

AD-A144 798

COST EFFECTIVENESS OF 'NOLA' CONTROLLED MOTORS
INCLUDING EFFECT OF HIGHER HARMONICS(U) AIR FORCE INST
OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI..

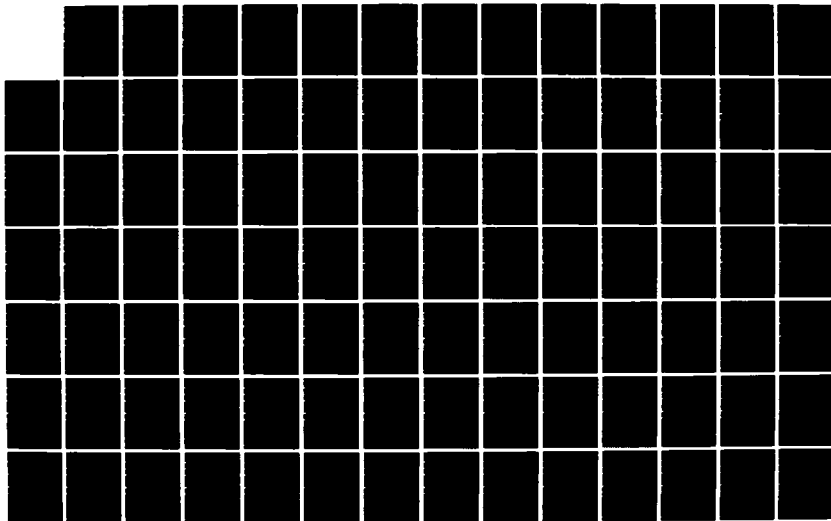
1/2

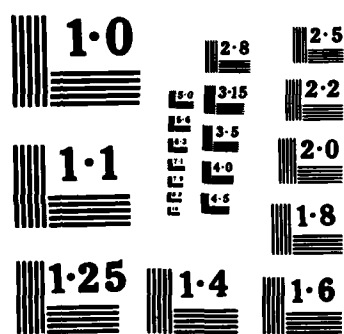
UNCLASSIFIED

R D MCMASTER DEC 80 AFIT/GE/EE/845-10

F/G 9/3

NL





AD-A144 798



RESEARCH MOTORS,
INDICATING EFFECT OF HIGHER HARMONICS

THESIS

E/EE/84S-10

Roy D. McMaster
Capt. USAF

DTIC FILE COPY

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

COST EFFECTIVENESS OF
"NOLA" CONTROLLED MOTORS,
INCLUDING EFFECT OF HIGHER HARMONICS

THESIS

AFIT/GE/EE/84S-10

Roy D. McMaster
Capt. USAF

Approved for public release; distribution unlimited.

800 13 104

A

COST EFFECTIVENESS OF
"NOLA" CONTROLLED MOTORS,
INCLUDING EFFECT OF HIGHER HARMONICS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University

In Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Roy D. McMaster

Capt. USAF

Graduate Electrical Engineer

December 1980



Approved for public release; distribution unlimited.

Preface

The Air Force has a need to conserve energy and to correct the power factor on electric motors. This need brought about a thesis topic. It was proposed that a graduate student do an economic analysis of the "NOLA" Power Factor Motor Controller and the effects the controller may have on the power circuits. A computerized motor and controller simulation would be used to produce the economic analysis and effects on the power circuit.

I chose this thesis topic because I have an undergraduate background in power systems and a desire to better understand these systems. In this thesis I develop a digital-analog simulation model for the motor and controller and implement them on the computer. The data from the simulation is used to make the economic analysis and to determine the effects on the power system.

I would like to thank Dr. Frederick Brockhurst for his guidance throughout all stages of the thesis effort. I would also like to thank my wife for transcribing the rough draft and for her tolerance of me during the preparation of this thesis.

Roy D. McMaster



Abstract

An economic analysis of the 'NOLA' Power Factor Motor Controller is accomplished and the effects of the harmonics produced by the controller are studied. The controller is placed in series with each leg of various sizes of wye-connected three-phase motors. The energy saved by the controller, the power factor correction, and the reflected harmonics under varying load conditions are studied to determine the economic advantages. Also the data from the controlled motor is compared to an energy efficient motor.

An analog-digital computer program is developed which models an induction motor and the 'NOLA' controller. The computer model is used to determine and analyze the reflected wave shape produced by the controller.

The results of the study indicates that the energy efficient motor is the most cost effective alternative at the present time because of the high initial cost of the "NOLA" controller. Continued studies are recommended to determine the effects of the higher harmonics.



Contents

	Page
Preface	i
Abstract	ii
List of Figures	v
List of Tables	viii
I. Introduction	1
Background	1
Approach	2
Assumptions	2
Sequence of Presentation	3
II. Computer Simulation of the "NOLA" Power Factor Controller	6
PFC Theory of Operation	6
Computer Simulation of PFC	7
III. Mesh Analysis of a Wye-Connected Induction Motor	12
Per-Phase Equivalent Circuit	12
Derivation of the Mesh Equations	12
Analog Configuration	14
IV. Analog-Digital Simulation of the Induction Motor and Controller	17
Computation of Equivalent Circuit Values	17
Alpha Angles	17
Analog Digital Integration	17
Computation of Harmonic Content of the Reflected Current	18
V. Cost Analysis of Controller Motor	20
VI. Conclusion and Recommendations	30
Conclusions	30
Recommendations	30
Bibliography	32
Appendix A: Digital Program to Determine Motor Element Values And The ALPHA Values for Controlled State	33
List of Input Variables	34
Appendix B: Tables of Input/Output Data for Motor Element and ALPHA Values	41
Appendix C: Analog-Digital Simulation Computer Program	50
List of Input Variables	51

Appendix D:	Figures of Reflective Waves	
	of the Controlled Motors	70
	5 Horse Power Energy Efficient Motor . .	71
	5 Horse Power Standard Motor	80
	10 Horse Power Energy Efficient Motor .	89
	10 Horse Power Standard Motor	94
Appendix E:	Representation of the Harmonics Data	
	From a Fast Fourier Transform	
	of the Reflected Motor Current	102
Appendix F:	Calculations and Tables Showing	
	Cost Comparisons	123
	Calculations for 5 HP Motors	124
	Tables Showing Cost Comparisons	
	for 5 Horse Power Motor	131
	Tables showing Cost Comparisons	
	For 10 Horse Power Motor	141
Appendix G:	Tables Showing Comparisons of	
	Actual Motor Data and Simulated Data . .	151
Vita		156

List Of Figures

Figures	Page
1. PFC Percent Savings Versus Torque Various Motors.	5
2. PFC Block, Diagonal and Wave Forms	9
3. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 0.95 . .	10
4. "Mini" Flow Chart for Subroutine V3CONT.	11
5. Per-Phases Equivalent Circuit.	13
6. Loop Equation Symbols.	14
7. Analog Integrating and Summing Elements.	15
8. Per Phase Analog Configuration for a Wye-Connected Induction Motor.	16
9. Mini Flow Chart of Computer Simulation	19
10. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 0.0.	72
11. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 0.3.	73
12. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 0.65	74
13. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 0.95	75
14. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 1.10	76
15. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 1.25	77
16. Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 1.55	78

17.	Reflected Voltage and Current Wave for 5 Horse Power Energy Efficient with ALPHA equal 1.75	79
18.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 0.0. . .	81
19.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 0.2. . .	82
20.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 0.55 . .	83
21.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 0.8. . .	84
22.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 1.0. . .	85
23.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 1.15 . .	86
24.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA Equal 1.45 . .	87
25.	Reflected Voltage and Current Wave for 5 Horse Power Standard with ALPHA equal 1.7. . .	88
26.	Reflected Voltage and Current wave for 10 Horse Power Energy Efficient with ALPHA equal 0.0.	90
27.	Reflected Voltage and Current Wave for 10 Horse Power Energy Efficient with ALPHA Equal 0.45	91
28.	Reflected Voltage and Current Wave for 10 Horse Power Energy Efficient with ALPHA Equal 0.7.	92
29.	Reflected Voltage and Current Wave for 10 Horse Power Energy Efficient with ALPHA equal 1.05	93
30.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA equal 0.0.	95
31.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA equal 0.5.	96
32.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA	

	equal 0.7.	97
33.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA equal 1.05	98
34.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA equal 1.4.	99
35.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA equal 1.6.	100
36.	Reflected Voltage and Current Wave for 10 Horse Power Standard with ALPHA equal 1.9.	101

List Of Tables

Table	Page
A. 5 HP Wattage for (Situation).	24
B. 5 HP Savings/Year Based on \$0.06 KWH.	26
C. #1 5 HP Simple Payback.	27
D. 5 Horse Power Motor and Controller Comparisons. .	28
E. 10 Horse Power Motor and Controller Comparisons .	29
F. 5 HP Energy Efficient (A)	42
G. 5 HP Energy Efficient (B)	43
H. 5 HP Standard (A)	44
I. 5 HP Standard (B)	45
J. 10 HP Standard (A).	46
K. 10 HP Standard (B).	47
L. 10 HP Energy Efficient (A).	48
M. 10 HP Energy Efficient (B).	49
N. 5 Horse Power Motor and Controller Comparisons. .	132
O. 5 HP Savings/Year Based on \$0.06 KWH.	133
P. 5 HP Wattage for (Situation).	134
Q. #1 5 HP Simple Payback.	135
R. #2 5 HP Simple Payback.	136
S. #3 5 HP Simple Payback.	137
T. #4 5 HP Simple Payback.	138
U. #5 5 HP Simple Payback.	139
V. #6 5 HP Simple Payback.	140
W. 10 Horse Power Motor and Controller Comparisons .	142
X. 10 HP Savings/Year Based on \$0.06	143
Y. 10 HP wattage for (Situation)	144

Z.	#1 10 HP Simple Payback	145
AA.	#2 10 HP Simple Payback	146
BB.	#3 10 HP Simple Payback	147
CC.	#4 10 HP Simple Payback	148
DD.	#5 10 HP Simple Payback	149
EE.	#6 10 HP Simple Payback	150
FF.	5 Horse Power Energy Efficient.	151
GG.	5 Horse Power Standard.	152
HH.	10 Horse Power Energy Efficient	153
II.	10 Horse Power Standard	154

I. Introduction

Background

In the last few years the public and industrial interest has turned to conserving energy due to the increase in cost of a barrel of oil from about four dollars in the early 1970's to over thirty dollars in 1980. This increase in energy cost led to the invention and development of a power factor motor controller by Frank Nola, an aerospace engineer working at the National Aeronautics and Space Administration's Marshall Space Flight Center in Huntsville, Alabama.

"By interrupting the voltage applied to the motor during portions (Alpha electrical degrees) of each half cycle, the NOLA controller attempts to achieve an essentially constant power factor operation. This results in lower core and winding losses, improving the efficiency of the Machine." The power factor controller (PFC) has been tested on over 50 motors at the Marshall Space Flight Center and has shown energy savings ranging from 0 to 10 percent at rated load and up to 75 percent at no load (Ref. 1: 197). Typical percentage savings versus load for two 3-phase motors and a single phase motor are shown in figure 1 (Ref. 1: 197). Other hardware test results are illustrated in Reference 1; therefore, the purpose of this thesis was not to test the validity of the controller, but, rather, to conduct an economic analysis of the cost of using the controller with conventional induction motors versus the cost of using high

efficiency induction motors.

To conduct the economic analysis, it was necessary to have some way of obtaining real and reactive power consumption by the motor for a variety of load conditions, both with and without the NOLA controller. Therefore a computer model of the PFC and motor was developed and used to generate the data required to determine the economic advantages of using the PFC and it's effects on the power system.

A secondary objective was to investigate the nature of the harmonics impressed on the power system by the PFC.

Approach

The induction motor was modelled by an equivalent circuit and the mesh equations for the circuit were derived. The equations were put into a form suitable for solution on an analog computer and the analog computer was then simulated on a digital computer. This technique is here-after referred to as the analog-digital simulation. The motor was then coupled to the model for the PFC. Power requirements were obtained for a variety of operating conditions both with and without the controller for both conventional and energy efficient motors. These results were then used to conduct an economic analysis of each of the different possibilities.

Assumptions

The primary assumption underlying this approach is that

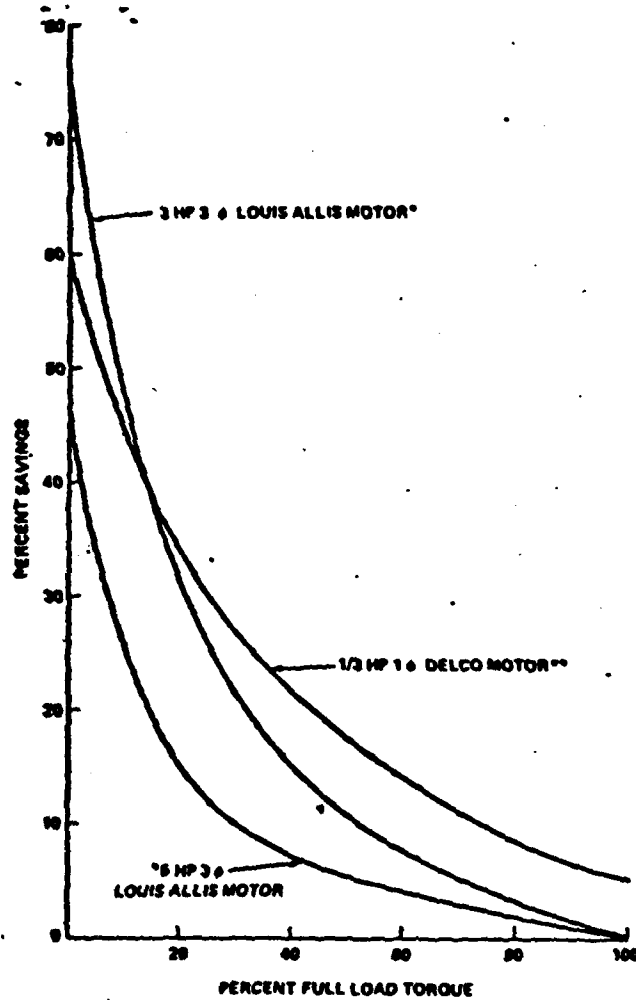
the computer simulation of PFC and induction motor provides reasonably accurate estimates of the real and reactive power requirements of the machine. Clearly the cost comparisons are only as valid as the data used to generate them. Fortunately, machine modeling techniques are well established and have been validated over the years. In addition, results obtained from the model compared closely to manufacturers' test results. The parameters used in the models were obtained from manufacturers' data. Additional assumptions regarding costs (motors, electricity, and controller) as well as period of operation were required to conduct the economic analysis. These are described in detail in Chapter V.

Sequence of Presentation

Chapter II describes the theory of operation of the PFC and how it was modelled in the computer program. Chapter III describes the equivalent circuit of the induction machine and presents a derivation of the equations required for the analog computer simulation of the machine. Chapter IV describes the over-all analog-digital simulation of the PFC and induction motor. Chapter V gives the assumptions and methods used to conduct the economic analysis. The final chapter contains conclusions and recommendations.

There are seven appendices. Appendix A contains the digital program to determine equivalent circuit parameter values and Alpha values for controlled states. Appendix B contains the tables listing the input/output data for motor

elements and Alpha values. Appendix C is the FORTRAN listing of the analog-digital simulation of the PFC and motor. Appendix D contains figures showing the reflected waves of the controlled motors. Appendix E presents a sampling of harmonic data from a Fast Fourier Transform. Appendix F contains the calculations and tables used in the economic analysis. Finally, Appendix G contains tables showing comparisons of actual motor data and the simulated data.



* DATA OBTAINED FROM AUBURN UNIVERSITY REPORT
 ** NASA/MARSHALL SPACE FLIGHT CENTER (MSFC) DATA

PFC percent savings versus torque
 for various motors.

Figure 1

II Computer Simulation of the "NOLA" Power Factor Controller

The "NOLA" Power Factor Controller, here after referred to as the PFC, is placed in series with each phase of a wye-connected three phase induction motor. The PFC corrects the power factor and reduces the power losses within the motor when the motor is operated at less than full load. Although the PFC is an electronic control system, it is modelled as an opened or closed switch (TRIAC) in Subroutine V3CONT.

This chapter begins with a brief discussion of the PFC's theory of operation as presented by the inventor. This is followed by how the PFC is modelled for computer simulation.

PFC Theory of Operation

The PFC is an electronic circuit that monitors and controls the terminal voltage and the phase angle, or power factor, of the current applied to the motor.

The PFC senses the line voltage and current and produces a voltage proportional to the phase angle between the two. This voltage is summed with a reference voltage that is indicative of a desired phase angle. The difference in these two voltages is an error voltage which, after conditioning, controls the turn-on or firing angle of a solid

state switch (TRIAC) that is in series with the motor (see Figure 2). The TRIAC is turned on for a portion of each half cycle as in a typical phase control circuit such as used in a light dimmer switch. This varies the applied voltage to the motor as a function of the load and forces the phase angle between voltage and current to remain constant, within the limits of the motor, at the commanded value regardless of changes in load. Thus, by controlling the magnitude of the motor terminal voltage to only that necessary to overcome torques attendant to less than fully loaded conditions, the losses associated with full line voltage are minimized (Ref 1:194).

Computer Simulation of PFC

As mentioned in the opening paragraph of this chapter, the PFC is modelled as an opened or closed switch which is switched open when the current approaches zero. The switch will stay open for a preset period of time which is called Alpha. Typical results of the switching action on the current and voltage are shown in Figure 3.

The logic of the 3-phase voltage controller, subroutine V3CONT, determines the correct position of the switch of each phase independently and is the same for each phase. Therefore, only one phase of the three-phase controller will be explained. A "Mini" flow chart for subroutine V3CONT is shown in Figure 4.

The logic for phase one is as follows: Check the position of the switch. If the switch is closed then see if the preset point counter value has been exceeded. If the point counter value has not been exceeded, then the controller will skip all other tests on phase one and will not change the position of the switch. The point counter test allows the current time to leave zero value once the switch is closed. If the preset counter value is exceeded then the magnitude of the current is sampled. If the current is less than one tenth of an ampere then the current is approaching a zero crossing and the switch will be opened for the preset time of Alpha. When the switch is opened the voltage and current are set to equal zero and the point counter is reset. The switch is closed then the above tests are repeated until another current zero crossing is sensed.

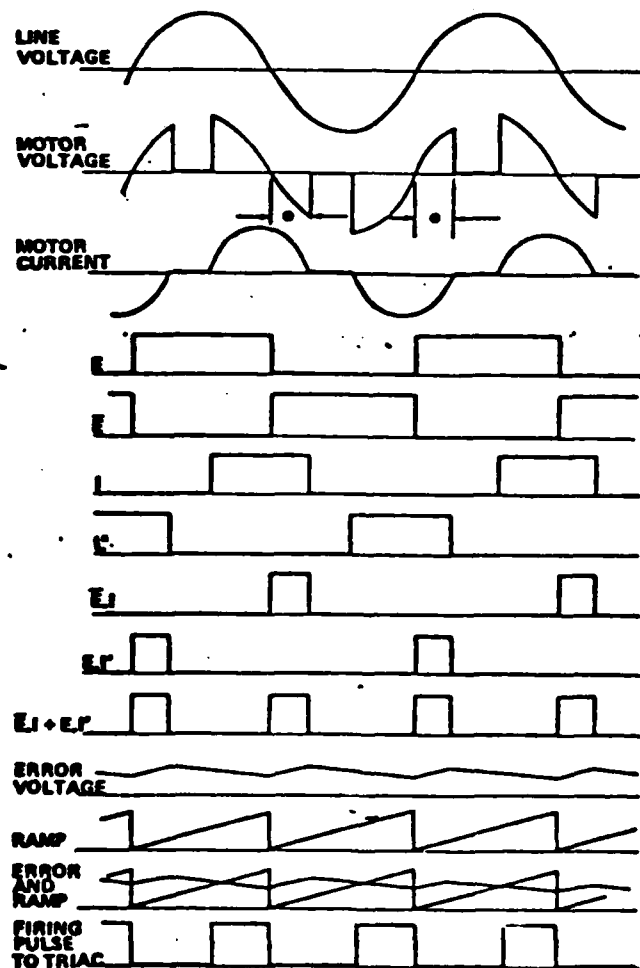
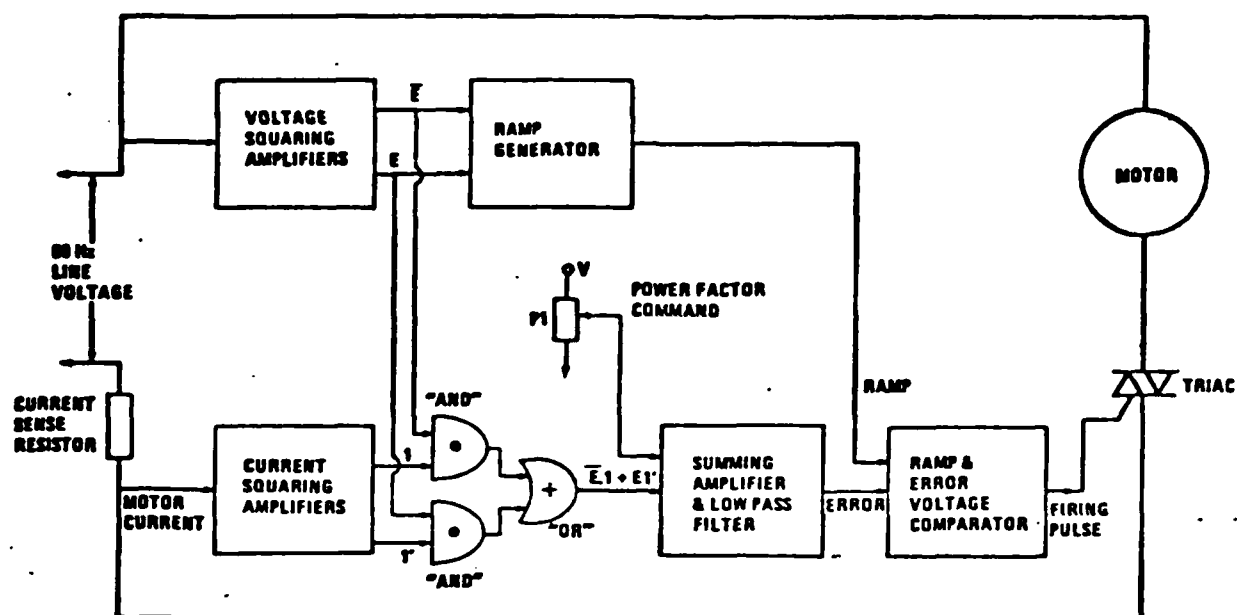


Figure 2 PFC Block, Diagonal and Wave Forms

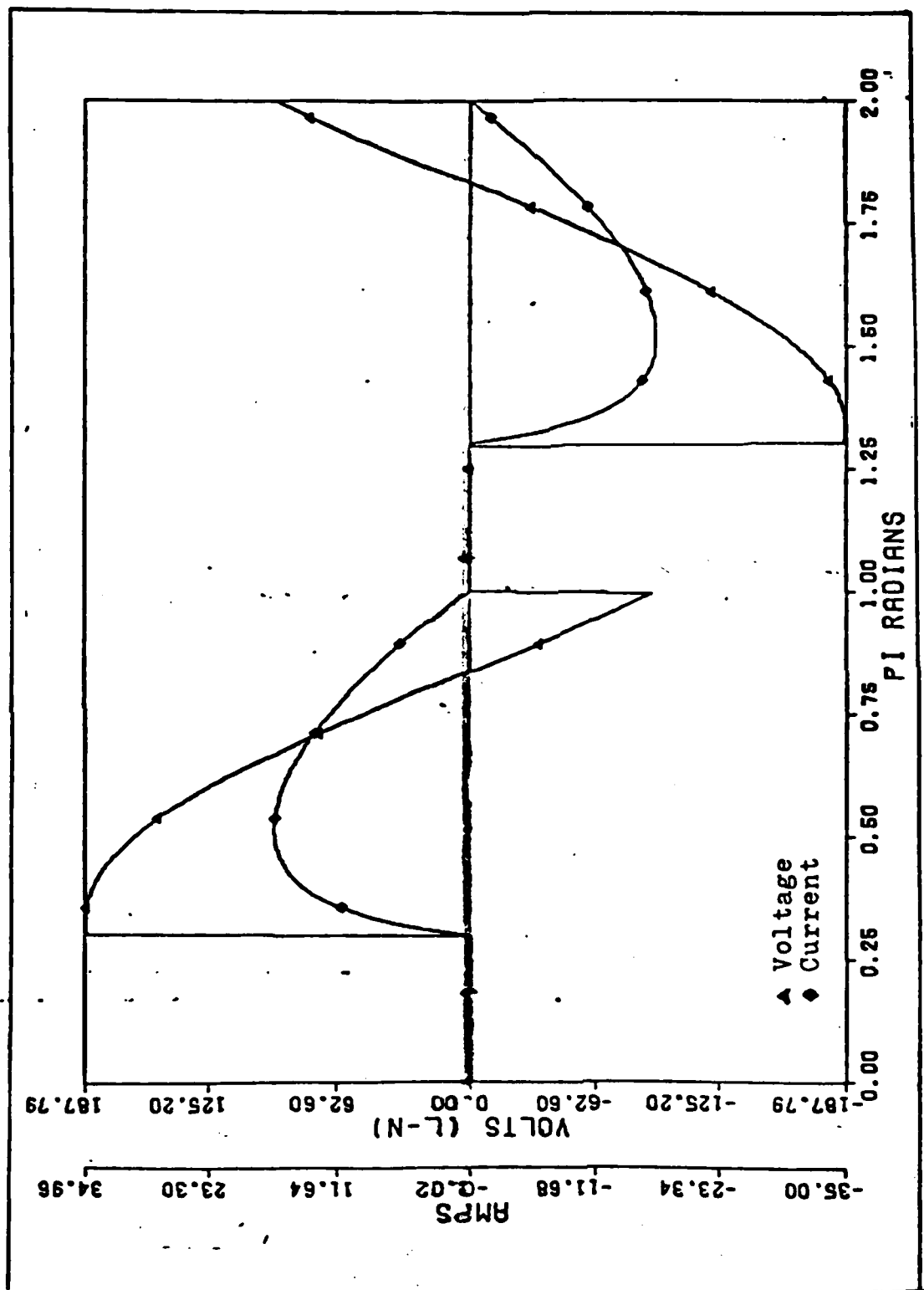


Figure 3

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 0.95

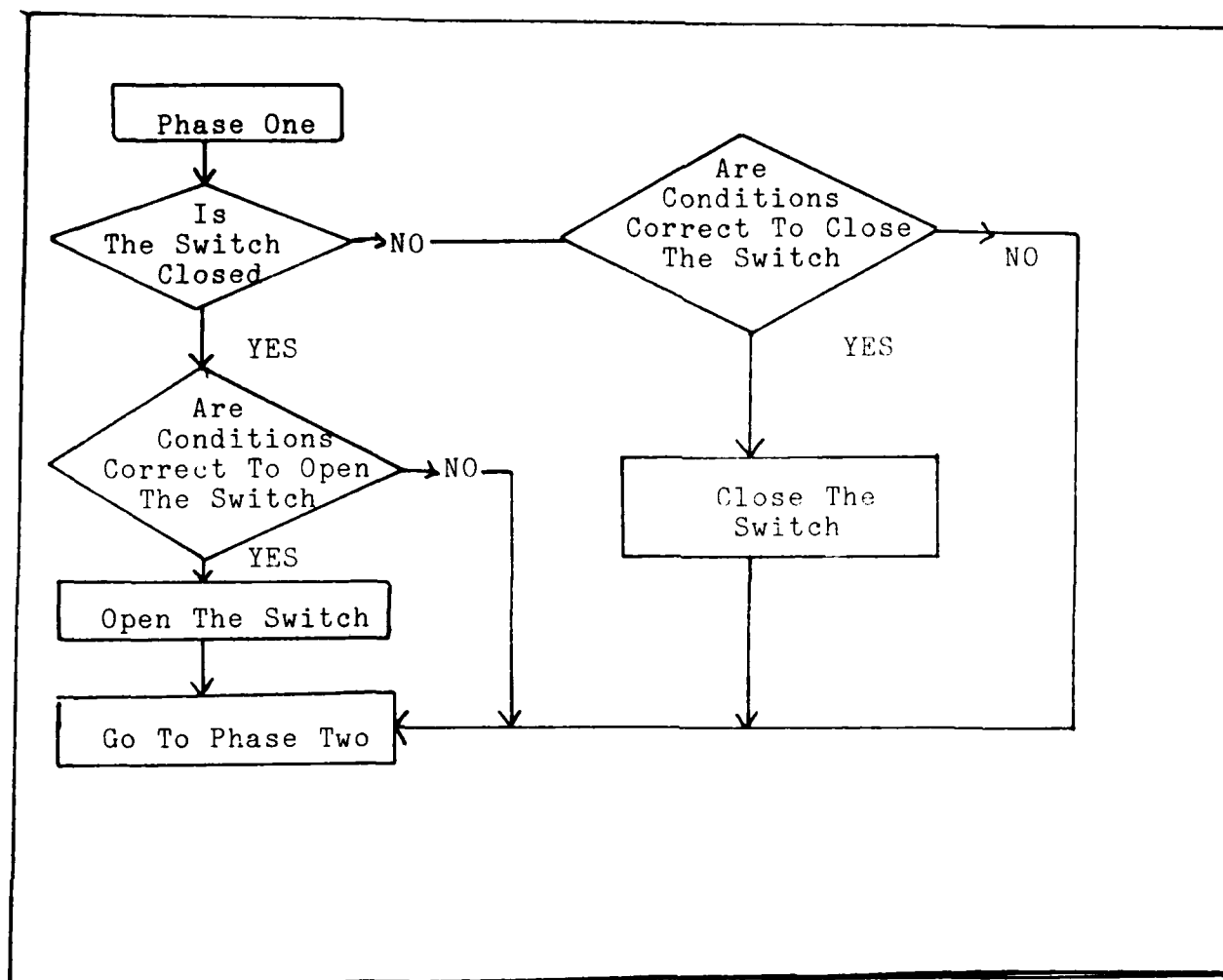


Figure 4 "Mini" Flow Chart For Subroutine V3CONT

III Mesh Analysis of a Wye-Connected Induction Motor

A mesh analysis of the per-phase equivalent circuit of a wye-connected induction motor is used to determine the currents within each portion of the motor.

Per-Phase Equivalent Circuit

The per-phase equivalent circuit is shown in Figure 5 (Ref.: 3) and represents the three major components of the motor which are typical of both energy efficient and standard motors. First, the stator is represented by elements R_1 and L_1 , where R_1 is the stator resistance and L_1 is the stator inductance. The input current I_1 is the total circulating current in the stator. Next, L_2 and R_2 represent the magnetizing inductance and core loss resistance in the core. The current I_2 circulates in the core. The elements L_3 and R_3 represent the inductance and resistance in the rotor.

$$P_o = I_3^2(R_3(1-S)/S) \quad (1)$$

If the values of elements of the equivalent circuit and the voltage applied are known, then the power output and losses of the motor may be calculated using mesh equations.

Derivation of the Mesh Equations

The mesh equations are derived by writing loop equations around each loop of the equivalent circuit (Figure 5).

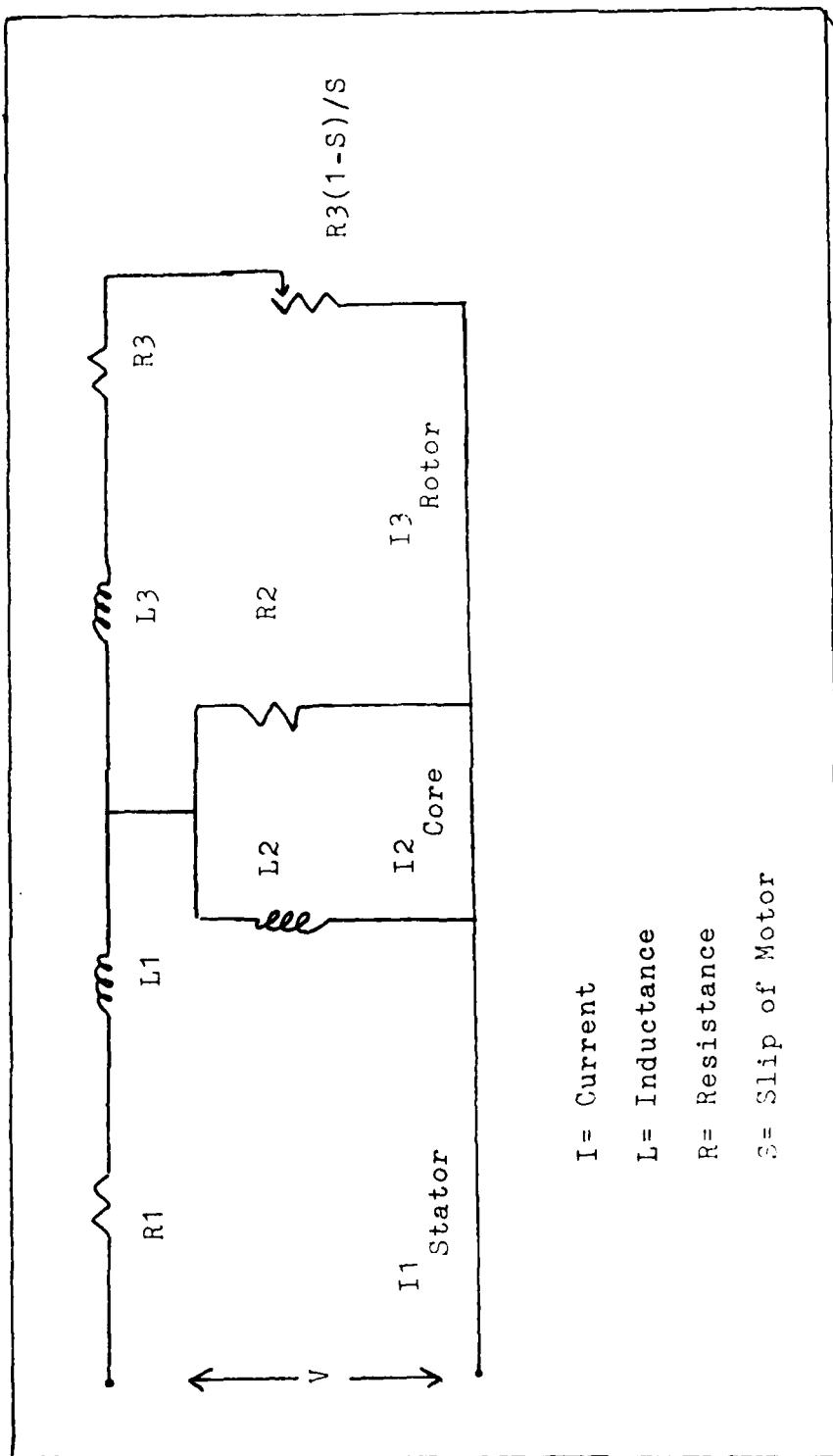


Figure 5 Per-Phase Equivalent Circuit

Then, combine the loop equations to solve for the current derivatives.

Figure 6 contains the current symbols used in the loop equations and the computer simulation.

$$\begin{aligned} Y1 &= I1, & Y2 &= I2, & Y3 &= I3 \\ X1 &= \frac{dI1}{dt}, & X2 &= \frac{dI2}{dt}, & X3 &= \frac{dI3}{dt} \\ V &= \text{Input Voltage} \end{aligned}$$

Figure 6. Loop Equation Symbols

The Loop equations are as follows:

$$V = R1Y1 + L1X1 + L2X1 - L2X2 \quad (2)$$

$$0 = -L2X1 + L2X2 + R2Y2 - R2X3 \quad (3)$$

$$0 = -R2Y2 + L3X3 + R3Y3 + R2Y3 + R4Y3 \quad (4)$$

The equations are combined to solve for the derivatives X1, X2, and X3.

$$X1 = (-R1Y1 + R2Y2 - R2Y3 + V) / L1 \quad (5)$$

$$\begin{aligned} X2 &= (L2R1Y1 / (L1 + L2) - L2V / (L1 + L2) \\ &\quad + R2(Y2 - Y3)) / ((L2 / (L1 + L2)) - L2) \end{aligned} \quad (6)$$

$$X3 = (R2Y2 - (R3 + R2 + R4) Y3) / L3 \quad (7)$$

Analog Configuration

An analog integration of equations (5), (6), and (7) is

used to obtain point by point data for the steady state solution.

Figures 7 and 8 represent the analog configuration of the per-phase equivalent circuit as used in the analog-digital simulation. The program for this is contained in Appendix C.

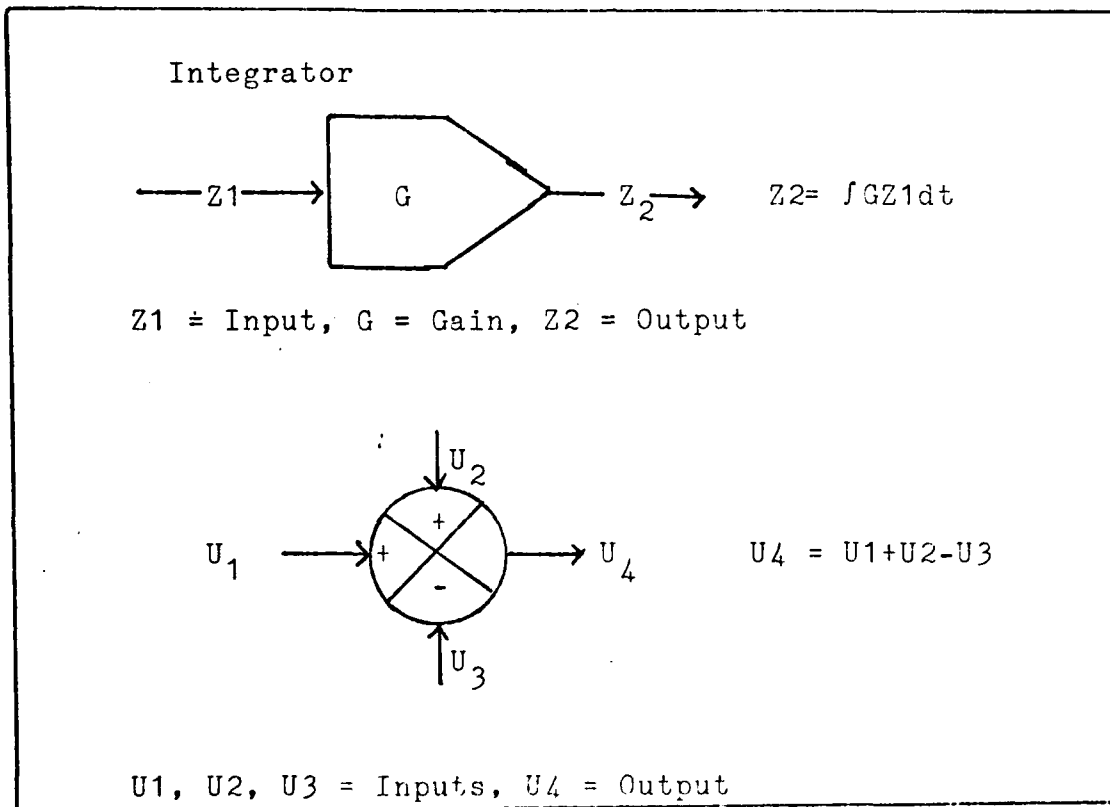


Figure 7 Analog Integrating and Summing Elements

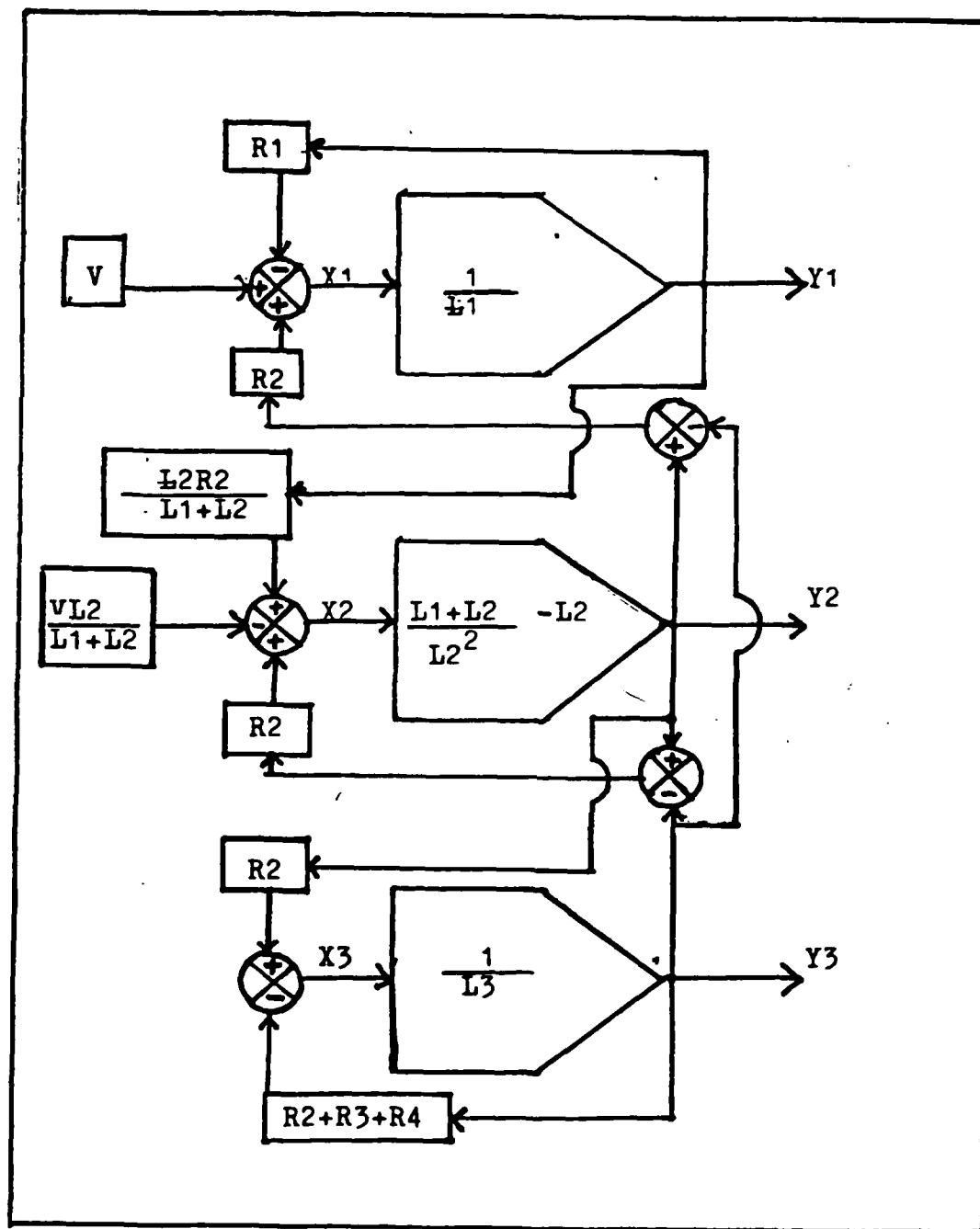


Figure 8 Per-Phase Analog Configuration for A Wye-Connected Induction Motor

IV. Analog-Digital Simulation of the Induction Motor and Controller

This chapter gives a brief description of the procedures and computer programs used to produce the data generated for the cost analysis and for the harmonic reflected wave shapes. Figure 9 is a mini flow chart showing the steps taken to generate the required data.

Computation of Equivalent Circuit Values

The equivalent circuit values were computed using the program listed in Appendix A. Manufacturer's no load and full load test data (Appendix G) were used to generate the values for the parameters of the motor equivalent circuit shown in Chapter III.

The program and data were furnished by Dr. Frederick Brockhurst (Ref. 2).

Alpha Angles

The same program and reference data which were used to compute the equivalent circuit values were also used to compute the power factor and Alpha angle to be used in the motor controller simulation.

The Alpha angle was computed in subroutine CONT which uses an estimating parameter technique. The input/output data is shown in Appendix B.

Analog-Digital Integration

A program was written to simulate the combined operation

of the PFC and induction motor. The program (listed in Appendix C) is capable of calculating the motor losses for a variety of load conditions. This program was used to generate the data required to plot the reflected voltage and current wave shapes listed in Appendix D. The data may also be used to determine harmonic content of the reflective wave

The performance of the machine simulation was verified by comparing calculated values of current, power, speed, efficiency, and power factor to manufacturers' data. These results are shown in Appendix G and agreed quite closely.

Computation of Harmonic Content of the Reflected Current

The harmonic content of the reflected current was calculated by using a Fast Fourier Transform program as listed in Appendix C.

A sampling of the results of the Fourier Transform data is shown in Appendix E.

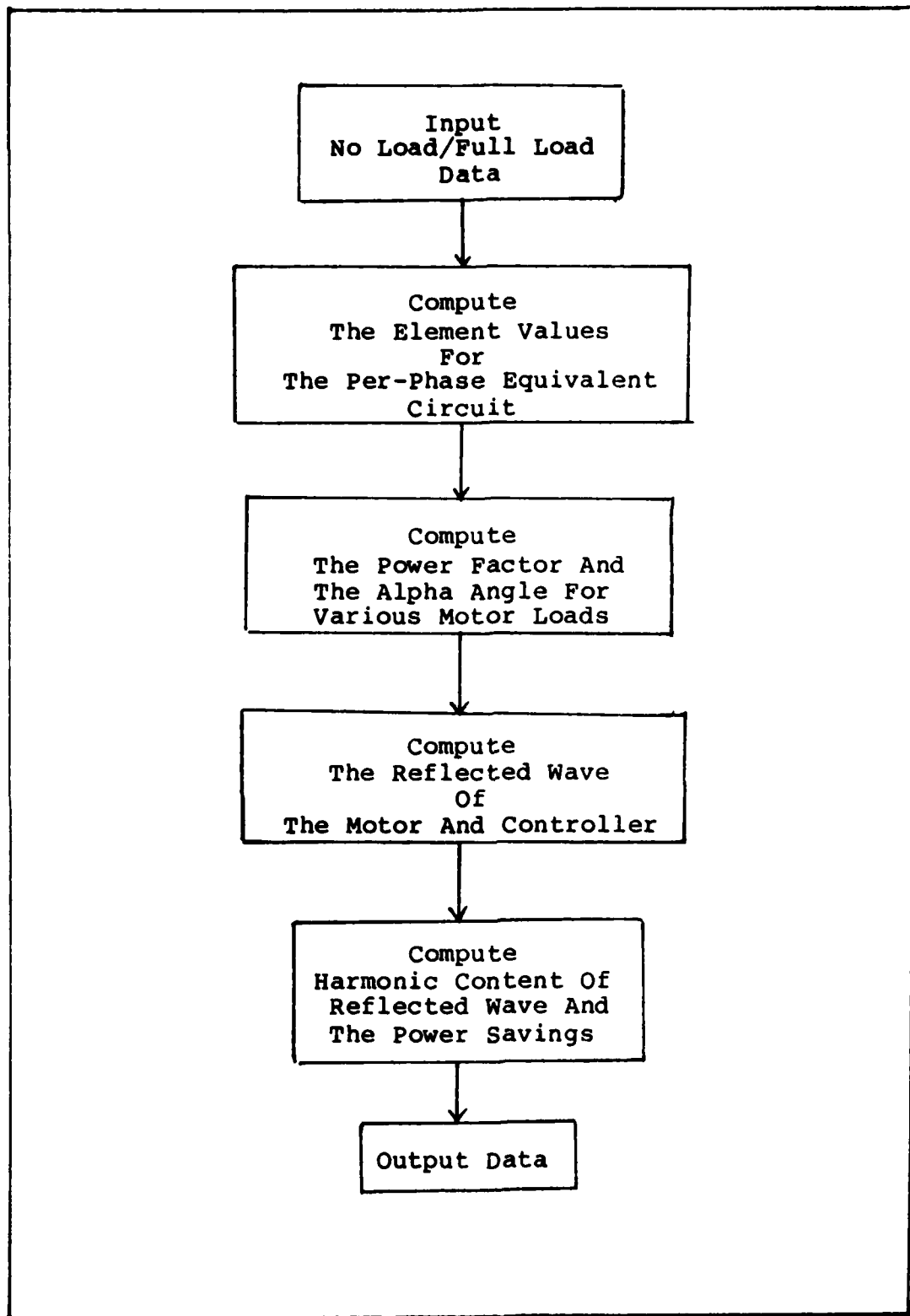


Figure 9 Mini Flow Chart of Computer Simulation

V. Cost Analysis of Controller and Motor

This chapter introduces 6 possible cases for motor/controller configurations. The assumptions that apply to the analysis and the method by which the analysis was prepared.

The cost analysis is separated into 6 possible cases for the 5 horsepower and the 10 horsepower motors. Each case uses a simple payback method based on a fixed number of running hours per year, the calculated power savings and the estimated cost of the motor and controller.

Equation 8 shows the method used to calculate the estimated cost savings per year.

$$\begin{aligned} \$\text{saved}/\text{year} &= \text{hours}/\text{year} \times \text{estimated watts saved} \times \\ &\quad \$\text{cost}/\text{kilowatt hour} \times \text{kilowatt}/1000 \text{ watts} \end{aligned} \quad (8)$$

The following assumptions were used in the above equation.

1. 8760 hours per year was used to show continuous operation. If a motor does not operate continuously or operates at various loading then the motor data shown in tables A and B may be prorated to estimate the annual savings.
2. \$0.06 per kilowatt hour was used as an average cost for power. This cost can be adjusted to fit the estimated

energy cost in a particular area of the country.

3. A standard 5 horse power motor costs \$329.00.
4. An energy efficient 5 horse power motor costs \$370.00.
5. A controller for a 5 horse power motor costs \$550.00.
6. A standard 10 horse power motor costs \$505.00.
7. An energy efficient 10 horse power motor costs \$655.00.
8. A controller for a 10 horse power motor costs \$850.00.

Assumptions 3 through 8 were based on local vendor prices (1980).

The simple payback method is used to show the estimated payback in years. Once the exact cost of a system and power is known for a given location and time then a life cycle cost analysis may be used. The formula for the simple payback method used is

$$\text{yrs to payback} = \text{system cost} / \text{cost savings} / \text{year} \quad (9)$$

The following 6 cases were considered:

1. The first case is the comparison of an energy efficient motor without motor controller with a standard motor without motor controller.
2. The second case is the comparison of an energy efficient motor without controller with a standard motor with motor

controller.

3. The third case compares an energy efficient motor with motor controller with a standard motor with motor controller.

4. The fourth case compares an energy efficient motor with motor controller with a standard motor without a motor controller.

5. The fifth case compares a standard controlled motor with a standard uncontrolled motor.

6. The sixth case compares an energy efficient controlled motor with an energy efficient uncontrolled motor.

Each case except #2 and #3 also compare the simple payback in years for a new installation and retrofit for each motor loading.

All of the data and calculations for the six cases using 5 and 10 Hp motors are shown in Appendix F. A portion of the data is shown below to illustrate the method and results.

Table A shows the energy savings (or less) for each of the six cases using 5 Hp motors. For example case 1 shows the savings obtained by using an energy efficient motor (EEM) instead of a standard motor. Similarly case 2 shows the savings obtained by using an EEM instead of a controlled standard motor. Note that for cases 2 the EEM is more efficient down to about half-load, but below half-load the

controlled standard motor is more efficient. This is indicated by the negative signs for the last three entries in column #2. Note that from column 6, there appears to be little benefit from putting a controller on an EEM unless it is very lightly loaded.

Once the differences in wattage for the different cases and loads were known, equation 8 was used to calculate the annual dollar savings (loss). Table B shows these results for the 5 Hp motor. Again negative signs indicate that the second alternative is more economical.

Finally the payback period was calculated both for new installation and for retrofit installations. Table C shows the payback periods for Case I using 5 Hp motors. For new installations only the difference in cost must be repaid, while for a retrofit installation the entire cost of the motor, controller (if used), and labor must be repaid. Tables D and E show payback periods for the 5 Hp and 10 Hp motors, respectively, for all six cases. Negative numbers in these tables indicate that the option being considered has a higher operating cost. The details of the exact cost used to calculate the payback periods are shown in Appendix F.

5 HP

Δ Wattage for (Situation)

1. Energy Efficient (uncont) VS Standard (uncont)
2. Energy Efficient (uncont) VS Standard (Cont)
3. Energy Efficient (cont) VS Standard (cont)
4. Energy Efficient (Cont) VS Standard (uncont)
5. Standard (cont) VS Standard (uncont)
6. Energy Efficient (cont) VS Energy Efficient (uncont)

Savings in Watts

HP Load	#1	#2	#3	#4	#5	#6
5	64	64	67	67	0	3
4.5	97	151	110	56	-54	-41
4.0	129	108	63	84	21	-45
3.75	64	54	47	57	10	-7
3.0	120	77	46	90	43	-30
2.5	118	20	80	178	98	60
2.0	116	-41	3	161	158	45
1.25	113	-79	18	209	192	97
0.75	113	-130	20	263	243	150

Table A

5 HP Savings/Year Based on \$0.06 KWH

HP Load (Situation)	Comparison					
	#1	#2	#3	#4	#5	#6
5	\$33.63	\$ 33.63	\$35.22	\$ 35.22	\$ 0	\$ 1.58
4.5	\$50.98	\$ 79.36	\$57.82	\$ 29.43	\$-28.38	\$-21.55
4.0	\$67.80	\$ 56.76	\$33.11	\$ 44.15	\$ 11.04	\$-23.65
3.75	\$33.63	\$ 28.38	\$24.70	\$ 29.96	\$ 5.26	\$ -3.68
3.0	\$63.07	\$ 40.47	\$24.18	\$ 47.30	\$ 22.60	\$-15.77
2.5	\$62.02	\$ 10.51	\$42.05	\$ 93.55	\$ 51.50	\$ 31.54
2.0	\$60.97	\$-21.54	\$ 1.58	\$ 84.62	\$ 83.05	\$ 23.65
1.25	\$59.39	\$-41.52	\$ 9.46	\$109.85	\$100.92	\$ 50.98
0.75	\$59.39	\$-68.33	\$10.51	\$138.23	\$127.72	\$ 78.84

Table B

#1

5 HP

Simple Payback

Cost/Savings per Year

Standard \$329.00, Energy Efficient 370.00

A= Cost = \$41.00, B= Cost = \$370.00 + 20% = \$444.00

Installation Cost

HP Load	A	B
5	1.22 yrs	13.20 yr
4.5	0.80 yrs	8.71 yr
4.0	0.60 yrs	6.55 yr
3.75	1.22 yrs	13.20 yr
3.0	0.65 yrs	7.04 yr
2.5	0.66 yrs	7.16 yr
2.0	0.67 yrs	7.28 yr
1.25	0.69 yrs	7.48 yr
0.75	0.69 yrs	7.48 yr

B= Retrofit - Replacing Standard Motor with Energy Efficient
+ 20% Motor Cost Installation

A= New Installation, Cost of Energy Efficient vs Standard
Motor based on continuous operation

Table C

5 Horse Power Motor and Controller Comparisons

A=New Installation, B=Retrofit

Simple Payback in Years

Load Horse Power	Situation							
	1A	1B	2A	3A	4A	4B	5A	5B 6A 6B
5.0	1.22	13.22	0	1.16	16.78	28.22	-----no savings-----	
4.5	0.88	8.71	0	0.71	20.08	33.78	-19.37	-25.2 -25.5
4.0	0.60	6.55	0	1.24	13.39	22.51	49.81	49.81 -23.3 -23.3
3.75	1.22	13.20	0	1.66	19.73	33.18	104.56	104.56 -149.5 -149.5
3.0	0.65	7.04	0	1.70	12.49	21.0	24.33	24.33 -34.9 -34.9
2.5	0.66	7.16	0	0.98	6.32	10.23	10.68	10.68 17.4 17.4
2.0	0.67	7.28	+23.63	25.95	6.98	11.75	6.62	6.62 23.3 23.3
1.25	0.69	7.48	+12.26	4.33	5.38	9.05	5.45	5.45 10.8 10.8
0.75	0.69	7.48	+7.48	3.90	4.28	7.20	4.30	4.30 7.0 7.0

Table D

10 Horse Power Motor and Controller Comparisons

A= New Installation, B= Retrofit

Simple Payback in Years

Load Horse Power	Situation					
	1A	1B	2A	3A	4A	4B
10	1.15	5.75	NONE	3.27	20.66	33.72
7.5	2.14	10.60	NONE	1.10	11.50	18.77
5.0	3.20	15.98	NONE	2.19	11.24	18.31
2.5	4.83	24.10	-10.94	14.49	9.42	15.37
				5A	5B	6A
				NONE	NONE	-9.45
				-14.85	-14.84	67.40
				50.56	50.56	21.28
				8.84	8.84	11.47

Table E

VI. Conclusions and Recommendations

Conclusions

The analog-digital computer simulation of the PFC and motors is effective for generating the data required for the economic analysis of the "NOLA" controlled motors. The "NOLA Controller" showed an energy savings and effectively controls the power factor of motors operating at less than full load. Although it does conserve energy, the PFC does not provide a cost effective way to conserve energy at this time due to it's high initial cost.

The energy efficient motor proved to be cost effective when used in new installation or scheduled replacement. Retrofitting with energy efficient motors for the purpose of energy conservation is not cost effective.

No conclusions were reached about the effects of the higher harmonics produced by PFC.

The wave shapes of the reflective waves were produced in this thesis and lead one to believe that harmonic problems may be created by the PFC. Additional thoughts on this subject are covered in the recommendation section of this chapter.

Recommendations

Based on the data presented in this thesis and the cost of the PFC, future consideration should be given to the use of the PFC if the initial cost decreases. At the present time energy efficient motors should be used in lieu of

standard induction motors.

The effects of the higher harmonics should be explored.
The areas of explanation should be as listed below.

1. The effects of a harmonic dampening device (linear filter) used on the line side of the PFC using different motor load configuration.
2. The effects the harmonics may have on sensistive electronic equipment.
3. The effects of the harmonics on a typical secondary power distribution system versus motor size.

Bibliography

1. Nola, Frank Power Factor Controller - An Energy Saver.
George C. Marshall Space Flight Center Marshall Space
flight center, Alabama 35812, Conference Record IEEE
Industrial Applications Society IAS Annual Meeting 1980,
p. 194-198.
2. Brockhurst, F. Private Communications June 1979.
3. Hudson, Ralph G. The Engineers Manual. John Wiley And
Sons Inc. N.Y. 1944. Figure 1004, pg. 240.

Appendix A

Digital Program to Determine
Motor Element Values And
The ALPHA Values For Controlled
State.

List of Input Variables

M1 = Input Flag

V = Line to Line Voltage

IF = Full Load Current

Pin = No Load Input Power

PIF = Full Load Input Power

PFN = No load Power Factor

Pff = Full Load Power Factor

HP = Full Load Horse Power

RPM = Synchronous Speed

RPMF = Full Load Speed

PROGRAM NINE 7474 OPT=1 PHOMP FIN 4.8+51d 11/15/80 07.11.53 PAGE 1

PROGRAM NINE (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
 COMPLEX Z1,Z2,ZPHI,Z1,Z2,IPHY,V1,E,RC,XM,VA,IFC,INC,VIC
 COMPLEX X12,V10,ZSER

REAL I1,IF,I1,IFR,IFX,INR,INX ,IN
 COMMON R1 , XM , RC

KK=0

READ(5,101) M1

FORMAT(111)

IF (M1.EQ.1) GO TO 210

READ(5,100) P11,R22,X11,X22,RC,XMM,RPH,V11

FORMAT(6F9.6)

V11=V11/SORT(3.)

THETA = 0.0

PRINT, " "

PRINT, " R11= ",R11," R22= ",R22

PRINT, " X11= ",X11," X22= ",X22

PRINT, " RUC = ",RUC," XMM = ",XMM

PRINT, " RPH = ",RPH," V11 = ",V11

PRINT, " "

R1=R11

R2=R22

M=3.0*3.141593 * 60.0

X2=X22

V1=CPPLX(V11,0.0)

VMAX=CARS(V1)*SQRT(2.0)

Z1=CPPLX(R11,X11)

XM=CPPLX(0.0,XMM)

RC=CPPLX(RC,0.0)

ZPHI=(PC*XM)/(RC*XM)

GO TO 40

C*****

V = L-L VOLTAGE

IF = FULL LCAD CURRENT

IN = NO LOAD CURRENT

PIN = 45 LOAD INPUT POWER

PIF = FULL LCAD INPUT POWER

PFN = NO LOAD POWER FACTOR

PFF = FULL LCAD POWER FACTOR

HP = FULL LOAD HORSEPOWER

RPM = SYNCHRONOUS SPEED

RPMF = FULL LOAD SPEED

260 READ(5,210) V,IF,IN,PIN,PIF,PFN,PFF,HP,RPH,RPMF

WRITE(6,220) V,IF,IN,PIN,PIF,PFN,PFF,HP,RPH,RPMF

FORMAT(10F7.4)

FORMAT(10(2X,F9.4))

V=V/SORT(3.)

PIN=PIN/3.

PIF=PIF/3.

VAN= PIN/PFN

VAF = PIF/PFF

PC = HP* 746./3.

S = (PPF-RPH)/RPM

PLF = PIF-PIN-FO

THETN = ACOS(PFN)

THETF = ACOS(PFF)

IFR = IF/PFF

IFX = IF* 51/(THETF)

```
INR = IN* PFN
INX = IN* SIN(THETN)
60 IFC = C*PLX( IFR , -IFX)
INC = FMPLX(INR,-INX)
V1 = C*PLX(V,0.)
72 = YFC-INC
R2 = PO/ (CABS(I2)*2*(1.-S)/S))
FPOI = CABS(I2)*2*R2
R1=(CLF-POCT)/(CABS(IFC)*2)
ZSER = VI/YFC
X1R=AIMAG(ZSER)
VZ=J.005*V
70 X1=0.05*X1R
X2=0.001
240 X1=X1*X2
X2=X1
X12=C*PLX(0.,X1)
V1C = YFC*R1+I2*R2/S*X12*(I2+IFC)
75 V1D = V1-V1C
KKK= KKK + 1
IF (APSTATPAG(V1D)).LE.V2) GO TO 250
IF (X1.LT.2.*X1R) GO TO 240
X1=0.05*X1R
X2=X2/2.
80 GO TO 240
36 250 71=C*PLX(R1,X1)
X2= X1
E = V1-INC*Z1
RCC=CABS(E)*2/(PIN-CABS(INC)*2*R1)
EX = CABS(E)
XPH = EX/ INX
XM = C*PLX(0.,XMH)
ZPHI = (RCC*XH)/(RCC*XP)
PMECH = PC
90 VMX = CABS(VI)*SQRT(2.)
FRINT, " P1= ",R1," R2= ",R2, "FO= ",PO
FRINT, " X1= ",X1," XPH= ",XPH," RCC = ",RCC
FRINT, " VIC = ", VIC
95 40 READ(5,110) RP,M,N,J
110 FORMAT(F10.4,3I2)
IP=RP/3.0
FRINT, " HF=",HP," M=",M," N= ",N," J = ",J
PMECH=RP*746.0
100 IF (J.EQ.1) GO TO 70
IF (M.EQ.1) GO TO 50
70 THETA = 0.0
CALL URCONT(71,ZPHI,VI,R2,X2,RPH,PMECH,RCC,THETA)
THETA = THETA
105 IF (J.EQ.1) GO TO 50
IF (N.EQ.1) GO TO 60
GO TO 40
50 CALL CONT(21,ZPHI,VMAX,R2,X2,RPH,PMECH,THETA,RCC)
110 IF (N.EQ.1) GO TO 60
GO TO 40
60 STOP
END
```

1 SUPROUTINE UNCONT(Z1,ZPHI,V1,R2,X2,RPM,PMECH,RCC,THETA)
 COMPLEX Z1,Z2,ZPHI,I1,I2,I3PHI,V1,E,RC,XM,VA
 REAL I1L,R1

COMMON R1,XM,RC

S=0.0

S1=0.01

110 S=S+S1

RS=R2/S

Z2=CMPLX(RS,X2)

110 V1/(Z1*(ZPHI*Z2)/(ZPHI*Z2))

I=V1-I1*Z1

I2=E/Z2

PMECH=CABS(I2)**2/R2*(1.-S)/S

IF(.99*PMECH.LF.PMECH1.AND.PMECH1.LE.1.01*PMECH)GO TO 100

15 IF(S.GT.3.2) S1=S1/2.0

IF(S.GT.0.2) S=0.0

GO TO 110

100 PCORE=CABS(E)**2/RCC

PCU=CABS(I1)**2/R1+CABS(I2)**2/R2

FIN=PMECH1*PCORE+PCU

EFF=PMECH1/PIN

VA=V1*I1

THETA=ATAN2(AMAG(VA)/REAL(VA))

FF=CGS(THETA)

VA1=CABS(VA)

37 RPM1=(1.-S)*RPP

I1L=CABS(I1)

MP=PMECH1/746.C

THETAN=THETA

38 PRINT*, " UNCONT---OUTPUT-----"

WRITE(6,150) MP,RPM1, EFF, PF,VA, PIN, I1L

150 FORMAT(1X,7F10.4)

PRINT*, " -----"

RETURN

35 END

SYMBOLIC REFERENCE MAP (R=1)

ENTRY PCINTS

3 UNCONT

VARIABLES SN TYPE RELOCATION

VARIABLES	SN	TYPE	RELOCATION	235	EFF	REAL	COMPLEX	UNDEF
221 E		COMPLEX		235	EFF	REAL	COMPLEX	UNDEF
242 MP		REAL		237	IFHI	REAL	COMPLEX	UNDEF
217 I1		COMPLEX		225	I1L	REAL	REAL	
215 I2		COMPLEX		232	PCORE	REAL	REAL	
231 PCU		REAL		237	PF	REAL	REAL	
234 PIN		REAL		0	PMECH	REAL	REAL	F.P.
231 PMECH1		REAL		3	KC	COMPLEX	COMPLEX	/ /
0 FCC		REAL	F.P.	0	RPM	REAL	REAL	F.P.
241 RPM1		REAL	/ /	230	RS	REAL	REAL	
0 R1		REAL	/ /	0	R2	REAL	REAL	F.P.
221 S		REAL		227	S1	REAL	REAL	

```
1 SUBROUTINE CCNT(Z1,ZPHI,VHAX,R2,X2,RPV,PMECH,THETA,RCC)
  COMPLEX Z1,Z2,ZPHI,I1,I2,IPHI,V1,E,RC,XM,VA
  REAL I1L,R1
```

```
5 COMMON R1,XM,RC
```

```
PI=3.141593
```

```
SAFE=PI*THETA
```

```
ALPHA = 0.
```

```
ALPHA1=0.05
```

```
120 S = 0.0
```

```
10 S1=0.01
```

```
110 S=S+S1
```

```
THETO =ABS(THETA)
```

```
RS=R2/S
```

```
22=C*PLX(PS,X2)
```

```
15 V1=S*Q*OT((VHAX**2/(2.*PI))*(PI-ALPHA+COS(2.*THETO+ALPHA)
```

```
3*SIN( ALPHA)))
```

```
I1=C*PLX(V1A,0.0)
```

```
I1=V1/(Z1+(ZPHI*Z2)/(ZPHI*Z2))
```

```
E=V1-I1*Z1
```

```
20 I2=E/72
```

```
FMECH1=CARS(I2)**2*R2*(1.-S)/S
```

```
IF(1.98*PMECH.LE.PMECH1.AND.PMECH1.LE.1.02*PMECH) GO TO 100
```

```
IF (S.GT.0.2) S1=S1/2.0
```

```
IF(S.GT.0.2) S=0.0
```

```
GO TO 110
```

```
100 VA=V1*I1
```

```
THETA1=ATAN(IMPAG(VA)/REAL(VA))
```

```
THETO1 = ARG(THETA1)
```

```
IF(1.94*THETO1.LE.THETO1.AND.THETO1.LE.1.02*THETO)GO TO 130
```

```
30 IF(ALPHA.GE.0.9*SAFE) ALPHA1=ALPHA1/2.0
```

```
IF(ALPHA.GE.0.5*SAFE) ALPHA=0.0
```

```
ALPHA=ALPHA+ALPHA1
```

```
GO TO 120
```

```
130 PCORE=CARS(E)**2/RCC
```

```
PCU=CARS(I1)**2*R1+CARS(I2)**2*R2
```

```
FIN = PMECH1*PCORE*PCU
```

```
EFF=PMECH1/PIN
```

```
RPMI=(1.-S)*CPP
```

```
11L =CARS(I1)
```

```
HP=PMECH1/74C*3
```

```
FF=COS(THETA1)
```

```
PRINT*, " ----- CONT--OUTPUT-----"
```

```
WRITE(6,150) HP , RPMI ,EFF ,PF ,VA ,PIN ,I1L ,ALPHA ,V1
```

```
150 FORMAT(1X,9F10.4)
```

```
PRINT*, " -----"
```

```
PRINT*, "-----"
```

```
RETURN
```

```
END
```

SYMBOLIC REFERENCE MAP (R=1)

MP=1.666666667 P=0 N=0 J=0

UNCONF--OUTPUT--

1.6698 1778.3638 .8804 .7103 1416.8360-1402.0727 1414.8360

7.5101

MP=.833333333333 P=0 N=0 J=0

UNCONF--OUTPUT--

.8278 1789.5938 .8193 .4879 753.8649-1348.5675 753.8049

5.8172

MP=3.33333333333 P=0 N=0 J=1

UNCONF--OUTPUT--

3.4591 1752.7500 .8878 .8578 2825.1465-1698.8017 2825.1465

12.4127

CONF--OUTPUT--

3.3591 1752.7500 .8870 .8578 2825.1465-1698.8017 2825.1465 12.4127 0.0000

265.5811

MP=3. M=1 N=0 J=0

CONF--OUTPUT--

3.8278 1755.0000 .8883 .8519 2542.0646-1562.5134 2542.0646 11.5345 .2500

257.3522

MP=2.666666667 P=1 N=0 J=0

CONF--OUTPUT--

2.7847 1755.0000 .8883 .8519 2271.4144-1396.1547 2271.4144 10.9599 .5000

243.2664

MP=2.5 M=1 N=0 J=0

CONF--OUTPUT--

2.5433 1755.0000 .8883 .8519 2135.8175-1312.8883 2135.8175 10.6276 .6000

235.9919

MP=2.33333333333 P=1 N=0 J=0

CONF--OUTPUT--

2.3663 1755.0000 .8883 .8519 1987.2160-1221.4684 1987.2160 10.2514 .7000

227.5397

MP=2. M=1 N=0 J=0

CONF--OUTPUT--

1.9783 1755.0000 .8883 .8519 1661.3733-1021.1853 1661.3733 9.3733 .9000

209.9593

MP=1.666666667 P=1 N=0 J=0

CONF--OUTPUT--

1.6719 1755.0000 .8883 .8519 1404.0984 -863.0475 1404.0984 8.6171 1.0500

191.2641

MP=1.33333333333 M=1 N=0 J=0

CONF--OUTPUT--

1.3321 1752.7500 .8870 .8578 1111.9139 -668.6100 1111.9139 7.7872 1.2500

166.5143

Appendix B
Tables of Input/Output
Data for Motor Element and
Alpha Values

5 HP Energy Efficient (A)

Input V= 230.0 volts, I Full Load= 12.3 amps, I No Load= 4.54 amps, P_{IN} No Load= 225.0 watts, Power In Full Load= 4288.0, Power Factor NO Load= 0.125, Power Factor Full Load= 0.874, HP= 5.0, RPM= 1800, RPM Full Load= 1751.0

Equivalent CKT Values Calculated $R1= 0.5037$ ohms, $R2= 0.3286$ ohms, $RCC= 254.273$ ohms, $X1= 0.9623$ ohms, $X2= X1$, $XMM= 28.457$ ohms

HP	Output		RPM	EFF	PF	P_{IN} watts	I_L		ALPHA	S	V1 volts
	Hp						Amps				
5.0	5.04		1748.25	.8801	87.85	4275.63	12.225		0.0	0.02875	132.7
4.5	4.52		1750.5	.881	87.48	3828.27	11.39		0.3	0.0275	128.06
4.0	4.03		1750.5	.881	87.48	3412.59	10.75		0.55	0.0275	120.9
3.75	3.78		1750.5	.881	87.48	3204.99	10.42		0.65	0.0275	117.17
3.0	3.04		1748.25	.8801	87.85	2578.74	9.4		0.95	0.02875	103.1
2.5	2.46		1750.5	.881	87.48	2089.46	8.41		1.10	0.0275	94.6
2.0	2.01		1750.5	.881	87.48	1701.0	7.59		1.25	0.0275	85.4
1.25	1.27		1746.0	.8791	88.17	1079.5	6.23		1.55	0.03	65.4
0.75	0.748		1750.5	.881	88.48	633.6	4.63		1.75	0.0275	52.09

Table F

5 HP Energy Efficient (B)

V	R1	R2	R3	L1	L2
230.0	0.5037	254.273	0.3286	0.9623	28.457

M	ALP	S
0	0.0	0.02875
0	0.3	0.0275
0	0.65	0.0275
1	1.10	0.0275
0	0.95	0.02875
0	1.25	0.0275
0	1.55	0.03
1	1.75	0.0275

Table G

5 HP Standard (A)

Input V= 460.0 volts, I Full Load= 7.06 amps, I No Load= 3.85 amps, P_{IN} No Load= 335.0 watts, Power in Full Load= 4423.0 watts, Power Factor No Load= 0.11, Power Factor Full Load= 0.787 Horse Power= 5.0, RPM= 1800, RPM Full Load= 1747.0

Equivalent CKT Values Calculated $R1= 1.6227$ ohms, $R2= 1.4443$ ohms, $RCC= 735.012$ ohms, $X1= 2.9204$ ohms, $X2= X1$, $XMM= 66.316$ ohms

HP	Output HP	RPM	Eff	PF	P_{in} Watts	I _L Amp	ALPHA	S	V _L
5	5.02	1743.75	.8626	79.03	4342.65	6.897	0.0	0.03125	265.58
4.5	4.55	1746.00	.8624	78.23	3937.60	6.5172	0.2	0.03	257.44
4.0	4.02	1746.00	.8624	78.23	3476.13	6.123	0.45	0.03	241.88
3.75	3.759	1746.00	.8624	78.23	3252.16	5.923	0.55	0.03	233.96
3.0	3.033	1746.00	.8624	78.23	2624.83	5.321	0.80	0.03	210.18
2.5	2.508	1743.75	.8626	79.03	2169.02	4.8741	1.00	0.03125	187.69
2.0	1.967	1746.00	.8624	78.23	1704.00	4.2876	1.15	0.03	169.36
1.25	1.268	1741.50	.8627	79.76	1097.10	3.494	1.45	0.0325	131.22
0.75	0.756	1741.5	.8627	79.76	654.21	2.698	1.7	0.0325	101.33

Table H

5 HP Standard (B)

V	R1	R2	R3	L1	L2
460	1.6227	735.012	14443	2.9204	66.316

M	ALP	S
0	0.0	0.03125
0	0.2	0.03
0	0.55	0.03
1	1.0	0.03125
0	0.8	0.03
0	1.15	0.03
0	1.45	0.0325
1	1.70	0.0325

Table I

10 HP Standard (A)

Input V= 460 volts, I Full Load= 12.6 amps, I No Load= 5.1 amps, P_{in} No Load=379.0 watts, P_{IN} Full Load=8533.0 watts, PF No Load= .094, PF Full Load=.852, HP= 10.0, RPM= 1800, RPM Full Load= 1755

Equivalent CKT Values Calculated $R1= 1.0555$ ohms, $R2= .59318$ ohms, $RCC= 657.776$ ohms, $X1= 1.985757$ ohms, $X2= X1$, $XMM= 50.228416$ ohms

HP	Output HP	RPM	Eff	PF	P_{IN} Watts	I _L			ALPHA	S	V _L
						Amps	Watts	Alpha			
10.0	10.08	1752.75	.887	85.70	8475.42	12.41	0.00	.02625	265.6		
9.0	9.08	1755.0	.8883	85.19	7626.19	11.59	0.25	.025	257.4		
8.0	8.11	1755.0	.8883	85.19	6814.24	10.96	0.50	.025	243.3		
7.5	7.63	1755.0	.8883	85.19	6407.43	10.63	0.60	.025	235.9		
7.0	7.09	1755.0	.8883	85.19	5961.65	10.25	0.70	.025	227.5		
6.0	5.93	1755.0	.8883	85.19	4984.12	9.37	0.9	.025	208.1		
5.0	5.01	1755.0	.8883	85.19	4212.27	8.62	1.05	.025	191.3		
4.0	3.97	1752.75	.887	85.70	3335.73	7.78	1.25	.02625	166.6		
3.0	2.96	1755.0	.8883	85.19	2487.97	6.62	1.40	.025	147.0		
2.0	1.99	1755.0	.8883	85.19	1668.50	5.42	1.60	.025	120.4		
1.0	0.986	1752.75	.887	85.70	828.77	3.88	1.90	.02625	83.1		
0.5	0.507	175.75	.887	85.70	426.71	2.79	2.15	.02624	59.59		

Table J

10 HP Standard (B)

V	R1	R2	R3	L1	L2
460	1.0555	657.776	0.5932	1.9875	50.2284

M	ALP	S
0	0.0	0.02625
0	0.5	0.025
0	0.7	0.025
1	1.05	0.025
0	1.40	0.025
0	1.60	0.025
0	1.90	0.02625
1	2.15	0.02625

Table K

10 HP Energy Efficient

Input V= 230.0 volts, I Full Load= 24.2 Amps, I No Load=8.16 amps, P_{IN} no load=291.0 watts, Power in full Load= 8354.0 watts, Power Factor No Load= 0.09, P.F. Full Load= .867, HP= 10.0, RPM= 1800, RPM Full Load=1756.0

Equivalent CKT values calculated R1= 0.23682 ohms, R2= 0.14646 ohms, RCC= 200.2742 ohms,

X1= 0.624716 ohms, X2= X1, XMM= 15.6945 ohms

HP	Output HP	RPM	EFF	PF	P _{IN} Watts	I _L		ALPHA	S	V _L
						Amps				
10.0	10.11	1752.75	.9001	86.99	8382.4	24.18		0.0	.02625	132.8
9.0	9.14	1757.25	.9031	86.41	7548.7	22.14		0.1	.02375	131.5
8.0	8.08	1757.25	.9031	86.41	6678.6	20.82		0.45	.02375	123.74
7.5	7.42	1757.25	.9031	86.41	6131.0	19.95		0.60	.02375	118.5
7.0	6.92	1757.25	.9031	86.41	5716.8	19.26		0.70	.02375	114.48
6.0	6.06	1757.25	.9031	86.41	5038.65	18.08		0.85	.02375	107.48
5.0	4.93	1757.25	.9031	86.41	4072.88	16.26		1.05	.02375	96.6
4.0	4.04	1757.25	.9031	86.41	3343.68	14.73		1.20	.02375	87.55
3.0	3.00	1757.125	.9024	86.58	2481.28	12.81		1.40	.024375	74.58
2.0	1.98	1757.25	.9031	86.41	1632.3	10.29		1.60	.02375	61.17
1.0	1.01	1752.75	.9001	86.99	840.75	7.66		1.90	.02625	42.05
0.5	0.5	1752.75	.9001	86.99	414.99	5.38		2.15	.02625	29.54

Table L

10 HP Energy Efficient (B)

V	R1	R2	R3	L1	L2
230.0	0.23682	200.2742	0.14646	0.624716	15.6945

M	ALP	S
0	0.0	0.02375
0	0.45	0.02375
0	0.70	0.02375
1	1.05	0.02375

Table M

Appendix C
Analog-Digital Simulation
Computer Program

List of Input Variables

V = Phase to Phase Voltage
R1 = Resistance in Ohms
R2 = Resistance in Ohms
L1 = Inductive Reactance
L2 = Inductive Reactance
M = FLAG, if Equal to 0 then New DATA will be Read
S = Slip of Motor
ALP = ALPHA Angle

```

1  PROGRAM NINE(PLOT,INPUT,OUTPUT,TAPES=INPUT,TAPES=OUTPUT)
2  DIMENSION Y(21),X(21),GA(21),PE(21),XX(4,21),H(3)
3  DIMENSION Z1(21),Z2(21),Z3(21),ZFL(7),NN(5)
4  DIMENSION AC1(545),AC4(545),WT1(515)
5  DIMENSION RE(543),IM(543),IMK(3420),MK(342)
6  DIMENSION FREQ(543)
7  COMPLEX XO(544)
8  REAL L1,L2,L3,L12,L2SO,MAG(543),PER(350)
9
10 C SECTION **1** INSERTION-----
11 C
12 C VOLTAGE AND CIRCUIT VALUES -----
13 READ (5,107) V,R1,R2,R3,L1,L2
14 PRINT*, "V = ",V, " R1 = ",R1, " R2 = ",R2
15 C *** W = 2 * PI * FREQUENCY, T = TIME IN SECONDS.-----
16 A0 = 3.1415926
17 W = 2.0 * AP*E6.0
18 L1=L1/W
19 L2= L2/W
20 NF4 IS THE PLOTTER FLAG FOR
21 THE 2ND,3RD, AND 4TH PLOT.
22 NF4 = 0
23 INPUT ALPHA, SLIP, AND FLAG -- 1--
24 READ(5,106) M,ALP,S
25 PRINT*, " ALPHA = ",ALP
26 NF3 IS THE OUTPUT FLAG FOR THE 1-THIRD CYCLE OF CURRENT
27 NF3 = 0
28 T4=J.0
29 CUR2=0.0
30 NF=1
31 AAA=0.
32 NX=24.3
33 TO ENABLE THE VOLTAGE CONTROLLER SET CONTRL POSITIVE *****
34 CONTRL = 1.
35 SET FLAG NN TO ZERO FOR SUBROUTINE V3CONT
36 DO 1, I=1,3
37 K = I + 3
38 NN(K)= 0.0
39 NN(I)=0.
40 A50 = 6.0 * AP
41 A70=19.334223
42 A90 = 6.0 * AP
43 A90=2.0*AP*A7P
44
45 A = 2.0 * AP / 3.0
46
47 C ***S = SLIP **TO BE ITERATED LATER -----
48 C
49 C OCT VALUES -----
50 C
51 L3=L1
52 L12=L1+L2
53 L25=L2+2.6
54 R4= 2.0*(1.0 -S)/S
55 RT=R3+R2+R4
56 RL2= L2* R2 +P2
57 RX2= R1+L2

```

```

C ** VM = PEAK VOLTAGE -----
C
C VM = V* SORT(2,0) / SORT(3,0)
C
C ***IPNT = 0 HERE IF SUMMARY CURVES ARE DESIRED*****
C
C **NPLN = NUMBER OF RUNS TO BE MADE -----
C
NRUN = 1
DO 6 IRUN = 1, NRUN
  IPNT = 0
  WRITE(6,100)
  ISTOP = 4
  KEEP = 1
  IFL(1) = -1
  C *** NINT = NUMBER OF INTEGRATORS -----
  NINT = 9
  IFL(2) = -1
  CALL RKFOUR(NINT,Y,X,GA,PE,XX,M,ZZ1,ZZ2,ZZ3,TIME,PNTS,KEEP,IFL)
  IF(IFL(4)) 3,4,5
  INIT = 1
  TIME1 = -1.256789
  NC = 1
  C *** NCC = 1, PORTION OF PLONTS RELEASED TO SECTION 5-----
  NCC = 5
  C ***FINTIM = FINISH TIME *****
  FINTIM = 0.1
  C **QAX = MAXIMUM NUMBER OF POINTS *****
  QAX = 8.00
  C ** SECTION ** 2 **INSERTIONS -----
  C ** GA = GAIN OF INTEGRATER *****
  GA(1) = 1.0 / L1
  GA(2) = 1.0 / ((L2SQ/L12)-L2)
  GA(3) = 1.0 / L3
  GA(4) = GA(1)
  GA(5) = GA(2)
  GA(6) = GA(3)
  GA(7) = GA(1)
  GA(8) = GA(2)
  GA(9) = GA(3)
  WRITE(6,101)
  IF(TIME-TIME1) 7,8,7
  TIME1 = TIME
  C ** SECTION ** 3 ** INSERTIONS *****
  WT = W* TIME
  WTAP = WT + A

```

```

115      WTAP= WT- A
      V1T = VM * SIN(WT)
      V2T = VM * SIN(WTAP)
      V3T = VM * SIN(WTAM)
      IF (CONTRL) 13,13,12
      CALL VOLTAGE CONTROLLER V3CONT
120
125      CALL V3CONT(ALP,Y,V1T,V2T,V3T,WT,WTAP,WTAM,NN,PNTS)
      CONTINUE
      *****
      C ** SECTION ** 4 ** INSERTIONS *****
      *****
      I1 = Y(1) , I2 = Y(2) , I3 = Y(3) -----
      CUR1 V TOTAL CURRENT FOR PHASE ** 1 **
      *****
      X(1) = V1T - R1*Y(1) + R2*(Y(3) - Y(2))
      X(2) = PX2*Y(1)/L12 - V1T + L2/L12 + R2*(Y(2) - Y(3))
      X(3) = R2*Y(2) - R1*Y(3)
      X(4) = V2T - R1*Y(4) + R2*(Y(6) - Y(5))
      X(5) = PX2*Y(4)/L12 - V2T + L2/L12 + R2*(Y(5) - Y(6))
      X(6) = R2*Y(5) - R1*Y(6)
      X(7) = V3T - R1*Y(7) + R2*(Y(9) - Y(8))
      X(8) = PX2*Y(7)/L12 - V3T + L2/L12 + R2*(Y(8) - Y(9))
      X(9) = R2*Y(8) - R1*Y(9)
      IF NN FLAG FROM V3CONT IS SET (1) X = 3.
      *****
      IF (NN(1).EQ.1) X(1)=0.0
      IF (NN(2).EQ.1) X(4)=0.0
      IF (NN(3).EQ.1) X(7)=0.0
      GO TO 2
      IP2 = 3
      NC = NC - 1
      IF (NC) 9,3,11
      NC = NC
      IP2 = 1
      IF (TIME.GE.FINIM.OR.PNTS.GE.PTMAX) ISTOP = 1
      IF ((IPR+ISTOP).EQ.3) GO TO 11
      *****
      C ** SECTION ** 5 ** INSERTIONS *****
      *****
      ----IF -- WT -- IS BETWEEN SIX AND EIGHT PI OUTPUT DATA-----
      *****
      IF (ALP) 22,22,23
      IF (NF3.EQ.1) GO TO 15
      IF (WT.GT.ASP) GO TO 21
      GO TO 11
22

```

```

21      C4=ARS(Y(1))
      .IF(C4.LE.0.1) GO TO 19
      GO TO 11
175      23      IF(NF3.EQ.1) GO TO 15
      IF(WT.GT.A6P) GO TO 18
      GO TO 11
180      18      IF(NN(1).EQ.1) GO TO 19
      GO TO 11
      NF3=1
      T4=WT-A6P
      T3 = WT + (2.0*AP)
15      IF(W1.GT.T3) GO TO 11
      NF=NF+1
      AC1(NF)=V1T
      WT1(NF)=(WT-(ASP*T4))/AP
      AC4(NF)=Y(1)
      C1=ARS(Y(3))
      C2=ARS(Y(6))
      C3=ARS(Y(9))
      PO = C1
      CUR1= PO*2.0*R4
      CUR2=CUR2+CUR1
      CUR3=1.
      C
      11      INIT = 1
      IF(IISTOP) 1,1,6
      B
      C
      180      FORMAT(1H1,1X)
      181      FORMAT(5X," TIME , CYS , CYO , CYS , CURT, VITS ,WTS ")
      185      FORMAT(11,2F10.6)
      187      FORMAT(6F10.6)
      C
      PAVE = (CUR2 / NF ) * 3.0
      PRINT*, " AVERAGE POWER OUT = ", PAVE
      PHD= PAVE/746.
      PRINT*, " HORSE POWER OUTPUT = ", PHP
      PRINT*, " NF = ", NF, " PNTS = ", PNTS
      NF1=NF+1
      NF2=NF+2
      WT1(NF1)=0.0
      WT1(NF2)=0.25
      AC1(NF1)=-VM
      AC1(NF2)=2.0*VM / 6.0
      A2=AC1(NF2)
      A1=AC1(NF1)
      AC4(NF1)=-35.0
      AC4(NF2)=11.66t
      IF(10A) 16,16,17
      16      CONTINUE
      PRINT*, " G"
      NF4 = NF4 + 1
      IF(NF4.GT.1) GO TO 24
      CALL PLOT (C.2,-3)
      GO TO 25
225

```

SYMBOL: REFERENCE MAP (R=1)

```
1      SUBROUTINE RKFOUR(N,Y,X,GAIN,PEAK,XX,H,C1,C2,C3,TIME,PNTS,KEEP,FL)
5      DIMENSION Y(20),X(20),GAIN(20),PEAK(20),XX(4,20),
      INTEGER FL(7)
      DATA A(1)/C.1/,A(2)/0.0/,A(3)/1.058/,A(4)/1.414214/,A(5)/1.03E-4/
      DATA A(6)/1.6E-2/,A(7)/0.0/,A(8)/73.8/

      IF(FL(1)) 1,3,20
1      DO 2 I=1,N
      Y(I)=0.0
      PEAK(I)=0.0
      GAIN(I)=1.0
      TIME=0.0
      PNTS=0.0
      FL(4)=-1
      FL(5)=1
      FL(6)=0
      FL(7)=0
      DO 3 I=1,8
      H(I)=A(I)
      RETURN
3      Q=H(1)
      FL(4)=1
      FL(7)=H(4)
      H(1)=0
      FL(3)=0
      DO 5 I=1,N
      C2(I)=GAIN(I)*Q
      C1(I)=0.5*C2(I)
      C3(I)=C2(I)/6.0
      IF(FL(1)) 6,6,19
10     IF(FL(2)) 31,33,33
      FL(1)=1
      PNTS=PNTS+1.0
      DO 3 I=1,N
      XX(3,I)=Y(I)
      XX(4,I)=X(I)
      FL(4)=1
      H(9)=TIME
      RETURN
20     IF(FL(3)) 25,31,25
      IF(FL(2)-3) 26,60,60
      IF(FL(7)) 21,30,22
      Q=H(1)/H(4)
      IF(Q-H(2)) 23,4,4
      Q=H(2)
      IF(Q-H(1)) 4,30,4
      Q=H(1)+H(4)
      IF(Q-H(3)) 4,4,24
      Q=H(3)
      IF(Q-H(1)) 4,30,4
      FL(3)=0
      IF(FL(2)) 31,40,45
      FL(5)=KEEP
      KEEP=0
      DO 32 I=1,N
      XX(1,I)=XX(3,I)
      XX(2,I)=XX(4,I)
32
```

```
33 FL(2)=0
   TIME= H(9)+6.5*H(1)
   DO 34 I=1,N
34 Y(I)=XX(1,I)+C1(I)*XX(2,I)
35 KEEP=0
36 FL(4)=0
   RETURN
60 FL(2)=1
   DO 41 I=1,N
   XX(3,I)=X(I)
41 Y(I)=XX(1,I)+C1(I)*X(I)
   GO TO 35
70 IF(FL(2)-2) 46,48,60
46 FL(2)=2
   TIME=4(9)+H(1)
   DO 47 I=1,N
   XX(4,I)=X(I)
47 Y(I)=XX(1,I)+C2(I)*X(I)
   GO TO 35
75 FL(2)=3
   IF(H(7)) 49,52,52
49 KEEP=FL(5)
50 DO 51 I=1,N
51 Y(I)=XX(1,I)+C3(I)*XX(2,I)+X(I)+2.*XX(3,I)+XX(4,I))
52 ERR=.0
   DO 56 I=1,N
85 ESTERR=2(I)*ABS(XX(2,I)+X(I)-2.*XX(4,I))
   IF(PEAK(I)) 53,53,54
54 ESTERR=ESTERR/PEAK(I)
53 IF(EPH-ESTERR) 55,56,56
55 ERR=ESTERR
56 CONTINUE
90 IF(EEP-H(6)) 57,57,66
57 IF(ECP-H(5)) 58,59,59
58 FL(7)=FL(7)-1
65 IF(FL(7)) 65,65,49
   FL(3)=1
   GO TO 49
59 FL(7)=H(8)
   GO TO 49
60 FL(7)=H(6)
   GO TO 21
100 IF(H(7)) 7,61,61
51 DO 53 I=1,N
   ERR=ABS(Y(I))
   IF(ERP-PEAK(I)) 63,63,62
52 PEAK(I)=ERR
63 CONTINUE
   GO TO 7
   END
```

```

1  SUBROUTINE VSCONT(ALP,V,V1T,V2T,V3T,WT,WTAP,WTAM,NN,PNTS)
2  DIMENSION Y(2P), NN(6)
3  SUBROUTINE VSCONT IS THE VOLTAGE CONTROLLER
4  -- V -- IS THE ARRAY OF CURRENTS FROM SUBROUTINE RKFOUR
5  THE -- NN -- ARRAY ARE THE FLAGS FOR THE THREE VOLTAGES
6  -- PNTS -- IS THE OUTPUT COUNTER FROM RKFOUR
7  ALP IS ANGLE IN RADIAN FOR VOLTAGE TO BE ZERO
8
9  EACH CONTROLLER V1T, V2T, V3T, MARKS INDEPENDENTLY
10 AND ARE IDENTICAL IN LOGIC
11
12 ***** CONTROLLER FOR V1T *****
13
14 IF THE SCR IS SHUT OFF THEN NN(2)= 1
15 SET VOLTAGE AND CURRENT EQUAL TO 1.0
16 IF(NN(1).EQ.1) GO TO 1
17
18 THIS IF STATEMENT ALLOWS THE CURRENT
19 TO MOVE AWAY FROM ZERO ONCE THE
20 SCR IS TURNED ON
21
22 IF(PNTS.LT.NN(1)) GO TO 3
23 R1 IS THE ABSOLUTE VALUE OF CURRENT --Y(1) --
24 B1=ABS(Y(1))
25 SAMPLE CURRENT ONE TO CHECK FOR ZERO CROSSING
26 IF TRUE SET FLAG NN(1) = 1
27 IF(R1.GT.1)GO TO 3
28 NN(1)=1
29
30 THE SCR IS TURNED OFF
31 THE T1 TIMER IS SET FOR PERIOD
32 THAT THE SCR IS TO STAY OFF
33 STATEMENT -- 1 --WILL BE FALSE
34
35 T1=WT+ALP
36 IF(WT.GT.T1) GO TO 2
37
38 SET VOLTAGE AND CURRENT TO ZERO
39
40 V1T=1.0
41 Y(1)=1.0
42
43 RESET POINT COUNTER NN(4)
44 NN(4)= PNTS + 60
45
46 GO TO PHASE TWO VOLTAGE CONTROLLER
47 GO TO 3
48
49 SET FLAG NN(1)=0 TO INDICATE
50 THE SCR IS TURNED ON
51
52 NN(1)=0
53
54 ***** CONTROLLER FOR V2T *****

```

```
3 IF(NN(2).EQ.1) GO TO 4
  IF(PNTS.LT.NN(5)) GO TO 6
  B2= ARS(Y(4))
  IF(AR2.GT.0.10)GO TO 6
  NN(2)=1
  T2= WTAP + ALP
  IF(WTAP.GT.T2) GO TO 5
  V2T=0.0
  Y(4)=9.0
  NN(5)= PNTS + 60
  GO TO 6
  NN(2)=7

***** CONTROLLER FOR V3T *****
3 IF (NN(3).EQ.1) GO TO 7
  IF(PNTS.LT.NN(5)) GO TO 9
  33= ARS(Y(7))
  IF(AR3.GT.0.10)GO TO 9
  NN(3)=1
  T3= WTAM + ALP
  IF(WTAM.GT.T3) GO TO 8
  V3T=0.0
  Y(7)=0.0
  NN(5)= PNTS + 60
  GO TO 9
  NN(3)=0
  RETURN
  END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
3 V3CONT

VARIABLES	SV	TYPE	RELOCATION	
C ALP		REAL	F.P.	
116 B2		REAL		
J VN		INTEGER	ARRAY	
115 T1		REAL		
121 T3		REAL		
C V2T		REAL		
C WT		REAL		
C WTAP		REAL		
			ARRAY	
			F.P.	
			F.P.	
			F.P.	
			F.P.	
			F.P.	

INLINE FUNCTIONS
ARS REAL TYPE ARGS 1 INTRIN

STATEMENT LABELS

28 1	30 2	31 3
46 4	57 5	51 6
76 7	107 8	111 9

```

1  SURROUTINE FFTCC (A,N,IMK,NK)
2  SPECIFICATIONS FOR ARGUMENTS
3
5  INTEGER
6  REAL
7  COMPLEX
8
9  INTEGER
10 1
11 2
12 3
13 4
14 5
15 6
16 7
17 8
18 9
19 10
20 11
21 12
22 13
23 14
24 15
25 16
26 17
27 18
28 19
29 20
30 21
31 22
32 23
33 24
34 25
35 26
36 27
37 28
38 29
39 30
40 31
41 32
42 33
43 34
44 35
45 36
46 37
47 38
48 39
49 40
50 41
51 42
52 43
53 44
54 45
55 46
56 47
57 48
58 49
59 50
60 51
61 52
62 53
63 54
64 55
65 56
66 57
67 58
68 59
69 60
70 61
71 62
72 63
73 64
74 65
75 66
76 67
77 68
78 69
79 70
80 71
81 72
82 73
83 74
84 75
85 76
86 77
87 78
88 79
89 80
90 81
91 82
92 83
93 84
94 85
95 86
96 87
97 88
98 89
99 90
100 91
101 92
102 93
103 94
104 95
105 96
106 97
107 98
108 99
109 100
110 101
111 102
112 103
113 104
114 105
115 106
116 107
117 108
118 109
119 110
120 111
121 112
122 113
123 114
124 115
125 116
126 117
127 118
128 119
129 120
130 121
131 122
132 123
133 124
134 125
135 126
136 127
137 128
138 129
139 130
140 131
141 132
142 133
143 134
144 135
145 136
146 137
147 138
148 139
149 140
150 141
151 142
152 143
153 144
154 145
155 146
156 147
157 148
158 149
159 150
160 151
161 152
162 153
163 154
164 155
165 156
166 157
167 158
168 159
169 160
170 161
171 162
172 163
173 164
174 165
175 166
176 167
177 168
178 169
179 170
180 171
181 172
182 173
183 174
184 175
185 176
186 177
187 178
188 179
189 180
190 181
191 182
192 183
193 184
194 185
195 186
196 187
197 188
198 189
199 190
200 191
201 192
202 193
203 194
204 195
205 196
206 197
207 198
208 199
209 200
210 201
211 202
212 203
213 204
214 205
215 206
216 207
217 208
218 209
219 210
220 211
221 212
222 213
223 214
224 215
225 216
226 217
227 218
228 219
229 220
230 221
231 222
232 223
233 224
234 225
235 226
236 227
237 228
238 229
239 230
240 231
241 232
242 233
243 234
244 235
245 236
246 237
247 238
248 239
249 240
250 241
251 242
252 243
253 244
254 245
255 246
256 247
257 248
258 249
259 250
260 251
261 252
262 253
263 254
264 255
265 256
266 257
267 258
268 259
269 260
270 261
271 262
272 263
273 264
274 265
275 266
276 267
277 268
278 269
279 270
280 271
281 272
282 273
283 274
284 275
285 276
286 277
287 278
288 279
289 280
290 281
291 282
292 283
293 284
294 285
295 286
296 287
297 288
298 289
299 290
300 291
301 292
302 293
303 294
304 295
305 296
306 297
307 298
308 299
309 300
310 301
311 302
312 303
313 304
314 305
315 306
316 307
317 308
318 309
319 310
320 311
321 312
322 313
323 314
324 315
325 316
326 317
327 318
328 319
329 320
330 321
331 322
332 323
333 324
334 325
335 326
336 327
337 328
338 329
339 330
340 331
341 332
342 333
343 334
344 335
345 336
346 337
347 338
348 339
349 340
350 341
351 342
352 343
353 344
354 345
355 346
356 347
357 348
358 349
359 350
360 351
361 352
362 353
363 354
364 355
365 356
366 357
367 358
368 359
369 360
370 361
371 362
372 363
373 364
374 365
375 366
376 367
377 368
378 369
379 370
380 371
381 372
382 373
383 374
384 375
385 376
386 377
387 378
388 379
389 380
390 381
391 382
392 383
393 384
394 385
395 386
396 387
397 388
398 389
399 390
400 391
401 392
402 393
403 394
404 395
405 396
406 397
407 398
408 399
409 400
410 401
411 402
412 403
413 404
414 405
415 406
416 407
417 408
418 409
419 410
420 411
421 412
422 413
423 414
424 415
425 416
426 417
427 418
428 419
429 420
430 421
431 422
432 423
433 424
434 425
435 426
436 427
437 428
438 429
439 430
440 431
441 432
442 433
443 434
444 435
445 436
446 437
447 438
448 439
449 440
450 441
451 442
452 443
453 444
454 445
455 446
456 447
457 448
458 449
459 450
460 451
461 452
462 453
463 454
464 455
465 456
466 457
467 458
468 459
469 460
470 461
471 462
472 463
473 464
474 465
475 466
476 467
477 468
478 469
479 470
480 471
481 472
482 473
483 474
484 475
485 476
486 477
487 478
488 479
489 480
490 481
491 482
492 483
493 484
494 485
495 486
496 487
497 488
498 489
499 490
500 491
501 492
502 493
503 494
504 495
505 496
506 497
507 498
508 499
509 500
510 501
511 502
512 503
513 504
514 505
515 506
516 507
517 508
518 509
519 510
520 511
521 512
522 513
523 514
524 515
525 516
526 517
527 518
528 519
529 520
530 521
531 522
532 523
533 524
534 525
535 526
536 527
537 528
538 529
539 530
540 531
541 532
542 533
543 534
544 535
545 536
546 537
547 538
548 539
549 540
550 541
551 542
552 543
553 544
554 545
555 546
556 547
557 548
558 549
559 550
560 551
561 552
562 553
563 554
564 555
565 556
566 557
567 558
568 559
569 560
570 561
571 562
572 563
573 564
574 565
575 566
576 567
577 568
578 569
579 570
580 571
581 572
582 573
583 574
584 575
585 576
586 577
587 578
588 579
589 580
590 581
591 582
592 583
593 584
594 585
595 586
596 587
597 588
598 589
599 590
600 591
601 592
602 593
603 594
604 595
605 596
606 597
607 598
608 599
609 600
610 601
611 602
612 603
613 604
614 605
615 606
616 607
617 608
618 609
619 610
620 611
621 612
622 613
623 614
624 615
625 616
626 617
627 618
628 619
629 620
630 621
631 622
632 623
633 624
634 625
635 626
636 627
637 628
638 629
639 630
640 631
641 632
642 633
643 634
644 635
645 636
646 637
647 638
648 639
649 640
650 641
651 642
652 643
653 644
654 645
655 646
656 647
657 648
658 649
659 650
660 651
661 652
662 653
663 654
664 655
665 656
666 657
667 658
668 659
669 660
670 661
671 662
672 663
673 664
674 665
675 666
676 667
677 668
678 669
679 670
680 671
681 672
682 673
683 674
684 675
685 676
686 677
687 678
688 679
689 680
690 681
691 682
692 683
693 684
694 685
695 686
696 687
697 688
698 689
699 690
700 691
701 692
702 693
703 694
704 695
705 696
706 697
707 698
708 699
709 700
710 701
711 702
712 703
713 704
714 705
715 706
716 707
717 708
718 709
719 710
720 711
721 712
722 713
723 714
724 715
725 716
726 717
727 718
728 719
729 720
730 721
731 722
732 723
733 724
734 725
735 726
736 727
737 728
738 729
739 730
740 731
741 732
742 733
743 734
744 735
745 736
746 737
747 738
748 739
749 740
750 741
751 742
752 743
753 744
754 745
755 746
756 747
757 748
758 749
759 750
760 751
761 752
762 753
763 754
764 755
765 756
766 757
767 758
768 759
769 760
770 761
771 762
772 763
773 764
774 765
775 766
776 767
777 768
778 769
779 770
780 771
781 772
782 773
783 774
784 775
785 776
786 777
787 778
788 779
789 780
790 781
791 782
792 783
793 784
794 785
795 786
796 787
797 788
798 789
799 790
800 791
801 792
802 793
803 794
804 795
805 796
806 797
807 798
808 799
809 800
810 801
811 802
812 803
813 804
814 805
815 806
816 807
817 808
818 809
819 810
820 811
821 812
822 813
823 814
824 815
825 816
826 817
827 818
828 819
829 820
830 821
831 822
832 823
833 824
834 825
835 826
836 827
837 828
838 829
839 830
840 831
841 832
842 833
843 834
844 835
845 836
846 837
847 838
848 839
849 840
850 841
851 842
852 843
853 844
854 845
855 846
856 847
857 848
858 849
859 850
860 851
861 852
862 853
863 854
864 855
865 856
866 857
867 858
868 859
869 860
870 861
871 862
872 863
873 864
874 865
875 866
876 867
877 868
878 869
879 870
880 871
881 872
882 873
883 874
884 875
885 876
886 877
887 878
888 879
889 880
890 881
891 882
892 883
893 884
894 885
895 886
896 887
897 888
898 889
899 890
900 891
901 892
902 893
903 894
904 895
905 896
906 897
907 898
908 899
909 900
910 901
911 902
912 903
913 904
914 905
915 906
916 907
917 908
918 909
919 910
920 911
921 912
922 913
923 914
924 915
925 916
926 917
927 918
928 919
929 920
930 921
931 922
932 923
933 924
934 925
935 926
936 927
937 928
938 929
939 930
940 931
941 932
942 933
943 934
944 935
945 936
946 937
947 938
948 939
949 940
950 941
951 942
952 943
953 944
954 945
955 946
956 947
957 948
958 949
959 950
960 951
961 952
962 953
963 954
964 955
965 956
966 957
967 958
968 959
969 960
970 961
971 962
972 963
973 964
974 965
975 966
976 967
977 968
978 969
979 970
980 971
981 972
982 973
983 974
984 975
985 976
986 977
987 978
988 979
989 980
990 981
991 982
992 983
993 984
994 985
995 986
996 987
997 988
998 989
999 990
1000 991

```

```

60      X(K+1) = SUM FROM J = 0 TO N-1 OF
        A(J+1)*CEX2((J+1),(2.*PI*J*K)/N))
        FOR K=0,1,...,N-1 AND PI=3.1415...
65      NOTE THAT X OVERWRITES A ON OUTPUT.
        2. FFTCC CAN BE USED TO COMPUTE
        X(K+1) = (1/N)*SUM FROM J = 0 TO N-1 OF
          A(J+1)*CEX2((J+1),(-2.*PI*J*K)/N))
        FOR K=0,1,...,N-1 AND PI=3.1415...
70      BY PERFORMING THE FOLLOWING STEPS:
        DO 10 I=1,N
          A(I) = CONJG(A(I))
        10 CONTINUE
        CALL FFTCC (A,N,I4,NK)
        DO 20 I=1,N
          A(I) = CONJG(A(I))/N
        20 CONTINUE
80      COPYRIGHT - 1978 BY IMSL, INC. ALL RIGHTS RESERVED.
        WARRANTY - IMSL WARRANTS ONLY THAT IMSL TESTING HAS BEEN
        APPLIED TO THIS CODE. NO OTHER WARRANTY,
        EXPRESSED OR IMPLIED, IS APPLICABLE.
85      -----
        FIRST EXECUTABLE STATEMENT
        IF (N.EQ. 1) GO TO 9005
        K = N
        M = 1
        J = 2
        JJ = 4
        JF = 8
        IMK(1) = 1
        5 I = K/JJ
        IF (J=JJ.NE. K) GO TO 10
        M = M+1
        IMK(M+1) = J
        K = I
        GO TO 5
        10 J = J + 2
        IF (J.EQ. 4) J = 3
        JJ = J * J
        IF (JJ.LE. K) GO TO 5
        KT = J
        J = 2
        15 I = K / J
        IF (I=J.NE. K) GO TO 20
        M = M + 1
        IMK(M+1) = J
        K = I

```

```

115 GO TO 15
120 J = J + 1
    IF (J .EQ. 3) GO TO 15
    J = J + 1
    IF (J.LE.K) GO TO 15
    K = JWK(M+1)
    IF (IWK(KT+1) .GT. IWK(M+1)) K = IWK(KT+1)
    IF (KT.LE.0) GO TO 30
    KTP = KT + 2
    00 25 I = 1,KT
        J = KTP - I
        M = M+1
        IWK(M+1) = IWK(J)
25 CONTINUE
30 MP = M+1
    IC = MP+1
    ID = IC+MP
    ILL = ID+MP
    IRD = ILL+MP+1
    ICC = IPD+MP
    ISS = ICC+MP
    ICK = ISS+MP
    ISK = ICK+K
    ICF = ISK+K
    ISF = ICF+K
    IAP = ISF+K
    K72 = (K-1) / 2 + 1
    IAP = IAP + K02
    IAM = IAP + K02
    I9M = IAM + K02
    M41 = M-1
    I = 1
35 L = MP - I
    J = IC - I
    IWK(ILL+L) = 0
    IF ((IWK(J-1) + IWK(J)) .EQ. 4) IWK(ILL+L) = 1
    IF (IWK(ILL+L) .EQ. 0) GO TO 40
    I = I + 1
    L = L - 1
    IWK(ILL+L) = 1
60 I = I + 1
    IF (I.LE.M41) GO TO 35
    IWK(ILL+1) = 1
    IWK(ILL+MP) = 1
    IWK(IC) = 1
    IWK(IC) = N
    DO 45 J = 1,M
        K = IWK(J+1)
        IWK(IC+J) = IWK(IC+J-1) * K
        IWK(ID+J) = IWK(ID+J-1) / K
        WK(JRD+J) = RAC/IWK(IC+J)
        C1 = RAD/K
        IF (K.LE.2) GO TO 45
        WK(ICC+J) = COS(C1)
        WK(ISS+J) = SIN(C1)
45 CONTINUE
    MM = M

```

```

IF (IMK(ILL+H) .EQ. 1) MH = M - 1
IF (MH .LE. 1) GO TO 50
SM = IMK(IC+MH-2) + WK(IRD+H)
CM = COS(SM)
SM = SIN(SM)
50 K9 = C
K4 = N
JJ = 0
I = 1
C1 = ONE
S1 = ZERO
L1 = J
55 IF (IMK(ILL+I+1) .EQ. 1) GO TO 60
KF = IMK(I+1)
GO TO 65
60 KF = 4
I = I + 1
65 ISP = IMK(ID+I)
IF (L1 .EQ. 1) GO TO 70
S1 = JJ + WK(IRD+I)
C1 = COS(S1)
S1 = SIN(S1)

```

175

180

185

190

195

200

205

210

215

220

225

FACTORS OF 2, 3, AND 4 ARE
HANDLED SEPARATELY.

```

70 IF (KF .GT. 4) GO TO 140
GO TO (75,76,96,115), KF
75 K9 = K9 + ISP
K2 = K9 + ISP
IF (L1 .EQ. 1) GO TO 85
80 K9 = K9 - 1
IF (K9 .LT. K8) GO TO 190
K2 = K2 - 1
7A4 = A(K2+1)
A0 = A(C1-P4*S1)
B0 = A(S1+P4*C1)
A(K2+1) = A(K1+1)-7A0
A(K1+1) = A(K1+1)+7A0
GO TO 80
85 K9 = K9 - 1
IF (K9 .LT. K8) GO TO 190
K2 = K2 - 1
AK2 = A(K2+1)
A(K2+1) = A(K1+1)-AK2
A(K1+1) = A(K1+1)+AK2
GO TO 85
90 IF (L1 .EQ. 1) GO TO 95
C2 = C1 * C1 - S1 * S1
S2 = TWO * C1 * S1
95 JA = K8 + ISP - 1
K4 = JA + K8
IK9 = K8+1
IJA = JA+1
DO 119 II = IK8, IJA
K0 = KA - II + 1
K1 = K0 + ISP
K2 = K1 + ISP
7A0 = A(K0+1)

```

FFTP1720
FFTP1730
FFTP1740
FFTP1750
FFTP1760
FFTP1770
FFTP1780
FFTP1790
FFTP1800
FFTP1810
FFTP1820
FFTP1830
FFTP1840
FFTP1850
FFTP1860
FFTP1870
FFTP1880
FFTP1890
FFTP1900
FFTP1910
FFTP1920
FFTP1930
FFTP1940
FFTP1950
FFTP1960
FFTP1970
FFTP1980
FFTP1990
FFTP2000
FFTP2010
FFTP2020
FFTP2030
FFTP2040
FFTP2050
FFTP2060
FFTP2070
FFTP2080
FFTP2090
FFTP2100
FFTP2110
FFTP2120
FFTP2130
FFTP2140
FFTP2150
FFTP2160
FFTP2170
FFTP2180
FFTP2190
FFTP2200
FFTP2210
FFTP2220
FFTP2230
FFTP2240
FFTP2250
FFTP2260
FFTP2270
FFTP2280

```

230 IF (L1.EQ.1) GO TO 100
    7A4 = A(K1+1)
    A1 = A4*C1-P4*S1
    91 = A4*S1+R4*C1
    7A4 = A(K2+1)
    A2 = A4*C2-P4*S2
    92 = A4*S2+R4*C2
    GO TO 105
235
180 7A1 = A(K1+1)
    7A2 = A(K2+1)
105 A(KU+1) = CMPLX(A0+A1+A2,B0+B1+B2)
    A* = -HALF * (A1+A2) + A3
    A1 = (A1-A2) * C3
    93 = -HALF * (B1+B2) + 90
    91 = (B1-B2) * C3
    A(K1+1) = CMPLX(A0-B1,B0-A1)
    A(K2+1) = CMPLX(A0+B1,B0+A1)
245 110 CONTINUE
    GO TO 190
115 IF (L1.EQ.1) GO TO 120
    C2 = C1 * C1 - S1 * S1
    S2 = TWO * C1 * S1
    C3 = C1 * C2 - S1 * S2
    S3 = S1 * C2 + C1 * S2
120 JA = K9 + ISP - 1
    KA = JA + KB
    IK9 = KB+1
    IJA = JA+1
    DO 135 II = IK9,IJA
        K1 = KA - II + 1
        K2 = K1 + ISP
        K3 = K2 + ISP
        7A0 = A(K1+1)
        7A4 = A(K1+1)
        A1 = A4*C1-P4*S1
        91 = A4*S1+R4*C1
        7A4 = A(K2+1)
        A2 = A4*C2-P4*S2
        92 = A4*S2+R4*C2
        7A4 = A(K3+1)
        A3 = A4*C3-P4*S3
        93 = A4*S3+R4*C3
        GO TO 130
125 7A1 = A(K1+1)
    7A2 = A(K2+1)
    7A3 = A(K3+1)
130 A(K2+1) = CMPLX(A0+A2+A1+A3,B0+B2+B1+B3)
    A(K1+1) = CMPLX(A0+A2-A1-A3,B0+B2-B1-B3)
    A(K2+1) = CMPLX(A0-A2-B1-B3,B1-B2-A1-A3)
    A(K3+1) = CMPLX(A0-A2+B1-B3,B0-B2-A1+A3)
135 CONTINUE
    GO TO 190
140 JK = KF - 1
    KH = JK/2
    KI = IMK(I0+I-1)
245

```

```

290 K1 = K2 + ISP
    IF (L1.EQ. 1) GO TO 150
    K = JK - 1
    WK(ICF+1) = C1
    WK(ISF+1) = S1
    DO 155 J = 1, K
        WK(ICF+J+1) = WK(ICF+J) + C1 - 4*(ISF+J) + S1
        WK(ISF+J+1) = WK(ICF+J) + S1 + WK(ISF+J) + C1
155 CONTINUE
150 IF (KF.EQ. JF) GO TO 160
    C2 = WK(ICK+1)
    WK(ICK+1) = C2
    WK(ICK+JK) = C2
    S2 = WK(ISS+1)
    WK(ISK+1) = S2
    WK(ISK+JK) = -S2
    DO 175 J = 1, KH
        K = JK - J
        WK(ICK+K) = WK(ICK+J) + S2 - 4*(ISK+J) + S2
        WK(ICK+J+1) = WK(ICK+K)
        WK(ISK+J+1) = WK(ICK+J) + S2 + WK(ISK+J) + C2
        WK(ISK+K) = -WK(ISK+J+1)
155 CONTINUE
160 K1 = K2 - 1
    K1 = K2
    K2 = K2 + K3
    ZAK = A(K2+1)
    A3 = A2
    A3 = IP
    DO 175 J = 1, KH
        K1 = K1 + ISP
        K2 = K2 - ISP
        IF (L1.EQ. 1) GO TO 165
        K = KF - J
        ZA4 = A(K1+1)
        A1 = A4*WK(ICF+J) - 84*WK(ISF+J)
        A1 = A4*WK(ICF+J) + 84*WK(ICF+J)
        ZA6 = A(K2+1)
        A2 = A4*WK(ICF+K) - 84*WK(ISF+K)
        A2 = A4*WK(ICF+K) + 84*WK(ICF+K)
        GO TO 171
165 ZA1 = A(K1+1)
    ZA2 = A(K2+1)
170 AK(IAP+J) = A1 + A2
    WK(IAP+J) = A1 - A2
    WK(IAP+J) = 91 + B2
    WK(IAP+J) = 91 - B2
    A3 = A1 + A2 + A3
    A1 = 91 + B2 + B3
175 CONTINUE
    A(K1+1) = CMPLX(A3,93)
    K1 = K2
    K2 = K2 + K3
    DO 175 J = 1, KH
        K1 = K1 + ISP
        K2 = K2 - ISP
        JK = J

```

```

FF1P1430
FF1P1440
FF1P1450
FF1P1460
FF1P1470
FF1P1480
FF1P1490
FF1P1500
FF1P1510
FF1P1520
FF1P1530
FF1P1540
FF1P1550
FF1P1560
FF1P1570
FF1P1580
FF1P1590
FF1P1600
FF1P1610
FF1P1620
FF1P1630
FF1P1640
FF1P1650
FF1P1660
FF1P1670
FF1P1680
FF1P1690
FF1P1700
FF1P1710
FF1P1720
FF1P1730
FF1P1740
FF1P1750
FF1P1760
FF1P1770
FF1P1780
FF1P1790
FF1P1800
FF1P1810
FF1P1820
FF1P1830
FF1P1840
FF1P1850
FF1P1860
FF1P1870
FF1P1880
FF1P1890
FF1P1900
FF1P1910
FF1P1920
FF1P1930
FF1P1940
FF1P1950
FF1P1960
FF1P1970
FF1P1980
FF1P1990

```

```

345 A1 = 40
      B1 = 80
      A2 = ZERO
      B2 = ZERO
      DO 180 K = 1, KH
        A1 = A1 + WK(IAP+K) * WK(ICK+JK)
        A2 = A2 + WK(IAM+K) * WK(ICK+JK)
        B1 = B1 + WK(IAP+K) * WK(ICK+JK)
        B2 = B2 + WK(IAM+K) * WK(ICK+JK)
        JK = JK + J
      IF (JK .GE. KF) JK = JK - K*
180 CONTINUE
      A(K1+1) = CHPLX(A1-B2,B1-A2)
      A(K2+1) = CHPLX(A1+B2,B1-A2)
350 185 CONTINUE
      IF (KN .GT. KB) GO TO 160
      JF = KF
360 190 IF (I .GE. MM) GO TO 195
      I = I + 1
      GO TO 55
195 I = MM
      L1 = 0
      K1 = IWK(ID+I-1) + KB
      IF (K1 .GE. KN) GO TO 215
      JJ = IWK(IC+I-2) + JJ
      IF (JJ .LT. IWK(IC+I-1)) GO TO 205
      I = I - 1
      JJ = JJ - IWK(IC+I)
      GO TO 200
205 IF (I .NE. MM) GO TO 210
      C2 = C1
      C1 = CM * C1 - SM * S1
      S1 = SM * C2 + CM * S1
      GO TO 70
210 IF (IWK(ILL+I) .EQ. 1) I = I + 1
      GO TO 55
215 I = 1
      JA = KT - 1
      KA = KA + 1
      IF (JA .LT. 1) GO TO 225
      DO 220 II = 1, JA
        J = KA - II
        IWK(J+1) = IWK(J+1) - 1
        I = IWK(J+1) + 1
220 CONTINUE
      C
      C
390 225 IF (KT .LE. 1) GO TO 270
      J = 1
      I = 0
      K1 = 0
      K2 = IWK(ID+J) + KB
      K1 = K2
      JJ = IWK(IC+J-1)
      JK = JJ
      K1 = K1 + JJ
      IS0 = IWK(IC+J) - JJ
      THE RESULT IS NOW PERMUTED TO
      NORMAL ORDER.
395 230 K2 = IWK(ID+J) + KB
      K1 = K2
      JJ = IWK(IC+J-1)
      JK = JJ
      K1 = K1 + JJ
      IS0 = IWK(IC+J) - JJ

```

```

430      235 K = K1 + JJ
      240 744 = A(K1+1)
      744 = A(K1+1) = A(K2+1)
      A(K2+1) = 744
      K1 = K1 + 1
      K2 = K2 + 1
      IF (K1.LT. K) GO TO 243
      K1 = K1 + ISP
      K2 = K2 + ISP
      IF (K1.LT. K3) GO TO 235
      IF (K1.GE. K3 + ISP) GO TO 245
      K1 = K1 - IMK(ID+J) + JJ
      GO TO 235
      245 K1 = IMK(ID+J) + K3
      IF (K1 - KB .GE. IMK(ID+J-1)) GO TO 250
      K2 = K3 + JK
      JK = JK + JJ
      K3 = K3 - IMK(ID+J) + JK
      GO TO 235
      250 IF (J .GE. KT) GO TO 260
      K = IMK(J+1) + I
      J = J + 1
      I = I + 1
      IMK(ILL+I) = J
      IF (I.LT. K) GO TO 255
      GO TO 235
      255 K9 = K3
      IF (I .LE. 1) GO TO 265
      J = IMK(ILL+I)
      I = I - 1
      GO TO 235
      265 IF (K9 .GE. N) GO TO 270
      J = 1
      GO TO 235
      270 JK = IMK(IG+KT)
      ISP = IMK(ID+KT)
      M = M - KT
      K3 = ISP/JK-2
      IF (KT .GE. M-1) GO TO 9035
      ITA = ILL+KB+1
      ITB = ITA+JK
      IDM1 = ID-1
      IKT = KT+1
      IM = M+1
      DO 275 J = IKT,IM
      IMK(IDM1+J) = IMK(IDM1+J)/JK
      275 CONTINUE
      JJ = 0
      DO 280 J = 1,KB
      K = KT
      JJ = IMK(ID+K+1) + JJ
      IF (JJ.LT. IMK(ID+K)) GO TO 235
      JJ = JJ - IMK(ID+K)
      K = K + 1
      GO TO 275
      280 IMK(ILL+J) = JJ
      IF (JJ .EQ. J) IMK(ILL+J) = -J

```

```

468      230 CONTINUE
C
C
C
      DO 10 J = 1,K9
      IF (IMK(ILL+J) .LE. 0) GO TO 303
      K2 = J
      235  K2 = IABS(IMK(ILL+K2))
      IF (K2 .EQ. J) GO TO 302
      IMK(ILL+K2) = -IMK(ILL+K2)
      30 TO 295
      300 CONTINUE
C
C
      I = 0
      J = 0
      K9 = 0
      KN = N
      475  J = J + 1
      IF (IMK(ILL+J) .LT. 0) GO TO 305
      K = IMK(ILL+J)
      K1 = JK * K + KB
      310 7A4 = A(KU+I+1)
      WK(ITA+I) = A6
      WK(ITA+I) = B6
      I = I + 1
      IF (I .LT. JK) GO TO 310
      I = 1
      485  K = -IMK(ILL+K)
      JJ = K0
      K1 = JK * K + KB
      320  A(JJ+I+1) = A(KB+I+1)
      I = I + 1
      IF (I .LT. JK) GO TO 320
      I = 0
      IF (K .NE. J) GO TO 315
      325  A(K)+I+1) = CMPLX(WK(ITA+I),WK(ITA+I))
      I = I + 1
      IF (I .LT. JK) GO TO 325
      I = 0
      IF (J .LT. K2) GO TO 305
      J = 1
      K9 = KB + ISP
      IF (K9 .LT. KN) GO TO 305
      9005 CONTINUE
      RETURN
      END

```

REORDER A FOLLOWING THE
PERMUTATION CYCLES

FFTC579
FFTC580
FFTC581
FFTC582
FFTC583
FFTC584
FFTC585
FFTC586
FFTC587
FFTC588
FFTC589
FFTC590
FFTC591
FFTC592
FFTC593
FFTC594
FFTC595
FFTC596
FFTC597
FFTC598
FFTC599
FFTC600
FFTC601
FFTC602
FFTC603
FFTC604
FFTC605
FFTC606
FFTC607
FFTC608
FFTC609
FFTC610
FFTC611
FFTC612
FFTC613
FFTC614
FFTC615
FFTC616
FFTC617
FFTC618
FFTC619
FFTC620
FFTC621
FFTC622
FFTC623
FFTC624
FFTC625
FFTC626
FFTC627
FFTC628
FFTC629
FFTC630
FFTC631
FFTC632
FFTC633
FFTC634
FFTC635
FFTC636
FFTC637
FFTC638
FFTC639
FFTC640
FFTC641
FFTC642
FFTC643
FFTC644
FFTC645
FFTC646
FFTC647
FFTC648
FFTC649
FFTC650
FFTC651
FFTC652
FFTC653
FFTC654
FFTC655
FFTC656
FFTC657
FFTC658
FFTC659
FFTC660
FFTC661
FFTC662
FFTC663
FFTC664
FFTC665
FFTC666
FFTC667
FFTC668
FFTC669
FFTC670
FFTC671
FFTC672
FFTC673
FFTC674
FFTC675
FFTC676
FFTC677
FFTC678
FFTC679
FFTC680
FFTC681
FFTC682
FFTC683
FFTC684
FFTC685
FFTC686
FFTC687
FFTC688
FFTC689
FFTC690
FFTC691
FFTC692
FFTC693
FFTC694
FFTC695
FFTC696
FFTC697
FFTC698
FFTC699
FFTC700
FFTC701
FFTC702
FFTC703
FFTC704
FFTC705
FFTC706
FFTC707
FFTC708
FFTC709
FFTC710
FFTC711
FFTC712
FFTC713
FFTC714
FFTC715
FFTC716
FFTC717
FFTC718
FFTC719
FFTC720
FFTC721
FFTC722
FFTC723
FFTC724
FFTC725
FFTC726
FFTC727
FFTC728
FFTC729
FFTC730
FFTC731
FFTC732
FFTC733
FFTC734
FFTC735
FFTC736
FFTC737
FFTC738
FFTC739
FFTC740
FFTC741
FFTC742
FFTC743
FFTC744
FFTC745
FFTC746
FFTC747
FFTC748
FFTC749
FFTC750
FFTC751
FFTC752
FFTC753
FFTC754
FFTC755
FFTC756
FFTC757
FFTC758
FFTC759
FFTC760
FFTC761
FFTC762
FFTC763
FFTC764
FFTC765
FFTC766
FFTC767
FFTC768
FFTC769
FFTC770
FFTC771
FFTC772
FFTC773
FFTC774
FFTC775
FFTC776
FFTC777
FFTC778
FFTC779
FFTC780
FFTC781
FFTC782
FFTC783
FFTC784
FFTC785
FFTC786
FFTC787
FFTC788
FFTC789
FFTC790
FFTC791
FFTC792
FFTC793
FFTC794
FFTC795
FFTC796
FFTC797
FFTC798
FFTC799
FFTC800
FFTC801
FFTC802
FFTC803
FFTC804
FFTC805
FFTC806
FFTC807
FFTC808
FFTC809
FFTC810
FFTC811
FFTC812
FFTC813
FFTC814
FFTC815
FFTC816
FFTC817
FFTC818
FFTC819
FFTC820
FFTC821
FFTC822
FFTC823
FFTC824
FFTC825
FFTC826
FFTC827
FFTC828
FFTC829
FFTC830
FFTC831
FFTC832
FFTC833
FFTC834
FFTC835
FFTC836
FFTC837
FFTC838
FFTC839
FFTC840
FFTC841
FFTC842
FFTC843
FFTC844
FFTC845
FFTC846
FFTC847
FFTC848
FFTC849
FFTC850
FFTC851
FFTC852
FFTC853
FFTC854
FFTC855
FFTC856
FFTC857
FFTC858
FFTC859
FFTC860
FFTC861
FFTC862
FFTC863
FFTC864
FFTC865
FFTC866
FFTC867
FFTC868
FFTC869
FFTC870
FFTC871
FFTC872
FFTC873
FFTC874
FFTC875
FFTC876
FFTC877
FFTC878
FFTC879
FFTC880
FFTC881
FFTC882
FFTC883
FFTC884
FFTC885
FFTC886
FFTC887
FFTC888
FFTC889
FFTC890
FFTC891
FFTC892
FFTC893
FFTC894
FFTC895
FFTC896
FFTC897
FFTC898
FFTC899
FFTC900
FFTC901
FFTC902
FFTC903
FFTC904
FFTC905
FFTC906
FFTC907
FFTC908
FFTC909
FFTC910
FFTC911
FFTC912
FFTC913
FFTC914
FFTC915
FFTC916
FFTC917
FFTC918
FFTC919
FFTC920
FFTC921
FFTC922
FFTC923
FFTC924
FFTC925
FFTC926
FFTC927
FFTC928
FFTC929
FFTC930
FFTC931
FFTC932
FFTC933
FFTC934
FFTC935
FFTC936
FFTC937
FFTC938
FFTC939
FFTC940
FFTC941
FFTC942
FFTC943
FFTC944
FFTC945
FFTC946
FFTC947
FFTC948
FFTC949
FFTC950
FFTC951
FFTC952
FFTC953
FFTC954
FFTC955
FFTC956
FFTC957
FFTC958
FFTC959
FFTC960
FFTC961
FFTC962
FFTC963
FFTC964
FFTC965
FFTC966
FFTC967
FFTC968
FFTC969
FFTC970
FFTC971
FFTC972
FFTC973
FFTC974
FFTC975
FFTC976
FFTC977
FFTC978
FFTC979
FFTC980
FFTC981
FFTC982
FFTC983
FFTC984
FFTC985
FFTC986
FFTC987
FFTC988
FFTC989
FFTC990
FFTC991
FFTC992
FFTC993
FFTC994
FFTC995
FFTC996
FFTC997
FFTC998
FFTC999
FFTC1000

SYMBOLIC REFERENCE MAP (2=1)

ENTRY POINTS
3 FFTC

Appendix D

Figures of the Reflective
Waves of the Controlled Motors

5 Horse Power Energy Efficient Motor

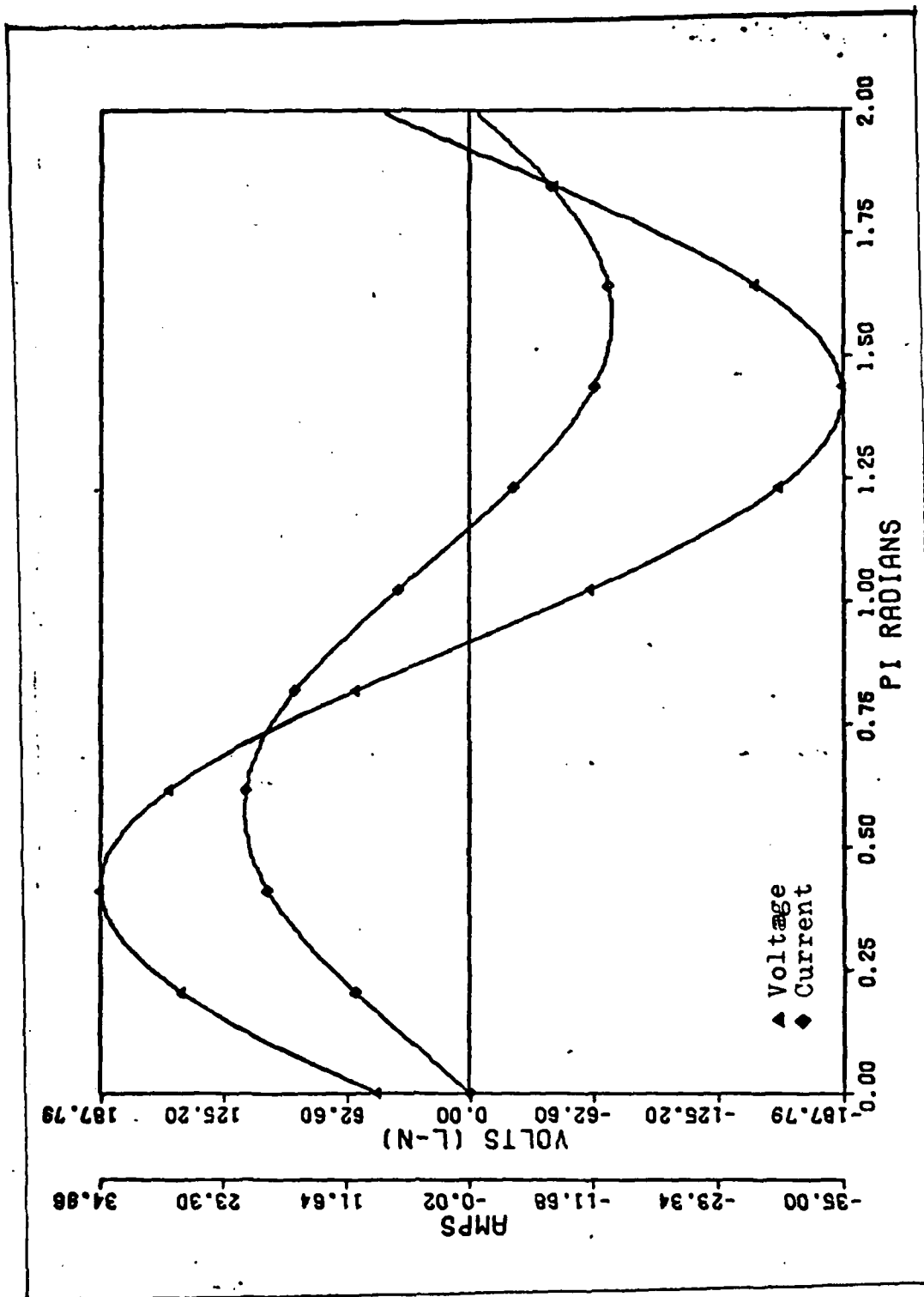


Figure 10

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 0.0

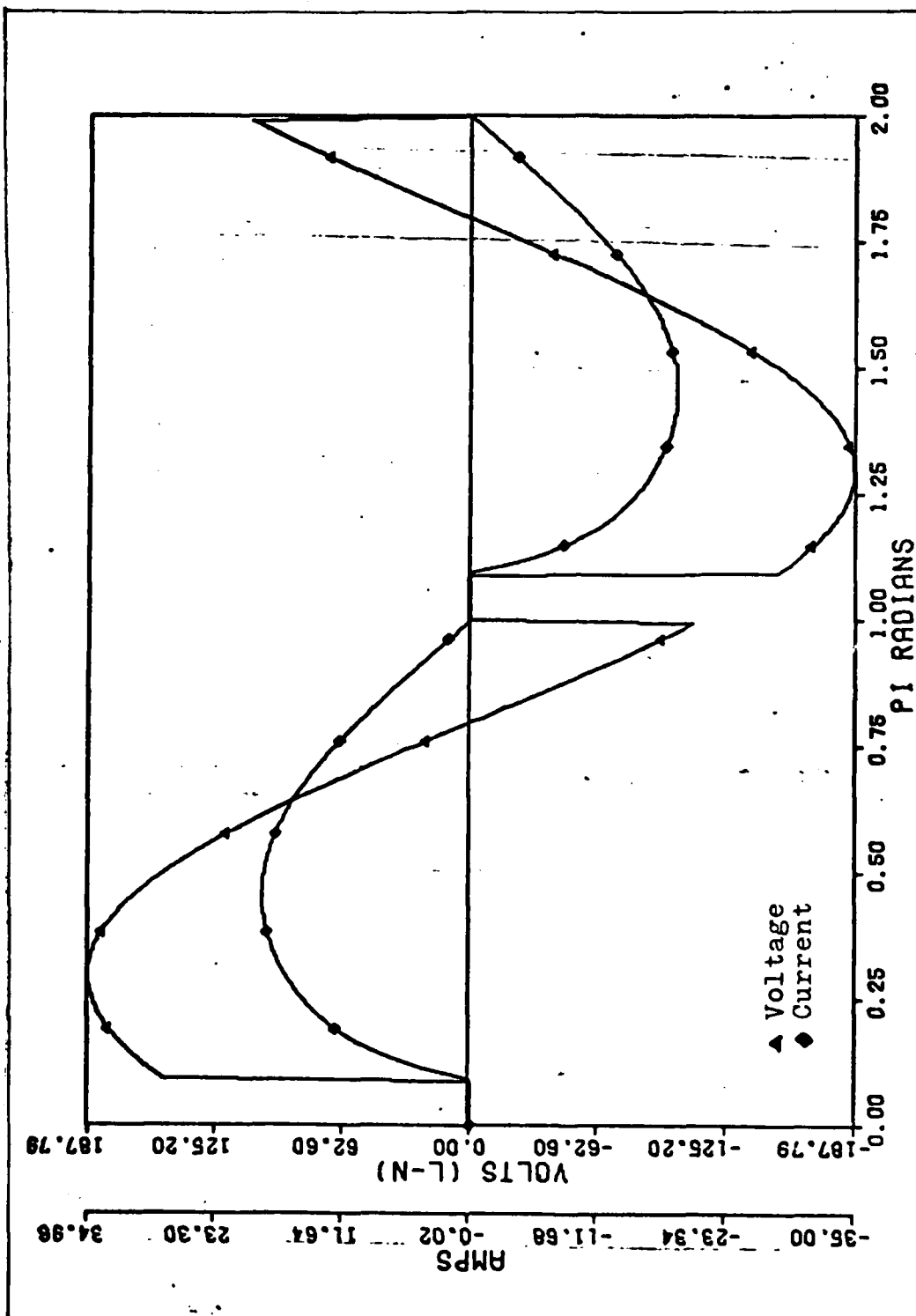


Figure 11

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 0.3

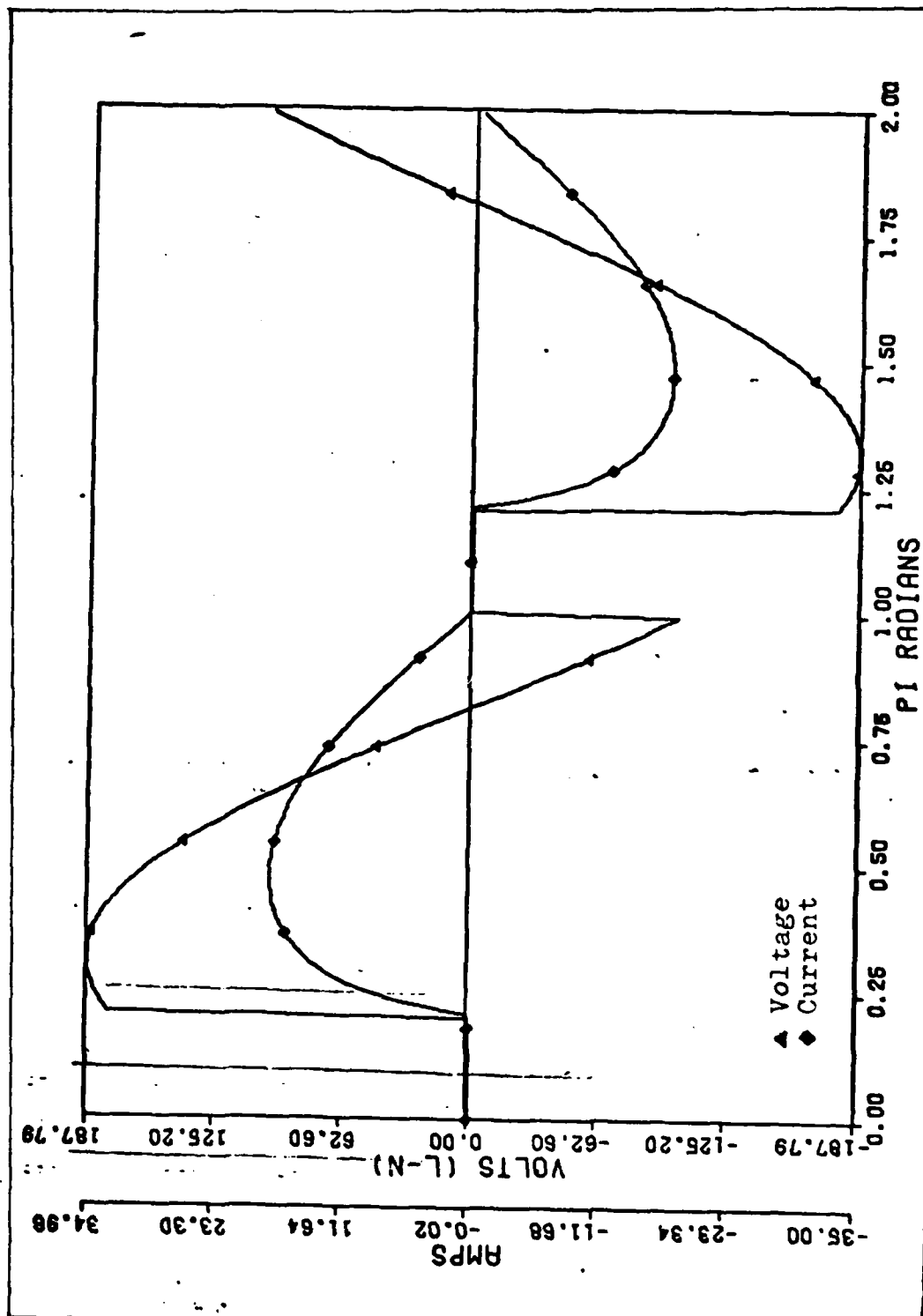


Figure 12

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 0.65

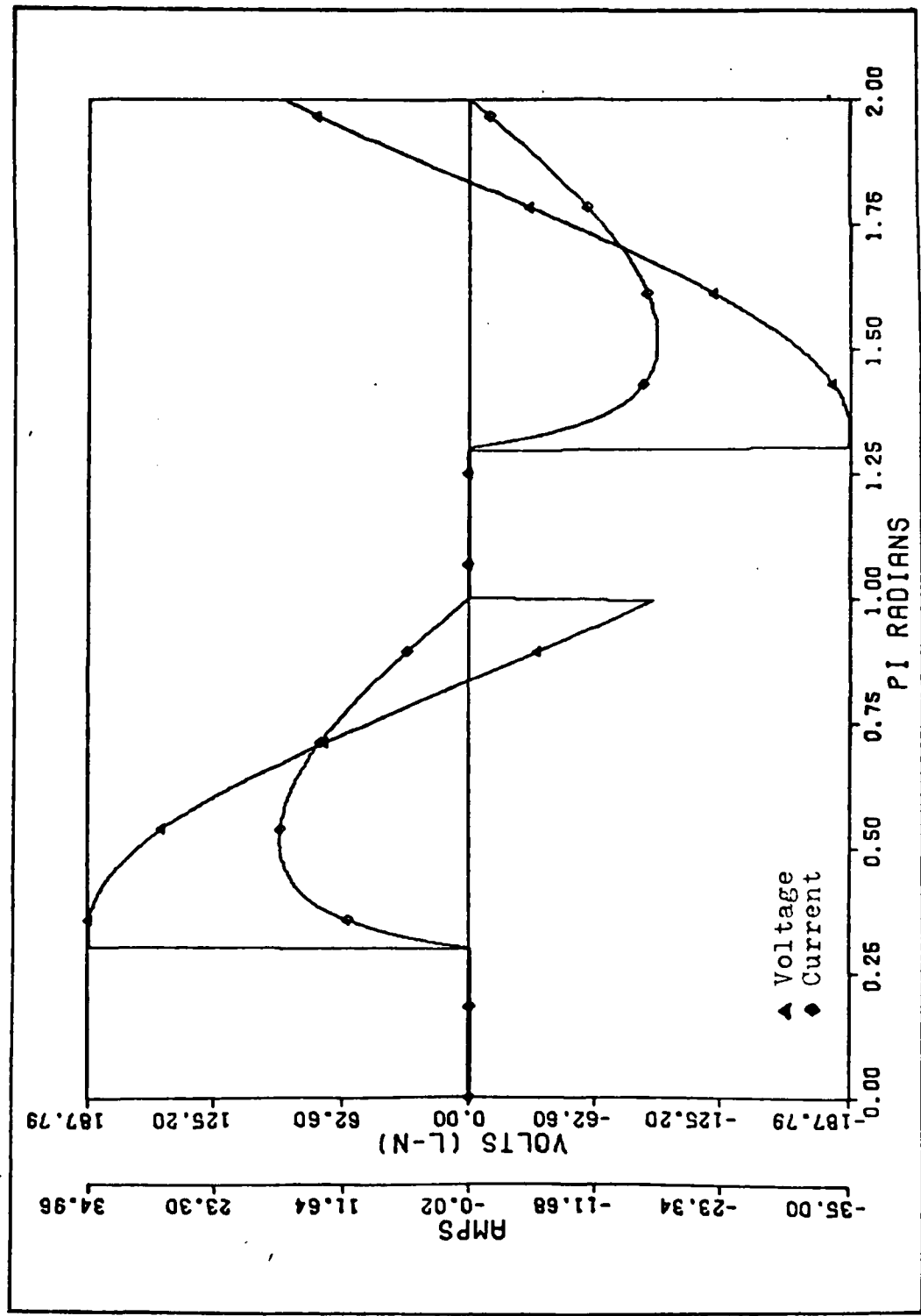


Figure 13

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 0.95

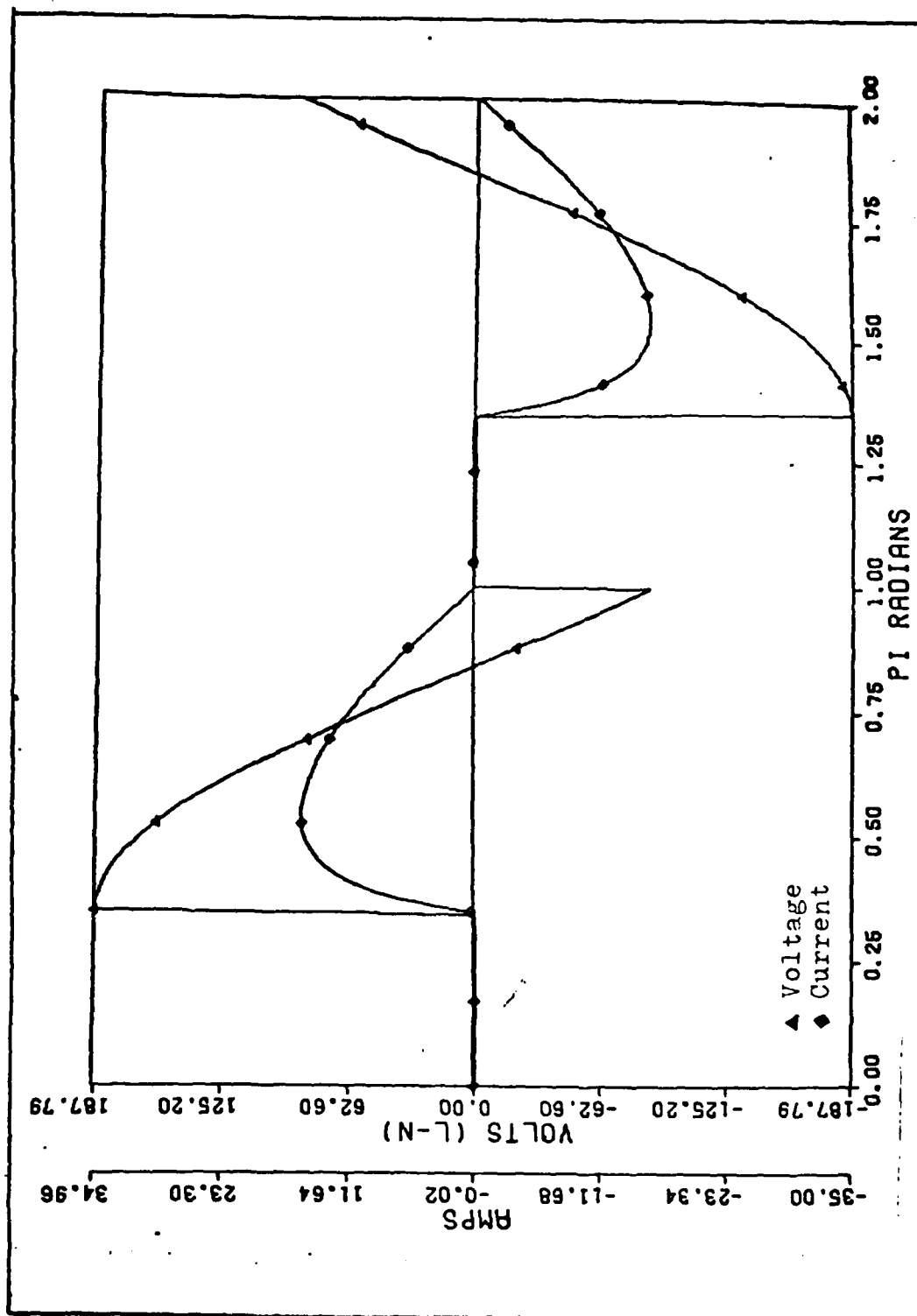


Figure 14

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 1.10

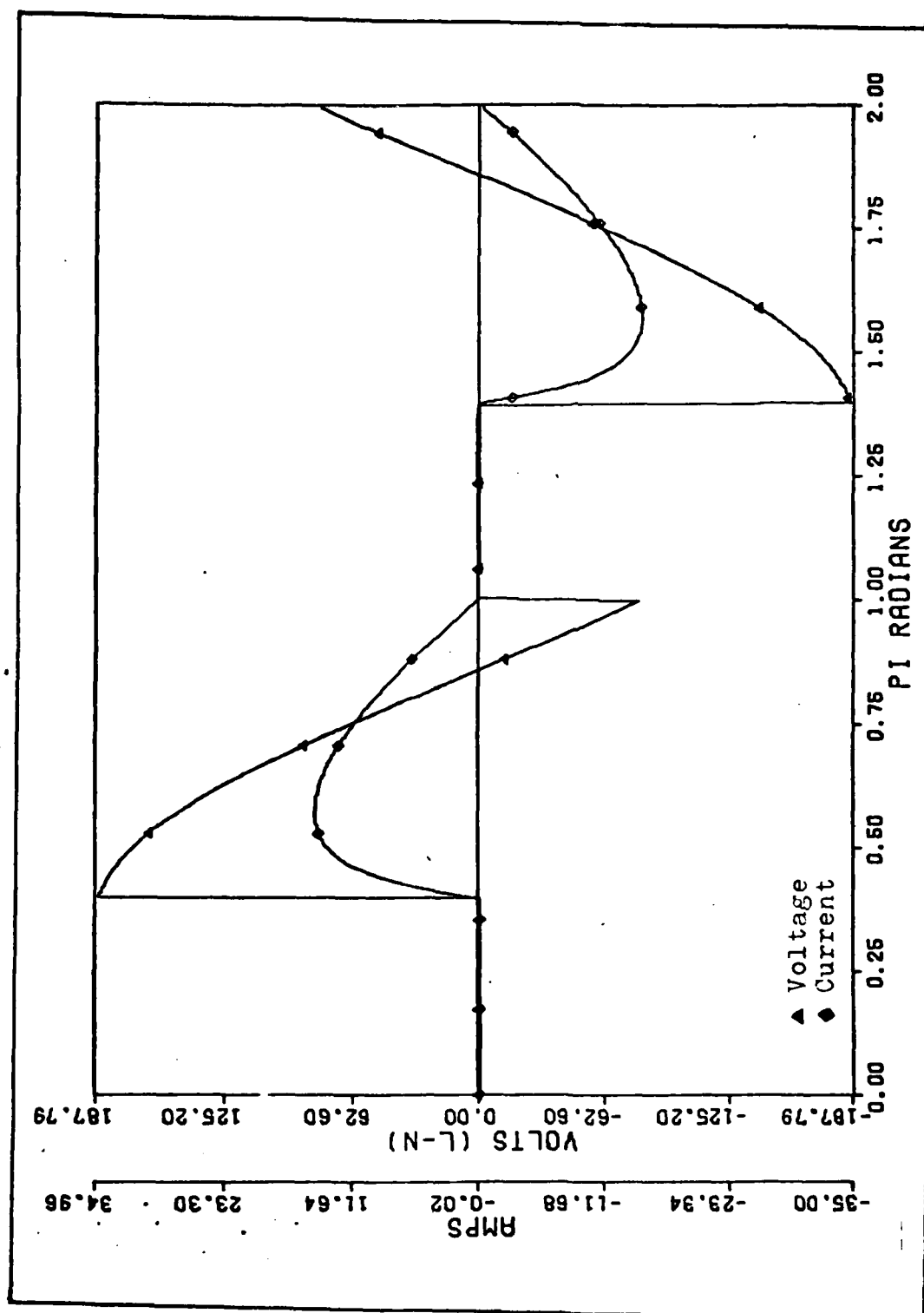


Figure 15
 Reflected Voltage and Current Wave for
 5 Horse Power Energy Efficient with ALPHA equal 1.25

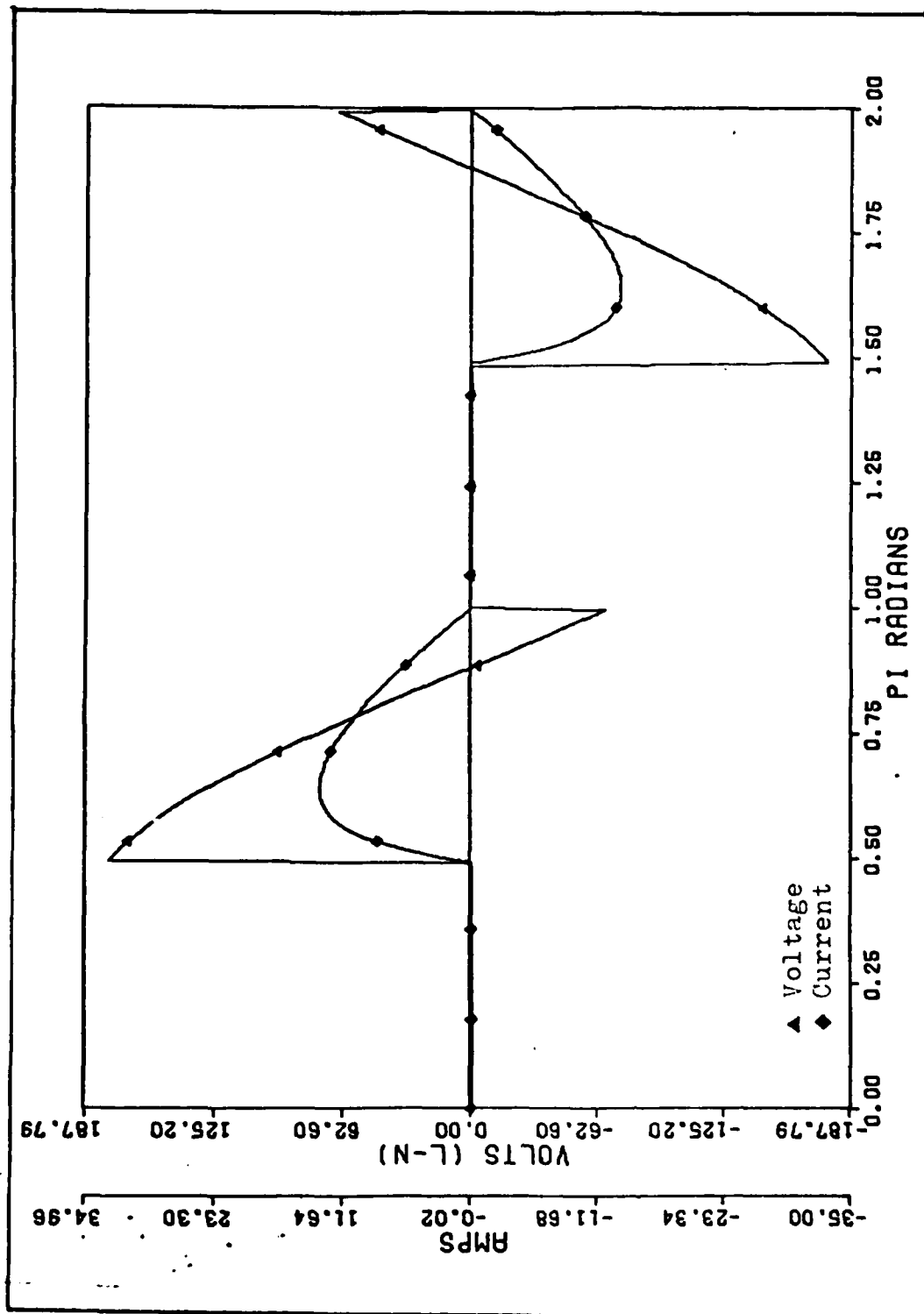


Figure 16

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA equal 1.55

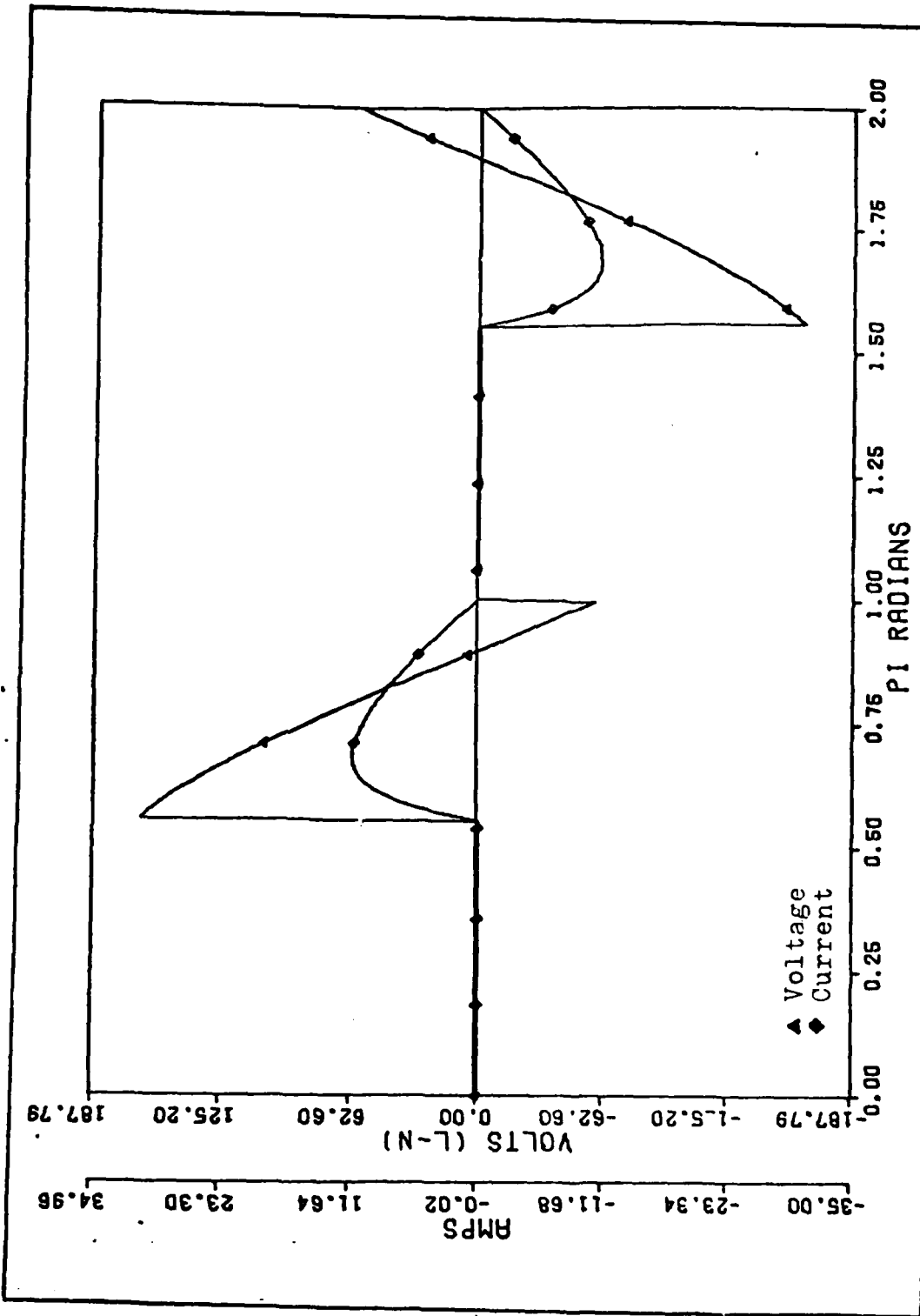


Figure 17

Reflected Voltage and Current Wave for

5 Horse Power Energy Efficient with ALPHA 1.75

5 Horse Power Standard Motor

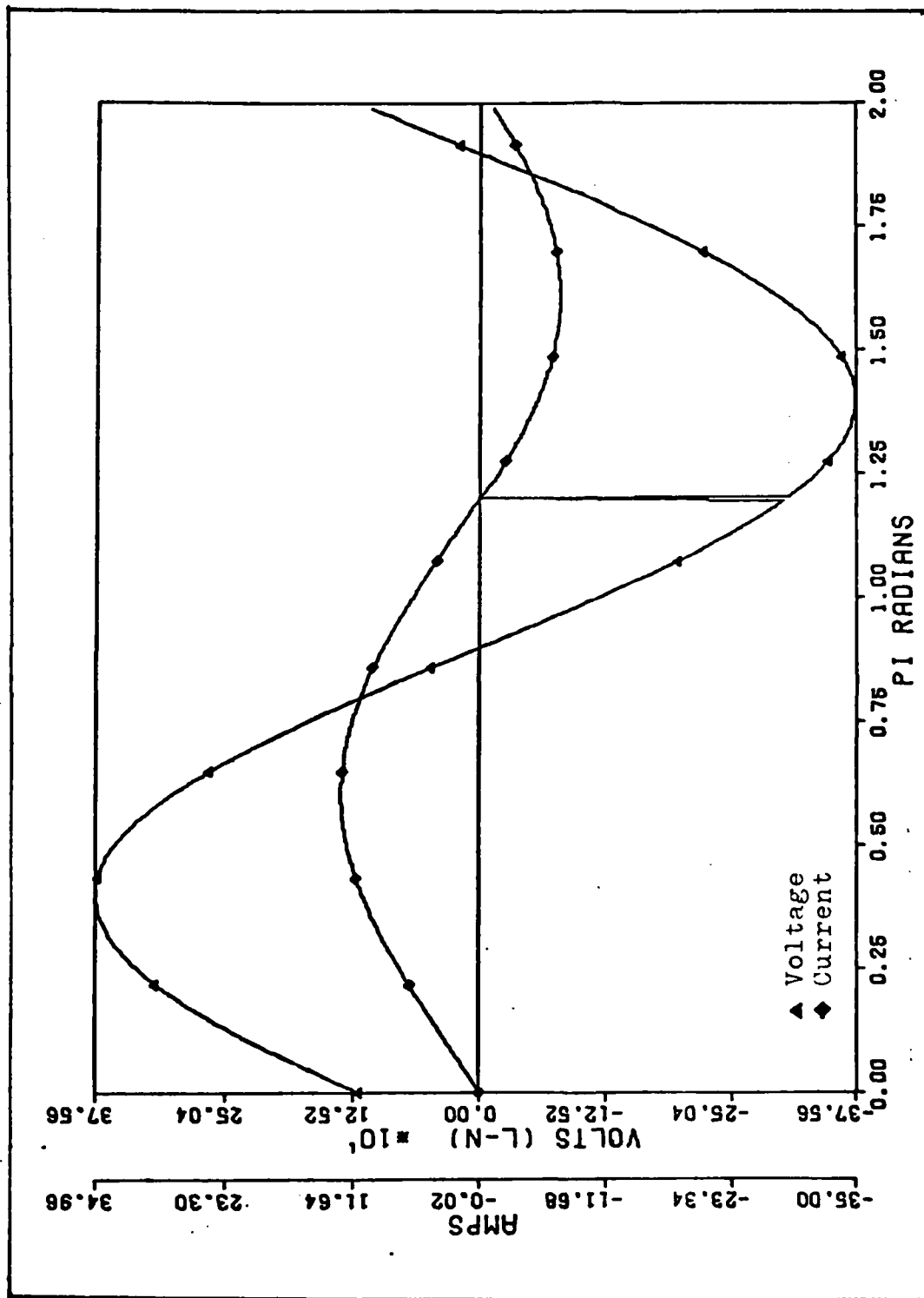


Figure 18

Reflected Voltage and Current Wave for

5 Horse Power Standard with ALPHA equal 0.0

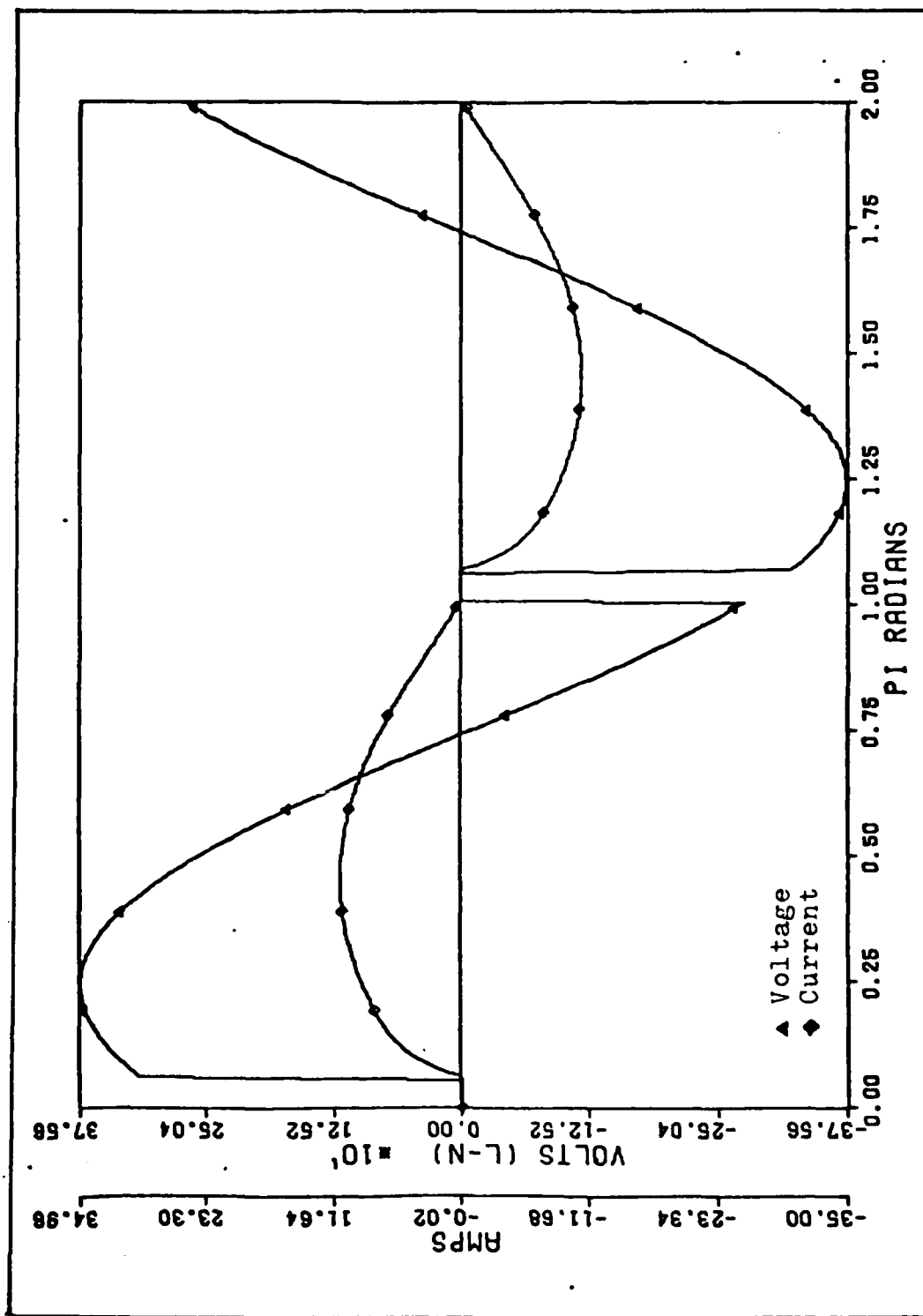


Figure 19

Reflected Voltage and Current Wave for

5 Horse Power Standard with ALPHA equal 0.2

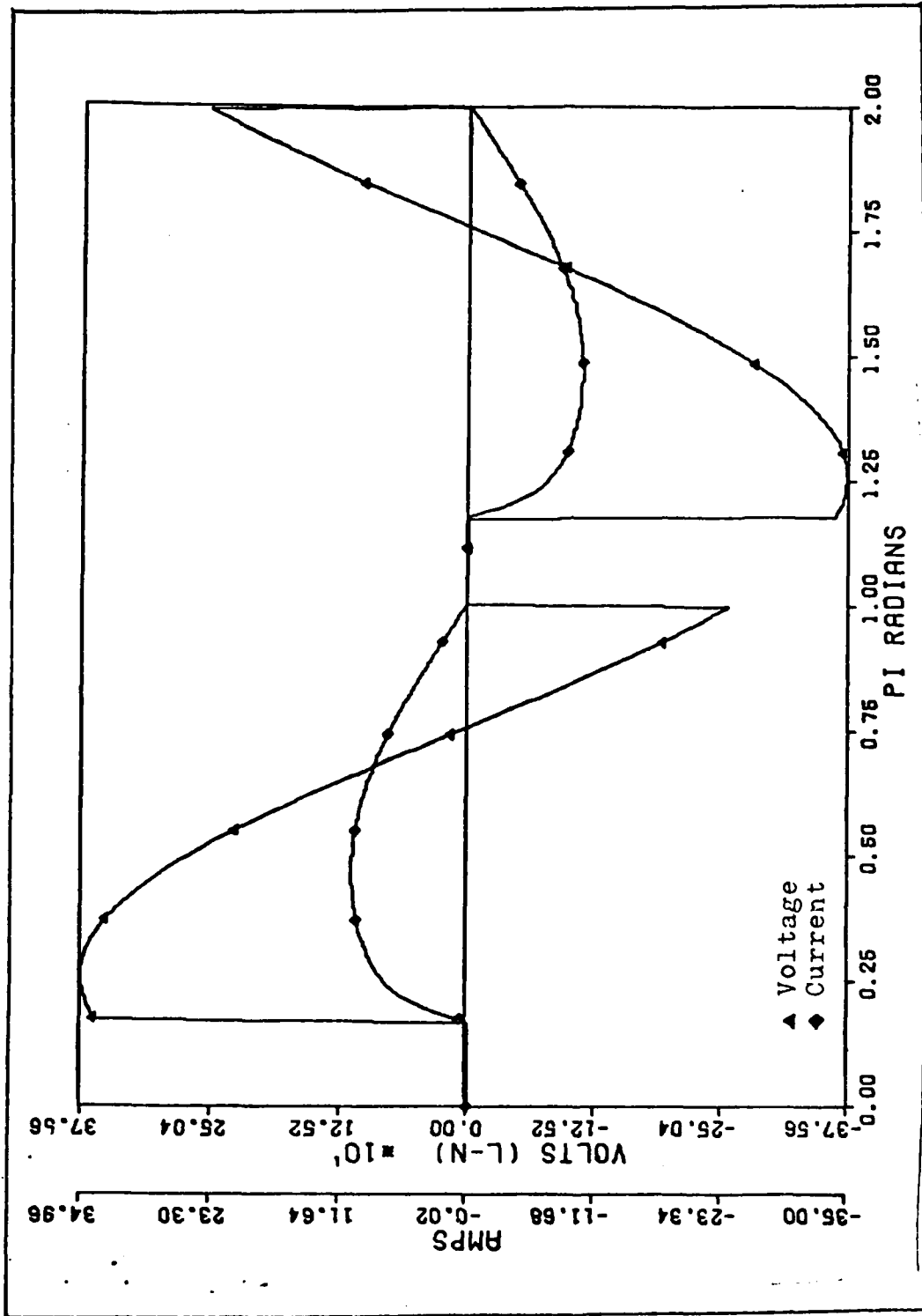


Figure 20

Reflected Voltage and Current wave for

5 Horse Power Standard with ALPHA equal 0.55

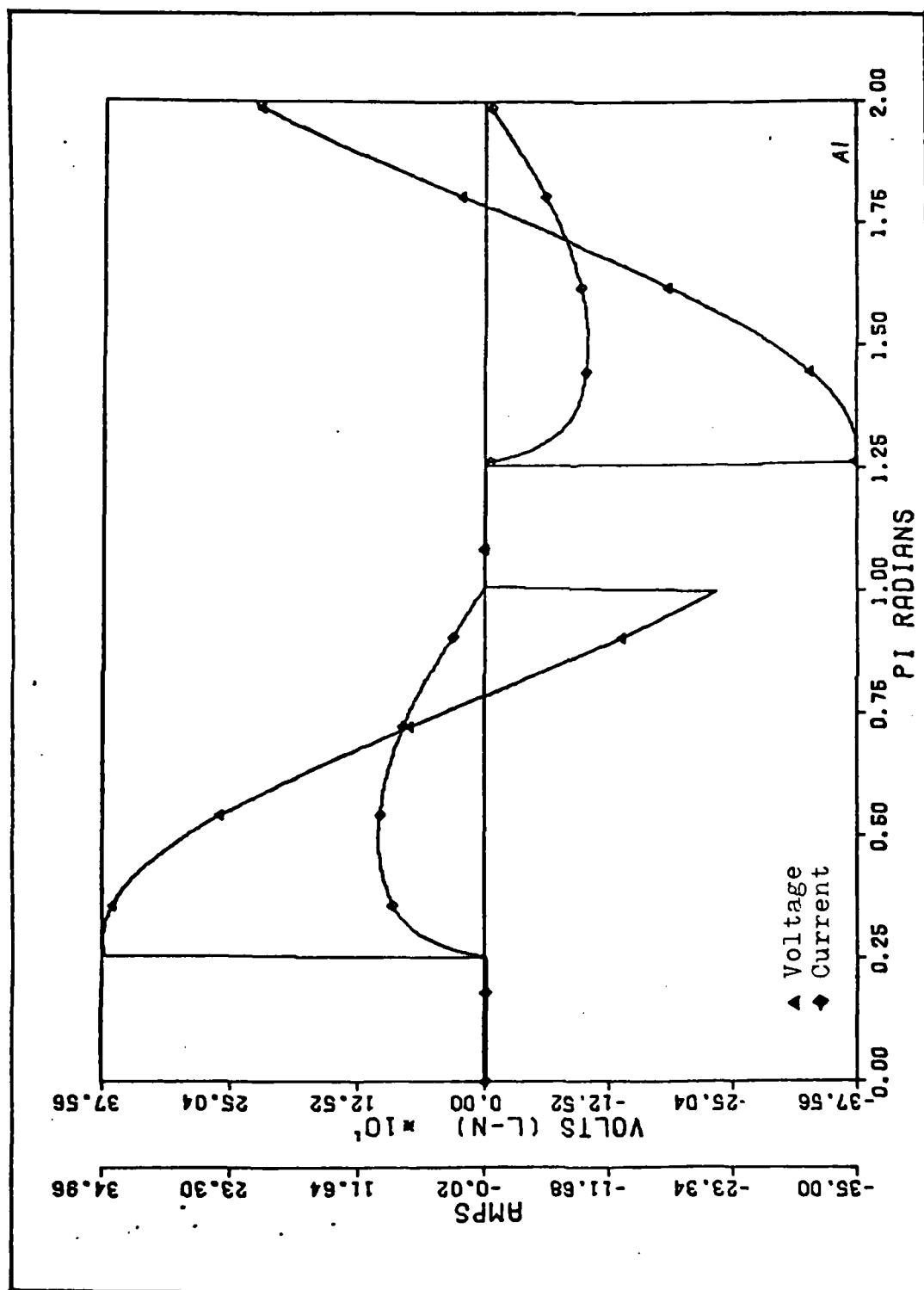


Figure 21

Reflected Voltage and Current Wave for

5 Horse Power Standard with ALPHA equal 0.8

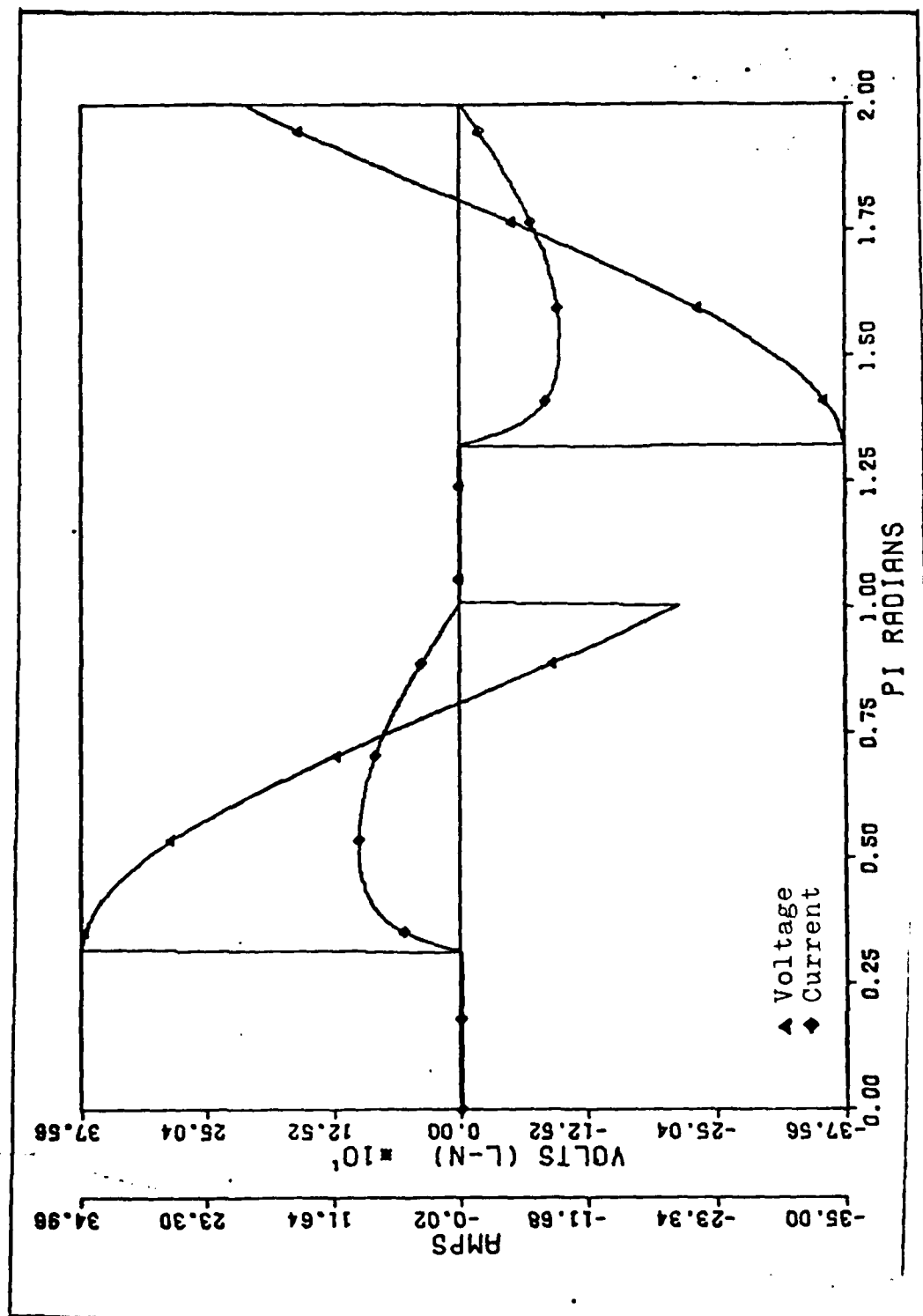


Figure 22

Reflected Voltage and Current Wave for

5 Horse Power Standard with ALPHA equal 1.0

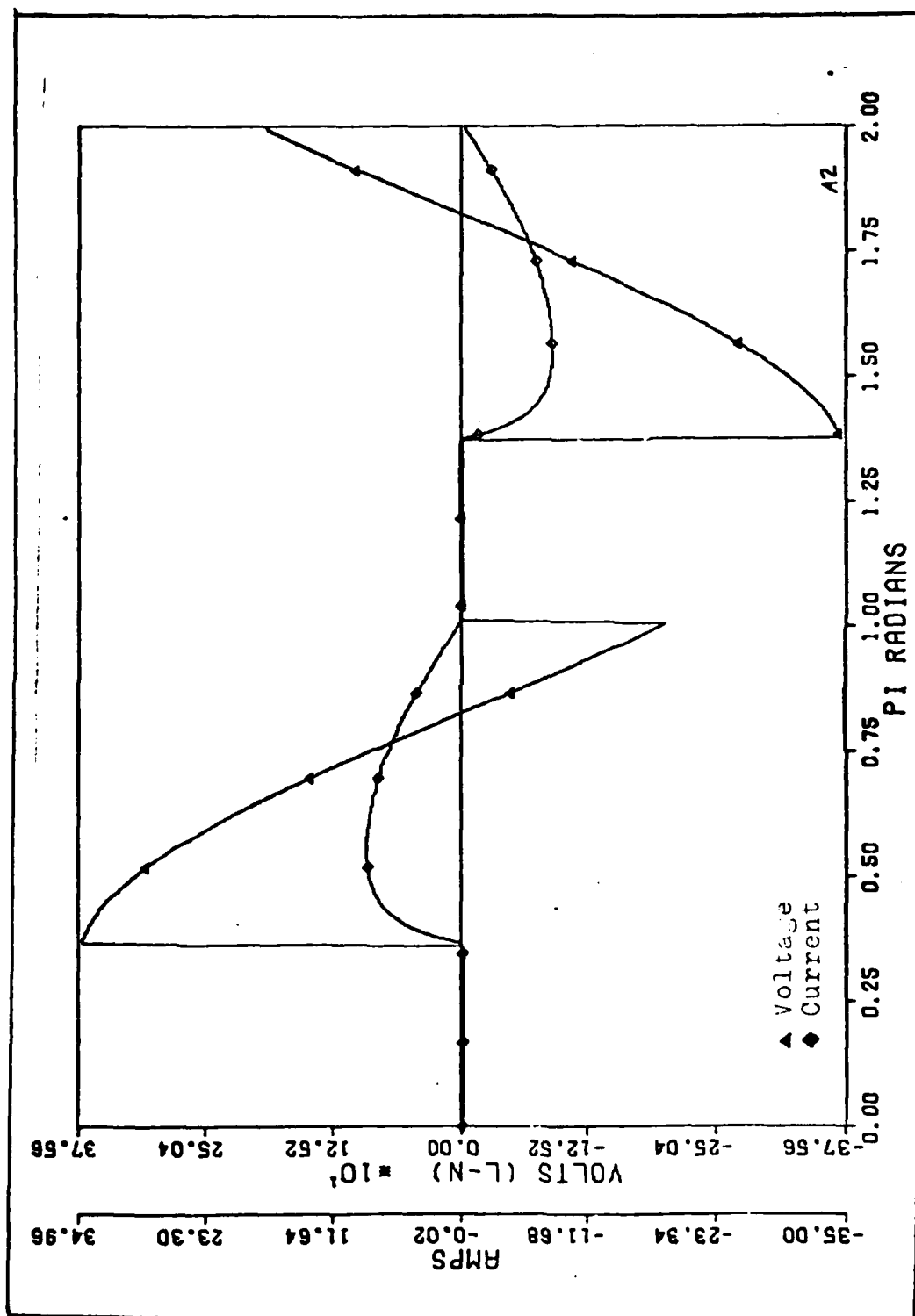


Figure 23
 Reflected Voltage and Current Wave for
 5 Horse Power Standard with ALPHA equal 1.15

AD-A144 798 COST EFFECTIVENESS OF 'NOLA' CONTROLLED MOTORS INCLUDING EFFECT OF HIGHER HARMONICS(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI... 2/2

UNCLASSIFIED R D MCMASTER DEC 88 AFIT/GE/EE/845-10 F/G 9/3 NL

NL

UNCLASSIFIED

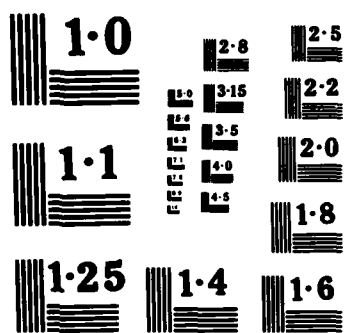
R D MCMASTER DEC 88 AFIT/GE/EE/845-10

F/G 9/3

NL

FILM ON

OTK.



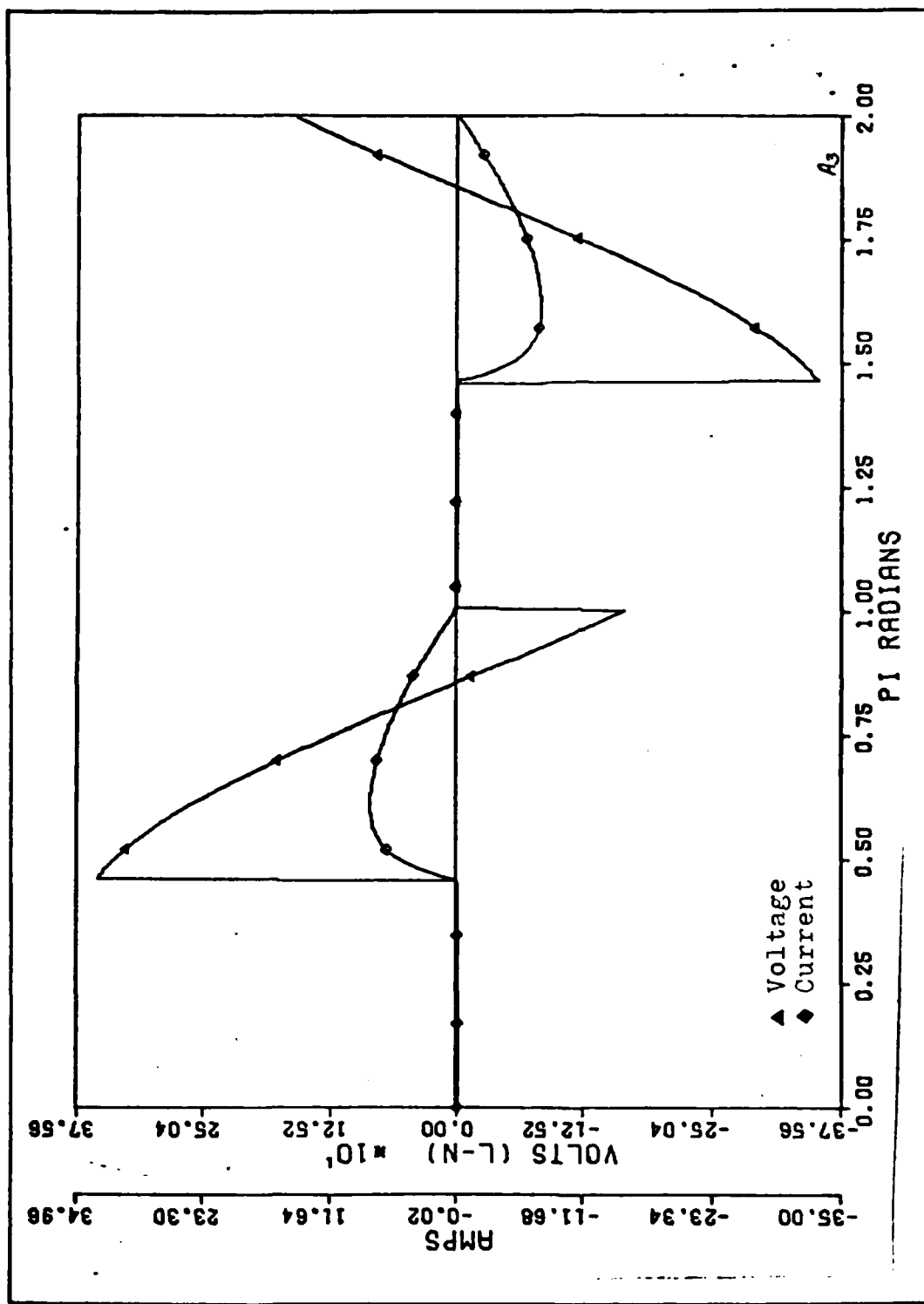


Figure 24

Reflected Voltage and Current Wave for

5 Horse Power Standard with ALPHA equal 1.45

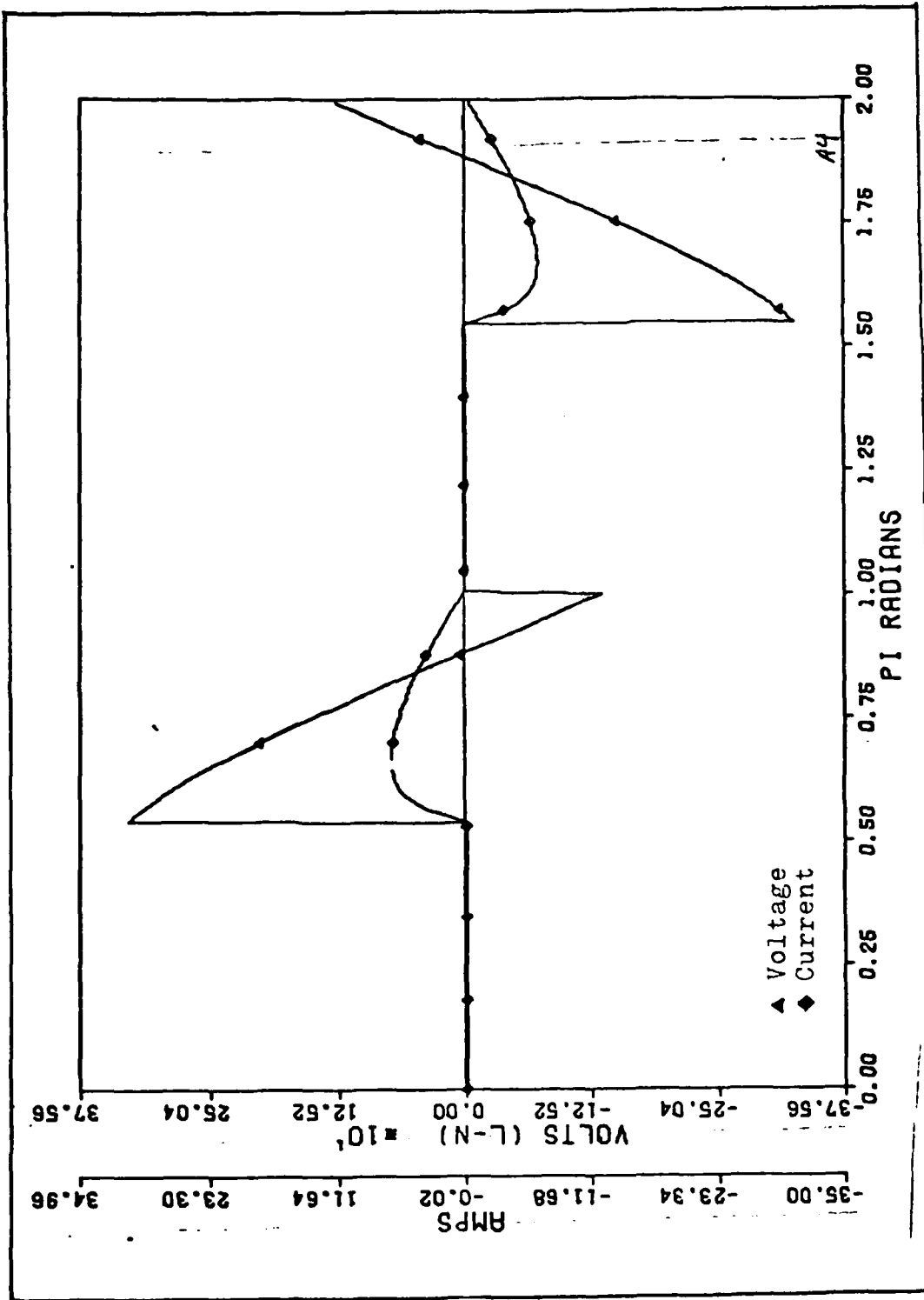


Figure 25

Reflected Voltage and Current Wave for

5 Horse Power Standard with ALPHA equal 1.7

10 Horse Power Energy Efficient Motor

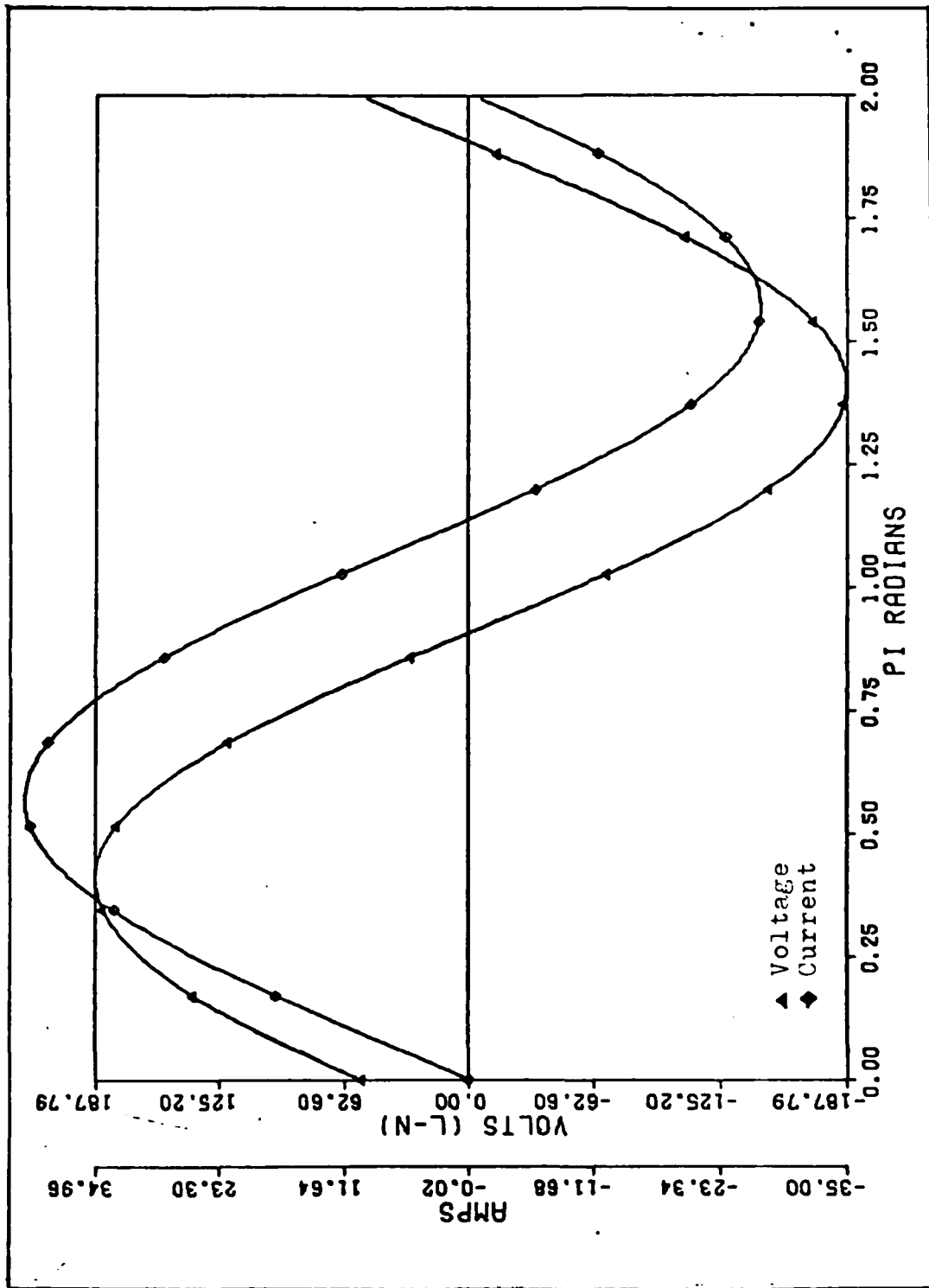


Figure 26

Reflected Voltage and Current Wave for

10 Horse Power Energy Efficient with ALPHA equal 0.0

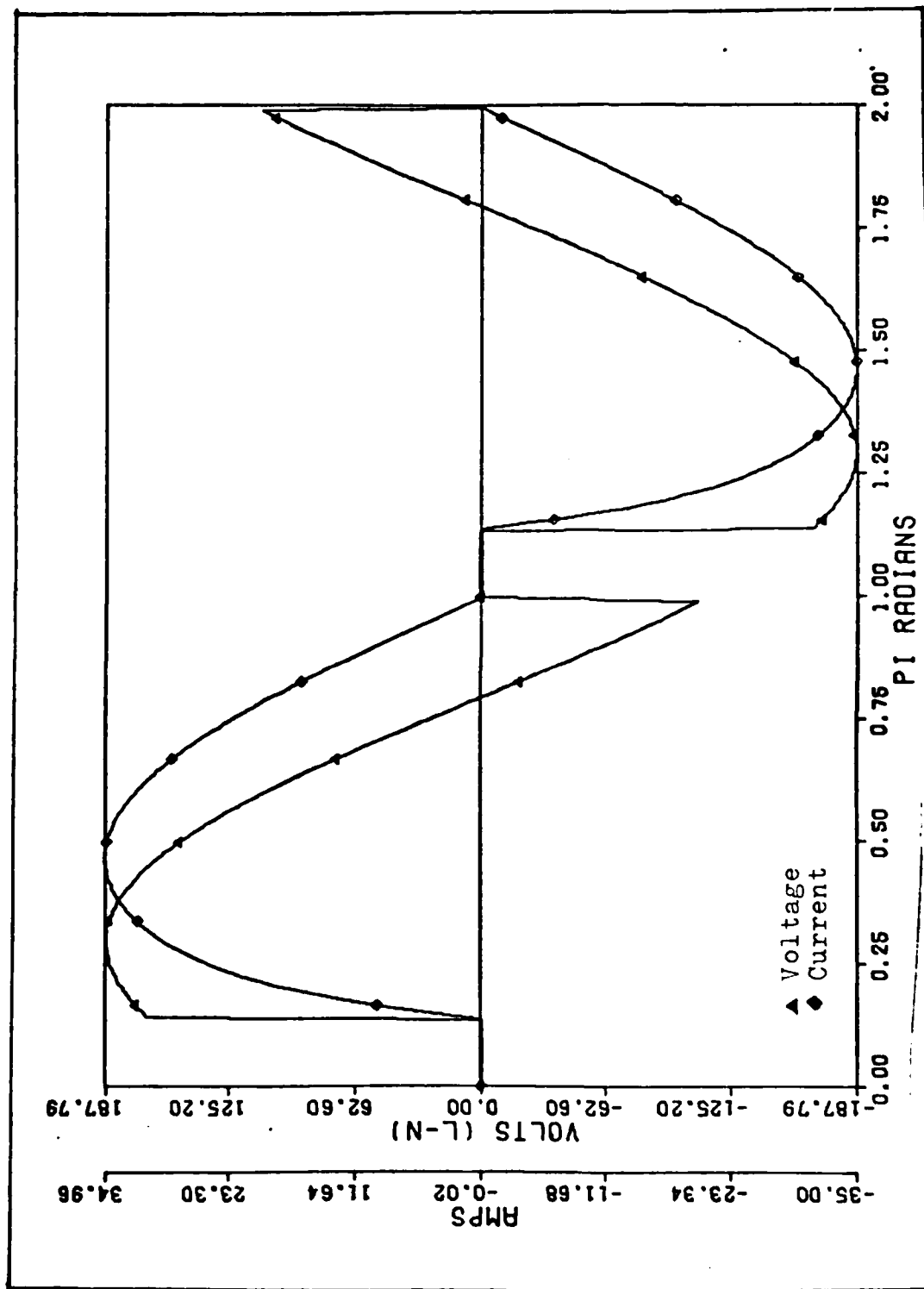


Figure 27

Reflected Voltage and Current Wave for

10 Horse Power Energy Efficient with ALPHA equal 0.45

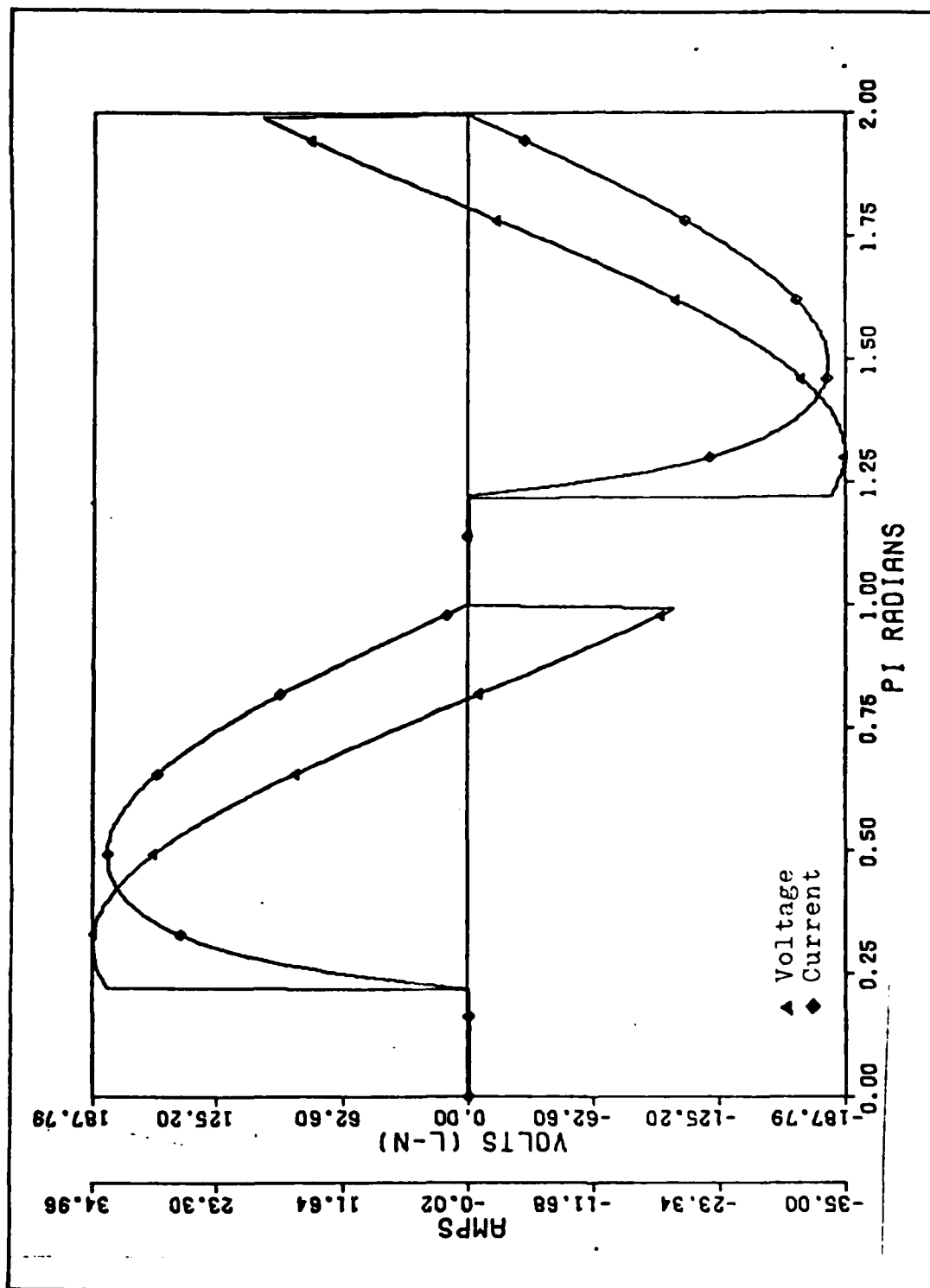
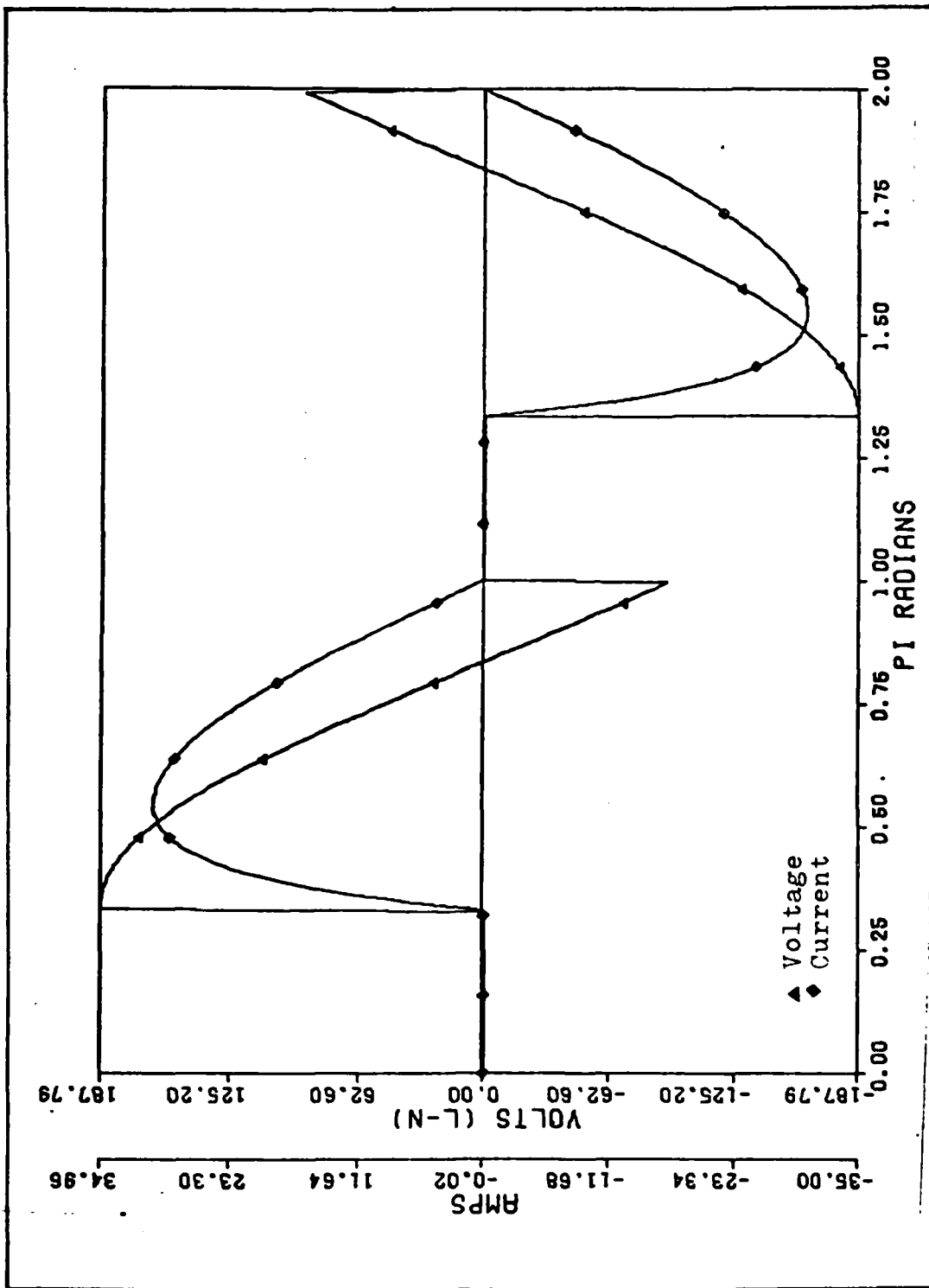


Figure 28
 Reflected Voltage and Current Wave for
 10 Horse Power Energy Efficient with ALPHA equal 0.7



Reflected Voltage and Current Wave for

10 Horse Power Energy Efficient with ALPHA equal 1.05

Figure 29

10 Horse Power Standard Motor

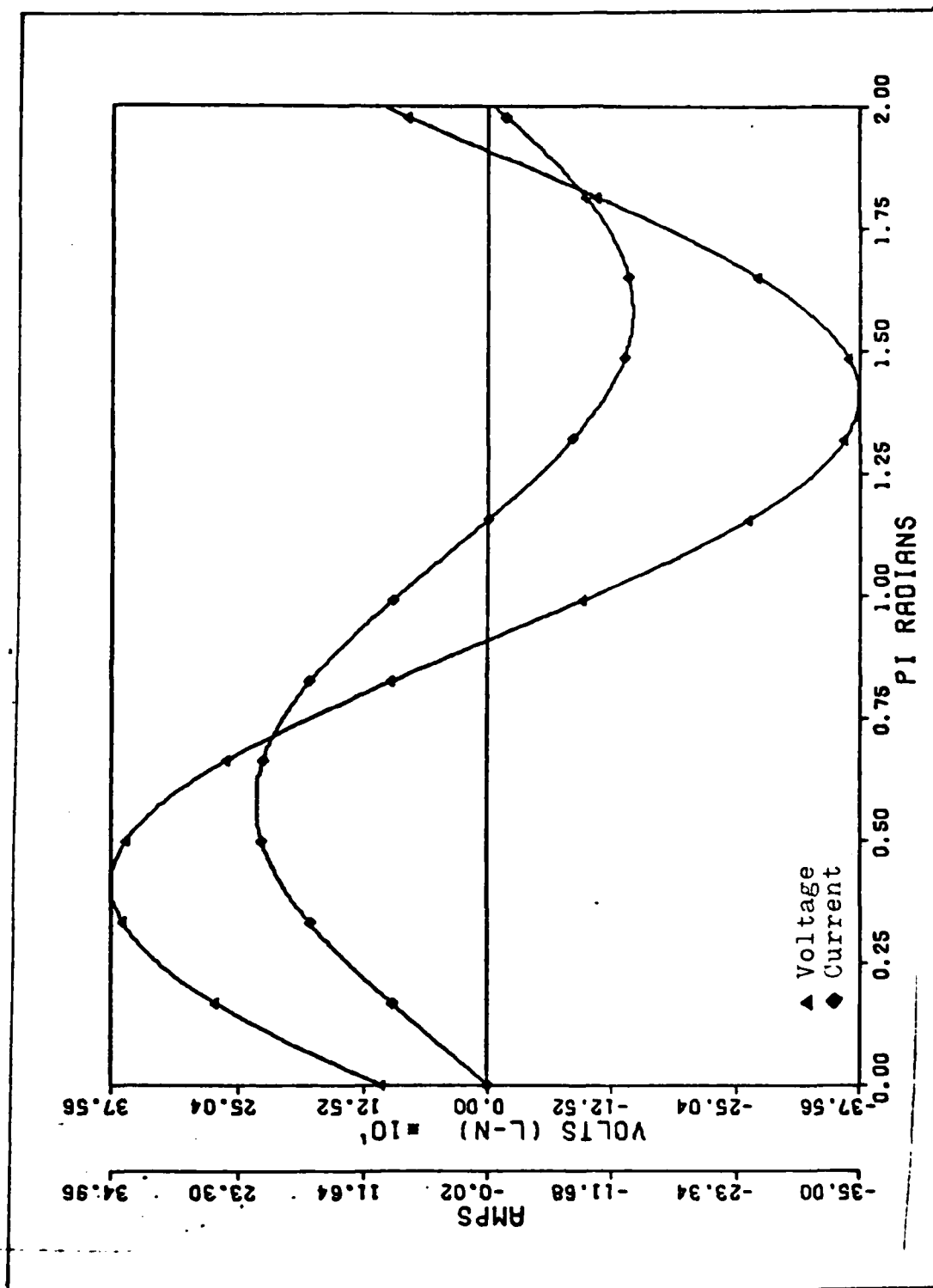


Figure 30

Reflected Voltage and Current Wave for

10 Horse Power Standard with ALPHA equal 0.0

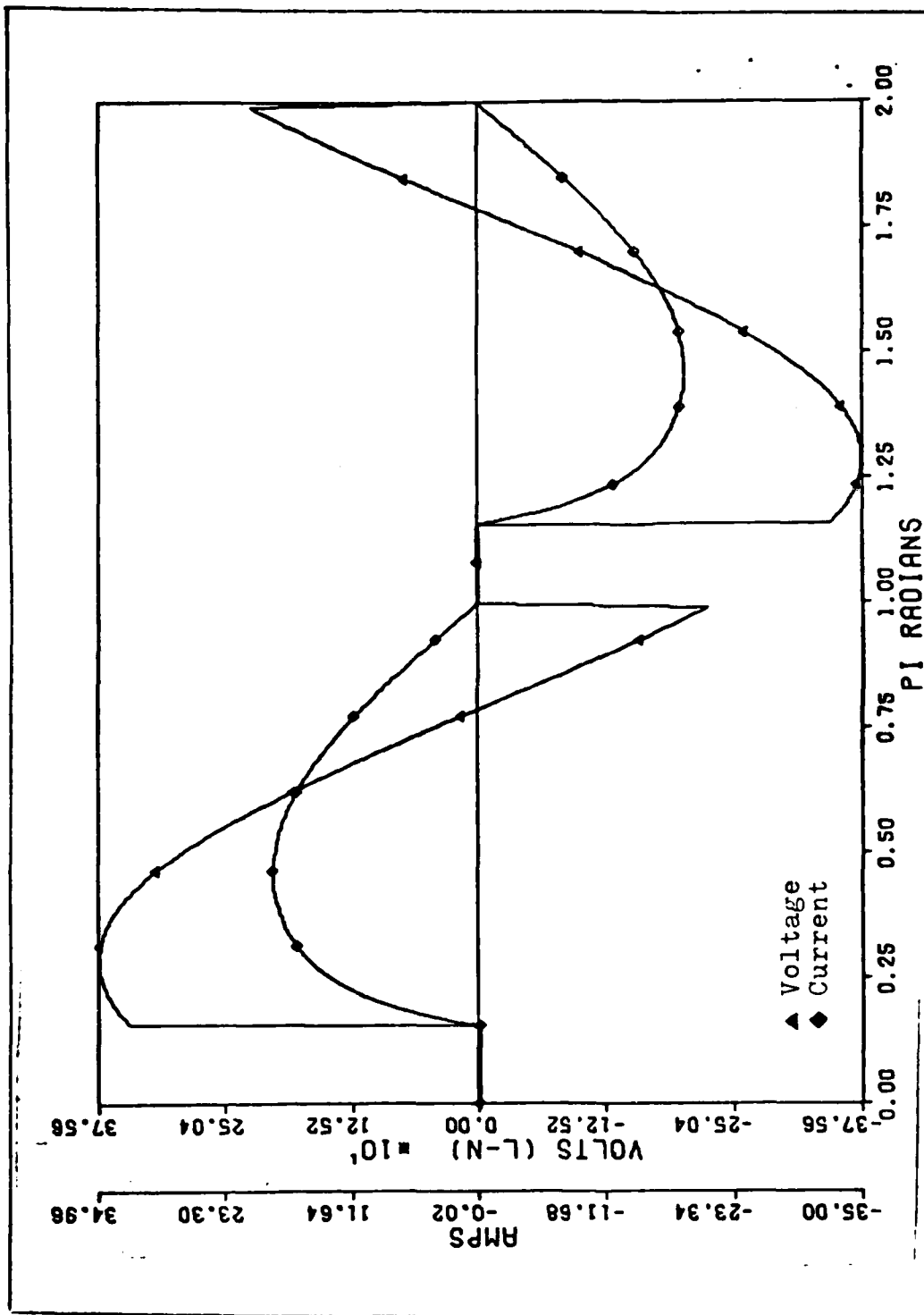


Figure 31

Reflected Voltage and Current Wave for

10 Horse Power Standard with ALPHA equal 0.5

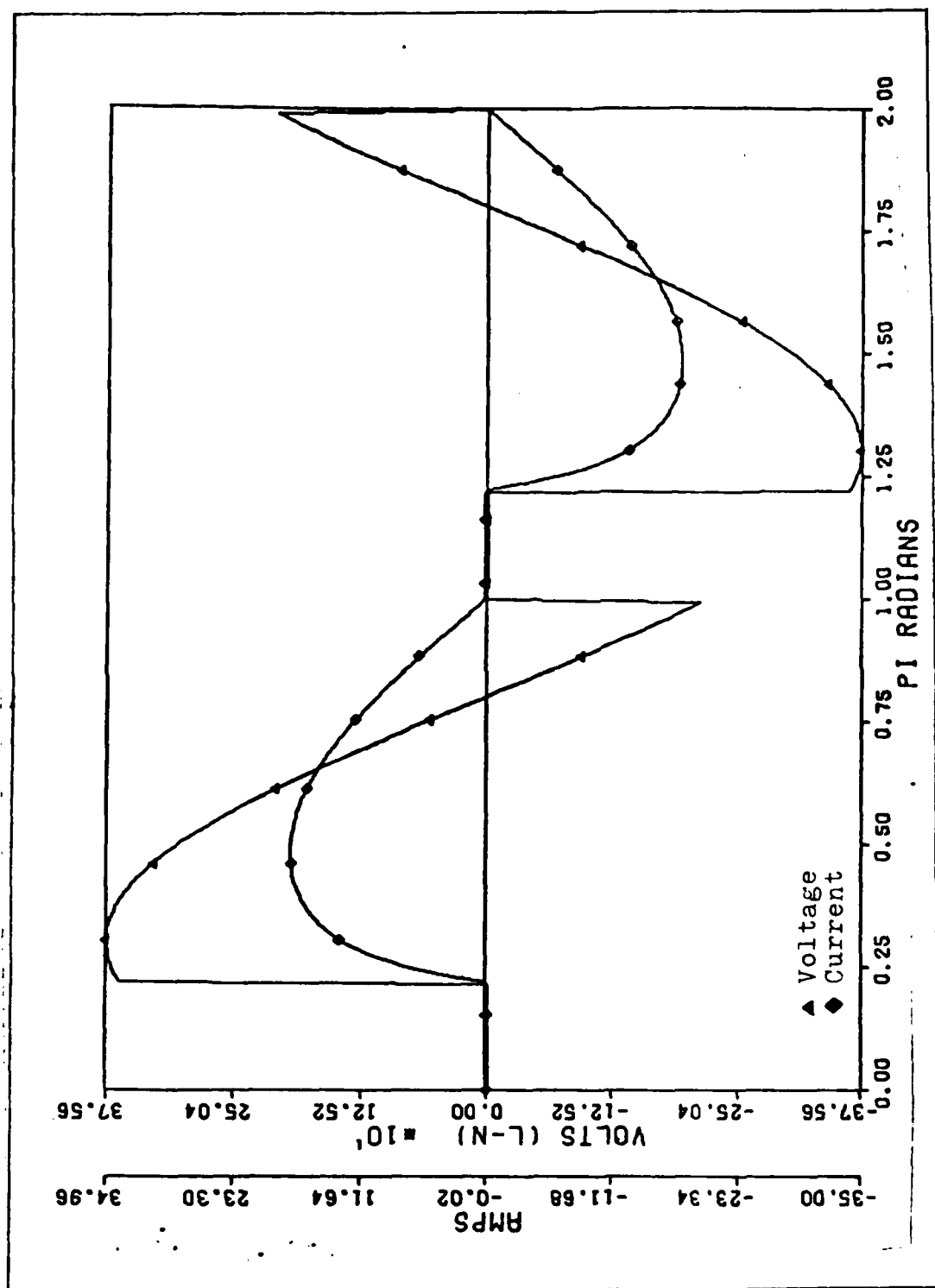


Figure 32

Reflected Voltage and Current Wave for

10 Horse Power Standard with ALPHA equal 0.7

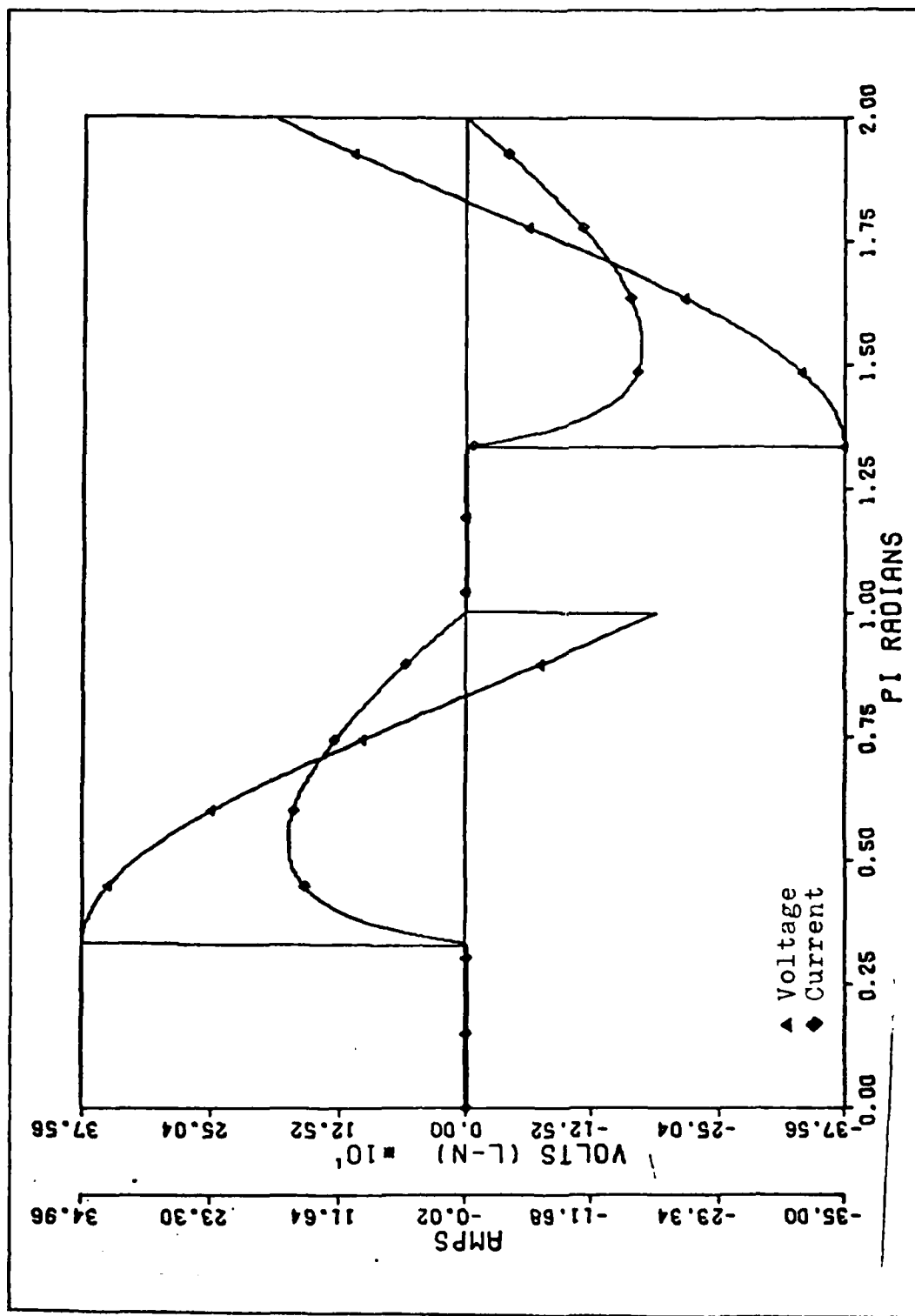


Figure 33

Reflected Voltage and Current Wave for

10 Horse Power Standard with ALPHA equal 1.05

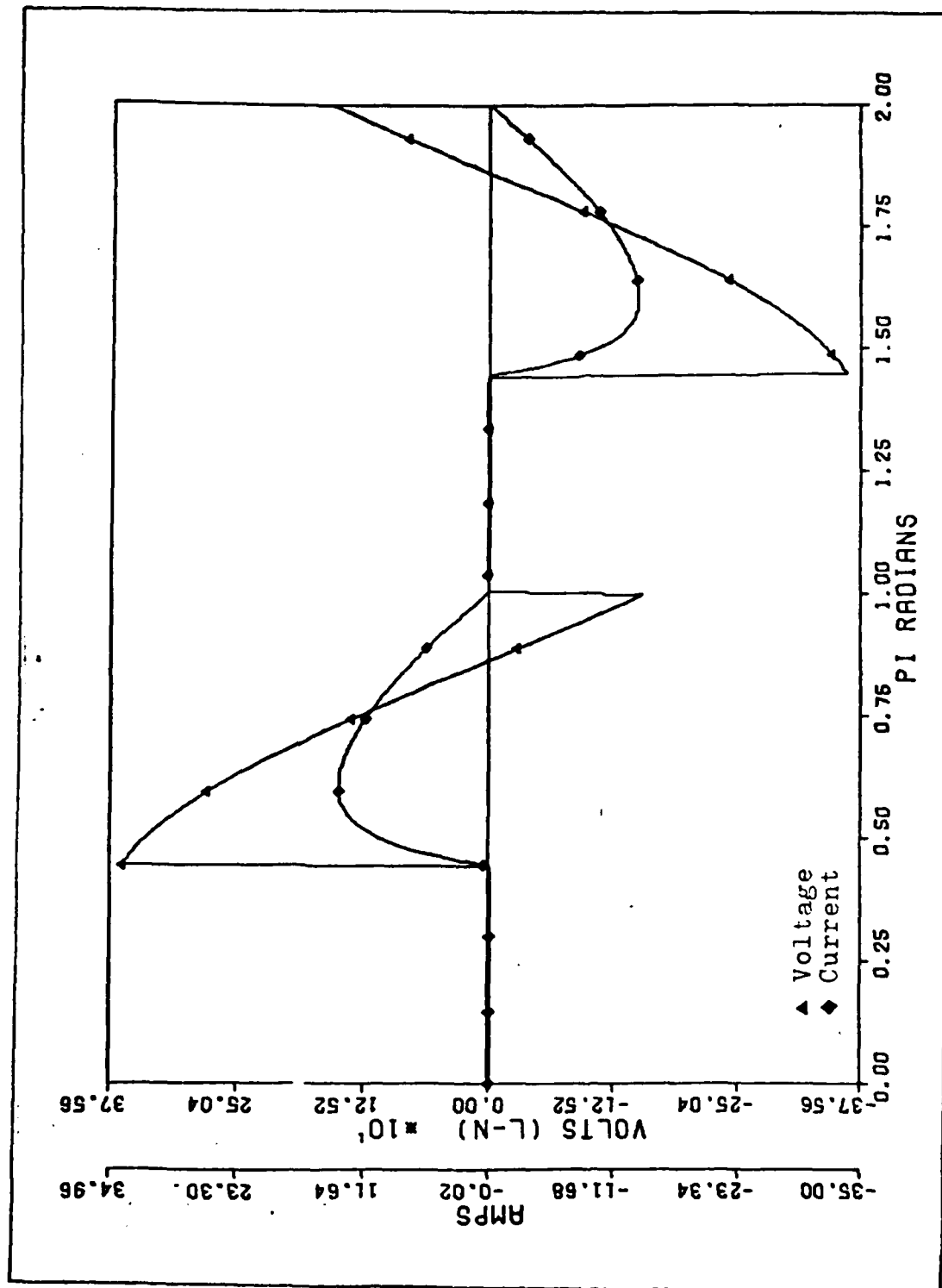


Figure 34

Reflected Voltage and Current Wave for
10 Horse Power Standard with ALPHA equal 1.4

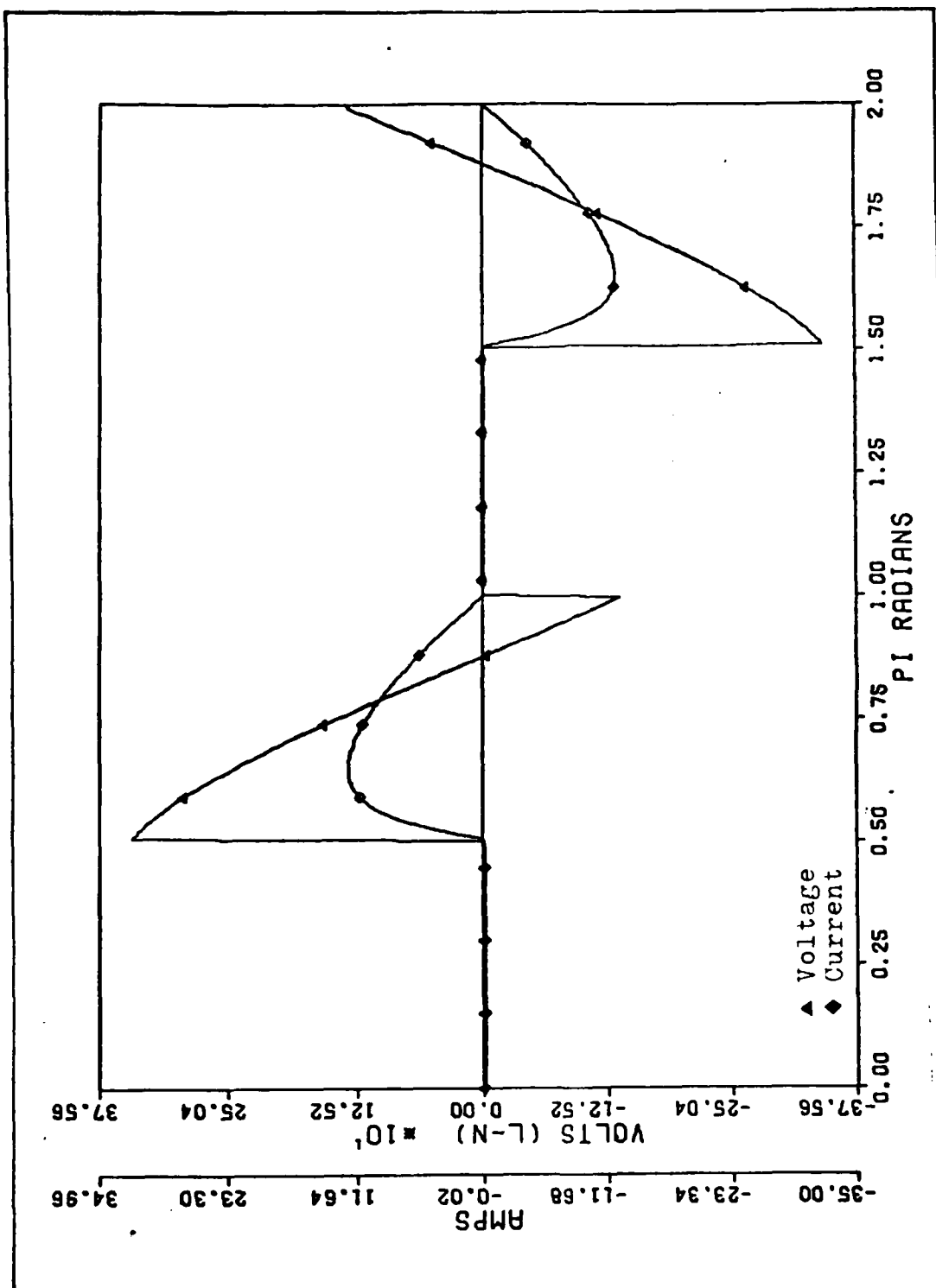


Figure 35

Reflected Voltage and Current Wave for

10 Horse Power Standard with ALPHA equal 1.6

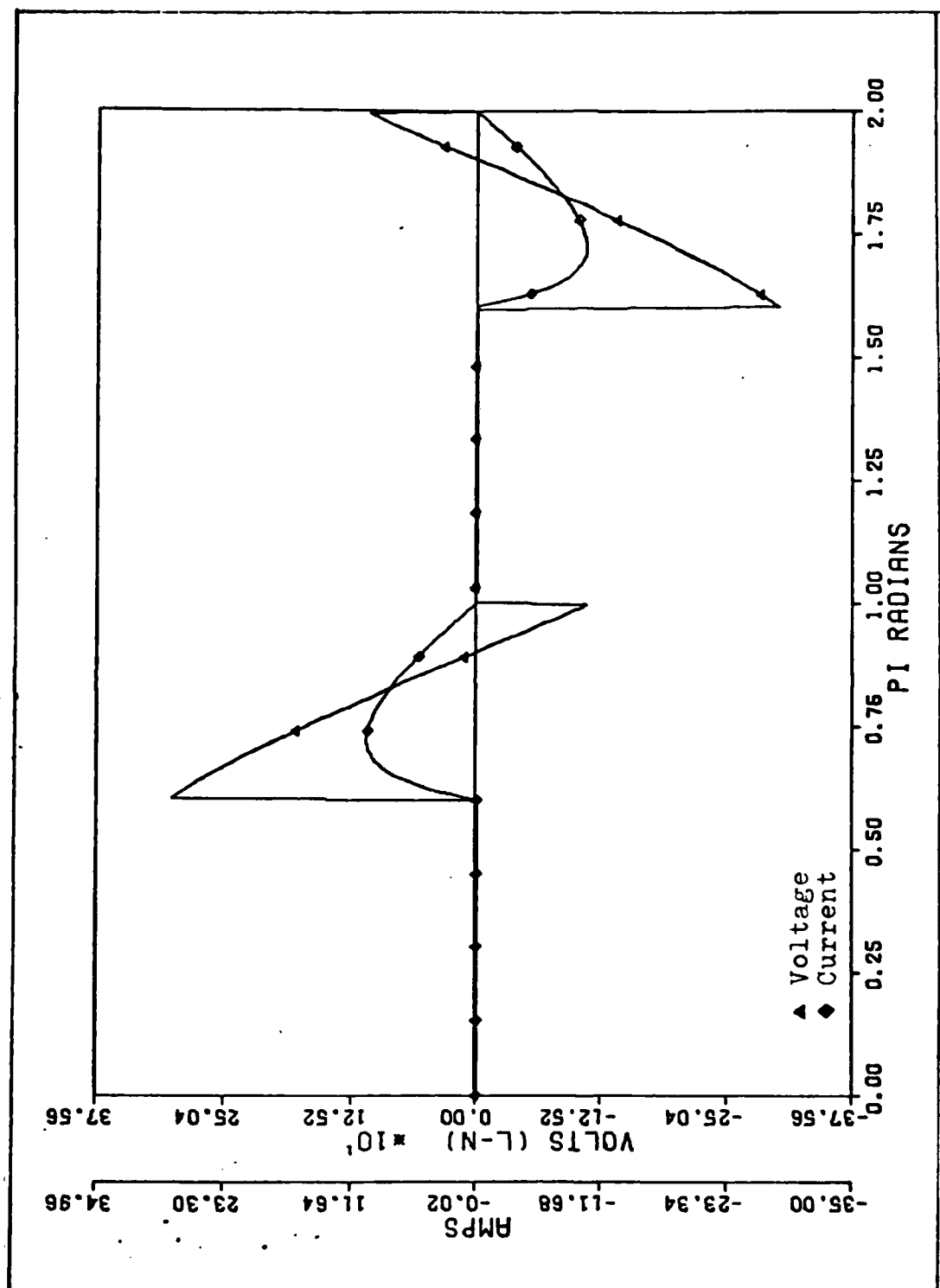


Figure 36

Reflected Voltage and Current Wave for

10 Horse Power Standard with ALPHA equal 1.9

Appendix E

Representation of the

Harmonics Data

From a Fast Fourier Transform

of the Reflected Motor Current

TIME : 21.30 , CYS , CURT, VITS ,MTS
AVERAGE POWER 3JT = 2124.514 445982
HORSE POWER OUTPUT = 2.848 88962443
NF = 337 PNTS = 8808.
6

BUOCE F

1	735588E+01	735588E+01	1.0	1.0	1.0
2	735517E+03	735517E+03	1.0	1.0	1.0
3	735517E+02	735517E+02	2.000	2.000	2.000
4	735517E+03	735517E+03	49.137	49.137	49.137
5	735517E+01	735517E+01	4.000	4.000	4.000
6	735517E+02	735517E+02	5.000	5.000	5.000
7	735517E+03	735517E+03	12.116	12.116	12.116
8	735517E+01	735517E+01	5.000	5.000	5.000
9	735517E+02	735517E+02	12.655	12.655	12.655
10	735517E+03	735517E+03	5.351	5.351	5.351
11	735517E+01	735517E+01	8.000	8.000	8.000
12	735517E+02	735517E+02	9.000	9.000	9.000
13	735517E+03	735517E+03	11.000	11.000	11.000
14	735517E+01	735517E+01	12.000	12.000	12.000
15	735517E+02	735517E+02	13.000	13.000	13.000
16	735517E+03	735517E+03	14.000	14.000	14.000
17	735517E+01	735517E+01	15.000	15.000	15.000
18	735517E+02	735517E+02	16.000	16.000	16.000
19	735517E+03	735517E+03	17.000	17.000	17.000
20	735517E+01	735517E+01	18.000	18.000	18.000
21	735517E+02	735517E+02	19.000	19.000	19.000
22	735517E+03	735517E+03	20.000	20.000	20.000
23	735517E+01	735517E+01	21.000	21.000	21.000
24	735517E+02	735517E+02	22.000	22.000	22.000
25	735517E+03	735517E+03	23.000	23.000	23.000
26	735517E+01	735517E+01	24.000	24.000	24.000
27	735517E+02	735517E+02	25.000	25.000	25.000
28	735517E+03	735517E+03	26.000	26.000	26.000
29	735517E+01	735517E+01	27.000	27.000	27.000
30	735517E+02	735517E+02	28.000	28.000	28.000
31	735517E+03	735517E+03	29.000	29.000	29.000
32	735517E+01	735517E+01	30.000	30.000	30.000
33	735517E+02	735517E+02	31.000	31.000	31.000
34	735517E+03	735517E+03	32.000	32.000	32.000
35	735517E+01	735517E+01	33.000	33.000	33.000
36	735517E+02	735517E+02	34.000	34.000	34.000
37	735517E+03	735517E+03	35.000	35.000	35.000
38	735517E+01	735517E+01	36.000	36.000	36.000
39	735517E+02	735517E+02	37.000	37.000	37.000
40	735517E+03	735517E+03	38.000	38.000	38.000
41	735517E+01	735517E+01	39.000	39.000	39.000
42	735517E+02	735517E+02	40.000	40.000	40.000
43	735517E+03	735517E+03	41.000	41.000	41.000
44	735517E+01	735517E+01	42.000	42.000	42.000
45	735517E+02	735517E+02	43.000	43.000	43.000
46	735517E+03	735517E+03	44.000	44.000	44.000
47	735517E+01	735517E+01	45.000	45.000	45.000
48	735517E+02	735517E+02	46.000	46.000	46.000
49	735517E+03	735517E+03	47.000	47.000	47.000
50	735517E+01	735517E+01	48.000	48.000	48.000
51	735517E+02	735517E+02	49.000	49.000	49.000
52	735517E+03	735517E+03	50.000	50.000	50.000
53	735517E+01	735517E+01	51.000	51.000	51.000
54	735517E+02	735517E+02	52.000	52.000	52.000
55	735517E+03	735517E+03	53.000	53.000	53.000
56	735517E+01	735517E+01	54.000	54.000	54.000
57	735517E+02	735517E+02	55.000	55.000	55.000
58	735517E+03	735517E+03	56.000	56.000	56.000
59	735517E+01	735517E+01	57.000	57.000	57.000
60	735517E+02	735517E+02	58.000	58.000	58.000

65	11	184700	225011100	255373E+0	80.00	11
66	188752501	175515100	175515100	2151731E+1	65.00	131
67	150122600	251736100	251736100	1333377E+0	56.00	128
68	141671000	111551001	111551001	171759E+1	67.00	109
69	172961000	139132600	139132600	524113E+0	58.00	141
70	151119500	113954E+1	113954E+1	1324522E+1	59.00	115
71	174719500	141220000	141220000	224322E+0	70.00	114
72	163481E+1	116505E+1	116505E+1	171168E+1	71.00	167
73	295595100	1551953E+0	1551953E+0	5235113E+0	72.00	140
74	213112500	171655E+1	171655E+1	175114E+1	73.00	110
75	151373E+1	216317E+0	216317E+0	423933E+0	74.00	127
76	1573632E+0	115172E+1	115172E+1	121134E+1	75.00	176
77	155923E+1	135265E+0	135265E+0	353333E+0	76.00	122
78	168445E+0	931932E+0	931932E+0	114132E+1	77.00	165
79	135677E+0	662836E+0	662836E+0	353333E+0	78.00	122
80	1251167E+1	716927E+0	716927E+0	353333E+1	79.00	130
81	1159124E+0	516627E+0	516627E+0	553253E+0	80.00	162
82	1367231E+0	661497E+0	661497E+0	924320E+0	81.00	158
83	1167127E+1	115583E+1	115583E+1	625635E+1	82.00	106
84	114173E+1	217926E+0	217926E+0	1154293E+1	83.00	167
85	1255351E+0	179238E+0	179238E+0	453137E+0	84.00	129
86	1162694E+1	214667E+0	214667E+0	117779E+1	85.00	167
87	171711E+0	199849E+0	199849E+0	717543E+0	86.00	146
88	122255E+1	322323E+0	322323E+0	1264353E+1	87.00	179
89	271181E+0	241495E+0	241495E+0	433333E+0	88.00	131
90	173511E+0	451731E+0	451731E+0	33156E+0	89.00	133
91	165791E+0	332177E+0	332177E+0	332531E+0	90.00	121
92	192942E+0	111317E+1	111317E+1	1253491E+1	91.00	182
93	145117E+0	531172E+0	531172E+0	531373E+1	92.00	141
94	173275E+0	656149E+0	656149E+0	439337E+0	93.00	157
95	169274E+0	337223E+0	337223E+0	432474E+0	94.00	131
96	146441E+0	921131E+0	921131E+0	953137E+0	95.00	160
97	155615E+1	352188E+0	352188E+0	357115E+0	96.00	125
98	154591E+0	144557E+1	144557E+1	122315E+1	97.00	177
99	164710E+1	831141E+0	831141E+0	432133E+0	98.00	157
100	118258E+1	152132E+1	152132E+1	152132E+1	99.00	190
101	167288E+0	676138E+0	676138E+0	824422E+0	100.00	152
102	1178120E+0	541151E+0	541151E+0	821234E+0	101.00	152
103	255519E+0	341174E+0	341174E+0	425513E+0	102.00	127
104	1116657E+1	120138E+1	120138E+1	155132E+1	103.00	100
105	131435E+1	1383011E+0	1383011E+0	142131E+1	104.00	189
106	115827E+1	115197E+1	115197E+1	1423143E+1	105.00	194
107	145377E+0	116820E+1	116820E+1	135213E+0	106.00	185
108	127553E+0	116718E+1	116718E+1	143111E+1	107.00	191
109	132151E+0	613225E+0	613225E+0	751217E+0	108.00	147
110	197191E+0	435761E+0	435761E+0	139337E+1	109.00	168
111	233412E+0	677115E+0	677115E+0	925112E+0	110.00	158
112	135693E+1	656384E+0	656384E+0	155161E+1	111.00	195
113	132922E+0	689295E+0	689295E+0	711335E+0	112.00	144
114	113249E+1	136822E+0	136822E+0	115953E+1	113.00	168
115	177183E+1	413313E+0	413313E+0	953525E+0	114.00	161
116	111646E+1	331515E+0	331515E+0	115133E+1	115.00	173
117	113671E+1	138634E+0	138634E+0	142333E+0	116.00	109
118	125121E+1	177147E+0	177147E+0	725532E+1	117.00	140
119	265121E+0	113237E+1	113237E+1	289335E+0	118.00	118
120	163512E+0	1329129E+0	1329129E+0	7751347E+0	119.00	149
121	111915E+1	611236E+0	611236E+0	611236E+0	120.00	138
122	159731E+0	272745E+0	272745E+0	534537E+0	121.00	174
123	139839E+0	311429E+1	311429E+1	547155E+0	122.00	134
124	174175E+0	324174E+0	324174E+0	435133E+0	123.00	131
125	159651E+1	161657E+0	161657E+0	213333E+0	124.00	116
126	286363E+1	1275463E+0	1275463E+0	425547E+0	125.00	127

132	1842237E+00	1671854E+00	2457754E+00	171.000	.116
133	2837131E+00	1411535E+00	3169335E+00	172.000	.221
134	36.192 E+01	4.18 42E-01	352188E+00	173.000	.129
135	1484132E+01	1816338E+00	1522133E+00	174.000	.311
136	3127378E+00	189572E-01	377313E+00	175.000	.319
137	143393E+00	5011917E-01	1533119E+00	176.000	.111
138	3285925E+00	2118639E+00	3783198E+00	177.000	.124
139	3949413E-11	333473E+00	335533E+00	178.000	.121
140	1811821E+00	344331E+00	353773E+00	179.000	.022
141	3221743E-11	787232E-01	944343E+00	180.000	.106
142	1364132E+00	304706E+00	6112420E+00	181.000	.026
143	2247295E+00	287539E+00	365031E+00	182.000	.323
144	187761E-11	355918E+00	3645324E+00	183.000	.023
145	3233725E-11	3585293E-01	8932155E-11	184.000	.006
146	1496132E-11	3936318E+00	4009123E+00	185.000	.025
147	3181179E+00	1021279E+00	3245323E+00	186.000	.320
148	2949018E+00	2621974E+00	441014E+00	187.000	.025
149	2413425E+00	1687483E+00	2333431E+00	188.000	.318
150	2349403E+00	1778592E+00	2345759E+00	189.000	.319
151	3625752E+10	1662135E-01	3531333E+00	190.000	.023
152	4217135E+00	5221836E-02	4823016E+00	191.000	.030
153	321714E-11	3125104E+00	3136635E+00	192.000	.320
154	3219192E+00	477630E-02	3213436E+00	193.000	.321
155	2159635E+00	2195936E+00	3511323E+00	194.000	.319
156	3651212E+00	255122E+00	4193333E+00	195.000	.020
157	456151E-01	6386461E+00	4414423E+00	196.000	.328
158	1552935E+00	2769465E+00	3175383E+00	197.000	.021
159	193917E-11	2511917E+00	2514335E+00	198.000	.316
160	2229154E+00	3961294E+00	4345439E+00	199.000	.029
161	2668751E+00	4167729E+00	4377364E+00	200.000	.331
162	353754E-11	3211253E+00	3325377E+00	201.000	.021
163	1551931E+00	1711243E+00	2334549E+00	202.000	.115
164	329871E-11	1217289E+00	4314933E+00	203.000	.027
165	44184E-11	1857353E+00	4777735E+00	204.000	.330
166	2843159E+00	2719608E+00	3327452E+00	205.000	.325
167	3181917E+00	1477216E-01	3144258E+00	206.000	.327
168	221723E+00	2116332E+00	3651172E+00	207.000	.319
169	893235E+00	2187161E-01	4998123E+00	208.000	.331
170	533235E+00	2187161E-01	4998123E+00	209.000	.331
171	2221723E+00	2116332E+00	3651172E+00	210.000	.319
172	319197E+00	1477216E-01	3144258E+00	211.000	.021
173	2843159E+00	2719608E+00	3327452E+00	212.000	.325
174	44184E-11	1857353E+00	4777735E+00	213.000	.330
175	339871E-11	1217289E+00	4314933E+00	214.000	.027
176	1551931E+00	1711243E+00	2334549E+00	215.000	.115
177	329871E-11	1217289E+00	4314933E+00	216.000	.027
178	44184E-11	1857353E+00	4777735E+00	217.000	.330
179	2229154E+00	3961294E+00	4377364E+00	218.000	.029
180	193917E-11	2511917E+00	2514335E+00	219.000	.316
181	1552935E+00	2769465E+00	3175383E+00	220.000	.328
182	3651212E+00	4414423E+00	4414423E+00	221.000	.021
183	3550212E+00	2655022E+00	4193333E+00	222.000	.328
184	2159635E+00	2195936E+00	3511323E+00	223.000	.319
185	3219192E+00	477630E-02	3213436E+00	224.000	.321
186	321714E-11	3125104E+00	3136635E+00	225.000	.320
187	4217135E+00	5221836E-02	4823016E+00	226.000	.331
188	1625752E+00	1812135E-01	3531333E+00	227.000	.323
189	2349403E+00	1778592E+00	2345759E+00	228.000	.319
190	2413425E+00	1687483E+00	2345759E+00	229.000	.318
191	284914E+00	2821974E+00	441014E+00	230.000	.025
192	3181179E+00	1021279E+00	3245323E+00	231.000	.320

197	--.196432E+00	--.361705E+00	.111221E+01	197.000	.226
198	--.3226743E+01	--.78723 2E+01	.3443+43E+01	197.100	.016
199	.1801821E+00	.3617331E+00	.7537175E+00	198.000	.122
200	--.38094 3E+01	.33347 15E+00	.3353331E+00	199.000	.123
201	--.3205925E+00	--.2186339E+00	.3763198E+00	200.000	.124
202	--.1433593E+00	--.501917E+01	.1533113E+00	201.000	.111
203	.3027374E+00	--.1854542E+01	.3133313E+00	202.000	.010
204	--.1494332E+01	.1816338E+00	.1822133E+00	203.000	.111
205	--.4601923E+00	.418423E+01	.1626359E+00	204.000	.029
206	--.2837131E+00	.1411535E+00	.3153335E+00	205.000	.121
207	.1862233E+00	--.1671854E+00	.2487754E+00	206.000	.110
208	.1142715E+00	.117 795E+00	.1535569E+00	207.000	.116
209	--.183754E+00	.3295321E+00	.3787483E+00	208.000	.024
210	--.1811733E+00	.1392917E+00	.2277427E+00	209.000	.014
211	--.4368542E+01	--.4319514E+00	.4391349E+00	210.000	.028
212	--.375605E+01	--.6616983E+01	.1174130E+00	211.000	.007
213	.2863663E+01	.4275460E+00	.4293147E+00	212.000	.027
214	--.1536119E+00	.1818572E+00	.2413333E+00	213.000	.115
215	--.3741752E+00	--.328743E+00	.4351153E+00	214.000	.031
216	--.3398399E+00	.3164429E+01	.5487565E+00	215.000	.034
217	--.537319E+00	.2727451E+00	.5345+97E+00	216.000	.034
218	.341554E+01	.6012361E+00	.6113225E+00	217.000	.038
219	--.7635546E+00	--.1329029E+00	.7750347E+00	218.000	.049
220	--.2881246E+00	.1422371E+01	.2893335E+00	219.000	.118
221	.7250241E+00	--.4771479E+01	.7265925E+00	220.000	.040
222	.315671E+01	.1388345E+00	.1423333E+00	221.000	.109
223	--.1111646E+01	.3360115E+00	.1150333E+01	222.000	.173
224	--.3771831E+00	.1133435E+00	.9595925E+00	223.000	.061
225	.1013249E+01	--.7982220E+00	.1899594E+01	224.000	.068
226	.1328262E+00	.6892995E+00	.7119395E+00	225.000	.044
227	--.135693E+01	.6943864E+00	.1535351E+01	226.000	.196
228	--.2974497E+00	.8771785E+00	.9251302E+00	227.000	.158
229	.3974534E+00	--.135751E+00	.1039337E+01	228.000	.068
230	.4324505E+00	.6131227E+00	.7502102E+00	229.000	.147
231	--.3279536E+00	.1167182E+01	.1431111E+01	230.000	.194
232	.5453677E+00	.1160249E+01	.1352196E+01	231.000	.055
233	.158278E+01	--.1753197E+01	.143343E+01	232.000	.094
234	.1344358E+01	--.530303E+00	.1420319E+01	233.000	.189
235	--.1146897E+01	.121383E+01	.1553325E+01	234.000	.194
236	.2555197E+00	--.3416174E+00	.4255053E+00	235.000	.127
237	.5178128E+00	--.5411504E+00	.9212341E+00	236.000	.052
238	--.088280E+01	--.8781365E+00	.8244224E+00	237.000	.152
239	--.102592E+01	.1526324E+01	.1529516E+01	238.000	.095
240	.5887009E+01	.8364049E+00	.8332119E+00	239.000	.053
241	.5659611E+00	--.1085557E+01	.1223106E+01	240.000	.077
242	.5684165E+01	--.3921889E+00	.3979105E+00	241.000	.025
243	.1488411E+00	.9521033E+00	.9530375E+00	242.000	.160

END FCRJ
ALPHA = 1.6

TIME : 36 , CYS , CUKT, VITS ,NTS
AVERAGE POWER DJT = 1557.93299937
HORSE POWER OUTPUT = 2.979078954339
NF = 333 PNTS = 8000.

A B C D E F

REAL

IMAG

MA

HARR

1	.142743E+02	6.	.143743E+12	1.000	1.160
2	-.312010E+03		.127323E+04	1.000	10.000
3	-.201164E+01		.583334E+01	2.000	.539
4	.365393E+03		.733333E+02	3.000	58.333
5	.375813E+01		.673473E+01	4.000	.531
6	-.109171E+03		.170537E+03	5.000	15.393
7	-.353202E+01		.754724E+01	6.000	.597
8	.123391E+03		.181557E+02	7.000	14.284
9	.297164E+01		.371342E+01	8.000	.292
10	-.123913E+02		.541333E+02	9.000	7.175
11	-.187173E+01		.654133E+01	1.000	.74
12	.374159E+02		.755135E+02	11.000	5.335
13	.331427E+00		.272183E+01	12.000	.214
14	.287495E+01		.551734E+02	13.000	4.334
15	-.512012E+03		.425327E+01	14.000	.335
16	.772247E+01		.393226E+02	15.000	3.188
17	.287511E+00		.233214E+01	16.000	.193
18	.374478E+01		.310739E+02	17.000	2.435
19	.143574E+00		.343124E+01	18.000	.274
20	.162422E+01		.269354E+02	19.000	2.117
21	-.519301E+01		.174219E+01	20.000	.137
22	.364235E+01		.210193E+02	21.000	1.583
23	.340535E+00		.315175E+01	22.000	.247
24	.511513E+00		.154333E+02	23.000	1.263
25	-.572016E+00		.131434E+01	24.000	.126
26	.325420E+01		.124755E+02	25.000	1.373
27	.612835E+00		.241753E+01	26.000	.190
28	-.339571E+01		.175323E+02	27.000	.317
29	-.717665E+00		.152223E+01	28.000	.122
30	.574965E+01		.111361E+02	29.000	.377
31	.339411E+00		.211195E+01	30.000	.166
32	.357722E+01		.951137E+01	31.000	.757
33	-.546122E+00		.112137E+02	32.000	.348
34	.572715E+01		.931323E+01	33.000	.532
35	.307319E+00		.200504E+01	34.000	.161
36	-.161925E+01		.512312E+01	35.000	.476
37	-.110915E+01		.127352E+01	36.000	.345
38	.513381E+01		.834474E+01	37.000	.655
39	.515173E+00		.153415E+02	38.000	.121
40	-.316178E+01		.631738E+01	39.000	.379
41	-.382503E+00		.123573E+01	40.000	.797
42	.395143E+01		.549333E+01	41.000	.437
43	.333784E+00		.137379E+01	42.000	.108
44	-.332283E+01		.465343E+01	43.000	.366
45	-.732611E+00		.944123E+01	44.000	.156
46	.149334E+01		.445413E+01	45.000	.351
47	.314231E+00		.142336E+01	46.000	.112
48	-.165149E+01		.231025E+01	47.000	.221
49	-.361504E+01		.971657E+01	48.000	.076
50	.125613E+01		.452343E+01	49.000	.367
51	.365179E+00		.137348E+01	50.000	.083
52	-.196239E+01		.213353E+01	51.000	.167
53	-.112195E+01		.144235E+02	52.000	.182
54	.266443E+01		.345365E+01	53.000	.241
55	.898024E+00		.915128E+00	54.000	.172
56	-.244115E+01		.254353E+01	55.000	.237
57	-.733656E+00		.742351E+01	56.000	.156
58	.246252E+01		.246253E+01	57.000	.193
59	.349638E+00		.111155E+01	58.000	.379
60	-.117431E+01		.142331E+01	59.000	.112

65	176374E+01	117949E+07	132260E+01	65.700	143
66	139311E+10	112554E+00	643120E+03	64.000	151
67	155922E+11	191759E+00	197137E+01	57.000	123
68	1703601E+10	1315654E+00	7157345E+00	68.000	156
69	1231157E+11	4461349E+00	135533E+01	69.000	177
70	742306E+10	1326974E+00	721559E+00	71.000	159
71	7726474E+10	2151793E+00	8020511E+00	71.000	163
72	7494165E+10	3301682E+00	8214273E+00	72.000	165
73	1751179E+11	6902671E+01	1733311E+01	73.000	141
74	3476126E+10	527633E+00	5252123E+00	74.000	141
75	3353817E+10	4166362E+00	5137222E+00	75.000	148
76	117181E+11	1307463E+00	3171307E+00	76.000	172
77	117181E+11	2126502E+00	1173936E+01	77.000	193
78	117181E+11	6050983E+00	5031195E+00	78.000	141
79	117181E+11	4735034E+00	1981337E+01	79.000	185
80	117181E+11	1817345E+00	771224E+00	80.000	159
81	117181E+11	2534972E+00	785557E+00	81.000	162
82	117181E+11	6819647E+01	547743E+00	81.000	143
83	117181E+11	708133E+00	6351133E+00	82.000	170
84	117181E+11	708981E+00	135163E+01	82.000	102
85	117181E+11	3147176E+00	3743398E+00	85.000	102
86	117181E+11	5826381E+00	5565715E+00	86.000	146
87	117181E+11	6357107E+00	9235109E+00	88.000	165
88	117181E+11	9722241E+01	9232411E+00	89.000	165
89	117181E+11	6633713E+00	9334734E+00	90.000	166
90	117181E+11	7714219E+00	7725554E+00	91.000	107
91	117181E+11	1519437E+00	5530735E+00	92.000	151
92	117181E+11	4707908E+00	9330125E+00	93.000	146
93	117181E+11	3644512E+00	4707922E+00	94.000	136
94	117181E+11	9840511E+00	5207375E+00	95.000	141
95	117181E+11	1145407E+01	9225343E+00	96.000	178
96	117181E+11	1666519E+00	1257639E+01	97.000	199
97	117181E+11	7593741E+00	1045551E+01	98.000	162
98	117181E+11	5137479E+00	5132555E+00	99.000	182
99	117181E+11	4323085E+00	5183375E+00	100.000	141
100	117181E+11	6476023E+00	9743583E+00	101.000	141
101	117181E+11	1253968E+01	1453331E+01	102.000	171
102	117181E+11	4187155E+00	5339381E+00	103.000	111
103	117181E+11	226679E+00	6593555E+00	104.000	142
104	117181E+11	2916075E+00	1045235E+01	105.000	152
105	117181E+11	1253165E+01	1253165E+01	106.000	182
106	117181E+11	3737911E+00	3121264E+00	107.000	198
107	117181E+11	6657115E+01	1745311E+01	108.000	125
108	117181E+11	7826329E+00	373315E+00	109.000	137
109	117181E+11	7466355E+00	9187233E+00	110.000	172
110	117181E+11	1919702E+00	103235E+01	111.000	186
111	117181E+11	1189193E+01	617552E+00	112.000	147
112	117181E+11	175963E+00	207399E+00	113.000	147
113	117181E+11	635422E+00	1183343E+01	114.000	116
114	117181E+11	139383E+00	4535302E+00	115.000	186
115	117181E+11	711545E+00	5232355E+00	116.000	136
116	117181E+11	8726232E+01	372393E+00	117.000	153
117	117181E+11	8712467E+00	924314E+00	118.000	173
118	117181E+11	5337261E+00	7113575E+00	119.000	155
119	117181E+11	627751E+00	635245E+00	120.000	155
120	117181E+11	2938191E+00	723593E+00	121.000	125
121	117181E+11	198127E+00	615553E+00	122.000	146
122	117181E+11	118227E+00	293352E+00	123.000	123
123	117181E+11	615553E+00	615553E+00	124.000	147
124	117181E+11	615553E+00	615553E+00	125.000	147
125	117181E+11	615553E+00	615553E+00	126.000	147

132	.286017E+00	.41154E+00	.574224E+00	.121.000	.019
133	.221665E+00	.931171E+01	.211575E+00	.122.000	.019
134	.213113E+00	.219595E+00	.307239E+00	.133.000	.019
135	.213113E+00	.151313E+00	.135737E+00	.134.000	.012
136	.201217E+00	.127614E+00	.459131E+00	.135.000	.036
137	.104174E+00	.142919E+01	.194532E+00	.136.000	.015
138	.355698E+00	.277241E+00	.470145E+00	.137.000	.035
139	.141175E+00	.169316E+00	.137478E+00	.138.000	.016
140	.165229E+00	.244667E+00	.235338E+00	.139.000	.023
141	.140632E+00	.173066E+00	.183319E+00	.140.000	.014
142	.297111E+00	.213297E+00	.428147E+00	.141.000	.033
143	.742256E+01	.132187E+00	.131513E+00	.142.000	.012
144	.265019E+00	.214329E+00	.214553E+00	.143.000	.027
145	.211495E+00	.121960E+00	.212543E+00	.144.000	.019
146	.255223E+00	.207176E+00	.337697E+00	.145.000	.027
147	.329631E+01	.225962E+00	.234572E+00	.146.000	.018
148	.226131E+00	.251963E+00	.735747E+00	.147.000	.028
149	.135006E+00	.104731E+00	.171357E+00	.148.000	.013
150	.321191E+00	.154736E+00	.787559E+00	.149.000	.017
151	.125764E+00	.218612E+00	.252139E+00	.150.000	.020
152	.223412E+00	.171741E+00	.281735E+00	.151.000	.022
153	.364702E+01	.217976E+00	.223239E+00	.152.000	.018
154	.317991E+00	.174491E+00	.333220E+00	.153.000	.031
155	.236195E+01	.174713E+00	.132733E+00	.154.000	.014
156	.271210E+00	.146673E+00	.291151E+00	.155.000	.023
157	.151113E+00	.217212E+00	.254515E+00	.156.000	.021
158	.322591E+00	.142910E+00	.352932E+00	.157.000	.028
159	.328214E+02	.258698E+00	.257154E+00	.158.000	.024
160	.315117E+00	.118942E+00	.259747E+00	.159.000	.026
161	.701611E+01	.155314E+00	.173972E+00	.160.000	.014
162	.361373E+00	.141207E+00	.356459E+00	.161.000	.029
163	.312572E+01	.255812E+00	.255715E+00	.162.000	.021
164	.295311E+00	.232132E+00	.139732E+00	.163.000	.024
165	.377245E+02	.235335E+00	.233335E+00	.164.000	.019
166	.367893E+00	.320705E+00	.386839E+00	.165.000	.031
167	.135713E+02	.146197E+00	.136512E+00	.166.000	.015
168	.293527E+00	.171634E+00	.299744E+00	.167.000	.024
169	.348732E+01	.240194E+00	.257473E+00	.168.000	.020
170	.375031E+00	.355714E+02	.376931E+00	.169.000	.024
171	.548173E+01	.249194E+00	.257473E+00	.170.000	.024
172	.293212E+00	.171634E+00	.299744E+00	.171.000	.024
173	.135075E+02	.186497E+00	.185512E+00	.172.000	.015
174	.387893E+00	.351715E+00	.388139E+00	.173.000	.031
175	.277245E+02	.235335E+00	.233335E+00	.174.000	.019
176	.293131E+00	.152192E+00	.309732E+00	.175.000	.024
177	.512972E+01	.255812E+00	.255715E+00	.176.000	.021
178	.351375E+00	.661237E+01	.355459E+00	.177.000	.029
179	.701611E+01	.155314E+00	.173972E+00	.178.000	.014
180	.315117E+00	.118942E+00	.185512E+00	.179.000	.020
181	.529214E+02	.258698E+00	.257154E+00	.180.000	.024
182	.322591E+00	.142910E+00	.352932E+00	.181.000	.028
183	.151113E+00	.217212E+00	.254515E+00	.182.000	.021
184	.271210E+00	.146673E+00	.291151E+00	.183.000	.020
185	.325191E+00	.174713E+00	.192753E+00	.184.000	.014
186	.357991E+00	.174491E+00	.792527E+00	.185.000	.031
187	.364702E+01	.217976E+00	.223239E+00	.186.000	.028
188	.223412E+00	.171741E+00	.281735E+00	.187.000	.022
189	.125764E+00	.218612E+00	.252139E+00	.188.000	.020
190	.351191E+00	.154736E+00	.387559E+00	.189.000	.031
191	.135006E+00	.104731E+00	.171357E+00	.190.000	.013
192	.255631E+00	.256963E+00	.358574E+00	.191.000	.026

190	..291111E+00	..301395E+00	..25079E+00	197.00	.31
199	..140592E+00	..173066E+00	..193313E+00	198.00	.314
200	..185522E+00	..244667E+00	..295331E+00	199.00	.323
201	..111175E+00	..165976E+00	..137479E+00	200.00	.316
202	..156687E+00	..277241E+00	..447045E+00	201.00	.335
203	..100731E+00	..142919E+00	..194532E+00	202.00	.315
204	..211275E+00	..155303E+00	..412761E+00	203.00	.336
205	..213125E+00	..319358E+00	..156777E+00	204.00	.312
206	..213113E+00	..503117E+00	..387299E+00	205.00	.330
207	..224169E+00	..412554E+00	..241573E+00	206.00	.319
208	..268677E+00	..791178E+00	..537422E+00	207.00	.347
209	..333123E+00	..619126E+00	..633131E+00	208.00	.305
210	..153572E+00	..171877E+00	..537599E+00	209.00	.314
211	..305693E+00	..171877E+00	..175175E+00	210.00	.314
212	..184624E+00	..171877E+00	..334538E+00	211.00	.331
213	..215721E+00	..312774E+00	..313539E+00	212.00	.325
214	..224135E+00	..561292E+00	..613451E+00	213.00	.347
215	..273517E+00	..116272E+00	..297556E+00	214.00	.323
216	..108515E+00	..198420E+00	..519133E+00	215.00	.348
217	..158219E+00	..283619E+00	..323589E+00	216.00	.325
218	..113467E+00	..627775E+00	..636244E+00	217.00	.350
219	..711944E+00	..533726E+00	..711950E+00	218.00	.356
220	..311158E+00	..871247E+00	..324314E+00	219.00	.373
221	..360385E+00	..872523E+00	..378239E+00	220.00	.330
222	..429374E+00	..711514E+00	..629236E+00	221.00	.365
223	..417645E+00	..136338E+00	..451557E+00	222.00	.336
224	..987013E+00	..175896E+00	..119934E+00	223.00	.386
225	..169301E+00	..315422E+00	..207159E+00	224.00	.316
226	..506395E+00	..118919E+00	..517562E+00	225.00	.347
227	..972718E+00	..491570E+00	..103053E+00	226.00	.386
228	..522266E+00	..746835E+00	..919723E+00	227.00	.372
229	..581378E+00	..782632E+00	..974911E+00	228.00	.377
230	..174375E+00	..665716E+00	..174396E+00	229.00	.337
231	..745934E+00	..333781E+00	..312154E+00	230.00	.325
232	..713835E+00	..129816E+00	..125313E+00	231.00	.398
233	..113419E+00	..291635E+00	..104529E+00	232.00	.382
234	..518019E+00	..228779E+00	..599555E+00	233.00	.352
235	..335973E+00	..167156E+00	..533931E+00	234.00	.342
236	..535644E+00	..125296E+00	..105331E+00	235.00	.311
237	..531836E+00	..147082E+00	..914959E+00	236.00	.371
238	..266192E+00	..132358E+00	..515497E+00	237.00	.341
239	..322104E+00	..137479E+00	..517525E+00	238.00	.341
240	..518126E+00	..799340E+00	..104545E+00	239.00	.382
241	..518312E+00	..488651E+00	..795116E+00	240.00	.362
242	..521735E+00	..114507E+00	..125735E+00	241.00	.399
243	..124465E+00	..984851E+00	..992694E+00	242.00	.378

END FFCRT
ALPHA = 1.9

TIME : CYS , CYS , CYS , CURT, VITS ,NTS
AVERAGE POWER JJT = 359.574181891
HORSE POWER OUTPUT = 1.132379606377
NF = 333 PNTS = 800.0.

ABCODE F

1	1679556E+01	4535556E+01	1.000	1.000	10.000	365
2	551675E+03	85177E+03	1.000	1.000	10.000	365
3	398983E+01	907331E+01	2.100	2.100	1.068	365
4	773.814E+03	6.78.95E+03	7.100	7.100	71.198	365
5	2192874E+01	825321E+01	4.000	4.000	371	365
6	1950963E+03	2513553E+03	5.000	5.000	33.167	365
7	2059697E+01	397773E+01	6.000	6.000	409	365
8	1101669E+03	173566E+03	7.000	7.000	12.183	365
9	1213642E+01	1582768E+01	8.000	8.000	198	365
10	365393E+02	1054.39E+02	9.000	9.000	12.399	365
11	2052332E+01	285375E+01	11.000	11.000	336	365
12	375436E+01	583997E+01	11.000	11.000	6.393	365
13	2024224E+01	122223E+01	12.000	12.000	144	365
14	3622275E+01	45.332E+02	13.000	13.000	5.297	365
15	468732E+01	153114E+01	14.000	14.000	199	365
16	371331E+02	42.373E+02	15.000	15.000	4.947	365
17	152433E+02	145103E+01	16.000	16.000	172	365
18	212398E+02	2.5587E+00	17.000	17.000	2.414	365
19	202839E+02	153271E+01	18.000	18.000	181	365
20	248261E+02	136129E+02	19.000	19.000	3.342	365
21	334163E+02	15847E+01	20.000	20.000	198	365
22	102143E+01	193335E+02	21.000	21.000	2.281	365
23	198717E+00	853716E+00	22.000	22.000	103	365
24	308219E+00	121299E+02	23.000	23.000	1.335	365
25	43623E+00	168757E+01	24.000	24.000	2.03	365
26	134779E+02	9.665E+01	25.000	25.000	2.134	365
27	119287E+01	6224.9E+00	26.000	26.000	158	365
28	443121E+01	349937E+01	27.000	27.000	1.173	365
29	159819E+01	585575E+00	28.000	28.000	1.072	365
30	33971E+01	384643E+01	29.000	29.000	1.195	365
31	115927E+01	991932E+00	30.000	30.000	171	365
32	763341E+01	112935E+02	31.000	31.000	1.226	365
33	788124E+01	2519.1E+00	32.000	32.000	897	365
34	223191E+01	422307E+01	33.000	33.000	626	365
35	11277E+01	41734.2E+00	34.000	34.000	351	365
36	326031E+01	631913E+01	35.000	35.000	822	365
37	513545E+01	13144E+01	36.000	36.000	196	365
38	343103E+01	819177E+00	37.000	37.000	648	365
39	258431E+01	261122E+00	38.000	38.000	331	365
40	38417E+01	245925E+01	39.000	39.000	537	365
41	197919E+01	4.165.2E+03	40.000	40.000	148	365
42	146639E+01	381775E+01	41.000	41.000	477	365
43	13217E+01	341080E+01	42.000	42.000	317	365
44	25876.8E+00	4.54759E+01	43.000	43.000	478	365
45	27121E+00	364585E+00	44.000	44.000	351	365
46	331732E+01	220994E+01	45.000	45.000	474	365
47	132714E+01	458145E+00	46.000	46.000	156	365
48	22933.2E+01	7141509E+00	47.000	47.000	282	365
49	66612E+01	49142.3E+00	48.000	48.000	158	365
50	93123E+01	116129E+01	49.000	49.000	493	365
51	336967E+01	7.87326E+00	50.000	50.000	792	365
52	3554037E+00	3.73375E+01	51.000	51.000	151	365
53	328224E+01	27.7361E+00	52.000	52.000	158	365
54	541005E+01	2.06782E+01	53.000	53.000	256	365
55	331787E+01	711742E+00	54.000	54.000	796	365
56	261517E+01	281313E+01	55.000	55.000	52	365
57	86152E+01	268149E+00	56.000	56.000	106	365
58	191422E+01	653101E+01	57.000	57.000	242	365
59	378311E+01	832849E+01	58.000	58.000	146	365
60	208953E+01	503516E+01	59.000	59.000	246	365

65	-1394674E+01	7412146E+01	1573435E+00	64.000	.119
66	3466111E+00	-1412422E+01	1515738E+01	65.000	.190
67	-3568017E+00	1232627E+00	5722283E+00	56.300	.167
68	-1725737E+01	-7214073E+01	1727244E+01	67.000	.293
69	-5137979E+01	4767239E+00	4734365E+00	68.000	.156
70	7512335E+00	589778E+00	552910E+00	60.000	.113
71	3617415E+01	-621823E+01	8232782E+01	70.000	.210
72	-3513126E+00	-786781E+00	113762E+01	71.000	.127
73	-1576937E+00	1426465E+00	2129253E+00	72.000	.125
74	2625449E+01	1187317E+01	1131255E+01	73.000	.140
75	2179611E+00	-637802E+03	2179310E+00	74.000	.120
76	744712E+00	-6547075E+00	9315135E+00	75.000	.117
77	-3596972E+01	-2968567E+00	3142316E+00	76.000	.036
78	-336266E+00	4712358E+00	7132476E+00	77.000	.084
79	-113370E+00	-1529212E+00	134559E+00	78.000	.122
80	143618E+01	6466495E+01	1441153E+01	79.000	.171
81	-1643931E+00	-3312011E+00	3593274E+00	80.000	.044
82	-2834391E+00	-1151272E+01	1732554E+01	81.000	.129
83	-3716939E+00	-1908531E+00	4215129E+00	82.000	.157
84	-276134E+00	6657403E+00	7533344E+00	83.000	.092
85	-346969E+00	-173449E+00	3933345E+00	84.000	.046
86	3781931E+00	-1433611E+01	1591418E+01	85.000	.198
87	-3294232E+00	-5716211E+01	5325621E+01	86.000	.063
88	-1122122E+01	-3329945E+00	117038E+01	87.000	.138
89	-619451E+00	1111168E+00	417222E+00	88.000	.049
90	3632198E+00	1247723E+00	8592216E+00	89.000	.102
91	-3116631E+00	816470E+01	5082561E+00	90.000	.060
92	-3223131E+00	-1581339E+01	156453E+01	91.000	.196
93	-416178E+00	442412E+00	6252215E+00	92.000	.074
94	-392621E+00	659378E+00	1191379E+01	93.000	.141
95	-127724E+00	331317E+00	3613245E+00	94.000	.043
96	3710732E+00	-376450E+00	7593335E+00	95.000	.091
97	-281651E+00	369781E+00	4648278E+00	96.000	.155
98	-1304735E+01	-608234E+00	1433342E+01	97.000	.169
99	3497952E+01	5618137E+00	553134E+05	98.000	.167
100	-257134E+00	119E463E+01	1223791E+01	99.000	.144
101	2067552E+00	1165368E+00	2373226E+00	100.000	.128
102	3816471E+00	-281241E+00	473336E+00	101.000	.156
103	-1231113E+00	1561159E+00	2043354E+00	102.000	.024
104	-511241E+00	4679512E+00	7743295E+00	103.000	.191
105	-2937605E+01	3611623E+00	3812343E+00	104.000	.145
106	3155116E+00	472215E+00	133136E+01	105.000	.121
107	132731E+00	5176301E+00	524739E+00	106.000	.162
108	735117E+03	-699168E+00	6998172E+00	107.000	.182
109	520929E+00	4964723E+00	755147E+00	108.000	.194
110	-299143E+01	517824E+00	519522E+00	109.000	.161
111	316568E+00	-1519346E+00	929571E+00	110.000	.109
112	740387E+00	-596951E+00	951163E+00	111.000	.112
113	665799E+00	-767373E+00	893220E+00	112.000	.166
114	-765151E+00	-491013E+00	922751E+00	113.000	.109
115	-256537E+00	-692773E+00	739232E+00	114.000	.187
116	154382E+00	435434E+00	652325E+00	115.000	.151
117	-44245E+00	-131451E+00	535321E+00	116.000	.150
118	-160911E+00	-1158493E+00	535321E+00	117.000	.175
119	-163425E+00	-226543E+01	186333E+00	118.000	.122
120	-385511E+00	711762E+00	925564E+00	119.000	.109
121	-265335E+00	641321E+01	221335E+00	120.000	.026
122	314962E+00	152237E+00	327545E+00	121.000	.109
123	119165E+00	737862E+01	141342E+00	122.000	.116
124	-376173E+00	-57653E+00	535132E+00	123.000	.181
125	-1161433E+00	-2471577E+00	2704571E+00	124.000	.032
126	5205629E+01	7146831E+00	7173723E+00	125.000	.184

132	3373115E+00	537287E-01	337312E+00	131.33	.033
133	3378527E-01	26278.4E+00	277555E+00	132.00	.069
134	3373221E-01	5832722E+00	5393.15E+00	133.00	.037
135	3345465E+00	2676332E+00	3376333E+00	134.00	.028
136	3323892E+00	6929573E-01	2632575E+00	135.00	.129
137	3342824E+00	266.409E-01	2642915E+00	136.00	.132
138	3345735E-01	2578993E+00	277555E+00	137.00	.028
139	3362834E+00	4967137E-01	3376339E+00	138.00	.037
140	3347555E+00	5412732E-01	3355589E+00	139.00	.041
141	3375313E+00	275349E+00	3393758E+00	140.00	.023
142	3322674E-01	3394314E-01	675737E-01	141.00	.041
143	3365989E-01	1911564E+00	3333373E+00	142.00	.029
144	3322856E+00	1151386E+00	3517395E+00	143.00	.032
145	3309187E-01	2467326E+00	259573E+00	144.00	.046
146	3375703E-01	267524E+00	2586822E+00	145.00	.032
147	334263.6E+00	1427149E+00	3592333E+00	146.00	.024
148	3378206E-01	2725916E+00	2752141E+00	147.00	.054
149	3320122E+00	5952358E-01	2611366E+00	148.00	.038
150	3320593E+00	31277.8E+00	2645243E+00	149.00	.041
151	3355641E+00	3379321E+00	3344.12E+00	150.00	.037
152	3336193E+00	3331061E-02	4735320E+00	151.00	.046
153	336117E-12	359773E+00	331.23E+00	152.00	.033
154	3394495E+00	2231618E+00	359397E+00	153.00	.037
155	3347194E+00	216.43E+00	253754E+00	154.00	.037
156	334518E+00	369197E+00	335532E+00	155.00	.034
157	338297.1E+00	157599E+00	3372537E+00	156.00	.054
158	338977.6E+00	4774779E+00	337339E+00	157.00	.038
159	331639E+00	1179459E+00	339553E+00	158.00	.033
160	3347653E+00	718.947E-01	3325321E+00	159.00	.035
161	3347415E+00	2516347E+00	3144.06E+00	160.00	.037
162	337885E+00	3375231E-02	3373195E+00	161.00	.029
163	3345622E-01	2399746E+00	2624356E+00	162.00	.032
164	3316417E+00	33679.5E+00	2594317E+00	163.00	.031
165	3359513E-01	2247478E+00	2445575E+00	164.00	.034
166	3351959E-01	189355E+00	1935379E+00	165.00	.032
167	3376415E+00	621.32E-01	2333153E+00	166.00	.031
168	3343614E-01	2627347E+00	253566E+00	167.00	.034
169	3376173E+00	1621226E-01	1130.31E+00	168.00	.035
170	33135.1E+00	875.924E-01	2593745E+00	169.00	.031
171	331375E+00	871.924E-01	2343745E+00	170.00	.034
172	3376173E+00	1621226E-01	1130.31E+00	171.00	.031
173	3343414E-01	2627347E+00	253566E+00	172.00	.034
174	3364139E+00	1621226E-01	253566E+00	173.00	.031
175	3361039E-01	159355E+00	1935.3E+00	174.00	.029
176	3365613E-01	2247478E+00	2445575E+00	175.00	.034
177	3316417E+00	33679.5E+00	4.34317E+00	176.00	.029
178	3345622E-01	2399746E+00	2624356E+00	177.00	.037
179	337885E+00	452816E-02	3373195E+00	178.00	.037
180	3376173E+00	2316947E+00	334505E+00	179.00	.034
181	3327653E+00	718.947E-01	3326321E+00	180.00	.038
182	3311639E+00	119459E+00	3214559E+00	181.00	.038
183	3389176E+00	4.7779E+00	3372537E+00	182.00	.047
184	3320593E+00	1574599E+00	3372537E+00	183.00	.047
185	331518E+00	369197E+00	335532E+00	184.00	.043
186	3347653E+00	1621226E-01	253566E+00	185.00	.046
187	3345622E-01	2399746E+00	2624356E+00	186.00	.047
188	3336117E-12	359773E+00	331.23E+00	187.00	.041
189	336117E-12	333160E-02	3333373E+00	188.00	.041
190	3355641E+00	3379321E+00	3344.12E+00	189.00	.037
191	3355641E+00	3379321E+00	3344.12E+00	190.00	.037
192	3355641E+00	3379321E+00	3344.12E+00	191.00	.037

197	..32255E+00	..1151386E+00	..1337375E+00	197.000	..023
198	..36594E+00	..19116E+00	..337375E+00	198.000	..076
199	..35247E+00	..38531E+00	..349578E+00	199.000	..041
200	..27553E+00	..22184E+00	..349578E+00	200.000	..037
201	..34555E+00	..54127E+00	..349578E+00	201.000	..121
202	..16828E+00	..198137E+00	..1736.33E+00	202.000	..032
203	..31473E+00	..25799E+00	..271303E+00	203.000	..129
204	..34284E+00	..261748E+00	..261748E+00	204.000	..137
205	..22319E+00	..89235E+00	..261748E+00	205.000	..169
206	..12454E+00	..287033E+00	..313439E+00	206.000	..033
207	..31232E+00	..502722E+00	..3393.13E+00	207.000	..128
208	..39785E+00	..26278.4E+00	..277535E+00	208.000	..137
209	..37340E+00	..517287E+00	..351324E+00	209.000	..045
210	..25233E+00	..152746E+00	..292725E+00	210.000	..033
211	..39841E+00	..2256.48E+00	..6373.53E+00	211.000	..054
212	..18873E+00	..644357E+00	..135117E+00	212.000	..122
213	..38531E+00	..674753E+00	..334312E+00	213.000	..098
214	..29525E+00	..104736E+00	..278353E+00	214.000	..133
215	..52052E+00	..714683E+00	..717372E+00	215.000	..184
216	..31014E+00	..171577E+00	..271577E+00	216.000	..032
217	..37177E+00	..171577E+00	..693133E+00	217.000	..081
218	..113745E+00	..13780E+00	..140154E+00	218.000	..116
219	..31492E+00	..152237E+00	..92754.5E+00	219.000	..109
220	..20535E+00	..841352E+00	..2213.35E+00	220.000	..126
221	..38551E+00	..716078E+00	..926556E+00	221.000	..179
222	..183125E+00	..32830.9E+00	..196343E+00	222.000	..122
223	..15.910E+00	..115049E+00	..633521E+00	223.000	..075
224	..114245E+00	..130.45E+00	..425652E+00	224.000	..050
225	..154382E+00	..693277E+00	..432332E+00	225.000	..154
226	..25657E+00	..459101E+00	..739219E+00	226.000	..087
227	..76568E+00	..76737.9E+00	..832775E+00	227.000	..105
228	..65759E+00	..569516E+00	..931220E+00	228.000	..106
229	..74387E+00	..31658E+00	..931653E+00	229.000	..112
230	..31658E+00	..154934E+00	..923571E+00	230.000	..109
231	..29914E+00	..117082E+00	..513545E+00	231.000	..161
232	..521962E+00	..491172E+00	..739734E+00	232.000	..194
233	..735107E+00	..199818E+00	..593817E+00	233.000	..182
234	..13273E+00	..517685E+00	..5247.99E+00	234.000	..162
235	..31515E+00	..1722158E+00	..1030155E+00	235.000	..121
236	..29376E+00	..281623E+00	..331264E+00	236.000	..145
237	..50124E+00	..4879512E+00	..774323E+00	237.000	..191
238	..12311E+00	..158119E+00	..273354E+00	238.000	..124
239	..18164E+00	..262241E+00	..473496E+00	239.000	..156
240	..21675E+00	..116508E+00	..273325E+00	240.000	..128
241	..25713E+00	..119646E+00	..122378E+00	241.000	..144
242	..948795E+00	..561613E+00	..356139E+00	242.000	..167
243	..130473E+00	..608234E+00	..143355E+00	243.000	..169

END FFCRT
JUT ALL-----
ALPHA = 2.15

LINE : 1, CVO, CYS, CUP1, VITS, MTS
AVERAGE POWER 3JT = 4415.733130665
HORSE POWER OUTPUT = 9.923513579899
NF = 311 PNTS = 8300.

6

A B C D E F

1	315933.5E+04	315933.5E+04	6.070	152.189
2	-276906E+04	277207E+04	1.010	10.101
3	-12.4385E+03	330523E+03	2.310	15.316
4	-311384E+03	325997E+03	3.030	15.742
5	-110351E+03	122577E+03	4.710	5.311
6	-1336161E+03	123256E+03	5.030	6.397
7	-1122743E+03	113225E+03	5.000	5.451
8	-7808234E+02	817545E+02	7.030	3.336
9	-6548536E+02	675219E+02	8.000	4.228
10	-671564E+02	631551E+02	9.000	3.281
11	-594753E+02	514532E+02	10.070	2.353
12	-102131E+02	626154E+02	11.070	3.014
13	-479874E+02	485112E+02	12.300	2.340
14	-490133E+02	511520E+02	13.070	2.458
15	-457823E+02	452423E+02	14.070	2.226
16	-3618453E+02	333537E+02	15.000	1.895
17	-4192597E+02	313355E+02	16.070	2.177
18	-343801E+02	349322E+02	17.370	1.580
19	-3473507E+02	303633E+02	18.300	1.751
20	-332159E+02	339555E+02	19.070	1.631
21	-2648997E+02	375512E+02	21.070	1.471
22	-312658E+02	313952E+02	21.070	1.711
23	-274275E+02	293315E+02	22.000	1.763
24	-268047E+02	279535E+02	23.070	1.346
25	-252735E+02	264533E+02	24.070	1.274
26	-248171E+02	257315E+02	25.070	1.239
27	-2287337E+02	240127E+02	26.070	1.155
28	-2295473E+02	242130E+02	27.070	1.166
29	-216185E+02	225212E+02	28.070	1.089
30	-213266E+02	213421E+02	29.070	1.156
31	-211633E+02	219915E+02	31.070	1.059
32	-165317E+02	137832E+02	31.070	.952
33	-192848E+02	129525E+02	32.070	1.001
34	-181705E+02	131970E+02	33.070	.919
35	-174118E+02	191391E+02	34.070	.917
36	-174405E+02	195591E+02	35.070	.894
37	-162175E+02	175519E+02	36.070	.850
38	-162425E+02	175956E+02	37.070	.847
39	-155230E+02	158892E+02	38.070	.913
40	-154362E+02	159493E+02	39.070	.811
41	-143924E+02	153947E+02	40.070	.765
42	-142195E+02	152432E+02	41.070	.782
43	-138277E+02	153735E+02	42.070	.724
44	-136255E+02	153358E+02	43.070	.739
45	-123629E+02	143756E+02	44.070	.721
46	-131567E+02	141934E+02	45.070	.583
47	-118735E+02	147335E+02	46.070	.709
48	-118735E+02	134776E+02	47.070	.647
49	-121731E+02	133215E+02	48.070	.671
50	-118479E+02	133553E+02	49.070	.643
51	-112153E+02	131784E+02	51.070	.634
52	-113219E+02	132335E+02	51.070	.527
53	-108373E+02	123255E+02	52.070	.608
54	-106832E+02	125225E+02	53.070	.583
55	-107563E+02	121538E+02	54.070	.585
56	-104953E+02	123793E+02	55.070	.595
57	-964292E+01	113922E+02	56.070	.558
58	-997745E+01	121525E+02	57.070	.579
59	-946206E+01	112417E+02	58.070	.546
60	-909635E+01	112734E+02	59.070	.543

66	..5297345+01	..1053365+02	64.000	..318
67	..5327415+01	..1032425+02	65.000	..319
68	..5312375+01	..1014579+02	66.000	..320
69	..5306105+01	..1015152+02	67.000	..321
70	..5312652+01	..9937235+01	68.000	..322
71	..5327642+01	..9723355+01	69.000	..323
72	..5307470+01	..1004509+02	70.000	..324
73	..5315580+01	..9264755+01	71.000	..325
74	..5317335+01	..9315735+01	72.000	..326
75	..5331402+01	..9250721+01	73.000	..327
76	..5319031+01	..9104333+01	74.000	..328
77	..5321245+01	..9524333+01	75.000	..329
78	..5326207+01	..8532754+01	76.000	..330
79	..5359121+01	..9350303+01	77.000	..331
80	..5355938+01	..9314354+01	78.000	..332
81	..5327649+01	..8933333+01	79.000	..333
82	..5327549+01	..8933333+01	80.000	..334
83	..5341002+01	..8491785+01	81.000	..335
84	..5327551+01	..8551995+01	82.000	..336
85	..5351211+01	..8514162+01	83.000	..337
86	..5313695+01	..9236355+01	84.000	..338
87	..5351315+01	..9503995+01	85.000	..339
88	..5339277+01	..8236237+01	86.000	..340
89	..5332119+01	..8417523+01	87.000	..341
90	..5337611+01	..8457373+01	88.000	..342
91	..5314672+01	..7976309+01	89.000	..343
92	..5351955+01	..8173315+01	90.000	..344
93	..5352354+01	..8012347+01	91.000	..345
94	..5316758+01	..7575333+01	92.000	..346
95	..5309122+01	..9539165+01	93.000	..347
96	..5303221+01	..6344535+01	94.000	..348
97	..5310154+01	..8714911+01	95.000	..349
98	..5379811+01	..6722314+01	96.000	..350
99	..5392552+01	..8553151+01	97.000	..351
100	..5391145+01	..6315225+01	98.000	..352
101	..5307065+01	..8091565+01	99.000	..353
102	..5381254+01	..7173233+01	100.000	..354
103	..5355747+01	..7575333+01	101.000	..355
104	..5385113+01	..7423333+01	102.000	..356
105	..5321831+01	..7343333+01	103.000	..357
106	..5360127+01	..7455478+01	104.000	..358
107	..5326457+01	..7153333+01	105.000	..359
108	..5349411+01	..7322345+01	106.000	..360
109	..5377132+01	..7195509+01	107.000	..361
110	..5351211+01	..7152545+01	108.000	..362
111	..5351955+01	..7255591+01	109.000	..363
112	..5328900+01	..6952288+01	110.000	..364
113	..5350417+01	..7173333+01	111.000	..365
114	..5329815+01	..6934425+01	112.000	..366
115	..5342417+01	..7139333+01	113.000	..367
116	..5347411+01	..7023132+01	114.000	..368
117	..5342635+01	..6934333+01	115.000	..369
118	..5346573+01	..6914233+01	116.000	..370
119	..5329411+01	..6929159+01	117.000	..371
120	..5327456+01	..6757385+01	118.000	..372
121	..5355911+01	..6913752+01	119.000	..373
122	..5353739+01	..6735458+01	120.000	..374
123	..5422681+01	..5342072+01	121.000	..375
124	..5350144+01	..6757375+01	122.000	..376
125	..5348955+01	..6538833+01	123.000	..377
126	..5348955+01	..6775752+01	124.000	..378

131	-337611E+01	-1599193E+01	-5925191E+01	17.000	319
132	-347667E+01	-1579755E+01	-656434E+01	131.000	321
133	-353069E+01	-1561675E+01	-651325E+01	132.000	315
134	-3603781E+01	-15715418E+01	-6528592E+01	173.000	319
135	-3631612E+01	-1472672E+01	-651353E+01	136.000	314
136	-3641498E+01	-1328377E+01	-6519372E+01	137.000	315
137	-3641572E+01	-126719E+01	-6553277E+01	177.000	316
138	-369311E+01	-1227304E+01	-6559573E+01	137.000	312
139	-3693175E+01	-1112938E+01	-6537640E+01	138.000	315
140	-376611E+01	-1106553E+01	-6454599E+01	139.000	311
141	-3814841E+01	-1132753E+01	-6437531E+01	141.000	313
142	-3815717E+01	-9425795E+00	-6453721E+01	141.000	312
143	-3841817E+01	-805913E+00	-6473965E+01	142.000	312
144	-3841817E+01	-621149E+00	-6434813E+01	143.000	313
145	-3861739E+01	-1931793E+00	-6395398E+01	144.000	308
146	-3864192E+01	-7223397E+00	-6434473E+01	145.000	313
147	-3864729E+01	-111112E+00	-6394373E+01	146.000	306
148	-3864821E+01	-535922E+00	-647778E+01	147.000	312
149	-3875156E+01	-2617215E+00	-6449395E+01	152.000	310
150	-3875156E+01	-159510E+00	-6439455E+01	153.000	311
151	-3875156E+01	-7818361E+00	-6451133E+01	154.000	308
152	-3875156E+01	-3038539E+00	-6451581E+01	155.000	309
153	-3875156E+01	-3038539E+00	-6451581E+01	156.000	309
154	-3875156E+01	-3038539E+00	-6451581E+01	157.000	309
155	-3875156E+01	-3038539E+00	-6451581E+01	158.000	310
156	-3875156E+01	-3038539E+00	-6451581E+01	159.000	310
157	-3875156E+01	-3038539E+00	-6451581E+01	160.000	310
158	-3875156E+01	-3038539E+00	-6451581E+01	161.000	310
159	-3875156E+01	-3038539E+00	-6451581E+01	162.000	310
160	-3875156E+01	-3038539E+00	-6451581E+01	163.000	310
161	-3875156E+01	-3038539E+00	-6451581E+01	164.000	310
162	-3875156E+01	-3038539E+00	-6451581E+01	165.000	310
163	-3875156E+01	-3038539E+00	-6451581E+01	166.000	310
164	-3875156E+01	-3038539E+00	-6451581E+01	167.000	310
165	-3875156E+01	-3038539E+00	-6451581E+01	168.000	310
166	-3875156E+01	-3038539E+00	-6451581E+01	169.000	310
167	-3875156E+01	-3038539E+00	-6451581E+01	170.000	310
168	-3875156E+01	-3038539E+00	-6451581E+01	171.000	310
169	-3875156E+01	-3038539E+00	-6451581E+01	172.000	310
170	-3875156E+01	-3038539E+00	-6451581E+01	173.000	310
171	-3875156E+01	-3038539E+00	-6451581E+01	174.000	310
172	-3875156E+01	-3038539E+00	-6451581E+01	175.000	310
173	-3875156E+01	-3038539E+00	-6451581E+01	176.000	310
174	-3875156E+01	-3038539E+00	-6451581E+01	177.000	310
175	-3875156E+01	-3038539E+00	-6451581E+01	178.000	310
176	-3875156E+01	-3038539E+00	-6451581E+01	179.000	310
177	-3875156E+01	-3038539E+00	-6451581E+01	180.000	310
178	-3875156E+01	-3038539E+00	-6451581E+01	181.000	310
179	-3875156E+01	-3038539E+00	-6451581E+01	182.000	310
180	-3875156E+01	-3038539E+00	-6451581E+01	183.000	310
181	-3875156E+01	-3038539E+00	-6451581E+01	184.000	310
182	-3875156E+01	-3038539E+00	-6451581E+01	185.000	310
183	-3875156E+01	-3038539E+00	-6451581E+01	186.000	310
184	-3875156E+01	-3038539E+00	-6451581E+01	187.000	310
185	-3875156E+01	-3038539E+00	-6451581E+01	188.000	310
186	-3875156E+01	-3038539E+00	-6451581E+01	189.000	310
187	-3875156E+01	-3038539E+00	-6451581E+01	190.000	310
188	-3875156E+01	-3038539E+00	-6451581E+01	191.000	310
189	-3875156E+01	-3038539E+00	-6451581E+01	192.000	310
190	-3875156E+01	-3038539E+00	-6451581E+01	193.000	310
191	-3875156E+01	-3038539E+00	-6451581E+01	194.000	310
192	-3875156E+01	-3038539E+00	-6451581E+01	195.000	310

199	..332980E+01	..208140E+01	..535122E+01	198.00	..335
200	..552417E+01	..213249E+01	..717134E+01	199.00	..340
201	..520954E+01	..303191E+01	..633239E+01	200.00	..336
202	..556956E+01	..314745E+01	..725631E+01	201.00	..357
203	..533123E+01	..329139E+01	..715215E+01	202.00	..344
204	..537707E+01	..331617E+01	..718350E+01	203.00	..346
205	..549451E+01	..336125E+01	..732230E+01	204.00	..352
206	..524045E+01	..349570E+01	..715333E+01	205.00	..345
207	..551027E+01	..353703E+01	..744359E+01	206.00	..350
208	..531827E+01	..368495E+01	..731430E+01	207.00	..352
209	..538511E+01	..379746E+01	..742139E+01	208.00	..358
210	..555747E+01	..379137E+01	..737531E+01	209.00	..365
211	..509129E+01	..361567E+01	..717921E+01	210.00	..346
212	..587065E+01	..425414E+01	..839135E+01	211.00	..389
213	..591141E+01	..357918E+01	..631152E+01	212.00	..333
214	..599015E+01	..495113E+01	..653131E+01	213.00	..412
215	..578811E+01	..341604E+01	..672214E+01	214.00	..324
216	..763515E+01	..517181E+01	..871493E+01	215.00	..420
217	..581832E+01	..331754E+01	..534523E+01	216.00	..334
218	..599932E+01	..491325E+01	..833365E+01	217.00	..411
219	..511738E+01	..461456E+01	..737559E+01	218.00	..365
220	..559355E+01	..465448E+01	..852347E+01	219.00	..388
221	..545186E+01	..501789E+01	..817749E+01	220.00	..393
222	..514612E+01	..461737E+01	..735533E+01	221.00	..370
223	..573781E+01	..503187E+01	..845737E+01	222.00	..407
224	..513651E+01	..531473E+01	..517523E+01	223.00	..391
225	..553277E+01	..511152E+01	..829629E+01	224.00	..399
226	..546324E+01	..553203E+01	..851332E+01	225.00	..409
227	..519695E+01	..542591E+01	..823595E+01	226.00	..397
228	..565121E+01	..545191E+01	..851419E+01	227.00	..415
229	..532751E+01	..595911E+01	..833199E+01	228.00	..418
230	..511402E+01	..557923E+01	..843175E+01	229.00	..479
231	..552904E+01	..617162E+01	..839523E+01	230.00	..433
232	..527264E+01	..601175E+01	..837333E+01	231.00	..418
233	..645593E+01	..611155E+01	..831435E+01	232.00	..424
234	..558121E+01	..664281E+01	..935137E+01	233.00	..451
235	..522817E+01	..607243E+01	..869755E+01	234.00	..419
236	..521204E+01	..692395E+01	..958457E+01	235.00	..461
237	..531983E+01	..659851E+01	..911593E+01	236.00	..436
238	..533444E+01	..675723E+01	..925072E+01	237.00	..446
239	..571133E+01	..716481E+01	..931573E+01	238.00	..473
240	..516504E+01	..691468E+01	..925447E+01	239.00	..446
241	..580763E+01	..744292E+01	..100160E+01	240.00	..482
242	..528764E+01	..742431E+01	..772984E+01	241.00	..468
243	..541282E+01	..745990E+01	..993720E+01	242.00	..474

END FORF JUT ALL-----

Appendix F
Calculations and Tables
Showing Cost Comparisons

Calculations For
5 HP Motors

5 HP

#1 Energy Efficient (uncont) VS Standard (uncont)

HP 8760 HR/YR X ____ Watts/HR X \$.06/KWH X KW/1000 =
Savings/YR

5 8760 HR/YR X 64 W/HR X \$.06/KWH X KW/1000 W =
\$33.63/YR

4.5 8760 HR/YR X 97 W/HR X \$.06/KWH X KW/1000 W =
\$50.98/YR

4.0 8760 HR/YR X 129 W/HR X \$.06/KWH X KW/1000 W =
\$67.80/YR

3.75 8760 HR/YR X 64 W/HR X \$.06/KWH X KW/1000 W =
\$33.63/YR

3.0 8760 HR/YR X 120 W/HR X \$.06/KWH X KW/1000 W =
\$63.07/YR

2.5 8760 HR/Yr X 118 W/HR X \$.06/KWH X KW/1000 W =
\$62.02/YR

2.0 8760 HR/YR X 116 W/HR X \$.06/KWH X KW/1000 W =
\$60.97/YR

1.25 8760 HR/YR X 113 W/HR X \$.06/KWH X KW/1000 W =
\$59.39/YR

0.75 8760 HR/YR X 113 W/HR X \$.06/KWH X KW/1000 W =
\$59.39/YR

5 HP

#2. Energy Efficient (uncont) VS Standard (cont)

HP	8760 HR/YR X ____ Watt/HR X \$.06/KWH X KW/1000W =
	\$__ /YR
5	8760 HR/YR X <u>64</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>33.63</u> /YR
4.5	8760 HR/YR X <u>151</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>79.36</u> /YR
4.0	8760 HR/YR X <u>108</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>56.76</u> /YR
3.75	8760 HR/YR X <u>54</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>28.38</u> /YR
3.0	8760 HR/YR X <u>77</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>40.47</u> /YR
2.5	8760 HR/YR X <u>20</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>10.51</u> /YR
2.0	8760 HR/YR X <u>-41</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>-21.54</u> /YR
1.25	8760 HR/YR X <u>-79</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>-41.52</u> /YR
0.75	8760 HR/YR X <u>-130</u> Watt/HR X \$.06/KWH X KW/1000W =
	\$ <u>-68.33</u> /YR

5 HP

#3. Energy Efficient (cont) VS Standard (cont)

HP 8760 HR/YR X ____ Watt/HR X \$.06/KW X KW/1000 W =
\$/YR

5 8760 HR/YR X 67 Watt/HR X \$.06/KW X KW/1000 W =
\$35.22/YR

4.5 8760 HR/YR X 110 Watt/HR X \$.06/KW X KW/1000 W =
\$57.82/YR

4.0 8760 HR/YR X 63 Watt/HR X \$.06/KW X KW/1000 W =
\$33.11/YR

3.75 8760 HR/YR X 47 Watt/HR X \$.06/KW X KW/1000 W =
\$24.70/YR

3.0 8760 HR/YR X 46 Watt/HR X \$.06/KW X KW/1000 W =
\$24.18/YR

2.5 8760 HR/YR X 80 Watt/HR X \$.06/KW X KW/1000 W =
\$42.05/YR

2.0 8760 HR/YR X 3 Watt/HR X \$.06/KW X KW/1000 W =
\$ 1.58/YR

1.25 8760 HR/YR X 18 Watt/HR X \$.06/KW X KW/1000 W =
\$ 9.46/YR

0.75 8760 HR/YR X 20 Watt/HR X \$.06/KW X KW/1000 W =
\$10.51/YR

5 HP

#4 Energy Efficient (cont) vs Standard (uncont)

8760 Hr/Yr x ____ Watt/HR x \$.06/KWH x KW/1000W=\$/YR

HP

5	67 W/HR	= \$35.22/YR
4.5	56 W/HR	= \$29.43/YR
4.0	84 W/HR	= \$44.15/YR
3.75	57 W/HR	= \$29.96/YR
3.0	90 W/HR	= \$47.30/YR
2.5	178 W/HR	= \$93.55/YR
2.0	161 W/HR	= \$84.62/YR
1.25	209 W/HR	= \$109.85/YR
0.75	263 W/HR	= \$138.23/YR

5 HP

#5 Standard (cont) VS Standard (uncont)

HP 8760 HR/YR X _____ Watts/HR X \$.06/KWH X KW/1000 W =
\$/YR

5 8760 HR/YR X 0 W/HR X \$.06/KWH X KW/1000 W =
\$000.00/YR

4.5 8760 HR/YR X -54 W/HR X \$.06/KWH X KW/1000 W =
\$-28.38/YR

4.0 8760 HR/YR X 21 W/HR X \$.06/KWH X KW/1000 W =
\$ 11.04/YR

3.75 8760 HR/YR X 10 W/HR X \$.06/KWH X KW/1000 W =
\$ 5.26/YR

3.0 8760 HR/YR X 43 W/HR X \$.06/KWH X KW/1000 W =
\$ 22.60/YR

2.5 8760 HR/YR X 98 W/HR X \$.06/KWH X KW/1000 W =
\$ 51.50/YR

2.0 8760 HR/YR X 158 W/HR X \$.06/KWH X KW/1000 W =
\$ 83.05/YR

1.25 8760 HR/YR X 192 W/HR X \$.06/KWH X KW/1000 W =
\$100.92/YR

0.75 8760 HR/YR X 243 W/HR X \$.06/KWH X KW/1000 W =
\$127.72/YR

5 HP

#6 Energy Efficient (cont) VS Energy Efficient (uncont)

HP	8760 HR/YR X ____ Watt/HR X \$.06/KWH X KWH/1000W =
	\$____/YR
5	8760 HR/YR X <u>3</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>1.58</u> /YR
4.5	8760 HR/YR X <u>-41</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>-21.55</u> /YR
4.0	8760 HR/YR X <u>-45</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>-23.65</u> /YR
3.75	8760 HR/YR X <u>-7</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>-3.68</u> /YR
3.0	8760 HR/YR X <u>-30</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>-15.77</u> /YR
2.5	8760 HR/YR X <u>60</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>31.54</u> /YR
2.0	8760 HR/YR X <u>45</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>23.65</u> /YR
1.25	8760 HR/YR X <u>97</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>50.98</u> /YR
0.75	8760 HR/YR X <u>150</u> Watt/HR X \$.06/KWH X KWH/1000W =
	\$ <u>78.84</u> /YR

Tables Showing
Cost Comparisons for
5 Horse Power Motor

5 Horse Power Motor and Controller Comparisons

A=New Installation, B=Retrofit

Simple Payback in Years

Load Horse Power	Situation									
	1A	1B	2A	3A	4A	4B	5A	5B	6A	6B
5.0	1.22	13.22	0	1.16	16.78	28.22	-----no savings-----			
4.5	0.88	8.71	0	0.71	20.08	33.78	-19.37	-19.37	-25.2	-25.5
4.0	0.60	6.55	0	1.24	13.39	22.51	49.81	49.81	-23.3	-23.3
3.75	1.22	13.20	0	1.66	19.73	33.18	104.56	104.56	-149.5	-149.5
3.0	0.65	7.04	0	1.70	12.49	21.0	24.33	24.33	-34.9	-34.9
2.5	0.66	7.16	0	0.98	6.32	10.23	10.68	10.68	17.4	17.4
2.0	0.67	7.28	+23.63	25.95	6.98	11.75	6.62	6.62	23.3	23.3
1.25	0.69	7.48	+12.26	4.33	5.38	9.05	5.45	5.45	10.8	10.8
0.75	0.69	7.48	+7.48	3.90	4.28	7.20	4.30	4.30	7.0	7.0

Table N

5 HP Savings/Year Based on \$0.06 KWH

HP Load (Situation)	Comparison					
	#1	#2	#3	#4	#5	#6
5	\$33.63	\$ 33.63	\$35.22	\$ 35.22	\$ 0	\$ 1.58
4.5	\$50.98	\$ 79.36	\$57.82	\$ 29.43	\$-28.38	\$-21.55
4.0	\$67.80	\$ 56.76	\$33.11	\$ 44.15	\$ 11.04	\$-23.65
3.75	\$33.63	\$ 28.38	\$24.70	\$ 29.96	\$ 5.26	\$ -3.68
3.0	\$63.07	\$ 40.47	\$24.18	\$ 47.30	\$ 22.60	\$-15.77
2.5	\$62.02	\$ 10.51	\$42.05	\$ 93.55	\$ 51.50	\$ 31.54
2.0	\$60.97	\$-21.54	\$ 1.58	\$ 84.62	\$ 83.05	\$ 23.65
1.25	\$59.39	\$-41.52	\$ 9.46	\$109.85	\$100.92	\$ 50.98
0.75	\$59.39	\$-68.33	\$10.51	\$138.23	\$127.72	\$ 78.84

Table 0

5 HP

Δ Wattage for (Situation)

1. Energy Efficient (uncont) VS Standard (uncont)
2. Energy Efficient (uncont) VS Standard (Cont)
3. Energy Efficient (cont) VS Standard (cont)
4. Energy Efficient (Cont) VS Standard (uncont)
5. Standard (cont) VS Standard (uncont)
6. Energy Efficient (cont) VS Energy Efficient (uncont)

Savings in Watts

HP Load	#1	#2	#3	#4	#5	#6
5	64	64	67	67	0	3
4.5	97	151	110	56	-54	-41
4.0	129	108	63	84	21	-45
3.75	64	54	47	57	10	-7
3.0	120	77	46	90	43	-30
2.5	118	20	80	178	98	60
2.0	116	-41	3	161	158	45
1.25	113	-79	18	209	192	97
0.75	113	-130	20	263	243	150

Table P

#1

5 HP

Simple Payback

Cost/Savings per Year

Standard \$329.00, Energy Efficient 370.00

A= Cost = \$41.00, B= Cost = \$370.00 + 20% = \$444.00

Installation Cost

HP Load	A	B
5	1.22 yrs	13.20 yr
4.5	0.80 yrs	8.71 yr
4.0	0.60 yrs	6.55 yr
3.75	1.22 yrs	13.20 yr
3.0	0.65 yrs	7.04 yr
2.5	0.66 yrs	7.16 yr
2.0	0.67 yrs	7.28 yr
1.25	0.69 yrs	7.48 yr
0.75	0.69 yrs	7.48 yr

B= Retrofit - Replacing Standard Motor with Energy Efficient

+ 20% Motor Cost Installation

A= New Installation, Cost of Energy Efficient vs Standard
Motor based on continuous operation

Table Q

Situation #2

5 HP

Simple Payback

Cost/Savings Year

Energy Efficient Motor \$370.00 + 20% Installation = \$444.00

Power Factor Controller \$550.00 Including Installation =
\$550.00

Standard Motor Cost \$329.00

A - New installation consider cost only motor/controller

B - Retrofit standard motor with controller vs Energy
Efficient motor

HP Load	A	(B not a valid Comparison)
5	0 yr	3.15 yr
4.5	0 yr	1.33 yr
4.0	0 yr	1.86 yr
3.75	0 yr	3.74 yr
3.0	0 yr	2.62 yr
2.5	0 yr	10.08 yr
2.0	-23.63 yr	-4.92 yr
1.25	-12.26 yr	-2.55 yr
0.75	-7.44 yr	-1.55 yr

A. Cost = Energy Efficient Motor - \$370.00 + (standard
motor \$329.00 + Controller \$550.00) Cost = \$509.00

B. - Energy Efficient Motor + Installation = \$444 +
Controller Cost \$550 = \$106 less to install Energy
Efficient Motor than a controll

Table R

Situation

#3

5 HP

Simple Payback

Cost/Saving year

Energy Efficient (cont) vs Standard (cont)

Energy Efficient Motor \$370.00

Controller \$550.00

Standard Motor \$329.00

A - New Installation - Consider Motor/Controller Cost only.

$$\text{Cost} = (\$370 + \$550) - (\$329 + \$550) = \$41.00$$

Cost = Cost of Energy Efficient Motor + Controller Minus
the Cost of Standard Motor + Controller

HP Load	A
5	1.16 yr
4.5	0.71 yr
4.0	1.24 yr
3.75	1.66 yr
3.0	1.70 yr
2.5	0.98 yr
2.0	25.95 yr
1.25	4.33 yr
0.75	3.90 yr

Table S

Situation

#4

5 HP

Simple Payback

Cost/Savings Year

Energy Efficient (cont) vs Standard (uncont)

A - New Installation - Cost = (Energy Efficient Motor +
Controller) - (Standard Motor)

$$\text{Cost} = (\$370.00 + \$550.00) - (\$329.00) = \$591.00$$

B - Retrofit - Cost = Energy Efficient Motor +
Installation + Controller

$$\text{Cost} = (\$444.00 + \$550.00) = \$994.00$$

HP Load	A	B
5	16.78 yr	28.22 yr
4.5	20.08 yr	33.78 yr
4.0	13.39 yr	22.51 yr
3.75	19.73 yr	33.18 yr
3.0	12.49 yr	21.00 yr
2.5	6.32 yr	10.63 yr
2.0	6.98 yr	11.75 yr
1.25	5.38 yr	9.05 yr
0.75	4.28 yr	7.20 yr

Table T

Situation

#5

5 HP

Simple Payback

Cost/Savings Year

Standard (cont) vs Standard (uncont)

A - New Installation - Cost = Cost of Controller

Cost = \$550.00

B - Retrofit - Same as New Installation

HP Load	A	B
5	No Savings	No Savings
4.5	-19.37 yr	-19.37 yr
4.0	49.81 yr	49.81 yr
3.75	104.56 yr	104.56 yr
3.0	24.33 yr	24.33 yr
2.5	10.68 yr	10.68 yr
2.0	6.62 yr	6.62 yr
1.25	5.45 yr	5.45 yr
0.75	4.30 yr	4.30 yr

Table U

Situation

#6

5 HP

Simple Payback

Cost/Saving Year

Energy Efficient (cont) vs Energy Efficient (uncont)

A - New Installation - Cost = Cost of Controller

Cost = \$550.00

B - Retrofit - Same as New Installation

HP Load	A	B
5	348.10 yr	348.10 yr
4.5	-25.52 yr	-25.52 yr
4.0	-23.25 yr	-23.25 yr
3.75	-149.45 yr	-149.45 yr
3.0	-34.87 yr	-34.87 yr
2.5	17.44 yr	17.44 yr
2.0	23.26 yr	23.26 yr
1.25	10.79 yr	10.79 yr
0.75	6.98 yr	6.98 yr

Table V

Tables Showing
Cost Comparisons for
10 Horse Power Motors

10 Horse Power Motor and Controller Comparisons

A= New Installation, B= Retrofit

Simple Payback in Years

Load Horse Power	Situation									
	1A	1B	2A	3A	4A	4B	5A	5B	6A	6B
10	1.15	5.75	NONE	3.27	20.66	33.72	NONE	NONE	-9.45	-9.45
7.5	2.14	10.60	NONE	1.10	11.50	18.77	-14.85	-14.84	67.40	67.40
5.0	3.20	15.98	NONE	2.19	11.24	18.31	50.56	50.56	21.28	21.28
2.5	4.83	24.10	-10.94	14.49	9.42	15.37	8.84	8.84	11.47	11.47

Table W

10 HP

Saving/Year

Based on \$0.06 KWH

Comparison
(Situation)

HP Load	#1	#2	#3	#4	#5	#6
10	\$138.75	\$138.75	\$48.88	\$48.88	0	\$-89.88
7.5	\$74.63	\$132.45	\$145.06	\$87.77	\$-57.29	\$12.61
5.0	\$49.93	\$33.11	\$73.06	\$89.88	\$16.81	\$39.94
2.5	\$33.11	\$-63.07	\$11.04	\$107.22	\$96.18	\$74.11

Table X

10 HP

Δ Wattage for (Situation)

1. Energy Efficient (uncont) VS Standard (uncont)
2. Energy Efficient (uncont) VS Standard (cont)
3. Energy Efficient (cont) VS Standard (cont)
4. Energy Efficient (cont) VS Standard (uncont)
5. Standard (cont) VS Standard (uncont)
6. Energy Efficient (cont) VS Energy Efficient (uncont)

Savings in Watts

HP	#1	#2	#3	#4	#5	#6
10	264	264	93	93	0	-171
7.5	142	252	276	167	-109	24
5.0	95	63	139	171	32	76
2.5	63	-120	21	204	183	141

Table Y

Situation

#1

10 HP

Simple Payback

Cost/Savings Per Year

Standard \$505.00, Energy Efficient \$665.00

A = Cost = \$160.00, B - Cost = \$665.00 + 20% = \$798.00

Installation Cost

HP Load	A	B
10	1.15 yr	5.75 yr
7.5	2.14 yr	10.60 yr
5.0	3.20 yr	15.98 yr
2.5	4.83 yr	24.10 yr

A - New installation, cost of Energy Efficient vs Standard Motor based on continuous operation.

B - Retrofit - Replacing Standard Motor with Energy Efficient plus 20% of motor cost for installation.

Table Z

Situation

#2

10 HP

Simple Payback

Cost/Savings Year

Energy Efficient motor \$66.00+20% installation=\$798.00

Power Factor Controller \$850.00 including installation

Standard motor cost \$505.00

A- New installation - consider only motor/controller cost

B- Retrofit standard motor with controller vs energy
efficient motor

A- Cost = energy efficient motor

(-\$665.00+\$850.00+\$505.00)

= \$690.00

B- Cost = energy efficient motor + Installation - \$798.00

+ Controller \$850.00

HP LOAD	A
10	4.97 yr
7.5	5.02 yr
5.0	20.84 yr
2.5	-10.94 yr

Table AA

Situation

#3

10 HP

Simple Payback

Cost/Saving Year

Energy Efficient (cont) vs Standard (cont)

Energy Efficient motor \$665.00

Controller \$850.00

Standard \$505.00

A - New Installation

$$\begin{aligned}\text{Cost} &= (\$665.00 + \$850.00) - (\$505.00 + 850) \\ &= \$160.00\end{aligned}$$

HP Load	A
10	3.27 yr
7.5	1.10 yr
5.0	2.19 yr
2.5	14.49 yr

Table BB

Situation

#4

10 HP

Simple Payback

Cost/Saving Year

Energy Efficient (cont) vs Standard (uncont)

A - New Installation - Cost = (Energy Efficient Motor +
Controller) - (Standard Motor)

$$\text{Cost} = (\$665.00 + \$850.00) - (\$505) = \$1010.00$$

B - Retrofit - Cost - Energy Efficient Motor +
Installation + Controller)

$$\text{Cost} = (\$798.00 + \$850.00) = \$1648.00$$

HP Load	A	B
10	20.66 yr	33.72 yr
7.5	11.50 yr	18.77 yr
5.0	11.24 yr	18.34 yr
2.5	9.42 yr	15.37 yr

Table CC

Situation

#5

10 HP

Simple Payback

Cost/Savings Year

Standard (cont) vs Standard (uncont)

A - New Installation - Cost = Cost of Controller

Cost = \$850.00

B - Retrofit - Same as New Installation

HP Load	A	B
10	No Savings	No Savings
7.5	-14.84 yr	-14.84 yr
5.0	50.56 yr	50.56 yr
2.5	8.84 yr	8.84 yr

Table DD

Situation

#6

10 HP

Simple Payback

Cost/Saving Year

Energy Efficient (cont) vs Energy Efficient (uncont)

A - New Installation - Cost = Cost of Controller

Cost = \$850.00

B - Retrofit - Same as New Installation

HP Load	A	B
10	-9.45 yr	-9.45 yr
7.5	67.40 yr	67.40 yr
5.0	21.28 yr	21.28 yr
2.5	11.47 yr	11.47 yr

Table EE

Appendix G

Tables Showing Comparisons
of Actual Motor Data and
Simulated Data

5 Horse Power Energy Efficient
Comparison of the Manufacturer's Motor Performance
Data Versus the Computer Generated Data

HP	Amps		Watts		Speed (RPM)		Efficiency (Percent)		Power Factor (Percent)	
	*	**	*	**	*	**	*	**	*	*
5.0	12.3	12.2	4288	4278	1751	1748	87.0	88.0	87.4	87.8
4.5	11.3	10.9	3424	3368	1761	1760	87.1	88.0	82.9	84.9
3.75	9.9	9.5	3214	3197	1763	1763	87.0	88.0	81.5	84.1
3.0	8.3	8.0	2586	2547	1771	1771	86.5	88.0	78.0	79.6
2.0	6.4	6.4	1775	1743	1781	1781	84.0	85.0	69.1	68.8
0.75	4.9	4.9	797	784	1792	1793	70.1	70.0	40.9	40.2

* Manufacturer's Data

** Computer Data

Table FF

5 Horse Power Standard

Comparison of the Manufacturer's Motor Performance

Data Versus the Computer Generated Data

HP	Amps		Watts		Speed (RPM)		Efficiency (Percent)		Power Factor (Percent)	
	*	**	*	**	*	**	*	**	*	**
5.0	7.0	6.9	4423	4342	1746	1744	84.3	86.0	78.7	79.0
4.5	6.5	6.4	3983	3882	1753	1750	84.3	86.0	76.6	76.4
3.75	5.8	5.7	3353	3261	1763	1759	83.4	85.0	72.5	71.6
3.0	5.2	5.2	2712	2668	1770	1768	82.5	84.1	65.7	65.1
2.0	4.5	4.5	1870	1870	1780	1779	79.8	80.0	52.1	52.1
0.75	3.9	3.9	874	896	1793	1792	64.0	62.0	27.7	28.4

* Manufacturer's Data

** Computer Generated Data

Table GG

10 Horse Power Energy Efficient

Comparison of the Manufacturer's Motor Performance

Data Versus the Computer Generated Data

HP	AMPS		Watts		Speed (RPM)		Efficiency (Percent)		Power Factor (Percent)	
	*	**	*	**	*	**	*	**	*	**
10	24.2	23.7	8354	8211	1756	1753	89.3	90.0	86.7	86.8
7.5	19.5	18.4	6275	6155	1770	1766	89.2	91.0	80.7	83.9
5.0	14.7	13.6	4246	4150	1780	1778	87.8	90.0	72.7	76.2
2.5	10.6	9.9	2222	2198	1790	1789	83.9	85.0	52.8	55.6

* Manufacturer's Data

** Computer Generated Data

Table HH

10 Horse Power Standard

Comparison of the Manufacturer's Motor Performance

Data Versus the Computer Generated Data

HP	Amps		Watts		Speed (RPM)		Efficiency (Percent)		Power Factor (Percent)	
	*	**	*	**	*	**	*	**	*	**
10	12.6	12.4	8533	8475	1755	1753	87.4	89.0	85.2	85.7
7.5	9.9	9.7	6427	6298	1771	1766	87.0	89.0	81.3	81.1
5.0	7.7	7.5	4329	4244	1780	1778	86.2	88.0	70.4	71.0
2.5	5.8	5.8	2314	2261	1790	1789	80.6	82.0	50.4	48.8

* Manufacturer's Data

** Computer Data

Table II

VITA

Roy D. McMaster was born on 1 July 1947 in Lampassas, Texas. He graduated from Elgin High School in Elgin, Texas in 1965. He then enlisted in the Air Force and served as an electronic navigational equipment repairman until 1972. He then attended New Mexico State University under the AFIT education and commission program. He received his commission and Bachelor of Science in Electical Engineering.

After commissioning he served as Base Electrical Engineer until being directed to the School of Engineering, Air Force Institute of Technology to study for a Masters degree in Electrical Engineering.

Permanent Address 402 E. Brenham St.
Elgin, Texas 781

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release, distribution unlimited			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE						
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GE/EE/84S-10			5. MONITORING ORGANIZATION REPORT NUMBER(S)			
5a. NAME OF PERFORMING ORGANIZATION Air Force Institute of Tech		5b. OFFICE SYMBOL (If applicable)		7a. NAME OF MONITORING ORGANIZATION		
5c. ADDRESS (City, State and ZIP Code) Wright-Patterson AFB, OH 45433				7b. ADDRESS (City, State and ZIP Code)		
6a. NAME OF FUNDING/SPONSORING ORGANIZATION		6b. OFFICE SYMBOL (If applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
6c. ADDRESS (City, State and ZIP Code)				10. SOURCE OF FUNDING NOS.		
				PROGRAM ELEMENT NO.		
				PROJECT NO.		
				TASK NO.		
				WORK UNIT NO.		
11. TITLE (Include Security Classification) EFFECTIVENESS OF "NOLA" CONTROLLED MOTORS INCLUDING EFFECT OF HIGHER HARMONICS						
12. PERSONAL AUTHOR(S) McMaster, Roy Dean						
13a. TYPE OF REPORT Thesis		13b. TIME COVERED FROM TO		14. DATE OF REPORT (Yr., Mo., Day) 84 Jul 2		
15. PAGE COUNT 147		15. PAGE COUNT 147-17				
16. SUPPLEMENTARY NOTATION L. E. WOLAVER Dean for Research and Professional Development Air Force Institute of Technology (ATC) Wright-Patterson AFB OH 45433						
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)			
FIELD	GROUP	SUB. GR.	Electric Motors			
			Motor Controllers			
			Power Systems			
			Economic Analysis			
			Energy Conservation			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) An economic analysis of the "NOLA" Power Factor Motor Controller is accomplished and the effects of the harmonics produced by the controller are studied. The controller is placed in series with each leg of various sizes of wye-connected three-phase motors. The energy saved by the controller, the power factor correction, and the reflected harmonics under varying load conditions are studied to determine the economic advantages. Also the data from the controlled motor is compared to an energy efficient motor. An analog-digital computer program is developed which models an induction motor and the "NOLA" controller. The computer model is used to determine and analyze the reflected wave shape produced by the controller. The results of the study indicates that the energy efficient motor is the most cost effective alternative at the present time because of the high initial cost of the						
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐			21. ABSTRACT SECURITY CLASSIFICATION Unclassified			
22a. NAME OF RESPONSIBLE INDIVIDUAL Maj T.L. Skvarenina			22b. TELEPHONE NUMBER (Include Area Code) (513) 255-6913		22c. OFFICE SYMBOL AFIT/ENG	

END

FILMED

10-84

DTIC