OPTIMUM WORKING FLUIDS FOR AUTOMOTIVE RANKINE ENGINES VOLUME IV - ENGINE DESIGN OPTIMIZATION

Prepared By

F. Sindermann

Sunstrand Aviation
4747 Harrison Ave.
Rockford, Illinois 61101

Prime Contract No. 68-04-0030
Subcontract No. E0030-1

EPA Project Officer:

K. F. Barber

Prepared For

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Mobile Source Air Pollution Control
Advanced Automotive Power Systems Development Division
Ann Arbor, Michigan 48105

June 1973

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Publication No. APTD-1566

ACKNOWLEDGEMENT

The author acknowledges with gratitude the many contributions made by D. B. Wigmore and R. E. Niggemann of Sundstrand Aviation, Division of Sundstrand Corporation, both in the Research Program and in the Engine Optimization Studies performed for this report.

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INTRODUCTION

This report (Volume IV) covers automotive engine optimization design studies performed by Sundstrand Aviation Division of Sundstrand Corporation under Subcontract E0030-1 to Monsanto Research Corporation. These studies were in response to a requirement of the prime Contract No. 68-04-0030 for "a comprehensive steady state automotive Rankine cycle systems analysis...to evaluate system performance and operating characteristics for each candidate working fluid."

In Volume II of this report, two final candidate fluids were selected and defined. They are:

RC-1 - a mixture containing 60 mol % pentafluorobenzene and 40 mol % hexafluorobenzene

RC-2 - a mixture containing 65 mol % water and 35 mol % 2-methylpyridine

Thermodynamic and transport properties of these fluids were supplied in tabular form by Monsanto Research Corporation to satisfy the fluid data requirements of the analyses.

SUMMARY

Making extensive use of Sundstrand-developed Rankine cycle engine optimization computer programs, optimum system designs were determined for two turbine engines operating on RC-1 and one reciprocating engine operating on RC-2. The principal results of the analyses are predictions of engine size, weight, and efficiency (vehicle miles per gallon), as summarized in Table 1.

Computations leading to these optimum designs took into account not one but five different steady-state load points carefully selected to represent typical driving conditions. Each final design, then, represents the best design for a vehicle over its whole operating spectrum.

Each optimization was carried out under a number of fixed constraints selected to ensure a practical system. Other design parameters were allowed to float in searching for the optimum. The latter are listed in Table 2 with their final converged values.

Table 1. PRINCIPAL RESULTS OF ENGINE OPTIMIZATION CALCULATIONS

Engine Type: / Working Fluid: / Weighting Factor, Effic. (vs Wt):	Turb RC-1 0.5	Turb RC-1 0.97	Recip RC-2 0.5
Overall miles/gallon	13.33	13.81	18.89*
Weights, lb			
Expander & Gear Box	146	178	225
Condenser & Fan	173	172	142
Regenerator	195	234	36
Burner & Vapor Generator	380	368	281
Transmission & Drive Train	355	355	355
All Other components & Fuel	322	319	322
Total System	1571	1626	1361
Volumes, cu ft			
Expander & Gear Box	0.23	0.28	2.25
Condenser & Fan	7.55	7.71	5.56
Regenerator	4.13	5.01	0.82
Burner & Vapor Generator	9.58	8.83	9.79
Transmission	1.50	1.50	1.50
Unoccupied Space	15.31	15.57	13.3
Total System	38.3	38.9	33.2

*Based on 3% of stroke clearance volume and square wave operation of valves porting 20% of piston area - see text.

Table 2. OPTIMIZED DESIGN POINT PARAMETERS

Engine Type: / Working Fluid: / Weighting Factor, Effic. (vs Wt):	Turb RC-1 0.5	Turb RC-1 0.97	Recip RC-2 0.5
Condensing Temperature, °F	179	179	242
Regenerator Pressure Drop/Pressure In %	1.27	1.27	1.43
Regenerator Effectiveness, %	93	95	87
Condenser Effectiveness, %	81	81	80
Condenser Air Power, kW	5.48	4.93	5.0
Expander Speed			
Tip Speed, ft/sec	677	677	--
Pitch Diam., in.	4.96	6.00	--
RPM (3 in. stroke)	--	--	1900
Admission			
Arc/Total Circum., %	77.1	100	--
Intake Angle, degrees	--	--	54
Flue Gas Pressure Split (Vap. Gen./Total), %	80.4	89.4	72.6

A special feature of the optimization was the inclusion of a trade-off weighting factor, which allowed the designer to assign relative importance to system efficiency versus engine weight. In extensive calculations with the turbine expander it was found that the optimum design was relatively insensitive to the value assigned to this factor. This is attributed to the dominance of restrictions on condenser dimensions in fixing the remaining components of the engine.

To carry out the optimizations it was necessary to develop five new subroutines to describe the performance of

- 3-speed automatic transmission
- condenser ram air effects
- reciprocating expander

CONCLUSIONS AND RECOMMENDATIONS

It is concluded that both the RC-1 and RC-2 candidate fluids are appropriate for automotive-size engines and are conducive to good efficiencies for automotive application.

It is recommended that additional optimization studies be carried out using computer models of components more closely representing advanced state of the art designs. Such models would give better descriptions of component weight, size, effectiveness, and efficiency. Further engine optimization studies should be performed using more variable parameters than used in this program. A more detailed optimizing criterion would be beneficial in determining an optimum engine.

DESIGN OPTIMIZATION PROGRAM DESCRIPTION

The Sundstrand Rankine cycle design optimization program is a comprehensive analytical design procedure in which detailed design and off-design cycle calculations are made, and components meeting the requirements of the cycles are calculated. In the design procedure a design point cycle is first calculated, and then engine components are designed. The performance of the system using these components is then evaluated by means of off-design cycle calculations. The overall system and its performance is then evaluated against an optimizing criterion, the results of which are used to vary the inputs to the design point cycle analysis. A new design point is then calculated, components designed, and off-design performance evaluated. This procedure repeats until an optimum system, based on the optimizing criterion, is found.

The design procedure commences with the read-in of the fluid data, component design parameters, cycle input parameters, permissible ranges and initial values of the optimizing variables, and the engine operating load points. Starting with the initial values of expander inlet pressure and temperature, condenser temperature, and cycle pressure drops, the thermodynamic cycle conditions for the expander are established. With these and the design point power, an iterative calculation is used to design an expander, determine its efficiency, and establish a cycle flow rate. Once the flow rate is determined, the other conditions for the cycle are established and the system components are designed. With the condenser frontal area known, a more accurate value of the condenser ram air effect can be determined and a more accurate value of the condenser fan power obtained. Using this new value of condenser fan power, the cycle and expander design are recalculated and new designs for all the components established. The fuel flow and system efficiency are then obtained.

The operation of the system for the off-design load points is then found by constructing an off-design cycle and evaluating the off-design performance of the system components. The off-design fuel flow and system efficiency are then obtained.

The system and its performance are then evaluated by means of a "pay off" function which embodies the optimizing criterion to which the system is to be designed. The value of this pay off function, along with the values of the optimizing parameters, are then operated on by a multi-variable optimization procedure. This varies the values of the optimizing parameters and sends back new values to the mainline program where a new system is designed and its design and off-design performance calculated, resulting in a new value of the pay off function. The optimizing procedure continues to vary the optimizing parameters in the direction of obtaining a minimum value of the pay off function. This process repeats itself until a minimum value of the pay off function is found. A minimum value of this function indicates an optimum engine has been found. The program gives an extensive list of design and off-design cycle, component, and performance parameter values that describe the optimum engine.

PROBLEM DEFINITION

The first step in defining an optimum engine is to define the load points for which the engine is to be optimized and to define the parameters of the optimizing criterion. For the purposes of this study only steady state load points were to be used, and the optimizing criterion selected was a trade-off between system efficiency and system weight. The optimizing criterion was based on

the fact that high efficiency systems tend to be high weight systems, and reduced weight systems result in lower efficiencies. As system weight is directly related to system volume, system size is also being optimized by this criterion.

The load points used in this analysis consisted of one design-point load and four off-design load conditions. The design-point load was the maximum power point and was the result of calculations from Section 11, "Start, Acceleration, and Grade Velocity Performance" of EPA's prototype vehicle performance specification.[1] Two of the off-design points represented steady speed at 60 and 30 mph and were taken from Section 13 "Fuel Consumption" of the above EPA specification. Twenty-five mile per hour and idle off-design points were obtained from an analysis of the Federal Driving Cycle and represent "steady state" accelerations. The amount of time spent at each of these points was determined from Section 13 of the EPA specification and the Federal Driving Cycle analysis.

The load points selected are:

		Speed, mph	Power, HP	% Time
Design point	Max. power acc.	70	108	0.5
Off-Design 1	Steady speed	60	32	16.5
Off-Design 2	Steady speed	30	8.4	33.0
Off-Design 3	Acceleration	25.1	9.92	28.0
Off-Design 4	Acceleration	1.74	1.143	22.0

The power is the power output from the transmission to the drive shaft, the required engine power being determined by the engine and transmission operating conditions as determined by the cycle calculations. Accessory power and condenser fan power were added in as a function of engine operating conditions. Other parasitic powers representing the burner fan and controls were also added to the required engine power. These load points with their relative times were used to calculate the fuel load required for a 200 mile range.

The optimizing pay-off function was constructed using miles per gallon as representative of engine efficiency weighed against system weight in pounds. In the optimizing process a weighting factor was varied to place more emphasis on system efficiency or system weight to see how this affected the system configuration. (See Appendix A.)

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[1]Anon., "Prototype Vehicle Performance Specification," AAPS, EPA, Ann Arbor, Michigan, 3 January 1972.

OPTIMIZATION - TURBINE ENGINE RESULTS

The turbine engine was optimized as a supercritical engine using RC-1. The engine was optimized for a turbine inlet temperature of 712°F which was required for a 220°F condenser in order to meet the EPA specifications of 42% Carnot cycle efficiency and a 425 psia turbine inlet pressure selected to keep pump work to a minimum and because the fluid properties did not indicate any significant benefit in increased adiabatic head or reduced regenerator size by going to a higher pressure. The turbine tip speed was limited to 1200 ft/sec to stay within economical materials and the condenser used was the AiResearch design for the EPA Thermo Electron engine.

The optimization analysis for the turbine engine was performed for six values of the optimization weighting factor, which can vary from 0 to 1. These values were 0, 0.1, 0.2, 0.5, 0.7, and 0.97. (The higher the weighting factor the greater the emphasis on maximum efficiency.) The result of this analysis showed that there was no appreciable variation in the weight of the engine or in miles per gallon over the range of the weighting factor. It was also seen that there was little variation in the design point condenser temperature, which varied from 179°F to 200°F. It appeared from an analysis of the results that this situation was the result of the fact that the condenser frontal area had been restricted to a size (8.5 ft^2 max.) that would fit in an automobile. For the power level required for this application the optimization analysis always led to the biggest condenser for each value of the weighting factor and, as a result, all the engines ended up with about the same size condenser. An engine being optimized with an emphasis on efficiency would tend to result in one having a very large condenser, so it could handle low density, low pressure vapors with low pressure loss and low condensing temperature. An engine being optimized for minimum weight would also want a large condenser to achieve high component efficiencies, but would more strongly trade off condenser size and weight for efficiency. The size restriction on the condenser for this application appears to restrict condenser size so severely for this power level that the same size condenser occurs for all values of the optimization weighting factor. This condenser size appears to favor vapor densities and pressures for 179-200°F condensing temperature. As a result, the condenser influence on the rest of the power system is such that there is very little variation in the optimum engine weight and efficiency throughout the range of the optimizing weighting factor.

Because there is not much variation in the engine for the six values of weighting factor, data are presented in Tables 3 to 7 of parameters of the engine for the 0.5 weighting factor (equal emphasis on weight and efficiency), and for the 0.97 weighting

Table 3. TURBINE ENGINE OPTIMIZING DESIGN POINT PARAMETER VALUES FOR WEIGHTING FACTORS OF 0.5 AND 0.97

	0.5	0.97
Condenser Temp. (100-270)	179°F	179°F
Regenerator Vapor Side DP/Pin (0.01-0.5)	0.0127	0.0127
Regenerator Liquid Side DP/P Turb. In.	0.0236	0.0236
Condenser Hot Side DP/Vapor Density	0.136	0.136
Vaporizer DP/P Turb. In.	0.0208	0.0208
Regenerator Eff. (0.5-0.95)	0.930	0.950
Economizer Eff.	0.800	0.800
Vaporizer Eff.	0.950	0.950
Condenser Eff. (0.3-0.9)	0.812	0.812
Burner Fan Power, kW	2.5	2.5
Condenser Hydraulic Air Power (0.1-20), kW	5.48	4.93
Turbine Tip Speed (100-1200), ft/sec	677	677
Turbine Pitch Dia. (3-10), in.	4.962	6.004
Turbine Arc of Admission/Total Circum. (0.1-1)	0.771	1.000
Regenerator Liquid to Vapor Flow Ratio	0.84	0.84
Flue Gas Vaporizer-Economizer DP Split $\frac{DP_{VAP}}{DP_{TOT}}$ (0.3-0.95)	0.804	0.894
Turbine Inlet Pressure, psia	425	425

Table 4. TURBINE ENGINE WEIGHT SUMMARY OF 0.5 AND 0.97 ENGINE

Component	Weight (lb) 0.5 Engine	0.97 Engine
Fan	33	33
Regenerator	195	234
Condenser	140	139
Fuel	92	88
Economizer Housing	66	62
Turbine-Gear Box	146	178
Economizer	80	94
Vaporizer	204	183
Burn Fan Motor	17	17
Burner	13	12
Transmission	155	155
Drive Train	200	200
Start Motor and Pump	20	20
Piping, Valves, and Ducting	60	60
Battery	40	40
Start Accumulator	10	10
Controls	30	30
Exhaust Pipe	55	55
Electric Generator	15	15
Total System	1571	1626

Table 5. TURBINE ENGINE VOLUME SUMMARY OF 0.5 AND 0.97 ENGINE

Component	Volume (ft^3) 0.5 Engine	0.97 Engine
Turbine Unit	0.23	0.28
Regenerator	4.13	5.01
Condenser	3.08	3.06
Hotwell	1.27	1.41
Condenser Fan	3.20	3.24
Vaporizer and Economizer	8.68	7.96
Burner	0.898	0.87
Transmission	1.5	1.5
Overall Vol. (0.6 Packing Density)	38.3	38.9

Table 6. COMPARISON OF DESIGN AND OFF-DESIGN PARAMETERS FOR 0.5 TURBINE ENGINE

Mode	DES PT WOT ACC	OFF 1 Steady Speed	OFF 2 Steady Speed	OFF 3 ACC	IDLE ACC
Car Speed, mph	70	60	30	25.1	1.74
Trans. Power Out, HP	108	32	8.4	9.92	1.143
Percent Time	0.5	16.5	33.0	28.	22.
Condenser Temp.	179	179	179	179	179
System Mass Flow, lb/sec	3.912	1.117	0.471	0.545	0.522
System Eff.	0.171	0.177	0.119	0.121	0.047
Turbine Speed, rpm	31281	24933	19189	26358	6786
Transmission Gear Ratio	1.0	1.0	1.52	2.52	1.85
Trans. Eff.	0.914	0.982	0.951	0.934	0.335
Engine HP	146	38	13	15.7	6.6
Condenser Fan HP	16.7	0.0	0.0	0.0033	0.0340
Condenser Air Flow, lb/sec	18.29	5.115	1.846	2.088	1.894
Miles per gallon	4.94	15.85	19.74	14.0	1.18

Overall time weighted miles per gallon = 13.33

Table 7. COMPARISON OF DESIGN AND OFF-DESIGN PARAMETERS FOR 0.97 TURBINE ENGINE

Mode:	DES PT WOT ACC	OFF 1 Steady Speed	OFF 2 Steady Speed	OFF 3 ACC	IDLE ACC
Car Speed, mph	70	60	30	25.1	1.74
Trans. Power Out, HP	108	32	8.4	9.92	1.143
Percent Time	0.5	16.5	33.0	28.	22.
Condenser Temp.	179	179	179	179	179
System Mass Flow, lb/sec	3.863	1.097	0.457	0.512	0.522
System Eff.	0.176	0.180	0.123	0.128	0.047
Turbine Speed, rpm	25852	20606	15858	21784	5608
Transmission Gear Ratio	1.0	1.0	1.52	2.52	1.85
Trans. Eff.	0.914	0.982	0.951	0.94	0.335
Engine HP	144.	38	13	15.7	6.58
Condenser Fan HP	14.8	0.0	0.0	0.0	0.034
Condenser Air Flow, lb/sec	17.77	5.04	2.054	1.981	1.905
Miles per gallon	5.10	16.16	20.32	14.85	1.176

Overall time weighted miles per gallon = 13.81.

factor (emphasizing maximum efficiency). These parameter values are typical for all of the engines. Table 3 shows the optimizing parameters used to size the engines. The values in parentheses show the range of that particular variable that was considered. For those parameters where no range is shown only the indicated value was used. The nine parameters in this table having a range of values were those that were optimized by the optimizing subroutine in the process of arriving at an optimum engine. The values of the parameters are those for the design point.

Tables 4 and 5 show a weight and volume summary, respectively, for the 0.5 and 0.97 engines. The total system weight is the sum of the listed weights and the total volume is the sum of the listed volumes divided by a 0.6 density packing factor.

Tables 6 and 7 show a comparison of a number of parameters for the design and off-design conditions for the 0.5 and 0.97 engines respectively.

Mode refers to the kind of operating condition that was evaluated, car speed is the velocity of the car for this point, transmission power out HP is the power delivered at the output of the transmission to the drive shaft, and percent time is the amount of time spent at a particular point when evaluating the overall driving cycle miles per gallon.

A comparison is shown of condenser temperature and system mass flow and of the system efficiency, which is defined as the power into the transmission divided by the total heat released by the fuel based on its higher heating value. Also shown is the turbine speed, transmission gear ratio and efficiency, and the total engine HP developed, which includes condenser fan power, accessory power, burner fan power, and all other parasitic powers. The condenser fan power in HP is shown along with the condenser air flow. The miles per gallon at each condition is also given.

The optimization program input and output print out of the major system parameters for the 0.5 and 0.97 engines are shown in Appendices B and C, respectively.

OPTIMIZATION - RECIPROCATING ENGINE RESULTS

The reciprocating engine was analyzed as a subcritical engine using R0-2. The engine was analyzed for an expander inlet temperature of 712°F and a 700 psia inlet pressure for the same reasons as for the turbine engine and to keep cylinder bore diameter a reasonable size for an automotive engine. The reciprocator used was a single acting, single expansion engine whose speed was limited to 2000 rpm to keep valve train forces within reasonable limits. The condenser core used was that of the AiResearch design developed for the Thermo Electron engine.

Because of the large amount of tabular data required to define the properties of this fluid for the reciprocator, and because of the many iterative convergence calculations involving the use of these data, the optimization analysis of this engine proved to be a long and tedious process. Because of this and the limitations of available time and funding for this project, a complete optimization of this engine was not completed. However, enough effort was carried out to achieve a partial optimization.

The results of this partial optimum are presented in Tables 8 to 11 and Appendix D, and are of similar form and content as described for the turbine engine. Those areas peculiar to the reciprocating expander are evident. (It should be noted that crank intake angle represents the angular turn of the crankshaft for which the intake valves are open and as such represents intake ratio.) Unfortunately, an error was spotted in the transmission subroutine at this point which affects the 60, 30, and 25.1 mph off-design points. The effect resulted in the expander speed at the design condition being ratioed by the car speed to obtain an off-design expander speed instead of using the gear ratios and torque converter characteristics in the transmission. An unreasonably low (66%) transmission efficiency also resulted from this error. However, the design and idle point calculations were correct. Using the turbine engine transmission results as a guide, more reasonable transmission efficiencies were estimated along with the gear ratio the transmission would be in and the off-design data were adjusted with these new values. These data are presented in Table 11.

As can be seen by the miles per gallon, the reciprocating engine shows very encouraging results. However, it must be taken into consideration that the simplified reciprocator model used assumed a three percent of stroke clearance volume and "square wave" valve operation that had flow areas equal to one fifth the piston area. These rather optimistic assumptions result in low valve losses and high volumetric efficiency which may be difficult to attain in an actual engine. The result of these assumptions is a high efficiency expander which results in the high miles per gallon figures. It should be borne in mind when comparing these figures to that of the turbine, that the turbine expander model used was a well developed turbine analysis that gave realistic results based on current state-of-the-art technology.

Because of the lack of variation in the results obtained with the turbine engine when the optimization weighting factor was varied from 0 to 0.97, an attempt was made to optimize a reciprocating engine for a 0.5 weighting factor only.

Table 8. RECIPROCATING ENGINE OPTIMIZING DESIGN POINT PARAMETER VALUES FOR WEIGHTING FACTOR OF 0.5

Condenser Temp. (100 - 270°F)	242°F
Regenerator DP/Pin (0.01 - 0.5)	0.0143
Regenerator DPL/P Expander In.	0.0344
Condenser Hot Side DP/Vapor Density	0.0208
Vaporizer DP/P Expander In.	0.1
Regenerator Effec. (0.5 - 0.95)	0.87
Econ. Effec.	0.80
Vaporizer Effec.	0.95
Condenser Effec. (0.3 - 0.9)	0.80
Burner Fan Power, kW	2.5
Condenser Hydraulic Air Power (0 - 20), kW	5.0
Expander Speed (0 - 2000), rpm	1900
Stroke, in.	3.0
Crankshaft Intake Angle (0 - 140), deg	54
Regenerator Liquid to Vapor Flow Ratio	0.84
Flue Gas Vaporizer-Economizer DP Split $\frac{DP_{VAP}}{DO_{TOT}}$ (0.3-0.95)	0.726
Expander Inlet Pressure, psia	700

Table 9. RECIPROCATING ENGINE WEIGHT SUMMARY OF 0.5 ENGINE

Component	Weight (lb)
Fan	28
Regenerator	36
Condenser	114
Fuel	91
Economizer Housing	66
Expander - Gear Box	225
Economizer	70
Vaporizer	113
Burner Fan Motor	17
Burner	15
Tranmission	155
Drive Train	200
Start Motor and Pump	20
Piping, Valves, and Ducting	60
Battery	40
Start Accumulator	10
Controls	30
Exhaust Pipe	55
Electric Generator	15
Total System	1361

Table 10. RECIPROCATING ENGINE VOLUME SUMMARY OF 0.5 ENGINE

Component	Volume (ft^3)
Expander - Accessory Gear Box	2.25
Regenerator	0.82
Condenser	2.47
Hotwell	0.71
Condenser Fan	2.38
Vaporizer/Econ.	8.6
Burner	1.19
Transmission	1.5
Overall Vol. (0.6 Packing Density)	33.2

Table 11. RECIPROCATING ENGINE COMPARISON OF DESIGN AND OFF DESIGN PARAMETERS FOR 0.5 RECIPROCATING ENGINE

	DES PT	OFF 1	OFF 2	OFF 3	IDLE
Mode:	WOT ACC	Steady Speed	Steady Speed	ACC	ACC
Car Speed, mph	70	60	30	25.1	1.74
Trans Power Out, HP	108	32	8.4	9.92	1.143
Percent Time	0.5	16.5	33.0	28.0	22.
Condenser Temp., °F	242	242	242	242	242
System Mass Flow, lb/sec	1.286	0.336	0.096	0.110	0.031
System Eff.	0.131	0.190	0.173	0.180	0.096
Expander Speed, rpm	1900	*	*	*	360
Transmission Gear Ratio	1.0	1.0	1.46	2.46	2.46
Trans. Eff.	0.894	0.98	0.95	0.94	0.497
Engine HP	144	37.0	11.6	13.3	5.3
Condenser Fan HP	12.5	0.0	0.0	0.0	0.000225
Condenser Air Flow, lb/sec	15.507	3.959	1.101	1.116	0.298
Miles per gallon	3.71	17.0	28.7	20.8	3.56

Overall time weighted miles per gallon = 18.89*

*See section on Optimization - Reciprocating Engine Results.

SPECIAL SUBROUTINE DESCRIPTION

Five new subroutines were written in the process of modifying the design optimization program to design an automobile engine. These subroutines described a transmission, reciprocating expander, and condenser ram air effect. A short description along with a listing of each subroutine follows.

TRANSMISSION SUBROUTINES "SHIFT" AND "DRIVE"

The transmission subroutines represent 3-speed automatic transmissions and were used to determine the optimum gear ratio for each design and off-design point. They did this in connection with the expander and were designed to select the most efficient expander speed-transmission gear ratio combination within the limits of the transmission design and the expander speed criteria. These subroutines also determined the transmission efficiency and the expander-to-transmission gear box ratio. This gear box ratio was determined at the design point load with the transmission in high gear and held at that value for the off-design points. Subroutine "Shift" used gear ratio and torque converter data for a GM T-350 transmission and was used with the turbine engine, while subroutine "Drive" used data from a Ford transmission with a Model 1942 torque converter and was used with the reciprocating engine. Listings of subroutine "Shift" and "Drive" are shown in Appendices E and F.

RAM AIR EFFECTS SUBROUTINE "RAMAR"

Subroutine "Ramar" was used to compute the effects of condenser ram air on the condenser fan power. It did this by first making an estimate of the fan power required and then after a condenser was designed, calculating the ram effect and adjusting the fan power accordingly. A new system was then designed with this new value of fan power by the design optimization program, the first condenser being an approximation of the second. To calculate the ram air effect, test data from a Ford automobile using the Thermo Electron test engine set-up was used. A listing of subroutine "Ramar" is shown in Appendix G.

RECIPROCATOR SUBROUTINE "RECIP."

Subroutine "Recip." was used to represent the reciprocating expander in the reciprocating engine and represents a simplified reciprocator model having square wave inlet and exhaust ports having one fifth the area of the piston. It incorporates provisions for valve losses and cylinder heat loss. This subroutine calculates both the design and off-design performance of the reciprocator and the expander mass flow and efficiency. In the design mode the subroutine determines the bore size required to develop the required power for given values of intake ratio, speed and stroke. In the off-design mode the intake ratio and valve timing are changed to achieve the required power with the design point bore diameter and stroke, the expander speed being determined in conjunction with the transmission subroutine "Drive". A listing of subroutine "Recip." is shown in Appendix H.

RECIPROCATOR WEIGHT SUBROUTINE "WEXPD"

Subroutine "WEXPD" is used to estimate the reciprocating expander weight and volume from cylinder bore diameter, mean effective pressure, connecting rod length, and number of cylinders. The expander weight model uses the reciprocating expander of Thermo Electron Report No. TE 4121-133-70, "Conceptual Design of Rankine Cycle Power System with Organic Working Fluid and Reciprocating Engine for Passenger Vehicles," as a base reference for the weight calculations. The feed pump and gear and accessory housing weight and volume are also computed in "WEXPD". A listing of "WEXPD" is shown in Appendix I.

LOAD POINT ANALYSIS FOR FEDERAL DRIVING CYCLE

To determine load points from the Federal Driving Cycle a computer program was written to analyze the driving cycle point by point. For each point, accelerations and engine power required based on EPA rolling and air resistance formulas were computed. The computed data were then divided up into speed and power ranges, and the amount of time spent in each range computed. By looking at the amount of time spent in each range, two speed-power load points were selected as most representative of the Federal Driving Cycle. This program used a fixed transmission efficiency and accessory HP to compute the engine power; however, the output data were later adjusted to remove these fixed quantities and obtain a transmission HP out. This allowed the variable transmission efficiencies and accessory HP as computed in the design

optimization program to be used to compute engine power required. A listing of this program along with sample output is shown in Appendix J.

In the sample output:

SPEDL - Lower limit of speed range (MPH)
SPEDU - Upper limit of speed range (MPH)
TTIME - Total time of driving cycle (sec)
WT - Weight of vehicle (LBS)
TSPED - Total at positive acceleration
A01-A910 - Time in acceleration range indicated (sec), range in MPH/sec
TSPDN - Total time at negative acceleration
A01N-A910N - Time in deceleration range indicated (sec) range in MPH/sec
TSPDH - Total time spent in speed range (sec)
HP10-HP140 - Time spent in indicated horsepower range (sec) horsepower is in increments of 10 HP, indicated number being the maximum horsepower in that range.

APPENDIX A

OPTIMIZING CRITERION "PAY OFF" FUNCTION

The Rankine cycle engines in this study were optimized by a criterion that embodied a trade-off between engine size, expressed in the form of engine weight, against engine efficiency, expressed in miles per gallon over a time weighted average of five operating points. This function was expressed in the form:

Pay off = C/MPG + (1-C) Wt

Where pay off = Optimization number whose minimum value indicates an optimum has been found.

C = Optimization weighting factor the value of which can vary between 0 and 1 and which varies the emphasis on keeping engine weight to a minimum or miles per gallon to a maximum. A high value of C emphasizes high MPG and a low value minimum engine weight (Wt).

MPG = Normalized overall time weighted miles per gallon of engine defined as:

MPG = [MPG (DES PT) x PCT time + MPG (off DES 1) x PCT time + MPG (off DES 2) x PCT time + MPG (off DES 3) x PCT time + MPG (Idle) x PCT time] / (Ref. MPG)

where Ref. MPG is a reference overall MPG used to normalize MPG and was given a value of 15 MPG.

WT = Normalized engine WT which was defined as:

WT = System weight/reference weight

Reference weight being used to normalize WT and had a value of 1400 lb.

The reason for normalizing the parameters of the "pay off" function is to get a better balance between numbers that have large differences in magnitudes of numerical values. Percentage changes put the weighting parameters on a more representative basis to compare degrees of change.

A penalty function was associated with this pay off function to keep the design optimization program from constructing engines with unacceptably large condensers. Whenever condenser frontal area exceeded 8.5 ft^2 the pay off number was multiplied by 1000. This indicated to the optimizing procedure that the last change in the optimizing variables was severely unacceptable. This forced the optimizing procedure to keep away from changes that would cause unacceptable values of condenser frontal area.

APPENDIX B

OPTIMIZATION - TURBINE: 0.5 WEIGHTING FACTOR

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR ACI FLUOROBENZINE MIXTURE FLS 2/12/73

INPUT

CYCLE CONDITIONS

ALT PWR FACT	ELEC COND EFF	NET POWER	PARA POWER	CNDSR SUBCOOL		
0.7500000E 00	0.1000000E 01	0.1000000E 01	0.3000000E 00	0.0		
PUMP FR	AMB AIR TEMP	GAS LHV	FUEL HHV	CRIT PRESS		
0.1500000E 01	0.8500000E 02	0.1926500E 05	0.2077000E 05	0.4010000E 03		
DES POWER	DES SPEED	OFF POWER 1	OFF SPEED 1	OFF POWER 2	OFF SPEED 2	
0.1080000E 03	0.7000000E 02	0.3200000E 02	0.6000000E 02	0.8400000E 01	0.3000000E 02	
OFF POWER 3	OFF SPEED 3	IDLE POWER	IDLE SPEED			
0.9919999E 01	0.2509999E 02	0.1143000E 01	0.1748000E 01			
PCT TIME DES	PCT TIME OFF1	PCT TIME OFF2	PCT TIME OFF3	PCT TIME IDLE	MAX ENG WT	CPAOF
0.5000000E 00	0.1650000E 02	0.3300000E 02	0.2800000E 02	0.2200000E 02	0.1400000E 04	0.5000000E 00
BASE MPG	FUEL LB/GAL					
0.1500000E 02	0.6099999E 01					

TURBINE

T REF(VISC)	VISC EXP	BLD DENS RTO	CHORD	NO BLADES		
0.1172000E 04	0.1000000E 01	0.5500000E 00	0.1000000E 01	0.1000000E 01		
NOZ EDG THICK	ROT EDG THICK	ZNY	ZN4Y	BLD/NOZ RTO		
0.9999998E-02	0.9999998E-02	0.1000000E 01	0.1000000E 01	0.1000000E 01		
AX CLEAR	TIP CLEAR					
0.1500000E-01	0.1500000E-01					
NOZ VEL COEF						
0.9600000E 00	0.0	0.0	0.0			
NOZ FLOW COEF						
0.9600000E 00	0.0	0.0	0.0			
EXH HEAD LOSS FACT						
0.1000000E 01	0.0	0.0	0.0			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

INPUT

REGENERATOR

TUBE FIN DESIGN

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.9130000E 00	0.0	0.8419998E-02	0.1920000E-01	0.2510000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.0	0.5999997E-02	0.0	0.2000000E-01	0.1650000E 02
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1330000E 03	0.1650000E 02	0.0	0.0	0.0
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.0	0.5599999E 00	0.1110000F 01	0.2690000E 03	0.1200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.0	0.6250000E-01	0.9789997E-01	0.3230000E 00	0.3230000E 00
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.2830000F 00	0.8000000E 01	0.0	0.0	

CONDENSER

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.8760000F 00	0.4960000E 00	0.6549999E-02	0.8339997E-02	0.1[illegible]30000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.2500000E-01	0.3999997E-02	0.3999997E-02	0.2000000E-01	0.1000000E 03
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1000000E 03	0.1000000E 03	0.5560000F 03	0.8950000E 03	0.3260000E 00
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.5000000E-01	0.7770000E 00	0.1111000E 00	0.4700000E 03	0.2200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.2000000F 02	0.6250000E-01	0.9799999E-01	0.9799999E-01	0.9799999E-01
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.9799999F-01	0.1000000E 01	0.0	0.1000000E 01	

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

INPUT

VAPORIZER

AVG DIA(FT)	NO STARTS	DIA BB INSIDE	DIA BB O'SIDE	DIA RTO
0.1500000F 01	0.1000000E 01	0.1000000F 01	0.1760000E 00	0.1099999E 01
POROSITY	K TUBE WALL	EXCESS AIR	H2/C RTO	LHV GAS
0.4500000E 00	0.2000000E 02	0.3000000E 00	0.1875000E 00	0.1926500E 05
GAS TEMP IN	CP GAS COLD	CP GAS HOT	FLAME TEMP	VISC GAS
0.3000000E 04	0.2800000E 00	0.3329999E 00	0.3300000E 04	0.1100000E 00
K GAS				
0.4500000F-01				

BLOCK DATA

(1)	(2)	(3)	(4)	(5)
0.1785031F 03	0.1271123E-01	0.2360000E-01	0.1360000E 00	0.2080000E-01
(6)	(7)	(8)	(9)	(10)
0.9296370F 00	0.8000000E 00	0.9500000E 00	0.8119854E 00	0.2500000E 01
(11)	(12)	(13)	(14)	(15)
0.5482265E 01	0.6772681E 03	0.4962111E 01	0.7713708E 00	0.8400000E 00
(16)	(17)			
0.8042591E 00	0.4250000E 03			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.7814461E 00	0.1089571E 03	0.9824064E 00	0.7000000E 00	0.7133888E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.9296370E 00	0.9500000E 00	0.8000000E 00	0.1247519E 02	0.2500000E 01

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.1773517E 00	0.1003000E 02	0.8839999E 01	0.1897522E 01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.16027E 02	0.56993E 03	0.20018E 03
COND IN	0.15850E 02	0.21123E 03	0.12205E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.44387E 03	0.18408E 03	0.38177E 02
REGEN LIQ IN	0.44387E 03	0.18408E 03	0.38177E 02
REGEN LIQ OUT	0.43384E 03	0.41295E 03	0.13119E 03
ECON OUT	0.43384E 03	0.41295E 03	0.11135E 03
VAP IN	0.43384E 03	0.41771E 03	0.12802E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.3911785E 01	0.8648700E 02	0.1796334E 07	0.1588479E 07	0.1200367E 07

SYSTEM EFF	SFC
0.1709069E 00	0.9614801E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

TURBINE

T REF(VISC)	VISC EXP	BLD DENS RTO	CHORD	NO BLADES
0.1172000E 04	0.1000000E 01	0.5500000E 00	0.2827018E 00	0.8100000E 02

NOZ EDG THICK	ROT EDG THICK	ZNY	ZN4Y	BLD/NOZ RTO
0.9999998E-02	0.9999998E-02	0.1000000E 01	0.1000000E 01	0.1000000E 01

AX CLEAR	TIP CLEAR
0.1500000E-01	0.1500000E-01

NOZ VEL COFF			
0.9600000E 00	0.0	0.0	0.0

NOZ FLOW COEF			
0.9600000E 00	0.0	0.0	0.0

EXH HEAD LOSS FACT			
0.1000000E 01	0.0	0.0	0.0

PRES RATIO
0.2651735E 02

P IN	T IN	REF VISC	RPM	PITCH DIA
0.4250000E 03	0.1172000E 04	0.4590000E-01	0.3128073E 05	0.4962111E 01

NOZ ANGLE	BLADE HT	BLADE ANGLES	ARC/T.CIRCUM	NOZ AREA RTO
0.1500000E 02	0.4058750E 00	0.3003462E 02	0.7713708E 00	0.4977407E 01

NOZ AREA	SPEC SPEED	SPEC DIA	WHEEL WT	TB EFF
0.1982206E 00	0.4046362E 02	0.1883761E 01	0.1600067E 01	0.7814461E 00

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.1080000E 03	0.7000000E 02	0.1205790E 03	0.3128073E 05	0.1000000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.1117023E 02	0.9139573E 00	0.3729998E 01	0.1460551E 03

COMBINED ROTATING UNIT

DIFF HOUS WT	NOZ HOUS WT	GEN HOUS WT	TURB WT	PUMP HOUS WT
0.2856792E 02	0.1184598E 01	0.8999998E 02	0.1600067E 01	0.0

ADD WT	TOT CRU WT
0.2427051E 02	0.1456231E 03

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR ACI FLUORORENZINE MIXTURE FLS 2/12/73

OUTPUT

REGENERATOR

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.9130000E 00	0.0	0.8419998E-02	0.1920000E-01	0.2510000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.0	0.5999997E-02	0.0	0.2000000E-01	0.1650000E 02
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1330000E 03	0.1650000E 02	0.0	0.0	0.0
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.0	0.5599999E 00	0.1110000E 01	0.2690000E 03	0.1200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.0	0.6250000E-01	0.9789997E-01	0.3230000E 00	0.3230000E 00
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.2830000E 00	0.8000000E 01	0.0	0.0	
T IN VAP	T OUT VAP	T IN LIQ	T OUT LIQ	
0.5699253E 03	0.2112302E 03	0.1840807E 03	0.4129492E 03	
FLOW VAP	FLOW LIQ	DP VAP	DP LIQ	CP VAP
0.3911785E 01	0.3285900E 01	0.1773517E 00	0.1003000E 02	0.2178230E 00
CP LIQ	VISC VAP	VISC LIQ	PR VAP	PR LIQ
0.4064094E 00	0.9531802E-05	0.1777613E-03	0.7806048E 00	0.6500905E 01
RHO IN VAP	RHO OUT VAP	RHO IN LIQ	RHO OUT LIQ	H T COEF VAP
0.4783944E 00	0.7699695E 00	0.8100099E 02	0.6480898E 02	0.2915422E 02
H T COEF LIQ	MASS VEL VAP	MASS VEL LIQ	ETAO VAP	ETAO LIQ
0.3508259E 03	0.5863213E 01	0.3419912E 03	0.8987604E 00	0.1000000E 01
RE VAP	RE LIQ	NO TUBES	COM LENG(FT)	LIQ LENG(FT)
0.5179316E 04	0.3693846E 05	0.3400000E 02	0.1969103E 00	0.5983661E 01
VAP LENG/PASS	VAP LENG(FT)	VOL/PASS	TOT VOL(CUFT)	TOT INV(VAP)
0.4380857E 00	0.3504684E 01	0.5161718E 00	0.4129375E 01	0.2172354E 01
HEADER INVENT	TOT INV(LIQ)	FIN STRES VAP	FIN STRES LIQ	PLATE STRES
0.1758238E 01	0.4662279E 02	0.0	0.2435994E 04	0.0
DRY WT	TOT WT	EFFEC		
0.1466527E 03	0.1954479E 03	0.9296370E 00		

OPTIMIZATION OF OPC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

CONDENSER

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.8760000E 00	0.4960000E 00	0.6549999E-02	0.8339997E-02	0.1430000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.2500000E-01	0.3999997E-02	0.3999997E-02	0.2000000E-01	0.1000000E 03
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1000000E 03	0.1000000E 03	0.5560000E 03	0.8950000E 03	0.3260000E 00
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.5000000E-01	0.7134771E 00	0.2242877E 00	0.4700000E 03	0.2200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.2000000E 02	0.6250000E-01	0.9799999E-01	0.9799999E-01	0.9799999E-01
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.9799999E-01	0.1000000E 01	0.0	0.1000000E 01	
RHO COND	PR COND			
0.8333339E 02	0.5709348E 01			
T IN VAP	T OUT VAP	T IN LIQ	T OUT LIQ	
0.8500000E 02	0.1609231E 03	0.2112302E 03	0.1785031E 03	
FLOW VAP	FLOW LIQ	DP VAP	DP LIQ	CP VAP
0.1829893E 02	0.3911785E 01	0.1127138E 00	0.1897522E 01	0.2399999E 00
CP LIQ	VISC VAP	VISC LIQ	PR VAP	PR LIQ
0.1786224E 00	0.1320000E-04	0.7288324E-05	0.7200000E 00	0.1000000E 01
RHO IN VAP	RHO OUT VAP	RHO IN LIQ	RHO OUT LIQ	H T COEF VAP
0.7287151E-01	0.6396121E-01	0.3692152E 00	0.3692152E 00	0.2539117E 02
H T COEF LIQ	MASS VEL VAP	MASS VEL LIQ	ETAO VAP	ETAO LIQ
0.5078235E 03	0.3047426E 01	0.6688901E 01	0.9262074E 00	0.9792332E 00
RE VAP	RE LIQ	NO TUBES	COM LENG(FT)	LIQ LENG(FT)
0.1512169E 04	0.7654078E 04	0.0	0.7123344E 01	0.1181485E 01
VAP LENG/PASS	VAP LENG(FT)	VOL/PASS	TOT VOL(CUFT)	TOT INV(VAP)
0.3660420E 00	0.3660459E 00	0.3080688E 01	0.3080688E 01	0.1358396E 00
HEADER INVENT	TOT INV(LIQ)	FIN STRES VAP	FIN STRES LIQ	PLATE STRES
0.5607953E 01	0.3919868E 00	-0.1724895E 02	-0.2635632E 02	-0.1394585E 02
DRY WT	TOT WT	EFFEC		
0.1398953E 03	0.1404231E 03	0.8119854E 00		

NOTE- VAP AND LIQ REFER TO AIR AND WORKING FLUID SIDES RESPECTIVELY

HEAT REJECTION FAN AND MOTOR

FAN PWR(KW)	W AIR	DP AIR	FAN RPM	FAN DIA
0.1247519E 02	0.1829893E 02	0.1127138E 00	0.1262493E 04	0.3481267E 02
FAN+MOTOR WT				
0.3254471E 02				
COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.1247519E 02	0.7000000E 02	0.8500000E 02	0.1127138E 00	0.1829893E 02
QREJ	CCA	CZL	CCTOT	APWRD
0.1200367E 07	0.7123344E 01	0.1181485E 01	0.3660459E 00	0.1040000E 03
RAMHP	COND AIR POWER			

0.3592685F 01 0.5482265E 01

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

VAPORIZER

AVG DIA(FT)	NO STARTS	DIA BB INSIDE	DIA BB O'SIDE	DIA RTO
0.1001657E 01	0.1000000E 01	0.1000000F 01	0.1760000E 00	0.1099999E 01
POROSITY	K TUBE WALL	EXCESS AIR	H2/C RTO	LHV GAS
0.4500000F 00	0.2000000E 02	0.3000000F 00	0.1875000F 00	0.1926500E 05
GAS TEMP IN	CP GAS COLD	CP GAS HOT	FLAME TEMP	VISC GAS
0.3000000E 04	0.2800000E 00	0.3329999E 00	0.3300000E 04	0.1099997E 00
K GAS				
0.4500000F-01				
W ORG	W GAS	T ORG IN	T ORG OUT	CP ORG IN
0.3911785E 01	0.4963682E 00	0.4177085E 03	0.7123101E 03	-0.2477261E 01
CP ORG OUT	MU ORG IN	MU ORG OUT	K ORG IN	K ORG OUT
0.2826294E 00	0.1319788E-03	0.2146040E-06	0.3142497E-01	0.1585057E-01
RHO ORG	RHO GAS	DP ORG	DP GAS	EFFEC
0.3075098F 02	0.1641427E-01	0.8839999E 01	0.5601633E 00	0.9500000F 00
T FLUF GAS	H ORG IN	H ORG OUT	RE GAS	F GAS
0.5618232E 03	0.6472986E 03	0.4022410E 03	0.1726880E 05	0.5004015E 00
H GAS	UO	H FLUX	NTU	ML
0.8257932E 02	0.6865111E 02	0.4913494E 05	0.3735613E 01	0.6451911E-01
WCH	TUBE I/D	TUBE O/D	TUBE LENG	NO TUBES
0.1652905E 00	0.1228836E 00	0.1351719E 00	0.7505031F 02	0.2384975E 02
FIN HT	VAP HT	VAP VOL	INVENT	TOT WT
0.1336991E-02	0.3287587E 01	0.3337002E 01	0.2737090E 02	0.2044871E 03

ECONOMISER

DIA BB O'SIDE	K TUBE WALL	PASSES	POROSITY	DIA RTO
0.1760000F 00	0.2000000E 02	0.3000000E 01	0.4500000E 00	0.1099999E 01
CP GAS	VISC GAS	K GAS		
0.2800000F 00	0.1099997E 00	0.4500000E-01		
W GAS	W ORG	RHO ORG	RHO GAS	CP ORG
0.4963682E 00	0.6258859E 00	0.4085236E 02	0.1641427E-01	0.3197379E 00
MU ORG	K ORG	DP ORG	DP GAS	ECON DIA
0.1332741F-03	0.3176762E-01	0.1003000E 02	0.1363328F 00	0.1272000E 01
H ORG	ZML	F GAS	TUBE I/D	TUBE O/D
0.2895798F 03	0.3906494E 00	0.5042200E 00	0.5947102E 00	0.6541808E 00
FIN HT	ECON HT	ML	F GAS	TUBE LENG
0.1289154F 00	0.3843412E 00	0.3906494E 00	0.5042200F 00	0.6062564E 02
INVENT	ECON WT			
0.1433285E 02	0.7978168E 02			

BURNER FAN AND MOTOR

FAN PWR(KW)	W AIR	DP AIR	FAN RPM	FAN DIA
0.2500000E 01	0.4723440E 00	0.6964961E 00	0.3896840E 04	0.1100000E 02
FAN+MOTOR WT				
0.1698999E 02				

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

HOTWELL

CAPACITYCU FT
0.1271900E 01

BLOCK DATA

(1)	(2)	(3)	(4)	(5)
0.1785031E 03	0.1271123E-01	0.2360000E-01	0.1360000E 00	0.2080000E-01
(6)	(7)	(8)	(9)	(10)
0.9296370E 00	0.8000000E 00	0.9500000E 00	0.8119854E 00	0.2500000E 01
(11)	(12)	(13)	(14)	(15)
0.5482265E 01	0.6772681E 03	0.4962111E 01	0.7713708E 00	0.8400000E 00
(16)	(17)			
0.8042591E 00	0.4250000E 03			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 32.00HP AND 60.00MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.7038947E 00	0.2847531E 02	0.9664640E 00	0.5599999E 00	0.6307173E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1005811E 01	0.9839965E 00	0.8750155E 00	0.0	0.1031607E 00

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.1858351E-01	0.1050976E 01	0.9262843E 00	0.1988286E 00	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.14170E 02	0.57762E 03	0.20213E 03
COND IN	0.14151E 02	0.18157E 03	0.11674E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42698E 03	0.18386E 03	0.38123E 02
REGEN LIQ IN	0.42698E 03	0.18386E 03	0.38123E 02
REGEN LIQ OUT	0.42593E 03	0.44345E 03	0.13978E 03
ECON OUT	0.42593E 03	0.35382E 03	0.89493E 02
VAP IN	0.42593E 03	0.43139E 03	0.13174E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.1116745E 01	0.2309605E 02	0.4797050E 06	0.4245033E 06	0.3213163E 06

SYSTEM EFF	SFC
0.1764207E 00	0.9314293E 00

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2915422E 02	0.3508259E 03	0.3911785E 01	0.3285900E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.1374197E 02	0.3508259E 03	0.1116745E 01	0.9380657E 00	0.1858351E-01

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.1050976E 01	0.9486797E 00	0.1223131E 04	0.1396730E 01	0.1005811E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6472986E 03	0.4022410E 03	0.8257932E 02	0.6865111E 02	0.3911785E 01

W FUEL
0.8648700E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.2691597E 03	0.1672599E 03	0.3388351E 02	0.9994310E 00	0.2860281E 02

NTU'S	EFFEC
0.5660088E 01	0.9839965E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 32.00HP AND 60.00MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2895798E 03	0.4848404E 02	0.6258859E 00	0.4963682E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.1062262E 03	0.1949593E 02	0.9977308E 00	0.1581868E 02	0.1786793E 00

W GAS	NTU'S	EFFEC
0.1325534E 00	0.1386886E 01	0.8750155E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2539117E 02	0.5078235E 03	0.1829893E 02	0.3911785E 01	0.1127138E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.1181815E 02	0.1922508E 03	0.5115292E 01	0.1116745E 01	0.1136521E-01

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.1988286E 00	0.9636958E 00	0.1082925E 05	0.2450272E 01	0.9287544E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.6000000E 02	0.8500000E 02	0.1136521E-01	0.5115292E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.3213163E 06	0.7123344E 01	0.1181485E 01	0.3660459E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.3200000E 02	0.1507889E 01	0.1545271E 00

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.3200000E 02	0.6000000E 02	0.3323909E 02	0.2493274E 05	0.1000000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.1117023E 02	0.9823689E 00	0.3275827E 01	0.3817065E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 8.40HP AND 30.00MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.5917104E 00	0.9896967E 01	0.9567720E 00	0.5599999E 00	0.5174190E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1014194E 01	0.9936368E 00	0.9196197E 00	0.0	0.6137565E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.3929302E-02	0.2222188E 00	0.1958538E 00	0.4204039E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.13998E 02	0.59450E 03	0.20635E 03
COND IN	0.13994E 02	0.17801E 03	0.11611E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42542E 03	0.18384E 03	0.38118E 02
REGEN LIQ IN	0.42542E 03	0.18384E 03	0.38118E 02
REGEN LIQ OUT	0.42520E 03	0.44648E 03	0.14554E 03
ECON OUT	0.42520E 03	0.34095E 03	0.85183E 02
VAP IN	0.42520E 03	0.43868E 03	0.13589E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.4714212E 00	0.9269564E 01	0.1925288E 06	0.1709860E 06	0.1345757E 06

SYSTEM EFF	SFC
0.1192328E 00	0.1378173E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2915422E 02	0.3508259E 03	0.3911785E 01	0.3285900E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.8190719E 01	0.3508259E 03	0.4714212E 00	0.3959938E 00	0.3929302E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.2222188E 00	0.9685555E 00	0.8525371E 03	0.2306207E 01	0.1014194E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6472986E 03	0.4022410E 03	0.8257932E 02	0.6865111E 02	0.3911785E 01

W FUEL
0.8648700E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1471732E 03	0.9145564E 02	0.1813423E 02	0.9996952E 00	0.1542306E 02

NTU'S	EFFEC
0.7551759E 01	0.9936368E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 8.40HP AND 30.00MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2895798E 03	0.4848404E 02	0.6258859E 00	0.4963682E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.5328384E 02	0.1038422E 02	0.9987777E 00	0.8344947E 01	0.7542741E-01

W GAS	NTU'S	EFFEC
0.5320011E-01	0.1822939E 01	0.9196197E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2539117E 02	0.5078235E 03	0.1829893E 02	0.3911785E 01	0.1127138E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.6410998E 01	0.8155475E 02	0.1845710E 01	0.4714212E 00	0.1814287E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.4204039E-01	0.9798478E 00	0.5414918E 04	0.3395587E 01	0.9818875E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.3000000E 02	0.8500000E 02	0.1814287E-02	0.1845710E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.1345757E 06	0.7123344E 01	0.1181485E 01	0.3660459E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.8400000E 01	0.8611029E-01	0.8900743E-02

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.8400000E 01	0.3000000E 02	0.9016057E 01	0.1918851E 05	0.1520000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.1117023E 02	0.9506847E 00	0.2864853E 01	0.1326671E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR ACl FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 9.92HP AND 25.10MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.6338688E 00	0.1172279E 02	0.9094335E 00	0.5599999E 00	0.5301310E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1013564E 01	0.9923355E 00	0.9096826E 00	0.2486167E-02	0.9162948E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.5101260E-02	0.2884980E 00	0.2542694E 00	0.5457940E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.14012E 02	0.58806E 03	0.20473E 03
COND IN	0.14007E 02	0.17836E 03	0.11617E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42554E 03	0.18384E 03	0.38119E 02
REGEN LIQ IN	0.42554E 03	0.18384E 03	0.38119E 02
REGEN LIQ OUT	0.42525E 03	0.45021E 03	0.14355E 03
ECON OUT	0.42525E 03	0.33744E 03	0.84023E 02
VAP IN	0.42525E 03	0.43611E 03	0.13403E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.5451623E 00	0.1093783E 02	0.2271788E 06	0.2010198E 06	0.1557464E 06

SYSTEM EFF	SFC
0.1206883E 00	0.1361553E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2915422E 02	0.3508259E 03	0.3911785E 01	0.3285900E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.8937008E 01	0.3508259E 03	0.5451623E 00	0.4579363E 00	0.5101260E-02

DP LIQ	ETAQ VAP	U O	NTU'S	EFFEC
0.2884980E 00	0.9658191E 00	0.9094897E 03	0.2127481E 01	0.1013564E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6472986E 03	0.4022410E 03	0.8257932E 02	0.6865111E 02	0.3911785E 01

W FUEL
0.8648700E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1629336E 03	0.1012493E 03	0.2032224E 02	0.9996586E 00	0.1724289E 02

NTU'S	EFFEC
0.7157937E 01	0.9923355E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 9.92HP AND 25.10MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2895798E 03	0.4848404E 02	0.6258859E 00	0.4963682E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.5985347E 02	0.1164034E 02	0.9986320E 00	0.9355889E 01	0.8722603E-01

W GAS	NTU'S	EFFEC
0.6277466F-01	0.1732056E 01	0.9096826E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2539117E 02	0.5078235E 03	0.1829893E 02	0.3911785E 01	0.1127138E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.6903422E 01	0.9106613E 02	0.2087987E 01	0.5451623E 00	0.2265280E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.5457940E-01	0.9783459E 00	0.5910723E 04	0.3276417E 01	0.9818875E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.2486167E-02	0.2509999E 02	0.8500000E 02	0.2265280E-02	0.2087987E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.1557464F 06	0.7123344E 01	0.1181485E 01	0.3660459E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.9919999E 01	0.2508154E-01	0.1257206E-01

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.9919999E 01	0.2509999E 02	0.1076856E 02	0.2635800E 05	0.2520000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.1117023E 02	0.9399999F 00	0.3377798E 01	0.1571420E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 1.14HP AND 1.74MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.2838672E 00	0.4906994E 01	0.9952421E 00	0.5599999E 00	0.2318258E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1013775E 01	0.9943973E 00	0.9392807E 00	0.2547529E-01	0.4596610E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.4712835E-02	0.2665310E 00	0.2349086E 00	0.5042357E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.14008E 02	0.64110E 03	0.21819E 03
COND IN	0.14003E 02	0.17754E 03	0.11603E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42550E 03	0.18384E 03	0.38118E 02
REGEN LIQ IN	0.42550E 03	0.18384E 03	0.38118E 02
REGEN LIQ OUT	0.42523E 03	0.47603E 03	0.15974E 03
ECON OUT	0.42523E 03	0.32993E 03	0.81569E 02
VAP IN	0.42523E 03	0.44694E 03	0.14724E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.5217814E 00	0.9029198E 01	0.1875364E 06	0.1688474E 06	0.1487943E 06

SYSTEM EFF	SFC
0.4730715E-01	0.3473546E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2915422E 02	0.3508259E 03	0.3911785E 01	0.3285900E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.8705016E 01	0.3508259E 03	0.5217814E 00	0.4382963E 00	0.4712835E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.2665310E 00	0.9666674E 00	0.8920586E 03	0.2180212E 01	0.1013775E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6472986E 03	0.4022410E 03	0.8257932E 02	0.6865111E 02	0.3911785E 01

W FUEL
0.8648700E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1580200E 03	0.9818973E 02	0.1778329E 02	0.9997012E 00	0.1531771E 02

NTU'S	EFFEC
0.7715630E 01	0.9943973E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 1.14HP AND 1.74MPH
ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2895798E 03	0.4848404E 02	0.6258859E 00	0.4963682E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.5779094E 02	0.1019767E 02	0.9987993E 00	0.8348767E 01	0.8348507E-01

W GAS	NTU'S	EFFEC
0.5182059E-01	0.1872325E 01	0.9392807E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2539117E 02	0.5078235E 03	0.1829893E 02	0.3911785E 01	0.1127138E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.6512876E 01	0.8360788E 02	0.1894853E 01	0.5217814E 00	0.1902160E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.5042357E-01	0.9795367E 00	0.5520156E 04	0.3371803E 01	0.9818875E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.2547529E-01	0.1740000E 01	0.8500000E 02	0.1902160E-02	0.1894853E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.1487943E 06	0.7123344E 01	0.1181485E 01	0.3660459E 00	0.1040000E 03

APWR(I)	RAMHP	COND AIR POWR
0.1143000E 01	0.0	0.9580307E-02

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.1143000E 01	0.1740000E 01	0.3484475E 01	0.6785992E 04	0.1849999E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.1117023E 02	0.3347206E 00	0.1977507E 01	0.6577740E 01

DESIGN AND PART LOAD PERFORMANCE

SFCO	ECYCL(1)	ECYCL(2)	ECYCL(3)	ECYCL(4)
0.9614801E 00	0.9314293E 00	0.1378173E 01	0.1361553E 01	0.3473546E 01

WEIGHT SUMMARY

TOTAL SYS WT	FAN WT	REGEN WT	CONDENSER WT	FUEL WT
0.1570827E 04	0.3254471E 02	0.1954479E 03	0.1404231E 03	0.9150642E 02

ECON HOUS WT	TR-GR BOX WT	ECON WT	VAPORIZER WT	BRN FAN MT WT
0.6626634E 02	0.1456231E 03	0.7978188E 02	0.2044871E 03	0.1698999E 02

BURNER WT	TRANS WT	DRIVE TRN WT	ST MT PMP WT	PVD WT
0.1275725E 02	0.1550000E 03	0.2000000E 03	0.2000000E 02	0.6000000E 02

BATT WT	ST ACCUM WT	CONTROLS WT	EXH PIPE WT	ELEC GEN WT
0.4000000E 02	0.1000000E 02	0.3000000E 02	0.5500000E 02	0.1500000E 02

VOLUME SUMMARY

CRU	REGENERATOR	CONDENSER	HOTWELL	COND FAN
0.2310041E 00	0.4129375E 01	0.3080688E 01	0.1271900E 01	0.3195999E 01

VAP/ECON	BURNER	TRANSMISSION	TOT(.6 PACK DENS)
0.8681779E 01	0.8981670E 00	0.1500000E 01	0.3831483E 02

```
DES PT MPG      OFF 1 MPG       OFF 2 MPG       OFF 3 MPG       IDLE PT MPG
0.4937159E 01   0.1584687E 02   0.1974203E 02   0.1399821E 02   0.1175519E 01

OVER ALL MPG
0.1333240E 02

*****PAOFF=   0.1123549E 01*****
```

APPENDIX C

OPTIMIZATION - TURBINE: 0.97 WEIGHTING FACTOR

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

INPUT

CYCLE CONDITIONS

ALT PWR FACT	ELEC COND EFF	NET POWER	PARA POWER	CNDSR SUBCOOL
0.7500000E 00	0.1000000E 01	0.1000000E 01	0.3000000E 00	0.0

PUMP FR	AMB AIR TEMP	GAS LHV	FUEL HHV	CRIT PRESS
0.1500000E 01	0.8500000E 02	0.1926500E 05	0.2077000E 05	0.4010000E 03

DES POWER	DES SPEED	OFF POWER 1	OFF SPEED 1	OFF POWER 2	OFF SPEED 2
0.1080000E 03	0.7000000E 02	0.3200000E 02	0.6000000E 02	0.8400000E 01	0.3000000E 02

OFF POWER 3	OFF SPEED 3	IDLE POWER	IDLE SPEED
0.9919999F 01	0.2509999E 02	0.1143000E 01	0.1740000E 01

PCI TIME DES	PCI TIME OFF1	PCI TIME OFF2	PCI TIME OFF3	PCI TIME IDLE	MAX ENG WT	CPAOF
0.5000000E 00	0.1650000E 02	0.3300000E 02	0.2800000E 02	0.2200000E 02	0.1400000E 04	0.9700000E 00

BASE MPG	FUEL LB/GAL
0.1500000F 02	0.6099999E 01

TURBINE

T REF(VISC)	VISC EXP	BLD DENS RTO	CHORD	NO BLADES
0.1172000E 04	0.1000000E 01	0.5500000E 00	0.1000000E 01	0.1000000E 01

NOZ EDG THICK	ROT EDG THICK	ZNY	ZN4Y	BLD/NOZ RTO
0.9999998E-02	0.9999998E-02	0.1000000E 01	0.1000000E 01	0.1000000E 01

AX CLEAR	TIP CLEAR
0.1500000E-01	0.1500000E-01

NOZ VEL COEF			
0.9600000E 00	0.0	0.0	0.0

NOZ FLOW COEF			
0.9600000E 00	0.0	0.0	0.0

EXH HEAD LOSS FACT			
0.1000000E 01	0.0	0.0	0.0

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR ACI FLUOROBENZINE MIXTURE FLS 2/12/73

INPUT

REGENERATOR

TUBE FIN DESIGN

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.9130000E 00	0.0	0.8419998E-02	0.1920000E-01	0.2510000E 00
FIN LENG LIQ	**FIN THICK VAP**	**FIN THICK LIQ**	**WALL THICK**	**WALL T CON**
0.0	0.5999997E-02	0.0	0.2000000E-01	0.1650000E 02
FIN T CON VAP	**FIN T CON LIQ**	**BETA VAP**	**BETA LIQ**	**PLT SPACE VAP**
0.1330000E 03	0.1650000E 02	0.0	0.0	0.0
PLT SPACE LIQ	**SIGMA VAP**	**SIGMA LIQ**	**ALPHA VAP**	**FIN/IN VAP**
0.0	0.5599999E 00	0.1110000E 01	0.2690000E 03	0.1200000E 02
FIN/IN LIQ	**HEADER THICK**	**RHO FIN VAP**	**RHO FIN LIQ**	**RHO PLATE**
0.0	0.6250000E-01	0.9789997E-01	0.3230000E 00	0.3230000E 00
RHO HEADER	**NO PASS LIQ**	**DPTES**	**COND CODE**	
0.2830000E 00	0.8000000E 01	0.0	0.0	

CONDENSER

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.8760000E 00	0.4960000E 00	0.6549999E-02	0.8339997E-02	0.1630000E 00
FIN LENG LIQ	**FIN THICK VAP**	**FIN THICK LIQ**	**WALL THICK**	**WALL T CON**
0.2500000E-01	0.3999997E-02	0.3999997E-02	0.2000000E-01	0.1000000E 03
FIN T CON VAP	**FIN T CON LIQ**	**BETA VAP**	**BETA LIQ**	**PLT SPACE VAP**
0.1000000E 03	0.1000000E 03	0.5560000E 03	0.8950000E 03	0.3260000E 00
PLT SPACE LIQ	**SIGMA VAP**	**SIGMA LIQ**	**ALPHA VAP**	**FIN/IN VAP**
0.5000000E-01	0.7770000E 00	0.1111000E 00	0.4700000E 03	0.2200000E 02
FIN/IN LIQ	**HEADER THICK**	**RHO FIN VAP**	**RHO FIN LIQ**	**RHO PLATE**
0.2000000E 02	0.6250000E-01	0.9799999E-01	0.9799999E-01	0.9799999E-01
RHO HEADER	**NO PASS LIQ**	**DPTES**	**COND CODE**	
0.9799999E-01	0.1000000E 01	0.0	0.1000000E 01	

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

INPUT

VAPORIZER

AVG DIA(FT)	NO STARTS	DIA BB INSIDE	DIA BB O'SIDE	DIA RTO
0.1500000E 01	0.1000000E 01	0.1000000E 01	0.1760000E 00	0.1099999E 01
POROSITY	K TUBE WALL	EXCESS AIR	H2/C RTO	LHV GAS
0.4500000E 00	0.2000000E 02	0.3000000E 00	0.1875000E 00	0.1926500E 05
GAS TEMP IN	CP GAS COLD	CP GAS HOT	FLAME TEMP	VISC GAS
0.3000000E 04	0.2800000E 00	0.3329999E 00	0.3300000E 04	0.1100000E 00
K GAS				
0.4500000E-01				

BLOCK DATA

(1)	(2)	(3)	(4)	(5)
0.1785031E 03	0.1271123E-01	0.2360000E-01	0.1360000E 00	0.2080000E-01
(6)	(7)	(8)	(9)	(10)
0.9500000E 00	0.8000000E 00	0.9500000E 00	0.8119854E 00	0.2500000E 01
(11)	(12)	(13)	(14)	(15)
0.4934037E 01	0.6772681E 03	0.6004147E 01	0.1000000E 01	0.8400000E 00
(16)	(17)			
0.8936213E 00	0.4250000E 03			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.7756125E 00	0.1075478E 03	0.9898624E 00	0.7000000E 00	0.7130285E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.9500000E 00	0.9500000E 00	0.8000000E 00	0.1106589E 02	0.2500000E 01

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.1773517E 00	0.1003000E 02	0.8839999E 01	0.1897522E 01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.16027E 02	0.57080E 03	0.20040E 03
COND IN	0.15850E 02	0.20342E 03	0.12061E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.44387E 03	0.18408E 03	0.38177E 02
REGEN LIQ IN	0.44387E 03	0.18408E 03	0.38177E 02
REGEN LIQ OUT	0.43384E 03	0.41487E 03	0.13316E 03
ECON OUT	0.43384E 03	0.41487E 03	0.11217E 03
VAP IN	0.43384E 03	0.41369E 03	0.12980E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.3863138E 01	0.8379115E 02	0.1740342E 07	0.1545710E 07	0.1165427E 07

SYSTEM EFF	SFC
0.1764055E 00	0.9315103E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

TURBINE

T REF(VISC)	VISC EXP	BLD DENS RTO	CHORD	NO BLADES
0.1172000E 04	0.1000000E 01	0.5500000E 00	0.3000691F 00	0.9800000E 02
NOZ EDG THICK	ROT EDG THICK	ZNY	ZN4Y	BLD/NOZ RTO
0.9999998F-02	0.9999998E-02	0.1000000E 01	0.1000000E 01	0.1000000E 01
AX CLEAR	TIP CLEAR			
0.1500000F-01	0.1500000E-01			
NOZ VEL COFF				
0.9600000E 00	0.0	0.0	0.0	
NOZ FLOW COEF				
0.9600000E 00	0.0	0.0	0.0	
EXH HEAD LOSS FACT				
0.1000000F 01	0.0	0.0	0.0	
PRES RATIO				
0.2651735E 02				
P IN	T IN	REF VISC	RPM	PITCH DIA
0.4250000F 03	0.1172000E 04	0.4590000E-01	0.2585188F 05	0.6004147E 01
NOZ ANGLE	BLADE HT	BLADE ANGLES	ARC/T.CIRCUM	NOZ AREA RTO
0.1500000F 02	0.2565450E 00	0.3003462E 02	0.1000000E 01	0.4977407E 01
NOZ AREA	SPEC SPEED	SPEC DIA	WHEEL WT	TB EFF
0.1957556F 00	0.3324710E 02	0.2292645E 01	0.2807349E 01	0.7756125E 00

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.1080000E 03	0.7000000E 02	0.1205790E 03	0.2585188E 05	0.1000000E 01
TURB GEAR BOX RATIO		TRANS EFF	ACCESSORY KW	ENG HP TOT
0.9231607F 01		0.9139573E 00	0.3730000E 01	0.1441659E 03

COMBINED ROTATING UNIT

DIFF HOUS WT	NOZ HOUS WT	GEN HOUS WT	TURB WT	PUMP HOUS WT
0.5080252F 02	0.2946433E 01	0.8999998E 02	0.2807349E 01	0.1887559E 01
ADD WT	TOT CRU WT			
0.2968875F 02	0.1781326E 03			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

REGENERATOR

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.9130000E 00	0.0	0.8419998E-02	0.1920000E-01	0.2510000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.0	0.5999997E-02	0.0	0.2000000E-01	0.1650000E 02
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1330000E 03	0.1650000E 02	0.0	0.0	0.0
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.0	0.5599999E 00	0.1110000E 01	0.2690000E 03	0.1200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.0	0.6250000E-01	0.9789997E-01	0.3230000E 00	0.3230000E 00
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.2830000E 00	0.8000000E 01	0.0	0.0	
T IN VAP	T OUT VAP	T IN LIQ	T OUT LIQ	
0.5707981E 03	0.2034167E 03	0.1840807E 03	0.4148665E 03	
FLOW VAP	FLOW LIQ	DP VAP	DP LIQ	CP VAP
0.3863138E 01	0.3245037E 01	0.1773517E 00	0.1003000E 02	0.2171774E 00
CP LIQ	VISC VAP	VISC LIQ	PR VAP	PR LIQ
0.4115698E 00	0.9495397E-05	0.1772690E-03	0.7805553E 00	0.6576509E 01
RHO IN VAP	RHO OUT VAP	RHO IN LIQ	RHO OUT LIQ	H T COEF VAP
0.4779733E 00	0.7807283E 00	0.8100099E 02	0.6141315E 02	0.2769829E 02
H T COEF LIQ	MASS VEL VAP	MASS VEL LIQ	ETAO VAP	ETAO LIQ
0.3294277E 03	0.5405981E 01	0.3149377E 03	0.9031749E 00	0.1000000E 01
RE VAP	RE LIQ	NO TUBES	COM LENG(FT)	LIQ LENG(FT)
0.4793727E 04	0.3411089E 05	0.3600000E 02	0.1864240E 00	0.6769550E 01
VAP LENG/PASS	VAP LENG(FT)	VOL/PASS	TOT VOL(CUFT)	TOT INV(VAP)
0.4962286E 00	0.3970156E 01	0.6262953E 00	0.5010363E 01	0.2663960E 01
HEADER INVENT	TOT INV(LIQ)	FIN STRES VAP	FIN STRES LIQ	PLATE STRES
0.1528668E 01	0.5475232E 02	0.0	0.2435994E 04	0.0
DRY WT	TOT WT	EFFEC		
0.1765029E 03	0.2339192E 03	0.9500000E 00		

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

CONDENSER

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.8760000E 00	0.4960000E 00	0.6549999E-02	0.8339997E-02	0.1630000E 00
FIN LENG LIQ	**FIN THICK VAP**	**FIN THICK LIQ**	**WALL THICK**	**WALL T CON**
0.2500000E-01	0.3999997E-02	0.3999997E-02	0.2000000E-01	0.1000000E 03
FIN T CON VAP	**FIN T CON LIQ**	**BETA VAP**	**BETA LIQ**	**PLT SPACE VAP**
0.1000000E 03	0.1000000E 03	0.5560000E 03	0.8950000E 03	0.3260000E 00
PLT SPACE LIQ	**SIGMA VAP**	**SIGMA LIQ**	**ALPHA VAP**	**FIN/IN VAP**
0.5000000E-01	0.7134771E 00	0.2242877E 00	0.4700000E 03	0.2200000E 02
FIN/IN LIQ	**HEADER THICK**	**RHO FIN VAP**	**RHO FIN LIQ**	**RHO PLATE**
0.2000000E 02	0.6250000E-01	0.9799999E-01	0.9799999E-01	0.9799999E-01
RHO HEADER	**NO PASS LIQ**	**DPTFS**	**COND CODE**	
0.9799999E-01	0.1000000E 01	0.0	0.1000000E 01	
RHO COND	**PR COND**			
0.8333339E 02	0.5709348E 01			
T IN VAP	**T OUT VAP**	**T IN LIQ**	**T OUT LIQ**	
0.8500000E 02	0.1609231E 03	0.2034167E 03	0.1785031E 03	
FLOW VAP	**FLOW LIQ**	**DP VAP**	**DP LIQ**	**CP VAP**
0.1776630E 02	0.3863138E 01	0.1044837E 00	0.1897522E 01	0.2399999E 00
CP LIQ	**VISC VAP**	**VISC LIQ**	**PR VAP**	**PR LIQ**
0.1786224E 00	0.1320000E-04	0.7288324E-05	0.7200000E 00	0.1000000E 01
RHO IN VAP	**RHO OUT VAP**	**RHO IN LIQ**	**RHO OUT LIQ**	**H T COEF VAP**
0.7287151E-01	0.6396121E-01	0.3692152E 00	0.3692152E 00	0.2478583E 02
H T COEF LIQ	**MASS VEL VAP**	**MASS VEL LIQ**	**ETAO VAP**	**ETAO LIQ**
0.4957166E 03	0.2934219E 01	0.6676015E 01	0.9277931E 00	0.9797040E 00
RE VAP	**RE LIQ**	**NO TUBES**	**COM LENG(FT)**	**LIQ LENG(FT)**
0.1455995E 04	0.7639332E 04	0.0	0.7156988E 01	0.1185752E 01
VAP LENG/PASS	**VAP LENG(FT)**	**VOL/PASS**	**TOT VOL(CUFT)**	**TOT INV(VAP)**
0.3604850E 00	0.3604888E 00	0.3059257E 01	0.3059257E 01	0.1348959E 00
HEADER INVENT	**TOT INV(LIQ)**	**FIN STRES VAP**	**FIN STRES LIQ**	**PLATE STRES**
0.5464660E 01	0.3841109E 00	-0.1729222E 02	-0.2642247E 02	-0.1398084E 02
DRY WT	**TOT WT**	**EFFEC**		
0.1388801E 03	0.1393990E 03	0.8119854E 00		

NOTE- VAP AND LIQ REFER TO AIR AND WORKING FLUID SIDES RESPECTIVELY

HEAT REJECTION FAN AND MOTOR

FAN PWR(KW)	W AIR	DP AIR	FAN RPM	FAN DIA
0.1106589E 02	0.1776630E 02	0.1044837E 00	0.1210483E 04	0.3495773E 02
FAN+MOTOR WT				
0.3276794E 02				
COND FAN PWR	**CAR MPH**	**AMB AIR TEMP**	**AIR PRES DROP**	**COND AIR FLOW**
0.1106589E 02	0.7000000E 02	0.8500000E 02	0.1044837E 00	0.1776630E 02
QREJ	**CCA**	**CZL**	**CCTOT**	**APWRD**
0.1165427E 07	0.7156988E 01	0.1185752E 01	0.3604888E 00	0.1080000E 03
RAMHP	**COND AIR POWER**			

0.3681794E 01 0.4934037E 01

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

VAPORIZER

AVG DIA(FT)	NO STARTS	DIA BB INSIDE	DIA BB O'SIDE	DIA RTO
0.9911393E 00	0.1000000E 01	0.1000000E 01	0.1760000E 00	0.1099999E 01
POROSITY	K TUBE WALL	EXCESS AIR	H2/C RTO	LHV GAS
0.4500000E 00	0.2000000E 02	0.3000000E 00	0.1875000E 00	0.1926500E 05
GAS TEMP IN	CP GAS COLD	CP GAS HOT	FLAME TEMP	VISC GAS
0.3000000E 04	0.2800000E 00	0.3329999E 00	0.3300000E 04	0.1099997E 00
K GAS				
0.4500000E-01				
W ORG	W GAS	T ORG IN	T ORG OUT	CP ORG IN
0.3863138E 01	0.4808961E 00	0.4136858E 03	0.7123101E 03	-0.3196478E 01
CP ORG OUT	MU ORG IN	MU ORG OUT	K ORG IN	K ORG OUT
0.2826294E 00	0.1330712E-03	0.2146040E-06	0.3171459E-01	0.1585057E-01
RHO ORG	RHO GAS	DP ORG	DP GAS	EFFEC
0.3483284E 02	0.1642740E-01	0.8839999E 01	0.6424286E 00	0.9500000E 00
T FLUE GAS	H ORG IN	H ORG OUT	RE GAS	F GAS
0.5580017E 03	0.6956851E 03	0.4281194E 03	0.1888180E 05	0.5001183E 00
H GAS	UO	H FLUX	NTU	ML
0.8782756E 02	0.7306407E 02	0.5213083E 05	0.3748218E 01	0.6193722E-01
WCH	TUBE I/D	TUBE O/D	TUBE LENG	NO TUBES
0.1601383E 00	0.1180423E 00	0.1298464E 00	0.7143896E 02	0.2294301E 02
FIN HT	VAP HT	VAP VOL	INVENT	TOT WT
0.1244548E-02	0.3036174E 01	0.2996511E 01	0.2723259E 02	0.1826055E 03

ECONOMISER

DIA BB O'SIDE	K TUBE WALL	PASSES	POROSITY	DIA RTO
0.1760000E 00	0.2000000E 02	0.3000000E 01	0.4500000E 00	0.1099999E 01
CP GAS	VISC GAS	K GAS		
0.2800000E 00	0.1099997E 00	0.4500000E-01		
W GAS	W ORG	RHO ORG	RHO GAS	CP ORG
0.4808961E 00	0.6181030E 00	0.4032671E 02	0.1642740E-01	0.3205931E 00
MU ORG	K ORG	DP ORG	DP GAS	ECON DIA
0.1327478E-03	0.3162959E-01	0.1003000E 02	0.7647622E-01	0.1250832E 01
H ORG	ZML	F GAS	TUBE I/D	TUBE O/D
0.2775422E 03	0.4192212E 00	0.5067043E 00	0.6054717E 00	0.6660185E 00
FIN HT	ECON HT	ML	F GAS	TUBE LENG
0.1534345E 00	0.4581649E 00	0.4192212E 00	0.5067043E 00	0.6662091E 02
INVENT	ECON WT			
0.1611534E 02	0.9432532E 02			

BURNER FAN AND MOTOR

FAN PWR(KW)	W AIR	DP AIR	FAN RPM	FAN DIA
0.2500000E 01	0.4576208E 00	0.7189049E 00	0.4054183E 04	0.1100000E 02
FAN+MOTOR WT				
0.1698999E 02				

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OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR ACl FLUOROBENZINE MIXTURE  FLS 2/12/73
OUTPUT
HOTWELL
 CAPACITYCU FT
 0.1417641E 01
BLOCK DATA
 (1)             (2)             (3)             (4)             (5)
 0.1785031E 03   0.1271123E-01   0.2360000E-01   0.1360000E 00   0.2080000E-01

 (6)             (7)             (8)             (9)             (10)
 0.9500000E 00   0.8000000E 00   0.9500000E 00   0.8119854E 00   0.2500000E 01

 (11)            (12)            (13)            (14)            (15)
 0.4934037E 01   0.6772681E 03   0.6004147E 01   0.1000000E 01   0.8400000E 00

 (16)            (17)
 0.8936213E 00   0.4250000E 03
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OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 32.00HP AND 60.00MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.7056679E 00	0.2847987E 02	0.9809446E 00	0.5599999E 00	0.6419105E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1010304E 01	0.9839734E 00	0.8716984E 00	0.0	0.1077189E 00

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.1841984E-01	0.1041719E 01	0.9181262E 00	0.1970775E 00	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.14168E 02	0.57734E 03	0.20206E 03
COND IN	0.14149E 02	0.17980E 03	0.11642E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42696E 03	0.18386E 03	0.38123E 02
REGEN LIQ IN	0.42696E 03	0.18386E 03	0.38123E 02
REGEN LIQ OUT	0.42592E 03	0.44401E 03	0.14008E 03
ECON OUT	0.42592E 03	0.35315E 03	0.89266E 02
VAP IN	0.42592E 03	0.43158E 03	0.13195E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.1097411E 01	0.2264922E 02	0.4704242E 06	0.4161815E 06	0.3145087E 06

SYSTEM EFF	SFC
0.1799013E 00	0.9134090E 00

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2769829E 02	0.3294277E 03	0.3863138E 01	0.3245037E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.1301699E 02	0.3294277E 03	0.1097411E 01	0.9218253E 00	0.1841984E-01

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.1041719E 01	0.9512138E 00	0.1397801E 04	0.1629141E 01	0.1010304E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6956851E 03	0.4281194E 03	0.8782756E 02	0.7306407E 02	0.3863138E 01

W FUEL
0.8379115E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.2882791E 03	0.1774048E 03	0.3630408E 02	0.9994717E 00	0.3062459E 02

NTU'S	EFFEC
0.5652532E 01	0.9839734E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 32.00HP AND 60.00MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2775422E 03	0.3941615E 02	0.6181030E 00	0.4808961E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.1014080E 03	0.1598285E 02	0.9969417E 00	0.1326474E 02	0.1755859E 00

W GAS	NTU'S	EFFEC
0.1299888E 00	0.1355454E 01	0.8716984E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2478583E 02	0.4957166E 03	0.1776630E 02	0.3863138E 01	0.1044837E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.1163752E 02	0.1877066E 03	0.5039165E 01	0.1097411E 01	0.1081485E-01

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.1970775E 00	0.9642236E 00	0.1056232E 05	0.2425979E 01	0.9265478E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.6000000E 02	0.8500000E 02	0.1081485E-01	0.5039165E 01

QREJ	CCA	CZL	CCIOT	APWRD
0.3145087E 06	0.7156988E 01	0.1185752E 01	0.3604888E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.3200000E 02	0.1527811E 01	0.1448559E 00

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.3200000E 02	0.6000000E 02	0.3323909E 02	0.2060560E 05	0.1000000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.9231607E 01	0.9823689E 00	0.3275828E 01	0.3817677E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 8.40HP AND 30.00MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.5986517E 00	0.9899955E 01	0.9750747E 00	0.5599999E 00	0.5340891E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1015131E 01	0.9936640E 00	0.9168378E 00	0.0	0.9125624E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.3797905E-02	0.2147877E 00	0.1893045E 00	0.4063455E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.13997E 02	0.59343E 03	0.20608E 03
COND IN	0.13993E 02	0.17764E 03	0.11604E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42540E 03	0.18384E 03	0.38118E 02
REGEN LIQ IN	0.42540E 03	0.18384E 03	0.38118E 02
REGEN LIQ OUT	0.42519E 03	0.44673E 03	0.14530E 03
ECON OUT	0.42519E 03	0.34030E 03	0.84968E 02
VAP IN	0.42519E 03	0.43838E 03	0.13565E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.4568315E 00	0.9004318E 01	0.1870197E 06	0.1660268E 06	0.1303030E 06

SYSTEM EFF	SFC
0.1227452E 00	0.1338737E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2769829E 02	0.3294277E 03	0.3863138E 01	0.3245037E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.7693833E 01	0.3294277E 03	0.4568315E 00	0.3837385E 00	0.3797905E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.2147877E 00	0.9703889E 00	0.9698821E 03	0.2715477E 01	0.1015131E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6956851E 03	0.4281194E 03	0.8782756E 02	0.7306407E 02	0.3863138E 01

W FUEL
0.8379115E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1560932E 03	0.9605856E 02	0.1930565E 02	0.9997189E 00	0.1640236E 02

NTU'S	EFFEC
0.7560897E 01	0.9936640E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 8.40HP AND 30.00MPH
ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2775422E 03	0.3941615E 02	0.6181030E 00	0.4808961E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.5030154E 02	0.8457438E 01	0.9983603E 00	0.6955794E 01	0.7309306E-01

W GAS	NTU'S	EFFEC
0.5167780E-01	0.1787866E 01	0.9168378E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2478583E 02	0.4957166E 03	0.1776630E 02	0.3863138E 01	0.1044837E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.6791672E 01	0.8820074E 02	0.2053769E 01	0.4568315E 00	0.2149651E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.4063455E-01	0.9786863E 00	0.5739977E 04	0.3234781E 01	0.9759165E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.3000000E 02	0.8500000E 02	0.2149651E-02	0.2053769E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.1303030E 06	0.7156988E 01	0.1185752E 01	0.3604888E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.8400000E 01	0.8724970E-01	0.1173482E-01

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.8400000E 01	0.3000000E 02	0.9016057E 01	0.1585829E 05	0.1520000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.9231607E 01	0.9506847E 00	0.2864853E 01	0.1327072E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 9.92HP AND 25.10MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.6464850E 00	0.1171975E 02	0.9472042E 00	0.5599999E 00	0.5641096E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1014900E 01	0.9925800E 00	0.9077192E 00	0.0	0.8602183E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.4663423E-02	0.2637365E 00	0.2324457E 00	0.4989490E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.14007E 02	0.58610E 03	0.20425E 03
COND IN	0.14002E 02	0.17785E 03	0.11608E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42550E 03	0.18384E 03	0.38118E 02
REGEN LIQ IN	0.42550E 03	0.18384E 03	0.38118E 02
REGEN LIQ OUT	0.42523E 03	0.44954E 03	0.14308E 03
ECON OUT	0.42523E 03	0.33778E 03	0.84137E 02
VAP IN	0.42523E 03	0.43576E 03	0.13365E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.5121357E 00	0.1031251E 02	0.2141908E 06	0.1895739E 06	0.1461436E 06

SYSTEM EFF	SFC
0.1280065E 00	0.1283711E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2769829E 02	0.3294277E 03	0.3863138E 01	0.3245037E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.8239869E 01	0.3294277E 03	0.5121357E 00	0.4301940E 00	0.4663423E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.2637365E 00	0.9683746E 00	0.1020499E 04	0.2548652E 01	0.1014900E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6956851E 03	0.4281194E 03	0.8782756E 02	0.7306407E 02	0.3863138E 01

W FUEL
0.8379115E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1690926E 03	0.1040583E 03	0.2119743E 02	0.9996914E 00	0.1796515E 02

NTU'S	EFFEC
0.7232004E 01	0.9925800E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 9.92HP AND 25.10MPH
ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2775422E 03	0.3941615E 02	0.6181030E 00	0.4808961E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.5511693E 02	0.9287289E 01	0.9982020E 00	0.7633731E 01	0.8194178E-01

W GAS	NTU'S	EFFEC
0.5918579E-01	0.1713215E 01	0.9077192E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2478583E 02	0.4957166E 03	0.1776630E 02	0.3863138E 01	0.1044837E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.6646503E 01	0.8538010E 02	0.1981127E 01	0.5121357E 00	0.2014732E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.4989490E-01	0.9791288E 00	0.5594328E 04	0.3268301E 01	0.9759165E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.2509999E 02	0.8500000E 02	0.2014732E-02	0.1981127E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.1461436E 06	0.7156988E 01	0.1185752E 01	0.3604888E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.9919999E 01	0.2541313E-01	0.1060928E-01

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.9919999E 01	0.2509999E 02	0.1076856E 02	0.2178350E 05	0.2520000E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.9231607E 01	0.9399999E 00	0.3377799E 01	0.1571012E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR ACl FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 1.14HP AND 1.74MPH

CYCLE CONDITIONS

TURB EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.2834604E 00	0.4907433E 01	0.9967456E 00	0.5599999E 00	0.2317674E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1014855E 01	0.9942877E 00	0.9362606E 00	0.2549907E-01	0.5010065E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.4823111E-02	0.2727675E 00	0.2404053E 00	0.5160344E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.42500E 03	0.71231E 03	0.22911E 03
REGEN VAP IN	0.14009E 02	0.64116E 03	0.21821E 03
COND IN	0.14004E 02	0.17705E 03	0.11594E 03
PUMP IN	0.13952E 02	0.17850E 03	0.36813E 02
ALT IN	0.42551E 03	0.18384E 03	0.38118E 02
REGEN LIQ IN	0.42551E 03	0.18384E 03	0.38118E 02
REGEN LIQ OUT	0.42524E 03	0.47631E 03	0.15987E 03
ECON OUT	0.42524E 03	0.33007E 03	0.81615E 02
VAP IN	0.42524E 03	0.44712E 03	0.14735E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.5219741E 00	0.9021797E 01	0.1873827E 06	0.1667143E 06	0.1486845E 06

SYSTEM EFF	SFC
0.4734595E-01	0.3470699E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2769829E 02	0.3294277E 03	0.3863138E 01	0.3245037E 01	0.1773517E 00

DP LIQ
0.1003000E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.8334478E 01	0.3294277E 03	0.5219741E 00	0.4384583E 00	0.4823111E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.2727675E 00	0.9680268E 00	0.1029089E 04	0.2521664E 01	0.1014855E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.6956851E 03	0.4281194E 03	0.8782756E 02	0.7306407E 02	0.3863138E 01

W FUEL
0.8379115E 02

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1713598E 03	0.1054535E 03	0.1930025E 02	0.9997190E 00	0.1661337E 02

NTU'S	EFFEC
0.7661262E 01	0.9942877E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC1 FLUOROBENZINE MIXTURE FLS 2/12/73

OUTPUT

SYSTEM CONDITIONS FOR 1.14HP AND 1.74MPH
ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.2775422E 03	0.3941615E 02	0.6181030E 00	0.4808961E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.5596231E 02	0.8468762E 01	0.9983581E 00	0.7089316E 01	0.8351588E-01

W GAS	NTU'S	EFFEC
0.5177812E-01	0.1818655E 01	0.9362606E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2478583E 02	0.4957166E 03	0.1776630E 02	0.3863138E 01	0.1044837E 00

DP LIQ
0.1897522E 01

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.6491867E 01	0.8256311E 02	0.1904904E 01	0.5219741E 00	0.1877356E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.5160344E-01	0.9796008E 00	0.5443719E 04	0.3307569E 01	0.9759165E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.2549907E-01	0.1740000E 01	0.8500000E 02	0.1877356E-02	0.1904904E 01

QREJ	CCA	CZL	CCTOT	APWRD
0.1486845E 06	0.7156988E 01	0.1185752E 01	0.3604888E 00	0.1040000E 03

APWR(I)	RAMHP	COND AIR POWR
0.1143000E 01	0.0	0.9505540E-02

TRANSMISSION AND TURBINE GEAR BOX

TRANS PWR OUT	CAR MPH	ENG HP OUT	TURB SPEED	GEAR RATIO
0.1143000E 01	0.1740000E 01	0.3484475E 01	0.5608266E 04	0.1849999E 01

TURB GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.9231607E 01	0.3347206E 00	0.1977508E 01	0.6578327E 01

DESIGN AND PART LOAD PERFORMANCE

SFCO	ECYCL(1)	ECYCL(2)	ECYCL(3)	ECYCL(4)
0.9315103E 00	0.9134090E 00	0.1338737E 01	0.1283711E 01	0.3470699E 01

WEIGHT SUMMARY

TOTAL SYS WT	FAN WT	REGEN WT	CONDENSER WT	FUEL WT
0.1625980E 04	0.3276794E 02	0.2339192E 03	0.1393990E 03	0.8831256E 02

ECON HOUS WT	TB-GR BOX WT	ECON WT	VAPORIZER WT	BRN FAN MT WT
0.6203831E 02	0.1781326E 03	0.9432532E 02	0.1826055E 03	0.1698999E 02

BURNER WT	TRANS WT	DRIVE TRN WT	ST MT PMP WT	PVD WT
0.1249076E 02	0.1550000E 03	0.2000000E 03	0.2000000E 02	0.6000000E 02

BATT WT	ST ACCUM WT	CONTROLS WT	EXH PIPE WT	ELEC GEN WT
0.4000000E 02	0.1000000E 02	0.3000000E 02	0.5500000E 02	0.1500000E 02

VOLUME SUMMARY

CRU	REGENERATOR	CONDENSER	HOTWELL	COND FAN
0.2809345E 00	0.5010363E 01	0.3059257E 01	0.1412641E 01	0.3236119E 01

VAP/ECON	BURNER	TRANSMISSION	TOT(.6 PACK DENS)
0.7962449E 01	0.8701710E 00	0.1500000E 01	0.3888654E 02

```
DES PT MPG      OFF 1 MPG      OFF 2 MPG      OFF 3 MPG      IDLE PT MPG
0.5096004E 01  0.1615950E 02  0.2032359E 02  0.1484702E 02  0.1176483E 01

OVER ALL MPG
0.1381457E 02

*****PAOFF=  0.1088078E 01*****
```

APPENDIX D

OPTIMIZATION - RECIPROCATOR: 0.5 WEIGHTING FACTOR

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

INPUT

CYCLE CONDITIONS

ALT PWR FACT	ELEC COND EFF	NET POWER	PARA POWER	CNDSR SUBCOOL		
0.7500000E 00	0.1000000E 01	0.1000000E 01	0.3000000E 00	0.0		
PUMP FR	AMB AIR TEMP	GAS LHV	FUEL HHV	CRIT PRESS		
0.1500000F 01	0.8500000E 02	0.1926500E 05	0.2077000E 05	0.1732000E 04		
DES POWER	DES SPEED	OFF POWER 1	OFF SPEED 1	OFF POWER 2	OFF SPEED 2	
0.1080000F 03	0.7000000E 02	0.3200000F 02	0.6000000E 02	0.8400000E 01	0.3000000E 02	
OFF POWER 3	OFF SPEED 3	IDLE POWER	IDLE SPEED			
0.9919999E 01	0.2509999E 02	0.1143000E 01	0.1740000E 01			
PCI TIME DES	PCI TIME OFF1	PCI TIME OFF2	PCI TIME OFF3	PCI TIME IDLE	MAX ENG WI	CPAOF
0.5000000F 00	0.1650000E 02	0.3300000E 02	0.2800000E 02	0.2200000E 02	0.1400000E 04	0.5000000E 00
BASE MPG	FUEL LB/GAL					
0.1500000E 02	0.6099999E 01					

RECIPROCATOR

BORE	STROKE	CRANK INT ANG	ENGINE RPM	NO OF CYLIN	
0.3000000E 01	0.3000000E 01	0.5400000E 02	0.1900000E 04	0.4000000E 01	
PCI CL LENG	PCI REL PORT	ROD/STROKE	VALV FLOW COEF		
0.3000000E-01	0.2000000E 00	0.2000000E 01	0.6000000E 00		

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

INPUT

REGENERATOR

TUBE FIN DESIGN

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.9130000E 00	0.0	0.8419998E-02	0.1920000E-01	0.2510000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.0	0.5999997E-02	0.0	0.2000000E-01	0.1650000E 02
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1330000E 03	0.1650000E 02	0.0	0.0	0.0
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.0	0.5599999E 00	0.1110000E 01	0.2690000E 03	0.1200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.0	0.6250000E-01	0.9789997E-01	0.3230000E 00	0.3230000E 00
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.2830000E 00	0.8000000E 01	0.0	0.0	

CONDENSER

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.8760000E 00	0.4960000E 00	0.6549999E-02	0.8339997E-02	0.1630000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.2500000E-01	0.3999997E-02	0.3999997E-02	0.2000000E-01	0.1000000E 03
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1000000E 03	0.1000000E 03	0.5560000E 03	0.8950000E 03	0.3260000E 00
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.5000000E-01	0.7770000E 00	0.1111000E 00	0.4700000E 03	0.2200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.2000000E 02	0.6250000E-01	0.9799999E-01	0.9799999E-01	0.9799999E-01
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.9799999E-01	0.1000000E 01	0.0	0.1000000E 01	

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

INPUT

VAPORIZER

AVG DIA(FT)	NO STARTS	DIA BB INSIDE	DIA BB O'SIDE	DIA RTO
0.1500000E 01	0.1000000E 01	0.1000000E 01	0.1760000E 00	0.1099999E 01
POROSITY	K TUBE WALL	EXCESS AIR	H2/C RTO	LHV GAS
0.4500000E 00	0.2000000E 02	0.3000000E 00	0.1875000E 00	0.1926500E 05
GAS TEMP IN	CP GAS COLD	CP GAS HOT	FLAME TEMP	VISC GAS
0.3000000E 04	0.2800000E 00	0.3329999E 00	0.3300000E 04	0.1100000E 00
K GAS				
0.4500000E-01				

BLOCK DATA

(1)	(2)	(3)	(4)	(5)
0.2420000E 03	0.1430000E-01	0.3440000E-01	0.2080000E-01	0.9999996E-01
(6)	(7)	(8)	(9)	(10)
0.8699999E 00	0.8000000E 00	0.9500000E 00	0.8000000E 00	0.2500000E 01
(11)	(12)	(13)	(14)	(15)
0.5000000E 01	0.1900000E 04	0.3000000E 01	0.5400000E 02	0.8400000E 00
(16)	(17)			
0.7259995E 00	0.7000000E 03			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

CYCLE CONDITIONS

EXPANDER EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.6455327E 00	0.1077667E 03	0.9574988E 00	0.7000000E 00	0.5797526E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.8699999E 00	0.9500000E 00	0.8000000E 00	0.9324546E 01	0.2500000E 01

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.3614014E 00	0.2407999E 02	0.6999997E 02	0.5256747E 00	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.70000E 03	0.71231E 03	0.69801E 03
REGEN VAP IN	0.26160E 02	0.47904E 03	0.60953E 03
COND IN	0.25798E 02	0.27515E 03	0.52458E 03
PUMP IN	0.25273E 02	0.24200E 03	0.16102E 03
ALT IN	0.79408E 03	0.24469E 03	0.16468E 03
REGEN LIQ IN	0.79408E 03	0.24469E 03	0.16468E 03
REGEN LIQ OUT	0.77000E 03	0.35615E 03	0.26581E 03
ECON OUT	0.77000E 03	0.45580E 03	0.37262E 03
VAP IN	0.77000E 03	0.37349E 03	0.28290E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.1285718E 01	0.1150284E 03	0.2389138E 07	0.2075343E 07	0.1682762E 07

SYSTEM EFF	SFC
0.1313010E 00	0.1251502E 01

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

RECIPROCATOR

INLET PRESS	INLET TEMP	EXHAUST PRES	ENGINE HP	CRANK INT ANG
0.7000000E 03	0.7123101E 03	0.2615988E 02	0.1508900E 03	0.5400000E 02
BORE DIA	STROKE	ENGINE RPM	NO OF CYLIND	CLEAR LENGTH
0.3061781E 01	0.3000000E 01	0.1900000E 04	0.4000000E 01	0.7499997E-02
EXP LENGTH	ROD LENGTH	PISTON AREA	INT VALV AREA	EXH VALV AREA
0.2075000E 00	0.5000000E 00	0.5110401E-01	0.1022080E-01	0.1022080E-01
VALV LENGTH	AVG PIST SPD	EXPAN RATIO	MEAN EFF PRES	EXP EFF HM
0.6180471E-01	0.9500000E 03	0.2994024E 01	0.4648665E 03	0.6180968E 00

RECIPROCATOR DIAGNOSTIC

FLOWV	SIIN	HIN	P1CIP	V1CIP	H1CIP	S1CIP
0.112E 00	0.882E 00	0.698E 03	0.700E 03	0.348E 00	0.698E 03	0.882E 00
HEXVI	SEXS	HEXS	P2CIP	V2CIP	H2CIP	S2SCP
0.561E 03	0.882E 00	0.561E 03	0.226E 03	0.104E 01	0.647E 03	0.882E 00
H2SCP	TGCIP	TWCIP	P3EXV	V3CIP	H3CIP	H3EXV
0.648E 03	0.667E 03	0.485E 03	0.262E 02	0.858E 01	0.608E 03	0.609E 03
H2TCP	DHTCP	HVDHT	QHTCP	EXHDH	DPIV	
0.647E 03	0.137E 03	0.713E-04	0.109E 01	0.750E-03	0.104E 00	
DPEXV	HP1CP	ZNVCP	ZNMCP	ZNTCP	ZNECP	H3EXE
0.547E-01	0.151E 03	0.999E 00	0.957E 00	0.646E 00	0.618E 00	0.608E 03
ZNEH						
0.646E 00						

PRES RATIO
0.2675853E 02

TRANSMISSION AND EXPANDER GEAR BOX RATIO

TRANS PWR OUT	CAR MPH	ENG HP OUT	EXPAND SPEED	GEAR RATIO
0.1080000E 03	0.7000000E 02	0.1232067E 03	0.1900000E 04	0.1000000E 01
EXPAND GEAR BOX RATIO		TRANS EFF	ACCESSORY KW	ENG HP TOT
0.5601294E 00		0.8944646E 00	0.3730000E 01	0.1444594E 03

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

REGENERATOR

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.9130000E 00	0.0	0.8419998E-02	0.1920000E-01	0.2510000E 00
FIN LENG LIQ	FIN THICK VAP	FIN THICK LIQ	WALL THICK	WALL T CON
0.0	0.5999997E-02	0.0	0.2000000E-01	0.1650000E 02
FIN T CON VAP	FIN T CON LIQ	BETA VAP	BETA LIQ	PLT SPACE VAP
0.1330000E 03	0.1650000E 02	0.0	0.0	0.0
PLT SPACE LIQ	SIGMA VAP	SIGMA LIQ	ALPHA VAP	FIN/IN VAP
0.0	0.5599999E 00	0.1110000E 01	0.2690000E 03	0.1200000E 02
FIN/IN LIQ	HEADER THICK	RHO FIN VAP	RHO FIN LIQ	RHO PLATE
0.0	0.6250000E-01	0.9789997E-01	0.3230000E 00	0.3230000E 00
RHO HEADER	NO PASS LIQ	DPTES	COND CODE	
0.2830000E 00	0.8000000E 01	0.0	0.0	
T IN VAP	T OUT VAP	T IN LIQ	T OUT LIQ	
0.4790449E 03	0.2751521E 03	0.2446854E 03	0.3561519E 03	
FLOW VAP	FLOW LIQ	DP VAP	DP LIQ	CP VAP
0.1285718E 01	0.1080004E 01	0.3614014E 00	0.2407999E 02	0.4166582E 00
CP LIQ	VISC VAP	VISC LIQ	PR VAP	PR LIQ
0.9073137E 00	0.8921141E-05	0.2444834E-03	0.8385819E 00	0.7060693E 01
RHO IN VAP	RHO OUT VAP	RHO IN LIQ	RHO OUT LIQ	H T COEF VAP
0.1161448E 00	0.1476704E 00	0.5570267E 02	0.4944901E 02	0.4809186E 02
H T COEF LIQ	MASS VEL VAP	MASS VEL LIQ	ETAO VAP	ETAO LIQ
0.1052066E 04	0.5171558E 01	0.4888179E 03	0.8462272E 00	0.1000000E 01
RE VAP	RE LIQ	NO TUBES	COM LENG(FT)	LIQ LENG(FT)
0.4881047E 04	0.3838830E 05	0.8000000E 01	0.8492029E-01	0.5170216E 01
VAP LENG/PASS	VAP LENG(FT)	VOL/PASS	TOT VOL(CUFT)	TOT INV(VAP)
0.2335901E 00	0.1868723E 01	0.1025593E 00	0.8204741E 00	0.9082073E-01
HEADER INVENT	TOT INV(LIQ)	FIN STRES VAP	FIN STRES LIQ	PLATE STRES
0.1542759E 00	0.6121993E 01	0.0	0.4354906E 04	0.0
DRY WT	TOT WT	EFFEC		
0.3023216E 02	0.3644496E 02	0.8699999E 00		

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

CONDENSER

AFIN/ATOT VAP	AFIN/ATOT LIQ	HYD DIA VAP	HYD DIA LIQ	FIN LENG VAP
0.8760000E 00	0.4960000E 00	0.6549999E-02	0.8339997E-02	0.1630000E 00
FIN LENG LIQ	**FIN THICK VAP**	**FIN THICK LIQ**	**WALL THICK**	**WALL T CON**
0.2500000E-01	0.3999997E-02	0.3999997E-02	0.2000000E-01	0.1000000E 03
FIN T CON VAP	**FIN T CON LIQ**	**BETA VAP**	**BETA LIQ**	**PLT SPACE VAP**
0.1000000E 03	0.1000000E 03	0.5560000E 03	0.8950000E 03	0.3260000E 00
PLT SPACE LIQ	**SIGMA VAP**	**SIGMA LIQ**	**ALPHA VAP**	**FIN/IN VAP**
0.5000000E-01	0.7134771E 00	0.2242877E 00	0.4700000E 03	0.2200000E 02
FIN/IN LIQ	**HEADER THICK**	**RHO FIN VAP**	**RHO FIN LIQ**	**RHO PLATE**
0.2000000E 02	0.6250000E-01	0.9799999E-01	0.9799999E-01	0.9799999E-01
RHO HEADER	**NO PASS LIQ**	**DPTES**	**COND CODE**	
0.9799999E-01	0.1000000E 01	0.0	0.1000000E 01	
RHO COND	**PR COND**			
0.5555560E 02	0.9079579E 01			
T IN VAP	**T OUT VAP**	**T IN LIQ**	**T OUT LIQ**	
0.8500000E 02	0.2106000E 03	0.2751521E 03	0.2420000E 03	
FLOW VAP	**FLOW LIQ**	**DP VAP**	**DP LIQ**	**CP VAP**
0.1550670E 02	0.1285718E 01	0.1213092E 00	0.5256747E 00	0.2399999E 00
CP LIQ	**VISC VAP**	**VISC LIQ**	**PR VAP**	**PR LIQ**
0.3766113E 00	0.1320000E-04	0.7537299E-05	0.7200000E 00	0.1000000E 01
RHO IN VAP	**RHO OUT VAP**	**RHO IN LIQ**	**RHO OUT LIQ**	**H T COEF VAP**
0.7287151E-01	0.5922309E-01	0.1518118E 00	0.1518118E 00	0.2589445E 02
H T COEF LIQ	**MASS VEL VAP**	**MASS VEL LIQ**	**ETAO VAP**	**ETAO LIQ**
0.5178889E 03	0.3142718E 01	0.2234048E 01	0.9248949E 00	0.9788426E 00
RE VAP	**RE LIQ**	**NO TUBES**	**COM LENG(FT)**	**LIQ LENG(FT)**
0.1559454E 04	0.2471966E 04	0.0	0.7188787E 01	0.9620066E 00
VAP LENG/PASS	**VAP LENG(FT)**	**VOL/PASS**	**TOT VOL(CUFT)**	**TOT INV(VAP)**
0.3569372E 00	0.3569408E 00	0.2468481E 01	0.2468481E 01	0.1050779E 00
HEADER INVENT	**TOT INV(LIQ)**	**FIN STRES VAP**	**FIN STRES LIQ**	**PLATE STRES**
0.5381426E 01	0.1471653E 00	0.1090726E 03	0.1666626E 03	0.8818567E 02
DRY WT	**TOT WT**	**EFFEC**		
0.1135282E 03	0.1137804E 03	0.8000000E 00		

NOTE- VAP AND LIQ REFER TO AIR AND WORKING FLUID SIDES RESPECTIVELY

HEAT REJECTION FAN AND MOTOR

FAN PWR(KW)	W AIR	DP AIR	FAN RPM	FAN DIA
0.9324546E 01	0.1550670E 02	0.1213092E 00	0.1444864E 04	0.3155716E 02
FAN+MOTOR WT				
0.2772617E 02				
COND FAN PWR	**CAR MPH**	**AMB AIR TEMP**	**AIR PRES DROP**	**COND AIR FLOW**
0.9324546E 01	0.7000000E 02	0.8500000E 02	0.1213092E 00	0.1550670E 02
QREJ	**CCA**	**CZL**	**CCTOT**	**APWRD**
0.1682762E 07	0.7188787E 01	0.9620066E 00	0.3569408E 00	0.1080000E 03
RAMHP	**COND AIR POWER**			
0.3366343E 01	0.5000000E 01			

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

VAPORIZER

AVG DIA(FT)	NO STARTS	DIA BB INSIDE	DIA BB O'SIDE	DIA RTO
0.1101548E 01	0.1000000E 01	0.1000000E 01	0.1760000E 00	0.1099999E 01
POROSITY	K TUBE WALL	EXCESS AIR	H2/C RTO	LHV GAS
0.4500000E 00	0.2000000E 02	0.3000000E 00	0.1875000E 00	0.1926500E 05
GAS TEMP IN	CP GAS COLD	CP GAS HOT	FLAME TEMP	VISC GAS
0.3000000E 04	0.2800000E 00	0.3329999E 00	0.3300000E 04	0.1099997E 00
K GAS				
0.4500000E-01				
W ORG	W GAS	T ORG IN	T ORG OUT	CP ORG IN
0.1285718E 01	0.6601734E 00	0.3734854E 03	0.7123101E 03	0.1002441E 01
CP ORG OUT	MU ORG IN	MU ORG OUT	K ORG IN	K ORG OUT
0.5451171E 00	0.1758080E-03	0.2087052E-06	0.1130998E 00	0.2517153E-01
RHO ORG	RHO GAS	DP ORG	DP GAS	EFFEC
0.2530841E 02	0.1655976E-01	0.6999997E 02	0.3801900E 00	0.9500000E 00
T FLUE GAS	H ORG IN	H ORG OUT	RE GAS	F GAS
0.5198113E 03	0.2126145E 04	0.1047288E 04	0.2011240E 05	0.5000000E 00
H GAS	UO	H FLUX	NTU	ML
0.9173820E 02	0.8500891E 02	0.5901995E 05	0.3877963E 01	0.3491646E-01
WCH	TUBE I/D	TUBE O/D	TUBE LENG	NO TUBES
0.2198377E 00	0.6208049E-01	0.6828845E-01	0.1669179E 03	0.4823358E 02
FIN HT	VAP HT	VAP VOL	INVENT	TOT WT
0.6864842E-03	0.3360018E 01	0.3611444E 01	0.1278697E 02	0.1133920E 03

ECONOMISER

DIA BB O'SIDE	K TUBE WALL	PASSES	POROSITY	DIA RTO
0.1760000E 00	0.2000000E 02	0.3000000E 01	0.4500000E 00	0.1099999E 01
CP GAS	VISC GAS	K GAS		
0.2800000E 00	0.1099997E 00	0.4500000E-01		
W GAS	W ORG	RHO ORG	RHO GAS	CP ORG
0.6601734E 00	0.2057151E 00	0.4274368E 02	0.1655976E-01	0.9849291E 00
MU ORG	K ORG	DP ORG	DP GAS	ECON DIA
0.1290146E-03	0.1130998E 00	0.2407999E 02	0.1434881E 00	0.1238125E 01
H ORG	ZML	F GAS	TUBE I/D	TUBE O/D
0.9236326E 03	0.1903459E 00	0.5026083E 00	0.3785105E 00	0.4163613E 00
FIN HT	ECON HT	ML	F GAS	TUBE LENG
0.5747497E-01	0.5304394E 00	0.1903459E 00	0.5026083E 00	0.1397989E 03
INVENT	ECON WT			
0.1400811E 02	0.6982256E 02			

BURNER FAN AND MOTOR

FAN PWR(KW)	W AIR	DP AIR	FAN RPM	FAN DIA
0.2500000E 01	0.6282212E 00	0.5236781E 00	0.2728319E 04	0.1100000E 02
FAN+MOTOR WT				
0.1698999E 02				

```
OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX.    FLS 5/1/73
OUTPUT
HOTWELL
 CAPACITYCU FT
 0.7110075E 00
BLOCK DATA
 (1)             (2)             (3)             (4)             (5)
 0.2420000E 03   0.1430000E-01   0.3440000E-01   0.2080000E-01   0.9999996E-01

 (6)             (7)             (8)             (9)             (10)
 0.8699999E 00   0.8000000E 00   0.9500000E 00   0.8000000E 00   0.2500000E 01

 (11)            (12)            (13)            (14)            (15)
 0.5000000E 01   0.1900000E 04   0.3000000E 01   0.5400000E 02   0.8400000E 00

 (16)            (17)
 0.7259995E 00   0.7000000E 03
```

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

SYSTEM CONDITIONS FOR 32.00HP AND 60.00MPH

CYCLE CONDITIONS

EXPANDER EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.9152226E 00	0.4067783E 02	0.9420966E 00	0.5599999E 00	0.8289049E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.9931618E 00	0.9766468E 00	0.8448664E 00	0.0	0.1047236E 00

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.4046667E-01	0.2696272E 01	0.7838001E 01	0.5886058E-01	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.70000E 03	0.71231E 03	0.69801E 03
REGEN VAP IN	0.25372E 02	0.39104E 03	0.57142E 03
COND IN	0.25332E 02	0.24540E 03	0.51325E 03
PUMP IN	0.25273E 02	0.24200E 03	0.16102E 03
ALT IN	0.71053E 03	0.24439E 03	0.16428E 03
REGEN LIQ IN	0.71053E 03	0.24439E 03	0.16428E 03
REGEN LIQ OUT	0.70784E 03	0.32226E 03	0.23354E 03
ECON OUT	0.70784E 03	0.35448E 03	0.26418E 03
VAP IN	0.70784E 03	0.32751E 03	0.23844E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.3363619E 00	0.3195634E 02	0.6637333E 06	0.5758485E 06	0.4265159E 06

SYSTEM EFF	SFC
0.1897847E 00	0.8658413E 00

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.4809186E 02	0.1052066E 04	0.1285718E 01	0.1080004E 01	0.3614014E 00

DP LIQ
0.2407999E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2151137E 02	0.1052066E 04	0.3363619E 00	0.2825440E 00	0.4046667E-01

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.2696272E 01	0.9226093E 00	0.4438684E 03	0.8797618E 00	0.9931618E 00

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.2126145E 04	0.1047288E 04	0.9173820E 02	0.8500891E 02	0.1285718E 01

W FUEL
0.1150284E 03

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.8316785E 03	0.4096648E 03	0.3901483E 02	0.9998270E 00	0.3625549E 02

NTU'S	EFFEC
0.5710300E 01	0.9766468E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

SYSTEM CONDITIONS FOR 32.00HP AND 60.00MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.9236326E 03	0.5791138E 02	0.2057151E 00	0.6601734E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.3159573E 03	0.2393056E 02	0.9997317E 00	0.2194995E 02	0.5381793E-01

W GAS	NTU'S	EFFEC
0.1834046E 00	0.2011318E 01	0.8448664E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2589445E 02	0.5178889E 03	0.1550670E 02	0.1285718E 01	0.1213092E 00

DP LIQ
0.5256747E 00

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.1141409E 02	0.1776831E 03	0.3958921E 01	0.3363619E 00	0.1038958E-01

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.5886058E-01	0.9648774E 00	0.8259598E 04	0.2414728E 01	0.9257255E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.6000000E 02	0.8500000E 02	0.1038958E-01	0.3958921E 01

QREJ	CCA	CZL	CCIOI	APWRD
0.4265159E 06	0.7188787E 01	0.9620066E 00	0.3569408E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.3200000E 02	0.1376606E 01	0.1093281E 00

RECIPROCATOR

INLET PRESS	INLET TEMP	EXHAUST PRES	ENGINE HP	CRANK INT ANG
0.7000000E 03	0.7123101E 03	0.2537215E 02	0.5510474E 02	0.2461301E 02

BORE DIA	STROKE	ENGINE RPM	NO OF CYLIND	CLEAR LENGTH
0.3061781E 01	0.3000000E 01	0.1590363E 04	0.4000000E 01	0.7499997E-02

EXP LENGTH	ROD LENGTH	PISTON AREA	INT VALV AREA	EXH VALV AREA
0.2075000E 00	0.5000000E 00	0.5110401E-01	0.1022080E-01	0.1022080E-01

VALV LENGTH	AVG PIST SPD	EXPAN RATIO	MEAN EFF PRES	EXP EFF HM
0.1406103E-01	0.7951814E 03	0.9623843E 01	0.2062543E 03	0.8622280E 00

RECIPROCATOR DIAGNOSTIC

FLOWV	SIIN	HIN	P1CIP	V1CIP	H1CIP	S1CIP
0.292E-01	0.882E 00	0.698E 03	0.700E 03	0.348E 00	0.698E 03	0.882E 00

HEXVI	SEXS	HEXS	P2CIP	V2CIP	H2CIP	S2SCP
0.560E 03	0.882E 00	0.560E 03	0.640E 02	0.335E 01	0.594E 03	0.882E 00

H2SCP	TGCIP	TWCIP	P3EXV	V3CIP	H3CIP	H3EXV
0.595E 03	0.594E 03	0.467E 03	0.254E 02	0.799E 01	0.570E 03	0.571E 03

H2TCP	DHTCP	HVDHT	QHTCP	EXHDH	DPIV
0.594E 03	0.138E 03	0.530E-05	0.102E 01	0.168E-02	0.703E-02

DPEXV	HP1CP	ZNVCP	ZNMCP	ZNTCP	ZNECP	H3EXF
0.411E-01	0.551E 02	0.998E 00	0.942E 00	0.917E 00	0.862E 00	0.570E 03

ZNEH
0.915E 00

TRANSMISSION AND EXPANDER GEAR BOX RATIO

TRANS PWR OUT	CAR MPH	ENG HP OUT	EXPAND SPEED	GEAR RATIO
0.3200000E 02	0.6000000E 02	0.4947433E 02	0.1590363E 04	0.2459999E 01

EXPAND GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.5601294E 00	0.6600000E 00	0.3365279E 01	0.5452791E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

SYSTEM CONDITIONS FOR 8.40HP AND 30.00MPH

CYCLE CONDITIONS

EXPANDER EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.9866294E 00	0.1244210E 02	0.9318725E 00	0.5599999E 00	0.8869478E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1013623E 01	0.9895603E 00	0.8881815E 00	0.0	0.3657554E-02

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.3643598E-02	0.2427710E 00	0.7057297E 00	0.5299777E-02	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.70000E 03	0.71231E 03	0.69801E 03
REGEN VAP IN	0.25282E 02	0.36702E 03	0.56140E 03
COND IN	0.25278E 02	0.24269E 03	0.51223E 03
PUMP IN	0.25273E 02	0.24200E 03	0.16102E 03
ALT IN	0.70095E 03	0.24436E 03	0.16424E 03
REGEN LIQ IN	0.70095E 03	0.24436E 03	0.16424E 03
REGEN LIQ OUT	0.70071E 03	0.31061E 03	0.22276E 03
ECON OUT	0.70071E 03	0.34167E 03	0.25183E 03
VAP IN	0.70071E 03	0.31566E 03	0.22742E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.9604484E-01	0.9190706E 01	0.1908909E 06	0.1675588E 06	0.1214361E 06

SYSTEM EFF	SFC
0.1732203E 00	0.9486387E 00

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.4809186E 02	0.1052066E 04	0.1285718E 01	0.1080004E 01	0.3614014E 00

DP LIQ
0.2407999E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.1014072E 02	0.1052066E 04	0.9604484E-01	0.8067763E-01	0.3643598E-02

DP LIQ	ETAQ VAP	U O	NTU'S	EFFEC
0.2427710E 00	0.9614483E 00	0.2412961E 03	0.1674919E 01	0.1013623E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.2126145E 04	0.1047288E 04	0.9173820E 02	0.8500891E 02	0.1285718E 01

W FUEL
0.1150284E 03

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.3458777E 03	0.1703711E 03	0.1670102E 02	0.9999260E 00	0.1554317E 02

NTU'S	EFFEC
0.8372654E 01	0.9895603E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

SYSTEM CONDITIONS FOR 8.40HP AND 30.00MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.9236326E 03	0.5791138E 02	0.2057151E 00	0.6601734E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.1159211E 03	0.1012791E 02	0.9998861E 00	0.9186214E 01	0.1536721E-01

W GAS	NTU'S	EFFEC
0.5274753E-01	0.2971680E 01	0.8881815E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2589445E 02	0.5178889E 03	0.1550670E 02	0.1285718E 01	0.1213092E 00

DP LIQ
0.5256747E 00

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.5294852E 01	0.5972354E 02	0.1100519E 01	0.9604484E-01	0.1037134E-02

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.5299777E-02	0.9832760E 00	0.3413988E 04	0.3590466E 01	0.9879850E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.0	0.3000000E 02	0.8500000E 02	0.1037134E-02	0.1100519E 01

QREJ	CCA	CZL	CCIOI	APWRD
0.1214361E 06	0.7188787E 01	0.9620066E 00	0.3569408E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.8400000E 01	0.7861137E-01	0.3033818E-02

RECIPROCATOR

INLET PRESS	INLET TEMP	EXHAUST PRES	ENGINE HP	CRANK INT ANG
0.7000000E 03	0.7123101E 03	0.2528175E 02	0.1679216E 02	0.1390302E 02

BORE DIA	STROKE	ENGINE RPM	NO OF CYLIND	CLEAR LENGTH
0.3061781E 01	0.3000000E 01	0.8134255E 03	0.4000000E 01	0.7499997E-02

EXP LENGTH	ROD LENGTH	PISTON AREA	INT VALV AREA	EXH VALV AREA
0.2075000E 00	0.5000000E 00	0.5110401E-01	0.1022080E-01	0.1022080E-01

VALV LENGTH	AVG PIST SPD	EXPAN RATIO	MEAN EFF PRES	EXP EFF MM
0.4560292E-02	0.4067126E 03	0.1720522E 02	0.1242980E 03	0.9194127E 00

RECIPROCATOR DIAGNOSTIC

FLOWV	SIIN	HIN	P1CIP	V1CIP	H1CIP	S1CIP
0.836E-02	0.882E 00	0.698E 03	0.700E 03	0.348E 00	0.698E 03	0.882E 00

HEXVI	SEXS	HEXS	P2CIP	V2CIP	H2CIP	S2SCP
0.560E 03	0.882E 00	0.560E 03	0.337E 02	0.599E 01	0.570E 03	0.882E 00

H2SCP	TGCIP	TWCIP	P3EXV	V3CIP	H3CIP	H3EXV
0.571E 03	0.559E 03	0.466E 03	0.253E 02	0.779E 01	0.560E 03	0.560E 03

H2TCP	DHTCP	HVDHT	QHTCP	EXHDH	DPIV
0.570E 03	0.138E 03	-0.176E-05	0.102E 01	0.762E-03	0.575E-03

DPEXV	HP1CP	ZNVCP	ZNMCP	ZNTCP	ZNECP	H3EXF
0.110F-01	0.164E 02	0.999E 00	0.932E 00	0.987E 00	0.919E 00	0.560E 03

ZNEH
0.987E 00

TRANSMISSION AND EXPANDER GEAR BOX RATIO

TRANS PWR OUT	CAR MPH	ENG HP OUT	EXPAND SPEED	GEAR RATIO
0.8400000E 01	0.3000000E 02	0.1298701E 02	0.8134255E 03	0.2459999E 01

EXPAND GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.5601294E 00	0.6600000E 00	0.2450129E 01	0.1667841E 02

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OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX.    FLS 5/1/73
OUTPUT
SYSTEM CONDITIONS FOR  9.92HP AND 25.10MPH
CYCLE CONDITIONS
 EXPANDER EFF    ENG POWR KW     MECH EFF        PUMP EFF        CRU EFF
 0.9721822E 00   0.1413014E 02   0.9411755E 00   0.5599999E 00   0.8821878E 00
REGEN EFFEC      VAP EFFEC       ECON EFFEC      COND FAN PWR    BURN FAN PWR
 0.1012913E 01   0.9888119E 00   0.8825544E 00   0.0             0.3748462E-02
REG DP VAP       REG DP LIQ      VAP DP          COND DP VAP     REGEN WL/WV
 0.4915290E-02   0.3275031E 00   0.9520441E 00   0.7149510E-02   0.8400000E 00
 STATE POINT                 PRESS(PSIA)   TEMP(F)       ENTHALPY(B/LB)
 TB IN                       0.70000E 03   0.71231E 03   0.69801E 03
 REGEN VAP IN                0.25285E 02   0.37186E 03   0.56340E 03
 COND IN                     0.25280E 02   0.24272E 03   0.51224E 03
 PUMP IN                     0.25273E 02   0.24200E 03   0.16102E 03
 ALT IN                      0.70128E 03   0.24436E 03   0.16424E 03
 REGEN LIQ IN                0.70128E 03   0.24436E 03   0.16424E 03
 REGEN LIQ OUT               0.70095E 03   0.31320E 03   0.22514E 03
 ECON OUT                    0.70095E 03   0.34452E 03   0.25455E 03
 VAP IN                      0.70095E 03   0.31829E 03   0.22985E 03

 MASS FLOW       WFUEL LB/HR     Q RELEASED      Q ABSORBED      Q REJECTED
 0.1096679E 00   0.1045660E 02   0.2171836E 06   0.1905371E 06   0.1386646E 06
SYSTEM EFF       SFC
 0.1798000E 00   0.9139240E 00
REGENERATOR
 DESIGN CONDITIONS
 H VAP           H LIQ           W VAP           W LIQ           DP VAP
 0.4809186E 02   0.1052066E 04   0.1285718E 01   0.1080004E 01   0.3614014E 00
 DP LIQ
 0.2407999E 02
 PART LOAD CONDITIONS
 H VAP           H LIQ           W VAP           W LIQ           DP VAP
 0.1098075E 02   0.1052066E 04   0.1096679E 00   0.9212101E-01   0.4915290E-02
 DP LIQ          ETAQ VAP        U Q             NTU'S           EFFEC
 0.3275031E 00   0.9584290E 00   0.2583513E 03   0.1570539E 01   0.1012913E 01

VAPORIZER
 DESIGN CONDITIONS
 H ORG IN        H ORG OUT       H GAS           U Q             W ORG
 0.2126145E 04   0.1047288E 04   0.9173820E 02   0.8500891E 02   0.1285718E 01
 W FUEL
 0.1150284E 03
 PART LOAD CONDITIONS
 H ORG IN        H ORG OUT       H GAS           ETA FIN         U Q
 0.3795305E 03   0.1869477E 03   0.1823637E 02   0.9999191E 00   0.1697363E 02
 NTU'S           EFFEC
 0.8049020E 01   0.9888119E 00
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OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX.    FLS 5/1/73
OUTPUT

SYSTEM CONDITIONS FOR  9.92HP AND 25.10MPH
ECONOMISER
 DESIGN CONDITIONS
 H ORG          H GAS          W ORG          W GAS
 0.9236326E 03  0.5791138E 02  0.2057151E 00  0.6601734E 00
 PART LOAD CONDITIONS
 H ORG          H GAS          ETAV O         U O            W ORG
 0.1288982E 03  0.1107103E 02  0.9998755E 00  0.1005656E 02  0.1754689E-01
 W GAS          NTU'S          EFFEC
 0.6001277E-01  0.2844037E 01  0.8825544E 00
CONDENSER
 DESIGN CONDITIONS
 H VAP          H LIQ          W VAP          W LIQ          DP VAP
 0.2589445E 02  0.5178889E 03  0.1550670E 02  0.1285718E 01  0.1213092E 00
 DP LIQ
 0.5256747E 00
 PART LOAD CONDITIONS
 H VAP          H LIQ          W VAP          W LIQ          DP VAP
 0.5338453E 01  0.6046596E 02  0.1115664E 01  0.1096679E 00  0.1062967E-02
 DP LIQ         ETAO VAP       U O            NTU'S          EFFEC
 0.7149510E-02  0.9831415E 00  0.3448047E 04  0.3577059E 01  0.9879850E 00

 COND FAN PWR   CAR MPH        AMB AIR TEMP   AIR PRES DROP  COND AIR FLOW
 0.0            0.2509999E 02  0.8500000E 02  0.1062967E-02  0.1115664E 01
 QREJ           CCA            CZL            CCIOI          APWRD
 0.1386646E 06  0.7188787E 01  0.9620066E 00  0.3569408E 00  0.1080000E 03
 APWR(I)        RAMHP          COND AIR POWR
 0.9919999E 01  0.2289713E-01  0.3152176E-02
RECIPROCATOR
 INLET PRESS    INLET TEMP     EXHAUST PRES   ENGINE HP      CRANK INT ANG
 0.7000000E 03  0.7123101E 03  0.2528488E 02  0.1911099E 02  0.1760272E 02
 BORE DIA       STROKE         ENGINE RPM     NO OF CYLIND   CLEAR LENGTH
 0.3061781E 01  0.3000000E 01  0.7581028E 03  0.4000000E 01  0.7499997E-02
 EXP LENGTH     ROD LENGTH     PISTON AREA    INT VALV AREA  EXH VALV AREA
 0.2075000E 00  0.5000000E 00  0.5110401E-01  0.1022080E-01  0.1022080E-01
 VALV LENGTH    AVG PIST SPD   EXPAN RATIO    MEAN EFF PRES  EXP EFF HM
 0.7276654E-02  0.3790513E 03  0.1404242E 02  0.1501373E 03  0.9149940E 00
RECIPROCATOR DIAGNOSTIC
  FLOWV          SIIN           HIN            P1CIP          V1CIP          H1CIP          S1CIP
 0.954E-02      0.882E 00      0.698E 03      0.700E 03      0.348E 00      0.698E 03      0.882E 00
  HEXVI          SEXS           HEXS           P2CIP          V2CIP          H2CIP          S2SCP
 0.560E 03      0.882E 00      0.560E 03      0.422E 02      0.489E 01      0.577E 03      0.882E 00
  H2SCP          TGCIP          TWCIP          P3EXV          V3CIP          H3CIP          H3EXV
 0.579E 03      0.571E 03      0.466E 03      0.253E 02      0.784E 01      0.562E 03      0.562E 03
  H2TCP          DHTCP          HVDHT          QHTCP          EXHDH          DPIV
 0.577E 03      0.138E 03     -0.176E-05      0.111E 01      0.525E-03      0.750E-03
  DPEXV          HP1CP          ZNVCP          ZNMCP          ZNTCP          ZNECP          H3EXF
 0.954E-02      0.191E 02      0.999E 00      0.941E 00      0.973E 00      0.915E 00      0.562E 03
  ZNEH
 0.972E 00
TRANSMISSION AND EXPANDER GEAR BOX RATIO
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TRANS PWR OUT	CAR MPH	ENG HP OUT	EXPAND SPEED	GEAR RATIO
0.4919999E 01	0.2509999E 02	0.1533704E 02	0.7581028E 03	0.2459999E 01

EXPAND GEAR BOX RATIO	TRANS EFF	ACCESSORY KW	ENG HP TOT
0.5601794E 00	0.6600000E 00	0.2384964E 01	0.1894121E 02

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

SYSTEM CONDITIONS FOR 1.14HP AND 1.74MPH

CYCLE CONDITIONS

EXPANDER EFF	ENG POWR KW	MECH EFF	PUMP EFF	CRU EFF
0.9944340E 00	0.3966533E 01	0.9129505E 00	0.5599999E 00	0.8761100E 00

REGEN EFFEC	VAP EFFEC	ECON EFFEC	COND FAN PWR	BURN FAN PWR
0.1015663E 01	0.9943748E 00	0.9237234E 00	0.1679697E-03	0.9539563E-04

REG DP VAP	REG DP LIQ	VAP DP	COND DP VAP	REGEN WL/WV
0.1005337E-03	0.6698500E-02	0.1947239E-01	0.1462307E-03	0.8400000E 00

STATE POINT	PRESS(PSIA)	TEMP(F)	ENTHALPY(B/LB)
TB IN	0.70000E 03	0.71231E 03	0.69801E 03
REGEN VAP IN	0.25273E 02	0.36437E 03	0.56030E 03
COND IN	0.25273E 02	0.24248E 03	0.51216E 03
PUMP IN	0.25273E 02	0.24200E 03	0.16102E 03
ALT IN	0.70003E 03	0.24436E 03	0.16423E 03
REGEN LIQ IN	0.70003E 03	0.24436E 03	0.16423E 03
REGEN LIQ OUT	0.70002E 03	0.30929E 03	0.22155E 03
ECON OUT	0.70002E 03	0.30929E 03	0.22155E 03
VAP IN	0.70002E 03	0.30929E 03	0.22155E 03

MASS FLOW	WFUEL LB/HR	Q RELEASED	Q ABSORBED	Q REJECTED
0.3099459E-01	0.2982710E 01	0.6195088E 05	0.5418667E 05	0.3917977E 05

SYSTEM EFF	SFC
0.9641367E-01	0.1704358E 01

REGENERATOR

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.4809186E 02	0.1052066E 04	0.1285718E 01	0.1080004E 01	0.3614014E 00

DP LIQ
0.2407999E 02

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.5144652E 01	0.1052066E 04	0.3099459E-01	0.2603545E-01	0.1005337E-03

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.6698500E-02	0.9799414E 00	0.1312965E 03	0.2824132E 01	0.1015663E 01

VAPORIZER

DESIGN CONDITIONS

H ORG IN	H ORG OUT	H GAS	U O	W ORG
0.2126145E 04	0.1047288E 04	0.9173820E 02	0.8500891E 02	0.1285718E 01

W FUEL
0.1150284E 03

PART LOAD CONDITIONS

H ORG IN	H ORG OUT	H GAS	ETA FIN	U O
0.1567080E 03	0.7719061E 02	0.7718535E 01	0.9999658E 00	0.7183651E 01

NTU'S	EFFEC
0.1184345E 02	0.9943748E 00

OPTIMIZATION OF ORC AUTOMOBILE ENGINE FOR AC2 PYRIDINE/WATER MIX. FLS 5/1/73

OUTPUT

SYSTEM CONDITIONS FOR 1.14HP AND 1.74MPH

ECONOMISER

DESIGN CONDITIONS

H ORG	H GAS	W ORG	W GAS
0.9236326E 03	0.5791138E 02	0.2057151E 00	0.6601734E 00

PART LOAD CONDITIONS

H ORG	H GAS	ETAV O	U O	W ORG
0.4690413E 02	0.4658973E 01	0.9999475E 00	0.4174974E 01	0.4959136E-02

W GAS	NTU'S	EFFEC
0.1711844E-01	0.4267745E 01	0.9237234E 00

CONDENSER

DESIGN CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2589445E 02	0.5178889E 03	0.1550670E 02	0.1285718E 01	0.1213092E 00

DP LIQ
0.5256747E 00

PART LOAD CONDITIONS

H VAP	H LIQ	W VAP	W LIQ	DP VAP
0.2417646E 01	0.1843317E 02	0.2979630E 00	0.3099459E-01	0.9873079E-04

DP LIQ	ETAO VAP	U O	NTU'S	EFFEC
0.1462307E-03	0.9922674E 00	0.1295449E 04	0.5032050E 01	0.9879850E 00

COND FAN PWR	CAR MPH	AMB AIR TEMP	AIR PRES DROP	COND AIR FLOW
0.1679697E-03	0.1740000E 01	0.8500000E 02	0.9873079E-04	0.2979630E 00

QREJ	CCA	CZL	CCIOI	APWRD
0.3917977E 05	0.7188787E 01	0.9620066E 00	0.3569408E 00	0.1080000E 03

APWR(I)	RAMHP	COND AIR POWR
0.1143000E 01	0.0	0.7819373E-04

RECIPROCATOR

INLET PRESS	INLET TEMP	EXHAUST PRES	ENGINE HP	CRANK INT ANG
0.7000000E 03	0.7123101E 03	0.2527306E 02	0.4691812E 01	0.2946824E 01

BORE DIA	STROKE	ENGINE RPM	NO OF CYLIND	CLEAR LENGTH
0.3061781E 01	0.3000000E 01	0.3601531E 03	0.4000000E 01	0.7499997E-02

EXP LENGTH	ROD LENGTH	PISTON AREA	INT VALV AREA	EXH VALV AREA
0.2075000E 00	0.5000000E 00	0.5110401E-01	0.1022080E-01	0.1022080E-01

VALV LENGTH	AVG PIST SPD	EXPAN RATIO	MEAN EFF PRES	EXP EFF MM
0.2063513E-03	0.1800765E 03	0.2692584E 02	0.7999818E 02	0.9078690E 00

RECIPROCATOR DIAGNOSTIC

FLOWV	SIIN	HIN	P1CIP	V1CIP	H1CIP	S1CIP
0.236E-02	0.882E 00	0.698E 03	0.700E 03	0.348E 00	0.698E 03	0.882E 00

HEXVI	SEXS	HEXS	P2CIP	V2CIP	H2CIP	S2SCP
0.560E 03	0.882E 00	0.560E 03	0.205E 02	0.937E 01	0.551E 03	0.882E 00

H2SCP	TGCIP	TWCIP	P3EXV	V3CIP	H3CIP	H3EXV
0.552E 03	0.533E 03	0.465E 03	0.253E 02	0.777E 01	0.559E 03	0.559E 03

H2TCP	DHTCP	HVDHT	QHTCP	EXHDH	DPIV
0.551E 03	0.138E 03	0.0	0.997E 00	0.187E-03	0.460E-04

DPEXV	HP1CP	ZNVCP	ZNMCP	ZNTCP	ZNECP	H3EXE
0.217E-02	0.469E 01	0.100E 01	0.913E 00	0.995E 00	0.908E 00	0.559E 03

ZNEH
0.994E 00

TRANSMISSION AND EXPANDER GEAR BOX RATIO

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 TRANS PWR OUT   CAR MPH         ENG HP OUT      EXPAND SPEED    GEAR RATIO
 0.1143000E 01   0.1740000E 01   0.2345910E 01   0.3601531E 03   0.2459999E 01

 EXPAND GEAR BOX RATIO           TRANS EFF       ACCESSORY KW    ENG HP TOT
 0.5601294E 00                   0.4971740E 00   0.1916222E 01   0.5317067E 01

  PADES        PA10        PA20        PA30        PAIDL       PAWI        PAOFF
 0.124E-02   0.126E 00   0.438E 00   0.273E 00   0.522E-01   0.972E 00   0.105E 01

DESIGN AND PART LOAD PERFORMANCE

 SFCO            ECYCL(1)        ECYCL(2)        ECYCL(3)        ECYCL(4)
 0.1251502E 01   0.8658413E 00   0.9486387E 00   0.9139240E 00   0.1704358E 01

WEIGHT SUMMARY

 TOTAL SYS WT    FAN WT          REGEN WT        CONDENSER WT    FUEL WT
 0.1361150E 04   0.2772617E 02   0.3644496E 02   0.1137804E 03   0.9130481E 02

 ECON HOUS WT    TB-GR BOX WT    ECON WT         VAPORIZER WT    BRN FAN MT WT
 0.6623926E 02   0.2250220E 03   0.6982256E 02   0.1133920E 03   0.1698999E 02

 BURNER WT       TRANS WT        DRIVE TRN WT    ST MT PMP WT    PVD WT
 0.1542861E 02   0.1550000E 03   0.2000000E 03   0.2000000E 02   0.6000000E 02

 BATT WT         ST ACCUM WT     CONTROLS WT     EXH PIPE WT     ELEC GEN WT
 0.4000000E 02   0.1000000E 02   0.3000000E 02   0.5500000E 02   0.1500000E 02

VOLUME SUMMARY
 CRU             REGENERATOR     CONDENSER       HOTWELL         COND FAN
 0.2250000E 01   0.8204741E 00   0.2468481E 01   0.7110075E 00   0.2380611E 01

 VAP/ECON        BURNER          TRANSMISSION      TOT(.6 PACK DENS)
 0.8620868E 01   0.1194569E 01   0.1500000E 01   0.3324124E 02


 DES PT MPG      OFF 1 MPG       OFF 2 MPG       OFF 3 MPG       IDLE PT MPG
 0.3712129E 01   0.1145313E 02   0.1991141E 02   0.1464243E 02   0.3558509E 01

 OVER ALL MPG
 0.1336184E 02

 *****PAOFF=  0.1047424E 01*****

IHC217I FIOCS - END OF DATA SET ON UNIT    5

TRACEBACK  ROUTINE  CALLED FROM ISN   REG.  14    REG.  15    REG.   0    REG.   1
           IBCOM                      00098454    000B2610    00000000    000993F8
           MAIN                       00027052    010917C8    FD000008    000CC7F8

ENTRY POINT=  010917C8
```

APPENDIX E

SUBROUTINE "SHIFT"

```
      SUBROUTINE SHIFT(APOWR,AN,CRMPH,PRENG,TBGXR,EFTB,GEARR,IO,IOFF,
     1IOFFT,L,EFFTR,DIA)
C
C     AUTOMATIC TRANSMISSION SUBROUTINE FOR ORC TURBINE AUTOMOBILE ENGINE
C
      DIMENSION ZKIDT(30),ZKODT(30),RTDT(30),RNDT(30)
      DATA ZKIDT /105.4,107.6,111.9,116.0,119.1,125.5,130.9,140.2,150.9,
     1162.4,168.9,183.6,221.7,316.3,379.8/
      DATA ZKODT /0.,7.82,16.65,26.65,37.80,51.6,67.4,88.1,114.3,143.0,
     1151.9,169.0,210.2,308.5,372.0/
      DATA RTDT /2.0,1.9,1.8,1.7,1.59,1.48,1.36,1.24,1.11,1.0,1.0,1.0,
     11.0,1.0,1.0/
      DATA RNDT /.0,.1,.2,.3,.4,.5,.6,.7,.8,.88,.90,.92,.95,.975,.98/
      NDATA=15
      ZKOFL=372.0
      L=0
      IF(IOFF)10,10,11
   10 GEAR1=1.65
      GEAR1=2.52
      GEAR2=1.52
      GEAR3=1.0
      EFF1=.20
      EFF1=.66
      EFF2=.77
      EFF3=.82
      EFFG1=.94
      EFFG1=.94
      EFFG2=.96
      EFFG3=.98
      DIFFR=2.93
      TIRED=2.2
      EFTBX=.98
      GEARR=GEAR3
      EFFR=EFF3
      EFFRG=EFFG3
    9 TRPMO=(CRMPH*88.*DIFFR)/(3.1416*TIRED)
      ZNO=TRPMO*GEARR
      EFFLL=.0
      EFFUL=1.0
      EFFG=EFFR
      NTER=0
   35 PRENG=APOWR/EFFR/EFTBX
      TOG=(PRENG*63025.)/ZNO/12.0
      TCLL=0.
      TCUL=1.1*TCG
      ITER=0
   30 ZKO=ZNO/(TCG**.5)
      IF(ZKO-ZKOFL)500,500,600
  500 CONTINUE
      CALL INTPL(NDATA,4,ZKODT,RNDT,ZKO,RN,INIT,KR)
      CALL INTPL(NDATA,4,RNDT,RTDT,RN,RT,INIT,KR)
      CALL INTPL(NDATA,4,RNDT,ZKIDT,RN,ZKI,INIT,KR)
      TI=TOG/RT
      ZNI=ZKI*(TI**.5)
      GO TO 601
  600 TI=TCG
      ZNI=ZNO
  601 CONTINUE
      PENGT=(TI*12.0*ZNI)/63025./EFTBX
  412 FORMAT('0  TRPMO        ZNO        PRENG        TOG          RN
     1  RT          ZKI'/7E11.3)
```

```
413 FORMAT('0     TI          ZNI         PENGT'/3E11.3)
    IF(ABS(1.-PENGT/PRENG)-.001)19,19,21
 21 CALL CNVRG(TOG,TOLL,TOUL,PENGT,PRENG,ITER,DUM1,DUM2,IO)
    IF(ITER-30)30,30,31
 31 WRITE(IO,310)
310 FORMAT('0 ITERATION TROUBLE IN SUBROUTINE SHIFT')
    WRITE(IO,311)TOG,TOLL,TOUL,PENGT,PRENG,IOFFT
311 FORMAT('0    TOG         TOLL        TOUL        PENGT       PRENG
   1IOFFT'/5E11.3,1I7)
    L=1
    RETURN
 19 TRQPI=TI*12.*ZNI/63025.
    TRQPO=TOG*12.0*ZNO/63025.
    EFFR1=TRQPO/TRQPI*EFFRG
    IF(ABS(1.-EFFR1/EFFR)-.001)20,20,18
 18 CALL CNVRG(EFFG,EFFLL,EFFUL,EFFR1,EFFR,NTER,DUM3,DUM4,IO)
    EFFR=EFFG
    IF(NTER-30)35,35,36
 36 WRITE(IO,320)
320 FORMAT('0 ITERATION TROUBLE IN SUBROUTINE SHIFT ON TRANSMISSION EF
   1F.')
    WRITE(IO,321)EFFR,EFFLL,EFFUL,EFFR1,TRQPI,TRQPO,IOFFT
321 FORMAT('0    EFFR        EFFLL       EFFUL       EFFR1       TRQPI
   1TRQPO       IOFFT'/6E11.3,1I7)
    L=1
    RETURN
 20 IF(IOFF)22,22,41
 22 TBGXR=AN/ZNI
    EFFTR=EFFR
    ICFFT=1
    RETURN
 41 AN=ZNI*TBGXR
    IF(IOFFT-1)71,71,72
 71 AN1=AN
    PENG1=PRENG
    EFFT1=EFFR
    EFFTR=EFFT1
    ICFFT=2
    VTIP=PI*AN*DIA/720.
    IF(VTIP-1200.)501,501,551
501 RETURN
551 EFTB=0.
    GO TO 3
 72 IF(IOFFT-2)73,73,74
 73 AN2=AN
    PENG2=PRENG
    EFFT2=EFFR
    EFFTR=EFFT2
    ICFFT=3
    VTIP=PI*AN*DIA/720.
    IF(VTIP-1200.)502,502,552
502 RETURN
552 EFTB=0.
    GO TO 5
 74 IF(IOFFT-3)75,75,76
 75 AN3=AN
    PENG3=PRENG
    EFFT3=EFFR
    EFFTR=EFFT3
    ICFFT=4
 76 EFFTR=EFFR
```

```
      RETURN
   11 IF(IOFFT-1)1,1,2
    1 GEARR=GEAR1
      EFFR=EFF1
      EFFRG=EFFG1
      GO TO 9
    2 IF(IOFFT-2)3,3,4
    3 GEARR=GEAR2
      EFFR=EFF2
      EFFRG=EFFG2
      SEL1=EFFT1*EFTB
      GO TO 9
    4 IF(IOFFT-3)5,5,6
    5 GEARR=GEAR3
      EFFR= EFF3
      EFFRG=EFFG3
      SEL2=EFFT2*EFTB
      GO TO 9
    6 IF(IOFFT-4)7,7,8
    7 SEL3=EFFT3*EFTB
      IF(SEL1-SEL2)50,51,51
   50 IF(SEL2-SEL3)53,54,54
   51 IF(SEL1-SEL3)53,57,57
   54 AN=AN2
      PRENG=PENG2
      GEARR=GEAR2
      EFFTR=EFFT2
      ICFFT=5
      RETURN
   53 AN=AN3
      PRENG=PENG3
      GEARR=GEAR3
      EFFTR=EFFT3
      ICFFT=5
      RETURN
   57 AN=AN1
      PRENG=PENG1
      GEARR=GEAR1
      EFFTR=EFFT1
      ICFFT=5
      RETURN
    8 GEARR=GEAR1
      EFFR=EFF1
      EFFRG=EFFG1
      GO TO 9
      END
```

APPENDIX F

SUBROUTINE "DRIVE"

```
      SUBROUTINE DRIVE(APOWR,AN,CRMPH,PRENG,TBGXR,EFTB,GEARR,IO,IOFF,
     1IOFFT,L,EFFTR)
C
C     AUTOMATIC TRANSMISSION SUBROUTINE FOR ORC RECIPROCATING AUTO ENGINE
C
      DIMENSION ZKIDT(30),ZKODT(30),RTDT(30),RNDT(30)
      DATA ZKIDT /140.,141.5,142.5,144.,145.5,147.,148.5,151.,153.5,
     1156.,159.,162.5,167.,172.,177.5,185.,193.5,210.,218.5,230.,239.,
     2249.,263.,280.,297.2,339.,370./
      DATA ZKODT /0.,4.91,10.,15.4,21.1,27.2,33.4,40.4,47.7,55.6,64.4,
     174.1,85.3,97.6,111.8,129.,149.,181.,193.,208.,218.,230.,244.,264.,
     2283.,326.,359./
      DATA RTDT /2.14,2.075,2.020,1.962,1.9,1.841,1.78,1.715,1.655,1.59,
     11.52,1.455,1.385,1.31,1.235,1.16,1.084,.993,.993,.993,.993,.993,
     2.993,.993,.993,.993,.993/
      DATA RNDT /0.,.05,.1,.15,.2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,
     1.75,.8,.86,.88,.9,.91,.92,.93,.94,.95,.96,.97/
      ZKOFL=359.0
      NDATA=27
      L=0
      IF(IOFF)10,10,11
   10 GEARI=2.46
      GEAR1=2.46
      GEAR2=1.46
      GEAR3=1.0
      EFFI=.20
      EFF1=.66
      EFF2=.77
      EFF3=.82
      EFFGI=.94
      EFFG1=.94
      EFFG2=.96
      EFFG3=.98
      DIFFR=3.5
      TIRED=2.2
      EFTBX=.98
      GEARR=GEAR3
      EFFR=EFF3
      EFFRG=EFFG3
    9 TRPMO=(CRMPH*88.*DIFFR)/(3.1416*TIRED)
      ZNO=TRPMO*GEARR
      EFFLL=.0
      EFFUL=1.0
      EFFG=EFFR
      NTER=0
   35 PRENG=APOWR/EFFR/EFTBX
      TOG=(PRENG*63025.)/ZNO/12.0
      TGLL=0.
      TGUL=1.1*TOG
      ITER=0
   30 ZKO=ZNO/(TOG**.5)
      IF(ZKO-ZKOFL)500,500,600
  500 CONTINUE
      CALL INTPL(NDATA,4,ZKODT,RNDT,ZKO,RN,INIT,KR)
      CALL INTPL(NDATA,4,RNDT,RTDT,RN,RT,INIT,KR)
      CALL INTPL(NDATA,4,RNDT,ZKIDT,RN,ZKI,INIT,KR)
      TI=TOG/RT
      ZNI=ZKI*(TI**.5)
      GO TO 601
  600 TI=TOG
      ZNI=ZNO
```

```
601 CONTINUE
    PENGT=(TI*12.0*ZNI)/63025./EFTBX
412 FORMAT('0  TRPMO        ZNO        PRENG        TOG          RN
   1  RT         ZKI'/7E11.3)
413 FORMAT('0     TI         ZNI        PENGT'/3E11.3)
    IF(ABS(1.-PENGT/PRENG)-.001)19,19,21
 21 CALL CNVRG(TOG,TOLL,TOUL,PENGT,PRENG,ITER,DUM1,DUM2,IO)
    IF(ITER-30)30,30,31
 31 WRITE(IO,310)
310 FORMAT('0 ITERATION TROUBLE IN SUBROUTINE SHIFT')
    WRITE(IO,311)TOG,TOLL,TOUL,PENGT,PRENG,IOFFT
311 FORMAT('0    TOG         TOLL       TOUL        PENGT       PRENG
   1IOFFT'/5E11.3,1I7)
    L=1
    RETURN
 19 TRQPI=TI*12.*ZNI/63025.
    TRQPO=TOG*12.0*ZNO/63025.
    EFFR1=TRQPO/TRQPI*EFFRG
    IF(ABS(1.-EFFR1/EFFR)-.001)20,20,18
 18 CALL CNVRG(EFFG,EFFLL,EFFUL,EFFR1,EFFR,NTER,DUM3,DUM4,IO)
    EFFR=EFFG
    IF(NTER-30)35,35,36
 36 WRITE(IO,320)
320 FORMAT('0 ITERATION TROUBLE IN SUBROUTINE SHIFT ON TRANSMISSION EF
   1F.')
    WRITE(IO,321)EFFR,EFFLL,EFFUL,EFFR1,TRQPI,TRQPO,IOFFT
321 FORMAT('0    EFFR       EFFLL       EFFUL       EFFR1       TRQPI
   1TRQPO       IOFFT'/6E11.3,1I7)
    L=1
    RETURN
 20 IF(IOFF)22,22,41
 22 TBGXR=AN/ZNI
    EFFTR=EFFR
    IOFFT=1
    RETURN
 41 AN=ZNI*TBGXR
    IF(IOFFT-1)71,71,72
 71 AN1=AN
    PENG1=PRENG
    EFFT1=EFFR
    EFFTR=EFFT1
    IOFFT=2
    IF(AN-2000.)501,501,551
501 RETURN
551 EFTB=0.
    GO TO 3
 72 IF(IOFFT-2)73,73,74
 73 AN2=AN
    PENG2=PRENG
    EFFT2=EFFR
    EFFTR=EFFT2
    IOFFT=3
    IF(AN-2000.)502,502,552
502 RETURN
552 EFTB=0.
    GO TO 5
 74 IF(IOFFT-3)75,75,76
 75 AN3=AN
    PENG3=PRENG
    EFFT3=EFFR
    EFFTR=EFFT3
```

```
      ICFFT=4
   76 EFFTR=EFFR
      RETURN
   11 IF(ICFFT-1)1,1,2
    1 GEARR=GEAR1
      EFFR=EFF1
      EFFRG=EFFG1
      GO TO 9
    2 IF(ICFFT-2)3,3,4
    3 GEARR=GEAR2
      EFFR=EFF2
      EFFRG=EFFG2
      SEL1=EFFT1*EFTB
      GO TO 9
    4 IF(ICFFT-3)5,5,6
    5 GEARR=GEAR3
      EFFR= EFF3
      EFFRG=EFFG3
      SEL2=EFFT2*EFTB
      GO TO 9
    6 IF(ICFFT-4)7,7,8
    7 SEL3=EFFT3*EFTB
      IF(SEL1-SEL2)50,51,51
   50 IF(SEL2-SEL3)53,54,54
   51 IF(SEL1-SEL3)53,57,57
   54 AN=AN2
      PRENG=PENG2
      GEARR=GEAR2
      EFFTR=EFFT2
      ICFFT=5
      RETURN
   53 AN=AN3
      PRENG=PENG3
      GEARR=GEAR3
      EFFTR=EFFT3
      ICFFT=5
      RETURN
   57 AN=AN1
      PRENG=PENG1
      GEARR=GEAR1
      EFFTR=EFFT1
      ICFFT=5
      RETURN
    8 GEARR=GEAR1
      EFFR=EFF1
      EFFRG=EFFG1
      GO TO 9
      END
```

APPENDIX G

SUBROUTINE "RAMAR"

```
      SUBROUTINE RAMAR(IRMAR,CFANP,CONPW,TAIN,DPAIR,WAIR,QREJD,CCA,CZL,
     1CCTOT,APWRD,CMPHD,APWR,CMPH,IOFF,IO,RAMHP)
C
C     CONDENSER RAM AIR MODIFICATION SUBROUTINE FOR AUTOMOBILE APPLICATION
C
      DIMENSION TMPH(10),TMBTU(10),TFANP(10),TFLOW(10)
      DIMENSION TMPHF(10),FMBTU(10),FANPF(10),FLOWF(10)
      DATA TMPH /0.,10.,20.,30.,40.,50.,60.,70.,80./
      DATA TMBTU /.067,.067,.1,.14,.204,.29,.402,.576,.77/
      DATA TFANP /.01,.01,.08,.04,.07,.15,.32,.73,1.47/
      DATA TFLOW /4903.,4903.,8988.,8795.,14281.,19634.,24980.,32180.,
     140000./
      DATA TMPHF /0.,10.,21.3,31.,35.,39.,47.,54.,60.,70./
      DATA FMBTU /1.755,1.755,1.845,1.845,1.847,1.853,1.857,1.859,1.862,
     11.874/
      DATA FANPF /9.85,9.85,13.41,15.94,17.4,13.02,13.99,15.02,15.96,
     112.73/
      DATA FLOWF /46507.,46507.,54126.,60050.,62628.,55736.,59239.,
     162350.,64660.,61264. /
      JDATA=10
      NDATA=9
      IF(IOFF)20,20,21
   20 APWRO=APWRD
      CRMPH=CMPHD
      GO TO 23
   21 APWRO=APWR
      CRMPH=CMPH
   23 IF(IRMAR)10,10,11
   10 CALL INTPL(NDATA,4,TMPH,TMBTU,CRMPH,BTUMT,INIT,KR)
      CALL INTPL(NDATA,4,TMPH,TFLOW,CRMPH,FLOWT,INIT,KR)
      CALL INTPL(NDATA,4,TMPH,TFANP,CRMPH,FANPT,INIT,KR)
      CP=.240
      DTT=FLOWT*CP/BTUMT/1.E6
      TINT=TAIN
      TAVGT=TINT+DTT/2.
      PINT=14.69*144.
      FLOTM=72800.
      DPTM=.264*144.
      DPT=DPTM*(FLOWT/FLOTM)**2
      PAVGT=PINT+DPT/2.
      R=53.34
      RHOT=PAVGT/R/(TAVGT+460.)
      RHPT1=FLOWT*DPT/RHOT/550./3600.-.6*FANPT
      CFNT1=FANPT
      FLOCM=75300.
      DPTCM=.148*144.
      DPTC=DPTCM*(FLOWT/FLOCM)**2
      CNPW1=FLOWT*DPTC/RHOT/550./3600.
      CALL INTPL(JDATA,4,TMPHF,FMBTU,CRMPH,BTUTF,INIT,KR)
      CALL INTPL(JDATA,4,TMPHF,FLOWF,CRMPH,FLWTF,INIT,KR)
      CALL INTPL(JDATA,4,TMPHF,FANPF,CRMPH,FNPTF,INIT,KR)
      DTTF=FLWTF*CP/BTUTF/1.E6
      TAVTF=TINT+DTTF/2.
      DPTF=DPTM*(FLWTF/FLOTM)**2
      PAVTF=PINT+DPTF/2.
      RHOTF=PAVTF/R/(TAVTF+460.)
      RHPT2=FLWTF*DPTF/RHOTF/550./3600.-.6*FNPTF
      CFNT2=FNPTF
      DPTCF=DPTCM*(FLWTF/FLOCM)**2
      CNPW2=FLWTF*DPTCF/RHOTF/550./3600.
      CFANP=CFNT1+(CFNT2-CFNT1)*APWRO/APWRD
```

```
      RAMHP=RHPT1+(RHPT2-RHPT1)*APWRO/APWRD
      IF(RAMHP)40,41,41
   40 RAMHP=0.
   41 CONTINUE
      CONPW=CNPW1+(CNPW2-CNPW1)*APWRO/APWRD
  112 FORMAT('0  RHPT1       CFNT1       RHPT2       CFNT2       CFANP
     1RAMHP       CONPW       CNPW1       CNPW2'/9E11.3)
      CFANP=CFANP*.746
      CONPW=CONPW*.746
      IRMAR=1
      RETURN
   11 ZLT=4.2/12.
      ZLD=CCTOT
      AD=CCA*CZL
      AT=1192.7/144.
      TIND=TAIN
      FLOWD=WAIR*3600.
      DTD=FLOWD*CP/QREJD
      TAVGD=TIND+DTD/2.
      PIND=14.69*144.
      DPD=DPAIR*144.
      PAVGD=PIND+DPD/2.
      RHOD=PAVGD/R/(TAVGD+460.)
      RMHPD=RAMHP*((ZLT/ZLD)*(AD/AT)*(RHOD/RHOT)*(.148/.264)+((.264-.148
     1)/.264))
      DPTOT=DPTM*(FLOWD/FLOTM)**2-DPTCM*(FLOWD/FLOCM)**2+DPD
      TOTPW=FLOWD*DPTOT/RHOD/550./3600.
      CFANP=(TOTPW-RMHPD)/.6
      IF(CFANP)30,31,31
   30 CFANP=0.
   31 CONTINUE
      RAMHP=RMHPD
  113 FORMAT('0  RMHPD       CFANP        DPTC        TOTPW       DPTOT'/5E11
     1.3)
  110 FORMAT('0    DPD         ZLT         FLOWT        RHOD         AD
     1  ZLD        FLOWD'/7E11.3)
  111 FORMAT('0    RHOT         AT         FANPT       FLWTF       RHOTF
     1FNPTF'/6E11.3)
      IRMAR=0
      CFANP=CFANP*.746
      RETURN
      END
```

APPENDIX H

RECIPROCATOR PROGRAM

```
C
C      RECIPROCATOR MODEL FOR SYSTEM DESIGN OPTIMIZATION PROGRAM
C
       COMMON IR,IO,GRAV,PI
       COMMON PSH(100),NP(99),NPP,TSH(2500),HSH(2500),SSH(2500),VSH(2500)
       COMMON PSC(100),NPSC(99),NPSCP,TSC(1000),HSC(1000),VSC(1000),
      1SSC(1000)
       COMMON PL(100),NPL(99),NPPL,TL(1000),HL(1000),VL(1000)
       COMMON TTV(100),ZMTV(100),ZKTV(100),TTL(100),ZMTL(100),ZKTL(100)
       IRCIP=0
       NCLPW=0
       PINSV=PIN
       CLENG=PCTCL*STROK
       ELENG=CLENG+STROK-PCTRP*STROK
       RODLG=RDXSK*STROK
       SPIST=2.0*STROK*RPM
       IF(MODE)210,213,210
  210  CIANG=0.
       MCLPW=0
       PINLL=PEX
       PINUL=PIN
       INTPI=0
       GO TO 182
  212  ANGLL=0.0
       ANGUL=180.0
       CIANG=45.
       MCLPW=1
       INTRT=0
       GO TO 182
  213  BORLL=0.0
       BORUL=3.0*STROK
       BORE=STROK
       INTRS=0
  182  IF(PCR-PIN)910,910,911
  910  CALL D3NTP(VIN,TIN,PIN,TSC,VSC)
       CALL D3NTP(HIN,TIN,PIN,TSC,HSC)
       CALL D3NTP(SIIN,TIN,PIN,TSC,SSC)
       GO TO 912
  911  CALL D2NTP(VIN,TIN,PIN,TSH,VSH)
       CALL D2NTP(HIN,TIN,PIN,TSH,HSH)
       CALL D2NTP(SIIN,TIN,PIN,TSH,SSH)
  912  CONTINUE
   58  APIST=(3.14*(BORE**2))/4.0
       AINTV=APIST/5.0
       AEXHV=APIST/5.0
   80  VLENG=(STROK/2.0)*(1.0-COS(6.28*(CIANG/360.0)))+RODLG-(0.5*((4.0*(
      1RODLG**2)-(STROK**2)*((SIN(6.28*(CIANG/360.0)))**2))**0.5))
       FLOWV=(RPM/60.)*(VLENG+CLENG)*APIST
       DPIV=(FLOWV**2)/(2.0*32.2*VIN*((C*AINTV)**2)*144.)
       P1=PIN-2.0*DPIV
       H1=HIN
       SEXS=SIIN
       IF(PCR-P1)920,920,921
  920  CALL D3NTP(S1,H1,P1,HSC,SSC)
       CALL D3NTP(V1,S1,P1,SSC,VSC)
       GO TO 922
  921  CALL D2NTP(S1,H1,P1,HSH,SSH)
       CALL D2NTP(V1,S1,P1,SSH,VSH)
  922  CONTINUE
       IF(PCR-PEX)930,930,931
  930  CALL D3NTP(HEXS,SEXS,PEX,SSC,HSC)
```

```
      CALL D3NTP(HEXVI,S1,PEX,SSC,HSC)
      GO TO 932
  931 CALL D2NTP(HEXS,SEXS,PEX,SSH,HSH)
      CALL D2NTP(HEXVI,S1,PEX,SSH,HSH)
  932 CONTINUE
      DHT=HIN-HEXS
      HVDHT=(DHT-(H1-HEXVI))/DHT
      EXPRT=ELENG/(CLENG+VLENG)
      V2=V1*EXPRT
      S2S=S1
      P2GS=P1/EXPRT
      P2GSL=.7*P2GS
      P2SLL=P2GS*.675*60./(CIANG+.1)
      IF(P2SLL-P2GSL)88,88,89
   89 P2SLL=P2GSL
   88 CONTINUE
      P2SUL=PIN
      IF(NCLPW)250,250,251
  251 P2SLL=.5*P2GS
      P2SUL=2.*P2GS
  250 CONTINUE
      INTRU=0
   33 IF(PCR-P2GS)940,940,941
  940 CALL D3NTP(H2S,V2,P2GS,VSC,HSC)
      CALL D3NTP(H2S1,S2S,P2GS,SSC,HSC)
      GO TO 942
  941 CALL D2NTP(H2S,V2,P2GS,VSH,HSH)
      CALL D2NTP(H2S1,S2S,P2GS,SSH,HSH)
  942 CONTINUE
      IF(ABS(1.0-(H2S/H2S1))-.0005)31,31,32
   32 CALL CNVRG(P2GS,P2SLL,P2SUL,H2S,H2S1,INTRU,SO7,SO8,IWO)
      IF(INTRU-30)33,33,34
   34 WRITE(IWO,2308)
 2308 FORMAT('0ITERATION TROUBLE ON ISENTROPIC RELEASE ENTHALPY - STAT 3
     12')
      WRITE(IWO,2309)P2GS,P2SLL,P2SUL,H2S,H2S1
 2309 FORMAT('0    P2GS       P2SLL       P2SUL        H2S         H2S1'/5E11
     1.3)
      GO TO 66
   31 H2LL=.9*HEXS
      H2UL=H2S
      H2=(H2S+HEXS)/2.0
      DUMH2=H2
      INTRP=0
   47 P2G=P2GS
      P2GTL=.85*P2G
      P2LL=P2G*.675*60./(CIANG+.1)
      IF(P2LL-P2GTL)85,85,86
   86 P2LL=P2GTL
   85 CONTINUE
      P2UL=PIN
      IF(NCLPW)260,260,261
  261 P2LL=.5*P2G
      P2UL=2.*P2G
  260 CONTINUE
      INTRV=0
  133 IF(PCR-P2G)950,950,951
  950 CALL D3NTP(T2,V2,P2G,VSC,TSC)
      CALL D3NTP(T21,H2,P2G,HSC,TSC)
      GO TO 952
  951 CALL D2NTP(T2,V2,P2G,VSH,TSH)
```

```
      CALL D2NTP(T21,H2,P2G,HSH,TSH)
  952 CONTINUE
      IF(ABS(1.0-(T2/T21))-.0005)131,131,132
  132 CALL CNVRG(P2G,P2LL,P2UL,T2,T21,INTRV,SO9,SO10,IWO)
      IF(INTRV-30)133,133,134
  134 WRITE(IWO,2318)
 2318 FORMAT('0ITERATION TROUBLE ON GAS TEMP FOR CYL HEAT LOSS - STAT 13
     12')
      WRITE(IWO,2319)P2G,P2LL,P2UL,T2,T21
 2319 FORMAT('0   P2G         P2LL        P2UL         T2         T21'/5E11.
     13)
      H2=H2S
      P2G=P2GS
      GO TO 44
  131 TG=TIN*(VIN/V2)+(((V2-VIN)/(2.0*V2))*(TIN+T2))
      TW=465.+181.*(VIN/V2)**2
      CALL INTPL(NTV,4,TTV,ZKTV,TG,CNDUC,INIT,KR)
      CALL INTPL(NTV,4,TTV,ZMTV,TG,VSCOS,INIT,KR)
      VSCOS=VSCOS*3600.
      QHT=0.26*((CNDUC*V2)/(BORE*SPIST*60.0))*(((BORE*SPIST*60.0)/(V2*VS
     1CCS))**0.75)*(TG-TW)
      H2T=H2S-QHT
      IF(ABS(1.0-(H2/H2T))-.0005)44,44,45
   45 CALL CNVRG(DUMH2,H2LL,H2UL,H2,H2T,INTRP,SO1,SO2,IWO)
      H2=DUMH2
      IF(INTRP-30)47,47,46
   46 WRITE(IWO,2009)H2,H2T
 2009 FORMAT('0ITERATION TROUBLE ON RELEASE ENTHALPY'/'0H2 =',1E11.3,'
     1H2T =',1E11.3)
      H2=H2S
      P2G=P2GS
   44 P2=P2G
      H3=H2+V2*(PEX-P2)*144./778.
      IF(PCR-PEX)960,960,961
  960 CALL D3NTP(V3,H3,PEX,HSC,VSC)
      GO TO 962
  961 CALL D2NTP(V3,H3,PEX,HSH,VSH)
  962 CONTINUE
      DPEXV=(((3.14*STROK*RPM)**2)*(BORE**4))/(2.0*32.2*V3*((60.0*4.0*C*
     1AEXHV)**2)*144.)
      P3EXV=PEX+DPEXV
      IF(PCR-P3EXV)970,970,971
  970 CALL D3NTP(H3EXV,V3,P3EXV,VSC,HSC)
      GO TO 972
  971 CALL D2NTP(H3EXV,V3,P3EXV,VSH,HSH)
  972 CONTINUE
      H3EXF=((H3EXV-H3)*V1*(STROK-PCTRP*STROK+CLENG))/(V3*(VLENG+CLENG))
     1+H3
      EXHDH=(H3EXF-H3)/DHT
      ZNV=1.0-HVDHT-EXHDH
      PMI=((778.0*(H1-H2))/V2/144.)+P2-PEX
      ZNM=1.-(SPIST*(174./PMI+1.6)*.00001)-(5.46/PMI)-.012
      ZNT=(H1-QHT-H2+((P2*144.*V2)/778.0)*(1.0-PEX/P2))/(H1-HEXVI)
      ZNE=ZNV*ZNM*ZNT
      HP1=(ZNM*PMI*144.*CYLNO*3.14*(BORE**2)*RPM*(ELENG-CLENG))/(4.0*60.
     10*550.0)
      ZNEH=(HIN-QHT-H3EXF)/(HIN-HEXS)
      ZNEHM=ZNEH*ZNM
      IF(MODE)10,10,11
   10 IF(ABS(1.0-(HP1/HP))-.0010)55,55,56
   56 CALL CNVRG(BORE,BORLL,BORUL,HP1,HP,INTRS,SO3,SO4,IWO)
```

```
      IF(INTRS-30)58,58,57
   57 BCRE=BCRE*12.0
      WRITE(IWO,2109)BORE,HP1,HP
 2109 FORMAT('0ITERATION TROUBLE ON BORE DIAMETER'/'0BORE =',1E11.3,'  H
     1P1 =',1E11.3,'  HP =',1E11.3)
      BCRE=BCRE/12.0
      GO TO 66
   55 GO TO 77
   11 IF(MCLPW)178,184,178
  184 IF(NCLPW)179,185,179
  185 NCLPW=1
      IF(HP-HP1)179,179,212
  179 IF(ABS(1.0-(HP1/HP))-.0010)77,77,181
  181 CALL CNVRG(PIN,PINLL,PINUL,HP1,HP,INTPI,SO13,SO14,IWO)
      IF(INTPI-30)182,182,183
  183 WRITE(IWO,2228)
 2228 FORMAT('0ITERATION TROUBLE IN OFF DESIGN INLET PRESSURE      STAT 18
     11')
      WRITE(IWO,2229)PIN,PINLL,PINUL,HP1,HP
 2229 FORMAT('0    PIN         PINLL       PINUL         HP1          HP'/5E11.
     13)
      GO TO 66
  178 IF(ABS(1.0-(HP1/HP))-.0010)77,77,78
   78 CALL CNVRG(CIANG,ANGLL,ANGUL,HP1,HP,INTRT,SO5,SO6,IWO)
      IF(INTRT-30)80,80,79
   79 WRITE(IWO,2209)CIANG,HP1,HP
 2209 FORMAT('0ITERATION TROUBLE ON CRANK INTAKE ANGLE'/'0CIANG =',1E11.
     13,'  HP1 =',1E11.3,'  HP =',1E11.3)
      GO TO 66
   77 WFLOW=(CYLNO*FLOWV)/V1
      PIN=PINSV
      RETURN
   66 IRCIP=1
      RETURN
      END
```

APPENDIX I

SUBROUTINE "WEXPD"

```
      SUBROUTINE WEXPD(CYLNO,RODLG,PMI,BORE,WTCRU,VCRU,WS,IO)
C     RECIPROCATING EXPANDER
      WTCRU=CYLNO*.284*3.14*RODLG*((1.22*PMI/127.4*BORE/4.42)**2+2.*(BOR
     1E/2.*1.22*PMI/127.4*BORE/4.42))+73.*CYLNO/4.
      VCRUR=WTCRU/.284
C     FEED PUMP
      WTFDP=45.*WS/2.05
      VFDP=WTFDP/.284
C     GEAR AND ACCESSORY HOUSING
      V=300.0
      GHWT=.3*V
      VGHWT=V
  200 FORMAT('0  WTCRU      VCRUR        WTFDP        VFDP        GHWT
     1VGHWT'/6E11.3)
      WTCRU=WTCRU+WTFDP+GHWT
      VCRU=VCRUR+VFDP+VGHWT
      RETURN
      END
```

APPENDIX J

FEDERAL DRIVING CYCLE ANALYSIS

```
C
C      FEDERAL DRIVING CYCLE ANALYSIS FOR ORC AUTO ENGINE OPTIMIZATION
C
       DIMENSION TIME(1300),SMPH(1300)
       IRD=2
       IWO=3
       JS=1
       JF=4
    1  READ(IRD,1000)(TIME(K),SMPH(K),K=JS,JF)
 1000  FORMAT(8E10.0)
       JS=JS+4
       JF=JF+4
       IF(TIME(K))1,2,1
    2  CONTINUE
       WRITE(IWO,1090)
 1090  FORMAT('1')
   31  READ(IRD,1000)SPEDL,SPEDU,TTIME,WT
       WRITE(IWO,2001)SPEDL,SPEDU,TTIME,WT
 2001  FORMAT('0 SPEDL       SPEDU       TTIME         WT'/1E10.3,3E11.3)
       CDAF=12.0
       RHO=0.00238
       AIRFT=(CDAF*RHO)/2.0
       ACPHP=5.0
       TSPED=0.0
       A01=0.0
       A12=0.0
       A23=0.0
       A34=0.0
       A45=0.0
       A56=0.0
       A67=0.0
       A78=0.0
       A89=0.0
       A910=0.0
       TSPDN=0.0
       A01N=0.0
       A12N=0.0
       A23N=0.0
       A34N=0.0
       A45N=0.0
       A56N=0.0
       A67N=0.0
       A78N=0.0
       A89N=0.0
       A910N=0.0
       TSPDH=0.0
       HP10=0.0
       HP20=0.0
       HP30=0.0
       HP40=0.0
       HP50=0.0
       HP60=0.0
       HP70=0.0
       HP80=0.0
       HP90=0.0
       HP100=0.0
       HP110=0.0
       HP120=0.0
       HP130=0.0
       HP140=0.0
       TOTHP=0.0
```

```
      TTSPD=0.0
      I=0
   17 I=I+1
      SPEDI=SMPH(I)*(88.0/60.0)
      ACC=(SMPH(I+1)-SMPH(I))/(TIME(I+1)-TIME(I))
      STIME=0.0
   15 STIME=STIME+1.0
      IF((ABS((TIME(I)+STIME)-(TIME(I+1)+1.0)))-.01)17,17,16
   16 SPEED=SMPH(I)+ACC*STIME
      IF(SPEED-SPEDL)26,27,12
   12 IF(SPEED-SPEDU)13,13,26
   27 IF(SPEED)26,13,26
   13 IF(ACC)201,200,200
  200 TSPED=TSPED+1.0
      IF(ACC-1.0)51,51,71
   71 IF(ACC-2.0)52,52,72
   72 IF(ACC-3.0)53,53,73
   73 IF(ACC-4.0)54,54,74
   74 IF(ACC-5.0)55,55,75
   75 IF(ACC-6.0)56,56,76
   76 IF(ACC-7.0)57,57,77
   77 IF(ACC-8.0)58,58,78
   78 IF(ACC-9.0)59,59,60
   51 A01=A01+1.0
      GO TO 25
   52 A12=A12+1.0
      GO TO 25
   53 A23=A23+1.0
      GO TO 25
   54 A34=A34+1.0
      GO TO 25
   55 A45=A45+1.0
      GO TO 25
   56 A56=A56+1.0
      GO TO 25
   57 A67=A67+1.0
      GO TO 25
   58 A78=A78+1.0
      GO TO 25
   59 A89=A89+1.0
      GO TO 25
   60 A910=A910+1.0
      GO TO 25
  201 TSPDN=TSPDN+1.0
      IF(-ACC-1.0)151,151,171
  171 IF(-ACC-2.0)152,152,172
  172 IF(-ACC-3.0)153,153,173
  173 IF(-ACC-4.0)154,154,174
  174 IF(-ACC-5.0)155,155,175
  175 IF(-ACC-6.0)156,156,176
  176 IF(-ACC-7.0)157,157,177
  177 IF(-ACC-8.0)158,158,178
  178 IF(-ACC-9.0)159,159,160
  151 A01N=A01N+1.0
      GO TO 25
  152 A12N=A12N+1.0
      GO TO 25
  153 A23N=A23N+1.0
      GO TO 25
  154 A34N=A34N+1.0
      GO TO 25
```

```
155 A45N=A45N+1.0
    GO TO 25
156 A56N=A56N+1.0
    GO TO 25
157 A67N=A67N+1.0
    GO TO 25
158 A78N=A78N+1.0
    GO TO 25
159 A89N=A89N+1.0
    GO TO 25
160 A910N=A910N+1.0
 25 CONTINUE
    FSPED=SPEED*(88.0/60.0)
    RCLLR=(WT/65.0)*(1.0+(0.0014*FSPED)+(0.000012*(FSPED**2)))
    AIRDR=AIRFT*(FSPED**2)
    DRGHP=((RCLLR+AIRDR)*FSPED)/550.0
    SPEDF=FSPED
    ACCHP=(WT/(2.0*32.2*550.0))*((SPEDF**2)-(SPEDI**2))
    SPEDI=FSPED
    HP=((DRGHP+ACCHP)/(0.96*0.80))+ACPHP
    IF(HP-ACPHP)401,401,402
401 HP=ACPHP
402 CONTINUE
    TOTHP=TOTHP+HP
    TTSPD=TTSPD+SPEED
    TSPDH=TSPDH+1.0
    IF(HP-10.0)251,251,271
271 IF(HP-20.0)252,252,272
272 IF(HP-30.0)253,253,273
273 IF(HP-40.0)254,254,274
274 IF(HP-50.0)255,255,275
275 IF(HP-60.0)256,256,276
276 IF(HP-70.0)257,257,277
277 IF(HP-80.0)258,258,278
278 IF(HP-90.0)259,259,279
279 IF(HP-100.0)260,260,280
280 IF(HP-110.0)261,261,281
281 IF(HP-120.0)262,262,282
282 IF(HP-130.0)263,263,283
251 HP10=HP10+1.0
    GO TO 26
252 HP20=HP20+1.0
    GO TO 26
253 HP30=HP30+1.0
    GO TO 26
254 HP40=HP40+1.0
    GO TO 26
255 HP50=HP50+1.0
    GO TO 26
256 HP60=HP60+1.0
    GO TO 26
257 HP70=HP70+1.0
    GO TO 26
258 HP80=HP80+1.0
    GO TO 26
259 HP90=HP90+1.0
    GO TO 26
260 HP100=HP100+1.0
    GO TO 26
261 HP110=HP110+1.0
    GO TO 26
```

```
 262 HP120=HP120+1.0
     GO TO 26
 263 HP130=HP130+1.0
     GO TO 26
 283 HP140=HP140+1.0
  26 IF((ABS((TIME(I)+STIME)-TTIME))-.01)30,30,15
  30 WRITE(IWO,2002)TSPED,A01,A12,A23,A34,A45,A56,A67,A78,A89,A910
2002 FORMAT('0 TSPED        A01         A12         A23         A34
    1A45         A56         A67         A78         A89         A910'/1E10.
    23,10E11.3,//)
     WRITE(IWO,2012)TSPDN,A01N,A12N,A23N,A34N,A45N,A56N,A67N,A78N,A89N,
    1A910N
2012 FORMAT('0 TSPDN        A01N        A12N        A23N        A34N
    1A45N        A56N        A67N        A78N        A89N        A910N'/1E10
    2.3,10E11.3,//)
     AVGHP=TOTHP/TSPDH
     AVGSP=TTSPD/TSPDH
     WRITE(IWO,2022)TSPDH,HP10,HP20,HP30,HP40,HP50,HP60,HP70,HP80,HP90,
    1HP100,HP110,HP120,HP130,HP140,AVGHP,AVGSP
2022 FORMAT('0 TSPDH        HP10        HP20        HP30        HP40
    1HP50        HP60        HP70        HP80        HP90       HP100'/1E10.
    23,10E11.3,/'0 HP110       HP120       HP130       HP140       AVGHP
    3   AVGSP'/1E10.3,5E11.3,//////)
     GO TO 31
     END
```

SPEDL	SPEDU	TTIME	WT
0.500E 02	0.600E 02	0.137E 04	0.460E 04

TSPED	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.410E 02	0.400E 02	0.100E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.310E 02	0.300E 02	0.100E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.720E 02	0.400E 01	0.500E 01	0.130E 02	0.140E 02	0.190E 02	0.120E 02	0.300E 01	0.200E 01	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.380E 02	0.538E 02

SPEDL	SPEDU	TTIME	WT
0.600E 02	0.700E 02	0.137E 04	0.460E 04

TSPED	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

SPEDL	SPEDU	TTIME	WT
0.700E 02	0.800E 02	0.137E 04	0.460E 04

TSPED	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N

SPEDL	SPEDU	TTIME	WT
0.000E 00	0.100E 02	0.137E 04	0.460E 04

TSPBD	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.317E 03	0.262E 03	0.220E 02	0.140E 02	0.120E 02	0.400E 01	0.300E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.910E 02	0.220E 02	0.220E 02	0.150E 02	0.200E 02	0.700E 01	0.400E 01	0.000E 00	0.100E 01	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.408E 03	0.369E 03	0.260E 02	0.100E 02	0.300E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.643E 01	0.174E 01

SPEDL	SPEDU	TTIME	WT
0.100E 02	0.200E 02	0.137E 04	0.460E 04

TSPBD	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.120E 03	0.390E 02	0.390E 02	0.270E 02	0.110E 02	0.400E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.930E 02	0.230E 02	0.250E 02	0.210E 02	0.160E 02	0.500E 01	0.300E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.213E 03	0.100E 03	0.240E 02	0.420E 02	0.340E 02	0.100E 02	0.300E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.175E 02	0.159E 02

SPEDL	SPEDU	TTIME	WT
0.200E 02	0.300E 02	0.137E 04	0.460E 04

TSPED	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.314E 03	0.255E 03	0.480E 02	0.100E 02	0.100E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N

0.203E 03 0.160E 03 0.220E 02 0.170E 02 0.300E 01 0.100E 01 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.517E 03	0.143E 03	0.204E 03	0.990E 02	0.460E 02	0.180E 02	0.500E 01	0.100E 01	0.100E 01	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.174E 02	0.251E 02

SPEDL	SPEDU	TTIME	WT
0.300E 02	0.400E 02	0.137E 04	0.460E 04

TSPBD	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.730E 02	0.620E 02	0.700E 01	0.200E 01	0.200E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.470E 02	0.380E 02	0.700E 01	0.100E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.100E 01

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.120E 03	0.250E 02	0.480E 02	0.230E 02	0.120E 02	0.400E 01	0.300E 01	0.200E 01	0.100E 01	0.100E 01	0.100E 01

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.220E 02	0.336E 02

SPEDL	SPEDU	TTIME	WT
0.400E 02	0.500E 02	0.137E 04	0.460E 04

TSPED	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.220E 02	0.180E 02	0.400E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.170E 02	0.120E 02	0.500E 01	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.390E 02	0.700E 01	0.200E 01	0.150E 02	0.300E 01	0.300E 01	0.500E 01	0.300E 01	0.100E 01	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.322E 02	0.468E 02

0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00 0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

SPEDL	SPEDU	TTIME	WT
0.800E 02	0.900E 02	0.137E 04	0.460E 04

TSPBD	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

SPEDL	SPEDU	TTIME	WT
0.900E 02	0.100E 03	0.137E 04	0.460E 04

TSPBD	A01	A12	A23	A34	A45	A56	A67	A78	A89	A910
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDN	A01N	A12N	A23N	A34N	A45N	A56N	A67N	A78N	A89N	A910N
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TSPDH	HP10	HP20	HP30	HP40	HP50	HP60	HP70	HP80	HP90	HP100
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

HP110	HP120	HP130	HP140	AVGHP	AVGSP
0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
APTD - 1566		

4. TITLE AND SUBTITLE	5. REPORT DATE
Optimum Working Fluids for Automotive Rankine Engines Volume IV - Engine Design Optimization	June 1973 6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
F. Sindermann	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Sunstrand Aviation 4747 Harrison Ave. Rockford, Illinois 61101	11. CONTRACT/GRANT NO. 68 - 04 - 0030

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
.S. ENVIRONMENTAL PROTECTION AGENCY ffice of Mobile Source Air Pollution Control dvanced Automotive Power Systems Development Division nn Arbor, Michigan 48105	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT Optimum system designs were determined for two turbine engines operating on C-1 and one reciprocating engine operating on RC-2 fluid. A Rankine cycle engine ptimization computer program was utilized. RC-1 fluid was a mixture containing 60 Mol , pentafluorobenzene and 40 Mol% hexaflurorbenzene. RC-2 fluid was a mixture containing 5 Mol% water and 35 Mol% 2-methylpyridine. The principal results of the analysis are redictions of engine size, weight and efficiency (vehicle miles per gallon) Computions leading to these optimum designs took into account five different steady-state oad points to represent typical driving conditions. Each optimization was carried out nder a number of fixed constraints selected to ensure a practical system. Five new omputer program subroutines were developed to describe the performance of (1) 3peed automatic transmission, (2) condenser ram air effects and (3) reciprocating xpander. It is concluded that both the RC-1 and RC-2 candidate fluids are appropriate or automotive size engines and are conducive to good efficiencies for automotive applications.

KEY WORDS AND DOCUMENT ANALYSIS

17. DESCRIPTORS	18. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Working Fluid	13 B
Rankine cycle	Mixed Fluorobenzenes	21 G
Engines	Aqueous Pyridines	21 E
Design		14 B
Turbines		7 C
Computer programs		
Reciprocating Engines		

DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO OF PAGES
Release Unlimited	Unclassified	107
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

A Form 2220-1 (9-73)