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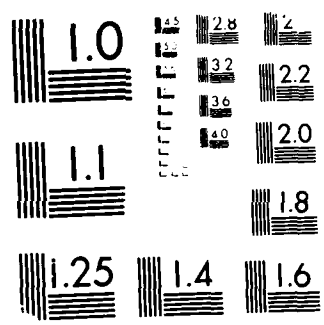

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VALUE ENGINEERING STUDY
OF
STANDARD FAMILY OF MILITARY HORIZONTAL AND VERTICAL AIR CONDITIONERS

Prepared for:

U. S. Army Belvoir Research, Development
and Engineering Center
Fort Belvoir, Virginia 22060-5606

29 January 1988

Final Report for Period 16 September 1986 - 29 January 1988

This document has been approved for public release and sale; it's distribution is unlimited.

Authors:

Yvonne Chang
M. N. Zabych

Prepared by:

VSE Corporation
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Alexandria, Virginia 22303-1499

The citation of trade names and names of manufacturers in this report is not to be construed as official endorsement of approval of commercial products or services referenced herein.

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A market survey was performed to select soft start controllers for use with the standard family of military horizontal and vertical air conditioners. Additionally, control logic circuitry was designed and a life cycle cost model was developed to show the economic impact of adding procurement costs for the controllers and control logic circuitry to obtain substantial savings in energy costs.

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SUMMARY

This report represents the engineering evaluation, prototype manufacturing, documentation and testing services associated with performance of in-depth Value Engineering (VE) studies of the standard family of military horizontal and vertical air conditioners by VSE Corporation (VSE) under Task Order 0039, Contract No. DAAK70-8[illegible]-D-0023. The Task required VSE to focus its major effort on the present technology of soft start controllers especially as applicable to environmental control equipment, and to facilitate their installation within the present military air conditioner envelopes. In this context, a market survey of the soft start controllers was performed to ascertain the availability of commercially manufactured controllers that would meet the design, size, and cost constraints furnished by the Belvoir Technical Advisor.

A significant accomplishment of this Task Order was the development and design of control logic circuitry and the visualization of air conditioner operation utilizing soft start controllers. Factors evaluated in the selection process included cost, size, efficiency, reliability and flexibility for modifications. Discrete logic, microprocessor/microcontroller, and microsequencer/microcoding technologies were evaluated in the process of selecting the most advantageous control logic circuitry. Taking all factors into consideration, the design group selected the microsequencer/microcoding design because it was low cost and compact in size, and provided the most efficient and reliable operation. In addition to selection and design of the control logic circuitry, flow diagrams were developed to depict air conditioner operation for heat, vent, and cool modes.

Although the normal requirements of a VE study are the production of cost reduction studies in the form of Engineering Change Proposals (ECPs) and Value Engineering Proposals (VEPs), the present level of completion of the controller selection process and the lack of definitive cost data for the controller and control logic circuitry precludes the completion of ECPs/VEPs as required under the Task Order. In lieu thereof, a Value Engineering/Life Cycle Cost model will be provided as a part of this report, from which appropriate proposals can be readily produced under follow-on Task Order 0074.

By definition, Value Engineering is a systematic effort directed at analyzing the functional requirements of Department of Defense (DOD) systems, equipment, facilities, procedures, and supplies for the purpose of achieving the essential functions at the lowest total cost, consistent with the needed performance, safety, reliability, quality, and maintainability. As noted above, lowest total cost, i.e., lowest Life Cycle Cost (LCC), is an integral part of the Value Engineering methodology. While VE seeks to develop additional worthy alternatives from which an economic decision can be made, LCC is used to compare and evaluate all costs incident to research, development, production, operation, maintenance, and disposal of a system. Thus made, the comparison and evaluation are used to select the best available alternative design.

PREFACE

This scientific and technical report was prepared under Contract No. DAAK70-86-D-0023, Task Order No. 0039, for the Belvoir Research, Development and Engineering Center (BRDEC), Fort Belvoir, Virginia. Mr. Mark Matonek served as the Contracting Officer's Representative, and Mr. Thomas Sgroi as the Contracting Officer's Technical Representative.

The scientific and technical report is the final report of the market survey and life cycle cost comparison to be performed under Task Order 0039. The major focus of the Task Order, as amended, is as follows:

"Perform in-depth Value Engineering studies on the 18,000 BTUH Horizontal and Vertical Military Standard Air Conditioners. This Task Order shall focus on new technology (soft start controllers, including inverters) and maintainability/producibility."

VALUE ENGINEERING STUDY

OF

STANDARD FAMILY OF MILITARY HORIZONTAL

AND VERTICAL AIR CONDITIONERS

I. INTRODUCTION

A. SCOPE

This report contains a summary of highlighted and major accomplishments concerning a market survey of commercially available motor controllers for potential installation in horizontal and vertical air conditioners. In addition, a Life Cycle Cost model was developed to show the economic impact of adding procurement costs for the controllers and logic circuitry to obtain substantial downstream savings in energy costs.

B. BACKGROUND

On 11 September 1986, the U. S. Army Belvoir Research, Development and Engineering Center tasked VSE Corporation to perform in-depth Value Engineering studies on the 9,000, 18,000, and 36,000 BTUH Horizontal and Vertical Military Standard Air Conditioners. At a meeting on 15 October 1986, between Mr. Thomas Sgroi and key VSE Corporation project personnel, the Task Order was modified to emphasize the focus on conducting a market survey to establish sources of supply for soft start controllers. A new Table was prepared to indicate controller capability to accept and deliver power input/output for each size of air conditioner. Subsequent meetings between Belvoir and VSE Corporation were used to modify the initial Task Order direction by concentrating all activities toward obtaining soft start capability for the 18,000 BTUH Horizontal and Vertical Air Conditioners. Additionally, cost data developed by Science Applications INternational Corporation in the Belvoir report titled, "Life Cycle Cost Estimate (LCCE) for the Total Environmental Control System (TECS), A Value Engineering Proposal (VEP)" were used to prepare the VE/LCC Model contained in this report.

II. DISCUSSION

A. MARKET SURVEY FOR CONTROLLERS

As an effort to thoroughly evaluate the economical feasibility of integrating commercial motor controllers into the TECS, VSE conducted a market survey of commercially available motor controllers. The search was initiated by obtaining several reliable sources from which good candidates of motor controller manufacturers could be found. The sources included the following:

- A list, naming potential motor controller manufacturer candidates, provided by Fort Belvoir.
- Electronic Engineers Master (EEM) catalog.
- VSMF, Vendor Catalog Service Product/Locator Code.
- Recommendations from the motor controller manufacturers obtained from the above sources, which could not provide us with our specifications.

1. Highlights

Upon obtaining a substantial list of manufacturers, over 100 telephone calls were made and documented. The intent of the calls was to screen the list for manufacturers that either carried off-the-shelf items closely resembling TECS specifications or possessed the ability and desire to work with the government to modify existing units or cooperatively build prototypes. As a result of the telephone calls, 41 companies and points of contact at those companies were obtained. A mailing list depicting the 41 manufacturers is shown at Appendix A-1. Consequently, a letter was written requesting information including catalogs and specification sheets describing the manufacturer's physical form, performance capabilities, electrical characteristics, features, and, if possible, any general pricing information. A sample of this letter is shown at Appendix B-1. A copy of the letter was then sent to each of the 41 manufacturers obtained, requesting a response within two weeks.

Within a couple of weeks 15 positive responses were received. The remaining 26 manufacturers did not yet respond. Therefore, a second telephone call was made to these manufacturers. Of these, 12 indicated they would respond to the solicitation letter. As a result of these efforts, a preliminary matrix was made listing 24 possible candidates. The matrix included operating characteristics, environmental factors such as temperature, humidity, shock and vibration, reliability factors, efficiency values, indicated costs, foreign/domestic make, and physical dimensions. An effort was made to fill out the above categories on the matrix as well as possible with the given available information. A copy of the preliminary matrix is depicted in Appendix C-1.

On February 26, 1987, a meeting was held to exchange information on the market survey. The matrix depicting 24 manufacturers was presented to the group. The result of the meeting was to eliminate 14 manufacturers whose controllers were expensive, excessive in size and weight, or would not operate at the required input voltage and frequency. As a result, a revised matrix was created containing the remaining 10 candidates plus 1 additional candidate recommended by

Fort Belvoir. Later, an additional four companies were added to this matrix by recommendation. A sample of this matrix is depicted at Appendix C-2. Additional information was requested from these 14 manufacturers and 8 representatives either came to VSE or to Fort Belvoir to provide the information. After physically reviewing as many samples as possible and collating all the given information, a final specification letter was sent to the resulting 14 companies and their representatives. A copy of the final mailing list is shown at Appendix A-2. The specification letter included detailed electrical, physical, and mechanical characteristics needed for the motor controller. At the commencement of the market survey, the search was made for three different size motor controllers for the 9,000, 18,000, and 36,000 BTU/HR air conditioners. However, since the projected buy data was the greatest for the 18,000 BTU/HR vertical and horizontal air conditioners in the final specifications, the efforts were solely concentrated on the 7 1/2 HP motor controller for the 18,000 BTU/HR unit. When the effort is continued for the other two air conditioners, the task will be greatly facilitated.

In the final specification letter, a request was made for quotes on engineering development cost, if any, and for price per unit for 8 units, 50 units, 100 units, and 500 units. A response was requested within a week. A copy of this letter is shown at Appendix B-2. By the specified deadline date, April 16, 1987, responses were received either by phone, telefax, or by mail. Six companies gave positive responses and the remainder stated that they could not bid. The collection of response letters from the manufacturers in shown at Appendix B-3.

A final matrix, shown at Appendix C-3, was then made depicting the six positive responses from the manufacturers. The VSE and Belvoir group then met on April 21, 1987, to discuss the final matrix and make a final selection. The remaining six companies were carefully reviewed. The lowest bidders were Central Power Company in Temmecula, CA; Southern Industrial Controls, Inc. in Charlotte, NC; Contraves Goerz Corporation in Pittsburg, PA; and Keco Industries in Florence, KY. Although Central Power Company had the lowest bid, the evaluation group did not have an opportunity to examine the product or personally speak to a representative. In addition, very little information was obtained from Central Power on their product. Therefore, a decision was made to put Central Power on hold until further information could be obtained. The next less expensive bid was Southern Industries Controls, Inc. Because the evaluation group had met previously with Southcon and had the opportunity to carefully examine their motor controller, a unanimous decision was made to make Southern Industrial Controls the first choice.

The third less expensive bidder was Contraves Goerz; however, since the manufacturer of these motor controllers was Japanese, we agreed that they would not be a good choice. In addition, their motor controller was quite complex and possessed many additional features that were not needed in this application. Thus, Contraves Goerz was eliminated. Keco Industries was the next lowest bidder; however, their cost was still higher than anticipated. Since Keco had a good military background and a good reputation for working with the Government in the past on similar endeavors, they were put on hold with Central Power as candidates for the second choice.

Within a few weeks, we determined that Central Power Company could not produce the motor controllers as claimed; hence, they were eliminated as a second choice. In the interim, however, Keco submitted a revised quote lowering their cost comparable to that of Southern Industrial Control, Inc. Therefore, Southern Industrial Controls and Keco Industries were chosen to be the two motor controller manufacturers for the 7 1/2 HP controller for the 18,000 BTU/HR units. A letter of thanks and declination to the other manufacturers was written and immediately sent to the remaining candidates. A copy of this letter is depicted at Appendix B-4. In addition, as a final confirmation of the two choices, representatives of the group travelled to Charlotte, NC, to examine the plant facilities at Southern Industrial Controls and also their quality control. The result was a positive decision to include this company in the program. Keco Industries had already been examined by several members of the group.

2. Major Accomplishments

In the TECS program, one of the major goals sought in conducting a market survey of motor controllers was to attain a substantial amount of pertinent information that would enable us to select the two most suited candidates of motor controller manufacturers in the industry. To successfully perform this task, the detailed matrix at Appendix C-1 was created listing all the manufacturers that responded with data.

One of the most important categories listed in the matrix is the operating characteristics block. In this particular section, emphasis was placed on giving data such as input and output voltages, input and output frequency, power output (either in HP, KVA, or KW) input and output frequency, current rating and, when available, any added information on the technology and operation of the motor controller. Although at the beginning of the task, complete detailed specifications were not available for the motor controllers, some general electrical characteristics were provided by Fort Belvoir. For the 9,000, 18,000, and 36,000 BTU/HR units the following input and output characteristics were given, respectively:

	Input Requirements	Output Requirements
a.	115V, 1ph, 50/60 and 400 HZ	3.6KW, .95PF, 115V, 1ph, 60HZ
b.	208V, 3ph, 50/60 and 400 HZ	6.5KW, .90PF, 208V, 3ph, 60HZ
c.	208V, 3ph, 50/60 and 400 HZ	10.5KW, .83PF, 208V, 3ph, 60HZ

Using the above data as a general guideline, the given electrical characteristics of the products in question were listed under operating characteristics, for comparison; while searching through the data items such catalogs and pamphlets provided by motor controller manufacturers, the models and styles of units chosen to be listed, were those that most closely possessed the electrical characteristics mentioned above. Although it was known that there was a large possibility of existing unit modification or of prototyping, a strong effort was made to find products that needed the least amount of modification to minimize development costs.

For the 9,000 BTU/HR, it was very difficult to find any manufacturers who had existing units that met the requirements. Therefore, large modifications or prototyping would be needed to obtain controllers for the 9,000 BTU/HR requirement. The 18,000 and 36,000 BTU/HR requirements appeared to be fairly standard in the industry.

The input and output requirements provided by Belvoir were listed in terms of KWs for power output and power factor. However, when searching in catalogues, the data for the motor controllers was represented in HP and output current ratings. There was a need to convert the given data into HP and output current ratings for the power output requirements. The following equations depict how the conversions were made:

$$KVA = \frac{KW}{PF}$$

current rating for 3-phase:

$$A = \frac{KVA \times 1000}{1.732V}$$

current rating for single-phase:

$$A = \frac{KVA \times 1000}{V}$$

To calculate HP from KW:

$$HP = KW \times 1.3410$$

Therefore, using the given parameters, the following was determined for the 9,000, 18,000, and 36,000 BTU/HR units, respectively:

	Input Requirements	Output Requirements
a.	115V, 1-ph, 50/60 and 400HZ	=3HP, 32A, 115V, 1-ph, 60HZ
b.	208V, 3-ph, 50/60 and 400HZ	=9HP, 20A, 208V, 3-ph, 60HZ
c.	208V, 3-ph, 50/60 and 400HZ	=14HP, 35A, 208V, 3-ph, 60HZ

The first matrix was done with the above parameters in mind; however, the requirements were later altered because the original parameters were considered to be too conservative by the group. The new output values were changed to the following for the 9,000, 18,000, and 36,000 BTU units, respectively:

a. 1-phase, 3HP, 35A

b. 3-phase, 7 1/2 HP, 18A

c. 3-phase, 10HP, 30A

Other important categories listed under environmental factors shown in Appendix C-1 are temperature, humidity, and shock and vibration. Operating temperature was determined to be between -50°F to +160°F. Humidity parameters had not yet been determined at this point. In addition, no final values had been set for shock and vibration. However, a search was made for this data in the given catalogues and pamphlets, and incorporated into the matrix.

Reliability of the unit was an ambiguous parameter, because different manufacturers had different standards and methods for its calculation. Regardless of this fact, reliability was incorporated into the matrix for consideration. Some of the Japanese units such as Yaskawa and Mitsubishi had extremely high reliability factors such as Mean Time Between Failure (MTBF) of 200,000 to 400,000 hours. American companies had a tendency to be more conservative in their testing of reliability and some had smaller values such as 20,000 hours of MTBF, such as Lovejoy Electronics. Some of the domestic companies claimed in their own defense that MTBF to them meant failure of any aspect of the unit. That is, even LED burn-outs were considered failures, while the Japanese companies did not consider a failure unless it was directly related to the actual operation of the unit.

Due to these discrepancies, the values offered by the manufacturers had to be accepted with skepticism. Efficiency values for most companies were rated around 95%. For this reason very little competition was apparent in this category.

In the initial phase of the market survey, anticipated cost for development and for the actual units had not yet been established. Therefore, in the preparation of the initial matrix, cost was not a discriminating factor. All inverters possessing the appropriate electrical and physical characteristics were included in the matrix. While surveying the market, large discrepancies were found in indicated costs. Some motor controllers had costs as low as $1,200 and some as high as $11,000. As the survey progressed, we learned that the added features included in the motor controllers could sometimes be quite elaborate; while in other cases, the units were very simplistic hardware-wise and in operation. The more simplistic units such as the ones manufactured by Zycron, Inc. and Southern Industrial Controls, Inc., possessed very few extra features such as an overabundance of diagnostic LED's, adjustable output frequencies, auto restart operations, and adjustable accel/decel time, to name a few. These extra features in some cases were quite extravagant and therefore increased the cost immensely. Another cost determining factor was the type of technology used in the motor controllers. The two motor control technologies used today are Pulse Width Modulation (PWM) and Adjustable Voltage Input (AVI), also known as Variable Voltage Input (VVI). Both technologies have advantages and disadvantages; in addition, in the latter mentioned technology, the cost tends to be considerably greater.

The adjustable voltage input inverter consists of a phase-controlled rectifier for voltage control, an inverter for frequency control, and a fixed DC bus to provide constant commutating capability. The input displacement factor of the phase-controller bridge varies with the output controlled voltage. At low output voltage of the converter, the displacement factor is poor which means power factor at the input is low. An output filter is required to smooth the ripple in the output voltage of the controlled rectifier. The output ripple voltage of the controlled rectifier is worst at low DC bus voltage and a constant output current. Discontinuous current conduction is possible at low output voltage. This condition can be prevented by large inductance at the output of the controlled rectifier. The inverter bridge can deliver power or regenerate, and consists of six thyristors which alternatively connect each phase to positive and negative DC bus. Each thyristor is on for 180° and the switching sequence produces a three-phase output voltage. The waveform at the output is referred to as a six-step waveform. The waveshape remains constant at all frequencies. The output frequency is controlled by the inverter and the amplitude VDC is controlled by the phase-controlled bridge. These two variables must be in a proper ratio to keep the ratio of voltage to frequency constant. It is also possible to use a three-phase full-wave diode bridge and a chopper to supply the variable DC voltage to the input of the inverter. This circuit has a good power factor at the AC input. If an AC source is not available, the chopper is also capable of operating from a DC source.

In the Pulse Width Modulated (PWM) inverter, the voltage and frequency control are accomplished with one power circuit and proper control logic. The output voltage waveform is of constant amplitude whose polarity reverses periodically to provide the output fundamental frequency. The output voltage is varied through pulse width control. The filtering of the output voltage is partially accomplished by the motor inductance. The chopping frequency of the output voltage is usually referred to as the carrier. It is desirable to keep the ratio of carrier to motor frequency as high as possible so that any additional motor losses due to carrier harmonics will be minimized, but too high a carrier frequency increases the commutation and other losses in the inverter; hence, a carrier frequency has to be chosen so that motor losses are kept to a minimum and the losses within the inverter are not too high. The logic circuit of a PWM is much more complicated than an inverter which is accomplishing only frequency control. The complicated control logic circuit is a distinct disadvantage of the PWM inverter. The PWM inverter could be designed to obtain square-wave or sine-wave modulation.

Throughout the course of the market survey both technologies, PWM and VVI, were quite often offered by manufacturers. PWMs were predominant in availability. Many manufacturers were in the process of phasing out the VVIs and moving towards the PWM. One of the major reasons for this trend was cost. PWMs were much less costly than the VVIs. The cost factor was as much as three or four times more for VVIs over PWMs. In addition, PWMs are generally physically much smaller and less complex. The disadvantage, however, of PWMs is the need to have greater protection against electromagnetic induction caused by the inverter itself. It was concluded that PWMs are more appropriate for this application, especially because of their small physical size and lower cost.

The manufacturing origin of the motor controllers was not restricted in any way at the beginning phase of the survey. Japanese, European, and domestic controllers were welcomed equally in the matrix. There was almost an equal number of foreign vendors versus domestic vendors; however, as the survey progressed, it was determined by the group that a foreign manufacturer would present a great disadvantage to the project. Namely, a foreign manufacturer would be very difficult to work with in terms of modifying existing units or even prototyping; therefore, this aspect became a deciding factor.

Physical dimension was a topic which, later in the course of the survey, became very important. However, in the beginning phase, very little was known as to what the required physical dimensions would be. Therefore, the preliminary matrix depicted in Appendix C-1, displayed many different size controllers with many varying weights.

After the completion of the preliminary matrix, a group discussion was held to determine the next phase of the survey. We unanimously decided that progression of the survey would be based on the 18,000 BTU/HR requirement, that is, the 7 1/2 HP controller. The reason for this decision was based on the fact that the 18,000 BTU/HR projected buy data was the greatest. Consequently, the other two sizes would be handled at a
later time.

The major deciding factors in eliminating manufacturers from the preliminary matrix were cost, size and, partially, manufacturing origin. A new revised matrix containing the surviving manufacturers is depicted in Appendix C-2. These manufacturers were then sent a detailed specification requirement letter which enabled them to respond with more precise information, in terms of engineering cost, cost per unit, and ability to meet physical and environmental constraints. The responses received by letter are depicted in Appendix B-3. These responses enabled us to create a final matrix depicted in

Appendix C-3. This matrix was reviewed carefully and, as a result, Southern Industrial Controls, Charlotte, NC and Keco Industries, Florence, KY were selected for the 18,000 BTU/HR controller manufacturers.

B. DESIGN CRITERIA

INTRODUCTION

A major requirement for the 18,000 BTU/HR vertical and horizontal TECS unit was the design of control logic circuitry. Upon deciding the type of technology to be used in the system, several factors were considered:

1. Cost
2. Size
3. Efficiency
4. Reliability
5. Flexibility for modification, when needed

When designing an electronic circuit, there are many avenues and approaches that can be taken. Similarly in this application many different approaches were available. The three most feasible technologies were the following:

1. Discrete logic
2. Microprocessor/microcontroller
3. Microsequencer/microcoding

1. Discrete Logic

The discrete logic design entails the use of discrete gates such as AND's, OR's, NOR's, NAND's, and inverters; also, J-K Flipflops, D-latches, buffers, timers, and discrete components such as resistors, capacitors and transistors may be used. Generally, this is a concrete hardware design, involving no software. The disadvantages lie in the fact that the cost is high, the size is great, efficiency and reliability are poor, and flexibility for modification is negative. The discrete logic design requires the use of many components. In the initial phase of the project, the logic requirements were less complex than the present requirements. At that time, it was estimated that approximately 15 integrated circuits (ICs) and 20 discrete components would be needed for the logic part, not including the interface ICs. However, since the requirement increased and time delays were added and changed more ICs would be needed to accommodate the different time delays. An assembly (parts only) costing approximately $165 would be needed in the discrete logic design to fulfill the initial requirements.

Due to the number of components needed, the size of the board would be fairly large, possibly about 48 square inches. This, however, may or may not have been a deterring factor since no stipulation was placed on size. However, due to the large number of components, efficiency and reliability are lessened. Ability is decreased due to the number of components that might fail.

Since the discrete logic is strictly a hardware design, any change in the handling of the logic might require major reconfiguration and rebuilding, and any deletions may require major rewiring. In the final stage where PC boards are made, new PC boards must be made if changes are incurred as an added note.

2. Microprocessor/Microcontroller Design

The possibility of using a software design was closely investigated. A software design has the advantage of having an extremely simplistic hardware design. One integrated circuit is basically all that is needed for the logic section. The actual design is completely done by software, which increases the efficiency and reliability since the component count is drastically reduced. The size of the board is also greatly reduced and results in an extremely flexible design, in that changes in the handling of the logic, require no change to the board only the software is revised.

A survey of commercial microprocessors and microcontrollers available in the market today display the Intel 8748 as the best choice. It is an 8-bit microcomputer integrated circuit with 27 I/O lines, an 8-bit timer/counter, on chip RAM and an on-board oscillator/clock circuits. This IC is ideal for the application, since all the needed features are self-contained on one IC, without the need for added hardware.

For the most part, this approach was very well suited; however, cost was the impeding factor. Commercial grade Intel 8748 microcomputer ICs are only $5-$10 per item. Military acceptable versions of these ICs are as high as $185 per item. Commercial ICs would not perform within temperature operating range. Therefore, the cost was not justified although other features were immensely positive.

3. Microsequencer/Microcoding Design

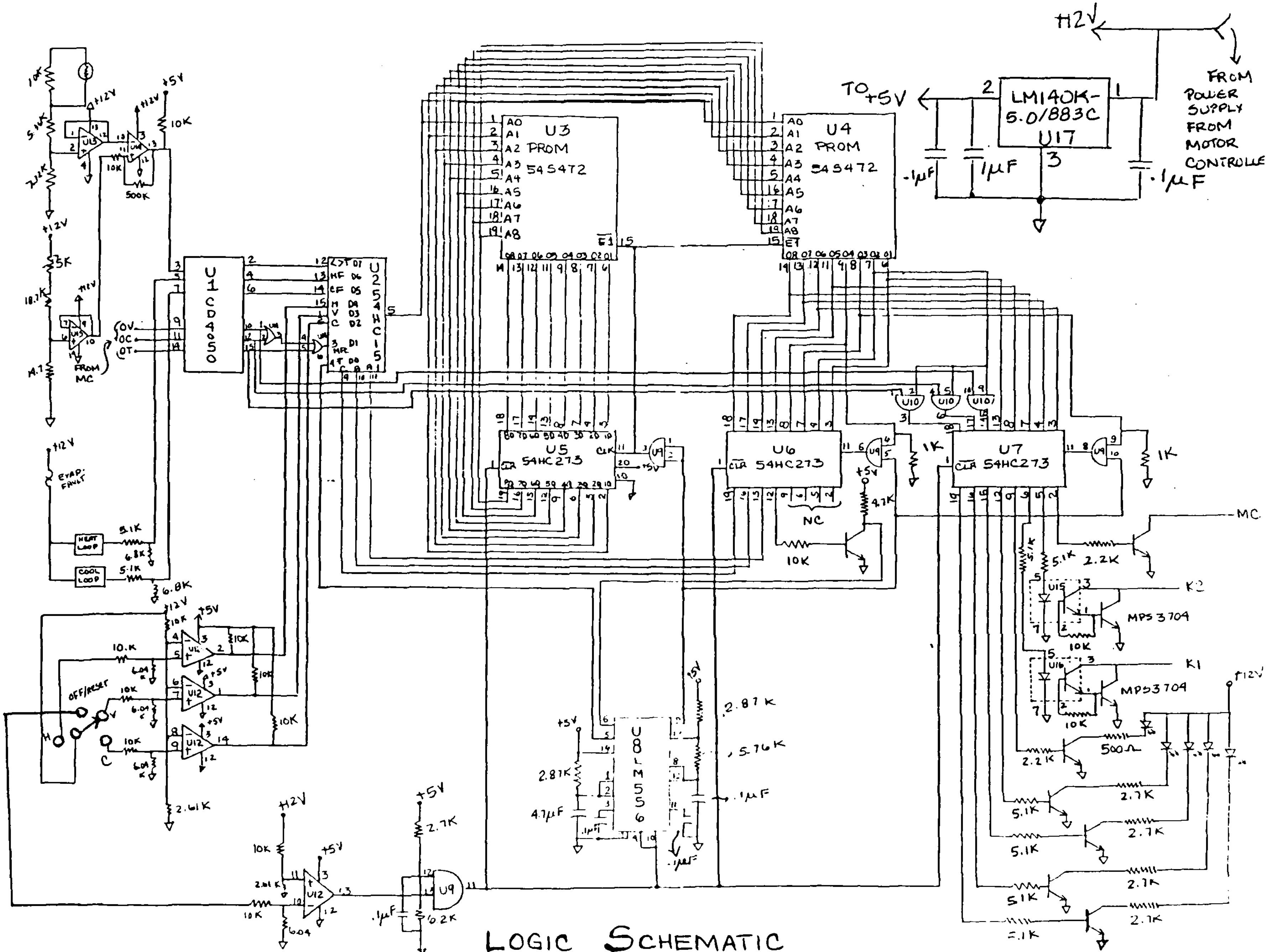
The final method investigated was the microsequencer/microcoding approach. This is a combination hardware and software design. The actual design is done in what is termed, firmware. It is a firmware design in that software bits perform the hardware control for the system. In actuality, the design is a compromise between the discrete logic and the microcomputer design. It simulates the same approach as in the microcomputer design, however it uses several inexpensive off-the-shelf ICs.

The components needed for a complete militarized logic design not including interface components is $58. This method has a great advantage due to its low cost. In addition, it is compact due to a low component count and also efficient and reliable. Taking all these factors into consideration, this design is very practical.

C. SYSTEM OPERATION

1. General

The final design selected for control of the system was the microsequencer design. A schematic showing the logic section and the analog interfaces to the system are depicted in Figure 1. As shown in the schematic the logic section is comprised of two PROMs, three latches, one timer, and one data selector. The software in the PROMs consists of machine coded binary bits that provide high bits and low bits for control. A logic 1 represents 5V and a logic 0 represents 0V. For simplicity and ease of modification, the software was written



Logic Schematic

FIGURE 1

on a meta assembler. A meta assembler enables one to create their own mnemonic code by defining the op code field and address field for each line of syntax to be used. Therefore by using this method, in essence a computer language can be created specifically for the application. By writing the code in a higher level meta language, modifications are very simple to perform. Conversely by using straight machine code, manipulation of 16 binary bits in each line of code is required in order to make a change in software. In addition, there are approximately 200 lines of code each containing 16 binary bits. Moreover the meta assembler allows for addition of comments explaining each line of code. Appendix D-1 contains a copy of the software, the actual source code and compiled version and a copy of the field definitions.

Once the program was written and compiled, the compilation displayed 4 hex code bits representing the control bits that should be placed into the PROMs. Since each hex code bit is representative of 4 binary bits, the hex code displayed, represented the 16 control bits for the 2 PROMs. The compilation displays the hex code and its corresponding location in memory. The hex codes are entered into a PROM programmer and consequently the program is burned into the PROMs.

The program possesses four major functions. It provides controls to the system in the event of a HEAT mode, COOL mode, VENT mode, or motor controller and/or system faults. Each of these modes and fault situations will be discussed in detail in the following text, including flowcharts explaining the functions.

2. Heat Mode

The flowchart representing the HEAT mode is depicted in Figure 2. As shown in the flowchart when the mode switch is placed on heat mode the logic will initiate a certain delay which has not yet been finalized. The determination of this delay will be established after some testing by the motor controller manufacturers. The delay might be needed for prevention of backward EMF due to immediate restart of motor while motor coast down is occurring. After the delay, the motor controller is then turned on so that the condenser and evaporator fan will start. Consequently, the circuit will test to check if the ambient temperature is 1.5^{o}F below the set temperature. If so, then K1 is initiated so that the heater will start. However, when the ambient temperature is 1.5^{o}F above the set point, then it will continue in a loop to check if it ever does go below the set temperature. During this loop the vent position of the heat mode is occurring, in that, the fans are running but the heater is not on. During this checking loop all faults are tested. The faults tests included all three different types of motor controller faults and all three different types of system faults. When any of these faults occur the logic jumps to the specific fault routine which will handle all the controls for the specific fault. This function will be discussed later in the text.

If the K1 relay is initiated, the software will check to see if the ambient temperature has approached 1.5^{o}F above the set point. It will continue to check in a loop (meanwhile it will test for faults as before) until the condition is true. When this occurs, K1 is disengaged and the cycle begins again at the point after initiating the motor controller. This process will continue until the

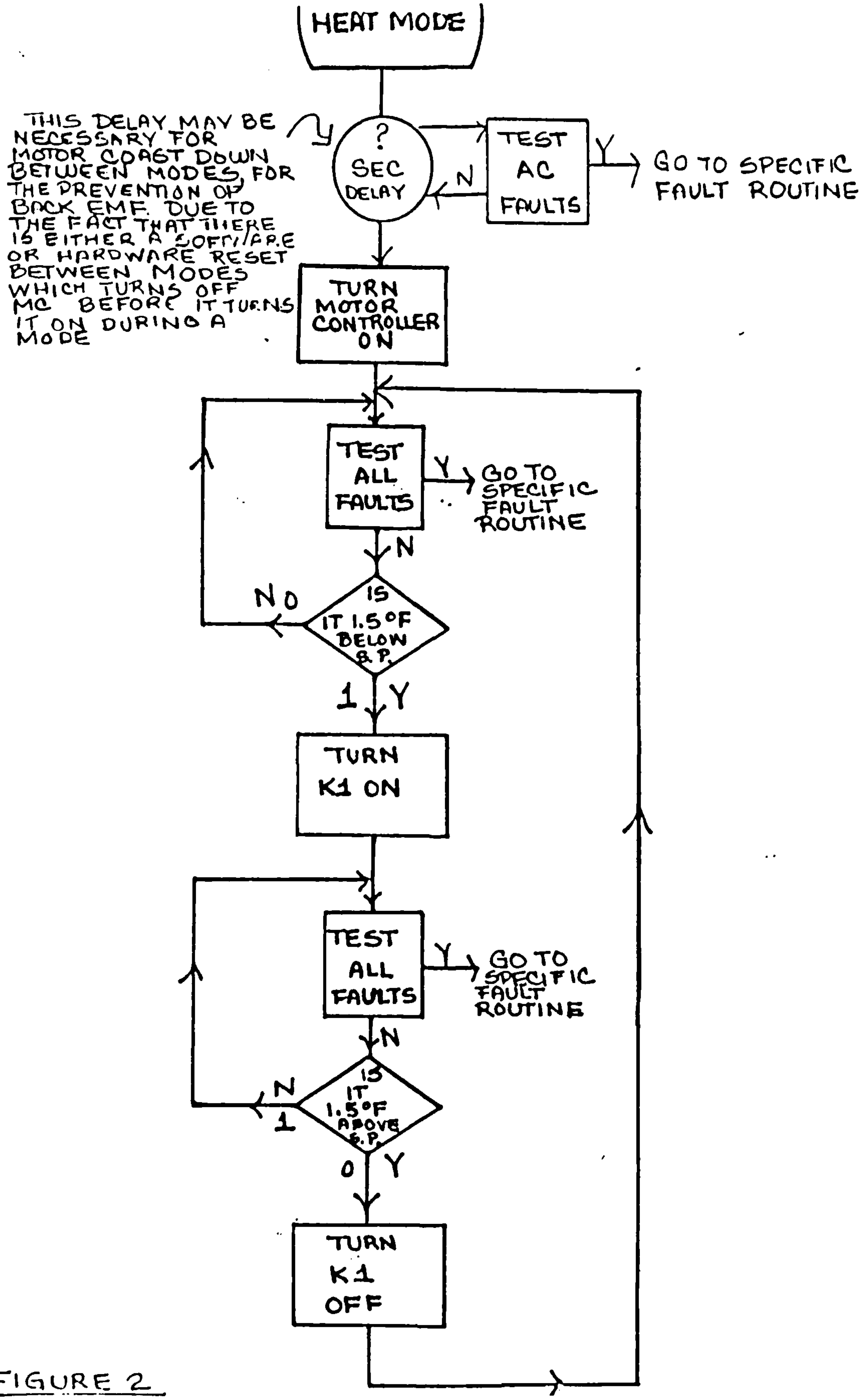

HEAT MODE
THIS DELAY MAY BE NECESSARY FOR MOTOR COAST DOWN BETWEEN MODES, FOR THE PREVENTION OF BACK EMF DUE TO THE FACT THAT THERE IS EITHER A SOFTWARE OR HARDWARE RESET BETWEEN MODES WHICH TURNS OFF MC BEFORE IT TURNS IT ON DURING A MODE
? SEC DELAY
TEST AC FAULTS
Y
N
GO TO SPECIFIC FAULT ROUTINE
TURN MOTOR CONTROLLER ON
TEST ALL FAULTS
Y
GO TO SPECIFIC FAULT ROUTINE
N
IS IT 1.5°F BELOW S.P.
NO
1
Y
TURN K1 ON
TEST ALL FAULTS
Y
GO TO SPECIFIC FAULT ROUTINE
N
IS IT 1.5°F ABOVE S.P.
N
1
0
Y
TURN K1 OFF

FIGURE 2

mode switch is taken away from the heat position. As an added note, hardware or software resets occur between modes.

3. Cool Mode

The cool mode flowchart is depicted in Figure 3. As shown on the flowchart the first check made in this mode is to determine whether the ambient temperature is 1.5°F above the set point. If so, the air conditioning portion of the cool mode is initiated. During this portion the motor controller is first turned off, because the motor controller may have been already turned on. In that case, the closing of K2 would cause an overload on the system. Therefore, everything on the line must be brought up simultaneously. K2 is then energized; however, a delay most likely must first be initiated before the motor controller is turned on again. The delay will be determined after some testing on motor coast down and the ability of the motor controller itself to handle backward EMF. If there is a substantial delay initiated at this time, the faults will be tested at this point. After the delay is complete, the motor controller is turned on, and air conditioning is occurring. If the ambient temperature ever goes below the set point by 1.5°F, K2 is deenergized and venting takes place. That is, the evaporator and condenser fans are running, the compressor is no longer running, and the cycle begins again.

In the event that at the initiation of the cool mode, the ambient temperature was 1.5°F below the set temperature, the vent portion of the cool mode would immediately occur, hence, a time delay of some length will occur. Again this delay may be needed for the prevention of backward EMF causing an overvoltage condition on the system. As before, determination of this delay will occur after

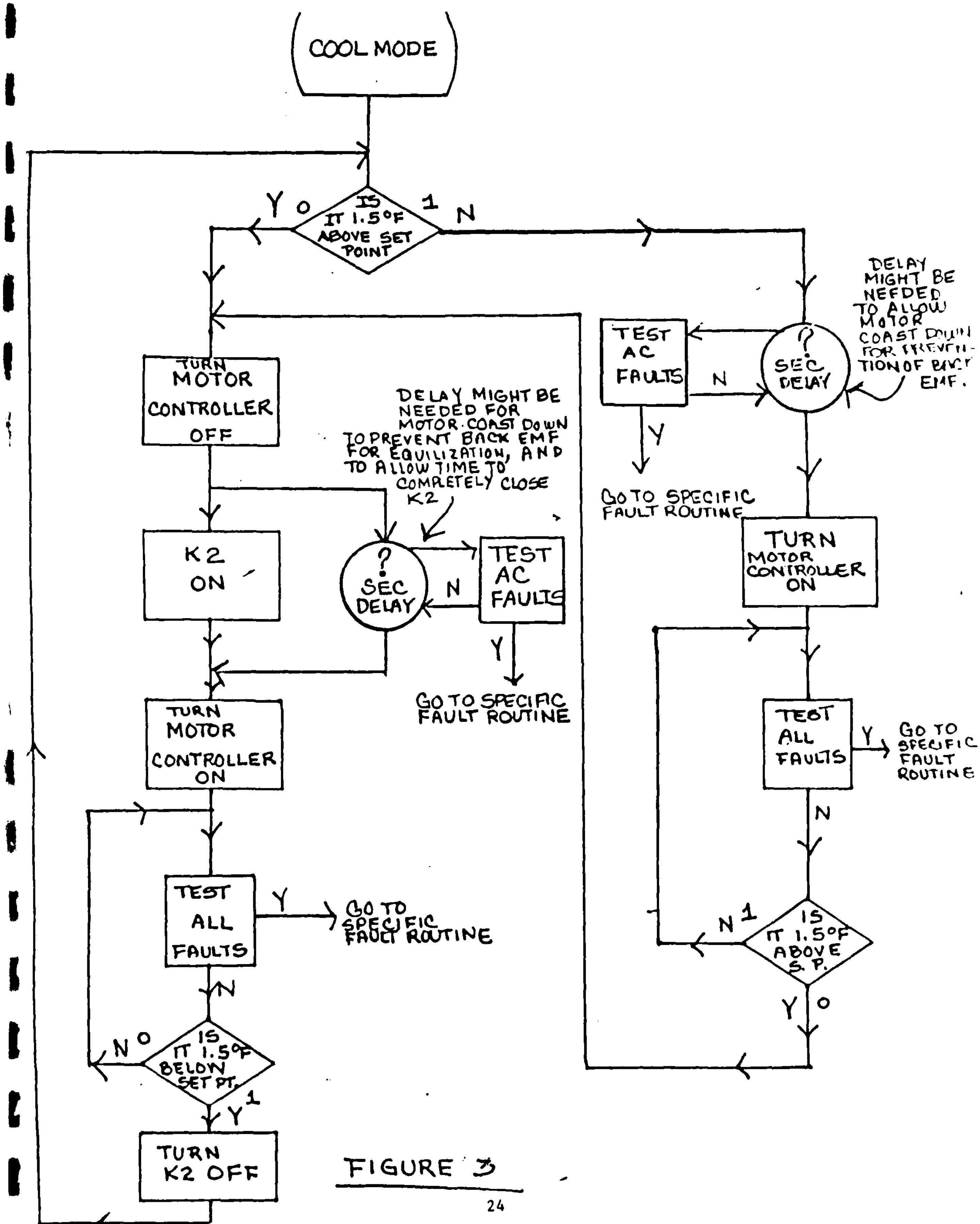

COOL MODE
IS IT 1.5°F ABOVE SET POINT
Y 0
1 N
TURN MOTOR CONTROLLER OFF
K2 ON
SEC DELAY
DELAY MIGHT BE NEEDED FOR MOTOR COAST DOWN TO PREVENT BACK EMF FOR EQUILIZATION, AND TO ALLOW TIME TO COMPLETELY CLOSE K2
TEST AC FAULTS
N
Y
GO TO SPECIFIC FAULT ROUTINE
TURN MOTOR CONTROLLER ON
TEST ALL FAULTS
Y
GO TO SPECIFIC FAULT ROUTINE
N
IS IT 1.5°F BELOW SET PT.
N 0
Y 1
TURN K2 OFF
TEST AC FAULTS
SEC DELAY
DELAY MIGHT BE NEEDED TO ALLOW MOTOR COAST DOWN FOR PREVENTION OF BACK EMF.
N
Y
GO TO SPECIFIC FAULT ROUTINE
TURN MOTOR CONTROLLER ON
TEST ALL FAULTS
Y
GO TO SPECIFIC FAULT ROUTINE
N
IS IT 1.5°F ABOVE S.P.
N 1
Y 0

FIGURE 3

testing is complete. After the completion of a delay, if any, the motor controller is initiated and venting occurs until the ambient temperature approaches 1.5^{o}F above the set point, and air conditioning begins as described earlier. During the temperature checking loop all faults are again tested.

4. Vent Mode

The vent mode flowchart is depicted in Figure 4. As shown in the flowchart a delay might be initiated for the same reasons discuss earlier in the other modes. After the delay, if any, the motor controller is turned on. This function continues indefinitely until a fault is detected or until the mode switch is taken away from the vent position.

5. Fault Handling

The four different types of faults handled in the system are as follows:

a. Motor controller faults
   (1) Over voltage/under voltage
   (2) Over current
   (3) Over temperature

b. Heater faults

c. Air conditioning faults

d. Vent faults

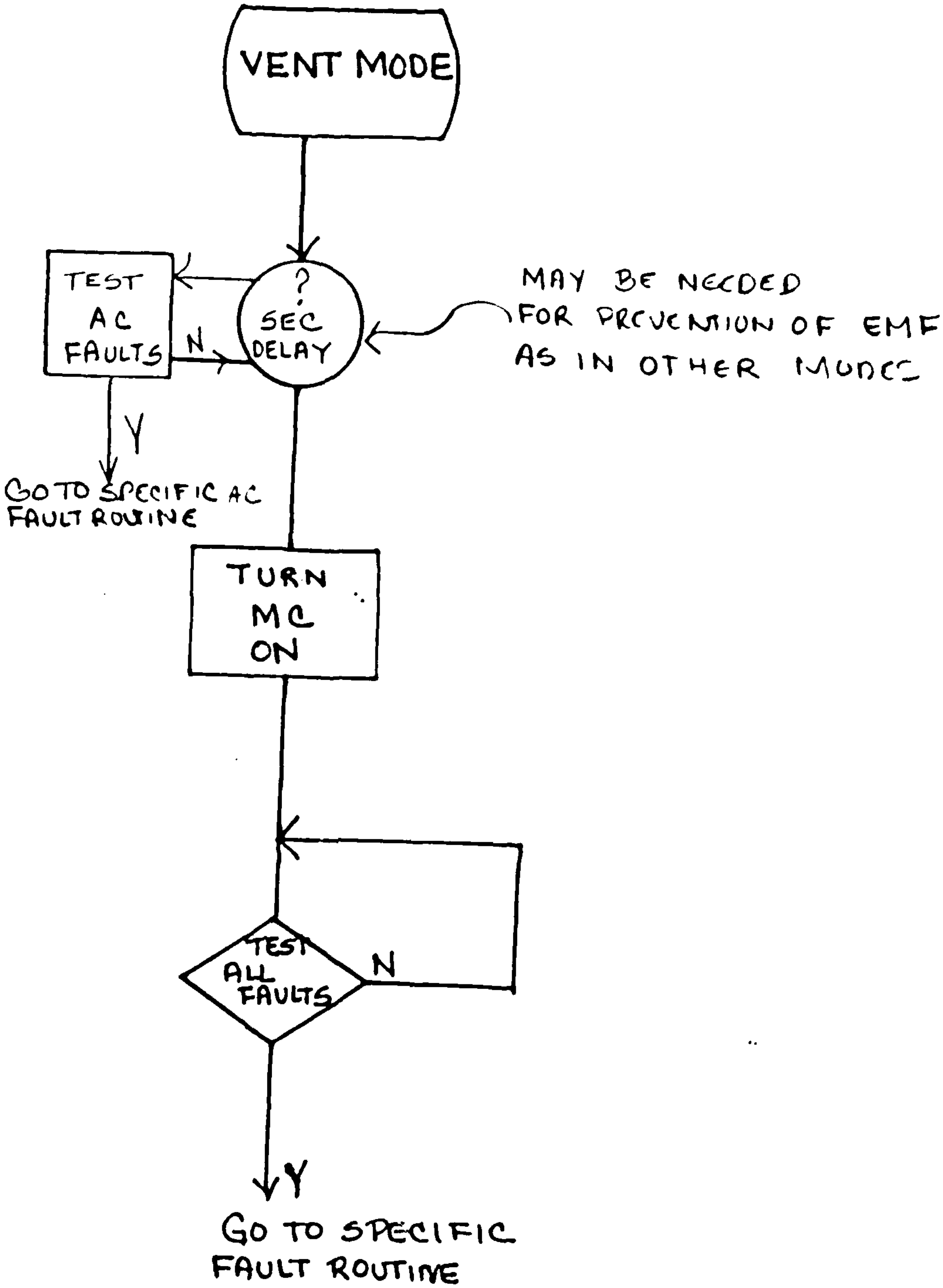

VENT MODE
TEST
AC
FAULTS
N
Y
?
SEC
DELAY
MAY BE NEEDED
FOR PREVENTION OF EMF
AS IN OTHER MODES
GO TO SPECIFIC AC
FAULT ROUTINE
TURN
MC
ON
TEST
ALL
FAULTS
N
Y
GO TO SPECIFIC
FAULT ROUTINE

FIGURE 4

All the motor controller faults are handled in the same way. When the controller acknowledges that there is an over voltage/under voltage, over current, or over temperature fault, it will send a +12V signal to the logic. When the logic receives the signal, it will perform the sequence described in the flowchart in Figure 5.

A heater fault is a system fault in the actual unit caused by a fault in the heater section of the TECS. Referring back to the schematic in Figure 1, it is shown that a heater fault will cause the heater fault cut-outs to open and 0 volts will be fed into the logic. The logic will then acknowledge a heater fault and perform the functions described in the flowchart in Figure 6.

The air conditioning fault is named the cool loop fault. Similarly as in the heater fault, when the cool loop cut-outs open, 0V is fed into the logic. The logic will then acknowledge an air conditioning fault and perform the functions described in the flowchart in Figure 7.

A vent fault is detected differently. As shown on the schematic in Figure 1, the evaporator cut-out is directly connected to both the heat loop and cool loop. When a vent fault comes in, the evaporator cut-out opens and both the heat fault loop cut-outs and the cool fault loop cut-outs both open. Therefore when the logic receives 0V from both the heat loop and the cool loop, it acknowledges a vent fault, and the sequence described in Figure 8 takes place.

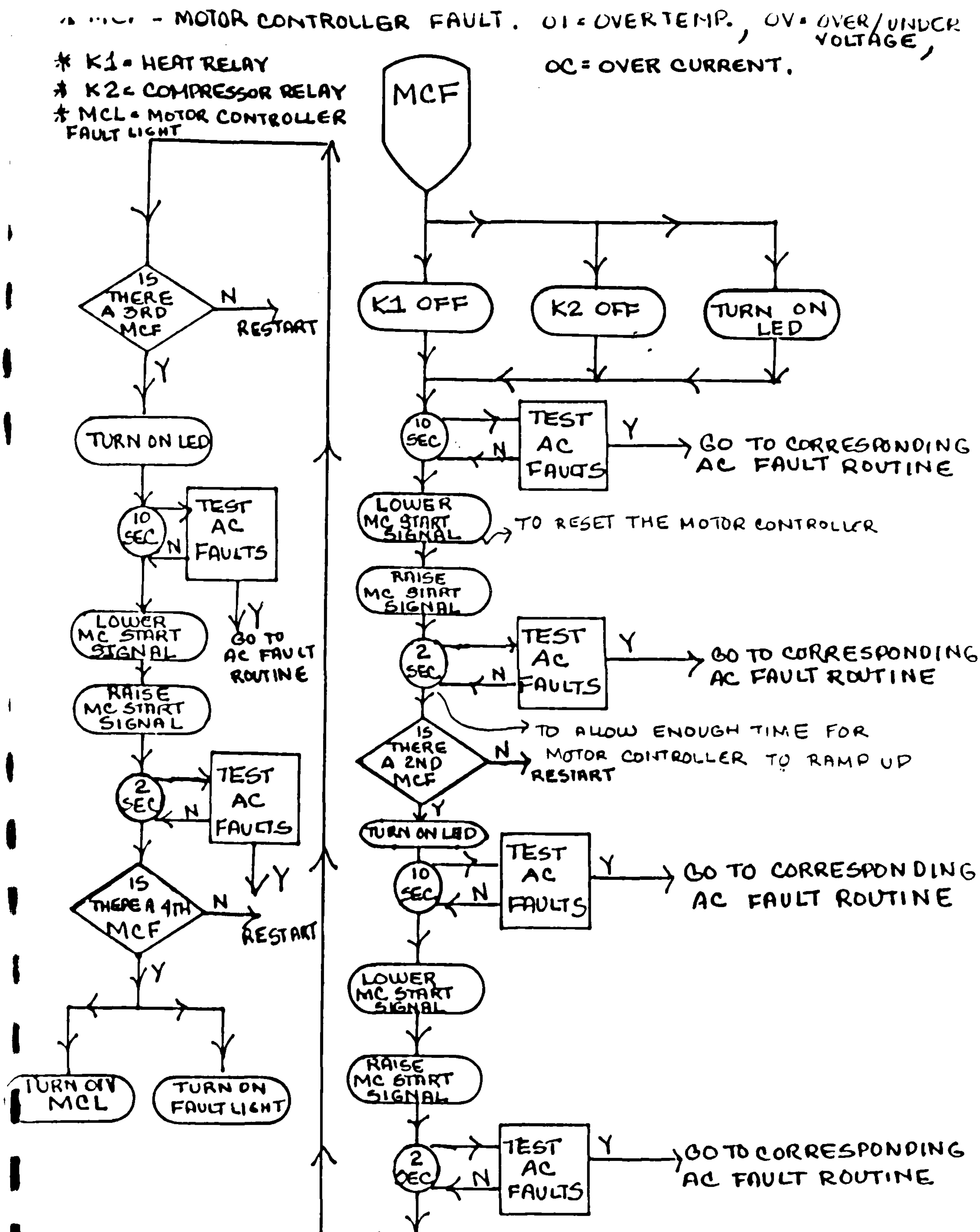

MCF - MOTOR CONTROLLER FAULT. OT = OVERTEMP., OV = OVER/UNDER VOLTAGE, OC = OVER CURRENT.
* K1 = HEAT RELAY
* K2 = COMPRESSOR RELAY
* MCL = MOTOR CONTROLLER FAULT LIGHT
MCF
K1 OFF
K2 OFF
TURN ON LED
10 SEC
TEST AC FAULTS
Y
N
GO TO CORRESPONDING AC FAULT ROUTINE
LOWER MC START SIGNAL
TO RESET THE MOTOR CONTROLLER
RAISE MC START SIGNAL
2 SEC
TEST AC FAULTS
GO TO CORRESPONDING AC FAULT ROUTINE
TO ALLOW ENOUGH TIME FOR MOTOR CONTROLLER TO RAMP UP
IS THERE A 2ND MCF
RESTART
TURN ON LED
10 SEC
TEST AC FAULTS
GO TO CORRESPONDING AC FAULT ROUTINE
LOWER MC START SIGNAL
RAISE MC START SIGNAL
2 SEC
TEST AC FAULTS
GO TO CORRESPONDING AC FAULT ROUTINE
IS THERE A 3RD MCF
RESTART
TURN ON LED
10 SEC
TEST AC FAULTS
GO TO AC FAULT ROUTINE
LOWER MC START SIGNAL
RAISE MC START SIGNAL
2 SEC
TEST AC FAULTS
IS THERE A 4TH MCF
RESTART
TURN ON MCL
TURN ON FAULT LIGHT

FIGURE 5

P/T = PRESSURE/TEMPERATURE FAULT INDICATION FOR AC.

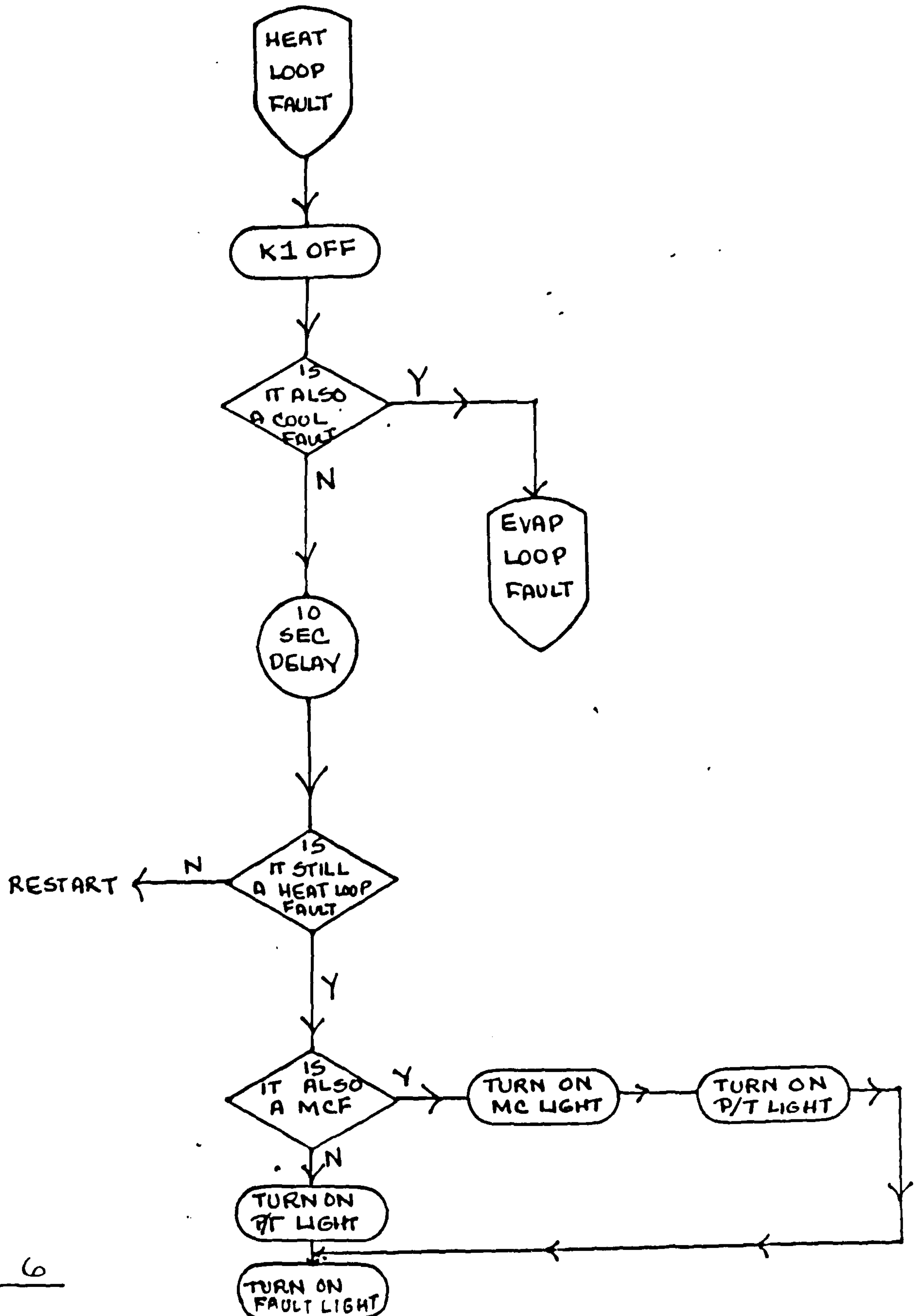


FIGURE 6

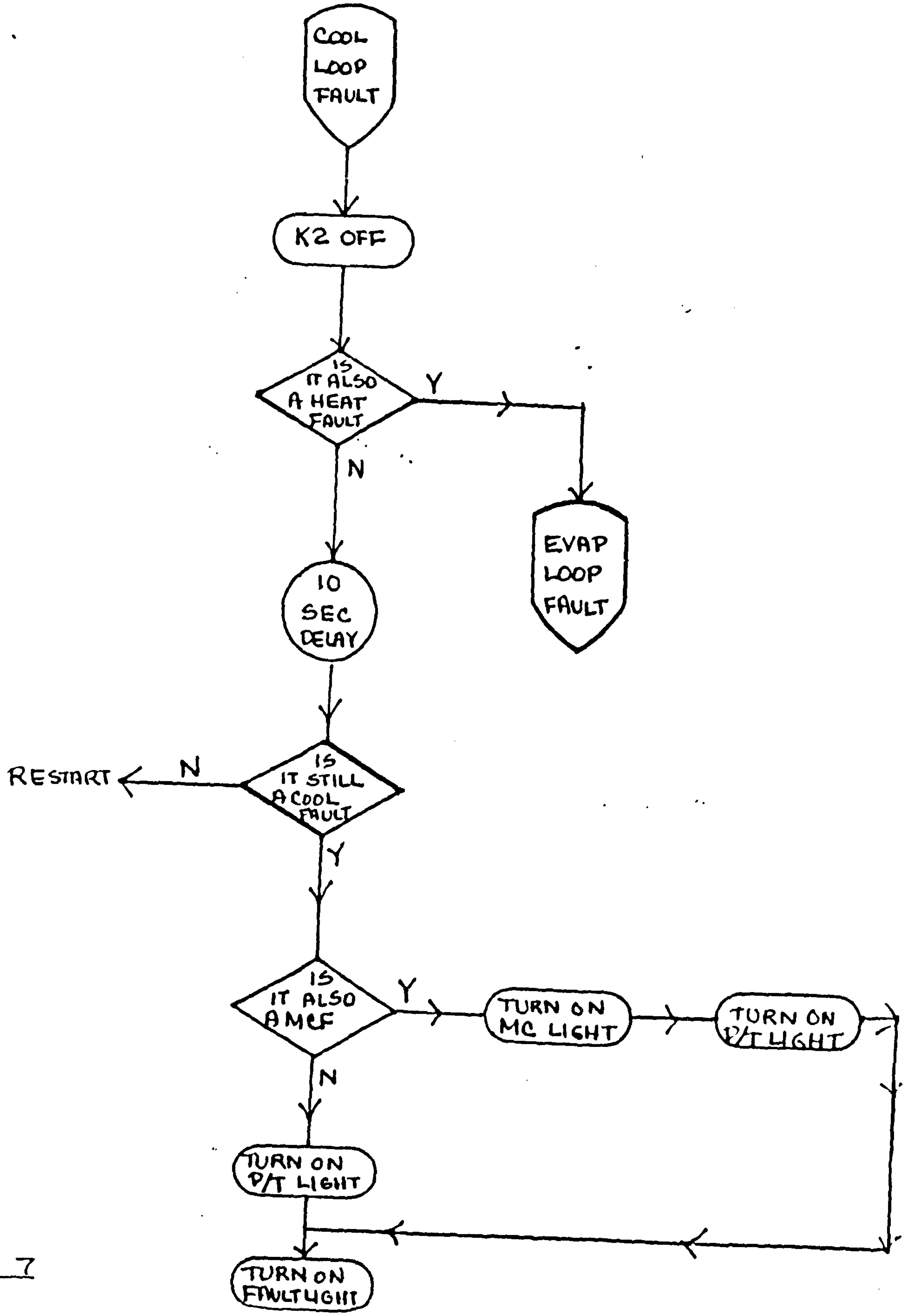

COOL LOOP FAULT
K2 OFF
IS IT ALSO A HEAT FAULT
Y
N
EVAP LOOP FAULT
10 SEC DELAY
IS IT STILL A COOL FAULT
N
RESTART
Y
IS IT ALSO A MCF
Y
TURN ON MC LIGHT
TURN ON P/T LIGHT
N
TURN ON P/T LIGHT
TURN ON FAULT LIGHT

FIGURE 7

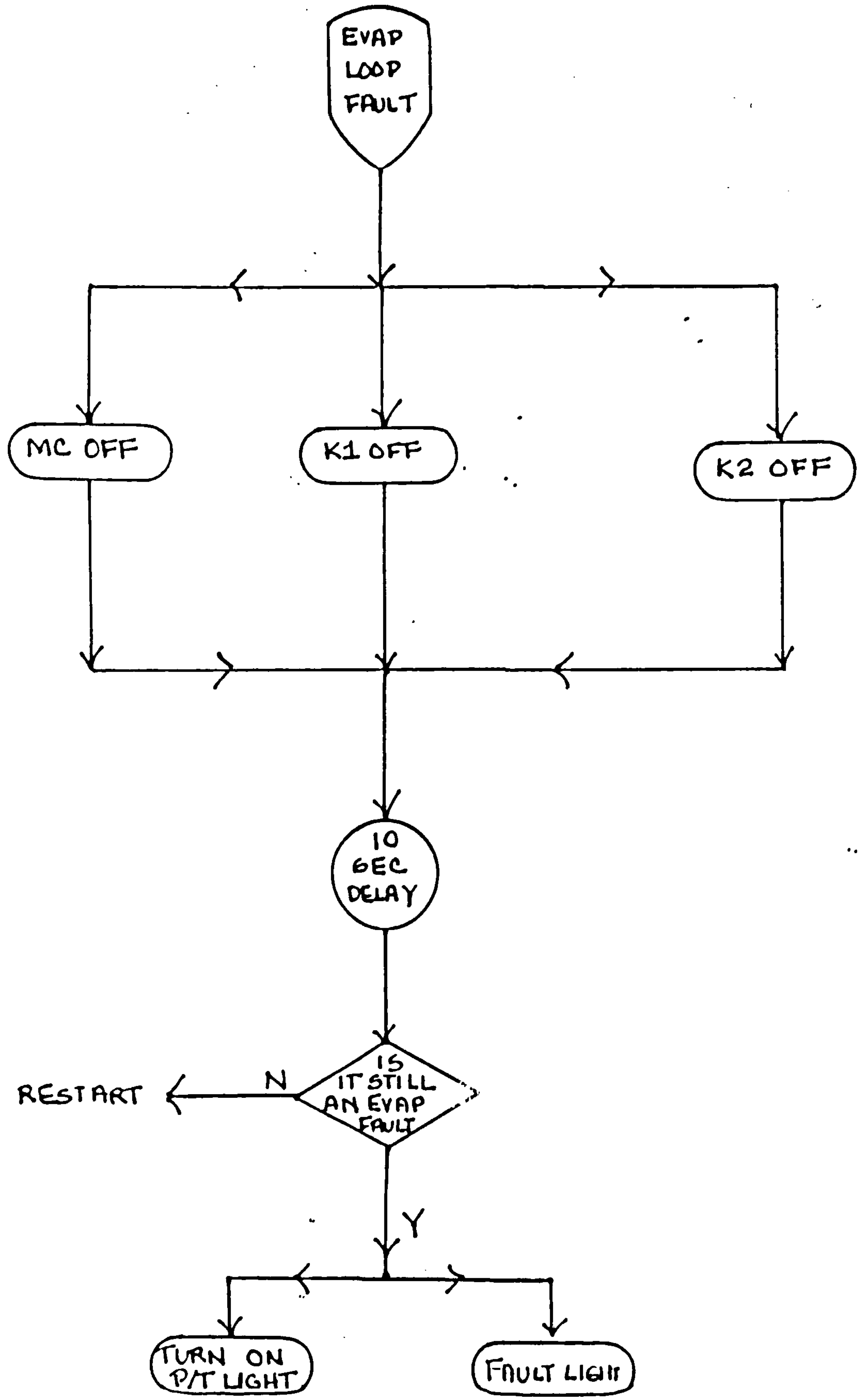

EVAP LOOP FAULT
MC OFF
K1 OFF
K2 OFF
10 SEC DELAY
IS IT STILL AN EVAP FAULT
N
RESTART
Y
TURN ON P/T LIGHT
FAULT LIGHT

FIGURE 8

D. LIFE CYCLE COST ANALYSIS

1. The Life Cycle Approach

Life cycle costing (LCC) is an evaluation method that accounts for relevant costs over time of an end item's design, development, components, materials, and operations. It includes initial investment costs, future replacement costs, operation and support costs, and salvage values. These costs are adjusted to a consistent time basis and combined into a single cost effectiveness measure that permits one to compare several alternatives on a common time basis with all dollars having equal value.

The value of money depends on the specific time that money is spent or received because of inflation and the opportunity cost of money. Inflation erodes the value of money over time, while the opportunity cost of money indicates that money on hand can be invested to yield a return on investment over time without regard for inflation.

With future amounts expressed in constant dollars, it is necessary to adjust them for the opportunity cost of money. The time adjustment is accomplished by applying appropriate multiplicative discount factors to the future amounts. This procedure is simply called "discounting". The effect of discounting is to reduce the present value of future cash amounts or anticipated future expenditures. The higher the discount rate, the lower the present value equivalent of a future amount; similarly, the farther into the future the anticipated expenditure, the lower its present value equivalent.

This LCC Analysis (LCCA) is made to compare Environmental Control Units (ECUs), representing the current family of military air conditioners, and the proposed Total Environmental Control System (TECS), which will use "soft start" controllers and solid state logic circuitry. All cost comparisons will be made on 18,000 BTUH units which have the greatest annual buy demand. The LCCA is based on annualizing all costs initially by applying appropriate discount factors, using a 10-year life cycle and a discount rate of 7%, consistent with the Office of Management and Budget Bulletin A-94 for energy related LCC comparisons.

2. Relationship Between VE and LCC

Life cycle costs are used to compare and evaluate the total cost of competing alternatives, taking into consideration the expected life of the product. VE is used to develop additional alternatives to consider before a decision is made. LCC emphasizes cost visibility, while VE seeks to attain optimum value. Costs of repair, operations, preventive maintenance, logistics support, power consumption, depreciation and periodic replacement, in addition to initial investment costs, represent the total value of the item to the user. LCC calculations for each alternative during performance of a value study provide the basis for judging the real benefits of adding additional development and acquisition costs to an existing system to achieve downstream savings from reduced operation and support costs during the expected life of the end item.

3. Life Cycle Cost Elements

a. Life Cycle Cost Estimate for TECS

In performing the LCC analysis, major emphasis has been placed on those cost elements that are statistically significant to the decision maker; however, the impact of any single cost element may not be known until the analysis has been completed. To preclude the need for developing new data, this study will make maximum use of data contained in the Science Applications International Corporation (SAIC) report for Belvoir Research, Development and Engineering Center (Belvoir), titled "Life Cycle Cost Estimate for the Total Environmental Control System (TECS), A Value Engineering Proposal (VEP)", since the SAIC report cost data was obtained from the U.S. Army Troop Support Command (TROSCOM) Cost Memorandum 85-5, "Investment and Operating and Support Costs for 56 Compact Horizontal and Vertical Air Conditioners", dated December 1984. After which all costs were converted to constant FY87 dollars using U.S. Army Materiel Command's "Revised Inflation Indices for Other Procurement", dated 22 December 1986. TECS addition of a controller and control logic circuitry will add approximately 400 electrical and electronic components, while the deletion of the hot gas bypass system removes 25 mechanical parts; therefore, we estimate that the TECS cost for acquisition, spare parts, maintenance and indirect support operations will be 10 percent greater than the baseline ECU. Assumptions made in preparing the SAIC report are as follows:

(1) The typical Environmental Control Unit (ECU) is used in a temperate climate.

(2) Air conditioners (A/C) will operate 2.35 hours/day at 25, 50, 75, and 100% capacity from May through October.

(3) Each air conditioner will operate 400 hours/year at each of the above capacities or a total of 1,600 hours.

(4) The Mean Time to Overhaul is 8,000 hours (5 years).

(5) Total Service Life of the military air conditioner is 16,000 hours.

(6) Power demand of the 18,000 BTUH A/C is 4.8 KW.

(7) 80% of the rated power (3.8 KW) is required for the hot gas bypass system.

(8) The life cycle of the Total Environment Control System (TECS) is 10 years.

(9) All costs are adjusted to FY87 constant dollars.

(10) Salvage value of the TECS air conditioner is 10% of the Unit Production Cost.

(11) The projected buy quantity will replace the current inventory of air conditioners.

(12) The LCC Analysis (Figure 9) is made between the baseline ECU and TECS Alternate 1 (100% Mobile Electric Power (MEP)) and Alternate 2 (50% MEP/50% Commercial Power).

b. Initial Investment Costs

In the annualized method for calculating LCC, all costs incurred are converted to equivalent annual costs (see Figure 9) using a baseline and a specified life span. The total initial investment cost is then amortized by determining the Annual Periodic Payment (PP) necessary to pay off a loan equaling the total initial investment cost. Using capital recovery tables, one can find the PP necessary to pay off a loan of $1.00. In our case, with a life span of 10 years and a 7% discount rate to take into consideration the opportunity cost of money, it requires an annual payment of $0.1424 to pay off a one dollar loan; hence, the total initial cost is multiplied by this factor (0.1424) to determine the annualized cost of this element.

(1) Research and Development. These are costs associated with conducting the value study, market search for controller manufacturers, testing, prototype, design and models. The planned expenditures during the last three quarters of FY87 of $1.954 million and $1.107 million (deflated to FY87) for FY88 represents the total development engineering costs associated with the TECS projects. Sunk costs of $854,000, which were incurred prior to the LCC analysis, are not considered in making current investment decisions.

(2) Investment. The total production cost for the baseline Environmental Control Unit (ECU) is derived by multiplying the unit production cost ($5,445) of the horizontal air conditioner (HC) by the total 10-year quantity (6,501) and adding the product obtained when the unit

STUDY TITLE: TOTAL ENVIRONMENTAL CONTROL SYSTEM	LIFE CYCLE COST COMPARISON PRESENT VALUE		
COST ELEMENT	BASELINE	ALTERNATE 1	ALTERNATE 2
INITIAL INVESTMENT	160,908	188,837	188,837
ANNUALIZED I.I. X PP (0.1424)	22,913	26,890	26,890
1.0 RESEARCH & DEVELOPMENT			
1.01 DEVELOPMENT ENGINEERING	0	3,061	3,061
1.01 R & D (SUNK COSTS) *	0	854*	854*
2.0 INVESTMENT	160,908	185,766	185,766
2.02 PRODUCTION	88,085	101,595	101,595
2.11 OTHER (DATA, TEST)	72,823	84,181	84,181
ANNUAL RECURRING	336,221	257,796	154,888
3.0 OPERATING & SUPPORT	336,221	257,796	257,796
3.01 MILITARY PERSONNEL	27,783	30,562	30,562
3.012 MAINTENANCE P&A	26,446	29,091	29,091
3.014 PERM CHANGE OF STA.	1,337	1,471	1,471
3.02 CONSUMPTION (REPL. SPARES)	899	989	989
3.05 OTHER DIRECT SUPPORT (ENERGY)	295,099	212,561	109,653
3.06 INDIRECT SUPPORT OPNS.	12,440	13,684	13,684
NON RECURRING	11,387	12,526	12,526
(PV X PP) PV_5 =0.7130, PP=0.1424			
3.03 DEPOT MAINTENANCE	112,151	123,366	123,366
3.031 LABOR	84,535	92,989	92,989
3.032 MATERIAL	27,616	30,377	30,377
2.01 SALVAGE VALUE			
BASELINE PV=0.5083 (8,808)	(638)		
ALTERNATES 1 & 2 (10,159)		(735)	(735)
TOTAL ANNUAL COSTS	369,883	296,477	193,569
ANNUAL DIFFERENCE (AD)		73,406	176,314
PRESENT VALUE OF AD PVA FACTOR 7.0236 X AD		515,574	1,238,359

PV - WHAT $1.00 DUE IN THE FUTURE IS WORTH TODAY.
PVA - WHAT $1.00 PAYABLE PERIODICALLY IS WORTH TODAY
PP - PERIODIC PAYMENT.
ALL COSTS ARE IN K DOLLARS
ALL CALCULATIONS ARE BASED ON A 10 YEAR LIFE SPAN AND A 7% DISCOUNT RATE
* - SUNK COSTS ARE EXCLUDED FROM LCC COMPARISON.

FIGURE 9

production cost ($4,820) of the vertical air conditioner (VC) is multiplied by the total 10-year quantity of 10,931. Similarly, the unit production costs of the Total Environmental Control System HC and VC units ($6,220 and $5,595, respectively) is multiplied by the total quantities of each to obtain the total production costs shown on Figure 9 for cost element 2.02. The expression for other investment cost at 2.11 is derived by the expression "total average investment cost - unit production cost x total quantity" for the HC and VC units. Data, training and testing for units which could not be broken out separately from total investment costs are included in this cost element.

c. Annual Recurring Costs

Average annual recurring costs for operation and support includes expressions, under the general heading of military personnel, for maintenance personnel and administration and permanent change of station. Replenishment of spare parts and the miscellaneous personnel category, indirect support operations, are also included in the category of annual recurring costs. However, the greatest impact on this life cycle cost analysis is caused by cost element 3.05, other direct support (energy), because it is the largest annual expenditure of funds incurred by the family of air conditioners. Since operating and support costs are already expressed as annual recurring costs, discounting is unnecessary for this category.

d. Non-recurring Costs

Non-annually recurring repair and replacement costs and salvage values are assumed to be a lump sum amount at the end of the year in which they are estimated to occur. For purposes of this analysis, we will assume that both the ECU and TECS air conditioners will require one major depot overhaul at the end of 8,000 hours of operation, which will occur at the end of the fifth year. Similarly, the salvage value of air conditioners is expected to accrue at the end of the tenth year and represents 10% of the unit production cost of the air conditioners. Each of the repair and replacement costs and salvage values is then discounted from the point in time when funds are to be expended using present value (PV) tables. The present value of these payments is reduced further by applying the same capital recovery periodic payment (PP) used to annualize initial investment costs. It is important to note that salvage (residual) values are negative as indicated by the parenthesis ( ). For the baseline ECU, the depot maintenance overhaul cost is \$112,150,000 in the fifth year. The annualized value is \$112,150,000 x PV_5 x PP, or \$112,150,000 x 0.7130 x 0.1424 = \$11,387,000. A total of 4,221 - 18,000 BTUH horizontal air conditioning units are planned for procurement at a cost of \$22.99M between FY87-FY92, which yields a UPC of \$5,447. Similarly, a total of 7,097 - 18,000 BTUH vertical air conditioning units will be procured during the same period for a total cost of \$34.21M, or a UPC of \$4,820.

The TECS units are estimated to cost \$775/unit more than the ECU; therefore, the average unit salvage values are as follows:

	ECU	TECS
Horizontal AC	\$ 545	\$ 622
Vertical AC	\$ 482	\$ 560

To obtain the expression for total salvage value at the end of their 10 year life, the avera salvage value of each air conditioner type is multiplied by their respective quantity and added together. Thus, the total salvage value of the ECU and TECS air conditioners is $8,808,000 and $10,159,000, respectively. The annualized salvage value of each air conditioner is obtained by multiplying the total salvage value by the periodic payment (0.1424) and the present value for a 7 percent discount and 10 year life (0.5083), which yields an annualized salvage value of $638,000 for ECU and $735,000 for TECS as indicated for line item 2.01, Figure 9.

e. Total Annual Costs

Total annual costs are determined by adding the annualized initial investment costs, annual recurring costs, and non-recurring depot maintenance costs and subtracting the salvage value. These costs represent the uniform baseline for comparing alternate designs over a projected life span at the selected interest rate.

f. Annual Difference

To determine the discounted value of the annual cost difference, the present value annuity table is used to show how much $1.00 paid out periodically is worth in real dollars today. In our analysis for a 10-year life span at a 7% discount rate, $1.00 paid out annually is the same as having $7.0236 today. The analysis indicates that Alternate 2 of the TECS is the recommended solution since it yields an annual saving of $176,314,000 that is worth over $1.2 billion today.

4. Conclusions.

a. The basic decision to replace the ECU with TECS units is justified both operationally and economically. The use of soft start controllers and logic circuitry offers the following advantages:

(1) The ability to use the air conditioner on any normal worldwide commercial power source.

(2) The elimination of the hot gas bypass system, resulting in a significant reduction in both the cost and demand for electric power.

(3) Increased life of the compressor and fan motors, and Mobile Electric Power (MEP) Units.

(4) Elimination of in-rush current that exceeds normal operating current and causes an interruption in the efficient operation of electronic equipment operating from the same MEP unit.

(5) Reduction in fuel demand required to generate electrical energy from MEP units.

b. Although the total cost increase for producing the TECS air conditioner remains subject to change, it is apparent that the cost benefits from reduced power consumption and the capability to use commercial power far outweigh the initial production cost increase and the R&D effort to improve the operational efficiency of air conditioners.

c. The most significant cost elements contributing to Total Life Cycle Costs (TLCC) are those elements related to electrical power generation costs and initial procurement of the air conditioners. Conversely, research and development costs, amortized over the TECS life span, and the estimated salvage value of the TECS have the least impact on life cycle costs. In keeping with VE project selection procedures, the development effort has concentrated on those cost elements having the greatest impact on TLCC; however, additional VE effort is needed to review major air conditioning components such as the compressor, and condensor and evaporation fan motors to reduce production costs, or to prove that the existing components represent the best value for the user.

5. Recommendations

Based upon LCC analysis of the ECU and TECS air conditioners, recommend that:

a. A Value Engineering study be performed on all major components of the ECU such as the compressor, and evaporation and condenser fan motors.

b. Accurate cost data be maintained on the controller and logic circuits added to the TECS.

c. Every effort be made to convert power frequencies of other field equipment from 400 Hertz to 50/60 Hertz, and that commercial power be used whenever and wherever feasible.

APPENDIX A

MAILING LISTS

PRELIMINARY MAILING LIST

Called:	
Person:	Larry Albrecht
Company:	Abacus Controls, Inc.
Address:	80 Readington Rd.
	Somerville, New Jersey 08876
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Dave Schneider
AC Technologies, Inc.
24 Hopedale St.
Hopedale, MA. 01747
(617) 478-4823

Bill Suba
Advanced Control Systems
205 Oak Street
Pembroke, MA 02359
(617) 826-4477

Allen Bradley-Sale Office
Attn: Doug Witmer
9115 Guilford Rd.
Suite 100
Columbia, MD. 21046
(414) 377-1200

W. Merel
Applied Controls
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Fairfield, N.J. 07006-2828
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JMR Electronics
1525 Blondell Avenue
Bronx, N.Y. 11050
(212) 597-6050

Ed Peterson
Louis Allls
Drives and Operations
16555 West Ryerson Road
New Berlin, WI 53151
(414) 782-0200

Pete Gennufo
Lovejoy Electronics
2655 Wisconsin Avenue
Downersgrove, Il. 60515
(312) 968-7089

Garry Mandell
Marine Electric RPD, Inc.
666 Pacific Street
Brooklyn, N.Y. 11217
(718) 857-2400

Michael Portelli
Mitzubishi Electric Sales America
800 Bierman Court
Mount Prospect, IL 60056
(312) 298-9223

Gordon Roberts
REP: for Parametrics
Transmission Engineering Com. (TECO)
8869 Citation Rd.
Baltimore, MD. 21221
(301) 682-4900

Bruce Stanley
Polyspede Electronics Corp.
P.O. Box 31024
Dallas, TX. 75231
(214) 363-7245

Dave Smith
Rae Corp.
5801 West Elm St.
McHenri IL., 60050

George Usher
Relcon Inc.
80 Walker Drive
Brampton, Ontario
Canada L6T4H6
(416) 458-1100

Mike Salvatore
Reliance Electric Co.
17 Govenors Ct.
Baltimore, Md. 21207
(301) 298-2200

Dan Rogers/Sales Office
Rondo Motor Control
745 Lakeside Dr.
Bridgeport, Ct. 06606
(303) 469-1742

Mark Duzinski
Rondo Motor Control
2150 West 6th Avenue
Broomfield, Co. 80020
(303) 469-1742

Bernie Vincent
Siemens Energy Automation, Inc.
P.O. Box 29265
New Orleans, LA. 70189

Mike Davis
Sierracin-Magnedyne Corporation
2258 Rutherford Road
Carlsbad, California 92208

Jeff Small
Southcon Industrial Controls, Inc.
3808 Rozzells Ferry Road
Charlotte, NC. 28206
(704) 393-1636

Ed Birkinshaw
Square D. Company
900 Hungerford Drive, Suite 235
Rockville, Maryland 20850

Larry Fuson
Toshlba International Corp.
13131 W. Little York Road
Houston, TX. 77041
(713) 466-0277

Gary Andrews
Unico Inc.
3725 Nicholson Rd.
Franksville, WI 53126
(414) 886-5678

Walter Nero
VEE-ARC CORP.
50 Milk Street
Westborough,MA. 01581
(617) 366-7451/Toni Harris (704) 331-0674

Bob Gibbs
Volth Transmissions, Inc.
7 Pearl Court
Allendale, N.J. 07401
(201) 825-8855

Mark Blashak
Warner Electric
P.O. Box 207
Manahin - Sabot, Virginia 23103
(804) 784-3442

John Armstrong
Warner Electric
Seco Div.
Route 4, Hwy.29
Lancaster, SC. 29720
(803) 286-6927

Tom Holmberg
Zycron Systems, Inc.
72 Acton Street
West Haven, Connecticut 06516
(203) 932-8471

Milton Frank
XYLOG CORP.
150 Tillman St.
Westwood, N.J. 07675
(201) 664-7997

FINAL MAILING LIST

AC Technologies In Care of Dynamation Inc.
612 Research Rd.
Richmond, VA.23235
Attention: Dave Jewett
(804) 794-7667

Als Corporation
1400 N. Baxter St.
Annaheim, CA. 92806-0606
Attention: Larry Schaeffer
(714) 956-9200

Automatic Equipment Sales
Representatiives For Mitzubishi
Of Washington, Inc.
300 Swann Avenue
Alexandria, VA. 22301
Attention: Carl Godwin
(703) 548-2045

Central Power Company
27495 Diaz Road
Temecula, CA. 92390
(714) 676-0555

Contraves Goerz Corporation
2600 Liberty Avenue
Pittsburgh, PA. 15222-4616
Attention: William Jollie
(412) 261-8600

General Electric Speed
Variator Products Department
1100 Lawrence Parkway
Building 63-2
Erie, PA. 16531
Attention: Dave Schrader
(814) 875-2963

Harmon Commonwealth
Representatives FOr Emmerson
ELectric Company
Drives And Control Systems
5411 Old Frederick Rd. Suite 21
Baltimore, MD. 21229
Attention: Terje Gulbrandsen
(301) 624-7100

Keco Industries
7375 Industrial Rd.
Florence, Kentucky 41042
Attention: John Dupps
(606) 525-2102

Lovejoy Electronics
9 Lexington Avenue
Montclair, NJ. 07442
Attention: Al. D. Williams
(201) 783-7442

Lovejoy Electronics, Inc.
2820 N. Marksheffel Rd.
Colorado Springs, Co. 80915
Attention: Rick Siekman
(303) 597-8080

Mitzubishi Electric Sales America
215 Oxford Rd.
West Chesterr, PA. 19380
Attention: Tony Fischetti
(215) 692-1911

Modern Power Technology, Inc.
Consultants For Central Power Co.
827 East Alosta
Glendora, CA. 91740
Attention: Rudy Armstrong

Polyspede Electronics Corp.
6770 Twin Hills Avenue
Dallas, TX 75231
Attention: Bruce Stanley
(214) 363-7245

Reliance Electric Co.
17 Govenors Ct.
Baltimore, MD. 21207
Attention: Mike Salvatore
(301) 298-2200

Southern Industrial Controls
3608 Rozzells Ferry Road
Charlotte, NC. 28216
Attention: Jeff Small
(804) 747-1197

The Superior Electric Co.
Unitron Div.
383 Middle St.
Bristol, Connecticut 06010
Attention: Martin Kaplan
(203) 582-9561

Total Control Inc.
Representatives For Polyspede
36 Allison Rd.
Hightstown, NJ 08520
Attention: Steve Schultz
(609) 448-3076

Transmission Engineering Company
Representatives For Parametrics
8869 Citation Rd.
Baltimore, MD. 21221
Attention: Gordon Roberts
(301) 682-4990

WESCO
Representatives For Contraves
1710 Edison Hwy.
Baltimore, MD. 21213
Attention: Solomon Turkel
(301) 563-8268

Zycron Systems Inc.
72 Acton Street
West Haven, Ct. 06516
Attention: Paul J. Landino
(203) 932-8471

APPENDIX B

LETTERS SENT AND RECEIVED DURING MARKET SURVEY

November 28, 1986
0500.0039

Name
Address
City

Attention: Sales Manager

Subject: Motor Controllers

Dear Sir/Madam:

VSE is conducting a market survey to find the most appropriate motor controllers for application to military air conditioners, under contract with the U.S. Army Belvoir Research, Development and Engineering Center, Fort Belvoir, Virginia. We understand that capabilities sought might exist in your line of equipment.

We request information including catalogs and specification sheets describing your products' physical form, performance capabilities, electrical characteristics, features, etc. Also important is information on cost and delivery time ARO.

The winning candidate of our choice from each size will be purchased in limited quantities for further evaluation and testing.

Based on these evaluations the chosen motor controllers may be incorporated into the design of military air conditioners with 9,000, 18,000 and 36,000 BTU/HR ratings for manufacture in quantities under review. The air conditioners will have "soft start" capability necessitating each controller's output to be both variable frequency and voltage, the upper limits of which are shown in the table under Output Requirements.

The order of preference in the choice of controllers is to:

1) Buy off the shelf, as is.
2) Buy modified units at a fixed price.
3) Cooperatively develop prototypes.

	Input Requirements	Output Requirements
Size 1	115 V, 1 ph, 50/60 Hz 115 V, 1 ph, 400 Hz	3.6 KW, .95 PF, 115 V, 1 ph, 60 Hz
Size 2	208 V, 3 ph, 50/60 Hz 208 V, 3 ph, 400 Hz	6.5 KW, .90 PF, 208 V, 3 ph, 60 Hz
Size 3	208 V, 3 ph, 50/60 Hz 208 V, 3 ph, 400 Hz	10.5 KW, .83 PF, 208 V, 3 ph, 60 Hz

This request is for information only. Your response shall not constitute any contractual arrangement with VSE Corporation and it is to be done completely without cost to VSE.

Please direct replies and information packages as well as questions you might have to Frank Pierce at the above address within two (2) weeks. Feel free to call me at (703) 739-4527, or Yvonne Chang at (703) 739-4525.

Your help and cooperation are greatly appreciated.

Very truly yours,

VSE CORPORATION

Frank Pierce
Project Engineer

9 Apr 1987
0500.0039

Attention:

Subject:

Dear :

As a continuing effort to evaluate the finalist manufacturers in our 7 1/2 HP motor controller market survey, we have generated a set of detailed specifications which we require in the units. Enclosed is a copy of these specifications, which we would like you to evaluate, and consequently submit to us an estimate depicting the following.

1) Development cost
2) Price per unit after development
   a) Price for 8 units
   b) Price for 50 units
   c) Price for 100 units
   d) Price for 500 units

Due to the fact that we are on a limited time schedule, we need to have your response either by mail or by a phone call proceeded by a letter no later than April 16, 1987.

This request is for information only. Your response will not constitute any contractual arrangement with VSE Corporation, and it is to be understood that whatever information is provided will be at no cost to VSE. Please submit your response by mail to myself, Yvonne Chang at the above address and/or by phone at (703) 739-4500 ext. 521.

Your response is greaty appreciated.

Very truly yours,

VSE CORPORATION

Yvonne Chang
Electronic Engineer
EE/TS Group

YC:lh

TECS INVERTER REQUIREMENTS

Nominal Power Input: 208V, 3 phase, 50 to 400 Hz, 3 wire plus ground.

Voltage and Frequency Variation:

Voltage	Frequency	Voltage	Frequency (Hz)	
Rated	Rated	208	60	400
High	High	219	63	420
Low	Low	197	47.5	380
Low	High	197	63	420
High	Low	219	47.5	380

Power Output: 208V ±4%, 3 phase, 61 Hz ±0.5%, nominal 7.5 horsepower, 18 amps.

Input Current Limit: No more than normal full load current at any time (after DC buss is charged).

Control Input: 10 vdc start and run signal.

Auxiliary Power Output: 12 vdc, 200 ma.

Features:

1. Load acceleration to full speed in 2 to 20 seconds, adjustable.

2. Inherent protection against back EMF.

3. Proper volts/hertz ratio for needed motor torque.

4. Overtemperature sensing of electronics or heat sink temperature with system shut-down and with a signal conducted out of the controller for LED BITE.

5. Provide approximately 5 vdc external BITE signals for standby, over/under voltage, over current and over temperature.

6. A fault within the inverter requiring shut-down will send a +5 vdc signal to one of the remote LED BITE indicators. This signal will be used by the air conditioner's electronic logic section to shut down the inverter. The logic will wait 10 seconds, and then automatically try to reset the fault indication and restart the system. If the fault remains, or re-occurs on start up, the logic will again shut down the inverter and lock it out, requiring a manual reset.

Operational Efficiency: 95% minimum at full load.

Reliability/life: Goal of 20,000 operating hours.

Enclosure: Totally enclosed with EMI protection. Configuration and dimensions are expected to be approximately as shown on sketch VSE 0074-1. MS connectors to be determined later.

Weight: 30 pounds maximum.

Ventilation air: Approximately 10 cfm of 95°F air at 0.10" w.g. is available for cooling a heat exchanger.

Protection: As a minimum, provide a remote circuit breaker for power input application by the user and varistors (or the equivalent) on the input power lines within the inverter box for transient protection.

Documentation: Provide complete drawings to the manufacturer's format describing the external form, fit and function of the final design inverter.

Manuals: Provide 11 copies of a commercial format operators manual to include operation and installation instructions, clearly showing and describing all electrical connections and their purposes.

Environmental Conditions:

Normal operating temperatures: +50°F to +95°F in the area of the inverter.

Storage temperatures: -60°F to +160°F.

Start-up temperatures: -50°F to 125°F.

Altitude: Operation to 3000 ft.

Humidity: Per MIL-STD-810D, Method 507.2, procedure III or Section II-3.3, which requires humidity of 85 to 100% during 240 hours of exposure with 10 temperature cycles from 85°F to 155°F (Non-operating). The unit must not be damaged by exposure to this humidity test and must start and operate properly after the test.

Salt Fog: Per MIL-STD-810D, Method 509.2, which specifies a 48 hour exposure to a fog generated from a 5% salt solution in water. This exposure is followed by a 48 hours drying period. The unit must not be damaged by this exposure and shall start and operate properly following the drying period.

Fungus: 28 days of daily temperature cycling between 77°F and 86°F with 95% RH and exposure to a combination of five specific fungus spores (non-operating). Failure criteria is failure of the item to function properly following the test, evidence of the use of materials supporting fungus growth, or indication that long range exposure would cause failure of the test item.

Vibration: Per MIL-STD-810C, Method 514.2, Category F, Procedure VIII, Table 514.2-VI, Figure 514.2-6, Curve V; which consists of sinusoidal cycling from 5 Hz to 200 Hz at 1.5 g throughout. Test sample shall be mounted in the normal operating position and tested for one hour in each of the longitudinal, transverse and vertical planes. Test equipment shall sweep logrithmically from 5 Hz to 200 Hz and back to 5 Hz in 12 minutes for a total of 5 complete sweeps per plane. Displacement at 5 Hz is one inch. Test sample shall not operate during test.

Test sample shall not be physically damaged and shall function normally following vibration.

Shock: Per MIL-STD-810C, Method 516.1, Procedure I. The first test simulates rail transportation impacts and consists of half-sine inputs of 12 g peak for 18 millisecond (ms) duration. There shall be three impacts in each of the four horizontal directions for a total of 12 impacts.

The second test simulates usage on a tactical vehicle. The half-sine inputs consist of the following:

Longitudinal: 3.5 g for 100 ms duration.
Transverse: 2.9 g for 100 ms duration.
Vertical: 8.0 g for 85 ms duration.

There shall be three shocks in each direction for a total of 18 impacts.

Test sample shall not be physically damaged and shall function normally following shock testing.

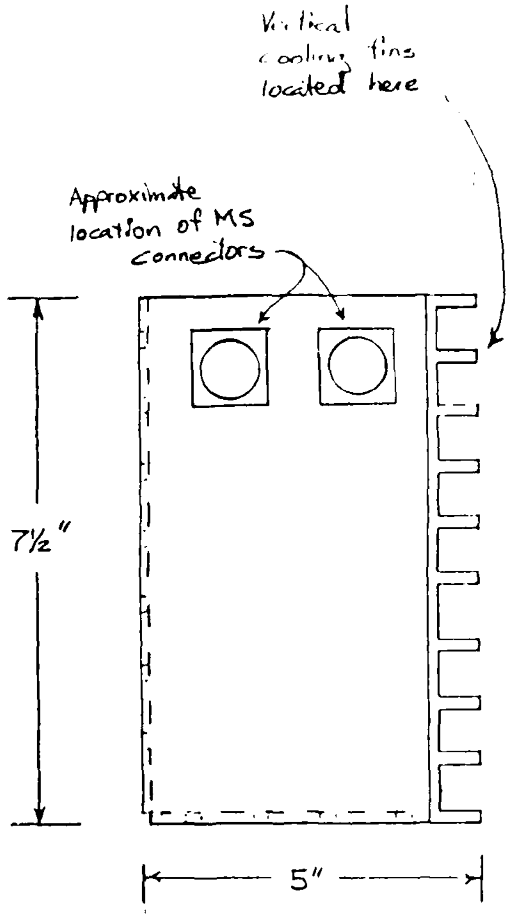
Electromagnetic Interference: The combination of inverter and air conditioner shall be designed to comply with the EMI requirements of MIL-STD-461B, Part 4, paragraphs 3 (CE03), Figure 4-4, Curve #1 and 15 (RE02) Figure 4-13, tested as specified in MIL-STD-462. CE03 encompasses conducted line emissions from 15 kHz to 50 kHz and RE02 covers radiated emissions from 14 kHz to 1000 Mhz (broadband), measured at 1 meter. The combination inverter and air conditioner will be tested for EMI during steady state and automatic transient (on/off cycling) conditions.

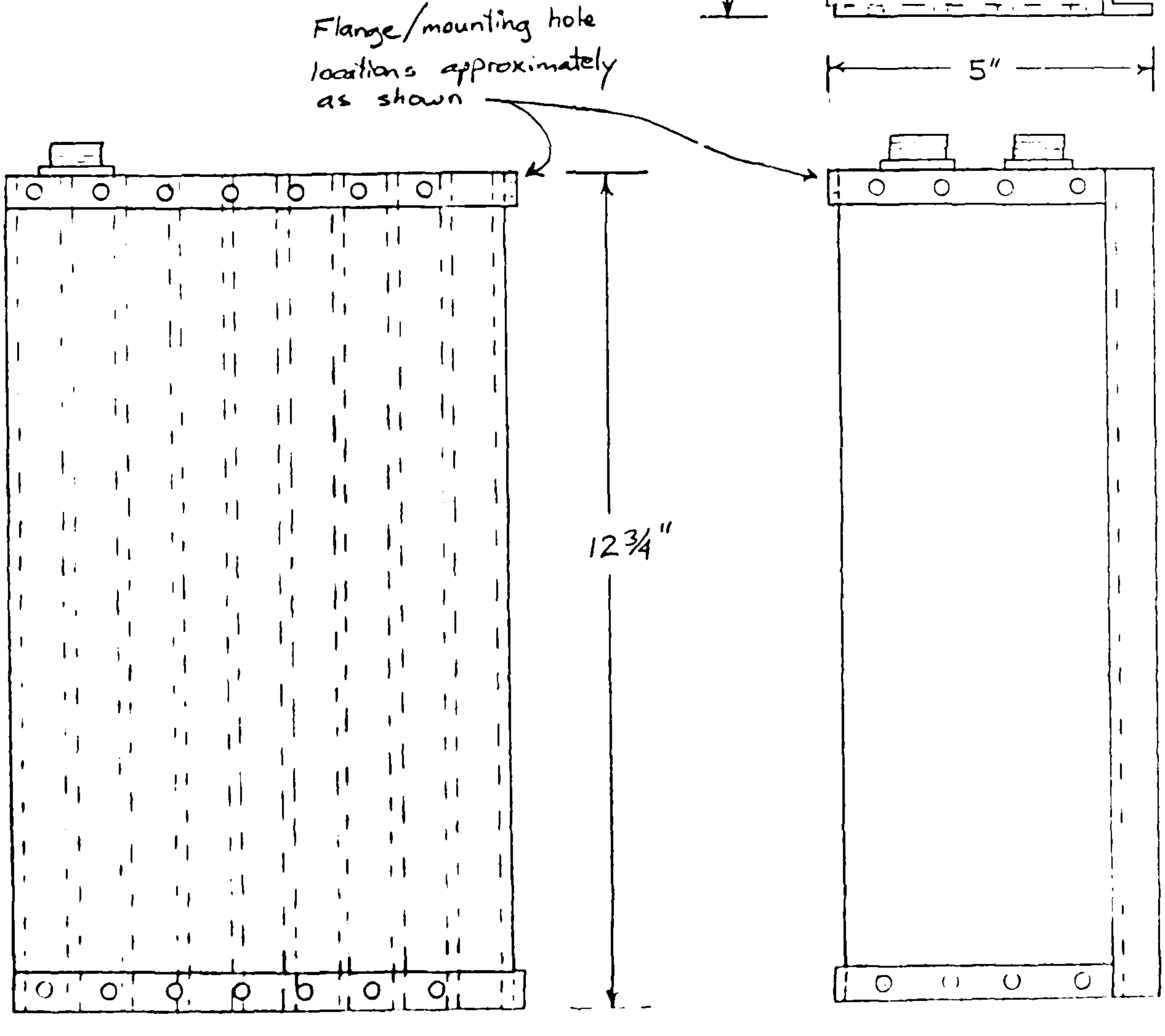
Design, Materials, Finishes, Coatings: The inverter shall be as light as possible, consistent with meeting other requirements herein. Aluminum or other lightweight materials shall be used where possible. Materials shall be selected and/or treated to resist corrosion and deterioration and dissimilar metals shall not be used in intimate contact with each other unless protected against galvanic corrosion.

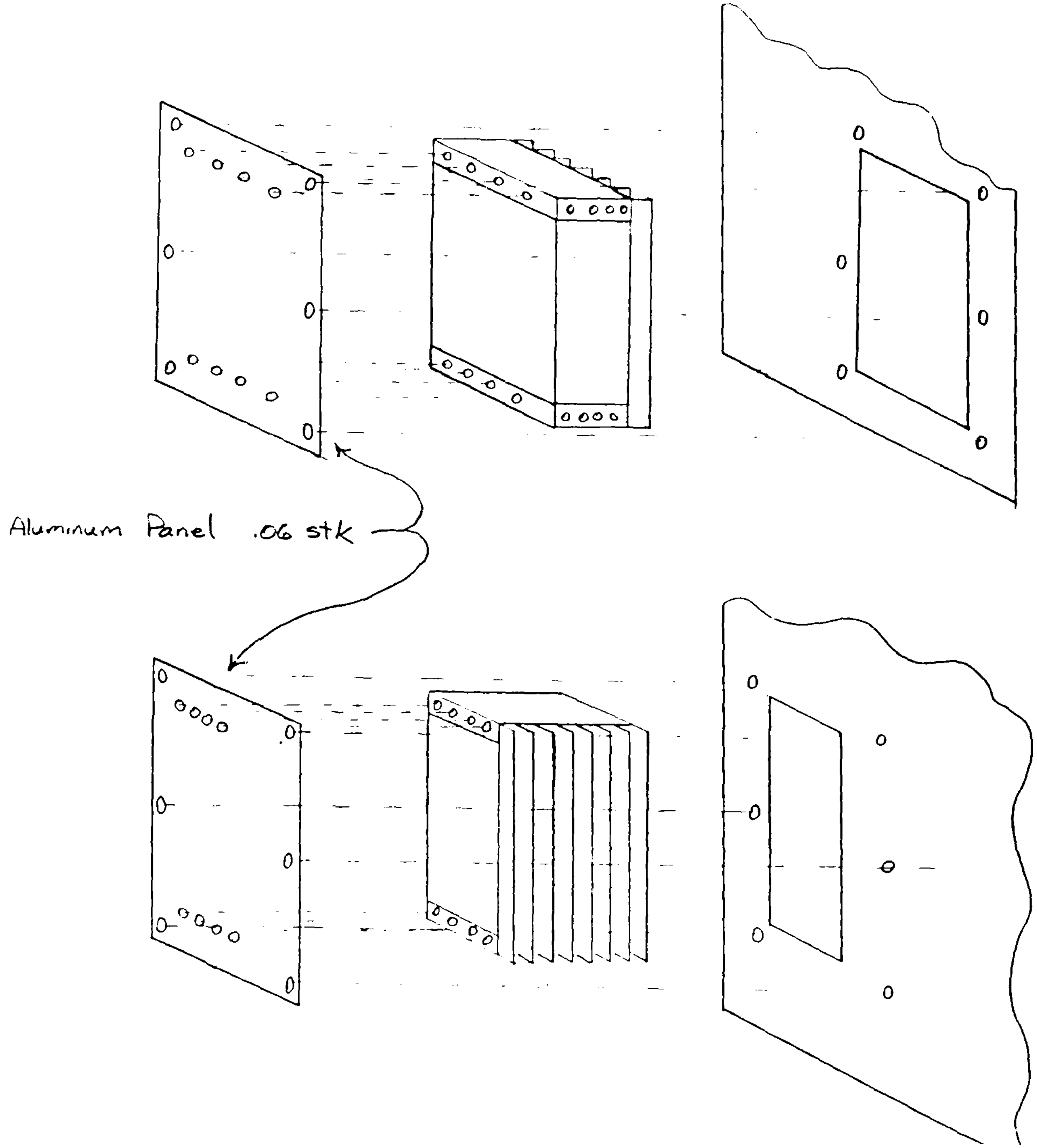
Motor Controller for 18 000BTUH
Vertical & Horizontal Compact
Air Conditioners

— GENERAL CONFIGURATION —

VSE SKETCH 0074-1
SHEET 1







Motor Controller should be desigr assuming a forc air supply of 1 @ 90°F over fir

VSE SKETCH
0074-1
SHEET 2

SOUTHCON
Southern Industrial Controls

April 22, 1987

Ms. Yvonne Chang, Electronic Engineer
VSE Corporation
900 Slaters Lane
Alexandria, VA 22314

Dear Ms. Chang:

Thank you for the opportunity to offer Southcon products for this 7.5 HP air conditioner application. We offer as follows below:

Southcon Magnum PWM AC adjustable frequency drive rated 7.5 HP 208/3 phase input and output packaged per VSE sketch 0074-1 sht. 1 and 0074-1 sht. 2.

Qty	
08	$1700.00 net each
50	1410.00 net each
100	1320.00 net each
500	922.00 to 1230.00 net each

All of the above pricing is based on the preliminary specifications and subject to review after complete examination of mil-specification requirements.

A developmental cost of $8000.00 dollars will apply. Compliance testing will be billed on a cost plus basis.

Delivery of first units will be 10-12 weeks ARO. Standard deliveries after prototyping 6-8 weeks ARO.

Terms: Net 30, US FUNDS
FOB Charlotte, NC
Freight Collect
Pricing in effect for 120 days

Please do not hesitate to call if questions arise.

Best regards,

Jeff Small

Jeff Small
Executive Vice-President
#JSYC CC: Clisby

3608 ROZZELLS FERRY RD. • CHARLOTTE, N.C. 28216 • 704/393-1636

TELEPHONE 606 525 2102

KECO

KECO INDUSTRIES, INC.

7375 INDUSTRIAL ROAD

FLORENCE, KENTUCKY 41042

22 April 1987

VSE
900 Slater Lane
Alexandria, Virginia 22314

Attention: Ms. Yvonne Chang
Electronic Engineer
EE/TS Group

Re: Revised Quotation
17 April 1987

Dear Ms. Chang:

We are pleased to be able to revise our non-recurring and production pricing as follows:

Non-recurring Engineering. **$37,643.**

By eliminating the EMI filter, we can reduce our production pricing as follows:

QUANTITY	8	50	100	500
PRICE	**$2,526.**	**$2,066.**	**$1,305.**	**$1,097.**

Production of 8 ea. test models, 10/12 weeks ARO.

We are looking forward to receiving an order in the near future.

Yours very truly,

Reginald L. Arthur
Reginald L. Arthur
Project Engineer

TELEPHONE 606 525 2102

KECO INDUSTRIES, INC.

7375 INDUSTRIAL ROAD

FLORENCE, KENTUCKY 41042

13 May 1987

VSE Corporation
900 Slater Lane
Alexandria, Virginia 22314

Attention: Ms. Yvonne Chang, Electronics Engineer
EE/TS Group

Re: KC-11, Inverter

Gentlemen:

This letter is to confirm my verbal quotation of 11 May 1987 concerning the Keco KC-11 Inverter.

8 ea.	$1886.
50 ea.	1936.25
100 ea.	1199.34
500 ea.	999.44

Total non-recurring Engineering is **$10,000.** Therefore, the total quotation is **$25,088.** We are looking forward to receiving your Purchase Order so we can start our final design configuration. If you have interface questions, please direct them, at this time, to John Dupps. We expect to hold the 12 week delivery after receipt of your order to proceed.

Yours very truly,

Reginald L. Arthur
Project Engineer

MANUFACTURERS OF SPECIALIZED REFRIGERATION AND AIR CONDITIONING EQUIPMENT

TELEPHONE 606 525 2102

KECO

KECO INDUSTRIES, INC.
7375 INDUSTRIAL ROAD
FLORENCE, KENTUCKY 41042

27 May 1987

VSE Corporation
2550 Huntington Avenue
Alexandria, Virginia 22303-1499

Attention: C. E. Anderson
Purchasing

Re: VSE Request for Quotation No. 081-87

Gentlemen:

Responding to the above solicitation, enclosed herewith are completed and signed copies of the following:

(1) VSE RFQ No. 081-87

(2) Attachment I -- Summary of exceptions taken by Keco and Keco's understanding of specific requirements

(3) Attachment II -- Statement of Income for period ending December 31, 1986

(4) Attachment III -- Detailed Cost Breakdown

(5) Attachment IV -- Representations, Certifications, and Other Statements of Offeror

To meet the required delivery dates as specified in the subject RFQ, Keco requires a Notice of Award by 1 June 1987.

CORPORATION

untington Avenue
.dria, Virginia 22303
/ 960-4600, TWX 710-832-1155

- [ ] Request for Proposal
- [x] Request for Quotation

THIS IS NOT A PURCHASE ORDER

AME AND ADDRESS, INCLUDING ZIP CODE	MAIL QUOTE TO ADDRESS ABOVE UNLESS OTHERWISE NOTED HERE
Keco Industries, Inc. 7375 Industrial Road Florence, Kentucky 41042 Attention: Rolf Tonseth	
MBER 081-87	REFERENCE REPLY TO: Carl E. Anderson, (703) 960-4600, Ext. 579
ABOVE NUMBER MUST APPEAR ON ALL QUOTATIONS RELATED CORRESPONDENCE.	PLEASE QUOTE ON THIS FORM. OFFEROR MUST FILL IN COLUMNS 1 THROUGH 13

	PJO NO.	1. TERMS	2. F O B
20, 1987	0500.0074	Net 30 Days	Florence, Kentucky
REPLY REQUIRED	CONTRACT NO.	3. SHIPMENT VIA	4. BEST SHIPPING DATE
27, 1987		Best Way	As required by contract

[ ] a. Offeror's quotation shall be in accordance with the specifications and drawings attached, if any.

[X] b. In the event an order is awarded pursuant to a U.S. Government prime contract, the flowdown of applicable Federal Acquisition Regulation (FAR) subcontract clauses, and Representations and Certifications of the vendor shall be applicable to any resultant procurement.

[X] c. Offeror is requested to complete and return the enclosed representations and certifications form if same is enclosed herewith

[ ] d. If Offeror's quotation consists of standard commercial catalog items, Offeror shall furnish a copy of his catalog pricelist for such items, otherwise, Offeror shall supply supporting documentation to justify/substantiate the prices quoted.

[ ] e. Proposals of $100,000 or more require Offeror's submission of SF 1411 and/or SF 1412 in accordance with attached instructions. (If this is a competitive procurement, buyer may delete this item e.)

[ ] Offeror certifies that the prices quoted do not exceed the prices charged all other customers, including the U.S. Government, for like or comparable quantities and conditions of sale.

IESS CLASSIFICATION [ ] SDB [ ] WOB [ ] SB [ ] LB

QUANTITY	SUPPLIES/SERVICES DESCRIPTION	7 UNIT PRICE	8 AMOUNT
8	Inverters and associated documentation in accordance with the attached Statement of Work entitled Exhibit "A" Specification No. 0074-1. Advise lead time. 4 ea. 13 weeks ARO 4 ea. 19 weeks ARO	LOT (See Atta	$25,088.00 chment I for
		1. exce	ptions taken
		2. Keco	s understanding of specific requirements.)

The offeror agrees that the prices proposed for each item are effective if this offer is accepted within ______ calendar days (60 calendar days unless offeror inserts a different time period).

MPANY NAME	10 SIGNATURE OF PERSON AUTHORIZED TO SIGN QUOTATION	11 DATE OF QUOTATION
[Ke]co Industries, Inc.	[signature]	27 May 1987
IF YOUR QUOTATION DEVIATES FROM SPECIFICATIONS	12 NAME AND TITLE OF SIGNER	13

7

Copy
[illegible]

ECO

Attachment I

EXCEPTIONS AND UNDERSTANDINGS WITH REGARD

TO KECO INDUSTRIES RESPONSE TO VSE RFQ 081-87

The following items are exceptions taken to Exhibit "A" specification VSE 0074-1; or are confirmations of Keco's understanding of certain portions of this specification. These exceptions and understandings, applied to Exhibit "A", represent the equipment which Keco proposes in response to RFQ-081-87.

1. POWER OUTPUT: The nominal inverter output voltage shall be 208V +/- 10%, 3 phase, 61 Hz +/- .5%.

2. CONTROL INPUT: Keco understands that the "sense" of this signal may be reversed, i.e., run signal to be more than 10 VDC, stop signal to be less than 1.5 VDC.

3. AUXILIARY POWER OUTPUT: Keco understands that this is to be changed to 5 VDC at 400 MA and that this would result in a lowering of the control input signal and the bite signals to about 5 VDC for high levels.

4. ITEM 6 OF THE "FEATURES" PORTION OF THE SPECIFICATION: "The +12 VDC signal to be sent to the logic indicating no faults" is available or is to be obtained from the bite signals specified elsewhere in the specification and is not a separate signal to be provided by the inverter.

5. RELIABILITY/LIFE: The value specified is understood to represent total service life not mean time between failures.

6. ENCLOSURE: EMI protection does not include an EMI filter at either the input power lines or the output power lines.

7. VENTILATION AIR: The pressure differential specified for the air flow over the heat exchanger is understood to be the preferred value, not a maximum upper limit.

8. ENVIRONMENTAL CONDITIONS: FUNGUS: The specific fungus spores to be used shall be those specified in MIL-STD-810D, Method 508.3, Table 508.3-II.

9. ELECTROMAGNETIC INTERFERENCE: As previously stated, no EMI filtering will be provided on either input or output lines.

ALS Corporation

24 April 1987

VSE Corporation
900 Slaters Lane
Alexandria, VA 22314

Attention: Ms. Yvonne Chang

Subject: Motor controllers

Reference: Your letter 0500.0039 of 9 April 1987

Dear Ms. Chang:

We have reviewed the specifications for the subject motor controllers as you requested. At this time our rough order of magnitude (ROM) estimates are as follows:

1) Development cost: $300,000 for Non-Recurring Engineering (NRE).

2) Price per unit after development:

a) Price for 8 units	$12,000 each
b) Price for 50 units	$10,000 each
c) Price for 100 units	$ 7,000 each
d) Price for 500 units	$ 6,000 each

Development costs include completion of package design and a unit ready for qualification testing. Additional estimates for qualification testing, reprocurement drawings, manuals and technical data can be furnished when the requirements have been established for these items.

ALS Corporation is very interested in being involved in the project and we look forward to the next step. I plan to call you in a few days to see if there is any assistance we can offer. Should you need additional information in the meantime, please contact me at (714) 956-9200.

Regards,

ALS Corporation

Stephen J. Jennings
Marketing Manager

SJJ/hjb

Copy [illegible]
Permit [illegible]

Total Control Inc.

36 Allison Road, Hightstown, NJ 08520 (609) 448-3076

[illegible] [illegible], 1987

Ms. Yvonne Chang
[illegible] Corporation
[illegible] Slaters Lane
Alexandria, Virginia 22314

Dear Yvonne:

Thank you for the opportunity to participate in the [illegible] controller development project.

Without a feasibility study, we cannot be sure if the [illegible] inverter requirements can be met.

Assuming that they can, a development project would [illegible] an estimated $500,000-$750,000. Actual cost would be based on time and materials. In quantities of 500-1000 pieces, the projected unit cost is $2000. Estimated development time is 12-18 months.

Once again, than you for considering Polyspede for [illegible] application.

Best regards,

Steven A. Schultz/SS.

Steven A. Schultz
Manufacturers' Representative

SAS:[illegible]
CC: Mr. Jim Walters, Polyspede Electronics Corp.

CENTRAL POWER ENGINEERING CORP

CPEC

27495 Diaz Road • Temecula, California 92390

April 17, 1987

VSE Corporation
900 Slaters Lane
Alexandria, VA 22314

Attention: Yvonne Chang

Reference: Letter of April 9, 1987 CPEC 11930
Phone Conversation 4/17/87

Dear Ms. Chang:

(1) As per our conversations delivery will occur 10 weeks ARO of (8) eight units. Cost for same will be $1,700 each as discussed balance will be 50 units - $1,160
100 units - 995
500 units - 895
net of all taxes and F.O.B. Temecula, California.

(2) No development changes for the initial design is contemplated. Qualification testing will be quoted on a per test basis.

(3) Units supplied will be within the envelope designated. As previously stated the power and control sections can be split allowing flexibility in application.

(4) Operation efficiency will be 94% MIN

(5) Input current can be limited to 100% of full load, however a motor trying to start against a "head" is most likely going to be at locked rotor. We are not aware of the motor characteristics you are using but suggest most motors use 254% voltage to start reach break away torque.

(6) Load acceleration adjustment is again available but is a function of torque requirements which is a function of current and volts. Again dependent on motor.

(7) Weight will be approximately 20 lbs. Electronics 8 lbs, contains heat sink, plugs etc. 12.

Phone USA (714) 676-0555 Telex 182-984 CPEC

(8) We have not quoted a remote circuit breaker.

(9) Input power will be spike suppressed to 20% max 20 u/s, overall 200 u/s.

(10) Manuals re: in/out and flow diagrams provided.

(11) All testing quoted on a by test basis upon order. R.O.M. costs are:

a.	altitude	- 1500
b.	temp	- 700
c.	humidity	- 2750
d.	fungus	- 6000
e.	vibration	- 2500
f.	shock	- 750
g.	EMI	- 2500

Thank you for considering our company in this opportunity.

Sincerely,

James F. Vallely

James F. Vallely
President, CFEC

JFV:po

AC MOTOR SPEED CONTROLS

ZYCRON

April 20, 1987

To: VSE Corporation
900 Slaters Lane
Alexandria, VA 22314

Att: Ms. Yvonne Chang

Dear Ms. Chang:

Confirming our telephone conversation of Thursday, April 16, 1987, we regret that we must decline to submit a proposal for the requirements of your April 9, 1987 letter to Paul Landino.

The extensive specifications and the amount of development time required to accomplish your requirements would be prohibitive for our company to undertake at this time.

Thank you for your continued interest in Zycron Systems, Inc. and we would like to be considered for future projects.

Respectfully,

Joseph E. Oliwa

Joseph E. Oliwa
Sales Manager

cc: Landino/Cloetingh

THE SUPERIOR ELECTRIC COMPANY

BRISTOL CONNECTICUT 06010
TELEPHONE (203) 582 9561

MARTIN KAPLAN
Vice President for Research & Development

April 16, 1987

Ms. Yvonne Chang
Electronic Engineer - EE/TS Group
VSE Corporation
900 Slaters Lane
Alexandria, VA 22314

Subject: Motor Controllers

Dear Yvonne:

We appreciated the opportunity to review your requirements, and also to meet with you and your colleagues at Fort Belvoir.

Although we have a motor drive product that we can modify to meet your requirements, we do not have the resources presently available to engineer the required modifications within your limited time frame.

We would appreciate being kept in mind for other opportunities.

Thank you for your consideration.

Very truly yours,

Marty Kaplan

MK:cl

MANUFACTURERS OF ELECTRONIC AND ELECTRICAL CONTROL EQUIPMENT

DYNAMATION INCORPORATED

process instrumentation

April 14, 1987

Ms. Yvonne Chang
VSE Corporation
900 Slaters Lane
Alexandria, Virginia 22314

Subject: Motor Controllers 0500.0039

Dear Ms. Chang:

Thank you very much for your inquiry of April 9.

Sorry we won't be able to be competitive this time.

Yours very truly,

DYNAMATION, INCORPORATED

Dave Jewett - lj

Dave Jewett

DJ:lj

REVERSE ENGINEERING

TELEPHONE CONVERSATION RECORD

Date: 4/16/87

~~NSN~~ JOB NO: 0500.0039

Nomenclature:

Part No.:

Person ~~Calling~~: ~~RECEIVE~~ RECEIVING CALL: YVONNE CHANG
VSE Reverse Engineering Center

Phone No.:

RECIEVED CALL FROM:
~~Person Called~~/Title: SOLOMON TURKEL, SALES REPRESENTATIVE
Company Name and FSCM: FROM WESCO FOR CONTRAVES GOERZ

Phone No.:

Called to Discuss:
TO GIVE QUOTATION FOR 7 1/2 HP INVERTER PER SPECIFICATION PROVIDED BY VSE.

Results of Conversation:
INITIAL $21,000.00 NONRECURRING ENGINEERING FEE
PRICES FOR UNITS AFTER THE ABOVE FEE:
1-8 UNITS @ 1,517.00
50 UNITS @ 1,445.00
100 UNITS @ 1,392.00
500 UNITS @ 1,351.00

Distribution: (1) Send copy to the Action Code
(2) Place Copy in Appropriate Package

28 Apr 1987
0500.0039

ALS Corporation
1400 N. Baxter Street
Annaheim, CA. 92806-0606

Attention: Larry Schaeffer

Subject: Motor Controllers

We would like to offer our thanks and appreciation for your rapid response to our request for information. We have closely reviewed your estimate for the 7 1/2 HP inverter per specifications provided by VSE, and carefully compared it with other estimates provided by other candidates.

Due to more simplistic designs and lower costs offered by other candidates, we must regretfully decline your proposal at this time.

Again, we greatly appreciate all your time and effort.

Very truly yours,

VSE CORPORATION

Yvonne Chang
Electronic Engineer
EE/TS Group

YC:lh

APPENDIX C

MATRICES

MATRIX I

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
ABACUS CONTROLS, INC. 80 Readington Rd. P. O. Box 893 Sommerville, NJ 08876-0893 Tel# 201-526-6010 Point of Contact: Larry Albrecht	Part No. 278-1M Output Power 7500 VA, Adjustable Output Frequency up to 450 Hz. Output Voltage of 120/208V for 60 Hz Output 3-Phase Input, Input Frequency 47 to 65 Hz. 380 to 420 Hz is a No Charge Option. Input Voltage 208VAC ± 10%.	Operating at 0°C - 40°C. Nonoperating -20° - 85°C.	Less than or equal to 95% to 25°C, Less Than or Equal to 75% to 40°C and Less Than or Equal to 45% to 50°C	Not Available	Proven Reliability	Between 70 to 80% (Typical 75%) At Least 70% From 40% of Full Load to Full Load	@ $11,058.00		(Inches) Height - 17 1/2 Width - 19 Depth - 24 Weight - 245 lbs.	Units less than 6 KVA are standard 19" Rack Mounted. Larger Units Are Cabinet Models. These Units Are Too Large and Would Not Be Good Candidates.
ALLEN-BRADLEY 9115 Guilford Rd. Suite 100 Columbia, MD 21046 Tel# 301-792-7881 Point of Contact: Steve Hurd	Bulletin 1332-DAA Input 3-Phase 208V Input, 24 Amps at 50/60 Hz. Output 7.5 - 10 HP. Not Tested at 400 Hz.	Operating Temp: -10° to +50°C. Storage -25° to +65°C. Altitude 3,300 Ft Without Derating.	Less than 90% Non-condensing.	Shock: 16 G Peak for 11 MS Duration. Vibration: Below .5 G, Amplitude 0.8 mm P-P, Direction X, Y, Z.	Not Available	Not Available	@ $2,086.20	Domestic	(Inches) Height - 25.6 Width - 12.2 Depth - 8.3 Weight - 44.1 lbs. Enclosure Nema Type 1 or Open Chassis.	Electrically Feasible, However More Information Is Needed.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS TEMP	HUMIDITY	SHOCK & VIBRATION	RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
AC TECHNOLOGIES 24 Hopedale St. Hopedale, MA 01747 Tel# 617-478-4823 Point of Contact: Larry Nugent (617) 473-3543 DYNAMATION Richmond, VA Point of Contact: Dave Jewett (804) 794-7667	Input 230 VAC ± 12% (208V Tap Change on Control Transformer) 50-60 Hz ± 2 Hz 3-Phase Output Output 0-230VAC, 3 PH (Adjustable to 208V @ 60 Hz or 220 @ 50 Hz) 0-60 Hz (to 90 or 120 Hz by Removing Jumpers) 100% Nominal 115% (1.15 Service Factor) 180% for 1 Minute.	0 - 55°C Chassis, 0-40°C Enclosed	Less Than 95% Non-condensing.	Not Available	Not Available	92% .95 PF	For 10HP Chassis @ $2,175.00 for Mass Quantities The OEM Multipliers Are: 1-4 Units = .85, 50-99 Units = .70 100-up = .67	Assemb, Domestic May Have Foreign Parts.	Height - 24.00" Width - 12.00" Depth - 9.00" Distance Between Mtg Holes Centers.	Has Possibility Of Being A Good Candidate.
EATON CORP.* Electrical and Electronic Sales Baltimore Office 21 Govenors Ct. Baltimore, MD 21207 Tel# (301) 265-1630 Point of Contact: Jim Sullivan *Has done work for Ft. Belvoir	For Standard Unmodified Unit Input Power: 480 VAC + 5%, -10%, 3-Phase, 50/60 Hz Output: 460VAC, 12.6 A 1-66 Hz ± 1% of Set 150% Current for 1 Minute	Storage Temp: -20°C to 65°C. Operating Temp: 0°-40°C Altitude 1000M (3300 ft.)	95% Non-condensing	Not Available	Pretested Components Printed Circuit Thermal Stress Cycle Computer Test and Precalibrated PCB's Final Test. Burn-In With Motor Load.	Not Available	For Unmodified Units: Variable Torque @ $3,175.00 Constant Torque @ $3,925.00	Domestic	Height - 15" Width - 14" Depth - 13" Weight - 42 lbs. for Nemai or Chassis	Could Be A Good Candidate By Using a Step Down Transformer We Would Get 208V. In Addition They Are Looking for Possibility of Modifying Unit So That It Can Be 208, Without a Transformer.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
CONTRAVES GOERZ CORP. 2600 Liberty Ave. Pittsburgh, PA 15222-4616 Tel# (412) 261-8600 Point of Contact: William Jollie (301) 563-8268 WESCO, INC. Westinghouse Supply Co. Turkel, Sol District Eng. Mgr. (703) 450-6880	Standard Unit Input: 208/230V 50/60 Hz They Claim That 400 Hz Should Not Be a Problem. 3-Phase Output; 208/200/208/ 220/230 VAC. 10 HP 30 AMPS, 7 1/2 HP 23 AMPS. 3-Phase Freq: 50, 60, 72, 90, 120, 180 Hz (240, 360 Hz Also Available)	Ambient Temp: -10 - 40°C Storage: -20 - 60°C	90% RH No condensation	Vibration: 1G Max at Less Than 20 Hz, 0.2 G Max at 20 to 50 Hz.	MTBF 2000,000 Hrs. (Meantime Between Failures)	Energy is Consumed Efficiently, Through Innovative Technique of Voltage Control. Includes Anti-Stall Protection.	Standard Unit for 10 HP @ $1,670.00 1-4 = .86 5-9 = .84 10-24 = .82 25-100 = .80 100-up = .77	Foreign	Weight - 29 lbs. Height - 13.8" Width - 7.9" Depth - 8.3"	Their Unit is a Yaskawa Unit.
FENNER INDUSTRIAL CONTROLS, INC. 1-050 - 21st. Ave., North Minneapolis, MN 55441 Tel# (612) 553-1596 Point of Contact: Barry Gleit	Input: 3-Phase AC 208/60 Hz Permissible Freq Range 5% Output: 10 HP 12.6 KVA Current: 33 A 3-Phase 208 VAC 7 1/2 HP is 24 A	Ambient: -10°C to +50°C. Atmosphere Should Be Free From Corrosive Gas. Altitude Less Than 1,000 M.	Ambient Humidity: Below 90% To Be Free From Condensation.	Vibration: Less Than 0.5 G.	Not Available	Not Available	Standard 1-25 @ $2,183.00	Foreign	Height - 15.60" Width - 9.75" Depth - 7.41" Weight - 20.9 lbs.	Called for extra information; will call back.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
FINCOR DRIVES AND MOTORS: Represented by: B&B MOTORS 114 Woodlawn Rd. Berun, CT 06037 Tel# (203) 828-8550 Point of Contact: Rick Seiler Also Represented by: GREGG & ASSOCIATES, INC. P. O. Box 1437 Midlothian, VA 23113 Tel# (804) 379-1562 Point of Contact: James D. Lochhead	Input: 230 VAC 50 or 60 Hz Output: 30 AMPS, 10 HP, 3-Phase 0-230 VAC 0-60 Hz Magnetic Control Voltage 24 VDC Control Reference Voltage 10 VDC 3-Phase	Ambient Temp: 0 to 40°C For Enclosed Models. 0 to 55°C For Un-enclosed Models	Not Available	Not Available	Not Available	Controller Alone: 95% Controller With Motor: 85%	Not Available	Domestic	Height: 26" Width: 20.75" Depth: 11.0" With Door Completely Ajar 27.0" FOR UNEN-CLOSED UNIT ENCLOSED UNIT: Height: 26" H_2: 34.3" Width: 20.75" Depth: 11.56" M1: Height Between Mounting Holes, 18" M2: Width Between Mounting Holes, 19.75"	Electrically This Drive Has Possi-bilities; However, More Information Is Needed To Make A Decision.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
GENERAL ELECTRIC Speed Variator Products Dept. Marketing - Building 63-2 1100 Lawrence Pkwy Erie, PA 16531 Point of Contact: Dave Schraeder Tel# (814)875-2234 Charlottesville, VA (804) 875-2963	Input: 208 or 230 VAC 3-Phase 60 Hz Voltage Var. ± 10%, Freq. ± 2 Hz Output: 10 HP 31 AMPS 1.5 HP 24 AMPS 208/230 VAC Range of Freq 0-60 Hz Constant Torque 60-240 Hz Extended Freq	Ambient Temp: -10 to 40°C Altitude 0-3300'	90% Non-Conden-sing	Vibration: Less Than 0.5G	Not Available	Loss: 200 Watts	For 10 HP @ $3,340.00 For 7 1/2 @ $2,195.00	Domestic Drives System in Japan	Weight: 27 lbs. Height: 19.5" Width: 9.7" Depth: 7.2"	Have a smaller, new unit which they feel would be better for us; will call us.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
HARMON COMMONWEALTH DRIVES AND CONTROL SYSTEMS 5411 Old Frederick Rd. Baltimore, MD 21229 Tel# (301) 624-7100 Point of Contact: Terje Gulbrandsen	As of Now Standard With Transformer or Modification Input: 460 VAC Current at 50/60 Hz 16.2A 3-Phase 13 KVA Output: 10 HP KVA = 12.0 KW = 9.5 Overload Current 12.5A 50% AMPS at 30 Seconds. Starting Current 26.3 AMPS. Constant Torque Freq. at 60 Hz Out ACUSPEDE 280	Storage $-30^{o}C$ to $65^{o}C$ Ambient (Chassis) $0^{o}C$ to $55^{o}C$	To 95%	Not Available	Not Available	Not Available	@ $2,873.00 For Unmodified Unit	Domestic	Width: 22.00" Height: 38.00" Depth: 11.00" Weight: ?	Recent Conversation Revealed That They Do Have Other Lines That Are Lower in Voltages Which Have Recently Been Introduced. Also They Do Have Toshiba Japanese Controllers Which Possess The Electrical Characteristics We Desire. He Will Send Added Information Immediately.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
LOUIS ALLIS DRIVES & SYSTEMS 16555 West Ryerson Rd. New Berlin, WI 53151 Tel# (414) 782-0200 Point of Contact: Ed Peterson	Input: 208/230 VAC ± 10% Nominal Rated Voltage. Freq.: 50/60 Hz ± 2 Hz. 3-Phase 3-Wire, Non-rotation Sensitive. Input RMS AMPS to 1.5 x Motor Full Load Amp. Output: Up to 0 230 Volts, 3-Phase Ungrounded Freq. Range: 3-60 Hz Constant 10 AMPS Output RMS, 11 KVA.	Ambient Temp: 0 to $40^{o}C$ Storage Temp: -20 to $60^{o}C$ Altitude: 3300'	Noncon-densing Relative Humidity to 90%	Vibration Less Than 0.5 G	Not Available	95%	@ $4,789.00	Domestic	Weight: 36 lbs. Height: 16.73" Width: 15.04" Depth: 7.71"	Have Not Been Tested at 400 Hz and Would Need Modification. However, It Does Seem to be Good Candidate.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
LOVEJOY ELECTRONICS INC. 9 Lexington Ave. Monclair, NJ 07042 Tel# (201) 783-7442 Point of Contact: Al D. Williams	They Have Units That Can Intake 208 Volts AC; However, Has Not Yet Been Forwarded. However, Info Has Been Forwarded On 460 VAC 3-Phase Units at 10 HP. Freq: 0-60 Hz Input Output - 0-480 Hz Tested. The 208 VAC Units Are Very Similar in Characteristic. According to Salesman, Info on 208 VAC Units Will Be Hand-Delivered 3/2/87 or 3/3/87.	Ambient 0-50°C Storage Temp: 0-70°C	0-95% Non-condensing Altitude: 3300 Ft.	Not Available	MTBF 20,000 Hrs.	.96 DF .05% 1°C	Will Be Forwarded Shortly @ $1,800.00 100 @ $1,485.00 500 @ $1,200.00 50 A $1,600.00	Domestic American Series Height: 13.4" Width: 10.3" Depth: 8.3" Weight: 25 lbs.	Dimenions Given Are Only For Larger 460 VAC Units. Dimensions For Smaller Units Will Be Forwarded Later.	They Do Have Military Experience and Are Familiar With Military Standards.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
NORDIC Represented by: BCS INDUSTRIAL 109 Evergreen Dr. Downington, PA 19335 Tel# (215) 269-7576	Do Not Make Variable Frequency Drive; Only SCR's.									
MITZUBISHI ELECTRIC SALES AMERICA 3205 Saturn Ct. Nocross, GA 30092 Point of Contact: Michael Protelli Tel# (312) 298-9223	Series FR-F2 Power Supply: 3-0, AC 208 V or AC 230 V at 60 Hz AC 208 V + 10%, + 5%. Control Method PWM, Voltage Control Output Rating: 10 HP, 13.1KVA Rated Output Current - 33A Attention: Michael Portelli	Ambient $14^{o}F$ to $122^{o}F$ Shall Not Freeze	Below 90% Non- condensing	Less Than 1/2 G	MTBF 400,000 hrs	Will Get It For Us - Not Yet Available	7 1/2 HP @ $2,598.00 1 - OEM .56 10 HP @ $3,624.00 1 - OEM .56	Foreign (Japanese)	7 1/2 HP: Width: 9.8" Height: 15.7" Depth: 7.5" Weight: 18.7 lbs. 10 HP: Width: 9.8" Height: 15.7" Depth: 7.5" Weight: 19.8 lbs.	Electrical Characteristics Are Workable; Size is Supposed To Be Small. Open Chassis Type But More Info Needed.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
BELCON INC. Formerly: RUMBLE EQUIPMENT LIMITED 60 Walker Drive Brampton, Ontario Tel# (416) 458-1100 Point of Contact: George Usher	Inputs: 208 V, 3-Phase 60 Hz, 50 Hz Outputs: 0-230 V Constant Torque Extended Ranges To 180 Hz Available Adjustable Current Limit 60 to 180% Output: 10 HP, 7.5 KW	Not Available	Not Available	Not Available	Not Available	95 to 97%	Not Available	Foreign	Cabinet Only Height: 24" Width: 2.5" Depth: 11.5" Weight: 115 lbs.	Too Large; Do Not Have Open Chassis.
POLYSPEDE ELECTRONICS CORP. P. O. Box 31024 Dallas, TX 75231 Tel# (214) 363-7245 Point of Contact: Bruce Stanley TOTAL CONTROL INC. Hightstown, NJ Steve Schultz	Input Power: 200 to 220/ 230 V ± 10%, 50/60 Hz ± 5%, 3-Phase Output Rating: 3-Phase 200 to 220/ 230 VAC, Continuous Output RMS Current: 32 AMPS, 7.5KW, 10 HP Output Freq.: 6 to 120 Hz	Ambient Temp.: 14-104°F Storage: 14-158°F Altitude: 3300 Ft.	20-90% RH (Non condensing)	Not Available	Not Available	Not Available	10 HP @ $1,897.00 OEM Schedule 1-4 Units Multiplier is .80 50-100 Units = .69	Foreign	Height: 15.6" Width: 10.8" Depth: 7.4" Weight: 22 lbs. NEMA 4 and 12 Enclosures	Electrically Feasible - Could Be A Good Candidate.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS TEMP	ENVIRONMENTAL FACTORS HUMIDITY	ENVIRONMENTAL FACTORS SHOCK & VIBRATION	RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
RELIANCE ELECTRIC 17 Govenors Ct. Baltimore, MD 21207 Point of Contact: Mike Salvatore Tel# (301) 298-2200	They Only Offer 3-Phase Input Up To 5 HP.	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Does Not Meet Our Power Ratings Off The Shelf. They Are Willing To Discuss Proto-typing; However, It Is Not Competitive.
[illegible]NDO MOTOR CONTROL [illegible]150 W. 6th Ave. [illegible]roomfield, CO 80020 [illegible]oint of Contact: [illegible]ark Duzinski [illegible]el# (303) 469-1742 [illegible] [illegible] Jeffreys [illegible] Jeffreys Co. [illegible] (301) 557-8881	For 208 VAC Only 1-0 Inputs Are Offered. For 3-Phase Input The Supply Voltage Would Be 380 V to 440 VAC. Output Voltage Would Be 35V + 0380 V 3- Phase ± 10% 11 KW, 14.5 KVA, [illegible] AMPS	Permissi-ble Coolant Temp. -10°C to 40°C Storage Temp.: -10°C to -70°C	20 to 90% RH No con-densation	Resistance to Shock 0.4 G	Not Available	Not Available	@ $1,838.00	Not Available	Height: 16" Width: 11" Depth: 7.3" Weight: 24 lbs.	Would Need Modi-fication For Voltage; Cannot Buy Off The Shelf.

AD-A189 853 VALUE ENGINEERING STUDY OF STANDARD FAMILY OF MILITARY HORIZONIAL AND VER..(U) USE CORP ALEXANDRIA VA ENGINEERING SYSTEMS GROUP Y CHANG ET AL. 29 JAN 88 2/2

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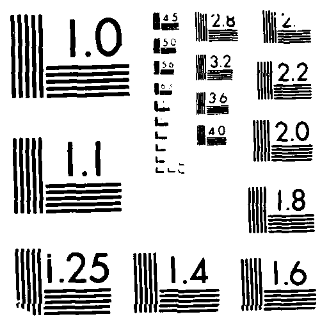

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU ... STANDARDS ...

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
SIERACCIN/ MAGNEDYNE 2258 Rutherford Rd. Carlsbad, CA 92008 Point of Contact: Mike Davis	Do Not Make AC Motor Controller; Expressed Desire To Prototype And Manufacture For Us At MIL Standard Requirement. They Do Have Military Experience With Military AC Motors.									
SQUARE D COMPANY 900 Hungerford Dr. Suite 235 Rockville, MD 20850 Point of Contact: E. E. Birkenshaw Tel# (301) 424-1442	200 VAC, 230 VAC, 460 VAC 3-Phase in 50/60 Hz 10 HP Output Rating At 22.0 AMPS For Open Chassis Model	Ambient Temp: 0 to 40°C Altitude: 3300 Ft.	Max 95% Non-condensing	Not Available	Not Available	Not Available	@ $6,322 16% Off For Federal Government	Domestic	Height: 23.5" Width: 15.5" Depth: 8" Weight: ?	They Are A Government Engineering Services Company. They Have Military Experience.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
SOUTHERN INDUSTRIAL CONTROLS 3808 Rozzelle Ferry Road Charlotte, NC 28206 Tel# (704) 393-1636 Point of Contact: Jeff Small	Input Voltages: 230 VAC ± 10% 3-Phase 50/60 Hz Output Up To 230 VAC 10 HP 60 Hz	Ambient Temp: $-10^{\circ}C$ To $50^{\circ}C$	0-95% Non-condensing	Not Available	Not Available	Not Available	7 1/2 HP @ $2,100 10 HP @ $2,750	Domestic	Open Chassis Dimensions Not Given In General Information Height: 21" Width: 18 1/2" Depth: 8"	Electrically and Physically It Is A Very Good Candidate.
Rep. for PARAMETRICS: TRANSMISSION ENGINEERING CO. 3569 Citation Rd. Baltimore, MD 21221 Tel# (301) 682-4900 Point of Contact: Gordon Roberts	Input: 208V/230V 3-Phase 50/60 Hz Output: 24 AMPS 0.6 Hz To Max Which Is 180 Hz. 3-Phase 10 KVA Can Handle 400 Hz With Slight Modification	Ambient Temp: $0-40^{\circ}C$ Altitude: 0-3000 Ft	0-95% RH	Not Available	Not Available	Not Available	Approx. @ $4,000	Domestic	Not Available	More Information Is Needed; However, Electrically It Is A Good Candidate.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS TEMP	ENVIRONMENTAL FACTORS HUMIDITY	ENVIRONMENTAL FACTORS SHOCK & VIBRATION	RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
VEE-ARC CORP. 50 Milk St. Westbourough, MA 01581 Tel# (617) 366-7451 Point of Contact: Walter Neru	Input Ratings: 230 VAC ± 10% 3-Phase 50/60 Hz ± 2 Hz .95 PF Min. Output. Sine-Weighted PWM Voltage: 0-230 VAC Freq: 3-60 Hz Constant Torque 10 HP, 11.2KVA RMS AMPS: 28.0A	Ambient Temp: 0-50°C	Not Available	Not Available	Not Available	95-97% At Full Load	@ $4,335.00	Domestic	Height: 19" Width: 18" Depth: 10"	Electrically Feasible.
VOITH TRANSMISSIONS INC. 7 Pearl Ct. Allendale, NJ 07041 Tel# (201) 825-8855 Point of Contact: Dieter Lagendorf	The Units Are Physically Too Large. They Are All Huge Rack Mounted For High Power Ratings.	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Foreign	Not Available	Not A Good Candidate.

PRELIMINARY MATRIX OF MOTOR CONTROLLER MANUFACTURERS
(continued)

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	ENVIRONMENTAL FACTORS			RELIABILITY FACTORS	EFFICIENCY VALUES	INDICATED COSTS	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS & CONCLUSIONS
		TEMP	HUMIDITY	SHOCK & VIBRATION						
ZYCRON SYSTEMS INC. 72 Acton St. West Haven, CT 06516 Tel# (203) 932-8471	Input 230V + 10%, -5% 30 Output 230 VAC 10 HP, 30 AMPS 3-0. Freq. Reg. ± 1% Standard	Operating 0-60°C Ambient Temp: -20 to 60°C	0-90% Non-condensing	Not Available	Not Available	Not Available	Not Available	Domestic	Height: 32" Width: 20" Depth: 8"	Electrically and Physically It Appears To Be A Very Good Candidate.

REVISED MATRIX FOR 10... [illegible]

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	TEMP.	HUMIDITY	SHOCK AND VIBRATIONS	RELIABILITY	EFFICIENCY VALUES	INDICATED COST	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS
AC TECHNOLOGIES 24 HOPEDALE ST. HOPEDALE, MA 01747 (617)478-4823 CONTACT: LARRY NUGENT LOCAL REP: DYNAMATION RICHMOND, VA DAVE JEWETT	INPUT 230 VAC PLUS OR MINUS 12% (208V TAP CHANGE ON TRANSFORMER) 50-60HZ, PLUS OR MINUS 2 HZ. THREE PHASE INPUT AND OUTPUT. OUTPUT: 0-60 HZ. IN PRO-CESS OF DEVELOP- 7.5 HP AND 10 HP FOR SAME DIMEN- SIONS AND PRICE AS THE 7.5 AND 10 HP FOR 460 VAC UNIT.	0 TO 55 DE- GREES CENTI- GRADE	LESS THAN 95% NON- CONDENSING	NOT AVAIL- ABLE	NOT AVAIL- ABLE	92%	FOR EXIST- ING UNITS FOR 7.5 HP: @$1360.00 OEM MULTI- PLIERS: 1-4: .85 5-9: .81 10-24: .77 25-49: .73 50-99: .70 100-UP .67	DOMESTIC ASSEMBLED IN US. PARTS MAY BE JAPA- NESE.	HEIGHT: 16 " WIDTH: 12 " DEPTH: 9 " WEIGHT:	MR. NUGENT WILL GET LOCAL REP. TO GIVE US EXTRA INFO NEEDED. THE 208V UNITS WILL BE AVAILABE IN A MONTH OR TWO. THEY WILL COST ABOUT THE SAME AS 460V UNITS AND WILL HAVE SAME DIM- ENSIONS.
CONTRAVES GOERZ CORPORATION 2600 LIBERTY AVE PITTSBURGH, PA 15222-4616 CONTACT: WILLIAM JOLLIE (412)261-8600 LOCAL REP: WESCO INC. BALTIMORE, MD. SAL TURKEL (301)563-8268	STANDARD UNIT HAS INPUT OF 208 VAC 50/60 HZ INPUT. THEY CLAIM THAT 400 HZ SHOULD NOT BE A PROBLEM. 3- PHASE. OUTPUT: 208/220/230/ VAC 7.5 HP, 23 AMPS. FREQUENCY: 50,60, 72,90,120,180 HZ.	AMB. TEMP: -10 TO 40 DE- GREES CENTI- GRADE	90 % RH NO CONDEN- SATION.	VIBRATION IS 1G MAX. AT LESS THAN 20 HZ .2G MAX AT 20 TO 50 HERTZ.	MTBF: 200,000 HOURS	ENERGY IS CON- SUMED EFFI- CIENTLY THROUGH INNOVA- TIVE TECH- NIQUE OF VOLTAGE CONTROL.	STANDARD UNIT OF 7.5 HP @$1670.00 OEM MULT.: 1-4: .86 5-9: .84 10-24 .82 25-100 .80 100-UP .77	FOREIGN MADE BY YASKAWA	HEIGHT: 13.8 " WIDTH: 7.9 " DEPTH: 8.3 " WEIGHT: 29 LBS.	LOCAL REP: WILL GET BACK TO US TO SET AN APPOINTMENT TO SHOW US A DEMO UNIT
FENNER INDUS- TRIAL CONTROLS, INC. 14050 21ST AVE. N. MINNEAPOLIS, MINNESOTA 55441 612-553-1596 CONTACT: GWEN OLSON LOCAL REP: BARRY GLEIT COLUMBIA, MD (301)995-1215	INPUT: 3-PHASE 208 VAC 60 HZ 5% PERMISSIBLE FREQ. RANGE OUTPUT: 3-PHASE 208 VAC 7.5 HP OUTPUT CAPACITY 9.2 KVA CURRENT RATING: 24 AMPS	AMB. -10 TO 50 DEG CENTI- GRADE ALTI- TUDE: LESS THAN 1,000 METERS	AMBIENT HUMIDITY: BELOW 90% TO BE FREE FROM CON - DENSATION	VIBRATION LESS THAN 0.5 G	HAS BEEN ASKED FOR.	HAS BEEN ASKED FOR	FOR STAN- DARD UNIT: @$2,183.00 OEM MULT. HAVE BEEN ASKED FOR	FOREIGN MADE BY MITZUBI- SHI	HEIGHT: 15.60" WIDTH: 9.75" DEPTH: 7.41" WEIGHT: 20.9 LBS	LOCAL REP IS TRYING TO ACQUIRE MORE INFO FOR US AND IS GETTING DEMO READY FOR A MEET- ING.

REVISED MATRIX FOR 18,000 BTU/HR AIR CONDITIONER

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	TEMP.	HUMIDITY	SHOCK AND VIBRATIONS	RELIA-BILITY	EFFICIENCY VALUES	INDICATED COST	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS
GENERAL ELECTRIC SPEED VARIATOR PRODUCTS DEPT. 1100 LAWRENCE PARKWAY ERIE, PA 16531 CONTACT: DAVE SCHRAEDER (814)875-2234	INPUT: 208 VAC THREE PHASE 60 HZ VOLTAGE VAR. PLUS OR MINUS 10%. FREQUENCY VAR: PLUS OR MINUS 2HZ OUTPUT: 7.5 HP 24 AMPS CURRENT RATING.10-60 HZ CONSTANT TORQUE OUTPUT FREQUENCY	AMB TEMP -10 TO 40 DEG CENTI-GRADE ALTI-TUDE 0 TO 3300FT	90 % NO CONDENSA-TION	VIBRATION IS LESS THAN 0.5 G	HAS BEEN ASKED FOR	LOSS: 200 WATTS MORE INFO. HAS BEEN ASKED FOR	STANDARD 7.5 HP UNIT: @$2,195.00 MORE INFO HAS BEEN ASKED FOR MASS QUAN-TITY PRICES	FOREIGN MADE IN JAPAN BY DRIVES SYSTEMS GE OWNS 50% OF THIS COMPANY.	HEIGHT: 19.5" WIDTH: 9.7" DEPTH: 7.2" WEIGHT: 27 LBS.	MR. SCHRAEDER IS TRYING TO FIND A LOCAL REP THAT CAN COME TO SEE US. THE PER-SON WHO WAS GOING TO HAN-DLE IT LEFT. HE FEELS THAT WE NEED A SPECIAL UNIT THAT IS SMALLER AND MORE FITTING TO OUR APP-LICATION. IT IS A SPECIAL PURPOSE DRIVE OFFERED TO SPECIAL CUST-OMERS. IT IS NOT LISTED IN REGULAR CATA-LOGUE. REP WILL GIVE MORE INFO.
HARMON COMMON-WEALTH DRIVES AND CONTROL SYSTEMS 1411 OLD FREDE-RICK RD BALTIMORE,MD CONTACT: . GULBRANDSEN (301)624-7100 REPRESENTATIVES FOR: EMERSON MOTOR CONTROLLERS	AS OF NOW INFO AVAILABLE IS FOR 460 VOLTS AC UNITS. REP IS TRYING GET US MORE INFO ON 208 VOLTS AC THEY HAVE DOMESTIC UNITS AND ALSO TOSHIBA UNITS. REP WILL ME WITH ME 3/18 AT 10:00 AM	STOR: -30 TO 65 DEG CENTI-GRADE AMB.: 0 TO 55 DEG CENTI-GRADE	UP TO 95 %	HAVE BEEN ASKED FOR	HAVE BEEN ASKED FOR	HAVE BEEN ASKED FOR	FOR THE TOSHIBA APPROX: @$1900.00	DOMESTIC UNITS ARE AVAILABLE ALSO HAVE JAPANESE UNITS BY TOSHIBA	HAVE BEEN ASKED FOR	

REVISED MATRIX FOR 18,000 BTU/HR AIR CONDITIONER

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	TEMP.	HUMIDITY	SHOCK AND VIBRATIONS	RELIABILITY	EFFICIENCY VALUES	INDICATED COST	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS
LOVEJOY ELECTRONICS 9 LEXINGTON AVE. MONTCLAIR, NJ 07442 CONTACT: AL D. WILLIAMS (201)783-7442	INPUT 3-PHASE 208 VAC (PLUS OR MINUS 10% OF NOMINAL VOLTAGE AT A FREQUENCY OF 50/60 HZ PLUS OR MINUS 5%. INCLUDES FAST ACTING CURRENT LIMITING FUSES AIC RATING OF 200,000. PRESENT OUTPUT CURRENT RATINGS ARE FROM 5 TO 27 AMPS. MAX OUTPUT FREQ 60,120,240,OR 480 HZ (SWITCH SELECTABLE) V/HZ RATIO 1.91 TO 10.20	OPERATING TEMP: 0 TO 50 DEG CENTIGRADE STOR: -10 TO 70 DEG CENTIGRADE	RH 0 TO 95% NO CONDENSATION MAX ALTITUDE: 3300 FT.	THEY ARE TESTING FOR THIS VALUE WILL GIVE A VALUE ASAP	THEY ARE TESTING FOR THIS VALUE WILL GIVE VALUE ASAP	INFO HAS BEEN ASKED FOR. WILL HAVE VALUE DURING NEXT MEETING	APPROX: @$1800.00 PRICE MIGHT BE LESS SINCE THIS IS FOR HIGHER VOLTAGE UNIT MASS QUANTITIES: 50: $1600 100: $1485 500: $1200	DOMESTIC UNIT.	APPROX: HEIGHT: 13.4" DEPTH: 8.3" WIDTH: 10.3" WEIGHT: 25 LBS DIMENSIONS MAY BE SMALLER OR LARGER DEPENDING ON WHAT VALUES WE ARE LOOKING FOR IN MTBF	I HAVE MET WITH SALES MANAGER AND APPLICATIONS ENGINEER AND VICE-PRES. FOR FOR A PRESENTATION. HAD MANY GOOD POINTS. ARE WILLING TO WORK CLOSELY WITH US TO GET US THE EFFICIENT AND BEST FITTED DRIVE FOR A GOOD PRICE. ALSO HAVE THE CAPABLITY TO HANDLE THE LOGIC.
MITZUBISI ELECTRIC SALES AMERICA 3205 SATURN CT. NOCROSS, GA 30092 CONTACT: MICHAEL PROTELLI	SERIES FR-F2 POWER SUPPLY 3-PHASE , 208VAC PLUS 10% AND MINUS 15% OF VOLTAGE. 60 HZ. PLUS OR MINUS 5%. CONTROL METHOD PWM. OUTPUT RATING 7.5 HP 24 AMPS. MAX OUTPUT VOLTAGE: 208VAC AT 60HZ.	AMB: 14 TO 122 DEG. F SHALL NOT FREEZE	BELOW 90% NONCONDENSING	LESS THAN .5 G	APPROX. 400,000 HOURS	HAVE BEEN ASKED FOR	FOR STANDARD UNIT: @$2598.00 OEM MULT. FOR 1 UNIT .56	FOREIGN MADE IN JAPAN	WIDTH: 9.8" HEIGHT: 15.7" DEPTH: 7.5" WEIGHT: 18.7 LB	PORTELLI IS TRYING TO GET US MORE INFO AND IS FINDING A LOCAL REF FOR US SO WE MAY MEET. WILL CALL BACK.

POSSIBLE CANDIDATES	OPERATING CHARACTERISTICS	TEMP.	HUMIDITY	SHOCK AND VIBRATIONS	RELIA-BILITY	EFFICIENCY VALUES	INDICATED COST	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS
POLYSPEDE ELECTRONICS CORP P.O. BOX 31024 DALLAS, TX. 75231 CONTACT: BRUCE STANLEY LOCAL REP : TOTAL CONTROL INC. STEVE SCHULTZ HIGHTTOWN, NJ.	INPUT POWER 200 TO 220/230 PLUS OR MINUS 5%, 3 PHASE. OUTPUT RATINGS 7.5 HP 23 AMPS. OUTPUT FREQ: 60 TO 120 HERTZ.	AMB: 14 TO 104 DEG F. STOR: 14 TO 158 DEG F. ALTI-TUDE: 3,300 FEET	20 TO 90% RH NON-CONDENSING	ASKED FOR	ASKED FOR	ASKED FOR	@$1347.00 OEM MULT: 1-4 UNITS .80 50-100 .69	FOREIGN MADE IN JAPAN BY HITACHI	HEIGHT 15.6" WIDTH 10.8" DEPTH 7.4" WEIGHT 22 LBS.	BRUCE STANLEY IS GETTING LO-CAL REP A CALL SO THAT HE CAN FIND US MORE INFO AND MEET WITH US FOR A DEMO WITHIN A FEW WEEKS.
SOUTHERN INDUS-TRIAL CONTROLS 3808 ROZELLE FERRY ROAD CHARLOTTE, NC 28206 (704)393-1636 CONTACT: JEFF SAMALL LOCAL REP: DAVID CLOETINGH RICHMOND, VA (804)747-1197	INPUT: 230 VAC PLUS OR MINUS 10% THREE-PHASE, 50/60 HZ. OUTPUT: 230VAC 7.5 HP	AMB: -10 TO 50 DEG CENT. ALTI-TUDE: 3300 FT	0 TO 95% NONCOND.	ASKED FOR	ASKED FOR	ASKED FOR	APPROX: @$2100.00 MASS QUANT PRICING HAS BEEN ASKED FOR	DOMESTIC	H-21" W-18.5" D-8" WEIGHT HAS BEEN ASKED FOR	THE LOCAL REP WILL GET BACK WITH MORE INFO AND WILL TRY TO MEET WITH ME NEXT WEEK
ZYCRON SYSTEMS INC. 72 ACTON STREET WEST HAVEN, CT 06516 (203)932-8471 CONTACT: TOM HOLMBERG LOCAL REP: BRIAN CLOETINGH (215)269-7576	FOR ZAC CONTROL-LER: 3-PHASE INPUT, 230 VAC 7.5 HP , 22 AMPS WILL GET BACK WITH VALUES FOR SPUD CONTROLLERS	OPER: 0 TO 60 DEG CENT. AMB: -20 TO 60 DEG C.	0-90% NONCOND.	ASKED FOR	ASKED FOR	ASKED FOR	FOR ZAC APPROX: @$2163.00 50 UNITS @$1705.00 100 UNITS @$1654.00 500 UBITS @$1384.00 ASKED FOR INFO ON SPUD DRIVE	DOMESTIC	W-20" H-32" D-8" WEIGHT AND SPUD DIM. ASKED FOR	BRIAN CLOETIGHN IS MEETING WITH ME 3/12 AT 2:00 PM TO TO GIVE MORE INFO ON SPUD DRIVES.

REVISED MATRIX FOR 18,000 BTU/HR AIR CONDITIONER

IBLE IDATES	OPERATING CHARACTERISTICS	TEMP.	HUMIDITY	SHOCK AND VIBRATIONS	RELIA-BILITY	EFFICIENCY VALUES	INDICATED COST	FOREIGN/ DOMESTIC	PHYSICAL DIMENSIONS	REMARKS
RAL POWER ANY 5 DIAZ RD. ECULA, CA 5 ACT: VALLEY /676-0555	THREE PHASE UNIT 298 VAC.7.5 HP MORE INFO HAS BEEN REQUESTED	HAS BEEN ASKED FOR	ASKED FOR	ASKED FOR	ASKED FOR	ASKED FOR	APPROX: @$1100.00	DOMESTIC	H-5" D-11" W-12" WEIGHT HAS BEEN ASKED FOR	JIM VALLEY WAS RECENTLY MAILED A FORMAL LETTER CONTAINING SPECS AND REQUESTING LITERATURE. AFTER RECENT TELEPHONE CONVERSATION WITH ME HE SAYS HE WILL MAIL MORE INFROMATION VERY SOON.

MATRIX OF QUOTES FROM FINALIST 7.5 HP INVERTER MANUFACTURERS RESPONDING TO SPECIFICATIONS GIVEN

CANDIDATES	ESTIMATED QUOTES	ESTIMATED TIME OF DELIVERY	REMARKS
CENTRAL POWER CO 27495 DIAZ ROAD TEMECULA, CA 92390 (714) 676-0555 CONTACT: JIM VALLEY	DEVELOPMENT COSTS ARE PRORATED IN UNIT COST NO ADDITIONAL COST ARE IMPOSED. NO. OF UNITS: / PRICE PER UNIT: 1-8 @$1700.00 50 @$1100.00 100 @$ 985.00 500 @$ 895.00	CAN HAVE DELIVERY OF FIRST UNIT IN 10 WEEKS OR LESS DEPENDINMG ON HOW SOON IT IS NEEDED.	THERE ARE SEVERAL ADVANTAGES WITH THIS PARTICULAR MANUFACTURER: THERE ARE NO ENGINEERING OR DEVE-LOPMENT COST INCURRED WHATSOEVER. IN ADDITION, THESE UNITS OFFERED BY THIS MANUFACTURER SEEM TO TO ALREADY EXIST OFF-THE-SHELF, VERY CLOSELY TO WHAT WE DESIRE. THEREFORE, TESTING AND RELIABI-ARE HAVE ALREADY BEEN ESTABLISHED. DELIVERY CAN ALMOST BE IMMEDIATE IF DESIRED. JIM VALLEY OF CENTRAL POWER CLAIMS THAT THE HARDWARE DESIGN IS SIMPLISTIC AND STRAIGHT FOWARD. RIGHT NOW THE DISADVANTAGES LIE IN THE FACT THAT JIM VALLEY HAS NOT PROVIDED US ANY PHYSICAL IN-FORMATION REGARDING THIS UNIT, AND WE HAVE NOT YET SEEN THE HARDWARE. JIM VALLEY IS GOING TO BE IN TOWN ON BUSINESS THE WEEK OF THE 27TH OF APRIL HE SAYS HE WILL BRING A UNIT DOWN FOR US TO SEE. I RECOMMEND THAT WE KEEP AN OPEN MIND UNTIL WE SEE THE UNIT NEXT WEEK. BECAUSE OF THE INEXPEN SIVENESS OF THE UNIT IT MIGHT BE A GOOD IDEA TO PURCHASE A SAMPLE UNIT FOR CLOSE EXAMINATION AND TESTING. ANOTHER GOOD POINT, IS THAT ACCORDING TO VALLEY THE UNIT IS MUCH SMALLER THAN WE REQUIRED.
CONTRAVES GOERZ CORPORATION 2600 LIBERTY AVE PITTSBURGH, PA 15222-4616 (412)261-8600 CONTACT: WILLIAM JOLLIE	COST FOR TOTAL DEVELOP-MENT AND TESTING @$21,000.00. NO. OF UNITS: / PRICE PER UNIT: 1-8 @$1517.00 50 @$1445.00 100 @$1392.00 500 @$1351.00	CAN DELIVER IN 4 MONTHS	THE ADVANTAGE OF THIS MANUFACTUFER IS THE RELA-TIVELY INEXPENSIVE DEVELOPMENT COST, WHICH THEY CLAIM INCLUDES COMPLETE VERIFICATION AND TESTING. THE YASKAWA UNIT IS A MODERATELY SIMPLISTIC AND STAIGHTFOWARD UNIT IN COMPARISON TO SEVERAL OTHER LEADING MANUFACRURES. OFF-THE-SHELF, IT IS RELATIVELY SMALL AND COMPACT AND HAS GOOD WORK-MANSHIP. THE DISADVANTAGE OF THIS UNIT IS THE FACT THAT IT IS NOT MANUFACTURED IN THE US AND MODIFICATION AND ENGINEERING WOULD NOT BE DIRECTLY MADE WITH A MANUFACTURER IN THE US. RECOMMENDATION: OF THE PHYSICAL UNITS THAT WE HAVE SEEN, THE CONTRAVES/YASKAWA UNIT OFFERS A PRICE THAT IS COMPETIVE AND AMONG THE LOWEST. IN THE SHORT RUN IT IS THE 2ND LEAST EXPENSIVE IN TERMS OF ENGINEERING COST NOT YET INCLUDING CENTRAL POWER (WITH NO ENGINEERING COST). IN THE LONG RUN AFTER BUYING LARGE QUANTITIES, IT BE-COMES 3RD LESSEXPENSIVE (EXCLUDING CENTRA POWER). TAKING ALL THESE FACTORS INTO ACCOUNT CONTRAVES WOULD BE A GOOD CANDIDATE.

MATRIX OF QUOTES FROM FINALIST 7.5 HP INVERTER MANUFACTURERS RESPONDING TO SPECIFICATIONS GIVEN

CANDIDATES	ESTIMATED QUOTES	ESTIMATED TIME OF DELIVERY	REMARKS
KECO INDUSTRIES 7375 INDUSTRIAL RD FLORENCE, KY 41042 (606) 525-21 CONTACT: JOHN DUFFS REGINOLD AURTHUR	TOTAL NONRECURRING ENGINEERING COSTS: $44,990.00. NO. OF UNITS: / PRICE PER UNIT: 1-8 @$2551.00 50 @$2041.00 100 @$1330.00 500 @$1122.00	HAVE NOT YET PROVIDED THE INFORMATION.	THE ADVANTAGE OF THIS MANUFACTURER IS HISTORY. THEY SUPPOSEDLY HAVE EXPERIENCE IN THIS FIELD, AND HAVE EXPERIENCE IN WORKING WITH THE MILITARY. THEY ARE CURRENTLY PROVIDING A SIMILAR TYPE OF INVERTER FOR ANOTHER BRANCH OF THE MILITARY. IN ADDITION THEY HAVE LEADING PEOPLE CONTRIBUTING TO THE DESIGN AND DEVELOPMENT OF THIS INVERTER. ALTHOUGH, I HAVE NOT PHYSICALLY SEEN THE KECO INVERTER, ACCORDING TO VERY DETAILED PICTURES DEPICTING THE HARDWARE, IT IS APPARENT THAT THE CONSTRUCTION IS STURDY AND RUGGED. THE MODULAR CONFIGURATION OF THE INVERTER WITH THE BOARDS PACKED CLOSELY AND DENSELY MAKE IT MORE PROBABALE TO WITHSTAND VIBRATION. THE CONNECTIONS ARE ALSO APPEAR TO BE STRONG AND STURDY. THE MAJORITY OF IC'S USED APPEAR TO BE MILITARIZED, WHILE OTHER MAY NOT BE. AS FOR COST, KECO RATES THIRD, IN TERMS OF MOST INEXPENSIVE IN ENGINEERING COST, NOT INCLUDING CENTRAL POWER (WITH NO ENGINEERING COST). AMONG THE THREE LEAST EXPENSIVE IN ENGINEERING COST IT RATES SECOND AT LARGE QUANTITY PRICES. THEREFORE IN THE LONG RUN AFTER BUYING 700 UNITS KECO BECOMES THE SECOND MOST INEXPENSIVE, AGAIN NOT YET INCLUSING CENTRAL POWER CO. RECOMMENDATION: KECO WOULD MAKE A GOOD CANDIDATE.
LOVEJOY ELECTRONICS 2820 N. MARKSHEFEL ROAD COLORADO SPRINGS, COLORADO 80915 (303)632-1911 CONTACT: AL WILLIAMS RICK SIEKMAN	TOTAL DEVELOPMENT COST IS $580,000.00. WITH A SPECIAL AGREEMENT THEY ARE WILLING TO SHARE DEVELOPMENT COST AND COST FOR DEVELOPMENT THEN BECOMES $290,000. NO. OF UNITS: / PRICE PER UNIT: 1 @$1822.00 8 @$1622.00 50 @$1548.00 100 @$1457.00 500 @$1367.00	CAN DELIVER FIRST 8 UNITS IN 10- 12 WEEKS.	LOVEJOY IS GOOD REFUTABLE INVERTER MANUFACTURER. AND, THEY ARE VERY WILLING TO WORK WITH US AND SEEM WILLING TO COMMIT TO DOING A GOOD JOB. HOWEVER, THE INVERTER IS EXTREMELY COMPLEX AND CONTAINS MANY EXTRAS WE DO NOT NEED. IN ADDITION THE DEVELOPMENT COST IS OUTRAGEOUSLY HIGH, AND THE QUANTITY PRICES ARE NOT MUCH MORE COMPETETIVE. THEREFORE IT IS NOT JUSTIFIABLE. RECOMMENDATION: LOVEJOY IS NOT A GOOD CANDIDATE.

MATRIX OF QUOTES FROM FINALIST 7.5 HP INVERTER MANUFACTURERS RESPONDING TO SPECIFICATIONS GIVEN

CANDIDATES	ESTIMATED QUOTES	ESTIMATED TIME OF DELIVERY	REMARKS
POLYSPEDE ELECTRONICS CORP. 6770 TWIN HILLS AVENUE DALLAS, TX 75231 (214)363-7245 CONTACT: BRUCE STANLEY STEVE SHULTZ	APPROXIMATE DEVELOPMENT COST IS $500,000.00 TO $1,000,000.00. FOR 500 UNITS: PRIAE PER TLIT HS $2,000.00	DELIVERY WOULD TAKE 6 MONTHS TO 1 YEAR FOR FIRST 8 UNITS.	POLYSPEDE IS A GOOD REPUTABLE INVERTER MANUFACTURER, HOWEVER DUE TO THEIR CANCELLATION OF A DEMO, I NEVER HAD AN OPPORTUNITY TO EVALUATE THEIR HARDWARE. NEVERTHELESS, THE DEVELOPMENT COST IS EXTREMELY HIGH AND NOT COMPETIVE AT ALL EVEN IN THE THE LARGE QUANTITY PRICE PER UNIT. RECOMMENDATION: POLYSPEDE IS NOT A GOOD CANDIDATE
SOUTHERN INDUSTRIAL CONTROLS INC. 3608 ROZZELLS RD. CHARLOTTE, NC 28216 (804) 747-1197 CONTACT: JEFF SMALL DAVID CLOETINGH	DEVELOPMENT COST WITHOUT ANY TESTING OF VERIFICATION WOULD BE $8,000.00. THEY DO NOT HAVE THE FACILITIES FOR ANY TESTING AND THEY WOULD LOOK TO VSE TO RECOMMEND A FACILITY FOR TESTNG AND VERIFICATION WITH WHOM THEY WOULD SUBCONTRACT AND CHARGE US AT COST WITH SMALL ADDITIONAL TO COVER TIME AND WORK. NO. OF UNITS: — PRICE PER UNIT: 1-8 — @$1700.00 50 — @$1410.00 100 — @$1320.00 500 — @$ 922.00 500 UNITS MAY CHANGE TO $922-1320, IN 18 MONTHS DUE TO PRICE INCREASE IN JAPANESE IC'S)		ADVANTAGES: SOUTHCON IS GOOD REPUTABLE COMPANY, THEIR PEOPLE ARE VERY POSITIVE ABOUT WORKING WITH US CLOSELY TO DEVELOP A GOOD PRODUCT THAT WOULD MEET OUR NEEDS. THEIR HARDWARE IS SIMPLE AND STRAIGHTFOWARD. THERE IS NOT A LARGE COMPONENT COUNT. COSTS: NOT YET INCLUDING CENTRAL POWER CO., SOUTHCON IS THE MOST INEXPENSIVE IN BOTH ENGINEERING COSTS, AND IN MASS QUANTITY PRICES. THERE DELIVERY TIME IS REASONABLE. RECOMMENDATION: SOUTHCON WOULD BE A VERY GOOD CANDIDATE.

APPENDIX D

SOFTWARE

```
0000 01481524
;*****************************************************************************
;
;        MOTOR CONTROLLER LOGIC CODE
;
;*****************************************************************************
;
;                                          NOT HEATER, IS IT COOL MODE ?
RESET:    FNXT + & FCOOL &
          TNXT HEATER & TMC & TSSB       ; IN HEADER, START MC

0001 026803E8
;
;                                         ; NOT COOLER, IS IT VENT MODE ?
FNXT + & FVNT &
          TNXT COOLER & TTMP             ; IN COOL MODE, TEST TEMP

0002 00881E24
;
;                                         ; NOT VENT MODE, TRY HEAT AGAIN ?
FNXT RESET & FHET &
          TNXT VENTER & TMC & TSSB       ; IN VENT MODE, START MC

0003 04441024
;
;*****************************************************************************
;
;        COOL MODE
;
;*****************************************************************************
;
;                                          TEMP > 2 ABOVE, K2 ON, GOTO ACON
COOLER:   FNXT ACON & FK2 & FSSB &
          TNXT ACOFF & TMC & TSSB        ; TEMP < 2 ABOVE, START MC, GOTO ACOFF

0004 05B805B8
;
;                                          TEST MOTOR CONTROL FAULTS
ACON:     FNXT + & FCLP & FTMR &
          TNXT + & TCLP & TTMR

0005 4C000648
;
;                                          COOL LOOP FAULT, SHUT DOWN
ACLPO:    FNXT CLFLT &
          TNXT + & TCOL                  ; NO COOL FLT, TEST COOL MODE

0006 00830703
;
FNXT RESET & FHET &
          TNXT + & TTME

0007 03B805A8
;                                         ; 5 SECS TIME UP, START ANOTHER
FNXT ACLP1 & FTMR & FCLP &
```

```
        TNXT ACLP0 & TCLP                    ; WAIT AGAIN, LOOP BACK, TEST CLP
0008 4C000948
;
;                                              COOL LOOP FAULT, SHUT DOWN
ACLP1:   FNXT CLFLT &
        TNXT + & TCOL                        ; NO COOL FLT, TEST COOL MODE
0009 00330A03
;
FNXT RESET & FHET &
        TNXT + & TTME
000A 0B6403A8
;                                             ; 10 SECS TIME UP, K2 ON, MC ON
FNXT + & FK2 & FMC & FSSB &
        TNXT ACLP1 & TCLP                    ; WAIT AGAIN, LOOP BACK, TEST CLP
000B 0C280C28
;
;                                             ; TEST MCF AGAIN
FNXT + & FMCF &
        TNXT + & TMCF
000C 0DA82300
;
;                                             ; NO MCF , TEST COOL LOOP FLTS
ACLP2:   FNXT + & FCLP &
        TNXT MCFLT                           ; MC FAULT, SHUT DOWN
000D 4C000L48
;
;                                             ; COOL LOOP FAULTS
FNXT CLFLT &
        TNXT + & TCOL                        ; TEST COOL MODE
000E 00330FE3
;
;
FNXT RESET & FHET &
        TNXT + & TTMP                        ; TEST TEMP
000F 0C280324
;
;                                             ; TEMP > 2 BELOW, TEST MCF AGAIN
FNXT ACLP2 & FMCF &
        TNXT COOLER & TMC & TSSB             ; TEMP < 2 BELOW, K2 OFF,MC ON, BEGIN
0010 11281128
;
;       TURN OFF COMPRESSOR JUST RUN FAN
;
;                                             ; TEST MC FLTS AGAIN
ACOFF:   FNXT + & FMCF &
        TNXT + & TMCF
```

```
0011 12A82300
;
;                                       ; NO MC FLT, TEST COOL LOOP
ACLP4:   FNXT + & FCLP &
         TNXT MCFLT                    ; MC FLT, SHUT DOWN

0012 4C001348
;
;                                       ; COOL LOOP FLT , SHUT DOWN
FNXT CLFLT &
         TNXT + & TCOL                 ; TEST COOL MODE

0013 008814E8
;
FNXT RESET & FHET &
         TNXT + & TTMP                 ; TEST TEMP

0014 04441128
;
;                                       ; TEMP < 2 ABOVE, KEEP ON LOOPING
FNXT ACON & FK2 & FSSB &
         TNXT ACLP4 & TMCF             ; TEMP > 2 ABOVE, TURN ON AC

0015 16281628
;
;****************************************************************************
;
;        HEATER MODE
;
;****************************************************************************
;
;                                       ; TEST MC FLTS AGAIN
HEATER:  FNXT + & FMCF &
         TNXT + & TMCF

0016 17C82300
;
;                                       ; NO MC FLT, TEST HEAT LOOP
HTLP1:   FNXT + & FHLP &
         TNXT MCFLT                    ; MC FLT, SHUT DOWN

0017 550018E8
;
;                                       ; HEAT LOOP FLT , SHUT DOWN
FNXT HLFLT &
         TNXT + & TTMP                 ; NO HEAT FLT, TEST TEMP

0018 162819A4
;
;                                       ; TEMP > 2 BELOW, KEEP ON LOOPING
FNXT HTLP1 & FMCF &
         TNXT + & TK1 & TMC & TSSB     ; TEMP < 2 BELOW, TURN ON K1 & MC

0019 1A281A28
```

```
;
;                                          ; TEST MC FLTS AGAIN
FNXT + & FMCF &
        TNXT + & TMCF

001A 1BC82300
;
;                                          ; NO MC FLT, TEST HEAT LOOP
HTLP2:   FNXT + & FHLP &
        TNXT MCFLT                        ; MC FLT, SHUT DOWN

001B 55001CE8
;
;                                          ; HEAT LOOP FLT , SHUT DOWN
FNXT HLFLT &
        TNXT + & TTMP                     ; NO HEAT FLT, TEST TEMP

001C 1D241A28
;
;                                          ; TEMP > 2 ABOVE, K1 OFF, MC ON
FNXT + & FMC & FSSB &
        TNXT HTLP2 & TMCF                 ; TEMP < 2 BELOW, LOOP BACK,TEST MCF

001D 16281628
;
;                                          ; TEST FOR MC FAULTS AND BEGIN AGAIN
FNXT HTLP1 & FMCF &
        TNXT HTLP1 & TMCF

001E 1F281F28
;
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
;        VENT MODE
;
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
;                                          ; TEST MC FLTS AGAIN
VENTER:  FNXT + & FMCF &
        TNXT + & TMCF

001F 20682300
;
;                                          ; ARE WE STILL IN VENT MODE ?
VTLP1:   FNXT + & FVNT &
        TNXT MCFLT                        ; MC FLT, SHUT DOWN

0020 008821C8
;
;                                          ; NO RESET FIND WHAT MODE?
FNXT RESET & FHET &
        TNXT + & THLP                     ; TEST HEAT LOOP FAULTS

0021 550022A8
;
```

```
;                                                   ; HAVE A HEAT LOOP FAULT
FNXT HLFLT &
        TNXT + & TCLP                              ; TEST COOL LOOP FAULTS

0022 4C001F28
;
;                                                   ; HAVE A COOL LOOP FAULT
FNXT CLFLT &
        TNXT VTLP1 & TMCF                          ; TEST MC FAULTS

0023 24262426
;
;*****************************************************************************
;
;         MOTOR CONTROLLER FAULT
;
;*****************************************************************************
;
MCFLT:    FNXT + & FSSB & FMC & FMCL &
        TNXT + & TSSB & TMC & TMCL                 ; ENABLE MCF LED'S

0024 25B825B8
;
;                                                   ; START TIMER AND TEST COOL LOOP
FNXT + & FCLP & FTMR &
        TNXT + & TCLP & TTMR

0025 4C002608
;
;                                                   ;  COOL LOOP FAULT
MCLP1:    FNXT CLFLT &
        TNXT + & THLP                              ;  TEST HEET LOOP FAULT

0026 55002708
;
;                                                   ;  HEET LOOP FAULT
FNXT HLFLT &
        TNXT + & TTME                              ;  TEST TIMER

0027 28B825A8
;
;                                       ;  5 SECS ARE UP, START ANOTHER & TEST COOL
FNXT + & FCLP & FTMR &
        TNXT MCLP1 & TCLP                          ;  TEST COOL LOOP AGAIN

0028 4C002908
;
;                                                   ; COOL LOOP FAULT
MCLP2:    FNXT CLFLT &
        TNXT + & THLP                              ; TEST HEAT LOOP

0029 55002A08
;
;                                                   ; HEET LOOP FAULT
FNXT HLFLT &
```

```
        TNXT + & TTME                           ; TEST TIMER

0028 2B0428A8
;
;                                                ; 10 SECS ARE UP , TURN MC OFF
FNXT + & FSSB &
        TNXT MCLP2 & TCLP                       ; NO YET,  TEST COOL LOOP

002B 2C242C24 .
;
FNXT + & FSSB & FMC &
        TNXT + & TSSB & TMC                     ; TURN MC BACK ON

002C 2DB82DB8
;
;                                                ; START 5 SEC DELAY BEFORE TEST MCF
FNXT + & FCLP & FTMR &
        TNXT + & TCLP & TTMR

002D 4C002EC8
;
;                                                ; GOT A COOL FAULT
MCLP3:   FNXT CLFLT &
        TNXT + & THLP                           ; TEST HEAT LOOP

002E 55002F08
;
;                                                ; HEET LOOP FAULT
FNXT HLFLT &
        TNXT + & TTME                           ; TEST TIMER

002F 30282DA8
;
;                                                ; 5 SECS ARE UP, TEST MC FAULTS
FNXT + & FMCF &
        TNXT MCLP3 & TCLP                       ; NO YET,  TEST COOL LOOP

0030 00083126
;
;                                                ; NO MORE MC FAULT, RESTART
FNXT RESET & FHET &
        TNXT + & TSSB & TMC & TMCL              ; HAVE ANOTHER MC FAULT

0031 32B832B8
;
;
;        SECOND MOTOR CONTROLLER FAULT - TRY AGAIN  !
;
;                                                ; START TIMER AND TEST COOL LOOP
MCFLT2:  FNXT + & FCLP & FTMR &
        TNXT + & TCLP & TTMR

0032 4C0033C8
;
;                                                ;  COOL LOOP FAULT
```

```
MCLP4:   FNXT CLFLT &
         TNXT + & THLP                  ;  TEST HEET LOOP FAULT

0033 55003408
;
;                                        ;  HEET LOOP FAULT
FNXT HLFLT &
         TNXT + & TTME                  ;  TEST TIMER

0034 35B832A8
;
;                              ;  5 SECS ARE UP, START ANOTHER & TEST COOL
FNXT + & FCLP & FTMR &
         TNXT MCLP4 & TCLP              ;  TEST COOL LOOP AGAIN

0035 4C0036C8
;
;                                        ; COOL LOOP FAULT
MCLP5:   FNXT CLFLT &
         TNXT + & THLP                  ; TEST HEAT LOOP

0036 55003708
;
;                                        ; HEET LOOP FAULT
FNXT HLFLT &
         TNXT + & TTME                  ; TEST TIMER

0037 380435A8
;
;                                        ; 10 SECS ARE UP , TURN MC OFF
FNXT + & FSSB &
         TNXT MCLP5 & TCLP              ; NO YET,  TEST COOL LOOP

0038 39243924
;
;
FNXT + & FSSB & FMC &
         TNXT + & TSSB & TMC            ; TURN ON MC

0039 3AB83AB8
;
;                                        ; START 5 SEC DELAY BEFORE TEST MCF
FNXT + & FCLP & FTMR &
         TNXT + & TCLP & TTMR

003A 4C003BC8
;
;                                        ; GOT A CÓOL FAULT
MCLP6:   FNXT CLFLT &
         TNXT + & THLP                  ; TEST HEAT LOOP

003B 55003C08
;
;                                        ; HEET LOOP FAULT
FNXT HLFLT &
```

```
        TNXT + & TTME                    ; TEST TIMER

003C 3D283AA8
;
;                                         ; 5 SECS ARE UP, TEST MC FAULTS
FNXT + & FMCF &
        TNXT MCLP6 & TCLP                ; NO YET,  TEST COOL LOOP

003D 00883E26
;
;                                         ; NO MORE MC FAULT, RESTART
FNXT RESET & FHET &
        TNXT + & TSSB & TMC & TMCL       ; HAVE ANOTHER MC FAULT

003E 3FB83FB8
;
;       THIRD MOTOR CONTROLLER FAULT, TRY ONLY ONE MORE TIME
;
;                                         ; START TIMER AND TEST COOL LOOP
MCFLT3:  FNXT + & FCLP & FTMR &
        TNXT + & TCLP & TTMR

003F 4C0040C8
;
;                                         ;  COOL LOOP FAULT
MCLP7:   FNXT CLFLT &
        TNXT + & THLP                    ;  TEST HEET LOOP FAULT

0040 55004108
;
;                                         ;  HEET LOOP FAULT
FNXT HLFLT &
        TNXT + & TTME                    ;  TEST TIMER

0041 42B83FA8
;
;                              ;  5 SECS ARE UP, START ANOTHER & TEST COOL
FNXT + & FCLP & FTMR &
        TNXT MCLP7 & TCLP                ;  TEST COOL LOOP AGAIN

0042 4C0043C8
;
;                                         ; COOL LOOP FAULT
MCLP8:   FNXT CLFLT &
        TNXT + & THLP                    ; TEST HEAT LOOP

0043 55004408
;
;                                         ; HEET LOOP FAULT
FNXT HLFLT &
        TNXT + & TTME                    ; TEST TIMER

0044 450442A8
;
;                                         ; 10 SECS ARE UP , TURN MC OFF
```

```
FNXT + & FSSB &
        TNXT MCLP8 & TCLP              ; NO YET,  TEST COOL LOOP

0045 46244624
;
FNXT + & FSSB & FMC &
        TNXT + & TSSB & TMC            ; TURN ON MC

0046 47B847B8
;
;                                       ; START 5 SEC DELAY BEFORE TEST MCF
FNXT + & FCLP & FTMR &
        TNXT + & TCLP & TTMR

0047 4C004808
;
;                                       ; GOT A COOL FAULT
MCLP9:  FNXT CLFLT &
        TNXT + & THLP                  ; TEST HEAT LOOP

0048 55004908
;
;                                       ; HEET LOOP FAULT
FNXT HLFLT &
        TNXT + & TTME                  ; TEST TIMER

0049 4A2847A8
;
;                                       ; 5 SECS ARE UP, TEST MC FAULTS
FNXT + & FMCF &
        TNXT MCLP9 & TCLP              ; NO YET,  TEST COOL LOOP

004A 00884B36
;
;                                       ; NO MORE MC FAULT, RESTART
FNXT RESET & FHET &
        TNXT + & TSSB & TFL & TMCL & TMC ; FINAL SHUT DOWN !!!!!!!!!!!!

004B 4B004B00
;
;       FORTH MOTOR CONTROLLER FAULT, SHUT DOWN AND TURN ON LIGHTS
;
;
FNXT $ &
        TNXT $                         ; INFINITE LOOP !!!!!!!!!!!!!!!!!!!!!!

004C 4D244D24
;
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
;       COOL LOOP FAULT ROUTINE
;
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
CLFLT:  FNXT + & FSSB & FMC &
```

```
         TNXT + & TSSB & TMC                ;  TURN OFF K2 LEAVE MC ON

0040 4ED84ED8
;
;                                            ;  START TIMER, TEST HEET LOOP
FNXT + & FHLP & FTMR &
         TNXT + & THLP & TTMR

004E 5E044F08
;
;                                            ;  BOTH COOL & HEET FAULTS
CLFLP1:  FNXT EVFLT & FSSB &
         TNXT + & TTIME                     ;  TEST TIME

004F 50D84EC8
;
;                                            ; 5 SECS ARE UP START AGAIN
FNXT + & FHLP & FTMR &
         TNXT CLFLP1 & THLP                 ; NO YET, TEST HEET LOOP

0050 5E045108
;
;                                            ;  GOT A EVAPORATOR FAULT, SHUT DOWN!
CLFLP2:  FNXT EVFLT & FSSB &
         TNXT + & TTIME                     ;  TEST TIME

0051 52A850C8
;
;                                            ; 10 SECS ARE UP, TEST COOL AGAIN
FNXT + & FCLP &
         TNXT CLFLP2 & THLP                 ; NO YET, TEST HEET LOOP

0052 53280088

;                                            ; STILL GOT IT, TEST MC FAULTS
FNXT + & FMCF &
         TNXT RESET & THET                  ; ALL CLEARED, TRY MODE SELECT

0053 54355437
;
;                                            ; TURN ON PT AND FL LIGHTS
FNXT + & FSSB & FPTL & FFL & FMC &
         TNXT + & TSSB & TMCL & TPTL & TFL & TMC ;TURN ON MC, PT AND FL LIGHTS

0054 54005400
;
FNXT $ &
         TNXT $                             ; INFINITE LOOP

0055 56245624
;
;*****************************************************************************
;
;        HEAT LOOP FAULT ROUTINE
;
```

```
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
HLFLT:    FNXT + & FSSB & FMC &
          TNXT + & TSSB & TMC

0056 57B857B8
;                                            ;  START TIMER, TEST COOL LOOP
FNXT + & FCLP & FTMR &
          TNXT + & TCLP & TTMR

0057 5E045808
;
;                                            ;  GOT A EVAPORATOR FAULT, SHUT DOWN!
HLFLP1:   FNXT EVFLT & FSSB &
          TNXT + & TTME                      ;  TEST TIME

0058 59B857A8
;
;                                            ; 5 SECS ARE UP START AGAIN
FNXT + & FCLP & FTMR &
          TNXT HLFLP1 & TCLP                 ; NO YET, TEST COOL LOOP

0059 5E045A08
;
;                                            ;  GOT A EVAPORATOR FAULT, SHUT DOWN!
HLFLP2:   FNXT EVFLT & FSSB &
          TNXT + & TTME                      ;  TEST TIME

005A 5BC859A8
;
;                                            ; 10 SECS ARE UP, TEST HFLT AGAIN
FNXT + & FHLP &
          TNXT HLFLP2 & TCLP                 ; NO YET, TEST COOL LOOP

005B 5C280088
;
;                                            ; STILL GOT IT, TURN ON LIGHTS
FNXT + & FMCF &
          TNXT RESET & THLT                  ; ALL CLEARED, TRY MODE SELECT

005C 5D355D37
;
;
;                                            ; TURN ON PT AND FL LIGHTS
FNXT + & FSSB & FPTL & FFL & FMC &
          TNXT + & TSSB & TPTL & TFL & TMCL & TMC ;ON MC, PT AND FL LIGHTS

005D 5D005D00
;
;
FNXT $ &
          TNXT $                             ;  INFINITE LOOP

005E 5E045E04
;
```

```
;+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
;        EVAPORATOR FAULT ROUTINE
;
;+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
EVFLT:   FNXT + & FSSB &
         TNXT + & TSSB

0O5F 60186018
;                                               ;  START TIMER, TEST TIMER
FNXT + & FTME & FTMR &
         TNXT + & TIME & TTMR

0060 61186008
;
;                                               ;  5 SECS ARE UP, START TIMER AGAIN
EVFLP1:  FNXT + & FTME & FTMR &
         TNXT EVFLP1 & TTME                     ;  TEST TIMER

0061 62A86108
;
;                                               ;  10 SECS ARE UP, TEST COOL LOOP
EVFLP2:  FNXT + & FCLP &
         TNXT EVFLP2 & TTME                     ;  TEST TIMER

0062 630865A8
;
;                                               ; STILL HAVE COOL LOOP, TEST HEAT LOOP
FNXT + & FHLP &
         TNXT HLFTST & TCLP                     ; NO CLF, TEST FOR HEAT LOOP

0063 64154C00
;
;                                               ; STILL HAVE HEAT LOOP, SHUT DOWN
FNXT + & FSSB & FPIL & FFL &
         TNXT CLFLT                             ; HAVE COOL BUT NO HEAT FAULT, TRY COOL

0064 64006400
;
FNXT $ &
         TNXT $

0065 55000088
;                                               ; HAVE HEAT BUT NO COOL FAULT, TRY HEAT
HLFTST:  FNXT HLFLT &
         TNXT RESET & THET                      ; ALL CLEAR START AGAIN AT MODE SELECT

0066 00000000
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