGINGS 6. MACHINING TURN FOR GEN 6. MACHINING TURN FOR GEN 7. WELGING VARE GENERATION / DUP CUTTERS 8. ASSN - FAD QE TRIM PARTIALS 9. CLEANING SET UP & CUT 9. CLEANING SET UP & CUT 9. CLEANING SET UP & CUT 10. COCCUMENTS BENCH 11. INSPECTION, SOURCE 12. INSPECTION, REC 13. INSIDELIAISON VENDOR INSPECTION, REC 14. SHIPPING 15. OUT SIDE THREAD GRIND PRODUCTION SPLINE 16.	NAME     INDUCER, PUMP       1. ADVANCE QUOTESCONSULTING     HRLY SAL       2. PROCUREMENT PLANNING     HRLY SAL       3. TOOLING     HRLY SAL       4. RAWSTOCK     HRLY SAL       5. SASTINGS DE FORGINGS     HRLY SAL       6. MACHINING TURN FOR SEME FINISH TOR FOR SEME SAL     HRLY SAL       7. WEIGHING VARY FOR SEME FINISH TOR FOR JOUR     HRLY SAL       8. ASSWE FAD QE TRIM PARTIALS     SAL       9. GLEANING SET UP & CUT SAMPLE TRACK     HRLY SAL       10. CERSIONING BENCE INSPECTION, SOURCE     HRLY SAL       11. INSPECTION, SOURCE     HRLY SAL       12. INSPECTION, REC SAL     VENDOR INSPECTION       13. INSIDELIAISON PRODUCTION     VENDOR INSPECTION       14. SHIPPING     HRLY SAL       15. OUT SIDE PRODUCTION     THREAD GRIND MRLY SAL       16.     HRLY SAL	NAME     INDUCER, PUMP       1     1       1. ADVANCE QUOTESCONSULTING     HRLY       2. PROCUREMENT PLANNING     HRLY       3. TOOLING     HRLY       3. TOOLING     HRLY       4. RAWSTOCK     SAL       5. CONSTRUCT ON FOR GEN     HRLY       6. MACHINING TURN FOR SPLIE     HRLY       7. WELSHIGS ON FOR GEN     HRLY       8. MACHINING TURN FOR SPLIE     HRLY       7. WELSHIGS ON FOR GEN     HRLY       8. MACHINING TURN FOR SPLIE     HRLY       9. GLEANING     SATIALS       10. CONSTRUCT ON SOURCE     HRLY       11. INSPECTION, SOURCE     HRLY       12. INSPECTION, REC     HRLY       13. INSIDELIAISON     VENDOR       14. SHIPPING     THREAD GRIND       15. OUT SIDE     THREAD GRIND       16.     HRLY	NAME     INDUCER, PUMP     MAN HOUI       1. ADVANCE QUOTE SCONSULTING     1     10       1. ADVANCE QUOTE SCONSULTING     HRLY     1       2. PROCUREMENT PLANNING     HRLY	NAME       INDUCER , PUMP       MAN HOURS         1       10       40         1. ADVANCE QUOTESCONSULTING       HRLY       1         2. PROCUREMENT PLANNING       HRLY       -         3. TOOLING       HRLY       -         4. RAWSTOCK       HRLY       -         5. CASENDARE OR FORGINGS       HRLY       -         6. MACHINING TURN FOR GEN       HRLY       -         7. WELDING TORY FOR SPLME       SAL       20.0         7. WELDING TORY FOR SPLME       SAL       30.0         9. CLEANING       SET UP & CUT       SAL         9. CLEANING       SET UP & CUT       SAL         10. COLTANING	NAME       INDUCER, PUMP       MAN HOURS       RATE         1       10       40       PER HR         1. ADVANCE QUOTESCONSULTING       HRLY       10       40         2. PROCUREMENT PLANNING       HRLY       2.0       1.0       6.92         3. TOOLING       HRLY	NAME         INDUCER : PUMP         MAN HOURS         RATE         NE           1         10         40         PER HR         1           1. ADVANCE QUOTESCONSULTING         HRLY SAL         1         10         40         PER HR         1           2. PROCUREMENT PLANNING         HRLY SAL         5.0         Z.O         1.O         6.96         10742           3. TOOLING         HRLY SAL         -         -         42012         -         42012           4. RAWSTOCK         HRLY SAL         -         -         -         100000           5. EXECUTESCON FORGINGS         HRLY SAL         -         -         1000000           6. MACHINING TURN FOR GEN FORGING SENCE INVEST FORGINGS         HRLY SAL         25.0         17.4         42.1         1000000           7. WEEDING CONSTRUCT FOR SENCE INVEST FOOLING HOLE WEYS FTOOLING HOLE WEYS FT	NAME         INDUCER, PUMP         MAN HOURS         RATE         NET DOLLA           1         10         40         PER HR         1         10           1. ADVANCE QUOTE SCONSULTING         HRLY SAL         1         10         40         PER HR         1         10           2. PROCURE MENT PLANNING         HRLY SAL         15.0         2.0         1.0         6.92         106.42         1222           3. TOOLING         HRLY SAL	NAME         INDUCER : PUMP         MAN HOURS         RATE         NET DOLLARS           1         10         40         PER HR         1         10         40           1. ADVANCE QUOTESCONSULTING         HRLY SAL	NAME         INDUCER, PUMP         MAN HOURS         RATE         NET DOLLARS         DL           1         10         40         PER IR         1         10         40         1           1. ADVANCE QUOTESCONSULTING         HRLY	NAME         INDUCER , PUMP         MAN HOURS         RATE         NET DOLLARS         OLO AT 260           1         10         40         PER HR         1         10         40         1         10           1. ADVANCE QUOTESCONSULTING         HRLY SAL         -         -         10         40         1         10         40         1         10           2. PROCUREMENT PLANNING         HRLY SAL         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -	NAME         INDUCER         PUMP         MAN HOURS         RATE         NET DOLLARS         DLO AT 260% *           1. ADVANCE QUOTESCONSULTING         HRLY         1         10         40         1         10         40           2. PROCUREMENT PLANNING         HRLY         5.0         2.0         1.0         6.4 %         10         40         1         10         40           3. TOOLING         HRLY         -         -         -         4222         6.% 271.45         36.12         1.92           4. RAWSTOCK         HRLY         -         -         -         420.42         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -         -	NAME         INDUCER, PUMP         MAN HOURS         RATE         NET DOLLARS         DLO AT 260%.*         6+           1         10         40         PER HR         1         10         40         1         40         1           1. ADVANCE QUOTE SCONSULTING         SAL         -         -         -         -         -         40         1           2. PROCUREMENT PLANNING         TELET         /5.0         2.0         1.0         4.9%         /1.2%         6.4%         271.44         5.6.4         /7.2%         5.3 5%           3. TOOLING         HRLY         -         -         -         -         -         -         5.785%           4. RAWSTOCK         SAL         -         -         -         -         -         -         7.75%           5. GESTIMENTE FORGINGS         HRLY         -         -         -         11.25         /25425         -         -         .         /7.8%           6. MACHINING TURM FOR SOLU         HRLY         -         -         -         .         .         .         .         .         .         .         .         .         .         .         .         .         .         .	NAME         INDUCER.PUMP         MAN HOURS         RATE         NET DOLLARS         DLO AT 260%.+         6 + A AT 14           1         10         40         PER HR         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         11         10         40         11         10         40         11         10         10         10         <	NAME_INDUCER.PUMP       MAN HOURS       RATE       NET DULLARS       DUO AT 260% *       G + A AT 14.25% *         1. ADVANCE QUOTESCONSULTING       HRLY       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       10       10 <td< td=""><td>NAME_INDUCER.PUTP       NAM HOURS       RATE       NET DOLLARS       DUO AT 260% *       6 + A AT 14.25% *       TOT         1. ADVANCE QUOTESCONSULTING       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       10       10</td><td>NAME         INDUCER.PUMP         MAN HOURS         RATE         NET DOLLARS         DLO AT 260%*         C+A AT 14.25%*         TOTAL DOLL           1         10         40         PER HR         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         11         10         10</td></td<>	NAME_INDUCER.PUTP       NAM HOURS       RATE       NET DOLLARS       DUO AT 260% *       6 + A AT 14.25% *       TOT         1. ADVANCE QUOTESCONSULTING       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       40       1       10       10       10	NAME         INDUCER.PUMP         MAN HOURS         RATE         NET DOLLARS         DLO AT 260%*         C+A AT 14.25%*         TOTAL DOLL           1         10         40         PER HR         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         1         10         40         11         10         10

ABOVE = NET DOLLARS (INHOUSE)

INHOUSE RATE AT \$4.87/HR (HRLY) *

EW SULLIVAN X7872

	OPERATION ITEM NO. 32 PN. //36909			,		LOW C U	FUE OST T INIT COS COST	L URBOPU T (BASE ( ANALYSI	MPSTU CASE) S <i>LAM</i>	10Y DCO 1112	DUST RIC	5	/ 0 - 3/-4	9				<b></b>
$\bigcirc$	NAME NUT ASSY. IMPELLE	R RETAINING	[	MAN HOU	RS	RATE	N	ET DOLL	RS	DL	0 AT 26	0% *	6+	A AT 14	254 +	70		4.0.0
			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	IAL DOLL	ARS
	1. ADVANCE QUOTES/CONSU	LTING HRLY SAL	1													1	1	
-	2. PROCUREMENT PLANNING	SAL	6.0	1.0	.5	694	41 <u>76</u>	696	343	10752	1310	9.05	21-12	357	129	157 21	28.63	1432
	3. TOOLING	HRLY SAL					1509	<u>↓</u>				••	2138	·		17/29		
_	4. RAWSTOCK	HRLY SAL					660	4 40	3 26				94	63	56	754	503	453
_	5. CASTINGS OR FORGINGS	HRLY				1							·			-		<u> </u>
-	6. MACHINING	HRLY SAL	<i>9.0</i>	5.5	4.0	12 00	10800	<i>66</i> œ	48 <u>00</u>				15 39	941	634	12339	7541	54 24
_	7. WELDING	HRLY SAL			1						······································					1		
0	8. ASSY & FAB QE	HRLY SAL											•			<u> </u>		
-	9. CLEANING	HRLY SAL		1												<u> </u>		
3	10. QCPLANNING	HRLY SAL																
1	11. INSPECTION	HRLY SAL	.ح ح	.5 .15	.5	4 <u>2</u> 2 6 <u>96</u>	244 348	109	299	6 <u>37</u> 905	63£ 270	6 <u>34</u> 270	125	125	125	1002	1002	1007
ī	12. INSPECTION SOURCE	HALLY SAL	1.0	1.0	1.0	6 96	6 9.6	6 <u>96</u>	696	18 10	1810	1300	357	357	351	2302	2862	2793
į	13. INSIDE LIAISON	HRLY SAL					'											
1	L4. SHIPPING	HRLY SAL					200	150	100				29	21	.14	229	121	114
]	15.	HRLY SAL		[														
	16.	HRLY SAL														i		
· _ ·	TOTAL	UNIT COST		1			17124	0930	11.39					7011012	171 79			117 30

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E W SULLIVAN X 7872

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(				597	-550					- 000	- 220'0	77.1.1	170	5.41	47.4	- <b>1</b> ¥5	PICO INDETRIES	·c
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<u>88</u>	17501	07858	72.01	<u>58 []</u>	01601	02+5	E+96	02649	8805	0846.	<u>07802</u>		3.0	2:0	370			
																142 HRLY	ADVANCE QUOTES/CONSULTING	٦.
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**NET DOLLARS** 

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SAUOH NAM

(HOW O JWHT SISATENY 1500 (ANITZA) 231972UDNI 02219 (INIT COST (EASE CASE)

+569E11 Nd ITEM NO. 33 NOITARAGO

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LOW COST TURBORUMP STUDY

× %092 1¥ 070

69-8-11-

C+A AT 14.25% *

TOTAL DOLLARS

•	OPERATION ITEM NO. 34 PN_1136910					LOW CO	FU OST TU NIT COST COST	EL RBOPU (BASE C ANALYSI)	MPSTU ASE) Si∠_AM	DY: nco (m	ACH 1	r.	~10-	<b>4-69</b> 0 CAST	- ⁽ C.A.	STING	)	
1	NAME VOLUTE, PUMP HOUSING	[	N	IAN HOUF	۶s	RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	<u>G</u> +/	A AT 14.	25% *	тот	AL DOLL	ARS
			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1	1. ADVANCE QUOTES/CONSULTING	HRLY SAL																
2	PERFECTO 2. PROCUREMENT PLANNING	MREY	15.0	2.0	1.0	6.96	10440	15 92	646	27/44	36 19	1810	3350	714	357	42940	5725	28
	LAMCO	SAL	240	3.0	1.5		125-0	2088	1044	35152	5421	2714	6936 575 CC	1011	514	536 <u>03</u>	YSZI	421
3	3. TOOLING	SAL.	•				57.53						81.14	•		6.56**		
4	4. RAWSTOCK	HRLY SAL													-			
5	5. CASTINGS OPERATION	HRLY SAL	114.0	98.0	89.0	14 <u>00</u>	160000	137500	12500				22800	19591	/78 <u>/3</u>	182800	1570 92	MZE
ŧ	6. MACHINING (LAMCO)	HRLY SAL	140.0	80.C	700	12 00	163000	96000	840.00				239 40	136 20	11970	19194_0	1096 🔁	95
7	7. WELDING	HRLY SAL					· · · · ·											
	8. ASSY & FAB QE	HRLY SAL																
9	9. CLEANING	HRLY SAL																
10	10. Q C PLANNING	HRLY SAL															,	ł
11	11. INSPECTION SOURCE	SAL	80	5.0	5.0	6.96	5563	3480	3720	144 <u>71</u> 171049	, 91: <u>+1</u>	90 21	2756	1725	1785	229 <u>04</u> 427 <u>75</u>	143 <u>15</u> 21422	7 <b>73</b> 143
			<u>.5</u>	.5	.5	481	244	244	244	639	634	6 34	725	725	725	1002	7003	70
12	12. INSPECTION, AZE CARACTOR	SAL	2.0	1.5	1.0	6 96	1.292	1000	696	3619	27/4	18:2	7/4	536	3 E Z	5725	42 2 <u>4</u>	28
11	13. INSIDE LIAISON	HRLY		Į														
·	FERFECTO	MALE	•		<u> </u>		30 00	2500	2500				421	356	356	3471	2755	27
14	14. SHIPPING LAMCO	340-					5000	4000	4000				7/3	5 70	520	5713	45 20	15
15	15. INSPECTION, REC. (LAMCO)	HRLY SAL	10	7.0	1.0	487	411	431	411	7200	11 00	18:0	719	536	357	5725	42.24	199
16	16.	HRLY	2.2	<u>,                                    </u>	10	<u> </u>	<u> </u>											
	TOTAL UNIT COST	JAL		<u> </u>			3794 43	1549 9	226323			ZCLIN	¢	5231	24	5255	13579	2907
*	* MIDPOINT OF EFFORT - JAN '71			<u> </u>	NET OP D	ULLARS X	PERCEN	TAGES					OP RAT	E AT \$12	.00/HR	+ +		

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/11-4-69

OPERATION ITEM NO. * ASSEMBLE TURBOPUMP PN 1136900

(1) Z. 1767 (4)

N. N.

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#### FUEL LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

.

$\bigcirc$	N	AME TURBOPUMP ASSEMBLY		M	AN HOUR	s	RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	G + A	AT 14.	25% *	TOT	AL DOLLA	RS
				1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1.	ADVANCE QUOTES/CONSULTING	HRLY Sal																
•	2.	PROCUREMENT PLANNING	SAL	30	10	1.0	696	<b>2</b> 0 <u>88</u>	6 <u>9 6</u>	696	5429	1810	1819	1071	35I	357	85 E	2863	2893
•	3.	ROTOR LOCKS (IEACH END TOOLING (3 P) LEAK CHECK HIT (4 PLATES)	HRIEY SEE					700 <u>90</u> 400 <u>9</u>											
	4.	SHAFT PEITIONING FIXTURE REMATTORX TOOLING OF SPANNER WRENCHES(3)	HALEY Sinc		·			900°°						3/3 50	•		25/352		
-	5.	BUILD /UP CASTINGS OR FORGINGS STAND TOOLING (OP)	SHE	-				50000											
-	6.	MACHINING	HRLY SAL																
-	7.	WELDING	HRLY SAL																
$\square$	8.	ASSY & FAB QE	HRLY SAL	250	25.0	\$5.0	696	174 00	17400	174 <u>00</u>	452 40	452 49	45240	87 <u>26</u>	3926	3926	7/5 66	715 66	7/5 65
	9.	CLEANING	HRLY	16.0 3.0	10.0 Z.O	8.0	4.87	77 9 <u>2</u> 2011	48 <u>70</u> 13 72	38 <u>96</u> // <u>/ 4</u>	20259 5429	126 <u>e</u> 36 <u>19</u>	101 <u>30</u> 28 <u>96</u>	399 <u>4</u> 10 <u>71</u>	714	57	85 2	5725	45 <u>8</u>
	10.	(LOG BOOK)	HRET SAL	30.0	220	15:0	696	208-20	/53!2	10400	54283	39811	27/14	107 <u>11</u> _	7855	5351	BSB 12	62123	42905
	11.	INSPECTION	HRLY		+101.	+10%			161	129		417	335		83	66		663	530
	12.	INSPECTION, PERS	HRLY SAL	48.0 13.0	30.0 8.0	24.0	437.	2337 <u>6</u> 90 <u>48</u>	5568	4524	6077 <u>8</u> 23525	37936	303 39	4642	2856	2321	961 <del>2</del> 6 372 15	22901	18607
	13.	INSIDE LIAISON	SAL	600	38.0	30.0	696	41760	264 41	20830	1085 76	68765	542 28	\$14 <u>23</u>	13568	107.11	171752	10878	8582
	14.	SHITTEL PRADUCTION CONTRAL	SAL	12.0	12.0	12.0	696	8552	83-2	R352	2/7/5	217 <u>15</u>	217 <u>15</u> 1115	4285	4235	4235	34352	74352 2205	3435 176 <b>4</b>
	15.	ASSEMBLY LABOR	HRLY SAL	160.0	100.0	80.0	4.87	77920	48700	38760 16704	202572 B6861	26620	10129£ 434-39	399 <u>73</u>   7/32	24983	199569	320435 137407	2003 <u>0</u> 8587	68703
	16.	SHOP PLANNING (MFG. ENG.)	SAL	40.0	4.0	2.0	6.96	278 🛨	2784	1392	72384	10400	3619	14282	1879	7/4	11 45 94	15063	5725
		TOTAL UNIT COST						271952	1670-2	1360 44			ד ציצא	DOLING	251352		11/8534	20532	5575
-	*	MIDPOINT OF EFFORT - JAN '71				NET OP I ABOVE =	NET DOL	X PERCEN LARS (INI	TAGES					OP RAT	E AT \$12 SE RATE /	2.00/HR AT \$4.87	*** '/HR (HRL	+ <b>3.2</b> .Y) *	-51 -51

EW SULLIVAN X 7872

## APPENDIX I

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1. .

### BASE CASE OXIDIZER TURBOPUMP COST ANALYSIS

OPERATION						LOZ				- 11-	17-69						
ITEM NO. () PN_1/37010					LOW CO	OST TU NIT COST COST A	RBOPU (BASE C ANALYSIS	MP STU ASE) S	DY								
NAME HOUSING, BEARING	,	N	AN HOUR	 ₹S	RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	G + /	A AT 14.	25% *	TOT	AL DOLL	RS
········		1	10	40	PER HR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES/CONSULTING	HRLY Sal																
PERFECTO CAST 2. PROCUREMENT PLANNING LAMCO	HALA SAL	9.0 15.0	1.0 7.5	.7 5.0	6.96 6.96	62.6 <b>4</b> 104.00	6.96 52.20	4.87 34.80	/62.86 270 <b>:</b> +0	18:10 135.72	12.66 90. <b>48</b>	32 13 53, 75	3.57	2,50	257.63 427.75	2863	20¥ /43./3
3. TOOLING PERFECTO CAST LAINCO	HRLY SAL					250°	 		,		• ···	156.75 121.13	•		1256.75	·	
4. RAWSTOCK	HRLY SAL																
5. CASTINGS ON POREMOL PERFECTO CAST	HRLY SAL	7/.4	50.0	44.6	14.00	1000空	700≌	625.00	<u> </u>			142.50	99.75	89.06	//42.50	799.75	7/4.9
6. MACHINING TURN COMPLETE DRILL & TAP	SAL	40.0 40.0	30.8 30.8	26.4	11.95	47800 47800	363.06	3/5748 3/5.48				/36,23	104,*0	89.91	1092 # 3	paroz	120.
7. WEEDING MISC MILLING	HIREY SME	16.0	12.3	10.6	11.95	19/20	147.22	126.19				27.25	20.98	17.42	2/8:4-5	168,20	/ + + . '
8. BENCH	HREN Sale	20.0 12.0	15:4 9.2	13.2 7.9	9/3	13560	10.7.41	09.50				45.40	34.96	29.96	364.00	290.2	Z <del>4</del> 0.4
9. CLEANING	HRLY SAL		ļ			ļ		ļ							· · · ·		
LO. Q C PLANNING	HRLY SAL					ļ							1070	944	12022	25.88	773
11. INSPECTION BOURCE PERFECTO	SAL	4.5	3.0 7.5	2.7 5.0	6.96	31,32 62.64	20.88 52.20	18.79 34.80	81.43	34.24	48:55	32.13	26.78	17.85	257.63	2/4.70	143.4
12. INSPECTION REC (PERFECTO)	HRLY	.5 2	.5 1.5	. 5 1.0	4.87 6.96	2.4+ 13.92	244 10,44	2.44	6,34 36.19	6,3+ 27.1+	6.34	7.14	5.36	3.51	57.25	42,94	28.6
13. INSIDE LIAISON	HRLY	Ί								ļ			ļ				
14. SHIPPING PERFECTO PARAGON	11000 342	1-				20°0 30°0	1400 2400	1200				7./3	5.42	4,20	57.13	43:42	39.2
15. INSPECTION REC LAMCO	HRLY SAL	1.0 2.0	1.0 1.5	k0 1.0	4.91	4.81 13.92	4.77 10:44	431 6.96	12.60 36.19	12.66	12.66 18.10	2.50	5,36	3.57	57.25	42.94	28.
16.	HRLI	1							<u> </u>	<u> </u>		077788	<u> </u>	<u> </u>	405076	97000	
		1	1	1	1	1221155	12027P	n/736 92	1	1	VOULING	1666 1.00	1	I	TVIN -	15 / / C.Y.	<b></b>

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EW SULLIVAN X7972

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بالا أتناصحه الأرا

	OPERATION
ITEM	NO(2)

PN_//370//

#### LO2 LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

NAME SHOFT		Ī	M	AN HOUF	RS	RATE	· NE	T DOLLA	RS	DL	0 AT 260	%*	G + A	AT 14.	25% *	TOT	AL DOLL	IRS
NAME ONTI			1	10	40	PER HR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTE	SCONSULTING	HRLY SAL																
2. PROCUREMENT P	LANNING	SAL	15.0	2.0	1.0	696	10990	13 <u>92</u>	646	27/ <del>44</del>	3619	1810	<u> </u>	7 <u>/4</u>	357	429 <u>4</u> 0	5725	2863
3. TOOLING	<u></u>	HRLY SAL																
4. RAWSTOCK		HREY SAL	·				49900	329 <u>00</u>	29600				7925	46 88	4218	56525	375 22	338.E
5. CASTINGS OR FO	RGINGS	HRLY SAL													ļ			
6. MACHINING	N COMPLETE	HRIET SÆL	60.0 16.0	46.2 12.3	396	1195	717 <u>00</u> 192 <u>20</u>	53209 1 <del>4</del> 7 <u>9</u> 9	473. <u>22</u> 126 <u>es</u>				12750	99 <u>16</u>	85 <u>51</u>	103876	799.84	685 <u>37</u>
7. WELDING /////	SPLINES	HRET SAE	40.0	30.B	26.4	1195	<i>478∞</i>	36300	3/5 48		· ·		68 <u>12</u>	52 95	44 <u>96</u>	54612	42051	360 ++
8. <b>1557 1 FAD QL</b>	BENCH INSPECT	SAL	10.0	7.7 6.9	6.6 5.9	9 <u>15</u> 11 <u>30</u>	7/ <u>50</u> /45 <u>77</u>	70 <u>44</u> 112 <u>2 4</u>	60 <u>34</u> 96 <u>21</u>				33 71	2603	22 32	27/ <u>08</u>	20813	17874
9. CLEANING		HRLY SAL					:											
10. QCPLANNING		HRLY													2.50	2003	2003	120.07
11. INSPECTION. RE	c	HRLY	1.0 1.0	1.0 .3	1.0 .3	4 <u>87</u> 6 <u>46</u>	4 <u>3</u> 1 6 <u>86</u>	4 <u>37</u> 2 <u>39</u>	437 299	1266 1810	12 66 5 <u>4 3</u>	1266 543	250	1 07	107	2863	857	857
12. INSPECTION SO	URCE	HRLY SAL	6.0	5.0	3.5	694	41 <u>76</u>	.9430	2436	10853	90-1	6834	2/42	1735	1250	/7/ 76	/43/3	10020
13. INSIDE LIAISON		HRLY	,											ļ				
14. SHIPPING		HRLY	/				24 <u>00</u>	2000	18 <u>00</u>				342	2. <u>85</u>	251	2742	22 .5	2057
15.		HRLY	1								ļ		ļ	ļ	<b> </b>		ļ	ļ
16.		HRLY	1								ļ				<b>_</b>	1909/ 6 S	015101	170110
<u></u>	TOTAL UNIT COST		1				22999	165550	142443	1			L	L	1	13076-22	12000	
* MIDPOINT OF EFF	DRT - JAN '71			1	NETOP	DOLLARS	× PERCE	TAGES					OP RA	TE AT \$1	2.00/HR	*		

ABOVE = NET DOLLARS (INHOUSE)

INHOUSE RATE AT \$4.87/HR (HRLY) *

-11-17-69

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				1	BOVE =	NET DOLI	HNI) SAA.	(3SNO					SNOHN	E RATE	78. MS TI	<b>.'HE (HE</b> L	- <b>+ (A</b>	
* MIDPOINT OF EFF	<u> </u>	r		/ 	1 1 0 1 3		DERCEN						TAN 90	E AT ST	AH/00.1	*		
·	TOTAL UNIT COST						5622	125661	99°&7E/							1596+5	559548	25757/
.91																		
· • • • • • • • • • • • • • • • • • • •		ALL SAL																•
T4 * CHIBBINC	, <u>, , , , , , , , , , , , , , , , , , </u>	SAL HRLY					<del></del>	5025	5000				69°01	ε:L	02:5	49:58	eil.S	04:50
13. INSIDE LINISON		SAL HRLY																
		SAL	0.1	٤.	٤.	959	26.51	++01	959	41.95	+112	0181	+11	95'5	155	52% 5	+47+	5972
a NULTIANI CI		HELY	0%	0.1	0.1	18.4	187	187	18:4	15.66	15.66	15.66	520	5'20	520	5003	5003	£0'02
JT' INSPECTION'S	חאכב	JAS WREW	02	الاي	07	959	26.51	++01	959	61.95	÷122	0181	+,Z	2:30	321	szis	+4'2+	586ع
TO' OC BEVINING		אר אארא																
9' CLEANING		ראר אצרג																
8. ASSY & FAB QE		אר אצרא																
1' WELDING		צער אארא																
UNC UNINIHOW '9	TODE ZWWYS JON						5773 ت	1815.20	00:50E/				90'\$15	#2°852	96:58/	90'666Z	20101a	960641
AND CONFICED .C	CONION	JAR					ε	sz	ØЬ									-
		ныга					ษกฮ	11111	ב סעי	03830					·			
4. RAWSTOCK		אר אצרא					00:528 07	00:52/_ 2.1. 64	290°00 СН									
3. TOOLING		אר אגרא																
2. PROCUREMENT	SNINNAL	T∀S MUSEA	QЪ	04	Ľ	36.9	+9'27	969	184	98.291	0181	9921	\$175	3.2.2	5.20	52.58	5382	50'02
1. ADVANCE QUOTE	SCONSULTING	אר אארא																i
		1	τ	οτ	07	ян язч	τ		40	ĩ	στ	40	ĩ	τ0	40	τ	στ	01
AMAR BEPRING.	83M07 - 7768	]	٧	RUOH NA	S	RATE	ЭN	T DOLLA	SE	<b>1</b> 0	0 AT 260	* %	/+9	AT 14.	52% ¥	101	אר מסררי	Sal
005EAFION 1.1-D(3) 00.(3) 01 01 01 01 01 01 01 01 01 01 01 01 01	ـــــــــــــــــــــــــــــــــــــ					0 0 x01	/ 1500 1500 11N 01 150 07	MALYSIS (BASE C) (BASE C) 22	<i>LI)</i> (12) ND SIN	<i>ו) שבו</i> גע	11- 11-	Þ2&&0	7-72-6	E9\$\$) \$	יזש ברי	0 11407 00	E 15 )	<u>.</u>

398		OPERATION					LOW C	ل ost tu	D2 RBOPU	MP STU	DY		711-	-19-69	<i>(</i> )				
	PN	1137013					U	NIT COST	F (BASE C ANALYSIS	ASE) S <i>GE</i> '	TTSA	(P) NFG. i	V 7/24	09-29) []=[[]]	(rref.) 1777 - (	елен	6		<del></del>
С	NZ	MESEAL ASSY, BELLOWS-UPPER	1		MAN HOU	RS	RATE	NE	TDULLA	RS	DLO AT 260% *			G + A AT 14.25% *			TOTAL DOLLARS		
		·····•=		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1.	ADVANCE QUOTES/CONSULTING	HRLY SAL													L			
	2.	PROCUREMENT PLANNING	HREY SAL	150	Z.O	1.0	6.96	104.40	13.92	6.96	271.++	36.19	18.10	53.56	7.14	3.57	429.40	57,25	28.63
	3.	TUCEING	HRLY SAL				**	OUANT 2	TILS OF	DERED 44									
	4.	RAWSTOCK	HRLY					C'OST 2400.00	Са.сн 2000.00	1+00.00									
	5.	CASTINGS OR FORGINGS	HRLY SAL												L				ļ
	6.	MACHINING BETTS MFG	HRLY SAL		—			4.800.00	2430.00	1540.00				684.00	342 00	219.45	5489.00	2742.00	1768.45
	7.	WELDING	HRLY SAL													ļ	ļ		ļ
· (	8.	ASSY & FAB QE	HRLY SAL														<b></b>	ļ	ļ
	9.	CLEANING	HRLY SAL													ļ	<b></b>		ļ
	10.	Q C PLANNING	HRLY SAL												<u> </u>		ļ	ļ	ļ
	11.	INSPECTION, SOURCE	HRLY SAL	2.0	1.5	1.0	6.96	13.92	1044	6.96	36.19	27:14	18.10	7./4	5.36	3,57	57.25	42.94	28.03
	12.	INSPECTION, REC.	HRLY	1.0	1.0	1.0	4.81	4,87	4.87	4,87	12.66	12,66	12.66	2,50	2.50	2.50	20.03	2003	2003
	13.	INSIDE LIAISON	HRLY	1					,							ļ	ļ		<b></b>
	14.	SHIPPING	HRLY					90.00	25.00	20.00				4.28	3.56	2.85	39.28	28.56	22.85

HRLY

HRLY SAL

E W SULLIVAN X7892

INHOUSE RATE AT \$4.87/HR (HRLY) *

OP RATE AT \$12.00/HR *

6024. 2870.7 1868.5

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* * INCLUDES SPARES

15.

16.

* MIDPOINT OF EFFORT - JAN '71

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TOTAL UNIT COST

ABOVE = NET DOLLARS (INHOUSE)

NET OP DOLLARS × PERCENTAGES

495349245423 1578.79

(Later Land)

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	OPERATION	LOZ						///-18-69													
	ITEM NO. 5 PN <u>//370/4</u>						LOW C	OST TU NIT COSI	REOPU (BASE C	MP STU ASE)	DY	(	, ROM &	UOTE	FROM	ozw .	11-20-6	• 9 - <i>SIA</i> K	LAR P		
		COST AN/LYSIS (B4W MFG) (FLAME PLATED 34														7)					
	NAME SEAL RING.	RUNNING -UPPER	·	MAN HOURS			RATE	NET DOLLARS			DLO AT 260% *			G + A AT 14.25% *			TOTAL DOLLARS				
				1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40		
1	. ADVANCE QUOTE	SCONSULTING	HRLY SAL				**	2 2	17/ES 12	DRDER 44	<i>–</i>	-			_						
2	. PROCUREMENT P	LANNING	SAL	4.5	.7	.7	6.96	31.32	624	4.87	81.43	16.22	12.66	16.07	3.20	2,50	128.32	25:44	20.0		
3	. TOOLING IJNU	N CARCIDE	HRLY	·			TOOLING SET UP	50.00						9.48			79.18				
ĉ	. NHUSTOCK FLA.	ON CARBIDE ME PLATING	HREF Sike					13.70 COST	24.45 reac	17.95								—			
5	OPCOST F	LAME PLATING	HREP SAL					67.40	27.34	19.75			—	9.60	4.18	2.81	77.00	<u>83</u> 52	22.5		
6	. MACHINING TL GRIND & LA	P COMPLETE	HRLY SAL	5.0 23.0	2.2 9.9	1.3 6.0	11.95	56.50 274.85	25.73 118.37	15 <b>.45</b> 71.07				47.22	20.53	12.33	378.57	164.63	98.8		
7	. WELENIC B	ENCH PECT	HRLY SAL	1.0 5.0	.7 2.3	.4 1.4	9.15 11.30	9.15 56.50	5.95 25.73	3.09 15.95				9.36	4.57	2.5+	75:01	36.19	21.1		
8	. ASSY & FAB QE		HRLY SAL																		
9	. CLEANING		HRLY SAL																		
10	. Q C PLANNING		HRLY SAL																		
11	. INSPECTION, RE	.C	HRLY SAL	.5 .5	.5	.5 .15	4.87 6.96	2.44	2.44	1.09	6.3+ 7.05	6.34 2.70	63 <del>4</del> 2.70	1.25 1.79	1 <u>25</u> .53	<u>,25</u> .53	10.03 1 <b>4</b> .32	/0.03 4,27	10.03 4,27		
12	. INSPECTION, SO	URCE	SAL	1.0	8،	. 6	6.96	6.96	5.57	4.18	17.10	14.48	10.87	3.57	2.57	2:4	28.63	2262	17/		
13	. INSIDE LIAISON	<u> </u>	HRLY																		
14	. SHIPPING	<u>, , , , , , , , , , , , , , , , , , , </u>	HRLY					10.00	4.00	3,50				1.43	.57	.50	11.43	4:57	4.0		
15	•	<u>, , , , , , , , , , , , , , , , , , , </u>	HRLY				·														
16	•		HRLY																		
		TOTAL UNIT COST						518.60	22-1.41	14084	l		TOOLING	7493			729 <i>8</i> 1	501.47	198/1		

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EWSULLIVAN X7872

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111-18-69

OPERATION ITEM NO. 6 PN //37015

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NAME SEAL RING . RUNNING -L	DWER	N	AN HOUR	S	RATE	NE	T DJLLA	RS	, DL	0 AT 260	% *	G + /	A AT 14.	25% *	TOT	AL DOLL	ARS
		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES/CONSULT	ING HRLY SAL	<i>′</i>			**	QUANT 2	ITIES O 12	RDERED 4-4									
2. PROCUREMENT PLANNING	MRC	6.0	1.0	-ى	6.96	41.76	6.96	3.43	108.58	18:0	9.05	21.42	357	1.79	15939	28:03	14,32
3. TOOLING UNION CARRIE	E HREY SAE					125,00	—					17.81			142.81		
4. ELWSTOCK UNION CARBIN (LWSMAT) FLAME PLAT	02 .002 HRLY 1NG.004 SAL	COST 144.75	EACH 115.45	99.25		289.50	/38.54	109.18				<u>4)</u> ,25	19.74	15.56	330,75	<i>\58</i> .2₹	12474
5. CHSTINGS OR FOROINGS A	HRET SAL	1			1755												
6. MACHINING TURN COMPLE GRIND & LAF	TE HRLY SAE	150	6.0 13.8	4.0 9.3	11.95	180.00 414.00	7200 165:60	48.42 111.37				84.65	33.36	22.77	678.65	27/.46	182.56
7. WELDING BENCH		2.0	.8 1.9	· 5 1· 3	9.15	18.00	7:20 21.60	4.54 14.53				10.26	4.10	2,76	82.26	<b>\$2</b> .90	22.13
8. ASSY & FAB QE	HRLY SAL	1															
9. CLEANING	HRLY SAL	·															
10. Q C PLANNING	HRLY SAL	1															
11. INSPECTION REC	HRLY SAL	1.D 1.0	1.0 _3	1.0 .3	4,31 6,96	4.87 6.96	4,87 2 ,09	4.87 2.09	12.66 18.10	12.66 5.93	1266	250 3.57	2,50	2.50	20.03	2003 8,54	2003
12. INSPECTION SOURCE	MRLY SAL	2.0	1.5	1.0	6.96	13.92	10+7	6.96	36.19	27.14	18:00	7./+	5,36	3.57	57.25	42.94	28.63
13. INSIDE LIAISON	HRLY	·															
14. SHIPPING	HRLY SAL	, ,				18.00	7.00	6.00				2.57	1.00	·86	20.57	8.00	6.86
15.	HRLY SAL	1															
16.	HRLY	1	T														
TOTAL U	NIT COST	1	1			1041.01	43630	311.69			TCOLING	142.31			1376.55	570.83	407.86

EW SULLIYAN X 7872

	OPERATION
ITE	m NO. (7)
PN	1137016

#### LO2 LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

NAME SEAL ASSY, SHAFT RIDING MAN HOURS RATE NET DOLLARS DLO AT 260% * G + A AT 14.25% * TOTAL DOLLARS 1 10 40 PERHR 1 10 40 1 10 40 10 1 40 10 40 COST CACH QUENT TIES ORDERED HRLY SEALOL COMMERCIAL ASSY -1. ADVANCE QUOTES/CONSULTING - SEALOL COMMERCUAL ASSY ONLY 325.00 140.00 SAL 11500 90 3 25 90 41.76 6.0 1.0 .5 18.10 9.05 257 159.39 28.63 1482-12 6.96 3.48 08.58 21.42 1.79 1432 6.96 2. PROCUREMENT PLANNING SAL 16.07 3.20 2.50 128.82 25.66 20.03 45 .9 .7 31.32 4.81 81.43 SEALOL 6.24 1622 12.66 123.24 3. RAW STOCK 27.76 40.50 27.00 24.30 5.77 3.85 3.46 44.27 30.05 1== 4. REF: COML ANDO 48817 HRLY REF. 40. 102957 ZCa 97500 35000 25875 36.07 1113.94 399.00 295.62 138.94 49.84 SHAFT RIDER SEAL ASSY SAL 186.90 P.L. IN LOTS OF IS REQ. HRLY 5. CASTINGS OR FORGINGS SAL TURN COMPLETE 14340 11244 10111 HREAT 12.0 9.4 8.5 11.95 6. MACHINING 28.95 22.70 20.41 232.10 181.91 169.65 SAL 3.5 5.0 3.9 59.75 46.85 4213 MISC MILLING DRILL HREY 3.0 2.4 2.1 35.85 2.8.11 25.28 11.95 7.Z. 81.92 57.76 7. 100000 10.22 6423 801 SAL 30 2.4 2.1 35.85 2211 25.24 BRIND 9.15 9.15 7.17 6.45 BENCH 1.0 .8 .7 REEY 613 8. ASSY & FAB QE 4.81 4.32 47.18 38.56 24.67 SAL 11.30 33.90 86.58 23.90 2.4 2.1 INSPECT 3.0 HRLY 9. CLEANING SAL HRLY 10. Q C PLANNING SAL 2.50 20.03 20.07 20.03 12.66 2.50 250 HRLY 1.0 1.0 1.0 4.21 4.87 4.81 4.87 12.66 12.66 11. INSPECTION, REC. SAL 696 2.09 2.09 18.10 5.43 3.57 1.07 1.07 28.63 857 8.57 5.43 1.0 .3 .3 696 MAREY 1810 2.57 2.14 21.63 22 62 1729 12. INSPECTION, SOURCE 5.57 418 14.48 10.87 257 1.0 .8 6 6.96 6.96 SAL HRLY 13. INSIDE LIAISON SAL .57 .21 4.57 3.43 2.27 OP 4.00 3.00 2,00 43 7626-30 14. SHIPPING SAL 1.14 6.36 8.00 6.00 400 .86 .57 7.14 4.57 SEAL OL HRLY 15. SAL HRLY 16. SAL TOTAL UNIT COST 143727 6:0.99 532.70 1902.42 231.35 446 \$ * MIDPOINT OF EFFORT - JAN '71 NET OP DOLLARS x PERCENTAGES OP RATE AT \$12.00/HR +

ABOVE = NET DOLLARS (INHOUSE)

WHOUSE RATE AT \$4.87/HR (HRLY) *

/11-19-69

EW SULLIVAN X7972

OPERATION						LOZ					ZII-1	9-69					
ITEM NO (8)					LOW CO	озт ти	RBOPU	MP STU	DY								
PN //370/7					U	NIT COST	GASE C	ASE)								J	
/ M						COST	ANALYSIS	; <i>G</i> I	י בדדב הת	nFG. ( <del>A</del>	PN 7/24	-10170.5 09-29					
NAME SEAL ASSY, BELL	OWS-LOWER		MAN HOU	RS	RATE	NE	T DOLLA	RS	DL	0 AT 260	% *	G + /	AT 14	.25% *	TOT	AL DOLL	ARS
<u> </u>		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES	CONSULTING HRLY																
2. PROCUREMENT PLA	NNING SAL	15.0	2.0	1.0	6.96	104.40	1 <u>3.</u> 92	6.96	271. <del>4</del> +	36.19	18.10	53,56	7./4	3.57	427.40	57.25	230
3. <del>TOOLING</del>	HRLY SAL	1			**	QUANT 2	TIES O	RDERED 44									
4. RAWSTOCK	HRLY SAL	Í —				COST 2,20000	EACH 175000	120000	—			300-000	-	ļ	•		
5. CASTINGS OR FORG	INGS HRLY SAL	1															ļ
6. MACHINING BETT	S MF& HRLY SAL	í				440000	1425.00	/320.00			<u> </u>	627.00	274.3/	188.10	502700	2199.31	1508
7. WELDING	HRLY SAL	, 												ļ			ļ
8. ASSY & FAB QE	HRLY S <b>AL</b>											ļ					<b> </b>
9. CLEANING	HRLY SAL	1						 						ļ			<b> </b>
10. QCPLANNING	HRLY SAL	1														10.51	
11. INSPECTION. SOUR	CE SAL	2.0	1.5	1.0	6.96	13.92	12.44	6.96	36.19	27./4	18,10	7.14	5.36	3.57	57.25	42,**	28.
12. INSPECTION, REC	HRLY SAL	1.0	1.0	1.0	4.87	4.87 13.92	4.37	4.87	1266 3619	12.66 27.14	12.46	2,50 7.14	2.50 5.36	2.50 3.57	2003 57.25	2.03 42.94	20 28.4
13. INSIDE LIAISON	HRLY SAL	1															 
14. SHIPPING	HRLY SAL	1-				30.00	25.00	20:00				4.28	3.5%	2.85	34.28	28.56	22.8
15.	HRLY SAL	(						L						ļ		ļ	<b></b>
16.	HRLY SAL	1										ļ			17953	797843	1/0/
	TOTAL UNIT COST					4567."	1789.67	1365.75					L	<u></u>	p625.21	23/303	1636
* MIDPOINT OF EFFOR	F - JAN '71 Es			NET OP ABOVE	DOLLARS >	PERCEN	ITAGES HOUSE)		·			OP RAT	E AT \$1 E RATE	2.00/HR AT \$4.8	* 7/HR (HRL	.Y) *	

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OPERATION
ITEM NO. (9)
PN 1137018

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#### レロ2 LOW COST TURBCPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

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• •	N	NAME NUT: SEAL RETAINING			MAN HOU	RS	RATE	NE	T DOLL	RS	DL	0 AT 260	)% *	G +	A AT 14	.25% *	TO	TAL DOLL	ARS
				1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
	1.	ADVANCE QUOTES/CONSULTING	HRLY SAL																
	2.	PROCUREMENT PLANNING	NRLY SAL	4.5	.9	.7	6.96	31.32	624	4.87	81.43	16.22	1256	16.07	3.20	2.50	128.82	25.66	20.03
	3.	TOOLING	HRLY								1		1			1			
	4.	RAWSTOCK	HRLY					34.50	23.00	20.70				4.72	328	2.75	39.42	26.28	23:55
	5.	CASTINGS OR FORGINGS	HRLY										1						
	6.	MACHINING TURN COMPLETE MISC MILLING	firer Side	6.0 5.0	4.6	40	11.95	71,70	55.21	47.32 39.49		[ <u> </u>		18.73	14.42	12.36	150.18	115.00	99.12
•	7.	MELENIE BENCH INSPECTION	HRLFF SAL	2.0	1.6	1.4	9.15	1-2,30 33,90	14.94 27,53	12.08				744	5.94	4.86	57.64	47.60	38.99
$\mathcal{O}$	8.	ASSY & FAB QE	HRLY		1	1		:				1							
	9.	CLEANING	HRLY SAL							<b> </b>						1			
	10.	Q C PLANNING	HRLY																
	11.	INSPECTION , REC.	HRLY	<u>، ج</u> ج	-5	.5	4.37	2.44	2.44	2.44	634	634	2.70	1.25	1.25	1.25	10.03 14.32	10.03	10.3
	12.	INSPECTION , SOURCE	SAL	1.0	.9	. 6	696	6.96	5.57	4.19	18:10	14:48	10.87	3.57	2.57	2.14	28.63	226	17.17
	13.	INSIDE LIAISON	HRLY							1									
	14.	SHIPPING	HRLY					2.00	1.50	1.00	-			.27	.21	.14	229	131	1.14
	15.	·	HRLY							1		1					1		
•.	16.		HRLY						1			1						1	
	••	TOTAL UNIT COS	т		<u> </u>		<u> </u>	26435	182.63	157.12		1	l		1	1	433,73	254.01	21454
403	* N	NIDPOINT OF EFFORT - JAN '71			1	NET OP D ABOVE =	OLLARS X	PERCEN ARS (INH	TAGES (OUSE)					OP RAT	E AT \$1	2.00/NR AT \$4.87	* ////R (MRL	.Y) *	

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| OPERATION        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Y) *                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <u></u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                           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                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                    |
|                  | OPERATION<br>TEM NO. O<br>N. 1/370/9<br>AME <u>FIL TER, S</u><br>ADVANCE QUOTE<br>PROCUREMENT P<br>TOOLING<br>RAWSTOCK " <u>B</u><br>CASTINGS OR FO<br>MACHINING <u>COI</u><br>MACHINING | OPERATION<br>TEM NO. O<br>N | OPERATION<br>TEM NO. O<br>N | OPERATION<br>TEM NO. O<br>N | OPERATION         TEM NO. (D)         MANE FILT TER, SS (ID MICRON)         MAN HOUR         AAME FILT TER, SS (ID MICRON)         MAN HOUR         ADVANCE QUOTES/CONSULTING         MAN HOUR         ADVANCE QUOTES/CONSULTING         MAN HELY         ADVANCE QUOTES/CONSULTING         MELY         ADVANCE QUOTES/CONSULTING         MELY         PROCUREMENT PLANNING         MELY         ADVANCE GOER         RAWSTOCK "BRANSPORE"         AL         CASTINGS OR FORGINGS         HRLY         ADVANCE GOER         MELY         CASTINGS OR FORGINGS         HRLY         CASTINGS OR FORGINGS         MAL         MACHINING COML PROD         HRLY         MELY         SAL         OR         ADVECTION , SOURCE         SAL <td c<="" td=""><td>OPERATION         TEM NO. OPERATION         MAME FILT TER. SS (ID MICRON)         MANE FILT TER. SS (ID MICRON)         MAN HOURS         ADVANCE QUOTE SCONSULTING         MARE FILT TER. SS (ID MICRON)         MAN HOURS         ADVANCE QUOTE SCONSULTING         MARE FILT COST         PROCUREMENT PLANNING         MARE FILT CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         ADDED         HRLY         MARCHINING COML PROD         HRLY         MAL         COML PROD         HRLY         SAL         COML PROD         HRLY         SAL<td>OPERATION         LOW C         N_//370/9         LOW C         MARE FILTER.SS (ID MICRON)       MAN HOURS       RATE         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         PROLUREMENT PLANNING       MARE 3.0       .6       .6         PROLURE MENT PLANNING       MARE 3.0       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       <th <="" colspan="2" td=""><td>OPERATION         Z           TEM NO.         O           IN</td><td>OPERATION<br/>TEM NO. ($\bigcirc$)<br/>N. 1/370/7       LO 2<br/>LOW COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TO PROLONSUL TING<br/>SAL       LO 2<br/>LOW COST TURBOPU<br/>COST ANALYSI         AMME FILT FER. SS (ID MICRON)       MAN HOURS       RATE       NET DOLLARS         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       1       10       40       PER HR       1       10         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       20.97       E.AC.M<br/>(20.97       GUAW F/ T/EF       2       /2         PROCUREMENT PLANNING       SAL       3.0       .6       .5       6.96       20.97       4.17         TOOLING       HRLY<br/>TOOLING       SAL       3.0       .6       .5       6.96       20.97       4.17         RAWSTOCK       BRANSYME"       SAL       3.0       .6       .5       6.96       20.97       4.17         CASTINGS OR FORGINGS       SAL                WELDING       HRLY<br/>F 40Sr                 Q C PLANNING       SAL                 <t< td=""><td>LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         &lt;</td><td>UPERATION           LOW COST TURBOUMP STUDY<br/>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         ///////////////////////////////////</td><td>UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST &amp; ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th></td></t<></td></th></td></td></td> | <td>OPERATION         TEM NO. OPERATION         MAME FILT TER. SS (ID MICRON)         MANE FILT TER. SS (ID MICRON)         MAN HOURS         ADVANCE QUOTE SCONSULTING         MARE FILT TER. SS (ID MICRON)         MAN HOURS         ADVANCE QUOTE SCONSULTING         MARE FILT COST         PROCUREMENT PLANNING         MARE FILT CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         ADDED         HRLY         MARCHINING COML PROD         HRLY         MAL         COML PROD         HRLY         SAL         COML PROD         HRLY         SAL<td>OPERATION         LOW C         N_//370/9         LOW C         MARE FILTER.SS (ID MICRON)       MAN HOURS       RATE         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         PROLUREMENT PLANNING       MARE 3.0       .6       .6         PROLURE MENT PLANNING       MARE 3.0       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       <th <="" colspan="2" td=""><td>OPERATION         Z           TEM NO.         O           IN</td><td>OPERATION<br/>TEM NO. ($\bigcirc$)<br/>N. 1/370/7       LO 2<br/>LOW COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TO PROLONSUL TING<br/>SAL       LO 2<br/>LOW COST TURBOPU<br/>COST ANALYSI         AMME FILT FER. SS (ID MICRON)       MAN HOURS       RATE       NET DOLLARS         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       1       10       40       PER HR       1       10         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       20.97       E.AC.M<br/>(20.97       GUAW F/ T/EF       2       /2         PROCUREMENT PLANNING       SAL       3.0       .6       .5       6.96       20.97       4.17         TOOLING       HRLY<br/>TOOLING       SAL       3.0       .6       .5       6.96       20.97       4.17         RAWSTOCK       BRANSYME"       SAL       3.0       .6       .5       6.96       20.97       4.17         CASTINGS OR FORGINGS       SAL                WELDING       HRLY<br/>F 40Sr                 Q C PLANNING       SAL                 <t< td=""><td>LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         &lt;</td><td>UPERATION           LOW COST TURBOUMP STUDY<br/>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         ///////////////////////////////////</td><td>UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST &amp; ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th></td></t<></td></th></td></td> | OPERATION         TEM NO. OPERATION         MAME FILT TER. SS (ID MICRON)         MANE FILT TER. SS (ID MICRON)         MAN HOURS         ADVANCE QUOTE SCONSULTING         MARE FILT TER. SS (ID MICRON)         MAN HOURS         ADVANCE QUOTE SCONSULTING         MARE FILT COST         PROCUREMENT PLANNING         MARE FILT CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         RAWSTOCK "BRAINSMICH" CORP.         ADDED         HRLY         MARCHINING COML PROD         HRLY         MAL         COML PROD         HRLY         SAL         COML PROD         HRLY         SAL <td>OPERATION         LOW C         N_//370/9         LOW C         MARE FILTER.SS (ID MICRON)       MAN HOURS       RATE         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         PROLUREMENT PLANNING       MARE 3.0       .6       .6         PROLURE MENT PLANNING       MARE 3.0       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       <th <="" colspan="2" td=""><td>OPERATION         Z           TEM NO.         O           IN</td><td>OPERATION<br/>TEM NO. ($\bigcirc$)<br/>N. 1/370/7       LO 2<br/>LOW COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TO PROLONSUL TING<br/>SAL       LO 2<br/>LOW COST TURBOPU<br/>COST ANALYSI         AMME FILT FER. SS (ID MICRON)       MAN HOURS       RATE       NET DOLLARS         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       1       10       40       PER HR       1       10         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       20.97       E.AC.M<br/>(20.97       GUAW F/ T/EF       2       /2         PROCUREMENT PLANNING       SAL       3.0       .6       .5       6.96       20.97       4.17         TOOLING       HRLY<br/>TOOLING       SAL       3.0       .6       .5       6.96       20.97       4.17         RAWSTOCK       BRANSYME"       SAL       3.0       .6       .5       6.96       20.97       4.17         CASTINGS OR FORGINGS       SAL                WELDING       HRLY<br/>F 40Sr                 Q C PLANNING       SAL                 <t< td=""><td>LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         &lt;</td><td>UPERATION           LOW COST TURBOUMP STUDY<br/>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         ///////////////////////////////////</td><td>UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST &amp; ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th></td></t<></td></th></td> | OPERATION         LOW C         N_//370/9         LOW C         MARE FILTER.SS (ID MICRON)       MAN HOURS       RATE         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         ADVANCE QUOTESCONSULTING       MAR HRLY       COST FACM         PROLUREMENT PLANNING       MARE 3.0       .6       .6         PROLURE MENT PLANNING       MARE 3.0       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6       .6 <th <="" colspan="2" td=""><td>OPERATION         Z           TEM NO.         O           IN</td><td>OPERATION<br/>TEM NO. ($\bigcirc$)<br/>N. 1/370/7       LO 2<br/>LOW COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TO PROLONSUL TING<br/>SAL       LO 2<br/>LOW COST TURBOPU<br/>COST ANALYSI         AMME FILT FER. SS (ID MICRON)       MAN HOURS       RATE       NET DOLLARS         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       1       10       40       PER HR       1       10         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       20.97       E.AC.M<br/>(20.97       GUAW F/ T/EF       2       /2         PROCUREMENT PLANNING       SAL       3.0       .6       .5       6.96       20.97       4.17         TOOLING       HRLY<br/>TOOLING       SAL       3.0       .6       .5       6.96       20.97       4.17         RAWSTOCK       BRANSYME"       SAL       3.0       .6       .5       6.96       20.97       4.17         CASTINGS OR FORGINGS       SAL                WELDING       HRLY<br/>F 40Sr                 Q C PLANNING       SAL                 <t< td=""><td>LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         &lt;</td><td>UPERATION           LOW COST TURBOUMP STUDY<br/>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         ///////////////////////////////////</td><td>UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST &amp; ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th></td></t<></td></th> | <td>OPERATION         Z           TEM NO.         O           IN</td> <td>OPERATION<br/>TEM NO. ($\bigcirc$)<br/>N. 1/370/7       LO 2<br/>LOW COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TURBOPU<br/>UNIT COST TO PROLONSUL TING<br/>SAL       LO 2<br/>LOW COST TURBOPU<br/>COST ANALYSI         AMME FILT FER. SS (ID MICRON)       MAN HOURS       RATE       NET DOLLARS         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       1       10       40       PER HR       1       10         ADVANCE QUOTE SCONSUL TING       HRLY<br/>SAL       20.97       E.AC.M<br/>(20.97       GUAW F/ T/EF       2       /2         PROCUREMENT PLANNING       SAL       3.0       .6       .5       6.96       20.97       4.17         TOOLING       HRLY<br/>TOOLING       SAL       3.0       .6       .5       6.96       20.97       4.17         RAWSTOCK       BRANSYME"       SAL       3.0       .6       .5       6.96       20.97       4.17         CASTINGS OR FORGINGS       SAL                WELDING       HRLY<br/>F 40Sr                 Q C PLANNING       SAL                 <t< td=""><td>LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         &lt;</td><td>UPERATION           LOW COST TURBOUMP STUDY<br/>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         ///////////////////////////////////</td><td>UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST &amp; ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th></td></t<></td> |              | OPERATION         Z           TEM NO.         O           IN | OPERATION<br>TEM NO. ( $\bigcirc$ )<br>N. 1/370/7       LO 2<br>LOW COST TURBOPU<br>UNIT COST TURBOPU<br>UNIT COST TURBOPU<br>UNIT COST TO PROLONSUL TING<br>SAL       LO 2<br>LOW COST TURBOPU<br>COST ANALYSI         AMME FILT FER. SS (ID MICRON)       MAN HOURS       RATE       NET DOLLARS         ADVANCE QUOTE SCONSUL TING       HRLY<br>SAL       1       10       40       PER HR       1       10         ADVANCE QUOTE SCONSUL TING       HRLY<br>SAL       20.97       E.AC.M<br>(20.97       GUAW F/ T/EF       2       /2         PROCUREMENT PLANNING       SAL       3.0       .6       .5       6.96       20.97       4.17         TOOLING       HRLY<br>TOOLING       SAL       3.0       .6       .5       6.96       20.97       4.17         RAWSTOCK       BRANSYME"       SAL       3.0       .6       .5       6.96       20.97       4.17         CASTINGS OR FORGINGS       SAL                WELDING       HRLY<br>F 40Sr                 Q C PLANNING       SAL <t< td=""><td>LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         &lt;</td><td>UPERATION           LOW COST TURBOUMP STUDY<br/>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         ///////////////////////////////////</td><td>UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST &amp; ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th></td></t<> | LO 2         LOW COST TURBOPUMP STU         UNIT COST (BASE CASE)         UNIT COST (BASE CASE)         COST ANALYSIS         AME FILTER SS (ID MICRON)         MAN HOURS       RATE       NET FOLLARS         AME FILTER SS (ID MICRON)         AMAN HOURS       RATE       NET FOLLARS         AND ADVANCE QUOTESCONSULTING       SAL       AUX COST TURBOPUMP STU         ANAN HOURS       RATE       NET FOLLARS         PROCUREMENT PLANNING       MARE Y 100 40         AUXIS WICH COMP       SAL       COM COMP       CONT         TOOLING       ALT COMP       CONT       CONT         AUXIS WICH COMP       MARE Y       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       MAREY         AUXIS WICH COMP       SAL         AUXIS WICH COMP         < | UPERATION           LOW COST TURBOUMP STUDY<br>UNIT COST (BASE CASE)           COST ANALYSIS         C/           AME FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ANNE FILTER.SS (ID MICRON)         MAN HOURS         RATE         NET JOLLARS         DU           ADVANCE QUOTESCONSULTING         SAL         100         400         COST ANALYSIS         C/           PROCUREMENT PLANNING         MAN         DU         ADVANCE QUOTESCONSULTING         SAL         20000         COST ANALYSIS         C/           PROCUREMENT PLANNING         MARE         XO         6         A/9         A/9         GUONN (7 00 PR           RAWSTOCK GORA         HRLY         /////////////////////////////////// | UPERATION         LOW COST TURBOPUND STUDY         LOW COST TURBOPUND STUDY         N. //370/4         LOW COST TURBOPUND STUDY         LOST ANALYSIS       CARCE         COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 100 40       PER HR 1       1040       400 40       1       10       400 40       1       0       COST ANALYSIS       CIPCLE         ADVANCE QUOTESCONSULTING       MAIL 20       RATE       NET COLLARS       DLO AT 260         ADVANCE QUOTESCONSULTING       MAIL Y COST & ACM       YEACH       QUART START       TICE COMPARE       COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE       TICE COMPARE <th colsp<="" td=""><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td><td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td></th> | <td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td> <td>OPERATION<br/>TEM NO. (2)         LO2         <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<></td> <td>OPERATION<br/>TEM NO. (9)         LO2         LIZO         <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<></td> | OPERATION<br>TEM NO. (2)         LO2         LO2 <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<> | OPERATION<br>TEM NO. (2)         LO2         LO2 <thlo2< th="">         LO2         <thlo2< th=""></thlo2<></thlo2<> | OPERATION<br>TEM NO. (9)         LO2         LIZO         LIZO <thlizo< th="">         LIZO         LIZO<!--</td--><td>Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK</td><td>Departion         LOT         <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<></td></thlizo<> | Dependion         LO2         LO3         LO3         LO3           LOW COST TUBBOURD STUDY           NITEON           LOW COST TUBBOURD STUDY           NITEON           COST AMALYSIS         CIRCLE SOUP FILTER DUN           NITEON           ATTACK           ATTACK           ATTACK           ATTACK           ATTACK           COST AMALYSIS           CIRCLE SECURE           ATTACK           ATTACK | Departion         LOT         LOT <thlot< th="">         LOT         <thlot< th=""> <thlot<< td=""><td><i>LO 2 LO 2</i>          L</td></thlot<<></thlot<></thlot<> | <i>LO 2 LO 2</i> L |

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	OPERATION
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PN	1197020

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### ل ک 2 LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

و بم به مرا المرافقة و میں چر اور روالی کر اور

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111-21-69

ار بر بر محمد میرد. ۱۹۰۶ - ۲۰۰۱ ۱۹۰۶ - ۲۰۰۱ - ۲۰

N	IAME SPACER BEARING	<u>-</u> -	<u> </u>	VAN HOU	RS	RATE	N	ET DOLLA	ARS	DL	0 AT 260	)% *	G +	A AT 14	.25% *	TO	TAL DOLL	ARS
	•		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1.	ADVANCE QUOTES/CONSULTING	HRLY SAL																
2.	PROCUREMENT PLANNING	SAL	3.0	.6	.5	6.96	20.88	4.18	3.48	54.29	10.81	9.05	1071	814	1.79	85.81	17.19	14.32
3.	TOOLING	HRLY SAL		1	1		1			1				<u> </u>	<b></b>	1	1	
4.	RAWSTOCK	HRLY SAL		[			70,00	47,00	43,00				9.98	6.70	6.13	79.98	5/3/11	49/3
5.	CASTINGS OR FORGINGS	HRLY			1		-			<b></b>				<b> </b>				<u> </u>
6.	MACHINING FURN COMPLETE MISC MILLING	HRL# SAL	170 10.0	13.1	11.2	11.95	203.15	156,42	134.07	—			45.98	35.78	31.16	368.63	286.85	249.54
7.	WELDING BENCH	HREY SAL	2.0	1.6	<i>1.4</i> <i>1.4</i>	9.15	1830 2240	14.49	12.96				5.83	4.62	4.13	46.73	\$7.01	\$3/0
8.	ASSY & FAB QE	HRLY SAL													1	1		
9.	CLEANING	HRLY SAL			<b> </b>											1		
10.	Q C PLANNING	HRLY SAL				1												
11.	INSPECTION , REC.	HRLY SAL	،ئ ج	.5 .15	.5 15	4.87	244	7.44	2.44	634 9.05	634 230	634	1.25	1 <u>25</u> 53	/25 \53	10.03 14:32	10.03 4:27	10.03 4.27
12.	INSPECTION ,SOURCE	MALAY SAL	15	1.0	.9	6.96	10.44	6.96	6.26	27.14	18:10	16.29	5,36	<b>3</b> ,57	3.21	42.94	28.43	25.01
13.	INSIDE LIAISON	HRLY SAL					,											$d^{1/2}$
14.	SHIPPING	HRLY SAL	<u> </u>				6.00	4,32	3.84	—			.96	.62	:55	6.**	4.94	4.37
15.	<u> </u>	HRLY SAL																
16.	<u>, , , , , , , , , , , , , , , , , , , </u>	HRLY			1				1									
<b></b>	TOTAL UNIT CO	ST					476.79	349.40	307.73							455.37	44270	390.4
* N	AIDPOINT OF EFFORT - JAN '71			1	NET OP D ABOVE =	OLLARS X	PERCEN ARS (INH	TACES OUSE)					OP RAT	E AT \$12 E RATE A	2.00/HR	+ //NR (HRL	Y) *	
									EWSK	LIVAN	X 727	2						

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#### ム O 2 LOW COTTTRBOPUMP STUDY UNIT COST(B./SE CASE) UNIT COST ANALYSIS SISY ANA T2OD

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aiw *	POINT OF EFFORT - JAN '71				0 90 T 30 A B 0 VE =	NET DOLI	PERCEN	CISES (3200)					raa 90 Suohni	E AT \$1	ян/00.5 78.4 <b>2</b> та	אצ (אצר/ *	* (A	
	TOTAL UNIT COS	1					89601	25.0L	6629							+1212	54: III	Dert
.91		ראר אצרא																200
:51		SAL HRLY																
14° 21	SNIGG	ראר אצרא					001	_5L'	_5 L`				<b>*</b> /	01'	011	+ 11		
NI 'ET	NOSIDE LIRISON	ארא אגרא																38
75° IN	SPECTION, SOURCE	1∀S	Qï	&`	9.	969	269	2.2.2	814	0 181	25:51	12.81	<u></u> 5Σ	1 57	-17	ce'87		
NI 'TT	SPECTION, REC	HBLY SAL	نې ک	<i>اح</i> بي	<i>اک۔</i> بو	959 187	348	+0' 1 +12 = 7	1'0t	50°6 +E9	5.10	510	66.1	55.	، <del>دع</del>	7541	120	124
זס [.] מ	C PLANNING	HBLY SAL										721	521	387	527	5001	2001	10:01
10 .6	SNING	ראג אגרא																/
2 <b>4</b> .8	APB QE	ר ארג									·							
<b>MA '</b> L	NQLL JAS NI SECURA BENCH	- <b>775</b>	01 ج	&` \$	لاً ج	05.11	0E'11	11.8	18.L R/E				9z'Z	<i><b>7</b>Ľ1</i>	/ بی ک	£181	Rot/	29.21
rW '9	CHINING בחעת כסטורדבב	ant H¥F	つや	٤ /	\$·2		0217	2128	05.52				127	2:29	51.4	1945	1+2+	28085
₹. CV	STINGS OR FORGINGS	ר אצרג																
4. RA	M210CK	SAL HRLY					52'11	052	519									
<b>3.</b> TO	סרואפ	ארץ אצרץ		,				:		<b> </b>								, <b>†</b>
89 .S	DUNNALA TNAMARU20	, TA2 Hatt	05.	9 [.]	. ج	969	5034	814	84'E	62:4 <u>9</u>	1201	so'b	1:01	+12	<u>+ 11</u>	22.58		
JA .I	VANCE QUOTES/CONSULTING	S≱L HRLY						1	†									CL P/
			t	οτ	40	рек нк	t	στ	40	τ	ΟT	40	τ	0T	40	t	στ	01
<b>TMAN</b>	ี จุ่มเม่ย ระบะเม จุ่มเมษรย 1 กก		W	AUOH NA	S	<b>BTA</b> R	. IN	L COLLAR	S	DTO	VAT 260	* %	v + 9	. AT 14 .	52% ¥	/101	יד מסרדי	K2

Start and

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67-12-11/

Garage

Same ora

Section Sector

Ser. A.S.

OPERATION					LOW C	602	RPODI	MP STU	אחו	,		//	2-5-6	.4			
ITEM NO.					1011	NIT COST	DRASE C	WF 310 Ase)									
PN_ <u>7737007</u>					U	COST	ANALYSI	S V	(ENDO	R:FLU		RBON C	0. (RO	M QU	OTE 12	- +-69	)
NAME SEAL , LABYRIN TH-LOWER		N	AN HOUR	S	RATE	NE	TPOLLA	RS	, DL	0 AT 260	)% *	G +	A AT 14	.25% *	T01	AL DOLL	ARS
		1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES/CONSULTING	HRLY	L'NIT 2	12	riry 49		COST 182.70	EACN 101.25	84.90									·
2. PROCUREMENT PLANNING	SAL	30	-ئ.	τ,	696	20.73	3.49	2.04	54,29	9.05	7.80	10.71	1.74	1.41	85.78	14.32	11.3
3. TOOLING	HRLY											1		1			
4. RAWSTOCK HEL-F AMS-3650	HRLY				(	YENDO	R FURI	ISHED	₽						-		
5. CASTINGS OR FORGINGS	HRLY SAL														1		
6. MACHINING	HRLY	30.5	10.1	7.8	EST. 12.00	365.00	121.50	93,39	—			52.07	17.31	15.31	417.47	139.7	106.7
7. WELDING	HRLY SAL																Γ
8. ASSY & FAB QE	HRLY																
9. CLEANING	HRLY														1		
10. Q C PLANNING	HRLY SAL																
1. INSPECTION, REC	HRLY SAL	ح.	.5 .15	.5 .15	4.87	2.44	2.74 1.04	2.44	634 9.05	634 2.70	6.34 2.70	125	125 53	125	/093 /4.32	1093 471	10.02
2. INSPECTION, SOURCE	SAL	1.0	.2	./	6.76	6.F6	1.39	.70	18:00	3.61	1.81	3.57	.71	.61	28.63	571	4.93
13. INSIDE LIAISON	HRLY SAL																
14. SHIPPING	HRLY SAL				-	30.00	14.00	11.00				4.28	2.00	1.57	34.28	1600	12.5
15.	HRLY SAL																
16.	HRLY SAL				1												
TOTAL UNIT COST	`				1	429.60	143.85	110:00							570.60	189.14	49.7
* MIDPOINT OF EFFORT - JAN '71			N A	BOVE =	OLLARS X	PERCEN	TAGES OUSE)					OP RAT	E AT \$12 E RATE /	2.00/HR	* 7/HR (HRL	• • • Y) *	

and the state of the

11-24-69

OPERATION ITEM NO. ⁽⁶⁾ PN_______

#### レク 2 LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST (ANALYSIS

				<u> </u>	DATE	'NET		S	DL	AT 260	% <b>*</b>	G + A	AT 14.	25% *	TOT	L DOLLA	RS
NAME <u>RETAINERLABYRINT</u>	H-LOWER	N	AAN HOUR	5	RATE		NO T	40	1	10	40	1	10	40	1	10	40
		1	10	40	PERHR			40									1
1. ADVANCE QUOTES/CONSU	JLTING HRLY SAL					ļ										0546	2003
2. PROCUREMENT PLANNIN	G SAL	4.5	.9	.7	6.96	<u>3/</u> 32	6.24	4.87	81.43	16.22	1266	16.07	3,20	2,50	128,82	23.00	
3. TOOLING	HRLY SAL												2/12	208	A1 (3	2742	24.63
4. RAWSTOCK	HRLY SAL	í			<u> </u>	36.00	24.00	21.60					3.42	3.00			
5. CASTINGS OR FORGINGS	HRLY SAL	( 					<i>ac</i> 07	79.97			ļ	24.06	2/23	2243	279.06	210,21	180.22
6. MACHINING TURN COMPL	ETE HRE	10.0	7.7 7.7	6.6	11.95	119.50	92.02	78.87			<u> </u>	37,00	26.00	246	29 72	27.96	19.69
7. TELEVICE BENCH	T HRE	1.0	. <b>*</b> 1.2	.7 1.0	9,15 11,30	9 15	13.25	6.04				3.12	2.00	2.00	27.0-		
8. ASSY & FAB QE	HRL' SAL					-						 			<b> </b>		
9. CLEANING	HRL SAL	Y					ļ		ļ	ļ	ļ						
10. Q C PLANNING	HRL SAL	Y			_			244	634	634	634	1.25	1.25	1.25	10.03	10.03	1003
11. INSPECTION, REC	HRL	Y .5 .5	.5	.15	4.37	2.44 3.43	244	1.04	9.05	2,70	2 ,70	1.79	.53	. 53	14.32	4.27	4,27
12. INSPECTION, SOURCE	E SAL	# 1.0	حتى ا	.6	6.96	6.96	5.57	4.18	18.10	/4.48	10.87	337	2.37	2.7 +			
13. INSIDE LIAISON	HRL SAL	Y								ļ			·				9/4
14. SHIPPING	HRL SAL	Y				12.00	10.00	8.00		<u> </u>	 	1.7/	/.43	1.14	/3.//		
15.	H RL SAL	Y														+	+
16.	HRU	Y							_ <b>_</b>						5395	2 234 66	2852
TOT	FAL UNIT COST					357.30	25393	2.17.10								1	
* MIDPOINT OF EFFORT - J	JAN '71			NET OF	DOLLARS	S x PERCE	NTAGES					OP RA	ISE RATE	12.00/H	< <del>*</del> }7 <i>/</i> HR (HR	(LY) *	

(14110032)

EWSULLIVAN X7472

408

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among

			1							•	1 .			
11. INSPECTION, SOURCE	ION) HREY	15.0	7.5	5.0	6.96	104.00	5220	34.80	270.40	135.72	90 <b>48</b> 126.67	5335	26.78	17.85
12. INSPECTION, REC (PRECISION)	) HRLY SAL	.5	1.5	.5	4.87	2.44	2.44 10.44	2.44	6.34 36 19	6.34	634 1810	125.00 7.14	125.00	125.00 3.57
13. INSIDE LIAISON	HRLY SAL	/	1		1									
14. SHIPPING PRECISION	++RL-+ Sal-	1	-	-		37.00	32,00	2700	,			13:40	11.12	10.40
15. INSPECTION , REC ( PARAGON )	HRLY SAL	1.0	10	1.D 1.0	4,81 6,96	4.37 13.92	4.81 12+4	4.87 6.96	12.66 36.19	12. <b>66</b> 27.14	12:00	2.50 7.14	250	250 3,57
16.	HRLY	1								ļ				
TOTAL UNIT	COST					7549.10	5 73474	488.2	1	<u> </u>	TOXING	11,310.75		
A MIDDOINT OF FEFORT - IAN 173				NETOD	DOLLARS	V PERCEN	ITAGES					OP RAT	E AT \$12	1.00/HR

E W SULLIVAN X 7972

10 40 1 40 1 1 10 40 PER HR 1 10 40 10 HRLY 1. ADVANCE QUOTES/CONSULTING SAL 18.10 53.56 7.14 957 271.44 36.19 PRECISION 20 1.0 12.92 6.96 15.0 104.90 1000 6.96 2. PROCUREMENT PLANNING 5.36 69.36 10.71 35152 59.21 27.14 SAL 200 3.0 1.5 13520 20.98 10.44 PARACON ...... 1146.00 FRECISION CASTING 1:00C HRLY . SAL 19115 276.75 × . . ----PARAGON HRLY SAL 35625 299.25 249.38 285625 239925 199338 HRE 2500002,0000175000 14.00 125.0 5. CASTINGS CRECONCINGS 179.0 1500 SHE PRECISION CASTING 896.25 679.59 625.58 178.29 2047.93 158214 1429.45 1101-1 75.0 58.1 52.4 255.43 197.96 TURN COMPLETE 11.95 896.25694.59 625.5 0 546 581 52.4 75.0 MISC. MILLING 29800 22946 19668 2389.25 1839.72 576.9

#### LOZ LOW COST TUREOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

1 NET DOLLARS

2091.25 161026 138023

201,30 153,00/32.86

28250 2,7.53 18445

NAME VOLUTE PUMP

ABOVE = NET DOLLARS (INHOUSE)

INHOUSE RATE AT \$4.87/NR (HRLY) *

RATE

11.95

9.15

11.30

MAN HOURS

115.5

14.5

16.5

134,80

16.9

19.3

OPERATION ITEM NO. (7 PN //37003

3. TOOLING

4. RAWSTOCK

6. MACHINING

8. ASSYA FAR OF

7. WEEDING

9. CLEANING

10. Q C PLANNING

DRILL ALL HOLES

BENCH

INSPECTION

AND PORTS

* MIDPOINT OF EFFORT - JAN '71

THREE

SAL

11013

546

HRLY

SAL HRLY

SAL

15.0

220

25.0

111-25-69

DLO AT 260% *

G + A AT 14.25% *

53.09

48.94

45.50

1

42940

536.07

7190.00

2170,75

TOTAL DOLLARS

10

5725

85.M

• ------

53274 425.62 364 \$1

427.75 214.70 1457

2377723626 2004

5725 42.94

0370: 7100

10.03

107.40

20.03

10.03

81/2

20.03

57.25 42.94 21.63

10.03

28.63

2140

2003

40

23.4

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42.74

ON WELL	

Sec. 3

لوير ميشون

فتسمعنا فأرث

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#### COST AVALYSIS UNIT COST (BASE CASE) LOW COST TURBOPUMP STUDY 207

	* (A	1748 (HBL	ХН/00.5 8.82 ТА	2E BVIE /	NUHNI AN 40					S304T	PERCEN	× SAAJJO	NET OP D				TT NAL - TROATA AO TNIO901M *	
									2522/	50051	00122						TOTAL UNIT COST	
5276/	1.57/6	56 + 28														אר אוורא	·91	
																SAL אוגרא	'ST	
		4 7 7	+/>	/2.	62.				001	،نحەت	002					S≱L HRLY	14' SHIPPING	
<b>•</b> /·/	121															ארא אפר	13. INSIDE LIAISON	
<i>(</i> ) <del>(</del> )	79'72	5922	\$1'2	2.52	<u>1_5'E</u>	1591	8441	0181	814	155	969	95.9	7 ·	K.	01	ר אבדא	ער האראבכדוסא, בסטתכב	
124	12.4	2541	:23	23	621	510	012	50°6	+0'l	+07 ++3	245	369 184	` `	۰۱ <u>ک</u> ۲	`ۍ کړ	ר אררא	ער ASPECTION, אבכ	
5001	[90]	2001	122	521	261	76/										צער אנרא	10. QCPLANNING	
																ראר אאר∧	6. CLEANING	
																צער אוור∧	8. ASSY & FAB QE	
					++'				5402	ESYZ	058	05.11	+·/	2.1	50 50	-3975 A-1811	HINDER INCH	
4 2.82	0929	+70.5 	787	••• ···	1.1.51				3122	18.92	010	5641	7.Z 7.Z	1.5	0.4	7₩5 2:2011	B. MACHINING TURY COMPLETE	
60 ZL	142	21.4//	0 4 G	89.41					5316	1674	Uall					ראר אצרא	5. CASTINGS OR FORGINGS	
1581	1502	58°0E	152	1.5'2	588				0291	0081	00'LZ					אר אארא	4. REWSTOCK	
				ł							· · · · ·					צער אוצרא	3. TOOLING	
~`07		70271	05'2	02'E	1091	1566	22'71	£#Y8	184	+2'9	2512	959	L`	Ь	54	<b>T</b> ∀S	2. PROCUREMENT PLANNING	
1006	77.5 6															SAL HRLY	1. ADVANCE QUOTES/CONSULTING	
40	στ	<u> </u>	07	στ	τ	40	στ	τ	40	10	τ	РЕ В НВ	40	<b>J</b> 0	τ	]		
Sa		V101	¥ %57	. AT 14	v+ 9	* %	092 14 (	o <b>n</b> a'	S	DOLLAR	NET	<b>BTAR</b>	S	RUOH NA	W	NAME NUTTY PUMP RETAINING		

S. S. S. S. S.

C. Set

(SUDALE SUCLARS (INHOUSE)

Sec. Sec.

Sugar Chier Store Store

a Cound

ZLELX NUALTINS M 3

* (YJAH) AH/T8. AZ TA BTAA BUOHNI

weeks 3

69-52-11/

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ZLELX MWAITTIS A 3

(0+) / E.EOE/ + (ATHH) WH/LE. 15 IN JINH JSOOHNI (+) 0-5:5842

+ MIDEOINT OF EFF(	IT' NAL - TR			♥ N	180AE = 1	ובד מסררי הרראצא א	PERCENT	ONZE) (VCEZ C	12 2 50.	, <i>י א</i> כלל	5892 91541 L -8 N 101	(●1) C (1) E 7 サルハロロ	BTAR 90 BZUOHNI	5 RATE A A 3749	* AH\00. \78.22 T	<b>.72H) XH</b>	<i>+</i> ()	
	TOTAL UNIT COST						95-+111	ટ્યુટટ્ટ	20.022	1		-9-117301	0122+51			#ZS02	asst N	952.46
.9		SAL HRLY																
S, INGPECTION,	BOURCE (LAMCO)	TAR	04	92	oיz	969	48°LZ	2024	2581	12.54	62:45	b 1 TE.	2271	1291	+12	05:#11	16:58	5725
SHIPPING		2AL HRLY					00'5Z	0081	0001	-			25°E	152	00'2	3.58Z	1503	009/
3. INSIDE LINISON		צער אוורא								ţ			1					al .
S. INSPECTION , S	(ш.~ ч) ээып	775	0'51	يجد	20	959	00:401	0275	08:45	00012	21:52/	<b>\$</b> \$66	5585	2192	58'LI	52227	02+18	E15>1
T. INSPECTION RE	כ	SAL HRLY	0 S 0 S	5° 0'1	_5` 0'1	957 184	88.02 \$1.0	24E 184	2+5	24 3 X 75 3 3 T	50°6 99`7/	50°6 99'21	12:51	12:5	er¥	+252/	+6'45	***
O. QCPLANNING		רע אצרא											_					•
9. CLEANING		אר אוויע																1.
3 <del>) 801 9 16 1</del> .8	1 7.3d SN I H 7.11.3B	JWS HENE	001 001-	08 0'8	02 08	0E'll _SIB	005/1 051b	0=16 025L	04°06 025L				<b>₩/8</b> Ζ	1282	15.52	+ <b>#</b> ££Z	1598/	14.98/
י א <b>פרסאט א</b> ודר \$	3N17d5	345 47884	0.9	0.4	0.2	0071	007L	00.84	00'98				9201	+87	ع:رع	9228	***5	£17#
AND SNINIHOW .9	רר א כמשערפגב	THES.	04 04-	0'E 5'E	5'Z	00.21	00°8# 008#	37°00 45°00	0052 0002				2.9'81	zi'll	0£ L	<b>29</b> 601	2/B&	0619
LSUJ WIEG SOUINES SOUT	50NI 	3955 49094	1.22	52'0	+·13	0041	0005t	-i 258	si 09E				E 149	2864	_s:2+	EHH.S	15:66 E	52245
4. RAWSTOCK		ALL HRLY																
3. TOOLING / PEN	( == NI_1 SU U	ARL ARL					~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~						SZ*8761	-		\$/EZ#_SI		-
2. PROCUREMENT	COUCO SNINNAJC SNINNAJC	T∀S XTXX	0.7 05	0:1 01	_5* ∠*	969	91'16 +939	969 959	8.85 1.84	85801 98791	o i E I o i E I	50% 9781	2513 2513	155	/'26 2'2ه	45251 57258	5883 5883	z£\$∕ 6√92
I. ADVANCE QUOTI	SMITJURNODAS	HBLY SAL																ŧ:
			t	TO	40	РЕЯ НВ	τ	10	40	T	<b>T</b> 0	07	Ţ	10	40	T	10	05
AAMI JMAN	4		V V	апон иал	. St	3TA9	I NE	A 1101 T	รย	DC	0.45 TA 0	¥ %(	ן ניי	ALTA A	* *56	LOT	100 10	2 <b>q</b> A

0958,8710N 175M NO. (19 700551 N9

د این از م دیرجانات

ا در بارد. افرار منطقه

SISYJANA T200 UNIT COST (BASE CASE) LOW COST TURBOPUMP STUDY

A . A . .

207

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67-72-11 /

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9002511 Nd OPERATION

Same 3

* MIDPOINT OF EFFORT - JAN YI

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de conta a

#### UNIT COST (BASE CASE) LOW COST TURBOPUMP STUDY 707

SISYJANA T200

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	1503 TIMIT NATOT						z9428	60263b	82.82%	l	£N17001	00959E				100+2	208822	E 16454
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NOUDOONA	211775							L										
		346					00001	≠68L	#19L			[	8075	10.57	1-1277	00% 57		10.01
<u></u>	UNIOS UVSAIL						15200	1926	1928				50 00	12.10	8000	90 000	ESGUG	0508/
DNIAGIHS 'I		ארג					2017	OORE	2000		·			0.74	0.01			
		X IGH					0000		0002	L			02.5	\$ 27	*27	02.5P	28.25	*2.05
NOSIVIT BOISNI "		רארג						1										
								<u> </u>								{		I
S' INSPECTION , RE	Ċ	S ∛Γ	0.2			35.9	2038	8-9.8	848	6245	50%	506						
		лин	02	04	07	752	+1'b	18.4	L8-7	25.32	75'21	75Z1	12.21	220	627	HE 521	72.25	3434
INSPECTION, 50	טאכב		0:52	0.8	0.9	a 1. 7												
		ASIGH					0000	22.73	92.14	07050	11.001	25801	98.98	22°2	2912	99:5/2	22801	2Ľ1/1
	NOLJJJUSN	<b>₩</b> \$	OEZ	1.11	7.51	ر بر سر بر											1	·····
<b>\</b>	800NAN	A#######				02/1	086.36	21.000	121 23				+022	2582	26.44	* <i>**</i> 76Z	33866	25561
	BENCH	345	009	5.94	268	516	00%45	51.720	45 298								1	
	- JANEL 374W05 103-P	A=184	002	8.82	2.95	<u>asib</u>	00-579	50'215	06:85+				00221	12281	21.411	09288/	10,200	24:516
7 30-87-1-9-7557 '8	5831111	<b>7</b> ₩\$	0.06	5.8	5.6	- 1'L	0.5.56B 54.601	9748	50%5									
	SOUGH GEN.	AFIBH	0:52	8.25	5.60		52.94	19	\$5700				53676	51.50	01.691	1220002	e:955/	p.50251
SHIDDLY SASA	E/TRIM PARTIAL	THES	021	1.51	5.11	er'll	50312	E+1951	20:681								1	
SINIS	SUNCLINO PASILL N		0.81	6.81	6.11		01.512	89:571	16.141				0963	6850	4592	SELL+	1_56°L98	85512
WACHINING TURN	INITUS YOU	<b>3</b>	0.51	9.11	6.6	ci'll	52861	20'821	1E'8//				an'Ch		-	1.25		
	1 EV& E W		0.04	8.05	7.25	30 "	p0814	90878	8+5/2				9960	2/2L	2817	160.72	02865	19:58+
	SONIO	JAS					0000	1057	NS/ C				- 0°+//		1.10			
		N 18H			ļ		00004	00 9_//	00_2 _3		L	I	0000	1920	+6 10	000016	E924L	+6957
. RAWSTOCK		JAS			1													
		N IGH		ļ					ļ	ļ								
1 TOOLING		SAL 1														- 2001		
		A IGH					000000		ļ	ļ	L	<u> </u>	007510			599592		
. Реосивементри	ONINNA.	<u></u> ZAL	0.51	0.2	01	4.7	05401	TA'E/	-17	1-117	1,35		- 10 0					
				, <u> </u>								012-1	952.7	\$/L	1.5%	0562+	5215	2863
ZETOUD EDNAVOA	DNILTASNOO/	S≱⊑		1	· ·				1									
				<u> </u>					1							1		
			τ	0τ	40	РЕ В НВ	τ	ΟT	40	τ	στ	40	τ	OT	40	î Î	OT	01
INDUCER		W	AUOH NA	S	RATE	. 3N	L DOLLAF	S	סדם	AT 260	* %	v+9	AT 14.	¥%52	101	יר ססררי	Sa	
		-							-									

ZLEL X NUNITASMJ

* (YJRH) RH\T8. 2 TA BTAR BUOHNI * 9H/00.51\$ TA 3TA9 90

67-92-11 /

ABOVE = NET DOLLARS (INHOUSE)

NET OP DOLLARS × PERCENTAGES



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#### LO2_ LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

1.1.1

مستحصور فاسترج

11-26-65

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N	AME MUT ASSEMBL	Y.IMPELLER RETAIL	NING	h	AN HOU	RS	RATE	NE	TUOLLA	RS	DL	0 AT 260	% *	G + A AT 14.25% * TOTAL DOLLARS				ARS	
				1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1.	ADVANCE QUOTE	CONSULTING	HRLY SAL																
2.	PROCUREMENT P	LANNING	SAL	60	1.D	.5	6.96	41.76	<i>6.</i> 96	3,48	108.58	1810	१९९५	21.42	3,57	1.79	15 9.34	28,63	14:32
3.	TOOLING	· · ·	HRLY SAL																
4.	RAWSTOCK							33.00	22.00	19.80				4.70	3.14	2.82	37,70	25.14	2262
5.	CASTINGS OR FO	RGINGS	HRLY SAL													 			
6.	MACHINING TURI	- THREAD	HRLY SAL	300	23.4	20.8	11.95	32.3.20	279.63	248,93	<u> </u>			57.09	39.75	35.48	409.57	\$/9##	284.94
7.	WELDING L	RENCH ECT	HRLY	Z.O Z.O	1.5	1.3 1.3	9.15 11.30	/8,30 22.60	14.09 17,40	12.08 14.92	—			5,83	<b>+</b> . <b></b>	3.85	46.73	25.78	27.00
8.	ASSY & FAB QE		HRLY SAL													L	ļ		
9.	CLEANING		HRLY SAL								 						ļ		
10.	Q C PLANNING		HRLY SAL																
11.	INSPECTION , M	iC.	HRLY	ر.	.5 .15	. 5 .15	4.87 696	244	2,44 1.04	2.44	63 <del>4</del> 9,05	6.34 2.70	634 2.70	1.25	1,25 .53	.25	10.03	427	427
12.	INSPECTION , SO	URCE	SAL	1.0	10	1.D	6.96	6.96	6.96	6.96	13.10	18.10	18!0	357	3.57	357	23:53	2753	23.63
:13.	INSIDE LIAISON		HRLY SAL																·
14.	. SHIPPING	<u></u>	HRLY				_	4.00	2.50	200				.57	36	,27	4.57	2.86	2,27
15.	•		HRLY SAL														ļ		
16.	•		HRLY											 		ļ			
<u> </u>	- <u> </u>	TOTAL UNIT COST						491,04	35.302	3//.70							710.96	453.02	39360
*	MIDPOINT OF EFFO	RT - JAN '71				NET OP	DOLLARS	× PERCEN	TAGES					OP RAT	E AT \$1	2.00/HR AT \$4.87	* //HR (HRL	Y) *	

EW SULLIVAN X7872

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OPERATION				_				AP STU	DY								
ITEM NO.					11		(FASE C/	ASE)								,	
PN_1137008					0	COST A	NALYSIS	. v	ENDOR	: FLU	DROCAR	BON CO	. (RON	0007	E 12-4	-69)	
					<del></del>								AT 14	254 +	TOT		29
NAME SEAL LABYRINTH - L	IPPER	N	IAN HOUR	s	RATE	NE	TOOLLA	RS		JA1 260	% *	1	10	40	1	10	40
		1	10	40	PERHR	1	10	40		10	40		10				
1. ADVANCE QUOTES/CONSULTING	HRLY SAL	דואע 2	QUAN 12	44		182.70	LACH ICI.25	84,90									
2. PROCUREMENT PLANNING	HRLY	3.0	.5	3 ،	6.96	20.83	3.48	2.09	54.29	9.05	780	10.71	/.77	1.41	83.85	/4:32	
3. TOOLING	HRLY SAL					VE	1008										
4. RAWSTOCK HEL-F AMS-3650	HRLY SAL					(FURA	ISHED)				· · · · ·						
5. CASTINGS OR FORGINGS	HRLY SAL														417.47	(199 84	101 70
6. MACHINING	HRLY SAL	30.5	10.1	7.8	237. 12.00	86540	121.50	93.39				52.07	/7.3/	13.51	417347	/38.07	106
7. WELDING	HRLY SAL			L													
8. ASSY & FAB QE	HRLY SAL	′										ļ					
9. CLEANING	HRLY SAL	1											<u> </u>		<b></b>		
10. Q C PLANNING	HRLY SAL	1							194	1.34	634	125	125	125	10.03	10.03	1003
11. INSPECTION, REC	HRLY SAL	(.5 .5	.5 .15	.5 \15	4.87	244	1.04	1.04	9.05	2.70	2.70	1.79	.53	.53	14.32	4.27	4,27
12. INSPECTION SOURCE	HRLA SAL	1.0	.2	./	6.96	6.96	137	,70	18,10	3.61	1.81	3.57		6/	28.05		
13. INSIDE LIAISON	HRLY SAL	1					 			 		ļ			<u> </u>		10.57
14. SHIPPING	HRL	1-				30.00	14.00	11.00	—			4.28	2.00	1,57	34.28	16.00	12,31
15.	HRLY	r				<u> </u>			<b>_</b>				ļ		<b>_</b>	<b> </b>	┟───┤
16.	HRL' SAL	Y							<u> </u>	ļ	<b>_</b>		<b></b>	<b>_</b>	570.01	18914	149.34
TOTAL UNI	TCOST		1			429.60	143.85	110.66		l		<u> </u>	<u></u>	1			teres d
* MIDPOINT OF EFFORT - JAN '71				NET OP ABOVE	DOLLARS	X PERCEN LARS (INI	ITAGES HOUSE)	W SULL	IVAN	x 7872	2	op ra Inhou	TE AT \$1 SE RATE	2.00/HR AT \$4.8	:* 7/HR (HRI	LY) *	

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OPERATION ITEM NO. 23 PN_1/37009

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### LOW COST TUPBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

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	NAME SPACER, SEAL-LABYRINTH			MAN HOU	RS	RATE	N	ET DOLL	ARS	D	LO AT 26	0% *	* G + A AT 14.25% * TOTAL DOLLARS						
			1_1_	10	40	PERHR	1	10	40	1	10	40	1	10	40	1 1	1 10	T A	
1	ADVANCE QUOTESCONSULTING	HRLY SAL													1-10-	•		1	
2.	. PROCUREMENT PLANNING	SAL	3.0	.5	۰3	6.96	20.80	3,48	Z	54,29	9.05	7.30	10.71	1.7 7	141	85.00	14,32	11,30	
3.	. TOOLING	HRLY		1		1	1			+	1		+					+	
4.	. RAWSTOCK	HRLY SAL			<b>†</b>	-	12.00	8.00	7.20	·		<u> </u>	1.71	1.14	1.03	13.71	914	8,23	
5.	CASTINGS OR FORGINGS	HRLY SAL		1	1					+		+		+				+	
6.	MACHINING TURN COMPLETE DRILL 24 HOLES	HRLY SAL	7.0	54	4.6	11.95	83.45	64.41	55.21				28.15	22.29	19.11	203:5	- 179.72	153.19	
7.	WELSING BENCH INSPECT	HREY SAL	1.0	8. 8.	.7 .7	9.15	9,15	7.05	6.04			<u> </u>	2.91	2.24	1.92	2336	17.99	15:42	
8.	ASSY & FAB QE	HRLY SAL		1	1.		1		1	1		1 .		1	<b> </b>	<del> </del>		<b> </b>	
9.	CLEANING	HRLY SAL					1		1			1					ł		
10.	Q C PLANNING	HRLY SAL					<b> </b>		1	1				<u> </u>		<u> </u>	†		
11.	INSPECTION , REC	HRLY SAL	.ج ج.	.5 .15	.5 .15	4.87	2.44	744 104	2.94	634 9.05	634 7.70	634	1.25	1.25	1,25	10.03	10.63	10.07	
12.	INSPECTION ,SOURCE	SAL	1.D	\$،	.6	6.96	696	5.57	4.18	18:10	14.43	10.87	3.57	2,57	214	2863	72.62	1719	
13.	INSIDE LIAISON	HRLY SAL									-						┣ <b>╼──</b> ┥		
14.	SHIPPING	HRLY SAL	-				4.00	3.00	250				.57	.43	36	4.51	3.43	2.56	
15.	· · · · · · · · · · · · · · · · · · ·	HRLY													<u></u>			{	
16.		HRLY																	
* * *	TOTAL UNIT COST						27336	195.71	167.03							933.45	26052	22200	
~ N	TUPUNT OF EFFORT - JAN '71			N	ET OP DO BOVE = N	LLARS X	PERCENT ARS (INH	AGES CUSE)					OP RAT	E AT \$12 E RATE A	.00/HR 1 T \$4 .87	/NR (HRL'			

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#### SISYJAAA T200 UNIT COST (JASE CASE) LOW COST TURSOPUMP STUDY 207

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			* AH\00.	E V1 \$75	ITAN 90					SECA.	ревсеит	× SaA	ET 0P DC	N			POINT OF EFFORT - JAN '71	01W +		
<b>N</b> LZ	H# 818	2/182						1	mbas	22922	338'32						TOTAL UNIT COST			
<b>y</b>											· .					SAL HRLY		. <b>9</b> 1		
																אר אוור∧		·s1		
008	12'01	1521	001	82Y	1.51			-	00°L	00%	11'00					רע אשרא	SNI991H	5 °₽T		
																ALLY HRLY	ISIDE FIVIZON	13° 19		
6121	22,62	5803	510	1.5'2	158	18.01	2541	0181	21.4	15.5	969	357	7`	e.	0'1	SAL HELET	ISPECTION SOURCE	15° II		
124	130	TE'E / E07/	<u>3 ح`</u>	تى رىخى 1	61' / 52' /	01'Z 2'10	01'Z 5E9	50'6 56'9	40V 544	+0'/ ++ 5	87E 772	96°9 18`4	، <i>ا</i> ک بک	اک ک	، تک بک	AL ARLY	ISPECTION, REC	11' II		
																AL HRLY	C PLANNING	10. Q		
																אר אארא	LEANING	o .e		
																S≱L HRLY	SY & FAB QE	A .8		
6961	35.22	2862	9 <b>+</b> 2	<b>36</b> , S	z1'£				6111 +09	5081	5571	0E'll 51'b	0'1	Z .1 &`	5'1 0'1		L D345NI DW000 DW000	<b>M</b> .T		
ozILI	*****	52,240	SE/Z	16.42	35.35				18°8L 86'0L	2075 1878	0_5'b11 5_5[01	50'11	7.9 6.5	L.L 15.9	001 06	.2¥F HKF∔	DUITE 2 & HOLES ACHINING LUM CONFLETE	N .ð		
																HRLY SAL	SOUDADA RO SOUTZA	5. C		
502	58.72	az #£	2`و_⊥	583	#z*b				0021	0002	0002				_	SAL BRLY	AWSTOCK	4.8		
																SAL SAL	OOLING	τ.ε		
007	3200	25.5.7/	520	028	20.71	9921	22.91	E# 18	184	*27	3135	959	۲.	6	5.4	JAS MRLY	ROCUREMENT PLANNING	ч.S		
																SAL HRLY	DVANCE QUOTES/CONSULTING	Α.Γ		
01	στ	τ	40	ΟΤ	τ	40	ΟΤ	τ	40	ΟT	τ	РЕ В НВ	40	στ	τ	1				
<b>S</b> RS	7700 77	101	* %52	ALTA A	/+9	¥ %	0 AT 260	<b>n</b> a'	SS	¥ 100 ⊥	ЭN	<b>BTA</b> R	S	RUOH NA	N	1	A 399U - HTNIRKARL, R.2N/KT 3R 3M AN			

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(3200HNI) SAAJJOO TAN = AVOBA

* (YJRH) RH\T8. # TA BTAR BRUNN

OPERATION ITEM NO. 25 PN_//37026

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### LO2 LOW COST TURBOPUMP STUDY UNIT COST (PASE CASE) COST ANALYSIS

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EW SULLIVAN X 7872

ļ	NAME ADAPTER, PUMP INLET			MAN HOU	RS	RATE	N	ET DOLL	ARS	, DL	LO AT 26	0% *	G +	A AT 14	.25% *	TO	TAL DOLL	ARS
			1	10	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1.	ADVANCE QUOTES/CONSULTING	HRLY SAL																
2.	PRECISION CASTIN PROCUREMENT PLANNING PARAGON	SAL	4.5 4.0	1.0	.7	6.96	3/32	1.96	4.87	81.43	18:10	1266	16.67	357	2.50	129.42	2863	200
3.	TOOLING PRECISION LASTING	HRLY				+   .	97.50	-	\	· · · · · · · · · · · · · · · · · · ·		1200	13894		<u> </u>	1/13.99		20.04
4.	RAWSTOCK	HRLY			1			1		1	1	1			1	1		1
5.	CASTINGS CARDING	HRLA SML	42.9	32.1	28.6	14.00	600.00	450,00	40000		<u> </u>		95.50	64.13	57,00	685.5	51413	\$57.00
6.	MACHINING TURN COMPLETE MISC MILLING	HRET SAL	20.D 4.0	15.4 3.1	13.2 2.6	11.95	239.00 47.80	189.00	31.55				40.37	3/47	26.97	327.67	25275	21626
7.	WELDING DRILL ALL HOLES	HREV SAE	15.0	11.6	9.9	11.95	179.25	1380Z	118.31				25,54	19.67	1690	204.74	157.64	135.17
8.	AENCH INSPECTION	HRLY SPIL	3.0 4.0	2.3 8-1	2.0 2.6	9.15 11.30	27.45 45.20	21.14 3480	18.12 29.83				10.35	7.97	633	8300	63.91	54.78
9.	CLEANING	HRLY SAL					· ·									1		· · · ·
10.	Q C PLANNING	HRLY SAL																
11.	INSPECTION, SOURCE PRECISION ) (PARAGON)	HRLY SAL	Z.O 4.5	1.5 3.0	1.0 2.7	6.96	13.92 31.32	10.44	6.96	36.19 71.43	27/4 54.29	17.10 48.35	7.14 16.97	5.56	3.57 9.64	57.25	42.94	28.67
12.	INSPECTION, RED (PRECISION)	HRLY SAL	.5 .5	.15	5	4.87 6.96	2.44 3.48	244 ; 04	2.44 1.04	6.34 9.05	634 2.70	63 <del>4</del> 2.70	1.25	1.25	1,25	10.03 14,32	10.03	10.03 4.27
13.	INSIDE LIAISON	HRLY SAL																
14.	SHIPPING PRECISION CASTING PARAGON	HRLEY SAL			<u> </u>		10.00	8.00 14.00	6.00 1200		·		3.85	3./4	2.57	30.85	25:14	20.57
15.	INSPECTION, REC (Parabon)	HRLY SAL	1.0 1.0	1.0	1.0	4.87 6.96	4 17 13,92	4.77 1644	4.87 696	12.66 36.19	12.66	12.66 18:00	2.50 7.14	2.50 5.36	25+ 587	20.03	2003	2007
16.		HRLY SAL																
	TOTAL UNIT COST			1		1	13294	750.00	824.35	1	[	TOLING	1342.44			2000.5%	12765	101
* 1	MIDPOINT OF EFFORT - JAN '71			<b>1</b>	NETOPD	OLLARS X	PERCEN	TAGES					OP RAT	E AT \$12	.00/HR	*		

ABOVE = NET DOLLARS (INHOUSE)

WHOUSE RATE AT \$4.87/HR (HRLY) *

12-1-69

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ITEM NO. 26 PN_1137022

OPERATION

#### レク2 LOW COST TURBOPUMP STUDY UNIT COST (BASE CASE) COST ANALYSIS

	504/5	Г		ANUOUD	c	PATE	NET		25	DLO	AT 260	/ <b>。★</b>	G + A	AT 14.	25% *	TOT	AL DOLLA	IRS
NAME ROTOR TU	TISINE	-	1 1	10	<u> </u>	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
			<u>+</u>															
1. ADVANCE QUOTES	CONSULTING	SAL																
2. PROCUREMENT PL	ANNING	HRLY SAL	15.0	2.0	1.0	6.96	10440	13.92	696	271.44	36.11	18! 0	53.56	7,14	3.57	429,40	57.25	28.03
3. TOOLING		HRLY					1. <u>75</u> 2?						216 63			1656.63	•	• • • •
4. RAWSTOCK FOR	NNB	HREY					105000	700.00	600.00	·			49.63	979.75	85.50	1199.63	799.75	685.50
5. <del>CHITTINGS OR</del> FOR	LATHE MILL	HRLY	65.0 35.0	50.00	42.9 23.1	11.95	776.75	577.10	515.66 276.05 94.64				190.72	146.86	/26.30	1429.12	//77. <b>43</b>	1012.55
6. <b>Macmanito</b>	DRILL PANTOBRAPH CUTTERS	HRET	/2.0 200.0 /2.0	9.2 154.0 9.2	1320	9.15	1830-00	1409.10	1207.80 72.47 452.73				374.21	288.14	218.48	3000.26	23/0.20	/757.6-7
7. WELDING	BENCH NENDOR	HAREN SHE	20.0	<u>57.8</u> 15.4	/3·Z	11,30	2260	174.02	149.16				327-1	24.80	21.20	258.21	199.82	/70.42
8. ASSY & FAB QE		HRLY SAL														<u> </u>		<b> </b>
9. CLEANING		HRLY SAL											ļ					
10. Q C PLANNING		HRLY SAL													10.95	42775	2/4.70	143.13
11. INSPECTION	URCE	SAL	15.0	7.5	5.0	6.96	10400	57.20	34.80	270.40	/35.72	90,48	53,35	26.78	1203	721,00		7434
12. INSPECTION T	E C	HRLY	2.0	1.0	1.0	4.87 6.96	9.74	1.87 3.48	4.81 3.48	25,31 54,29	9.05	9,05	15.71	4.28	4.28	125.34		
13. INSIDE LIAISON		HRLY	/	1										ļ	<u> </u>	ļ	┼	
14. SHIPPING		NRLY SAL	1				60.00	45.00	4000				8.55	6.41	5.70	68.55	57.41	45.70
15.		HRLY	1	1						ļ	<u> </u>	<u> </u>				<b>_</b>	<u> </u>	
16.		HRLY	1											<b></b>	<u> </u>	49 37	429	13770.01
	TOTAL UNIT COST		1	1			55384	404612	-3457.7	TOOLING	V656.C3				1	67.31		
* MIDPOINT OF EFFO	RT - JAN '71		<b>.</b>	<u></u>	NET OP	DOLLARS	x PERCE	NTAGES					OP RA INHOU	TE AT \$1 SE RATE	AT \$4.8	t * 17/HR (HR	LY) *	

DULLARS (INHOUSE)

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CONTEX IN

JA, SHIPPING				—		00'Ę	00'Z	597				54	62,	<b>≠</b> 2
T3" INRIDE FIVIZON	ארא אצר∧					:								
ואראבנדוטא _ו בסטאכבב	775	0"1	8'	9-	959	96'9	2.67	814	0181	85-61	1 <b>8</b> 01	73.5	137	\$12
II. INSPECTION , REC	אר אארא	<u>י</u> ב בי	5 <b>1:</b>	۲. ۲.	969 28-0	3*8 ++7	1,04 7,44	1000	50'b +E9	5.70	5'10 7'2+	411 921	23 1.52	29. 176
10. QCPLANNING	אר אארא													
S. CLEANING	אר או∛רא													
8. HORETO GRIND THREAD GRIND THREAD GRIND	7#5 1.7884					1500	656	148				121	551	.0/21
T DEGENI ONICE T	3#5 1.3###	0.1	<u>چ</u> .	۲.	05'11	// ٤٥	018	75%				171	+21	90'/
שורר 9. WECHINING בחצא כסשארבבנ (דכיר)	7₩S	0.5 0.01	57 22	5 ·/ 7 ·7	5641	045Z 05611	• 5 81 2026	11:51 11:81				£≠0Z	£2`51	\$\$`E!
S. CASTINGS OR FORGINGS	AL ARLY							``````````````````````````````````````						
4. RAWSTOCK	SAL HRLY	. <u></u>				0081	00Z/	0ë 91				2 و حد	11.1	<b>\$</b> \$^/
3. TOOLING	SAL HRLY					•								
2. PROCUREMENT PLANNING	JAS	05	7:	۰ کـ	959	202	814	275	6275	101	_So Z	1201	\$12	614
1. ADVANCE QUOTES/CONSULTING	SAL HRLY	<u></u>												
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* WIDEOINT OF EFFORT - JAN '71

TOTAL UNIT COST

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OPERATION ITEM NO. 28

PN_1137024

#### LOW COST TURLOPUMP STUDY UNIT COST (GASE CASE) PARAGON (MACH) COST ANALYSIS

L02

( 25 WEENS DEL.) PICCO INDUSTRIES (CASTING)

TOTAL DOLLARS G + A AT 14.25% * DLO AT 260% * NET JOLLARS NAME MANIFOLD, TURBINE INLET RATE MAN HOURS 10 40 10 40 10 40 1 . 1 40 PERHR 1 10 40 10 1 HRLY 1. ADVANCE QUOTES/CONSULTING SAL 25.80 208.30 34.30 20.88 54280 90.48 54.29 107.10 1887.70 143.13 17.85 10.71 HALT 30.0 3.0 PICCO 5.0 696 15.88 2. PROCUREMENT PLANNING 17.85 10.71 858.70 14913 107.10 90.41 54.29 542.30 SAL 320 7430 20.88 208.70 3.0 5.0 PARAGON 27,420 ..... 3420 3. TOOLING PICLO INDUSTRIES ZADOC HRLY 171.3.7.5 213.75 15:00 SAE I TITTA PARAGON -----245.00 176.70 159.00 2125.00 416.70 275.00 1860.00 12 40.00 1116.00 HRLY 4. RAWSTOCK PARAGON SAE 513.00 171.00 123:00 4113.00 1971.00 102800 360000 1200.00 900.00 14.00 HRET 557 643 2571 5. CASTINGS OR FORSINGS SAE PICCO INDUSTRIES 391.66 313.33 279.27 3140.16 2512132239.07 1792501422.051242.80 6. MACHINING TURN COMPLETE 104.0 HRLY 1500 1190 11.95 776.75 717.0 600 956.0 語 20.0 65.0 MISC. MILLING 167.05 149.00 1706.61 1338 35 1194.63 149375 1172.30 1045.63 7. WELLING DITILL ALL HOLES 212.86 HRLY 87.5 11.95 98.0 1250 SAL + PORTS 50.85 45.64 522.69 407.70 365.89 457.50 356.85 320.25 65.19 *** sao 39.0 35.0 7.15 8. ASHATABE BENCH SALF 4948 37.04 451.86 303.38 296.94 395.50305.10 259.90 5636 11.30 27.0 230 550 INSPECT 9. CLEMMIC-HRLY 10. Q C PLANNING SAL 28,79 286.26 229.01 35,70 2856 55.62 542.82 180.96 144.77 107.11 69.60 20830 10.0 8.0 PICCO HELET 30.0 1/45.06 429.40 28686 6.96 53,56 \$5,70 11. INSPECTION SOURCE 723.29271.49 20.96 14238 69.60 278.40 104.40 SAL 10.0 40.0 15.0 10:03 10:03 10.03 Paragon 1.25 125 634 634 125 6.34 2.44 2.44 244 4.87 .5 .5 .5 HRLY 57.25 4294 28.63 5,36 3.57 7.14 27.14 1810 12. INSPECTION, WEC. PICO 6.96 36.19 13.92 10,44 6.96 SAL 2,0 1.5 1.0 HRLY 13. INSIDE LIAISON SAL 118.82 60.00 55.00 175.95 131.39 5000 16.39 14.82 21.95 HARD T PICO ____ 14. SHIPPING 74.00 60.00 5400 500-5.00 5.00 40.06 40.06 40.06 PARAGON 25.32 25.32 25.32 5.00 9,14 9.74 9.14 4.87 2.0 2.0 HRLY 2.0 7.14 114.50 85.88 5725 15. INSPECTION, REC. PARAGON 14.28 10.71 13,92 72,38 54,29 3619 27.84 20.88 696 SAL 2.0 3.0 40 HRLY 16. SAL 16178 8662 7941 TUOLING 2413275 11668 6875 5.706 TOTAL UNIT COST OP RATE AT \$12.00/HR * NET OP DOLLARS & PERCENTAGES * MIDPOINT OF EFFORT - JAN '71

ABOVE = NET DOLLARS (INHOUSE)

INHOUSE RATE AT \$4.87/HR (HRLY) *

E W SULLIVAN X7872

											v / Z -	2-64					
OPERATION ITEM NO. ASSEMBLY TURBOPUMI PN 1137000	D				LOW CO	LO2 DST TUI NIT COST COST A	R B O P U N (BASE C/	AP STU NSE)	DY								
	v 1		1		DATE					AT 260	<u>6 *</u>	G + A	AT 14.	25% *	TOT	L DOLLA	RS
NAME LO2 TURBOPUMP ASSEMBL	<u> </u>	1	AN HOUR	40	PERHR	1	10	40	1	10	40	1	10	40	1	10	40
1. ADVANCE QUOTES/CONSULTING	HRLY SAL	-															
2. PROCUREMENT PLANNING	SAL	30	1.0	1.0	6.96	20.88	6.96	6.96	54.29	18.10	18.10	10.71	3.57	357	85.88	23.63	28.4
3. TOOLING, OP LEAK CHECK NIT (4FLATES)	Difference Sale				400.00										· · · · ·		
SWAFT POSITIANING FILTURE 4. RAWSTOOK SMANNER WRENCHES (3)	HRUY				30200	,					$\geq$	\$1.3,5 0	 		25/3.3 0		
5. CHSTINGS-ON-PENCINGS	HRLEY SAL				50000												<u></u>
6. MACHINING	HRLY				ļ												
7. WELDING	HRLY SAL										76181	7141	7/4/	7/4/	57852		578.5
8. ASSY & FAB QE	SAL	20.0	20.0	20.0	6.96	139.20	139.20	139.20	361.42	361.72	.) 67.7-			-			
9. CLEANING	HRLY	13.0	70	5.0 1.0	4.87 6.96	6331 1740	<u>34.09</u> 1247	29.35	164.61 45.24	27.19	63,10	41.40	22. <del>34</del> -	16.06	<u>\$</u> 3/ . <b>?•</b> `	/83/4	/28.7
10. CELANNING (LOG BOOK)	SAL	27.0	200	13.0	6.96	187.92	1.39.20	70.48	488.57	561.92	23575	96.40	7/.4/	46.42	772.91	57253	372.1
11. INSPECTION	HRLY	'	27.6	22		-	139	107		361	278					7445	540
12. INSPECTION, ASSY	HRLY	42.0	26.0	20.0 5.2	4.87	77.95	44.54	36.19	202.61	115.80	94.04	149.92	96,33	75.33	1167.80	772.33	604
13. INSIDE LIAISON	SAL	53.0	7.0 340	5.7 26.5	6.96	38280	2.36.69	/84,44	995.28	615,26	479,54	796.38	121.40	94.62	15 /4.10	97320	130:
14. SHIPPING	SAL	12.0	12.0	12.0	6.96	8352	23.52	83,52	217.5	217.15	217.15	42.85	42.85	42.35	54.9.5-2	34352	393
15. ASSEMBLY LABOR	HRL	480	800	65.0	4:87	681.89	1389.60 180.96	316.55	760.03	470.50	361.92	499.72	292.70	233,00	4006.55	1582.05	2061
16 SHOP PLANNING (MFR ENG)	HEL SAI	35.0	3.5	20	6.96	243.60	2'4.36	13.92	63376	63.34	36.19	124.97	12.50	7./4	1001.93	10070	578
	 [	+	+	<u> </u>		2375.2	1416.13	1139.17		RSSY	TOOLINB	25/3:50	1		7251.62	5925.07	4685
	•			1	1									A/74			

* MIDPOINT OF EFFORT - JAN '71

NET OP DOLLARS & PERCENTAGES ABOVE = NET DOLLARS (INHOUSE) OP RATE AT \$12.00/HR * INHOUSE RATE AT \$4.87/HR (HRLY) *****

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EW SULLIVAN X 7872

Sec. Summer	معتششهم	Carlin Carlos	Marine Social States	90.000)	<b>Wester</b>	ری <i>ستی</i> ن	لاستحمادها	635586 <b>0</b>	Section of		الاستعطفت	National States	Sandoli 💋	<u> 2005</u>	فتستخلفه	وسالته أصفيتها

# APPENDIX J

1 1

# OXIDIZER AND FUEL TURBOPUMP WEIGHT ANALYSES

الالك الرادي المقالة الأسب والدين الانتيا فليقا الاسته الشيابة المنابع المحط المحطة المقطة فتحط فتحط الاست السبا

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LOW COST TURBOPUMP (OXID)

P/N 1137000 (NPSH = 25 FT)

Item No.	Part Name	Material	Density	Area	Diameter	Weight	Part No.	Qty
1	Housing, Bearing	347	.290	9.90	5.74	52.0	1137010	1
2	Shaft	Inco-X	.296	10.36	1.8	17.3	1137011	1
3 & 13	Bearing, Ball-Upper & Lower	440 C	.280	.88	3.4	5.4	1137012	2
. 4	Seal Assy, Bellows-Upper	SS	• 290	1.28	4.38	5.1	1137013	1
5	Seal Ring, Running-Unner	347	.290	.24	2.8	.6	1137014	1
6	Seal Ring, Running-Lower	347	.290	1.24	3.54	4.0	1137015	1
7	Seal Assy. Shaft Riding	SS	.290	.94	5.60	4.8	1137016	1
8	Seal Assy, Bellows-Lower	SS	.290	.96	5.00	4.4	1137017	1
9	Nut, Seal Retaining	Inco-X	.296	.26	6.4	1.6	1137018	1
10	Filter, SS (10 Micron)	SS	.290	.3	5.2	1.5	1137019	1
12	Spacer, Bearing	Inco-X	.296	1.7	2.6	4.1	1137020	1
14	Nut. Bearing Retaining	A <b>-28</b> 6	.286	.22	2.82	.6	1137021	1
15	Seal, Labyrinth-Lower	Kel-F	.79	. 52	10.3	1.4	1137001	1
16	Retainer, Labyrinth-Lower	Alum	.10	.80	6.0	1.5	1137002	1
17	Volute, Pump	Alum	.10	32.56	14.3	146.0	113 <b>7003</b>	1
17	Strut Área	Alum	.10	Est.	Est.	4.0	1137 <b>003</b>	1
18	Nut, Volute-Pump Ret.	Inco-X	.296	.30	5.4	1.5	1137004	1
19	Impeller	Alum	.100	6.00	6.24	11.7	1137005	1
19	Blade Area x .20%	Alum	.100	5.92	8.65	3.2	1137 <b>005</b>	1
20	Inducer	Alum	.100	1.91	2.27	1.4	1137006	1
20	Blade Area x .20%	Alum	.100	8.66	5.35	2.9	1137006	1
21	Nut Assy, Impeller Ret.	K-Monel	.290	2.50	.62	1.4	1137007	1
22	Seal, Labyrinth-Upper	Kel-F	.79	.36	9.6	.9	1137008	1
23	Spacer, Seal Labyrinth	Alum	.100	.60	10.0	1.9	1137 <b>009</b>	1
24	Retainer, Labyrinth-Upper	Alum	.100	1.00	10.8	3.4	1137027	1
25	Adapter, Pump Inlet	Alum	.100	8.12	10.92	28.0	1137026	1
26 [°]	Rotor, Turbine	718	.296	5.32	5.96	29.4	1137022	1
26	Blade Area	718	.296	Est.	Est.	3.0	1137022	1
28	Manifold, Turbine Inlet	718	.296	8.52	18.60	147.0	1137024	1
28	Manifold, Flange	718	.296	Est.	Est.	15.5	1137024	1
28	Manifold, Blade Area	718	<b>.</b> 296	Est.	Est.	5.0	1137024	<u> </u>

TOTAL WEIGHT

511.5#

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27

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LOW COST TURBOPUMP (OXID)

P/N 1137050 (NPSH = 25 FT)

Item No.	Part Name	Material	Density	Area	Diameter	Weight	Part No.	Qty
1	Housing, Bearing	347	.290	9.62	5.08	44.5		. 1
2	Shaft	Inco-X	.296	10.24	1.45	13.8		1
3 & 13	Bearing, Ball-Upper & Lower	440 C	.280	.56	2.72	2.7		2
4	Seal Assy, Bellows-Upper	SS	.290	Est.	Est.	4.5		1
5	Seal Ring, Running-Upper	347	.290	Est.	Est.	.5		`1
6	Seal Ring, Running-Lower	347	.290	Est.	Est.	3.5		1
7	Seal Assy. Shaft Riding	SS	.290	Est.	Est.	4.0		·1
8	Seal Assy, Bellows-Lower	SS	.290	Est.	Est.	3.9		1
9	Nut. Seal Retaining	Inco-X	.296	Est.	Est.	1.3		1
10	Filter, SS (10 Micron)	SS	.290	Est.	Est.	1.1		1
12	Spacer, Bearing	Inco-X	.296	Est.	Est.	3.5		1
14	Nut, Bearing Retaining	A-286	.286	Est.	Est.	.5		1
15	Seal, Labyrinth-Lower	Kel-F	.97	Est.	Est.	1.1		1
16	Retainer, Labyrinth-Lower	Alum.	.10	Est.	Est.	1.1		1
17	Volute, Pump	Alum.	.10	31.44	12.52	123.6		1
17	Volute, Strut Area	Alum.	.10	Est.	Est.	4.0		1
18	Nut, Volute-Pump Ret.	Inco-X	.296	Est.	Est.	1.3		1
19	Impeller	Alum.	.100	5.66	5.66	10.1		1
19	Blade Area x .20%	Alum.	.100	4.68	7.42	2.2		1
20	Inducer	Alum.	.100	2.06	1.82	1.2		1
20	Blade Area x .20%	Alum.	.100	9.06	4.98	2.8		1
21	Nut Assy, Impeller Ret.	K-Monel	.290	Est.	Est.	1.1		1
22	Seal, Labyrinth-Upper	Kel-F	.79	Est.	Est.	7		1
23	Spacer, Seal Labyrinth	Alum.	.100	Est.	Est.	1.3		1
24	Retainer, Labyrinth-Upper	Alum.	.100	Est.	Est.	3.0		1
25	Adapter, Pump Inlet	Alum.	.100	6.4	9.7	19.5		1
26 [±]	Rotor, Turbine	718	.296	4.84	4.82	21.7		1
26	Blade Area	718	.296	Est.	Est.	2.8		1
28	Manifold, Turbine Inlet	718	.296	8.44	18.16	142.5		1
28	Flange	718	.296	1.94	9.52	17.2		1
28	Blade Area	718	.296	Est.	Est.	4.5		1

TOTAL WEIGHT

445.5#

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LOW COST TURBOPUMP (OXID)

P/N 1137040 (NPSH = 15 FT)

Item No.	Part Name	Material	Density	Area	Diameter	Weight	Part No.	Qty
1	Housing, Bearing	347	.290	10.18	7.80	7.2		1
2	Shaft	Inco-X	,296	10.92	2.84	28.8		1
3 6 13	Bearing, Ball-Hoper & Lower	440 C	.280	1.32	5.02	11.6		2
4	Seal Assy, Bellows-Upper	SS	.290	1.58	5,96	8.6		1
5	Seal Ring, Running-Upper	347	.290	.24	4.32	1.0		1
6	Seal Ring, Running-Lower	347	.290	1.46	5.30	7.1		1
7	Seal Assy, Shaft Riding	SS	.290	1.08	7.48	8.3		1
. 8	Seal Assy, Bellows-Lower	SS	.290	1.20	7.07	7.7		1
9	Nut. Seal Retaining	Inco-X	.296	.26	7.68	1.9		1
10	Filter SS (10 Micron)	SS	.290	.34	7.52	2.3		1
12	Spacer, Bearing	Inco-X	.296	1.6	3.8	5.7		1
14	Nut, Bearing Retaining	A-286	.286	Est.	Est.	.8		1
15	Seal. Labyrinth-Lower	Kel-F	.79	Est.	Est.	2.0		1
16	Retainer, Labyrinth-Lower	Alum	.10	Est.	Est.	2.1		1
17	Volute. Pump	Alum	.10	36.8	18.66	215.6		1
17	Volute, Strut Area	Alum	.10	Est.	Est.	8.0		1
18	Nut. Volute-Pump Ret.	Inco-X	.296	Est.	Est.	2.1		1
19	Impeller	Alum	.100	8.24	8.70	22.5		1
19	Blade Area x .20%	Alum	.100	8.16	11.68	6.0		1
20	Inducer	Alum	.100	2.00	3.2	2.1		1
20	Blade Area x .20%	Alum	.100	9.44	6.66	3.9		1
21	Nut Assy, Impeller Ret.	K-Monel	.290	Est.	Est.	1.9		1
22	Seal Labyrinth-Upper	Kel-F	.79	Est.	Est.	1.3		1
23	Spacer, Seal Labyrinth	Alum	.100	Est.	Est.	2.5		1
24	Retainer, Labyrinth-Upper	Alum	.100	Est.	Est.	6.0		1
25 [°]	Adapter, Pump Inlet	Alum	.100	14.48	14.36	64.8		1
26	Rotor, Turbine	718	.296	11.48	8 <b>.9</b> 2	95.2		1
26	Blade Area	718	.296	Est.	Est.	4.0		. <b>1</b> .
28	Manifold, Turbine Inlet	<b>7</b> 18	.296	9.68	26.72	240.4		1
28	Manifold Flange	718	.296	Est.	Est.	14.0		1
28	Manifold Blade Area	718	.296	1.92	12.00	7.0		11

TOTAL WEIGHT

792.4#

427

LOW COST TURBOPUMP (OXID)

P/N 1137040 (NPSH = 130 FT

Item No.	Part Name	Material	Density	Area	Diameter	Weight	Part No.	Qty
<u></u>							112(010	<b>-</b>
1	Housing, Bearing/Backplate	347	.290	19.92	11.50	209.0	1136912	10
1	Ribs (6" thick)	347	.290	16.92	-	35.4	1136912	12
2	Shaft	Inco-X	.296	5.08	2.10	9.9	1136913	1
5	Spacer, Bearing	Inco-X	.296	.86	2.60	2.1	1136915	1
3.5 & 6.5	Spacer, Bearing-Upper & Lower	Inco-X	.296	.06	2.50	.3	1136926	2
8	Coupling, Turbine	Inco-X	.269	2.92	2.30	6.3	1136916	1
9	Bolt, Shaft-Coupling	Inco-X	.296	2.30	.40	.9	1136917	Ţ
10	Nut, Coupling	A-286	.286	.24	1.00	. 2	1136918	1
11	Labyrinth, Shaft	Phos. Bronze	.320	.20	5.00	1.1	1136919	1
12	Carrier, Bearing-Upper	Inco-X	.296	.50	4.0	1.9	1136920	1
13	Carrier, Bearing-Lower	Inco-X	.296	.39	3.86	1.4	113 <b>692</b> 1	1
14	Spacer, Shim-Brg. Ret.	Inco-X	.296	.04	4.70	.2	113 <b>692</b> 2	1
15	Spacer, Bearing Ret.	Inco-X	.296	.10	4.70	.4	1136923	1
16	Labyrinth, Coupling	Phos. Bronze	.320	.40	4.00	1.6	1136 <b>92</b> 4	1
17	Seal Assy, Turbine Coupling	347	.280	1.28	6.00	6.7	113 <b>6925</b>	1
18	Rotor, Turbine #1	718	.296	4.80	3.86	16.6	1136930	1
18	Blade Area	718	.296	Est.	Est.	1.5	113 <b>6930</b>	1
19	Rotor, Turbine #2	718	.296	4.64	3.86	16.5	1136 <b>93</b> 1	1
19	Blade Area	718	.296	Est.	Est.	1.5	113 <b>69</b> 31	1
21	Vane. Stator	718	.296	1.08	11.26	11.7	1136 <b>93</b> 3	1
21	Blade Area	718	.296	Est.	Est.	1.5	1136933	1
22	Ring, Orifice, Low Pressure	7.18	.296	.16	6.3	.9	1136901	1
23	Nut, Ring Orifice - L.P.	347	.290	.08	6.8	• 5	1136902	1
27	Ring, Orifice-High Pressure	718	.296	.06	15.4	.9	1136904	1
28	Nut. Ring Orifice - H.P.	347	.290	.21	15.7	3.0	1136905	1
29	Vane, Diffuser-Pump	347	.290	1.14	16.4	17.0	113 <b>690</b> 6	1
29	Blade Area	347	.290	Est.	Est.	2.0	1136 <b>906</b>	1
30	Impeller, Pump	Titanium	.160	11.62	5.54	32.3	113 <b>690</b> 7	1
30	Blade Area x $20\%$	Titanium	.160	5.36	9.15	4.9	1136 <b>90</b> 7	1
31	Inducer, Pump	Titanium	.160 *	2,86	3.16	4.5	1136 <b>908</b>	1
31	Blade Area x $20\%$	Titanium	.160	5.34	5.95	3.2	1136908	1
32	Nut Assy, Impeller Ret.	Alum.	.100	.60	2.20	. 4	1136 <b>909</b>	1
33	Manifold Assy. Turbine Inlet	718	.296	8.36	13.50	110.4	113 <b>693</b> 4	1
33	Rlade Area	718	.296	Est.	Est.	2.0	1136 <b>93</b> 4	1
34	Valute Pump Housing	347	.290	25.88	16.47	388.0	1136910	1
34	Strut Area	347	.290	Est	Est.	2.0	1136910	
3467	Bearing Ball (4 ea)	440 C	. 280		3.0	4.4	1126014	4
J, T, U, I	bearing, barr (4 ca)	440 0	.200	• 42			1130714	4

TOTAL WEIGHT

**9**03.1#

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LOW COST TURBOPUMP (FUEL)

P/N 1136950 (NPSH - 75 FT)

Item No.	Part Name	Material	Density	Area	Diameter	Weight	Part No.	Qty
1	Housing, Bearing/Back Plate	347	. 290	26.92	14.96	366.7		. 1
1	Ribs (.6" Thick)	347	.290	29.90	21000	62.4	3	12
2	Shaft	Inco-X	.296	7.80	3.12	22.6		1
5	Spacer, Bearing	Inco-X	.296	1.12	3.34	3.8		1
3.5 & 6.5	Spacer, Brg-Upper-Lower	Inco-X	.296	Est.	Est.	.6		2
8	Coupling. Turbine	Inco-X	.296	3.26	4.12	12.5		ī
9	Bolt. Shaft Coupling	Inco-X	.296	3.48	1.26	4.1		1
10	Nut, Coupling	A-286	.286	.27	2.22	• 5		1
11	Labyrinth, Shaft	Phds. Bronze	.320	. 28	7,72	2.2		1
12	Carrier, Brg-Upper	Inco-X	.296	.84	6.58	4.5		1
13	Carrier, Brg-Lower	Inco-X	.296	.84	6.58	4.5		1
14	Spacer, Shim-Brg. Ret.	Inco-X	.296	Est.	Est.	.3		1
15	Spacer, Brg. Ret.	Inco-X	.296	Est.	Est.	.8		1
16	Labyrinth, Coupling	Phds. Bronze	.320	.70	5.24	3.7		1
17	Seal Assy, Turbine Coupling	.347	.280	.94	6.64	5.5		1
18	Rotor, Turbine #1	718	<b>.</b> 2 <b>9</b> 6	7.4	6.18	42.5		1
18	Blade Area	718	.296	7.4	6.18	4.00		1
19	Rotor, Turbine #2	718	.296	7.4	6.18	42.5		1
19	Blade Area	718	.296	7.4	6.18	4.0		1
21	Vane, Stator	718	.296	1.16	15.44	16.7		1
21	Blade Area	718	.296	1.16	15.44	3.0		1
22	Ring, Orifice-Low Pressure	718	.296	Est.	Est.	1.3		1
23	Nut, Ring Orifice-L.P.	347	.290	Est.	Est.	.8		1
27	Ring, Orifice-High Pressure	718	.296	Est.	Est.	1.3		1
28	Nut, Ring Orifice-H.P.	347	.290	.16	24.0	3.5		1 -
29	Vane, Diffuser-Pump	347	.290	1.24	20.2	22.8		1
- 2 <b>9</b>	Blade Area	347	.290	1.24	20.2	3.0		1
30	Impeller, Pump	Titanium	.160	14.92	7.30	54.7		1
30 ¹	Blade Area x .20%	Titanium	.160	8.32	12.08	10.1		1
31	Inducer, Pump	Titanium	.160	3.16	3.64	5.8		1
31	Blade Area x .20%	Titanium	.160	6.16	6.96	4.3		1
32	Nut Assy, Impeller Ret.	Alum	.100	.66	2.90	.6		1
33	Manifold Assy, Turbine Inlet	718	.296	11.08	19.32	175.4		1
33	Blade Area	718	.296	.72	.12	.8		1
34	Volute, Pump Housing	347	.290	28.20	21.62	555.2		1
34	Strut Area	347	.290	Est.	Est.	3.0		1
3,4,6,7	Bearing Ball (4 ea)	440 C	.280	1.34	5.08	24.0		4

LOW COST TURBOPUMP (FUEL)

P/N 1136960 (NPSH - 160 FT)

Itom No	Part Name	Material	Density	Area	Diameter	Weight	Part No.	<u>Qty</u>
ILEM NO.								1
1	Housing, Bearing/Back Plate	347	.2 <b>9</b> 0	17.04	12.76	198.0		10
1	Ribs (.6" Thick)	347	.290	14.28	-	29.8		12
2	Shaft	Inco-X	.296	3.78	1.51	5.3		1
5	Spacer, Bearing	Inco-X	.296	1.09	2.36	2.4		2
3.5 & 6.5	Spacer, Brg-Upper-Lower	Inco-X	.296	Est.	Est.	.2		2
8	Coupling, Turbine	Inco-X	.296	2.68	2.13	5.3		1
9	Bolt, Shaft-Coupling	Inco-X	.296	1.56	.35	•6		1
10	Nut, Coupling	A-286	.286	Est.	Est.	.2		1
11	Labyrinth, Shaft	Phos Bronze	.320	.44	3.73 •	1.6		1
12	Carrier, Bearing-Upper	Inco-X	.296	.41	3.80	1.5		1
13	Carrier, Bearing-Lower	Inco-X	.296	.41	3.80	1.5		1
14	Spacer, Shim-Brg. Ret.	Inco-X	.296	Est.	Est.	•1		1
15	Spacer, Bearing Ret.	Inco-X	.296	Est.	Est.	.3		1
16	Labyrinth, Coupling	Phos. Bronze	.320	.26	5.24	1.4		1
17	Seal Assy, Turbine Coupling	347	.280	.78	5.64	3.9		1
18	Rotor, Turbine #1	718	.296	4.38	3.52	14.3		1
18	Blade Area	718	.296	Est.	Est.	1.3		1
19	Rotor, Turbine #2	718	.296	4.38	3.52	14.3		1
19	Blade Area	718	.296	Est.	Est.	1.3		1
21	Vane, Stator	718	.296	.94	10.74	9.4		1
21	Blade Area	718	.296	Est.	Est.	.9		1
22	Ring, Orifice-Low Pressure	718	.296	Est.	Est.	•8		1
23	Nut, Ring Orifice - L.P.	347	.290	Est.	Est.	.4		1
27	Ring, Orifice-High Pressure	718	۰2 <b>9</b> 6	Est.	Est.	.0		1 1
28	Nut, Ring Orifice-H.P.	347	.290	.16	14.0	2.0		1
29	Vane, Diffuser-Pump	347	.290	_1.24	14./	10.0		1
29	Blade Area	347	.290	Est.	Est.	1./		1
30	Impeller, Pump	Titanium	.160	11.08	4.80	2/.1		1
30 ¹	Blade Area x 20%	Titanium	.160	4.60	8.55	3.9		1
31	Inducer, Pump	Titanium	.160	2.92	2.74	4.5		1
31	Blade Area x 20%	Titanium	.160	5.36	5.79	3.1		1
32	Nut Assy, Impeller Ret.	Alum.	.100	.58	1.90			1
33	Manifold Assy, Turbine Inlet	718	.296	9.//	12.50	102.0		1
33	Blade Area	718	.296	Est.	Est.	1.5		1
34	Volute, Pump Housing	347	.290	24.04	15.43	33/.0		1
34	Strut Area	347	.290	Est.	Est.	1.5		-
3,4,6,7	Bearing, Ball (4 ea)	440 C	.280	.53	2.17	4.0		4_
				TOTAL	WEIGHT	800.3#		
								•

# APPENDIX K

# DESIGN REQUIREMENTS, TURBOPUMP FUNCTIONAL ALTERNATIVES

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# DESIGN REQUIREMENTS TURBOPUMP FUNCTIONAL ALTERNATIVES

Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Bearing Housing/Backplate, Fuel (1)			
Size (OD)	25.0 in.	25.0 in.	25.0 in.
Material	Cast 347	Cast 347	Cast 347
Surface Finish	63	125	250
Tolerance			
Pilot Diameters	<u>+</u> 0.001	<u>+</u> 0.003	<u>+</u> 0.005
Bearing Diameters	+0.0005	<u>+</u> 0.0005	<u>+</u> 0.0005
Axial Dimensions	<u>+0.001</u>	<u>+</u> 0.003	<u>+</u> 0.005
Quality Control	Current Aerospace*	Current Aerospace	Minimum**
Shaft, Fuel (2)			· · ·
Size (Bearing Diameter)	2.25 in.		
Material	Inconel X		
Tolerance			
Diameters	<u>+</u> 0.0005	No Change	No Change
Axial Dimensions	<u>+</u> 0.001		
Surface Finish	16/63		
Quality Control	Current Aerospace		
Dynamic Balance	Required		

* 100% Dimensional, Material Certification and Traceability

** Critical Dimensions only, Material Certification and Traceability

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Bearings, Fuel (3) (4) (6) (7)			
Size	60 mm		
Number/Type	4/Preloaded Ball		
Material	440C/Armalon	No Change	No Change
Class	5		
Quality Control	Current Aerospace		
Spacer, Bearing-Upper and Lower (3.5) (6.5)			
Size (OD)	2.750		
Material	Inconel X		
Tolerance	·		
Diameter	<u>+</u> 0.0005	No Change	No Change
Surface Finished	16/63		
Quality Control	Current Aerospace		
Turbine Shaft Coupling, Fuel (8)			
Size (OD)	5.5 in.		
Material	Inconel X		
Surface Finish	16/63		
Tolerance			
Diameters	<u>+</u> 0.0005	No Change	No Change
Axial Dimensions	<u>+</u> 0.001		
Quality Control	Current Aerospace		
Dynamic Balance	Required		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Bolt, Shaft Coupling (9)			i.
Size (Thread Diameter)	1.125 in.		
Material	Inconel X		
Tolerance			
Diameter	<u>+</u> 0.0005		i 
	<u>+</u> 0.010		:
Thread	Class A	No Change	No Change
Concentricity	0.001		
Surface Finish	32/63		
Quality Control	Current Aerospace		
Nut, Coupling (10)			•
Size (OD)	1.5 in.		:
Material	A 286		
Tolerance			
Thread	0.625 Class A	No Change	No Change
Squareness	0.001		
Surface Finish	63		
Quality Control	Current Aerospace		
Labyrinth, Shaft (11)			
Size (OD)	4.5 in.		
Material	Phosphor Bronze		
Tolerance			
Diameter	<u>+</u> 0.001/-0.000	No Change	No Change

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Spacer, Shim-Bearing Retaining	(									
Quality Control	Current	əsedso								
Surface Finish	E9/9T			·						
Concentricity	τοο.ο									
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Diameter	0000.0+									
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Material	Inconel									
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Carrier, Bearing - Lower (13)										
Quality Control	Current	əsedso								
Surface Finish	£9/9T									
Concentricity	το0.0									
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Diaméter	0000.0+									
Solerance										
Material	Tancont									
(OD) ƏZIS	.ni 22.4									
Carrier, Bearing - Upper (12)										
Quality Control	Current	əsedso								
Surface Finish	32/63									
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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Material	Inconel X		
Tolerance			
Diameter	0.001		
Parallelism	0.001	No Change	No Change
Surface Finish	63		
Quality Control	Current Aerospace		
Spacer, Bearing Retaining (15)			
Size (OD)	5.0 in.		
Material	Inconel X		
Tolerance			
Diameter	0.001	No Change	No Change
Parallelism	0.001 (or less)		
Surface Finish	63		
Quality Control	Current Aerospace		
Labyrinth, Coupling (16)			
Size (OD)	5.0 in.		
Material	Phosphor Bronze		
Tolerance		· · ·	
Diameter	<u>+</u> 0.0005	No Change	No Change
Flatness	0.0005		
Surface Finish	63		
Quality Control	Current Aerospace		
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	01 20	Forged /18	Forged 718	Material
*NT 0.10	о <u>л</u> от	•ut 8•0T	.ni 8.01	(IO) szis
at 8 (	01			2nd Stage Turbine Rotor, Fuel (19)
nottab		redurted	Kequired	Dynamic Balance
parting		angentag 101	Sourcent Aerospace	Quality Control
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010	0 <del>+</del>	500 UT	500°0 <del>1</del>	Blade
010	0+	010 0+		Tolerance
	<b>C-</b>	C7T	63	Asini [¶] sosiru2
0	56		FOIBED ITO	Material
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.ni 8.	OT	.ut 8.01		lst Stage Turbine Rotor, Fuel (18)
				Ουαλίτυ Control
			c000.0 <del>1</del>	sinemelä gnilse2
	_	-9777710 - 011		Flange Dimensions
egned	οN	agard) ov	010 04	Solerance
			•NT C*7	(ID) SIZ
				Type
			<i>Dathia</i> +7042	Turbine Seal, Fuel (17)
cernative No. 2	TA	Alternative No. 1	Base Value	Subcomponent/Requirement

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Alternative No. 2 Alternative No. 1 Base Value Subcomponent/Requirement Current Aerospace Minimum Current Aerospace Quality Control Required Required Required Dynamic Balance No Change No Change Bolt, Turbine Rotor (20) 0.375 Size (shank) 718 Material Tolerance +0.0005 Diameters 0.001 Tir 32 Surface Finish Current Aerospace Quality Control Stator Vane, Fuel Turbine (21) 12.6 in. 12.6 in. 12.6 in. Size (OD) Forged 718 Cast and Machined 718 Cast 718 Material Tolerance +0.010 +0.005 +0.003 Vane Profile +0.010 +0.003 +0.003 Diameters 250 125 63 Surface Finish Current Aerospace Minimum Current Aerospace Quality Control Low Pressure Orifice, Fuel (22) 7.0 in. Size (OD) 718 Material No Change No Change Tolerance +0.003 Diameters

Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Flatness	<u>+0.001</u>		
Surface Finish	32		
Quality Control	Current Aerospace		
Nut, Ring Orifice - Low Pressure (23)			
Size (OD)	6.75 in.	No Change	No Change
Material	347		
Tolerance			
Diameters	<u>+</u> 0.0005		
Squareness	0.001		
Surface Finish	63		
Quality Control	Current Aerospace		
Ring, Orifice-High Pressure (27)			
Size (OD)	16.0 in.	No Change	No Change
Material	Inconel 718		
Tolerance			
Diameters	<u>+</u> 0.003		
Flatness	<u>+</u> 0.001		
Surface Finish	32		
Quality Control	Current Aerospace		
Nut, Ring Orifice-High Pressure (28)			
Size (OD)	16.0 in.	No Change	No Change
Material	347		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Tolerance			
Diameter (OD)	Class A Thread		
(ID)	0.001		
Squareness	0.001		
Surface Finish	63		
Quality Control	Current Aerospace		
Pump Diffuser, Fuel (29)			
Size (Base Circle Diameter)	15.5 in.	15.5 in.	15.5 in.
Material	347	Cast Aluminum (machined	) Cast Aluminum
Surface Finish	63	125	250
Vane Tolerance	<u>+</u> 0.003	<u>+</u> 0.003	<u>+</u> 0.010
Diameter Tolerance	<u>+</u> 0.003	<u>+</u> 0.003	<u>+</u> 0.010
Quality Control	Current Aerospace	Current Aerospace	Minimum
Impeller, Fuel (30)			
Size (OD)	14.6 in.	14.6 in.	14.6 in.
Material	Forged Titanium	Forged Titanium	Forged Titanium
Surface Finish	63	125	250
Vane Tolerance	+0.003	<u>+</u> 0.005	<u>+</u> 0.010
Diameter Tolerance	+0.003	<u>+</u> 0.005	<u>+</u> 0.010
Quality Control	 Current Aerospace	Current Aerospace	Minimum
Dynamic Balance	Required	Required	Required
Inducer, Fuel (31)			
Size (OD)	8.4 in.	8.4 in.	8.4 in.

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No.
Material	Forged Titanium	Forged Titanium	Forged Titanium
Surface Finish	63	125	250
Vane Tolerance	<u>+0.003</u>	<u>+</u> 0.005	<u>+</u> 0.010
Diameter Tolerance	<u>+</u> 0.003	<u>+</u> 0.005	<u>+</u> 0.010
Quality Control	Current Aerospace	Current Aerospace	Minimum
Dynamic Balance	Required	Required	Required
Nut Assembly, Impeller Retaining (32)			
Size (OD)	3.1 in.	No Change	No Change
Material	Aluminum		
Tolerance			
Diameter (Thread)	Class A		
(ID)	<u>+</u> 0.001		
Contour Thickness	<u>+</u> 0.002		
Surface Finish	63		
Quality Control	Current Aerospace		
Pump Housing, Fuel (34)			
Size (OD - 180° Sec)	24.0 in.	24.0 in.	24.0 in.
Material	Cast 347	Cast 347	Cast 347
Surface Finish	63/125	125/125	125/250
Tolerance			
Volute	<u>+0.03</u>	<u>+</u> 0.03	<u>+</u> 0.10
Contour	<u>+</u> 0.003	<u>+</u> 0.005	<u>+</u> 0.100
Pilots	<u>+</u> 0.001	<u>+</u> 0.003	<u>+</u> 0.005

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Alternative No. 1 Alternative No. 2 Base Value Subcomponent/Requirement Current Aerospace Current Aerospace Quality Control Housing, Bearing Oxidizer (1) No Change No Change 5.9 in. Size (OD) 347 Material 32/63* Surface Finish Tolerance +0.001 Pilot Diameters +0.0005 Bearing Diameters +0.001 Axial Dimensions Current Aerospace Quality Control Shaft, Oxidizer (2) 2.4 in. Size (Bearing Diameter) Inconel X Material Tolerance No Change No Change +0.0005 Diameters +0.001 Axial Dimensions 16/63 Surface Finish Current Aerospace Quality Control Required Dynamic Balance Bearings, Oxidizer (3) (13) 60mm Size 2/Preloaded Ball Number/Type

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* Bearing Surface ID

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Subcomponent/Requirement Base Value Alternative No. 1 Alternative No. 2 440C/Armalon Material No Change 5 No Change Class Quality Control Current Aerospace Seal Assembly, Bellows-Upper Oxidizer (4) Size (OD) 6.2 in. Material 347 Tolerance. +0.001 Diameters Flatness (Seal Surface) 1 Helium Light Band Purged and Vented No Change No Change Type Dual Seal Quality Control Current Aerospace +0.001 Axial Tolerance 63 Surface Finish (347 Material) Seal Ring, Running-Upper Oxidizer (5) 3.4 in. Size (OD) 347 Material Surface Finish 63 Seal Face (Flame Plated) Ground and Lapped No Change +0.001 No Change Diameters OD Diameters ID +0.0005 +0.001 Axial Dimensions Tolerance Current Aerospace Quality Control

Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Seal Ring, Running-Lower Oxidizer (6)			
Size (OD)	5.0 in.		
Material	347		
Surface Finish	63		
Seal Faces (2) (Flame Plated)	Ground and Lapped		
Tolerance		No Change	No Change
Diameter ID	<u>+</u> 0.0005		
Axial Dimension	<u>+</u> 0.001		
Squareness	0.0005		
Quality Control	Current Aerospace		
Seal Assembly, Shaft Riding Oxidizer	(7)		
Size (OD)	6.6 in.		
Material	347		
Surface Finish	63		
Tolerance			
Diameter (OD)	+0.001	No Change	No Change
Axial Dimensions	+0.001		
Squareness	<u>+</u> 0.0005		
Quality Control	Current Aerospace		
Seal Assembly, Bellows-Lower Oxidizer	: (8)		
Size (OD)	6.6 in.		
Material	347		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Tolerance			
Diameters	<u>+</u> 0.001	No Change	No Change
Axial Dimensions	+0.001		
Flatness (Seal Surface)	l Helium Light Band		
Туре	Purged and Vented Dual Seal		
Ouality Control	Current Aerospace		· · · · · · · · · · · · · · · · · · ·
Surface Finish (347 Material)			
Nut Seal Retaining Oxidizer (9)			
Size (OD)	6.8 in.		
Material	Inconel X		
Tolerance			
Diameters (OD Thread)	Class A	No Change	No Change
(ID)	0.003		
Squareness	0.001		
Surface Finish	63		
Quality Control	Current Aerospace		
Filter, Oxidizer (10)			
Size (OD)	5.3 in.		
Rating	10 Micron		
Material	CRES 300		
Tolerance			
Diameter (OD)	0.030	No Change	No Change

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Diameter (ID)	0.001	No Change	No Change
Axial Dimensions	0.010		
Surface Finish (Machined Ends)	63		
Quality Control	Current Aerospace		
Spacer, Bearing, Oxidizer (12)			
Size (OD)	3.0 in.		
Material	Inconel X		
Tolerance			
Diameter (OD)	<u>+</u> 0.005	No Change	No Change
Diameter (ID) (Pilot)	<u>+</u> 0.0005		
Squareness	0.001		
Surface Finish	32 ID and Ends Only		
Quality Control	Current Aerospace		
Nut, Bearing Retaining, Oxidizer (14)			
Size (OD)	3.3 in.		
Material	A286		
Tolerance			
Diameter (OD)	<u>+</u> 0.010	No Change	No Change
(ID) Thread	Class A		
Flatness	0.001		
Surface Finish	63		
Quality Control	Current Aerospace		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Seal Labyrinth-Lower, Oxidizer (1	5)		
Size (OD)	12.0	No Change	No Change
Material	KEL-F		
	+0.010		
	+0.002		
	+0.002		
(P110t)	0.002		
Concentricity	0.002		
Quality Control	current Aerospace		
Retainer, Labyrinth-Lower, Oxidize	r (16)		
Size (OD)	12.8 in.		
Material	Aluminum		
Tolerance			
Diameter (OD)	<u>+0.003</u>		
(ID Pilot)	<u>+</u> 0.002	No Change	No Change
Squareness	0.002		
Surface Finish	63		
Quality Control	Current Aerospace	:	
Volute Pump Oxidizer (17)			
Size $(OD)$ (360° Section)	23 in.	23 in.	23 in.
Material	Cast Aluminum	Cast Aluminum	Cast Aluminum
Surface Finish	63/126	63/250	125/250
Bullace Finish	•		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Tolerances			
Flow Passage	<u>+0.030</u>	<u>+0.10</u>	<u>+</u> 0.10
Pilot Diameters	<u>+0.001</u>	<u>+</u> 0.001	<u>+</u> 0.003
Axial Stack Up Dimensions	<u>+</u> 0.003	<u>+</u> 0.003	<u>+</u> 0.010
Quality Control	Current Aerospace	Current Aerospace	Minimum
Nut, Volute Pump Retaining, Oxidizer (	(18)		
Size (OD)	5.8 in.		
Material	Inconel X		
Diameters (OD)	<u>+</u> 0.010		
(ID Thread)	Class A	No Change	No Change
Squareness	<u>+</u> 0.001		
Surface Finish	63		
Quality Control	Current Aerospace		
Impeller, Oxidizer (19)			
Size (OD)	13 in.	13 in.	13 in.
Material	Shell Mold-Cast Aluminum	Shell Mold-Cast Aluminum	Investment Cast Aluminum
Vane Tolerance	<u>+</u> 0.025	<u>+0.025</u>	<u>+</u> 0.010
Tip Tolerance	<u>+</u> 0.010	+0.010	<u>+</u> 0.010
Sealing Surface Tolerance	<u>+0.002</u>	<u>+</u> 0.002	<u>+</u> 0.005
Pilot Diameter Tolerance	<u>+</u> 0.0005	<u>+0.0005</u>	<u>+</u> 0.0005
Axial Stackup Tolerance	<u>+</u> 0.010	+0.010	+0.010
Squareness	0.001	0.001	0.001

Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Dynamic Balance	Required	Required	Required
Surface Finish	63	125	125
Quality Control	Current Aerospace	Current Aerospace	Minimum
Inducer, Oxidizer (20)			
Size (OD)	8.1 in.	8.1 in.	8.1 in.
Material	Forged Aluminum	Forged Aluminum	Die Cast Aluminum
Tolerance			
Vane	<u>+</u> 0.005	<u>+</u> 0.015	<u>+</u> 0.015
Daimeters (OD)	+0.005	<u>+</u> 0.005	<u>+</u> 0.010
Pilots	<u>+</u> 0.0005	<u>+0.0005</u>	+0.0005
Axial Stack Up	<u>+</u> 0.010	<u>+</u> 0.010	<u>+</u> 0.010
Squareness	0.001	0.001	0.001
Dynamic Balance	Required	Required	Required
Surface Finish	63	125	125
Quality Control	Current Aerospace	Current Aerospace	Minimum
Bolt, Impeller Retaining, Oxidize	er (21)		
Size (OD)	0.8 in.		
Material	K-Monel		
Tolerance			
Diameters - Pilot	<u>+</u> 0.001		
Thread	Class A	No Change	No Change
Other	<u>+</u> 0.010		
Squareness	<u>+0.001</u>		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Quality Control	Current Aerospace		
Surface Finish	63		
Seal, Labyrinth-Upper, Oxidizer (22)			
Size (OD)	10.6 in.	No Change	No Change
Material	KEL-F		
Tolerance			
Diameter (OD)	<u>+</u> 0.010		
(ID)	<u>+</u> 0.002		
(Pilot)	<u>+</u> 0.002		
Concentricity	0.002		
Quality Control	Current Aerospace		
Spacer, Seal-Labyrinth, Oxidizer (23)			
Size (OD)	11.7 in.	No Change	No Change
Material	Aluminum		
Tolerance			
Diameter (OD)	<u>+</u> 0.010		
(Pilot)	<u>+</u> 0.002		
(ID)	<u>+</u> 0.005		
Surface Finish	63		
Quality Control	Current Aerospace		

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Retainer, Labyrinth-Upper, Oxidizer	(24)		
Size (OD)	11.72 in.	No Change	No Change
Material	Aluminum		
Tolerance			
Diameter (OD)	<u>+</u> 0.003		
(Pilots)	+0.002		
(ID)	<u>+0.003</u>		
Squareness	<u>+0.001</u>		
Surface Finish	63		
Quality Control	Current Aerospace		
Adapter, Pump Inlet, Oxidizer (25)			
Size (OD)	14.5 in.	No Change	No Change
Material	Cast Aluminum		
Tolerance			
Diameter (OD Pilots)	<u>+</u> 0.002		
(OD)	<u>+</u> 0.030		
(ID Bore)	<u>+</u> 0.002		
(ID at Labyrinth)	<u>+0.001</u>		
Squareness (at Labyrinth)	0.001		
Surface Finish	63		
Quality Control	Current Aerospace		
Rotor, Turbine, Oxidizer (26)			
Size (OD)	19.5 in.	19.5 in.	19.5 in.

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Subcomponent/Requirement	Base Value	Alternative No. 1	Alternative No. 2
Material (Forging)	Inconel 718	Inconel 718	Cast 718
Surface Finish	63	125	125
Tolerance			
Blades	<u>+0.003</u>	<u>+</u> 0.010	<u>+</u> 0.010
Diameters	<u>+</u> 0.001	<u>+</u> 0.001	<u>+</u> 0.005
Quality Control	Current Aerospace	Current Aerospace	Minimum
Dynamic Balance	Required	Required	Required
Bolt, Rotor, Oxidizer (27)			
Quantity	6 ea.		
Size	3/8 dia x 1.85 long		
Material	A-286		
Tolerance	Class A Thread		
Diameter (OD)	<u>+</u> 0.001	No Change	No Chan <b>ge</b>
Surface Finish	32		
Quality Control	Current Aerospace		
Manifold, Turbine Inlet, Oxidizer (28)	I		:
Size (Torus OD)	24.7 in.	24.7 in.	24.7 in.
Material (Cast. Formed and Welded)	Inconel 718	Inconel 718	CRES 347
Tolerance			
Diameters	<u>+0.003</u>	<u>+</u> 0.003	<u>+</u> 0.010
Vane Profiles	<u>+</u> 0.003	<u>+</u> 0.003	<u>+</u> 0.010
Surface Finish, Vanes	63	125	250
Quality Control	Current Aerospace	Current Aerospace	Minimum

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# APPENDIX L

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## OPTIMAL TURBOPUMP REQUIREMENTS AND DESIGN CRITERIA

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Subcomponent/Requirement	Optimum Value
Bearing Housing/Backplate, Fuel (1)	
Size (0.D.)	25.0 in.
Material	Cast 347
Surface Finish	125
Tolerance	
Pilot Diameters	<u>+</u> 0.003
Bearing Diameters	<u>+</u> 0.005
Axial Dimensions	<u>+</u> 0.003
lst Stage Turbine Rotor, Fuel (18)	
Size (0.D.)	10.8 in.
Material	Forged 718
Surface Finish	125
Tolerance	
Blade	<u>+</u> 0.010
Diameters and Axial Dimensions	<u>+</u> 0.005
Dynamic Balance	Require
2nd Stage Turbine Rotor, Fuel (19)	
Size (0.D.)	10.8 in.
Material	Forged 718
Surface Finish	250
Tolerance	
Blade	$\pm$ 0.010
Diameters	$\pm$ 0.010
Dynamic Balance	Required
Stator Vane, Fuel Turbine (21)	
Size (0.D.)	12.6 in.
Material	Inconel 718
Tolerance	
Vane Profile	<u>+</u> 0.005
Diameters	<u>+</u> 0.003
Surface Finish	125

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Appendix L

#### Subcomponent/Requirement

Pump Diffuser, Fuel (29) Size (Base Circle Dia.) Material Surface Finish Vane Tolerance Diameter Tolerance Impeller, Fuel (30) Size (0.D.) Material Surface Finish Vane Tolerance Diameter Tolerance Dynamic Balance Inducer, Fuel (31) Size (0.D.) Material Surface Finish Vane Tolerance Diameter Tolerance Dynamic Balance Pump Housing, Fuel (34) Size (0.D. - 180° Sect) Material Surface Finish Tolerance Volute Contour Pilots

#### Optimum Value

15.5 Cast Aluminum (Machined) 125 <u>+</u> 0.003 <u>+</u> 0.003

14.6 in.
Forged Tungsten
125
+ 0.005
+ 0.005
Required

8.4 in.
Forged Tungsten
125
± 0.005
± 0.005
Required

24.0 in. Cast 347 125/125

 $\pm 0.03$  $\pm 0.005$  $\pm 0.003$ 

Subcomponent/Requirement	Optimum Value
Volute, Pump. Oxid. (17)	
Size (0.D.) (360° Section)	23 in.
Material	Cast Aluminum
Surface Finish	63/250
Tolerances	
Flow Passage	<u>+</u> 0.10
Pilot Diameters	<u>+</u> 0.001
Axial Stack Up Dimensions	<u>+</u> 0.003
Impeller, Oxid (19)	
Size (0.D.	13.0 in.
Material	Shell Mold Cast Aluminum
Vane Tolerance	<u>+</u> 0.025
Tip Tolerance	<u>+</u> 0.010
Sealing Surface Tolerance	<u>+</u> 0.002
Pilot Diameter Tolerance	<u>+</u> 0.0005
Axial Stackup Tolerance	<u>+</u> 0.010
Squareness	$\pm$ 0.001
Dynamic Balance	Required
Surface Finish	125
Inducer, Oxid (20)	
Size (0.D.)	8.1 in.
Material	Forged Aluminum
Tolerance	
Vane	<u>+</u> 0.005
Diameters (0.D.)	<u>+</u> 0.005
Pilots	<u>+</u> 0.0005
Axial Stack Up	$\pm$ 0.010
Squareness	0.001
Dynamic Balance	Required
Surface Finish	63

## Appendix L

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Subcomponent/Requirement	<u>Optimum Value</u>
Rotor, Turbine, Oxid (26)	
Size (0.D.)	19.5 in.
Material (Forging)	Inconel 718
Surface Finish	125
Tolerance	
Blades	<u>+</u> 0.010
Diameters	<u>+</u> 0.001
Dynamic Balance	Required
Manifold, Turbine Inlet, Oxid (28)	
Size (Torus 0.D.)	24.7 in.
Material (Cast. Formed & Welded)	Inconel 718
Tolerance	
Diameters	<u>+</u> 0.003
Vane Profiles	<u>+</u> 0.003
Surface Finish, Vanes	125

All Other Fuel and Oxidizer Turbopump Component Requirements Constant at Base Case Values

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