Assessing the Effect of Design for Producibility

on Repairable Product Life-Cycle Cost

by

James Loyd Sowder

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APPROVED:

Wolter J. Fabrycky, Chairman

H. JoAnne Freeman

Reginald G. Mitchiner

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Blacksburg, Virginia

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(ABSTRACT)

A life-cycle cost evaluation model is presented to assess the effect of design decisions (made in an attempt to induce higher degrees of producibility) upon a product's life-cycle cost. The model provides a measure of effectiveness in terms of an expected annual equivalent total system life-cycle cost for a deployed population of the product being evaluated.

Parametric relationships are established between aspects of the product and the level to which the product is designed for producibility. These aspects include areas of cost arrising during each phase of the product life cycle. The model limits the number of product design alternatives to three scenarios which are defined as a product designed to be highly, moderately, and less producible. The best of the three design alternatives is selected based upon the life-cycle costs calculated.

Acknowledgements

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1.0 Introduction

One goal of our society is to generate wealth and improve the standard of living. Of the wealth generating activities in the U.S., manufacturing contributes approximately 70%. [5] As a consequence, if a competitive edge is not maintained in the area of manufacturing a reduction in these wealth generating activities will result. Manufacturing productivity in the past has been increased through innovation and large investments in capital equipment; however, in recent years increases in competition have limited price increases and higher interest rates have diminished returns from capital. [10] Recognizing the diminishing returns of conventional productivity improvement techniques, many companies have increased the attention given to the subject of design for product producibility.

1.1 What is Meant by Producibility

In the simpliest terms, product producibility refers to how easily or cost effectively a product can be produced. A highly producible product is said to possess the design characteristics which enable it to be produced from numerous different materials, all of which are highly available; by multiple production methods; and in the quantity required within the specified time frame. More formal definitions of producibility do exist, two of which are offered by the Department of Defense (DoD). DoD Directive 5000.34, *Defense Production Management,* [11] defines producibility as "the relative ease of producing an item or system that is governed by the characteristics and features of a design that enable economical fabrication, assembly, inspection, and testing using available production technology". Military Standard (MIL-STD) 1528, *Production Management,* [12] defines producibility as "the composite of characteristics, which, when applied to equipment design and production planning, leads to the most effective and economic means of fabrication, assembly, inspection, test, installation, checkout, and acceptance of systems and equipment". The key point in each of these definitions is that product producibility is recognized as a design characteristic, a result of the design effort during which stated design objectives are attempted to be met. Design objectives which are normally thought of as manifesting themselves in the form of physical performance, also present themselves as measures of reliability, maintainability, life-cycle cost, ergonomics, safety, etc.

The manner in which design objectives are met form the foundation for a product's producibility. During the entire design process the design engineer must evaluate the large number of alternative ways of meeting design objectives. While ensuring that the design remains functional in all respects, producibility concepts encourage the design to be produced and inspected in the quantity required while allowing a series of trade-offs to achieve the optimum combination of cost and time. Producibility concepts are generally presented in the form of design checklists. These checklists provide guidance which encourage the designer to consider a product's producibility during the design process. Appendix A presents one such checklist.

1.2 Design for Producibility as Practiced Today

Product producibility as a design characteristic faces the same obstacle as other related design disciplines in today's engineering environment. Design for producibility, like designs for serviceability, ergonomics, safety, etc., is most often viewed as an after-the-fact objective. [25] The problem lies in the inability or unwillingness of designers to implement the concept of concurrent engineering. Most often it is far into the design process before the producibility engineer is "handed off" a product's design. At this advanced stage of product development it is this engineer's responsibility to influence the design so that producibility concerns are included, rather than the ideal situation where the product has the benefit of full cooperation among each and every design discipline throughout the entire design process. Once within the realm of the producibility engineer, changes in product design made to induce higher degrees of producibility are not studied as to their effect upon other design attributes or the product's resulting life-cycle cost. This only leads to a perpetuation of this sequential rather than iterative design problem.

1.3 How Producibility Affects Product Life-Cycle Cost

The life cycle of a product forms the basis for assessing its life-cycle cost. Figure 1 depicts a simple representation of the product life cycle. This simplistic view of the product life cycle, while accurate in its treatment of the product, does not consider the entire system required to bring about and later support the product. The life cycle of the **total** system required to design, manufacture, use, and dispose of a product is composed of many things. Fabrycky [15] suggests the need to expand this simpler version of the product life cycle to one which includes the life cycles of the manufacturing

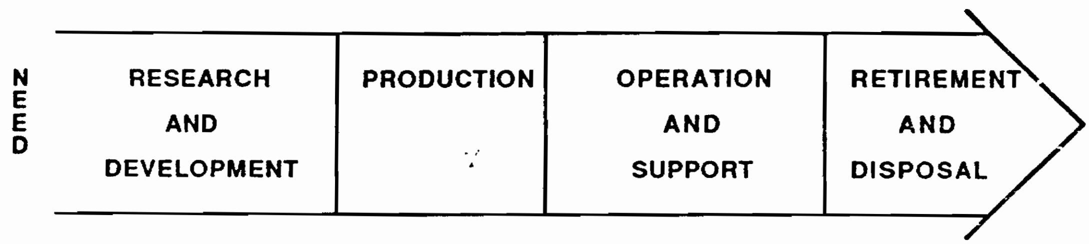


Figure 1. Product Life Cycle

and logistic support systems associated with the product. Figure 2 illustrates the three life cycles progressing in a parallel and coordinated fashion.

The four major phases of the simple product life cycle (Research and Development, Production, Operation and Support, and Retirement and Disposal) may still be used as a building block for life-cycle cost calculations. By identifying the applicable functions which occur (in any of the three life cycles depicted in Figure 2) during the periods of time defined by the four phases, costing these functions, applying the appropriate costs by function, and then accumulating these costs for the entire span of the life cycles, the product's **total** life-cycle cost is determined.

During research and development, all costs related to initial planning, market studies, feasibility studies, continuing through product design, manufacturing design, and test and evaluation must be included. It is during this phase that only a limited amount of dollars are actually spent, however large expenditures (estimated to be approximately 80% of a product's life-cycle cost) are committed. [1,3] The research and development phase is followed by the production or construction phase. Here the product is manufactured and all costs associated with this and initial logistic support must be included. Literature to date attribute the effects of product producibility to this phase of the

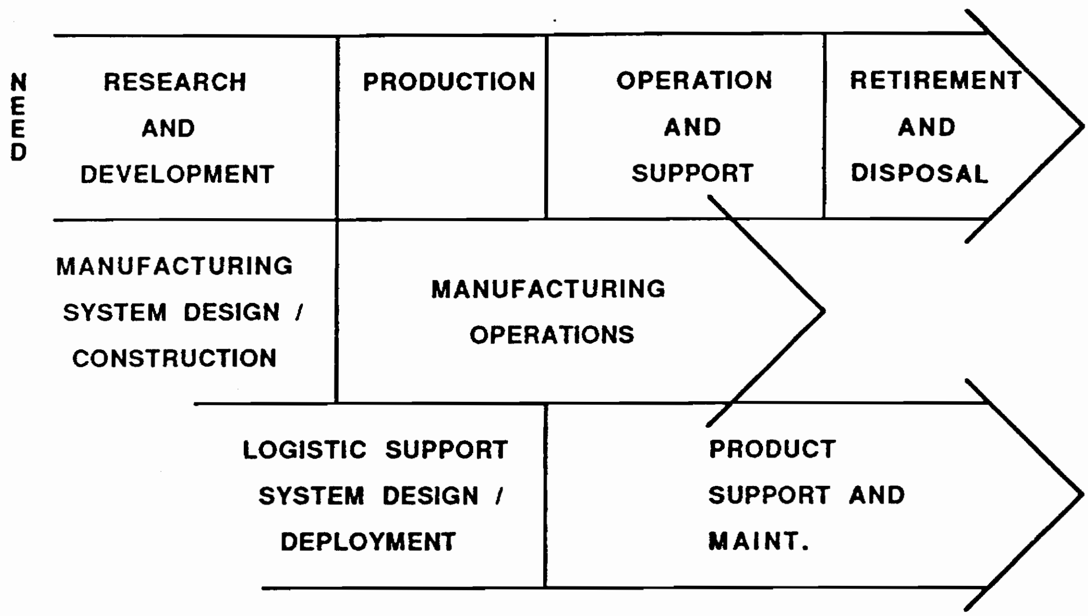


Figure 2. Product, Manufacturing, and Logistic Support System Life Cycles

product life cycle, discussing the role that design for assembly plays in determining the production or assembly costs of the product. [5,10,18] Additional costs are incurred during the operation and support phase of the product life cycle. All distribution, consumer or user operations, sustaining logistic support, maintenance activities and system modification costs are included. Finally, there is the phaseout or the retirement and disposal phase which includes the disposal cost of all nonrepairable items and equipment throughout the entire life cycle and the logistic support required to accomplish this.

A product's producibility clearly has an effect upon the its life-cycle cost. Most notable is the effect that design decisions have upon the production or assembly costs of the product, and this has been pointed out in the literature [26]. However, the effect of producibility does not stop there. Functions which occur during all four major phases of the product life cycle are influenced by producibility concepts and therefore the product's life-cycle cost is also affected. During the design segment of the research and development phase, the design engineer must endeavor to include producibility principles into the product design. It has been noted that, to be able to use automated manufacturing techniques effectively, products must be designed with manufactureability in mind. This need for increased awareness on the part of the designer, and the need to associate more closely with the manufacturing process to accomplish this, will influence the design cost of the product. During the production phase of the product's life cycle, the level to which the product was designed for ease of assembly will affect the manufacturing progress function of the product. This function describes the advances made in manufacturing due to the learning effect of workers.[1] In the event, the design enables the use of automated manufacturing techniques in place of human workers, the increment in capital costs associated with this new technology must be considered. Often much of a product's life-cycle cost can occur during the operation and support phase. On-going maintenance, both preventive and corrective, contribute greatly to a product's total cost and are in turn affected by decisions made in an attempt to incorporate producibility concerns. A final example of producibility affecting areas of a product's life-cycle cost, other than the assembly or production cost, is the salvage value of the product or the manufacturing equipment required to produce it.

Clearly the effects of product producibility are more far reaching than just assembly or production costs. With this being the case, it is surprising that the literature to date has not assessed the full effect that producibility concepts have upon the product's life-cycle cost. [5,10,24]

1.4 Research Objective

The objective of this research effort is to investigate the role producibility plays in determining a product's life-cycle cost. An obvious shortcoming of previous works pertaining to producibility is

[1] Banks and Fabrycky [2] provide an in depth discussion of the manufacturing progress function.

a lack of assessing what impact design decisions, made to include producibility concerns, have upon product costs arising during each phase of the product life cycle. [5,26] In an attempt to assess this impact, this thesis will present a framework for modeling the effect a product's producibility has upon the determination of its life-cycle cost by implementing a macro-level approach. This macro-level model of the product life cycle will emphasize the areas affected by producibility discussed in the previous section.

1.4.1 Product Producibility Evaluation Model (PPEM)

A life-cycle cost evaluation model will be presented to assess the effect of design decisions (made in an attempt to include producibility concepts) upon a product's life-cycle cost. The model will provide a measure of effectiveness in terms of an expected annual equivalent total system life-cycle cost for a deployed population of the product being evaluated.

Parametric relationships will be established between aspects of the product and the level to which the product is designed for producibility. Following the determination of product characteristics based upon these relationships, design data will be submitted to the design evaluation model to calculate the resulting expected annual equivalent total system life-cycle cost. Three scenarios of a product will be evaluated in terms of life-cycle cost. The three scenarios are defined as a product designed to be highly producible (full implementation of producibility concepts), moderately producible, and less producible (designed without the influence of producibility concepts).

1.4.2 REPS as a Foundation for PPEM

The framework for the Product Producibility Evaluation Model (PPEM) will be the Repairable Equipment Population System (REPS) presented by Banks and Fabrycky [2]. This finite population queuing model evaluates a population of repairable equipment items procured and deployed to meet a demand. A general schematic of the REPS model is shown in Figure 3.

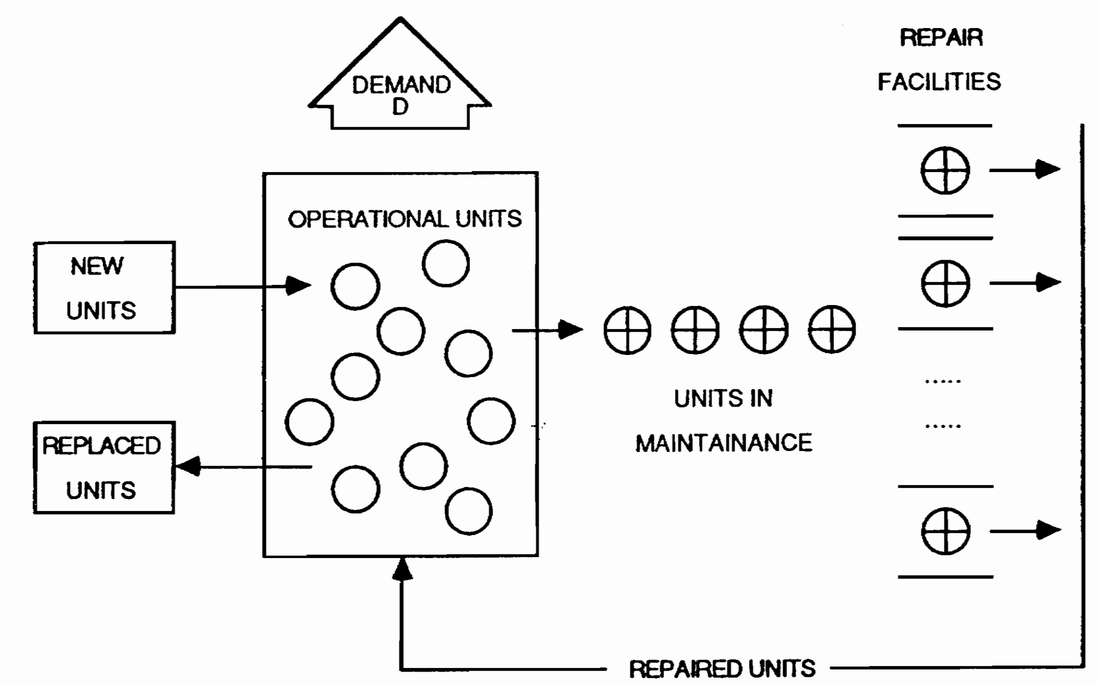


Figure 3. Repairable Equipment Population System (REPS)

The REPS system exists as a result of demand, (D). Units are procured and deployed to meet this demand. Units then separate into two groups: those in operation and available to meet the demand, and those out of operation and unavailable to meet the demand. The REPS model assumes that the units are not discarded upon failure, but are repaired and returned to operation. This requires the provision of repair facilities of sufficient number and capacity so that the system operates in an optimal manner.

The REPS model has been chosen as the building block for PPEM due to its treatment of the entire product life cycle. REPS provides the opportunity to assess the impact of product design, production, operation, maintenance, and retirement upon a product's life-cycle cost.

To build the macro-level producibility evaluation model desired, the REPS model must be enhanced to focus on producibility related aspects of the product. These enhancements to the present REPS model formulation will provide the means to investigate the interaction that producibility concepts have with the product's life-cycle cost. In its present form, REPS utilizes finite queuing theory to form an acquisition/maintenance model. By modifying the acquisition properties of REPS from an off-the-shelf procurement philosophy to one of manufacturing, and utilizing its treatment of product maintenance requirements, an improved evaluator will be created.

1.4.3 PPEM Enhancements of REPS

To use the REPS model as an evaluator of product producibility, enhancements/advances need to be made. The latest deterministic and probabilistic theory for REPS is found in Banks and Fabrycky. PPEM will step beyond this formulation in the following respects:

1. The connection between a product's level of producibility and components of the product's life-cycle cost must be formed. To achieve this, parametric relationships will be provided to account for the effect of producibility influenced design decisions upon a product. Those aspects of the product which will be related to the level of product producibility are:

    a. Cost of design.
    b. Parameters of the Manufacturing Progress Function.
    c. Capital equipment cost.
    d. Machine time and rate ($/hr).
    e. Material cost.

f. Mean time between failure (MTBF).

g. Mean time to repair (MTTR).

h. Salvage value.

2. The incorporation of the Manufacturing Progress Function for determining direct labor requirements.

3. The calculation of unit production cost by incorporating human labor, machine, and material costs with appropriate increases for overhead, general and administrative, and profit charges.

4. An optimization routine to perform a search for the optimal combination of system design variables.

1.4.4 Parametric Relationships to be Used

The relationship between producibility and aspects of the product listed above will be estimated using continuous functions. PPEM will present, for a given relationship, the general form of an equation to be used. The user, while limited to the general form of the equation suggested by PPEM for a relationship, may however, input specific equation parameter values which will cause this formulation to perform as desired for the particular product being evaluated. The intent of this research is to establish a reasonable basis for the shape of the parametric relationships used (i.e., to define the general form of the equations). It is not intended to provide the large amount of historical data needed to statistically validate the relationships.

2.0 Literature Review

A review of literature pertinent to this research effort comes under two major subject headings, Product Producibility and Repairable Equipment Population System. The first, Product Producibility, produced previous research and documentation which could be characterized as being under two separate topics. Design for Producibility, the first of these two Product Producibility subheadings, revealed only limited literature. The second subheading, Design for Assembly, produced numerous examples of prior work. A literature search pertaining to the Repairable Equipment Population System (REPS) constituted the review of the second major subject heading.

2.1 Product Producibility

Literature pertaining to this subject was found to be related to either one of two distinct topics. Both topics concerned the development of products with specific objectives in mind. Whether the objective was design for producibility or design for assembly, the literature discussed the characteristics which a product should process in order to achieve these objectives. Shortcomings in the treatment of these topics did however exist.

2.1.1 Design for Producibility

Clearly the most definitive source of knowledge found under the topic of design for producibility was the Military Handbook, *Design Guidance for Producibility* [13] issued by the Department of Defense. This document began by defining the scope and content of producibility,

> Producibility is the combined effect of the elements or characteristics of a design and the production planning for it that enables the item, described by the design, to be produced and inspected in the quantity required and that permits a series of trade-offs to achieve the optimum of the least possible cost and the minimum time, while still meeting the necessary quality and performance requirements.

The handbook continued by identifying the key elements of this definition having the greatest impact on producibility. Concerns such as simplicity of design, tolerance requirements, production rate and quantity, tooling requirements, and necessary quality and performance were given attention. However, a shortcoming of the handbook was the lack of assessing what effect these elements, manipulated to influence product producibility, would have upon the product's life-cycle cost. Although a relationship between producibility and life-cycle cost was recognized, little explanation was offered. In the form of a figure, the handbook attempted to provide insight as to the trade-offs between the objectives of a good product design. Figure 4 depicts the design engineer's need to balance performance, reliability, and producibility against the overall objective of minimizing life-cycle cost. The discussion relating design for producibility to life-cycle cost was limited to this figure.

The handbook continued by discussing the role a product's producibility plays in each phase of the product life cycle. Once again only a mere mention of the interaction between producibility and its resulting effects was given. While discussing the conceptual phase of product design, the handbook offered this account,

> .... all requirements of the system, such as performance, reliability, maintainability, safety, and producibility, etc., heavily interact with each other as shown in (Figure 5), which creates the need for trade-offs. These can only be considered in light of all their possible ramifications and with recognition that the means to achieve producibility must not result in performance that is less than the minimum required. Therefore, it is imperative that, as a separate task in the conceptual phase, the manufacturer be required to develop, for submission .... a producibility plan.

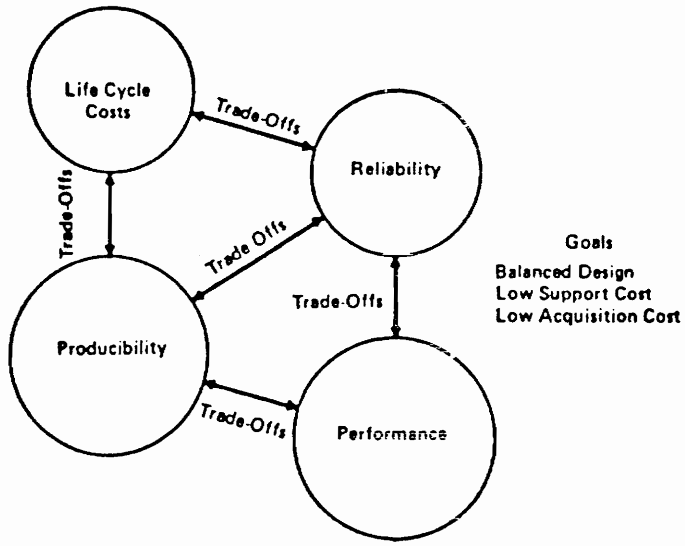


Figure 4. Trade-Offs Between Objectives of a Design (from [13])

While it is important to note that the handbook suggests the need for a producibility plan, which must include some type of evaluation of the effect that product producibility has upon performance (such as the one proposed in this thesis), no guidance for accomplishing this task was given. Again, this need is stated, referring to the production phase,

> Since there is considerable overlap between production and deployment, the producibility studies conducted during development and production can be viewed for their impact on operational activities, such as reliability and maintainability.

As before, no methodology for conducting the study was offered.

Whitney [26] also realized the need to scrutinize products for their level of producibility in the design cycle. He pointed out that by the end of the design process, a product's level of producibility and manufacturing costs have been determined and cited the need for a method to evaluate the product in terms of these design characteristics. Whitney, like the *Design Guidance for Producibility* handbook, offered no real suggestions for achieving this goal.

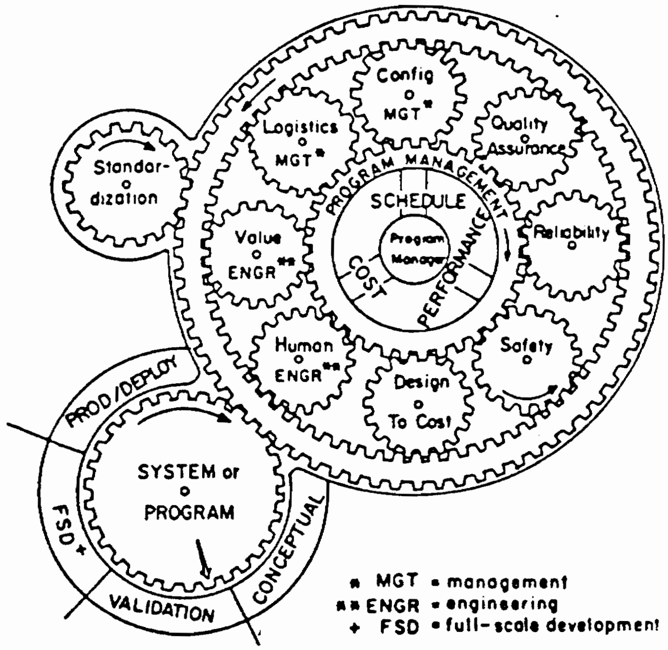


Figure 5. System Requirements Interaction (from [13])

2.1.2 Design for Assembly

A review of the literature concerning design for assembly produced numerous accounts on the subject. Many articles and books have been published describing the benefits of this design philosophy. The chief contributor to this area of work is Boothroyd [5] from the University of Rhode Island. Boothroyd in collaboration with Dewhurst, University of Rhode Island, and Redford [24], University of Salford, U.K., have made great advances in the assessment of product designs based upon their assembly characteristics and have presented the findings of their research.

Boothroyd et al. [4] established an elaborate method of assessing a proposed design in terms of its assembly cost. The method forces the designer to review systematically and consider each part in an assembly as to need, geometric relationship, ease of handling, and assembly technique. This method, presented in handbook form, describes a system, referred to as the UMass system, for rating the efficiency of designs for ease-of-assembly. The handbook presents an elaborate collection of charts and tables which would be used by the designer for guidance through the design process. A series of questions first lead the designer to the selection of the most economical assembly method. This method may either be manual, special purpose assembly machine, or some type of programmable machine. Upon determining the appropriate assembly method, features of the design are examined systematically and a "design efficiency" is calculated. This efficiency allows different designs to be compared for ease of assembly.

Fundamental to a design's efficiency is the concept of the theoretical minimum number of parts for a design. Significant amounts of work have been performed to assess the benefits of product simplification. Often separate parts can be manufactured as one component or eliminated altogether. An overall reduction in the number of parts, if possible, lowers the amount of time required to assemble the product thus contributing to a reduction in production costs. Boothroyd has formulated three questions that determine whether or not parts can be combined to reduce the number of parts and subsequently the number of assembly operations:

1. Does the part move during operation, and if so, can this movement be achieved through a combination of parts in a flexible material?

2. Must the part be of a different material or must the part be isolated for insulation purposes?

3. Must the part be disassembled or separated to allow assembly of others?

This approach provides the ability to model and evaluate the cost effectiveness of different design concepts in terms of assembly costs. The handbook presents a method of calculating the assembly cost of a design by estimating the cost of handling each part, either by manual or automated means, and by estimating the insertion cost of each part. The assembly cost associated with each part in the assembly can then be studied to determine how the total cost is distributed and to identify problem areas where changes would be most beneficial. The system claims that by integrating the requirements of the manufacturing system (assembly method, handling, and insertion requirements) with the product design, reductions of 20 to 40% in manufacturing costs and increases of 100 to 200% in assembly productivity can be achieved.

The handbook was later converted to a series of personal computer programs. Boothroyd et al. [6,7,8,9] subsequently encapsulated the underlying principles of the UMass system in a series of published articles.

The work performed by Boothroyd, Dewhurst, and Redford was well developed in its treatment of designing for and assessing assembly costs. However, their evaluation of the design stopped there. None of the articles resulting from their research ventured into assessing what effect design for assembly decisions would have upon later performance of the product or its life-cycle cost.

Other literature pertaining to the subject of design for assembly was found. Andreasen, Kahler, and Lund [1] published a book which dealt with the subject of design for assembly somewhat differently than did Boothroyd et al. This book explored many of the different ways individual parts could be produced by addressing the manufacturing options as well as the manner in which these parts could later be assembled. Andreasen et al., also did not address the resulting design's effects beyond the production phase.

2.2 Repairable Equipment Population System (REPS)

Fabrycky and Hart [16] presented an expected value version of the REPS model based upon thesis work by Hart [20] and Hinger [21]. Moore [23] enhanced this model by showing that an exact, steady state probability distribution for the number of shortages could be derived. This distribution was then used to compute the steady state expected number of shortages and the probability of one or more shortages. Fabrycky, Malmborg, Moore, and Brammer [17] then presented this formulation in an interactive program for a personal computer. This personal computer version was subsequently updated by a VPI & SU/Old Dominion University [14] team. This most recent version restructured the previous model to facilitate the distinction between design dependent and design independent parameters. A routine developed by Sowder was also incorporated to perform a search for the optimal combination of system design variables.

This framework of system design variables and design parameters is consistent with the theory of the general effectiveness function. This general equation is written:

$$E = f(D, X_{i}, X_{d}, Y) \qquad [2.1]$$

where E is the effectiveness of the system.

D is the demand or need.

X_i are the design independent parameters.

X_d are the design dependent parameters.

Y are the design variables.

The measure of effectiveness (E) provided by the REPS model is an expected annual equivalent total system life-cycle cost ($E[AETSLCC]$).

This cost is composed of three components as shown below:

$$E[AETSLCC] = UC + RC + SC \qquad [2.2]$$

where UC = annual equivalent unit cost

RC = annual equivalent repair facility cost

SC = annual equivalent shortage penalty cost

The design parameters, as mentioned, are divided into two categories. Those parameters which are design independent are ones which are common among any of the possible design alternatives. These would include:

1. The demand which the system is attempting to meet (D).

2. The time value of money, expressed as an annual percentage rate (i).

3. An annual equivalent fixed cost for a repair facility (RC_f) .

4. An annual equivalent operating cost for a repair facility (RC_o) .

5. The shortage penalty cost incured for each unit short per unit time (C_s) .

Design dependent parameters are particular to an individual design alternative. For the REPS model these parameters include:

1. The acquisition cost of an unit (P_i).

2. The salvage value of an unit at the end of its design life (F_i) .

3. The design life of the unit (L_i).

4. Mean time between failure (MTBF) profile over the unit's design life ($MTBF_j$).

5. Mean time to repair (MTTR) profile over the unit's design life ($MTTR_j$) .

6. An annual equivalent operating cost for fuel, operator, etc. (OC).

The system design variables for the REPS model are:

1. The number of units to procure and deploy (N).

2. The economic retirement age of the units (n).

3. The number of repair facilities to operate for maintenance purposes (M) .

3.0 PPEM Description

This chapter will define specific aspects of the Product Producibility Evaluation Model's (PPEM) formulation. Limits to PPEM's applicability in terms of the type of product it may evaluate is discussed. Design independent and design dependent parameters employed by the model are given. PPEM system design variables are presented along with a discussion of an optimization routine for determining the optimal value of the model's measure of effectiveness. The method of calculating the product's unit production cost is given. Assumptions made in the formulation of PPEM are stated. A system level flowchart depicts the general flow of information through the model and indicates the order in which calculations are performed. Finally, a description of each PPEM computer program component is given.

3.1 Subset of Products to be Evaluated by PPEM

PPEM's applicability will be limited in scope to a particular subset of products. A product to be included within this model's domain must meet two requirements:

1. The product must be a repairable item. An underlying premise of PPEM's formulation is the use of the reliability and maintainability metrics of mean time between failure (MTBF) and mean time to repair (MTTR) in the calculation of operation and support costs. A product to be evaluated by PPEM (upon failure) must possess the design characteristics which enable it to be repaired, thereby allowing its return to the population of deployed units.

2. The product must be one which is consistent with this "population of deployed units" concept. Products which are "one of a kind" are not considered to fit within this model's realm of applicability.

3.2 PPEM Design Independent Parameters

Consistent with the general effectiveness function (Equation [2.1]), the PPEM program processes both design independent and design dependent parameters. Of the ten design independent parameters identified in PPEM's formulation, six exist as a result of the REPS model's structure. These are:

1. Demand or need on the system (D).

2. Duration of need (l).

3. The time value of money, expressed as an annual interest rate (i).

4. Annual equivalent fixed repair facility cost (RC_f).

5. Annual equivalent operating repair facility cost (RC_o).

6. Shortage penalty cost (C_s).

The four additional design independent parameters included in PPEM provide the necessary inputs for the pricing structure used to cost-out the product. This pricing scheme incorporates the three major cost components (human labor, machine time, and material costs) into the calculation of a production cost for the units to be deployed. A more detailed explanation of the pricing structure will follow. These additional PPEM design independent parameters are:

1. Hourly labor rate ($/hr.) for human labor ($LR$).

2. Overhead rate (OH).

3. General and administrative rate (GA).

4. Profit rate (P).

3.3 PPEM Design Dependent Parameters

In the PPEM formulation, design dependent parameters are the mechanism by which specific aspects of the product are related to the extent to which it was designed for producibility. As discussed in Chapter 1, parametric relationships will be adopted to link the product's level of producibility to aspects of its life-cycle cost. The following are all design dependent parameters which are affected by a product's level of producibility and also contribute to the calculation of an expected annual equivalent total system life-cycle cost:

1. Cost of design (or redesign of base-line product) (C_d).

2. Number of direct labor hours required (manual assembly) for the first unit produced (K).

3. Number of direct machine hours required (automated assembly) (MH) .

4. Annual equivalent capital equipment cost (C_{ce}).

5. Hourly machine rate ($/hr.) for machine time ($MR$).

6. Direct material cost (C_{dm}).

7. Slope parameter of the manufacturing progress function (Φ).

8. MTBF multiplier ($MTBF_m$).

9. MTTR multiplier ($MTTR_m$).

10. Salvage value of the units (F_i).

Three additional design dependent parameters exist, and will not not be related to the product's level of producibility. These include:

1. MTBF profile of the base-line product ($MTBF_j$).

2. MTTR profile of the base-line product ($MTTR_j$).

3. Design life the product (L_i).

3.4 Optimization of System Design Variables

Two basic principles must be adhered to when comparing two or more design alternatives. The first requires that the alternatives being compared be done so by means of some equivalent measure of effectiveness (e.g., annual **equivalent** total system cost, future **equivalent** total system cost, etc.). The second states that when a measure of effectiveness, in the general form $E=f(D, X_i, X_d, Y)$ (Equation [2.1]) is employed, the system design variables (Y) must first be optimized before the resulting equivalent measure of effectivenesses can be compared. That is to say, it is not appropriate to compare two design alternatives unless the values of the system design variables present in the model have been found which assure an optimal value of E for each alternative.

The PPEM formulation processes three system design variables. As in the REPS model these are: the number of units to be produced and deployed, the retirement age of the units, and the number of repair facilities. An optimization routine is therefore needed to perform a three-way search of these system design variables to produce an optimal E. A search technique similar to the sequential design described by Hotelling [22], and Friedman and Savage [19] was developed. As was the case for the sequential search, this search technique is made possible due to the well behaved nature of the total cost function of PPEM. (Although an exact mathematical proof is not available experimentation to date suggests this function possesses a single local minimum (i.e., gobal minimum)).

The following algorithm (developed by Sowder and illustrated by Figure 6) describes this search technique. Note: This surface in space (shown in Figure 6) is actually defined by a discrete set of points rather then by a continuous surface.

Step 1. N (the number of units to deploy) = Demand (D).

Step 2. For the given value of N, advance along the section defined by n (the retirement age) = Design life and increasing values of M (the number of repair facilities) (i.e., (n,M = 1,...,N)).

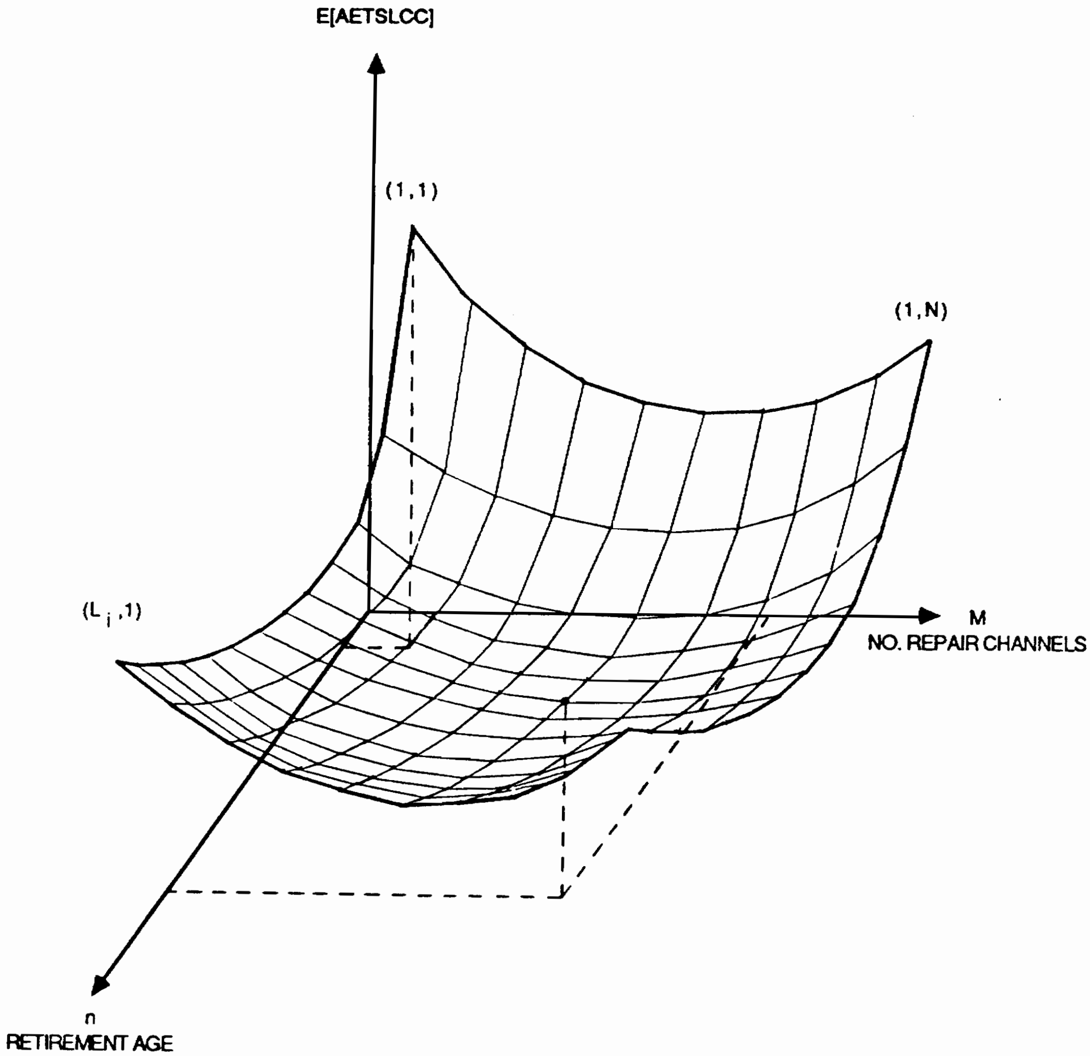


Figure 6. Design Variable Search Technique: **For each population size (N) (the number of units to deploy) one such surface exists.**

Step 3. Continue along this section until its minimum point is found (i.e., point (n,M) is the minimum if point (n,M+1) is greater than point (n,M)).

Step 4. nn = n, m = M. Decrement n. If n = 0 go to step 7.

Step 5. Advance along this section as described in step 3 (n,M = 1,...,N).

Step 6. If the minimum on section n is less than the minimum on section n + 1 go to step 4.

Step 7. The minimum point on this surface (for the given value of N) is at point (nn,m).

Step 8. If the minimum point for surface N-1 is greater than the minimum point for surface N, increment N, go to step 2.

Step 9. The optimal values of n and M are found on surface N-1.

3.5 Production Cost Pricing Structure

As described earlier, one aspect of PPEM which differs from that of the REPS model is its treatment of unit acquisition. The REPS model was based upon an off-the-shelf procurement of the necessary units, whereas PPEM will consider the production of these units. In order to accumulate costs and to derive a first cost for the units, PPEM will perform a cost-plus-fee calculation. The purpose of the pricing structure is to accumulate the three major sources of direct costs; human labor, machine time, and materials cost, and then apply the appropriate percentage increases for overhead, general & administrative charges, and profit. The cost-plus-fee pricing structure used here is a derivative of the direct-labor-cost method described by Banks and Fabrycky. Where the direct-labor-cost method uses a singular factory burden cost to allocate indirect costs the cost-plus-fee method employed by PPEM breaks this cost into overhead and general & administrative portions. Overhead charges are applied as an percentage of direct labor (Equation [3.1.2]) and general & administrative charges are applied to the sum of direct and indirect costs (Equation [3.1.4]). A margin of profit or fee is then applied to this subtotal (Equation [3.1.5]).

The first two of these direct costs, direct labor cost, and direct machine cost, will be the result of calculating beforehand the number of direct labor hours and direct machine hours required to produce a unit and then multipling by the appropriate rates ($/hr.). These direct costs and direct material cost are shown in the following equations which details the pricing scheme.

```
    Direct Labor Cost                          [3.1.1]
    Direct Machine Cost
  + Direct Materials Cost
    ----------------------------
    Total Direct Cost

    Direct Labor Cost                          [3.1.2]
  * Overhead Rate
    ----------------------
    Total Indirect Cost

    Total Direct Cost                          [3.1.3]
  + Total Indirect Cost
    -------------------------
    Unit Cost

    Unit Cost                                  [3.1.4]
  * General and Administrative rate
    -------------------------------------
    Subtotal

    Subtotal                                   [3.1.5]
  * Profit rate (Fee)
    --------------------------
    Unit Production Cost
```

3.6 PPEM Assumptions

The following assumptions were adopted in the development of the PPEM formulation:

1. Three design alternatives of a product are defined. Each alternative reflects a different level to which the product is designed with producibility concepts in mind. The base-line alternative is one in which information is presently known, perhaps a current design in production. The other two alternatives possess higher degrees of design for producibility.

2. The higher levels of producibility are achieved by redesigning the base-line alternative.

3. The product is produced utilizing human labor, machine time, or a combination of the two. The amount of human labor and machine time used are inversly related. That is say, if the base-line product requires both human labor and machine time to produce it, and if increasing the product's producibility enables the use of automatic assembly, the human labor element will decline in association with an increase in machine time.

4. The direct human labor hours required to produce a product reduces by a constant percentage on doubled production quantities (Manufacturing Progress Function).

5. Overhead is applied as a percentage of direct labor cost.

6. The relationship between a product's level of producibility and the resulting values for it's dependent parameters are known to the extent that the general form of the equation defining the relationship is given by PPEM.

7. The calculation of the total number of units to be produced over the duration of the stated need is made possible by knowing the value of the invariant demand, retirement age of the units, and the assumption that the population of deployed units are made up of equally sized subgroups of units. Each subgroup being of a certain age and as units retire they are replaced by new units so that the population operates in steady state with respect to its average age of units.

8. The design life of the product is defined in integer years. Likewise, the retirement age of the product is determined and presented in years. Note: Years as the unit of measure for equipment life was adopted to be consistent with the end-of-year cash flow convention used in engineering economy. This unit of measure is, however, inconsistent with many equipment design applications.

9. All assumptions stated for the REPS model formulation by Banks and Fabrycky [2] are valid.

a. Demand is deterministic and time invariant.

b. Each unit in the population will age until its time for retirement is reached.

c. The population will be made up of subgroups of units, with each subgroup being of a certain age.

d. Units upon retirement are replaced by new units so that the inventory operates in steady state with respect to its average age of units.

e. The number of new units procureed each year is constant so that the number of units in each age group will be equal to the ratio of the total number required in the population and the desired number of age groups.

f. The interarrivial times (MTBF) are exponentially distributed.

g. The repair times (MTTR) are exponentially distributed.

h. The interarrivial times are statistically independent of the repair times.

i. The number of units is small such that finite population queuing formulations must be used.

j. The repair facilities operate in parallel and each is capable of similar performance.

k. The number of repair facilities is less than or equal to the number of units.

l. Each repair facility may service only one unit at a time.

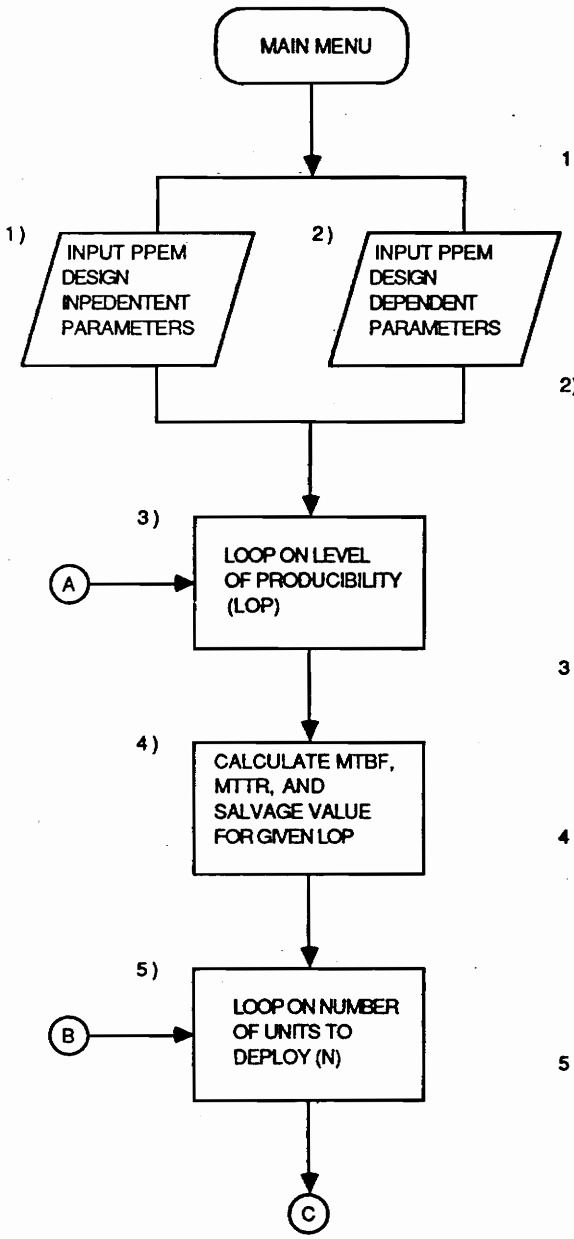
m. MTBF and MTTR values may vary for each age group and represent the expected values for these variables.

n. Units completing repair return to operation with the same operating characteristics of their age group.

o. The time spent in repair includes only the time units spend in the repair facility and does not include any time spent waiting in queue for service or any time spent in transportation to and from the repair facility.

3.7 PPEM System Level Flowchart

The flowchart depicted in Figures 7-9 describe the general flow of information through the PPEM program. It shows the order of calculations performed for each of the three design scenarios.



1) THERE IS A MAIN MENU WHICH BRANCHES INTO THE DESIGN INDEPENDENT AND DESIGN DEPENDENT PARAMETER INPUT SCREENS. A SUBROUTINE FOR EACH PARAMETER ALLOWS DATA ENTRY AND MODIFICATION. PPEM DESIGN INDEPENDENT PARAMETERS ARE ENTERED THROUGH SUBROUTINES IPiSUB (WHERE i = 1,...,9).

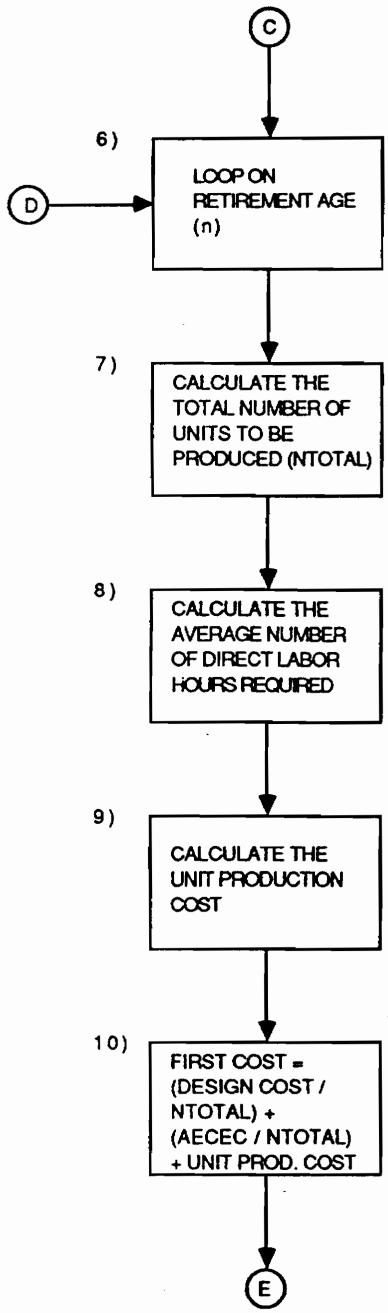
2) PPEM DESIGN DEPENDENT PARAMETERS ARE ENTERED THROUGH SUBROUTINES DPiSUB (WHERE i = 1,...,12). DESIGN DEPENDENT PARAMETERS WHICH RELATE TO THE PRODUCT'S LEVEL OF PRODUCIBILTY HAVE A PLOT OPTION WHICH ALLOWS THE USER TO VIEW THE RESULTING PARAMETRIC RELATIONSHIP. THIS ALSO PRESENTS THE VALUES TO BE USED FOR EACH OF THE THREE LEVELS OF PRODUCIBILTY CONSIDERED BY PPEM.

3) FOR EACH OF THE THREE LEVELS OF PRODUCIBILTY FOR A PRODUCT THE PROCESS DESCRIBED BY BLOCKS 3-16 IS FOLLOWED.

4) FOR THE GIVEN LEVEL OF PRODUCIBLITY THE RESULTING VALUES OF THE PRODUCT'S MTBF AND MTTR PROFILES ARE CALCULATED ALONG WITH ITS SALVAGE VALUE.

5) THE THREE WAY SEARCH FOR THE OPTIMAL COMBINATION OF THE PPEM DESIGN VARIABLES BEGINS AND CONTINUES THROUGH BLOCK 15. THIS SEARCH IS DESCRIBED IN DETAIL IN SECTION 3.4. THIS OUTER LOOP OF THE SEARCH PROCESS IS CONTROLLED BY SUBROUTING PPEMCL.

Figure 7. PPEM System Level Flowchart (page 1)



6) THE MIDDLE LOOP OF THE DESIGN VARIABLE OPTIMIZATION ROUTINE DETERMINES THE RETIREMENT AGE (n) OF THE PRODUCT. THIS PORTION OF THE SEARCH IS CONTROLLED BY SUBROUTINE OPTNN.

7) GIVEN N AND n THE TOTAL NUMBER OF UNITS TO BE PRODUCED OVER THE DURATION OF THE STATED DEMAND ON THE SYSTEM IS DETERMINED. THIS IS PERFORMED BY SUBROUTINE OPTNN.

8) BASED UPON THE TOTAL NUMBER OF UNITS TO BE PRODUCED SUBROUTINE MPF CALCULATES THE AVERAGE NUMBER OF DIRECT LABOR HOURS REQUIRED TO PRODUCE A UNIT OF THE PRODUCT.

9) SUBROUTINE UPC CALCULATES THE UNIT PRODUCTION COST OF THE PRODUCT.

10) AN EQUALLY PROPORTIONED AMOUNT OF DESIGN COST AND ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST IS ADDED TO THE UNIT'S PRODUCTION COST TO DERIVE THE PRODUCT'S FIRST COST.

Figure 8. PPEM System Level Flowchart (page 2)

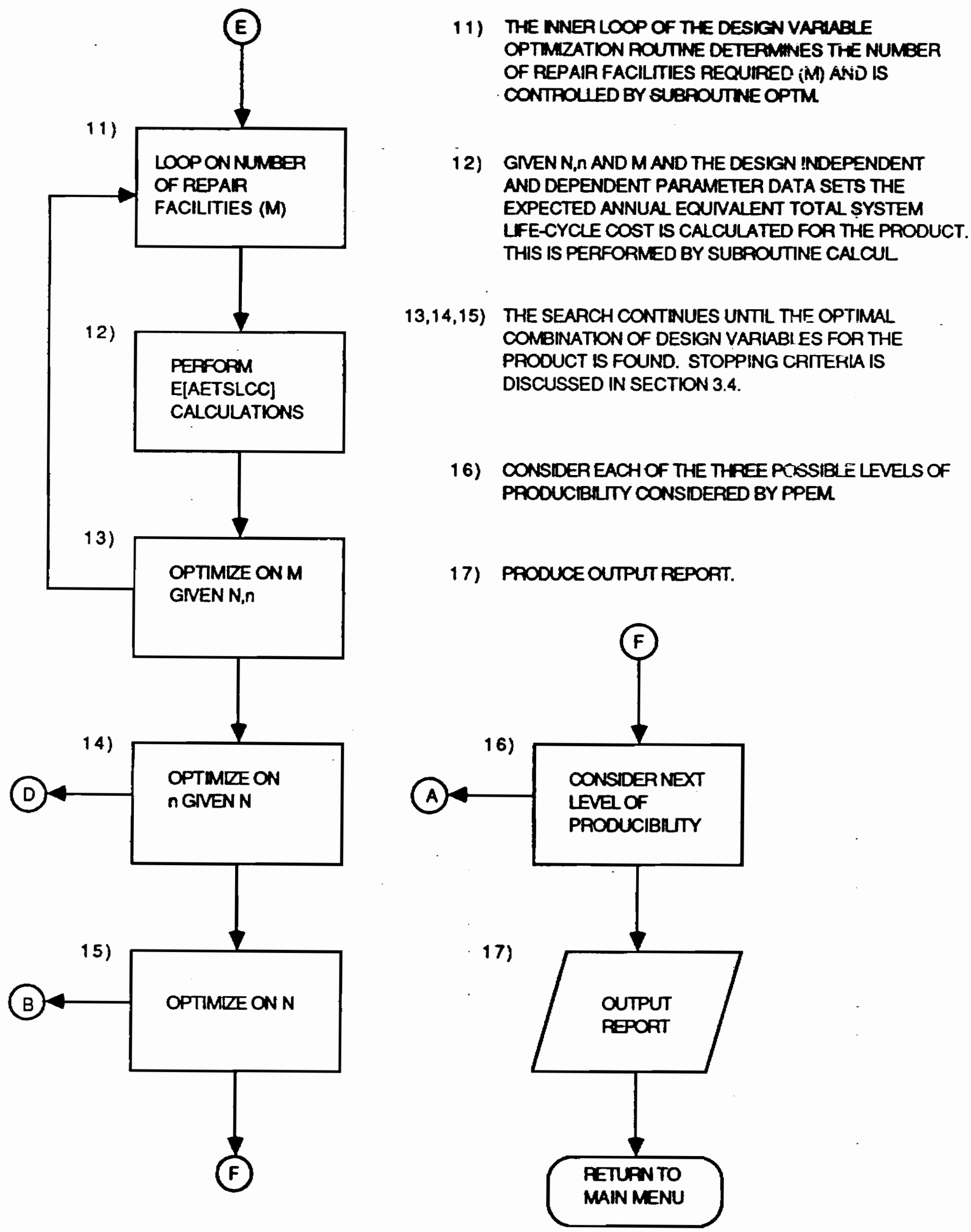


Figure 9. PPEM System Level Flowchart (page 3)

3.8 PPEM Program Components

The following sections describe each component of the PPEM program. PPEM is written in FORTRAN 77 utilizing the Microsoft FORTRAN77 Compiler V3.31 and operates on any IBM personal computer or compatible, PC/MS DOS operating system.

3.8.1 PPEM Main Program

The PPEM Main program declares variable types, lists the nine COMMON blocks used, and provides a dictionary for variables contained in the COMMON blocks and variables used within the Main program. The PPEM Main program writes the PPEM Main Menu screen. From this menu the user may select to perform any of 6 functions. Data entry and modification is performed through either the PPEM Design Independent Parameters menu screen or the PPEM Design Dependent Parameters menu screen. Both are written and controled within the PPEM Main program. The appropriate data entry subroutine is called by the PPEM Main program. Execution of the $E[AETSLCC]$ calculations are initiated by the call of subroutine PPEMCL from the PPEM Main program. Subroutines SAVE and RETRV are called to provide storage and retrieval capability for design parameter data sets. Exit from PPEM is controled by the PPEM Main program.

3.8.2 Subroutines IPiSUB

Subroutine IPiSUB (where i = 1,...,9) provides data input and modification capabilities for the ith PPEM design independent parameter. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Input data is stored in the appropriate variable within COMMON block

ABLK. The variable FLAG(i) within COMMON block FBLK is used to indicate data input has occured. The subroutine returns to the PPEM Main program.

3.8.3 Subroutine DP1SUB

Subroutine DP1SUB provides data input and modification capabilities for the 1st PPEM design dependent parameter, Cost of design. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable DCOST within COMMON block DBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP1P1 and DP1P2 within COMMON block IBLK. The variable FLAG(10) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP1SUB. The subroutine returns to the PPEM Main program.

3.8.4 Subroutine DP2SUB

Subroutine DP2SUB provides data input and modification capabilities for the 2nd PPEM design dependent parameter, Number of direct labor hours required for first unit. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable DLH1 within COMMON block CBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP2P1 and DP2P2 within COMMON block IBLK. The variable FLAG(11) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP2SUB. The subroutine returns to the PPEM Main program.

3.8.5 Subroutine DP3SUB

Subroutine DP3SUB provides data input and modification capabilities for the 3rd PPEM design dependent parameter, Number of direct machine hours required. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable MACHR within COMMON block BBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP3P1, DP3P2, and DP3P3 within COMMON block IBLK. The variable FLAG(12) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP3SUB. The subroutine returns to the PPEM Main program.

3.8.6 Subroutine DP4SUB

Subroutine DP4SUB provides data input and modification capabilities for the 4th PPEM design dependent parameter, Annual equivalent capital equipment cost. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable AECEC within COMMON block BBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP4P1 ,DP4P2, and DP4P3 within COMMON block IBLK. The variable FLAG(13) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP4SUB. The subroutine returns to the PPEM Main program.

3.8.7 Subroutine DP5SUB

Subroutine DP5SUB provides data input and modification capabilities for the 5th PPEM design dependent parameter, Hourly machine rate. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable MACHRT within COMMON block ABLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP5P1, DP5P2, and DP5P3 within COMMON block IBLK. The variable FLAG(14) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP5SUB. The subroutine returns to the PPEM Main program.

3.8.8 Subroutine DP6SUB

Subroutine DP6SUB provides data input and modification capabilities for the 6th PPEM design dependent parameter, Direct material cost. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable DIRMAT within COMMON block BBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP6P1 and DP6P2 within COMMON block IBLK. The variable FLAG(15) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP6SUB. The subroutine returns to the PPEM Main program.

3.8.9 Subroutine DP7SUB

Subroutine DP7SUB provides data input and modification capabilities for the 7th PPEM design dependent parameter, Slope parameter of the manufacturing progress function. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable PHI within COMMON block CBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP7P1, DP7P2, and DP7P3 within COMMON block IBLK. The variable FLAG(16) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP7SUB. The subroutine returns to the PPEM Main program.

3.8.10 Subroutine DP8SUB

Subroutine DP8SUB provides data input and modification capabilities for the 8th PPEM design dependent parameter, Design life of the product. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Input data is stored in variable DAGE within COMMON block EBLK. The variable FLAG(17) within COMMON block FBLK is used to indicate data input has occured. The subroutine returns to the PPEM Main program.

3.8.11 Subroutine DP9SUB

Subroutine DP9SUB provides data input and modification capabilities for the 9th PPEM design dependent parameter, MTBF and MTTR profiles. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Input data is stored in variables BMTBF and BMTTR within COMMON block DBLK. The variable FLAG(18) within COMMON block FBLK is used to indicate data input has occured. The subroutine returns to the PPEM Main program.

3.8.12 Subroutine DP10SB

Subroutine DP10SB provides data input and modification capabilities for the 10th PPEM design dependent parameter, MTBF multiplier. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable MTBFM within COMMON block DBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP10P1 and DP10P2 within COMMON block IBLK. The variable FLAG(19) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP10SB. The subroutine returns to the PPEM Main program.

3.8.13 Subroutine DP11SB

Subroutine DP11SB provides data input and modification capabilities for the 11th PPEM design dependent parameter, MTTR multiplier. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable MTTRM within COMMON block DBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP11P1 and DP11P2 within COMMON block IBLK. The variable FLAG(20) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP11SB. The subroutine returns to the PPEM Main program.

3.8.14 Subroutine DP12SB

Subroutine DP12SB provides data input and modification capabilities for the 12th PPEM design dependent parameter, Salvage value. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Design dependent parameter data is stored in variable SALVAG within COMMON block DBLK. Equation parameters used to define the design dependent parameter-level of producibility relationship are stored in variables DP12P1 and DP12P2 within COMMON block IBLK. The variable FLAG(21) within COMMON block FBLK is used to indicate data input has occured. Subroutine PLOT may be called by subroutine DP12SB. The subroutine returns to the PPEM Main program.

3.8.15 Subroutine PLOT

Subroutine PLOT generates a X,Y plot of design dependent parameter data vs. the product's level of producibility. Variable types are declared, and a dictionary is provided for variables used by the subroutine. The subroutine may be called by subroutines DP1SUB, DP2SUB, DP3SUB, DP4SUB, DP5SUB, DP6SUB, DP7SUB, DP10SB, DP11SB or DP12SB. The subroutine returns to the design dependent parameter input subroutine which called it.

3.8.16 Subroutine PPEMCL

Subroutine PPEMCL controls the outer loop of the *E[AETSLCC]* optimization algorithm. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. This outer loop of the optimization algorithm, which increments the value of *N*, calls subroutine OPTNN. Looping continues until the optimum value for *E[AETSLCC]* is found for each of the three levels of producibility defined for the product. The subroutine returns to the PPEM Main program.

3.8.17 Subroutine OPTNN

Subroutine OPTNN controls the middle loop of the *E[AETSLCC]* optimization algorithm. Variable types are declared, a COMMON block is listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by subroutine PPEMCL. This middle loop of the optimization algorithm, which increments the value of *n* and calculates the total number of units (*NTOTAL*) which are required to be produced over the duration of the stated need on the system. Subroutines MPF, UPC, and OPTM are called by this subroutine. The subroutine returns to subroutine PPEMCL.

3.8.18 Subroutine OPTM

Subroutine OPTM controls the inner loop of the *E[AETSLCC]* optimization algorithm. Variable types are declared, and a dictionary is provided for variables used by the subroutine. The subroutine is called by subroutine OPTNN. This inner loop of the optimization algorithm, which increments the value of *M*, calls subroutine CALCUL. The subroutine returns to subroutine OPTNN.

3.8.19 Subroutine CALCUL

Subroutine CALCUL calculates an $E[AETSLCC]$ value for a given set of design independent and design dependent parameters. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine performs calculations similar to those performed by the Repairable Equipment Population System (REPS). The subroutine returns to subroutine OPTM.

3.8.20 Subroutine MPF

Subroutine MPF calculates the average number of direct labor hours required to produce one unit of the product. Variable types are declared, a COMMON block is is listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by subroutine OPTNN. Utilizing a manufacturing progress function, the number of direct labor hours required the produce each of the first $NTOTAL$ units is found and an average taken. The subroutine returns to subroutine OPTNN.

3.8.21 Subroutine UPC

Subroutine UPC calculates the unit production cost of the product being designed. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by subroutine OPTNN. Labor, machine, and material costs are accumulated and percentage increases for overhead, general and administrative, and profit are added. The subroutine returns to subroutine OPTNN.

3.8.22 Subroutine OUTP

Subroutine OUTP writes the results of the PPEM program run. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. An input summary of PPEM design independent parameters is followed by summaries of the PPEM design dependent parameters corresponding to each of the three levels of producibility and derived values for the $E[AETSLCC]$. Additional output include the average number of direct labor hours required to produce an unit, expected number of units short of demand, probability of one or more units short, and the optimum combination of the system design variables. The subroutine returns to the PPEM Main program.

3.8.23 Subroutine SAVE

Subroutine SAVE saves all values needed to define the PPEM design independent and design dependent parameters. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM Main program. Data is written to the default disk drive with a user specified file name. The subroutine returns to the PPEM Main program.

3.8.24 Subroutine RETRV

Subroutine RETRV retrieves previously stored values used to define PPEM design independent and design dependent parameters. Variable types are declared, COMMON blocks are listed, and a dictionary is provided for variables used by the subroutine. The subroutine is called by the PPEM

Main program. Data is read from the default disk drive. The user must specify the correct file name. The subroutine returns to the PPEM Main program.

4.0 PPEM Demonstration Problem

This chapter is composed of three sections, PPEM Data Input Requirements, PPEM Output Report, and Observations. The first section, PPEM Data Input Requirements, describes the method of entering data and presents PPEM design independent and design dependent test data sets. The second section, PPEM Output Report, presents the output listing provided by the PPEM program and describes its content. The final section, Observations, briefly discusses some additional aspects of the model and its calculations.

4.1 PPEM Data Input Requirements

The PPEM program begins by presenting the user with the PPEM Main Menu screen. From this menu the user may elect to enter the design independent and design dependent parameter data required to execute the model. This may be accomplished by entering each design parameter value or by retrieving a set of previously stored parameter data. This demonstration will proceed under the assumption that all data must be entered.

4.1.1 PPEM Design Independent Parameter Data

From the PPEM Main Menu, shown in Figure 10, the user selects function 1 to begin the process of entering the PPEM design independent parameter data.

```
************************************************************
*                                                          *
*                    PPEM MAIN MENU                        *
*                                                          *
*    1  ENTER PPEM DESIGN INDEPENDENT PARAMETERS           *
*    2  ENTER PPEM DESIGN DEPENDENT PARAMETERS             *
*    3  RUN THE PPEM PROGRAM (OPTIMIZE UPON SYSTEM         *
*       DESIGN VARIABLES AND VIEW RESULTS)                 *
*    4  SAVE CURRENT PPEM DESIGN PARAMETER DATA            *
*    5  RETRIEVE PPEM DESIGN PARAMETER DATA FILE           *
*    6  EXIT TO DOS                                        *
*                                                          *
*  ENTER THE NUMBER (1,2,3,4,5,OR 6) OF THE FUNCTION YOU   *
*  WISH TO PERFORM.                                        *
*                                                          *
************************************************************
```

Figure 10. PPEM Main Menu screen

The PPEM Design Independent Parameters menu screen is then presented. From this screen all design independent parameter data is entered. The user selects the design independent parameter which is to be entered and following a brief explanation of the parameter the user is prompted for input. Once entered, the value for the design independent parameter is presented to the user for verification and an opportunity to modify the value is offered. If the value is not changed the PPEM Design Independent Parameters menu screen is presented and the next design independent parameter may be entered. At any time, via the PPEM Design Independent Parameters menu screen, a design independent parameter value may be viewed and changed if necessary. Figure 11 illustrates the PPEM Design Independent Parameters menu screen.

```
*****************************************************************
*                                                               *
*              PPEM DESIGN INDEPENDENT PARAMETERS               *
*                                                               *
* 1  MAGNITUDE AND DURATION OF DEMAND ON THE SYSTEM             *
* 2  THE TIME VALUE OF MONEY                                    *
* 3  ANNUAL EQUIVALENT FIXED REPARIR FACILITY COST              *
* 4  ANNUAL EQUIVALENT OPERATING REPAIR FACILITY COST           *
* 5  SHORTAGE PENALTY COST                                      *
* 6  HOURLY LABOR RATE                                          *
* 7  OVERHEAD RATE                                              *
* 8  GENERAL AND ADMINISTRATIVE RATE                            *
* 9  PROFIT RATE                                                *
* 10 RETURN TO TO PPEM MENU                                     *
*                                                               *
*  ENTER THE NUMBER OF THE DESIGN INDEPENDENT PARAMETER         *
*  YOU WISH TO DEFINE OR RETURN TO PPEM MAIN MENU.              *
*                                                               *
*****************************************************************
```

Figure 11. PPEM Design Independent Parameters menu screen

To illustrate the PPEM program a design independent parameter test data set will to used. The actual values to be used are presented in Table 1 and a brief discusion of these will follow.

Table 1. PPEM Design Independent Parameter test data inputs

PPEM Design Independent Parameter	Value
Demand on the system (D)	15 units
Duration of need (l)	10 years
Time value of money (i)	9.0 percent
Annual equiv. fixed repair facility cost (RC_f)	$9469.00
Annual equiv. operating repair facility cost (RC_o)	$35000.00
Shortage penalty cost (C_s)	$73000.00
Hourly labor rate (LR)	$27.00
Overhead rate (OH)	85 percent
General and administrative rate (GA)	13.5 percent
Profit rate (P)	10 percent

For the demand on the system a value of 15 units will be the quantity needed. Any integer value up to 33 is allowed. The computational limits of the personal computer placed restrictions on this value.[2] A demand of 15, while being well below this limit, should insure a deployed population of sufficient magnitude so that possible differences in population size exhibit influence on the expected annual equivalent total system life-cycle cost calculations. The duration of this need will be assumed to be 10 years. A figure for the time value of money, expressed as an annual interest rate, must be calculated external to the program. This calculation, like those for the shortage penalty cost, overhead rate, general and administrative rate, and the profit rate typically fall on the responsibility of company management and estimates for these design independent parameters must be obtained. For this PPEM demonstration problem it is assumed these values are as listed above. External calculations required by the PPEM program which are more attuned to the realm of the producibility engineer are those involving repair facility costs and the determination of an appropriate labor rate. The annual equivalent fixed repair facility cost may calculated using the following annual equivalent cost equation:

$$A = (P - F)(A/P,i,n) + Fi \quad [4.1]$$

where A = annual equivalent cost

P = present value

F = future value

$(A/P,i,n)$ = capital-recovery factor[3]

i = annual interest rate

n = number of years

The following values were used in the calculation of the annual equivalent fixed repair facility cost:

---

[2] The mathematics involved in the finite queuing theory analysis used to calculate the probability of being units short of demand and the expected number of units short require the factorial of the population size be taken. The personal computer can compute these factorials for values no greater than 33. DATA statements were not included to input larger values.

[3] The value for the capital-recovery factor may be found in an Interest Factors for Annual Compounding Table like that in reference 3, or by solving directly for $\left[\frac{(i(1+i)^n)}{((1+i)^n - 1)}\right]$.

repair facility first cost = \$65000.00

repair facility salvage value = \$10000.00

repair facility design life = 10 years

annual interest rate = 9.0 percent

Therefore, the annual equivalent fixed repair facility cost (RC_f) is:

$$(RC_f) = (\$65000 - \$10000)(0.1558) + \$10000(0.09) = \$9469.00$$

The annual equivalent operating repair facility cost must include such factors as administrative costs, maintenance manpower, small test equipment, and other overhead items. For this PPEM demonstration problem this value is assumed to be an annual equivalent cost of \$35000.00.

The determination of a labor rate first involves the selection of personnel who will perform the manual labor required. In the formulation of the PPEM program a simplifying assumption was made to limit the possible classifications of personnel to only one. Therefore the production of the product, whether the product is designed with a high level of producibility or low, will utilize a workforce with a singular computable average hourly labor rate. For this PPEM demonstration problem the hourly rate for direct labor is assumed to be \$27.00.

4.1.2 PPEM Design Dependent Data

From the PPEM Main Menu, shown in Figure 10, the user selects function 2 to begin the process of entering the PPEM design dependent parameter data. The PPEM Design Dependent Parameters menu screen is then presented. From this screen all design dependent parameter data is entered. The user selects the design dependent parameter which is to be entered and following a brief explanation of the parameter the user is prompted for input. Once entered, the value for the design dependent parameter is presented to the user for verification and an opportunity to modify the value is offered. If the value is not changed the PPEM Design Dependent Parameters menu screen is presented and the next design dependent parameter may be entered. At any time, via the PPEM Design Dependent Parameter screen, a design dependent parameter value may be viewed and changed if necessary. Figure 12 illustrates the PPEM Design Dependent Parameters menu screen.

```
************************************************************
*                                                          *
*              PPEM DESIGN DEPENDENT PARAMETERS            *
*                                                          *
* 1  COST OF DESIGN (REDESIGN OF BASE-LINE PRODUCT)        *
* 2  NUMBER OF DIRECT LABOR HOURS REQUIRED FOR FIRST UNIT  *
* 3  NUMBER OF DIRECT MACHINE HOURS REQUIRED               *
* 4  ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST              *
* 5  HOURLY MACHINE RATE                                   *
* 6  DIRECT MATERIAL COST                                  *
* 7  SLOPE PARAMETER OF THE MANUFACTURING PROGRESS FN.     *
* 8  DESIGN LIFE OF THE PRODUCT                            *
* 9  MTBF AND MTTR PROFILE OF THE BASE-LINE PRODUCT        *
* 10 MTBF MULTIPLIER                                       *
* 11 MTTR MULTIPLIER                                       *
* 12 SALVAGE VALUE                                         *
* 13 RETURN TO PPEM MAIN MENU                              *
*                                                          *
*  ENTER THE NUMBER OF THE DESIGN DEPENDENT PARAMETER      *
*  YOU WISH TO DEFINE OR RETURN TO PPEM MAIN MENU.         *
*                                                          *
************************************************************
```

Figure 12. PPEM Design Dependent Parameters menu screen

To illustrate the PPEM program a design dependent parameter test data set will be used. PPEM design dependent parameters are entered in a manner different then that used to enter the PPEM design independent parameters. PPEM design dependent parameters are related to the level to which the product is designed with producibility in mind. This relationship between producibility and the PPEM design dependent parameters will be estimated using continuous functions.

4.1.2.1 Choice of functions used in PPEM

The PPEM program uses continuous functions to relate the extent to which a product is designed for producibility and resulting values of the product's design dependent parameters. For a given relationship, the general form of the equation to be used is presented. By assigning specific values to this equation the design dependent parameter is determined for each of the levels of producibility considered by the PPEM program.

PPEM employs three different equations (continuous functions) for establishing the relationship between producibility and design dependent parameters. These three general equations include the linear or straight line function, the growth function, and the decay function. These functions were selected so as to provide the capability of modeling any relationship which may remain constant (linear function), increase or decrease at a constant rate (linear function), increase at a decreasing rate (growth function), or decrease at a decreasing rate (decay function). Equations which exponentially increased or decreased were not considered in the formulation of PPEM.

For each of the design dependent parameters which PPEM relates to varying degrees of design for producibility one of the three functions described above was selected. Included in the following discussions of each design dependent parameter is the reasoning behind the selection of the chosen function from among the three available functions. The discussion includes a brief statement as to whether the resulting relationship should be modeled as increasing at a decreasing rate (growth function), decreasing at a decreasing rate (decay function), or as the remaining option model the relationship using the linear function.

To demonstrate the PPEM program's design dependent parameter data input requirements the first three parameters listed in the PPEM Design Dependent Parameters menu screen will be described in detail. Each employs one of the three different equations presently used by the PPEM program to relate design dependent parameters to the various levels of producibility and demonstrates the different input requirements.

4.1.2.2 Cost of design

Cost of design is the first of twelve design dependent parameters identified by the PPEM program. During the design of a product efforts to include producibility concerns into the design process can often influence the design cost of the product. A concerted effort to include design engineers, producibility engineers, manufacturing engineers, and everyone it takes to design a highly producible product is only accomplished at the expense of additional time and money. Consequently this increased cost should be reflected in a product's life-cycle cost. The PPEM program uses a linear function (straight line) to estimate the effect of producibility induced design decisions on the cost of design. The user inputs the cost for product design required to reach the first level of producibility (if the product is already in production a cost of $0.00 could be entered), and a value for the slope of line that will determine the cost of design at higher levels of producibility.

The general form of the straight line equation is

$$y = mx + b \qquad [4.2]$$

where y = resulting value for cost of design

m = slope of the line

x = degree of producibility

b = y-intercept (design cost of base-line product)

Note: The values for x range from 0 to 2. Cost of design at the three defined levels of producibility are found as follows:

Level of Producibility 1, computed at $x = 0$

Level of Producibility 2, computed at $x = 1$

Level of Producibility 3, computed at $x = 2$

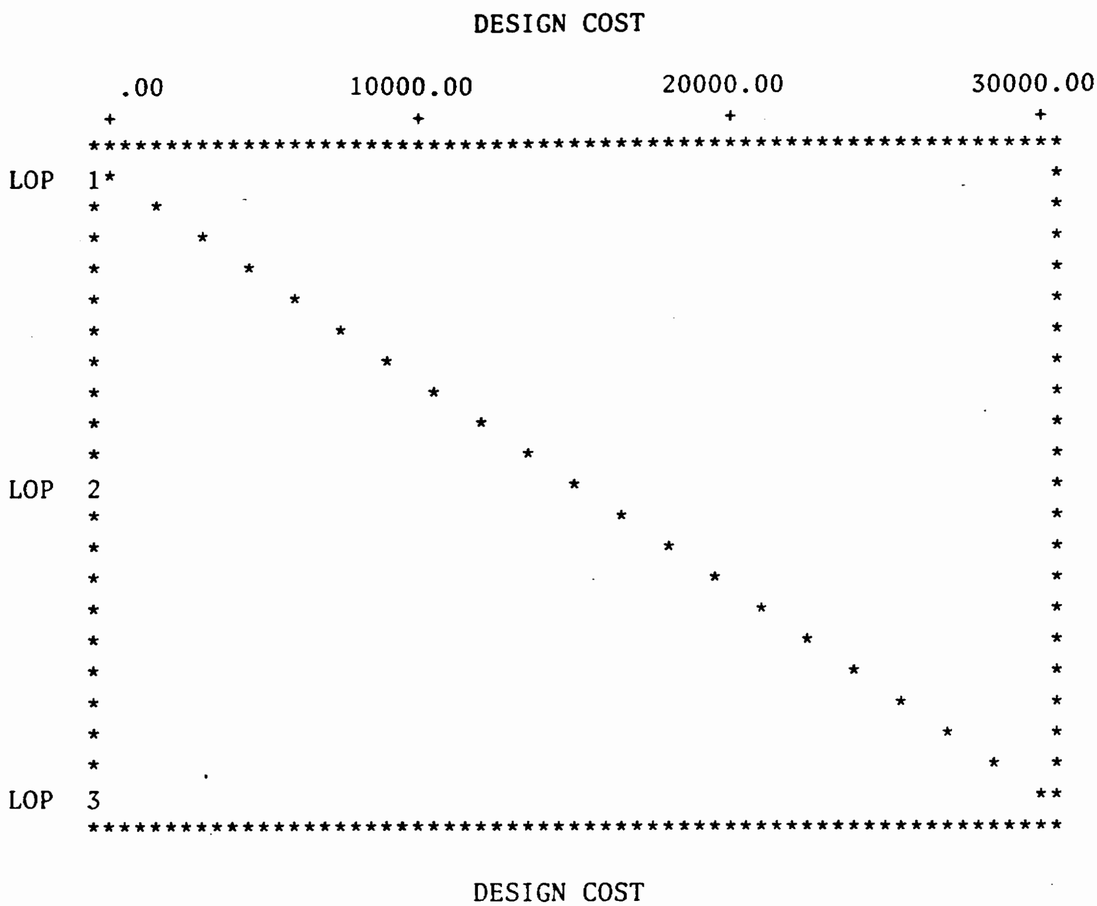
This remains true for each of the PPEM design dependent parameters.

For this PPEM demonstration problem the following values were used to determine the cost of design for the product.

Table 2. Cost of Design test data inputs

function	y-intercept	slope
linear	0.00	15000.00

Upon entering the values the user may view a graph of the relationship defined for the design dependent parameter. Figure 13 presents a graph of the function defined along with the actual values that will be used for the product's cost of design at each of the three levels of producibility considered by PPEM.




```
LEVEL OF PRODUCIBILITY  1        .00
LEVEL OF PRODUCIBILITY  2   15000.00
LEVEL OF PRODUCIBILITY  3   30000.00
```

Figure 13. Cost of Design

4.1.2.3 Number of direct labor hours required (1st unit)

The number of direct labor hours required to produce a product is highly dependent on the extent to which the product was designed for producibility. A product which is not designed so that automated manufacturing techniques can be taken advantage of will typically require a great deal of human labor to produce it. Exactly the opposite is true for a highly producible product. For this product, automated production processes may take the place of human workers. For this reason the decay function was chosen to relate the number of direct labor hours required to produce the first unit of the product to the level of producibility it is designed to achieve.

The general form of the decay function is

$$y = ce^{-rx} \quad [4.3]$$

where y = resulting value for direct labor hours (1st unit)

c = maximum value of the function (y-intercept)

r = decay rate

x = degree of producibility

For this PPEM demonstration problem the following values were used to determine the number of direct labor hours required to produce the first unit of the product.

Table 3. Direct Labor Hours (1st unit) test data inputs

function	maximum value	decay rate
decay	400.00	0.90

Upon entering the values the user may view a graph of the relationship defined for the design dependent parameter. Figure 14 presents a graph of the function defined along with the actual values that will be used for the product's direct labor requirement (1st unit) at each of the three levels of producibility considered by PPEM.

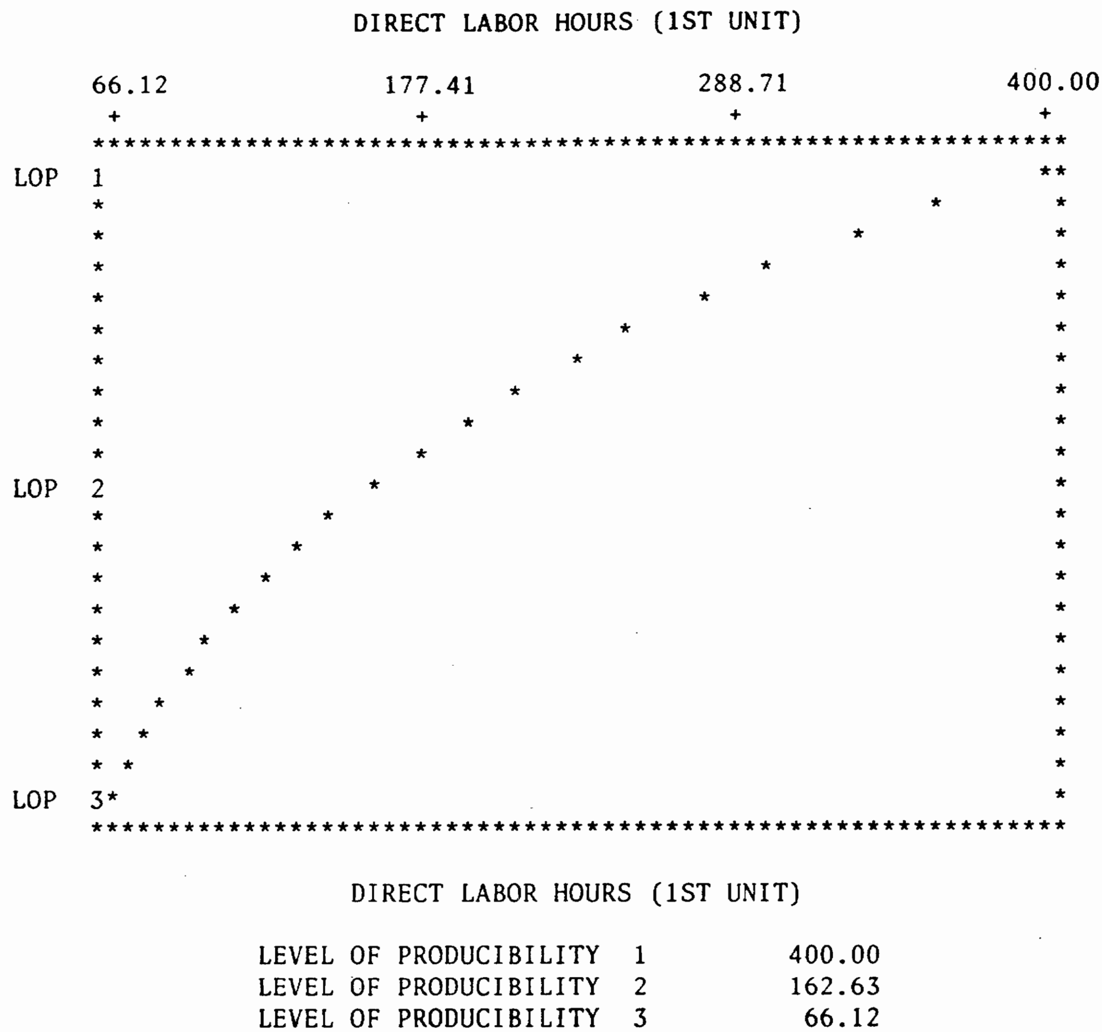


Figure 14. Direct Labor Hours Required (1st unit)

•

4.1.2.4 Number of direct machine hours required

The number of machine hours required is related to the product's level of producibility for the same reasons as the number of direct labor hours required. As the product's producibility is increased the opportunity to employ automated manufacturing techniques presents itself. As it becomes possible to increase the use of machinery in the production of the desired product a reduction in the amount of human labor is realized. To model this performance the growth function was chosen.

The general form of the equation is

$$y = c(1 - e^{-rx}) + b \qquad [4.4]$$

where y = resulting value for number of direct machine hours

c = maximum value added to b

r = growth rate

x = degree of producibility

b = y-intercept

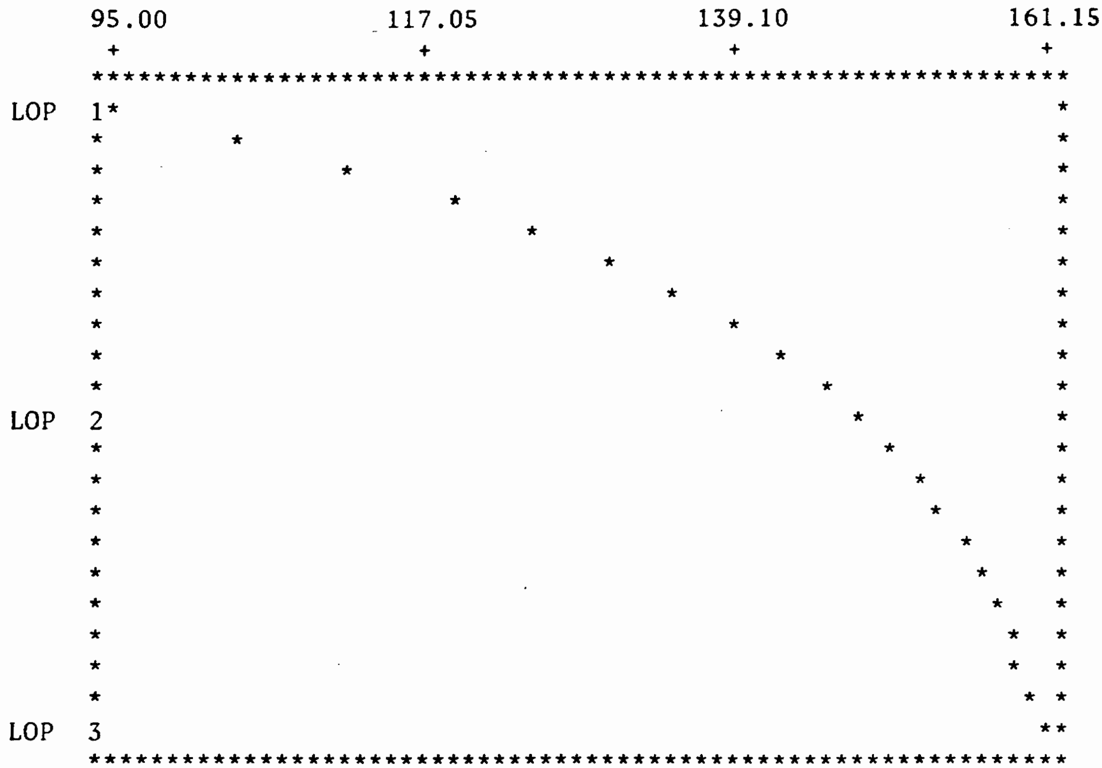
For this PPEM demonstration problem the following values were used to determine the number of direct machine hours required to produce the product.

Table 4. Direct Machine Hours test data inputs

function	max. value added	growth rate	y-intercept
growth	70.00	1.45	95.00

Upon entering the values the user may view a graph of the relationship defined for the design dependent parameter. Figure 15 presents a graph of the function defined along with the actual values that will be used for the product's direct machine hours requirement at each of the three levels of producibility considered by PPEM.

NUMBER OF MACHINE HOURS REQUIRED



NUMBER OF MACHINE HOURS REQUIRED

LEVEL OF PRODUCIBILITY	1	95.00
LEVEL OF PRODUCIBILITY	2	148.58
LEVEL OF PRODUCIBILITY	3	161.15

Figure 15. Direct Machine Hours Required

4.1.2.5 Annual equivalent capital equipment cost

A significant contributor to a product's life-cycle cost is the manufacturing facility required to product it. Costs arising from such things as the land and buildings composing the physical plant to the tools and equipment inside the plant must be considered. The actual derivation of such costs may be made using Equation [4.1]. Then a product is (re)designed with a high level of producibility allowing for the production of the product to be done so by automated means, often the acquisition of new technology is required. With this acquisition comes additional costs which must be accounted for. For this reason the growth function (Equation [4.4]) was chosen to relate the annual equivalent capital equipment cost required to produce the product to the level of producibility it is designed to achieve.

For this PPEM demonstration problem the following values were used to determine the annual equivalent capital equipment cost required to produce the product.

Table 5. Annual Equiv. Capital Equip. Cost test data inputs

function	max. value added	growth rate	y-intercept
growth	23000.00	1.45	0.00

4.1.2.6 Hourly machine rate

As discussed the product's design dictates the type of equipment and manufacturing process which may be employed to product it. A highly producible product, which is capable of being produced by technologically advanced equipment such as robotics, must absorb the cost of operating this costly equipment. A highly labor intensive product that utilizes little or no machine time of typically simpler production equipment would enjoy a lower usage charge for this service. For this reason the growth function (Equation [4.4]) was chosen to relate the hourly machine rate required to produce the product to the level of producibility it is designed to achieve.

For this PPEM demonstration problem the following values were used to determine the hourly machine rate required to produce the product.

Table 6. Hourly Machine Rate test data inputs

function	max. value added	growth rate	y-intercept
growth	16.00	1.45	35.00

4.1.2.7 Direct material cost

Product simplification plays a key role in improving the producibility of a product. An overall reduction in the number of parts which compose a product, if possible, not only lowers the amount of time required to assemble the product but can contribute to a reduction in the total cost of the parts themselves. Fewer parts by eliminating redundant or unnecessary items and combining parts when possible can lead to a reduction in material costs.[25] Judicious selection of parts available through vendors who insure desired price and quantity is considered to improve the producibility of a product while effectively lowering material costs. For these reasons the decay function (Equation [4.3]) was chosen to relate the direct material cost of the product to the level of producibility it is designed to achieve.

For this PPEM demonstration problem the following values were used to determine the direct material cost required to produce the product.

Table 7. Direct Material Cost test data inputs

function	maximum value	decay rate
decay	5000.00	0.40

4.1.2.8 Slope parameter of the manufacturing progress function

The manufacturing progress function is used to describe the advances made in manufacturing due to the learning effect of human workers. As the worker's familiarity with the task occurs the worker's performance will improve. The slope parameter defines this amount of manufacturing improvement as a percentage reduction of the amount of labor required on doubled production quantities of the product. A product which is labor intensive and involves a great deal of manual assembly would be a prime candidate for having a slope parameter which defines a significant reduction in the labor requirements for additional units. On the other hand, a product which is produced by highly automated means offers less opportunity for improvement of this type. For this reason the growth function (Equation [4.4]) was chosen to relate the slope parameter of the manufacturing progress function of the product to the level of producibility it is designed to achieve.

For this PPEM demonstration problem the following values were used to determine the slope parameter of the manufacturing progress function for the product.

Table 8. Slope Parameter of Manuf. Prog. Fn. test data inputs

function	max. value added	growth rate	y-intercept
growth	0.15	1.55	0.80

4.1.2.9 Design life of the product

The design life of the product is inputed as an integer value similar to the PPEM design independent parameters. This design dependent parameter in the PPEM program will not vary with the product's level of producibility. For this PPEM demonstration problem the design life of the product is assumed to be 7 years.

4.1.2.10 MTBF and MTTR profiles of the base-line product

The PPEM design dependent parameters mean time between failure (MTBF) and mean time to repair (MTTR) are entered for the base-line product. The base-line product in the PPEM program is defined to be at Level of Producibility 1. These profiles entered by age cohort are adjusted by the MTBF and MTTR multipliers to achieve the desired profiles for the each of the three levels of producibility considered by PPEM.

For this PPEM demonstration problem the following values were used as the MTBF and MTTR profiles of the base-line product.

Table 9. MTBF and MTTR Profiles test data inputs

age cohort	MTBF	MTTR
0 - 1	0.15	0.05
1 - 2	0.20	0.05
2 - 3	0.25	0.05
3 - 4	0.25	0.06
4 - 5	0.23	0.06
5 - 6	0.20	0.07
6 - 7	0.18	0.08

4.1.2.11 MTBF multiplier

The MTBF multiplier is used to adjust the MTBF profile of the base-line product (Level of Producibility 1). The desired MTBF profiles for each of the three levels of producibility considered by PPEM are found by multipling the previously defined MTBF value of each age cohort within the base-line profile by this multiplication factor. Product simplication and the careful selection of available parts can play a significant role in improving the producibility of a product. Likewise, these two activities can also improve the reliability of the product (the metric of reliability being

MTBF). For the reason the growth function was chosen to relate the determination of the MTBF multiplier to the level of producibility to which the product is designed to achieve.

A variation of the general form of the growth function (Equation [4.4]) is used for the determination of the MTBF multiplier. The MTBF profile of the base-line product (Level of Producibility 1) was entered as a separate PPEM design dependent parameter. Therefore the MTBF multiplier for Level of Producibility 1 must be 1.0. This is achieved by modifying Equation [4.4] as follows:

$$y = c(1 - e^{-rx}) + 1.0 \qquad [4.5]$$

where y = resulting value for the MTBF multiplier

c = maximum value added to 1.0

r = growth rate

x = degree of producibility

For this PPEM demonstration problem the following values were used to determine the MTBF multiplier for the product.

Table 10. MTBF Multiplier test data inputs

function	max. value added	growth rate
growth	0.04	1.75

4.1.2.12 MTTR multiplier

The MTTR multiplier is used to adjust the MTTR profile of the base-line product (Level of Producibility 1). The desired MTTR value of each of the three levels of producibility considered by PPEM are found by multipling the previously defined MTTR value of each age cohort within the base-line profile by this multiplication factor. Product simplication and the selection of available joining methods and fasteners can greatly effect the producibility of the product. Each of these also effect the ability to maintain or repair the product. If the product's casing has been simplified so that what was once several pieces is now only one or two the accessability of intercomponents of the product may be reduced. Likewise, if special joining methods or fasteners are used to facilitate assembly these same items may be detrimental to disassembly. For these reasons the special case of the growth function (Equation [4.5]) is used to relate the determination of the MTTR multiplier to the level of producibility to which the product is designed to achieve.

For this PPEM demonstration problem the following values were used to determine the MTTR multiplier for the product.

Table 11. MTTR Multiplier test data inputs

function	max. value added	growth rate
growth	0.05	1.78

4.1.2.13 Salvage value

The salvage value of the product is influenced by its design. The usefulness or value of the materials or parts which make up the product at the time of retirement determine the product's salvage value. Material and parts selection is realized as a major component in defining a product's producibility. The PPEM program uses the linear function (Equation [4.2]) to relate the effect of producibility induced design decisions on the salvage value of the product.

For this PPEM demonstration problem the following values were used to determine the salvage value of the product.

Table 12. Salvage Value test data inputs

function	y-intercept	slope
linear	2000.00	0.0

4.2 PPEM Output Report

The PPEM Output Report is automatically generated and printed to screen following the selection of function 3 (Run PPEM Program (Optimize Upon System Design Variables And View Results)) from the PPEM Main Menu screen (Figure 10). The output report provided by PPEM is organized into three sections, PPEM Results Summary, PPEM Input Summary, and PPEM Output Summary. The first section, PPEM Results Summary, presents the outcome of the PPEM calculations. Included are the expected annual equivalent total system life-cycle costs of each of the three design alternatives considered by PPEM and the selection of the optimal design alternative based solely upon these life-cycle costs.

The second section, PPEM Input Summary, presents the PPEM design independent parameter data followed by the PPEM design dependent parameter data. The PPEM design independent parameter data is simply a "dump" of the values entered via the PPEM Design Independent Parameters menu screen prior to execution. The PPEM design dependent parameter data presented is the result of the user specified equation parameters defining the design dependent parameters' relationship to each level of producibility considered by PPEM. The resulting values for each design dependent parameter are presented grouped by Level of Producibility.

The third section of the PPEM Output Report, PPEM Output Summary, presents derived information for each level of producibility considered by PPEM. This includes the average number of direct labor hours required per unit, average first cost of an unit, components of the expected annual equivalent total system life-cycle cost calculation, expected number of units short of demand, probability of one or more units short of demand, and the optimum values for the system design variables.

The following PPEM Output Report was the result of the PPEM program given the design independent and design dependent parameter test data sets presented in Sections 4.1.1 and 4.1.2.

```
*************************************************************
*************************************************************
**                                                         **
**                   PPEM RESULTS SUMMARY                  **
**                                                         **
*************************************************************
*************************************************************
```

E[AETSLCC] LEVEL OF PRODUCIBILITY 1 = $339161.50

E[AETSLCC] LEVEL OF PRODUCIBILITY 2 = $345994.50

E[AETSLCC] LEVEL OF PRODUCIBILITY 3 = $328248.10

```
*************************************************************
*************************************************************
**                                                         **
**  THE OPTIMAL DESIGN FOR THIS PRODUCT WAS FOUND TO       **
**  EXIST AT A PRODUCIBILITY LEVEL OF 3 (AS DEFINED        **
**  BY PPEM).                                              **
**                                                         **
*************************************************************
*************************************************************
```

```
*************************************************************
*************************************************************
**                                                         **
**                    PPEM INPUT SUMMARY                   **
**                                                         **
*************************************************************
*************************************************************
```

PPEM DESIGN INDEPENDENT PARAMETERS

DEMAND = 15 UNITS   DURATION OF DEMAND = 10 YEARS

ANNUAL INTEREST RATE = 9.00%

ANNUAL EQUIVALENT FIXED REPAIR FACILITY COST = $ 9469.00

ANNUAL EQUIVALENT OPERATING REPAIR FACILITY COST = $ 35000.00

SHORTAGE PENALTY COST = $ 73000.00 HR. LABOR RATE = $27.00

OVERHEAD RATE = 85.00%   GENERAL & ADMIN. RATE = 13.50%

PROFIT RATE = 10.00%

****

PPEM DESIGN DEPENDENT PARAMETERS

LEVEL OF PRODUCIBILITY 1

COST OF DESIGN = $ .00 DESIGN LIFE = 7 YEARS

ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST = $ .00

DIRECT LABOR HOURS REQUIRED (1ST UNIT) = 400.00

DIRECT MACHINE HOURS REQUIRED = 95.00

MACHINE HOURLY RATE = $ 35.00 DIRECT MATERIAL COST = $ 5000.00

SLOPE PARAMETER (MPF) = .80

MTBF MULTIPLIER = 1.00 MTTR MULTIPLIER = 1.00

RESULTING MTBF AND MTTR PROFILES

AGE COHORT	MTBF (YR)	MTTR (YR)
0 - 1	.150	.050
1 - 2	.200	.050
2 - 3	.250	.050
3 - 4	.250	.060
4 - 5	.230	.060
5 - 6	.200	.070
6 - 7	.180	.080

SALVAGE VALUE = $ 2000.00

****

****

PPEM DESIGN DEPENDENT PARAMETERS

LEVEL OF PRODUCIBILITY 2

COST OF DESIGN = $ 15000.00 DESIGN LIFE = 7 YEARS

ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST = $ 17604.88

DIRECT LABOR HOURS REQUIRED (1ST UNIT) = 162.63

DIRECT MACHINE HOURS REQUIRED = 148.58

MACHINE HOURLY RATE = $ 47.25 DIRECT MATERIAL COST = $ 3351.60

SLOPE PARAMETER (MPF) = .92

MTBF MULTIPLIER = 1.03 MTTR MULTIPLIER = 1.04

RESULTING MTBF AND MTTR PROFILES

AGE COHORT	MTBF (YR)	MTTR (YR)
0 - 1	.155	.052
1 - 2	.206	.052
2 - 3	.257	.052
3 - 4	.257	.062
4 - 5	.237	.062
5 - 6	.206	.073
6 - 7	.185	.083

SALVAGE VALUE = $ 2000.00

****

****

PPEM DESIGN DEPENDENT PARAMETERS

LEVEL OF PRODUCIBILITY 3

COST OF DESIGN = $ 30000.00 DESIGN LIFE = 7 YEARS

ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST = $ 21734.47

DIRECT LABOR HOURS REQUIRED (1ST UNIT) = 66.12

DIRECT MACHINE HOURS REQUIRED = 161.15

MACHINE HOURLY RATE = $ 50.12 DIRECT MATERIAL COST = $ 2246.64

SLOPE PARAMETER (MPF) = .94

MTBF MULTIPLIER = 1.04 MTTR MULTIPLIER = 1.05

RESULTING MTBF AND MTTR PROFILES

AGE COHORT	MTBF (YR)	MTTR (YR)
0 - 1	.156	.052
1 - 2	.208	.052
2 - 3	.260	.052
3 - 4	.260	.063
4 - 5	.239	.063
5 - 6	.208	.073
6 - 7	.187	.084

SALVAGE VALUE = $ 2000.00

****

```
*************************************************************
*************************************************************
**                                                         **
**                   PPEM OUTPUT SUMMARY                   **
**                                                         **
*************************************************************
*************************************************************


                LEVEL OF PRODUCIBILITY 1
                ------------------------


 AVG. NO. OF DIRECT LABOR HOURS REQUIRED PER UNIT = 138.23

 AVERAGE FIRST COST OF A UNIT = $19014.33

 ANNUAL EQUIVALENT UNIT COST                       = $ 88257.68
 ANNUAL EQUIVALENT REPAIR FACILITY COST            = $222345.00
 ANNUAL EQUIVALENT SHORTAGE COST                   = $ 28558.87
                                                     ---------
 EXPECTED ANNUAL EQUIVALENT TOTAL SYSTEM LCC       = $339161.50


 EXPECTED NUMBER OF UNITS SHORT OF DEMAND =    .39

 PROBABILITY OF ONE OR MORE UNITS SHORT =    .17


               PPEM SYSTEM DESIGN VARIABLES

 NUMBER OF UNITS DEPLOYED = 23

 NUMBER OF REPAIR FACILITIES =  4

 RETIREMENT AGE =  5


*************************************************************
```

****

LEVEL OF PRODUCIBILITY 2

AVG. NO. OF DIRECT LABOR HOURS REQUIRED PER UNIT = 107.99

AVERAGE FIRST COST OF A UNIT = $20076.93

ANNUAL EQUIVALENT UNIT COST	= $ 93511.09
ANNUAL EQUIVALENT REPAIR FACILITY COST	= $222345.00
ANNUAL EQUIVALENT SHORTAGE COST	= $ 30138.44

EXPECTED ANNUAL EQUIVALENT TOTAL SYSTEM LCC	= $345994.50

EXPECTED NUMBER OF UNITS SHORT OF DEMAND = .41

PROBABILITY OF ONE OR MORE UNITS SHORT = .17

PPEM SYSTEM DESIGN VARIABLES

NUMBER OF UNITS DEPLOYED = 23

NUMBER OF REPAIR FACILITIES = 4

RETIREMENT AGE = 5

****

****

LEVEL OF PRODUCIBILITY 3

AVG. NO. OF DIRECT LABOR HOURS REQUIRED PER UNIT = 48.68

AVERAGE FIRST COST OF A UNIT = $16540.80

ANNUAL EQUIVALENT UNIT COST	=	$ 79334.31
ANNUAL EQUIVALENT REPAIR FACILITY COST	=	$222345.00
ANNUAL EQUIVALENT SHORTAGE COST	=	$ 26568.74

EXPECTED ANNUAL EQUIVALENT TOTAL SYSTEM LCC	=	$328248.10

EXPECTED NUMBER OF UNITS SHORT OF DEMAND = .36

PROBABILITY OF ONE OR MORE UNITS SHORT = .15

PPEM SYSTEM DESIGN VARIABLES

NUMBER OF UNITS DEPLOYED = 24

NUMBER OF REPAIR FACILITIES = 4

RETIREMENT AGE = 5

WOULD YOU CARE TO VIEW THE PPEM OUTPUT REPORT
AGAIN? ENTER "Y" FOR YES, "N" FOR NO.

4.3 Observation

The selection of the "optimal" design alternative by PPEM was made based upon the use of $E[AETSLCC]$ as the sole measure of effectiveness. A required step in the calculation of this value for each design alternative is the determination of the optimal combination of system design variables. Within the PPEM formulation there exists three such variables, the number of units to deploy (N), the number of repair facilities (M), and the retirement age of the product (n). An algorithm was described in Section 3.4 which performs a three-way search over the possible combinations of these system design variables. As mentioned in that discussion the search technique employed is made possible due to the well behaved nature of the total cost function of PPEM. In an attempt to further investigate the properties of the PPEM total cost function and to ascertain whether the optimal combination of system design variables were found, three-dimensional plots were created for several of the surfaces defined by this function. The following figures depict three surfaces which the PPEM total cost function defined for the first design alternative (Level of Producibility 1) of the demonstration problem. These figures indicate that the surfaces defined possess a gobal minimum, which was a requirement of the search technique, and that the optimal combination of system design variables (the combination which provides the lowest $E[AETSLCC]$) was in fact $N = 23, M = 4, n = 5$ for Level of Producibility 1.

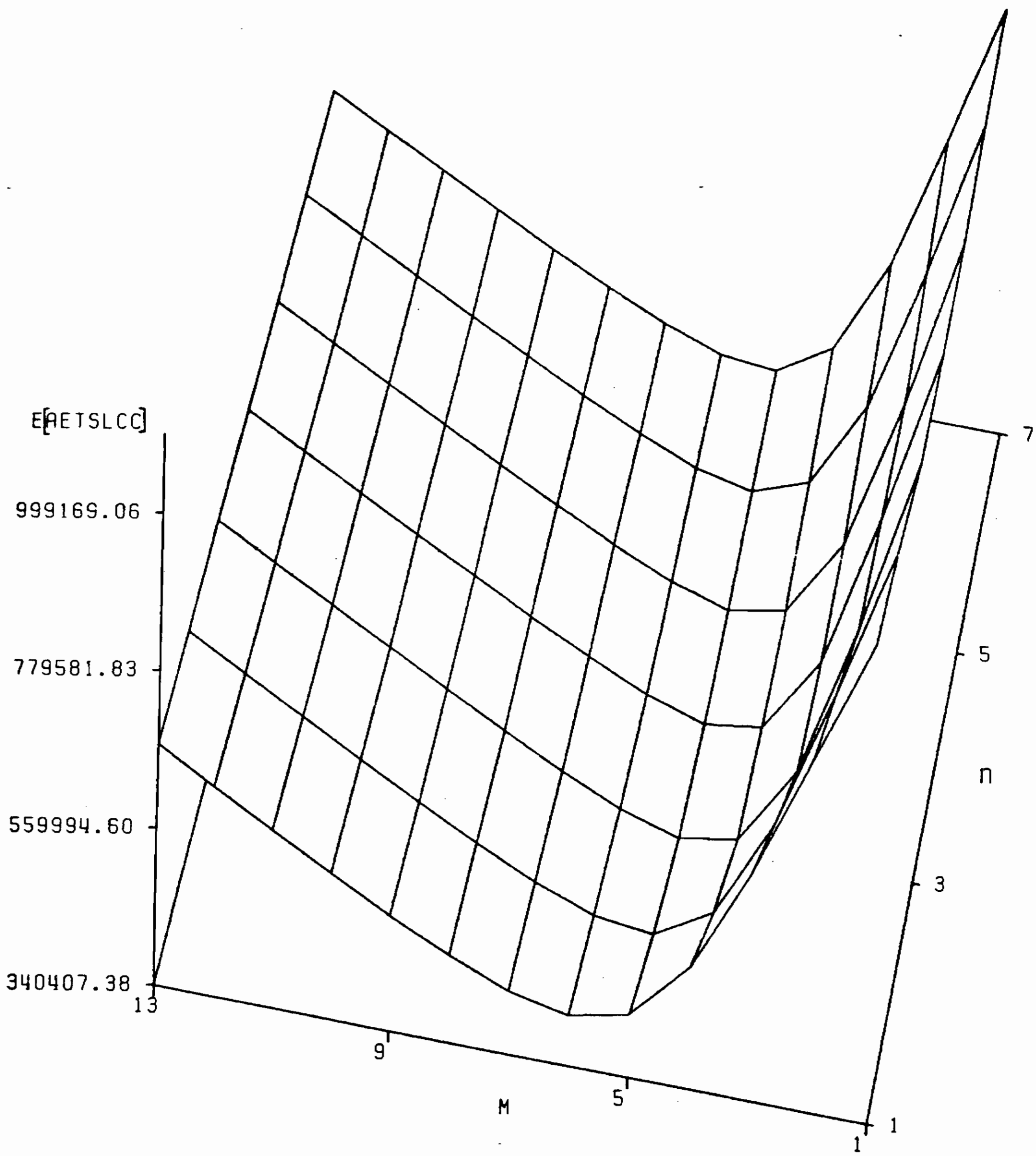


Figure 16. 3-Dimensional plot of M and n vs. E[AETSLCC] for N = 22

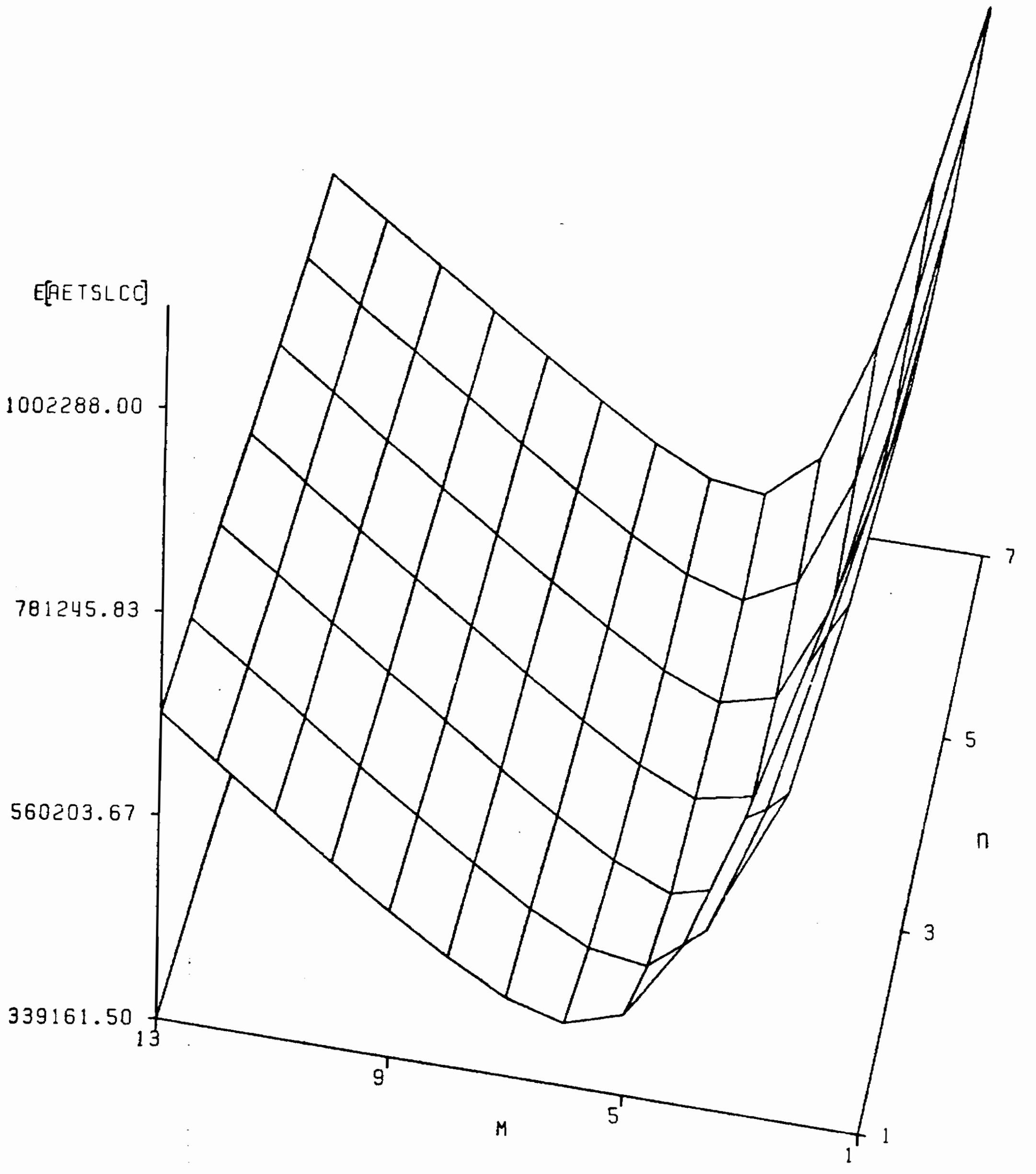


Figure 17. 3-Dimensional plot of M and n vs. E[AETSLCC] for N = 23

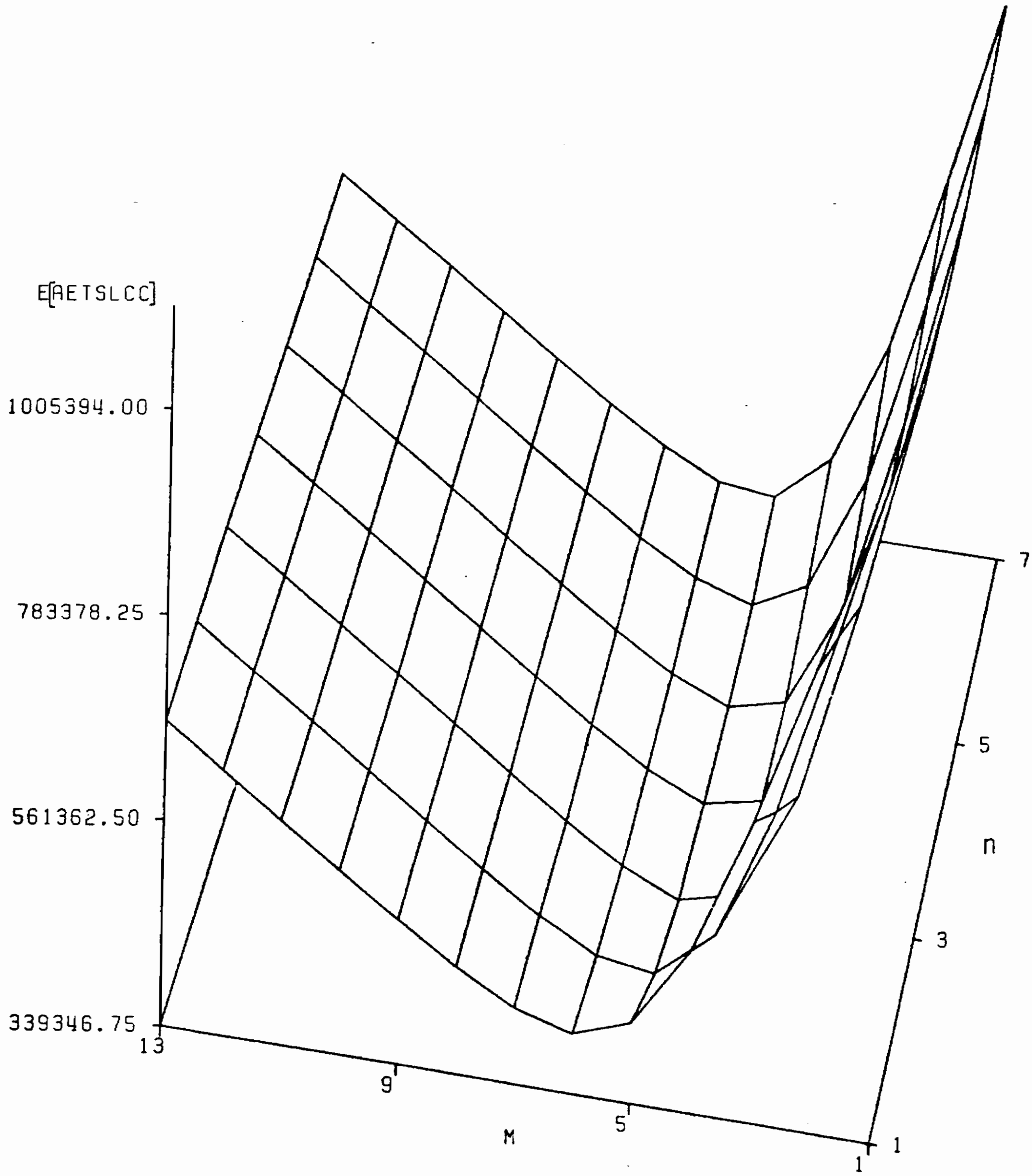


Figure 18. 3-Dimensional plot of M and n vs. E[AETSLCC] for N = 24

5.0 Conclusions and Recommendations

This final chapter presents conclusions/comments regarding the development of the Product Producibility Evaluation Model (PPEM). In addition, recommendations regarding further work in this area are given.

5.1 Conclusions

It was stated in Chapter 1 that a major shortcoming of the previous product producibility evaluation methods reviewed was a lack of addressing what impact design changes made to induce higher degrees of producibility would have upon the life-cycle cost of a product. From this shortcoming arose the objective of this research, the development of a life-cycle cost evaluation model which would incorporate the effect of producibility related design decisions into life-cycle cost calculations. As a result of this research it has been shown that a product producibility evaluation model with expected annual equivalent total system life-cycle cost as the sole measure of effectiveness is feasible. A FORTRAN 77 based personal computer program was written which incorporated each of the required enhancements/advances stated in Section 1.4.3. These being: a method of relating the effect of producibility influenced design decisions to aspects of the product which in turn affect its life-cycle cost, the incorporation of the Manufacturing Progress Function into the calculation of direct labor requirements, a method of calculating the product's first cost, and an optimization routine to perform a search for the optimal combination of system design variables. Most noteworthy of these enhancements was the inclusion of design dependent parameters and the ability to relate these to varying degrees of product producibility. These design dependent parameters represent sources of costs which occur during each of the major phases of the product life cycle and the associated life cycles of the manufacturing and logistic support systems.

Design dependent parameters which were identified by PPEM as being affected by producibility related design decisions were input using design dependent parameter-producibility parametric relationships. These parametric relationships take the form of continuous functions (i.e., linear, decay, growth). PPEM's modularized structure (extensive use of subroutines) will allow easy replacement of the function used to define a particular relationship if at any time the chosen function is deemed inappropriate. The responsibility of defining the exact shape of each relationship is placed with the designer(s).

The optimization technique employed by the PPEM program to locate the optimal combination of system design variables requires that the function possess a single local minimum (i.e., gobal minimum). As previously stated a mathematical proof that this requirement is met by the PPEM total cost function is not available. As an alternative three dimensional plots were created to investigate rather or not the PPEM total cost function performed as desired. All surfaces ploted possessed a gobal minimum suggesting that the optimal combination of system design variables were indeed found for each design alternative.

A final benefit of this research was the identification of data requirements for a comprehensive product producibility evaluation methodology. Data items which perhaps have not in the past been subject of close scrutiny have been identified as playing a significant role in determining the life-cycle cost of a product.

5.2 *Recommendations*

Recommendations regarding further research in this area pertain to three topics, relaxation of certain assumptions made in the formulation of PPEM, augmentation of PPEM with estimaters/predictors for the identified design independent and dependent parameters, and additions to the list of producibility related design dependent parameters identified by PPEM.

5.2.1 Assumptions to be Relaxed

All simplifying assumptions made during the formulation of PPEM are subject to examination. Two of these assumptions which are "prime" candidates to be relaxed are the steady-state assumption and the assumption with regard to the manner in which repair facilities are included in the PPEM calculations. Both originate in the REPS model.

5.2.1.1 Steady-state

PPEM assumes the population of units deployed to meet the stated demand operates in steady-state. In other words, the buildup phase until the desired number of units is met and the phase-out period during which the units are removed is ignored. If this assumption could be relaxed to include the non-steady-state periods a more realistic evaluation of the system would be the result.

5.2.1.2 Repair facilities

Repair capacity is measured in terms of the number of repair facilities in operation. Each repair facility is assumed to be identical so that repair times for each facility is equivalent regardless of the nature of the failure. By relaxing this assumption to include various levels of repair (e.g., operational, intermediate, depot) with varying repair times an improved evaluation of system would be possible.

5.2.2 Design Parameter Estimaters/Predictors

Clearly a shortfall of the PPEM program is the requirement that several calculations be made external to the program. Calculations which are needed to provide the various inputs of the model. The addition of estimaters/predictors to aid the designer in determining such values as the annual equivalent capital equipment cost or the estimation of MTBF and MTTR values for the design alternatives is strongly recommended. The addition of such estimaters/predictors would create a more fully developed model.

5.2.3 Additional Design Dependent Parameters

The last suggested topic for further research in the area of product producibility would be the expansion of the list of design dependent parameters presently identified by PPEM. Expansion in terms of additional parameters or the delineation of specific parameters which would more fully define the design alternative under consideration. By adding parameters which more fully describe characteristics of the product it may be more accurately evaluated in terms of its life-cycle cost.

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Appendix A. Producibility Design Checklist

The following producibility checklist was extracted from Department of Defense, MIL-HDBK-727, Military Handbook, *Design Guidance for Producibility* (pp. 2-14 - 2-16).

1. General Aspects of Design:
    a. Have alternative design concepts been considered and the simplest and most producible one selected?
    b. Does the design exceed the manufacturing state of art?
    c. Is the design conducive to the application of economic processes?
    d. Does a design already exist for the item?
    e. Does the design specify the use of proprietary items or processing?
    f. Is the item overdesigned or underdesigned?
    g. Can redesign eliminate anything?
    h. Is motion or power wasted?
    i. Can the design be simplified?
    j. Can a simpler manufacturing process be used?
    k. Can parts with slight differences be made identical?
    l. Can compromises and trade-offs be used to a greater degree?
    m. Is there a less costly part that will perform the same function?
    n. Can weight be reduced?
    o. Is there something similar to this design that costs less?
    p. Can the design be made to secure additional functions?
    q. Are quality assurance provisions too rigorous for design or functions?
    r. Can multiple parts be combined into a single net shape?
2. Specifications and Standards:
    a. Can the design be standardized to a greater degree?
    b. Can the design use standard cutting tools to a greater degree?
    c. Is there a standard part that can replace a manufactured item?
    d. Can any specifications be relaxed or eliminated?

e. Can standard hardware be used to a greater degree?

f. Can standard gages be used to a greater degree?

g. Are nonstandard threads used?

h. Can stock items be used to a greater degree?

i. Should packaging specifications be relaxed?

j. Are specifications and standards consistent with the planned product environment?

3. Drawings:

a. Are drawings properly and completely dimensioned?

b. Are tolerances realistic, producible, and not tighter than the function requires?

c. Are tolerances consistent with multiple manufacturing process capabilities?

d. Is required surface roughness realistic, producible, and not better than function requires?

e. Are forming, bending, fillet and edge radii, fits, hole sizes, reliefs, counterbores, countersinks, O-ring grooves, and cutter radii standard and consistent?

f. Are all nuts, bolts screws, threads, rivets, torque requirements, etc., appropriate and proper?

g. Have requirements for wiring clearance, tool clearance, component spare, and clearance for joining connectors been met?

h. Have all required specifications been properly invoked?

i. Are adhesives, sealants, encapsulants, compounds, primers, composites, resins, coatings, plastics, rubber, moldings, and tubing adequate and acceptable?

j. Has galvanic corrosion and corrosive fluid entrapment been prevented?

k. Are welds minimal and accessible, and are the symbols correct?

l. Have design aspects that could contribute to hydrogen embrittlement, stress corrosion, or similar conditions been avoided?

m. Are lubricants/fluids proper?

n. Are contamination controls of functional systems proper?

o. Have limited life materials been identified, and can they be replaced without difficulty?

p. Have radio frequency interference shielding, electrical, and static bond paths been provided?

q. Have spare connector contacts been provided?

r. Are identification and marking schemes for maximum loads, pressure, thermal, nonflight items, color codes, power, and hazards on the drawings properly?

s. Do drawings contain catchall specifications that manufacturing personnel would find difficult to interpret?

t. Have all possible alternatives of design configuration been shown?

4. Materials:

a. Have materials been selected that exceed requirements?

b. Will all materials be available to meet the required need dates?

c. Have special material sizes and alternate materials been identified, sources verified, and coordination effected with necessary organizations?

d. Do design specifications unduly restrict or prohibit use of new or alternate materials?

e. Does the design specify peculiar shapes requiring extensive machining or special production techniques?

f. Are specified materials difficult or impossible to fabricate economically?

g. Are specified materials available in the necessary quantities?

h. Is the design flexible enough so that many processes and materials may be used without functionally degrading the end item?

i. Can a less expensive material be used?

j. Can the number of different materials be reduced?

k. Can a lighter gage material be used?

l. Can another material be used that would be easier to machine?

m. Can use of critical materials be avoided?

n. Are alternate materials specified where possible?

o. Are materials and alternates consistent with all planned manufacturing processes?

5. Fabrication Processes:

a. Does the design involve unnecessary machining requirements?

b. Have proper design specifications been used with regard to metal stressing, flatness, corner radii, types of casting, flanges, and other proper design standards?

c. Does the design present unnecessary difficulties in forging, casting, machining, and other fabrication processes?

d. Do the design specifications unduly restrict production personnel to one manufacturing process?

e. Can parts be economically subassembled?

f. Has provision been made for holding or gripping parts during fabrication?

g. Are expensive special tooling and equipment required for production?

h. Have the most economical production processes been specified?

i. Have special handling devices or procedures been initiated to protect critical or sensitive items during fabrication and handling?

j. Have special skills, facilities, and equipment been identified and coordinated with all affected organizations?

k. Can parts be removed or disassembled and reinstalled or reassembled easily and without special equipment or tools?

l. Is the design consistent with normal shop flow?

m. Has consideration been given to measurement difficulties in the production process?

n. Is the equipment and tooling list complete?

o. Are special facilities complete?

p. Can a simpler manufacturing process be used?

q. Have odd size holes or radii been used?

r. In the case of net shape processes, have alternate processes been specified?

s. Can a fastener be used to eliminate tapping?

t. Can weld nuts be used instead of a tapped hole?

u. Can any machined surfaces be eliminated?

v. Can roll pins be used to eliminate reaming?

w. Do finish requirements prohibit use of economical speeds and feeds?

x. Are processes consistent with production quantity requirements?

y. Are alternate processes possible within design constraint?

6. Joining Methods:

a. Are all parts easily accessible during joining processes?

b. Are assembly and other joining functions difficult or impossible due to a lack of space or other reasons?

c. Can two or more parts be combined into one?

d. Is there a newly developed or different fastener to speed assembly?

e. Can the number of assembly hardware sizes be minimized?

f. Can the design be changed to improve the assembly or disassembly of parts?

g. Can the design be improved to minimize installation or maintenance problems?

h. Have considerations for heat-affected zones been considered when specifying a thermal joining process?

7. Coating Materials and Methods:

a. Are protective finishes properly specified:

b. Has corrosion protection been adequately considered from the standpoint of materials, protective measures, and fabrication and assembly methods?

c. Have special protective finish requirements been identified and solutions defined?

d. Can any special coating or treating be eliminated?

e. Can precoated materials be used?

8. Heat Treating and Cleaning Processes:

a. Is the specified material readily machined:

b. Are machining operations specified after heat treatment?

c. Have all aspects of production involving heat treating and cleaning processes and their interaction with other production areas been reviewed?

d. Are heat treatments properly specified?

e. Are process routings consistent with manufacturing requirements (straightness, flatness, etc.)?

9. Safety:

   a. Have static ground requirements been implemented in the design?

   b. Have necessary safety precautions been initiated for pyrotechnic items?

   c. Have radio frequency interference requirements been implemented in the design?

   d. Have necessary safety requirements for processing materials, such as magnesium and beryllium copper, been considered?

10. Environmental Requirements:

   a. Have adequate provisions been included to meet the thermal, humidity, or other special environmental requirements?

   b. Has adequate heating and/or cooling been identified and implemented?

11. Inspection and Test

   a. Are inspection and test requirements excessive?

   b. Is special inspection equipment specified in excess of actual requirements?

   c. Is the item inspectable by the most practical method possible?

   d. Have conditions or aspects anticipated to contribute to high rejection rates been identified and remedial action initiated?

   e. Have required mock-ups and models been provided?

   f. Are special and standard test and inspection equipment on hand, calibrated, proofed, and compatible with drawing requirements?

   g. Are master and special gages complete?

   h. Have nondestructive testing techniques been implemented?

   i. Have adequate provisions been made for the checkout, inspection, testing, or proofing of functional items per operational procedures?

   j. Is nonstandard test equipment necessary?

Appendix B. PPEM USER'S GUIDE

B.1 Introduction

The Product Producibility Evaluation Model (PPEM) is a menu driven design alternative life-cycle cost program. Written in FORTRAN 77 this program will run on any IBM personal computer or compatible, PC/MS DOS operating system. To begin the program:

1. Insert the PPEM program disk in Drive A:

2. Type A: and press ENTER.

3. Type PPEM and press ENTER.

The PPEM Main Menu will appear.

```
************************************************************
*                                                          *
*                     PPEM MAIN MENU                       *
*                                                          *
*   1  ENTER PPEM DESIGN INDEPENDENT PARAMETERS            *
*   2  ENTER PPEM DESIGN DEPENDENT PARAMETERS              *
*   3  RUN THE PPEM PROGRAM (OPTIMIZE UPON SYSTEM          *
*      DESIGN VARIABLES AND VIEW RESULTS)                  *
*   4  SAVE CURRENT PPEM DESIGN PARAMETER DATA             *
*   5  RETRIEVE PPEM DESIGN PARAMETER DATA FILE            *
*   6  EXIT TO DOS                                         *
*                                                          *
*  ENTER THE NUMBER (1,2,3,4,5,OR 6) OF THE FUNCTION YOU   *
*  WISH TO PERFORM.                                        *
*                                                          *
************************************************************
```

From this menu you may select to perform any of 6 functions. Data entry and modification is performed through either the PPEM Design Independent menu screen (select function 1) or the PPEM Design Dependent menu screen (select function 2). The PPEM life-cycle cost calculations are performed following the selection of function 3. Design parameter data sets may be either stored or retrieved via this menu (select function 4 or 5). You may exit the PPEM program by selecting function 6 or by striking [Ctrl][Break] at any time.

B.2 Enter PPEM Design Independent Parameters

From the PPEM Main Menu you may select function 1 to begin the process of entering the PPEM design independent parameter data.

1. Enter 1 from the PPEM Main Menu. (All PPEM input must be followed by ENTER.)

The PPEM Design Independent Parameters menu screen will appear.

```
************************************************************
*                                                          *
*           PPEM DESIGN INDEPENDENT PARAMETERS             *
*                                                          *
* 1  MAGNITUDE AND DURATION OF DEMAND ON THE SYSTEM        *
* 2  THE TIME VALUE OF MONEY                               *
* 3  ANNUAL EQUIVALENT FIXED REPARIR FACILITY COST         *
* 4  ANNUAL EQUIVALENT OPERATING REPAIR FACILITY COST      *
* 5  SHORTAGE PENALTY COST                                 *
* 6  HOURLY LABOR RATE                                     *
* 7  OVERHEAD RATE                                         *
* 8  GENERAL AND ADMINISTRATIVE RATE                       *
* 9  PROFIT RATE                                           *
* 10 RETURN TO TO PPEM MENU                                *
*                                                          *
*  ENTER THE NUMBER OF THE DESIGN INDEPENDENT PARAMETER    *
*  YOU WISH TO DEFINE OR RETURN TO PPEM MAIN MENU.         *
*                                                          *
************************************************************
```

From this menu all PPEM design independent parameter data is entered. You select the design independent parameter which is to be entered and following a brief explanation of the parameter you are prompted for input. Once entered, the value for the design independent parameter is presented for verification. You may modify the value at this time. If the value is not changed the PPEM Design Independent Parameters menu screen is presented and the next design independent parameter may be entered. At any time via the PPEM Design Independent Parameters menu screen a design independent parameter may be viewed and changed if necessary.

B.2.1 Enter the magnitude and duration of demand

1. Enter 1 from the PPEM Design Independent menu screen.

A description of the design independent parameters, magnitude and duration of the demand, is presented.

```
ENTER THE DEMAND OR NEED ON THE SYSTEM FOLLOWED BY THE
DURATION OF THIS NEED SEPERATED BY A COMMA (E.G., 15,10).
THE VALUES ENTERED WILL BE READ AS INTEGER NUMBERS AND
ARE ASSUMED TO BE DETERMINISTIC AND TIME INVARIANT.
NOTE: DUE TO COMPUTATIONAL LIMITATIONS OF PERSONAL
COMPUTERS, THE DEMAND OF THE SYSTEM AND THE SUBSEQUENT
NUMBER OF UNITS TO DEPLOY CAN NOT EXCEED 33.  THEREFORE
A MAXIMUM DEMAND OF APPROXIMATELY 25 IS SUGGESTED.
```

The demand is the quantity of units of the product under evaluation which is desired or required by the system over the period of time defined by duration (years). Both values must be entered as integer numbers. If a real number is entered for either you will be prompted to reenter the values by receiving the original description screen.

1. Enter the values for demand and duration separated by a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF 15 FOR THE DEMAND AND
10 FOR THE DURATION OF THIS NEED.
DO YOU WISH TO ALTER THIS?  ENTER "Y" FOR YES,
"N" FOR NO.
```

If you do not enter an appropriate response (i.e., "N", "n", "Y", or "y") the modification request screen will reappear. (This holds true for any PPEM requested response.)

Upon approving the values entered for Demand and Duration the PPEM Design Independent Parameters menu screen will appear.

B.2.2 Enter the time value of money

1. Enter 2 from the PPEM Design Independent menu screen.

A description of the design independent parameter, time value of money, is presented.

```
ENTER THE TIME VALUE OF MONEY TO BE USED OVER THE LIFE
OF THE SYSTEM UNDER STUDY.  THIS VALUE IS TO BE ENTERED
AS AN ANNUAL INTEREST RATE.
NOTE: AN INTEREST RATE OF NINE AND ONE QUARTER PERCENT
SHOULD BE ENTERED AS 9.25.
```

1. Enter the time value of money.

Upon entry, the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF  9.25% FOR THE ANNUAL
INTEREST RATE.  DO YOU WISH TO ALTER THIS?  ENTER "Y" FOR
YES, "N" FOR NO.
```

Upon approving the time value of money the PPEM Design Independent Parameters menu screen will appear.

B.2.3 Enter the annual equivalent fixed repair facility cost

1. Enter 3 from the PPEM Design Independent menu screen.

A description of the design independent parameter, annual equivalent fixed repair facility cost, is presented.

```
ENTER THE ANNUAL EQUIVALENT FIXED COST FOR A REPAIR
FACILITY.  THIS IS A PRECALCULATED VALUE WHICH INCLUDES
SUCH FACTORS AS LAND, BUILDINGS, CAPITAL EQUIPMENT,
ETC.  IT IS ASSUMED THAT EACH REPAIR FACILITY IS
IDENTICAL AND NO LIMITATIONS AS TO THE NUMBER OF REPAIR
FACILITIES EXIST.
```

1. Enter the annual equivalent fixed repair facility cost.

Upon entry, the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF $35000.00 FOR THE ANNUAL
EQUIVALENT FIXED REPAIR FACILITY COST.  DO YOU WISH TO
ALTER THIS?  ENTER "Y" FOR YES, "N" FOR NO.
```

Upon approving the value for the annual equivalent fixed repair facility cost the PPEM Design Independent Parameters menu screen will appear.

B.2.4 Enter the annual equivalent operating repair facility cost

1. Enter 4 from the PPEM Design Independent menu screen.

A description of the design independent parameter, annual equivalent operating repair facility cost, is presented.

```
ENTER THE ANNUAL EQUIVALENT OPERATING COST FOR A REPAIR
FACILITY.  THIS IS A PRECALCULATED VALUE WHICH INCLUDES
SUCH FACTORS AS LABOR, ENERGY, SMALL TEST EQUIPMENT, ETC.
IT IS ASSUMED THAT EACH REPAIR FACILITY'S REQUIREMENTS
ARE IDENTICAL.
```

1. Enter the annual equivalent operating repair facility cost.

Upon entry, the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF $15000.00 FOR THE ANNUAL
EQUIVALENT OPERATING REPAIR FACILITY COST.  DO YOU
WISH TO ALTER THIS?  ENTER "Y" FOR YES, "N" FOR NO.
```

Upon approving the value for the annual equivalent operating repair facility cost the PPEM Design Independent Parameters menu screen will appear.

B.2.5 Enter the shortage penalty cost

1. Enter 5 from the PPEM Design Independent menu screen.

A description of the design independent parameter, shortage penalty cost, is presented.

```
ENTER THE SHORTAGE PENALTY COST.  THIS IS AN ANNUAL
DOLLAR AMOUNT REPRESENTING AN INCOME LOSS, OPPORTUNITY
LOSS OR PENALTY COST INCURRED, PER UNIT SHORT PER YEAR,
OF THE SPECIFIED SYSTEM DEMAND.
```

1. Enter the shortage penalty cost.

Upon entry the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF $ 73000.00 FOR THE SHORTAGE
PENALTY COST.  DO YOU WISH TO ALTER THIS?
ENTER "Y" FOR YES, "N" FOR NO.
```

Upon approving the value for the shortage penalty cost the PPEM Design Independent Parameters menu screen will appear.

B.2.6 Enter the hourly labor rate

1. Enter 6 from the PPEM Design Independent menu screen.

A description of the design independent parameter, hourly labor rate, is presented.

```
ENTER THE LABOR RATE FOR HUMAN LABOR.   THE VALUE
SHOULD BE ENTERED AS A DOLLAR AMOUNT.  DO NOT INCLUDE
A "$" SIGN.  IT IS ASSUMED THAT THERE IS ONLY ONE LEVEL
OF SKILLED WORKER.  THEREFORE, ANY HUMAN LABOR WILL BE
PERFORMED AT THIS DOLLAR/HR RATE.
```

1. Enter the hourly labor rate.

Upon entry the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF $ 25.75 FOR THE LABOR
RATE.  DO YOU WISH TO ALTER THIS?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the value for the hourly labor rate the PPEM Design Independent Parameters menu screen will appear.

B.2.7 Enter the overhead rate

1. Enter 7 from the PPEM Design Independent menu screen.

A description of the design independent parameter, overhead rate, is presented.

```
ENTER THE OVERHEAD RATE TO BE APPLIED TO HUMAN LABOR.
THE OVERHEAD RATE IS ADDED TO HUMAN LABOR TO ACCOUNT
FOR VACATION, SICK LEAVE, OTHER EMPLOYEE BENEFITS, ETC.
NOTE: AN OVERHEAD RATE OF SIXTY FIVE AND ONE HALF PERCENT
SHOULD BE ENTERED AS 65.5
```

1. Enter the overhead rate.

Upon entry, the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF  65.50% FOR THE OVERHEAD
RATE.  DO YOU WISH TO ALTER THIS?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the value for the overhead rate the PPEM Design Independent Parameters menu screen will appear.

B.2.8 Enter the general and administrative rate

1. Enter 8 from the PPEM Design Independent menu screen.

A description of the design independent parameter, general and administrative rate, is presented.

```
ENTER THE GENERAL AND ADMINISTRATIVE RATE TO BE USED.
THE GENERAL AND ADMINISTRATIVE RATE IS ADDED TO
ACCOUNT FOR SUPERVISORY AND ADMINISTRATIVE PERSONNEL.
NOTE: A GENERAL AND ADMINISTRATIVE RATE OF FIFTEEN AND
AND A QUARTER PERCENT SHOULD BE ENTERED AS 15.25
```

1. Enter the general and administrative rate.

Upon entry, the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF  15.25% FOR THE GENERAL
AND ADMINISTRATIVE RATE.  DO YOU WISH TO ALTER THIS?
ENTER "Y" FOR YES, "N" FOR NO.
```

Upon approving the value for the general and administrative the PPEM Design Independent Parameters menu screen will appear.

B.2.9 Enter the profit rate

1. Enter 9 from the PPEM Design Independent menu screen.

A description of the design independent parameter, profit rate, is presented.

```
ENTER THE PROFIT RATE TO BE USED.
NOTE: A PROFIT RATE OF TEN AND ONE HALF PERCENT SHOULD
BE ENTERED AS 10.5
```

1. Enter the profit rate.

Upon entry, the value will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF  10.50% FOR THE PROFIT
RATE.  DO YOU WISH TO ALTER THIS?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the value for the profit rate the PPEM Design Independent Parameters menu screen will appear.

B.3 Enter PPEM Design Dependent Parameters

From the PPEM Main Menu you may select function 2 to begin the process of entering the PPEM design dependent parameter data.

1. Enter 2 from the PPEM Main Menu.

The PPEM Design Dependent Parameters menu screen will appear.

```
************************************************************
*                                                          *
*              PPEM DESIGN DEPENDENT PARAMETERS            *
*                                                          *
* 1  COST OF DESIGN (REDESIGN OF BASE-LINE PRODUCT)        *
* 2  NUMBER OF DIRECT LABOR HOURS REQUIRED FOR FIRST UNIT  *
* 3  NUMBER OF DIRECT MACHINE HOURS REQUIRED               *
* 4  ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST              *
* 5  HOURLY MACHINE RATE                                   *
* 6  DIRECT MATERIAL COST                                  *
* 7  SLOPE PARAMETER OF THE MANUFACTURING PROGRESS FN.     *
* 8  DESIGN LIFE OF THE PRODUCT                            *
* 9  MTBF AND MTTR PROFILE OF THE BASE-LINE PRODUCT        *
* 10 MTBF MULTIPLIER                                       *
* 11 MTTR MULTIPLIER                                       *
* 12 SALVAGE VALUE                                         *
* 13 RETURN TO PPEM MAIN MENU                              *
*                                                          *
*  ENTER THE NUMBER OF THE DESIGN DEPENDENT PARAMETER      *
*  YOU WISH TO DEFINE OR RETURN TO PPEM MAIN MENU.         *
*                                                          *
************************************************************
```

From this menu all PPEM design dependent parameter data is entered. You select the design dependent parameter which is to be entered and following a brief explanation of the parameter you are prompted for input. Once entered, the value for the design dependent parameter is presented for verification. You may modify the value at this time. If the value is not changed the PPEM Design Dependent Parameters menu screen is presented and the next design dependent parameter may be entered. At any time via the PPEM Design Dependent Parameters menu screen a design dependent parameter may be viewed and changed if necessary.

PPEM design dependent parameters are entered in a manner different then that used to enter the PPEM design independent parameters. PPEM design dependent parameters are related to the level to which the product is designed with producibility in mind. This relationship between producibility and the PPEM design dependent parameters will be estimated using continuous functions. The PPEM program presents, for a given relationship, a general form of an equation to be used. By assigning specific values to this equation the design dependent parameter is determined for each of the three levels of producibility considered by the PPEM program.

B.3.1 Enter the cost of design

1. Enter 1 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, cost of design, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER,
DESIGN COST.  IN THE PPEM PROGRAM DESIGN COST IS
RELATED TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (DESIGN COST) IS A STRAIGHT LINE.
THE GENERAL FORM OF THE EQUATION IS y = (m*x)+b
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
m - THE SLOPE OF THE LINE
b - THE y-INTERCEPT (DESIGN COST OF THE BASE-LINE PRODUCT)


ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH ITS
SLOPE.  (SEPERATED BY A COMMA.)
(e.g.,  45000, 15000 )
```

Note: the values of x range from 0 to 2. Cost of design at the three levels of producibility are found as follows:

Level of Producibility 1, computed at $x = 0$

Level of Producibility 2, computed at $x = 1$

Level of Producibility 3, computed at $x = 2$

This remains true for each of the PPEM design dependent parameters.

The cost of design (or redesign of a base-line case) should include all costs which would be incured during the entire design effort. If the product under evaluation is presently in production a cost of design of $0.00 would be entered for the y-intercept. The incremental costs of design required to achieve the higher levels of producibility would then estimated and the slope parameter of the linear function described above would be used to include these costs.

1. Enter the y-intercept and slope of the function separated by a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERTCEPT (DESIGN COST OF
BASE-LINE PRODUCT) A VAULE OF $ 45000.00 AND A VALUE
OF 15000.00 FOR THE SLOPE OF THE FUNCTION.



DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the cost of design-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the cost of design at each of the three levels of producibility defined by PPEM.

```
WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED
FOR THE DESIGN DEPENDENT PARAMETER (DESIGN COST) AND
THE RESULTING VALUES FOR THE PRODUCT'S THREE LEVELS OF
PRODUCIBILITY?  ENTER "Y" FOR YES, "N" FOR NO.
```

If you wish to view the graph, a graph similar to this will appear.

```
                              DESIGN COST

  45000.00            55000.00            65000.00            75000.00
      +                   +                   +                   +
     ***************************************************************
LOP  1*                                                            *
     *   *                                                         *
     *      *                                                      *
     *         *                                                   *
     *            *                                                *
     *               *                                             *
     *                  *                                          *
     *                     *                                       *
     *                        *                                    *
     *                           *                                 *
LOP  2                              *                              *
     *                                 *                           *
     *                                    *                        *
     *                                       *                     *
     *                                          *                  *
     *                                             *               *
     *                                                *            *
     *                                                   *         *
     *                                                      *      *
     *                                                         *   *
LOP  3                                                            **
     ***************************************************************

                              DESIGN COST

                  LEVEL OF PRODUCIBILITY  1        45000.00
                  LEVEL OF PRODUCIBILITY  2        60000.00
                  LEVEL OF PRODUCIBILITY  3        75000.00
```

Upon striking any key the PPEM Design Dependent menu screen will appear.

B.3.2 Enter the number of direct labor hours (1st unit)

1. Enter 2 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, number of direct labor hours (1st unit), is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, THE
NUMBER OF DIRECT LABOR HOURS REQUIRED TO PRODUC THE
FIRST UNIT.  IN THE PPEM PROGRAM THE NUMBER OF DIRECT
LABOR HOURS (1ST UNIT) IS RELATED TO THE PRODUCT'S
LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (DIRECT LABOR HOURS (1ST UNIT)) IS
THE DECAY FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = c(e(-r*x))
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
c - THE MAXIMUM VALUE OF THE FUNCTION (y-INTERCEPT).
r - THE DECAY RATE.


ENTER THE MAXIMUM VALUE OF THE FUNCTION ALONG WITH ITS
DECAY RATE.  (SEPERATED BY A COMMA.)
(e.g.,  25.50, .90 )
```

The number of direct labor hours required to produce the first unit of the product is used to describe the amount of hüman labor that is required to produce the first unit. This value and value for the slope parameter of the Manufacturing Progress Function (yet to be entered) will be used to calculate the average number of direct labor hours that will be needed to produce the required number of units. The maximum value (or y-intercept) should be the number of direct labor hours required for the first unit of the product defined at Level of Producibility 1 (the base-line case). Estimates for the number of direct labor hours required for the product at the higher levels of producibility would be included using the decay rate parameter.

1. Enter the maximum value of the function along with its decay rate separated by a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE MAXIMUM VALUE OF THE FUNCTION
A VALUE OF  25.50 HOURS AND VALUE OF   .90 FOR THE
FUNCTION'S DECAY RATE.


DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the number of direct labor hours required for the first unit-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the number of direct labor hours (1st unit) at each of the three levels of producibility defined by PPEM.

B.3.3 Enter the number of direct machine hours

1. Enter 3 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, number of direct machine hours required, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, NUMBER
OF MACHINE HOURS REQUIRED.  IN THE PPEM PROGRAM THE
NUMBER OF MACHINE HOURS REQUIRED TO PRODUCE A PRODUCT IS
RELATED TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.

YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.

THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (MACHINE HOURS) IS A GROWTH FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*x))+b
FOR THIS RELATIONSHIP THE THREE PARAMETERS ARE:
c - THE MAXIMUM VALUE ADDED TO b,
r - THE GROWTH RATE,
b - THE y-INTERCEPT.

ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE
MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)
(e.g.,  15.50, 12.00, 1.45 )
```

The number of direct machine hours required to produce a unit of the product requires that three equation parameters be entered. The y-intercept is the number of direct machine hours required to produce a unit of the product at Level of Producibility 1. The maximum value to be added is an estimate of the additional number of direct machine hours that will be needed for the product at Level of Producibility 3. The growth rate describes the rate at which the function increases between these two values.

1. Enter the maximum value of the function along with its growth rate and y-intercept separated by commas.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION
A VALUE OF  15.50 HOURS,  12.00 HOURS FOR THE MAXIMUM
VALUE ADDED, AND  1.45 FOR THE GROWTH RATE.


DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the number of direct machine hours required-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the number of direct machine hours required at each of the three levels of producibility defined by PPEM.

B.3.4 Enter the annual equivalent capital equipment cost

1. Enter 4 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, annual equivalent capital equipment cost, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, ANNUAL
EQUIV. CAPITAL EQUIP. COST.  IN THE PPEM PROGRAM THE
ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST FOR A PRODUCT IS
RELATED TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.

YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.

THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (MACHINE HOURS) IS A GROWTH FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*x))+b
FOR THIS RELATIONSHIP THE THREE PARAMETERS ARE:
c - THE MAXIMUM VALUE ADDED TO b,
r - THE GROWTH RATE,
b - THE y-INTERCEPT.

ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE
MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)
(e.g.,  0.00, 45000, 1.45 )
```

The annual equivalent capital equipment cost is a precalculated value for the cost of capital equipment (buildings, large production equipment, etc.). The y-intercept represents this cost for such items for the product at Level of Producibility 1. The maximum value to be added is an estimate of the additional capital equipment costs that would be incured for the product at Level of Producibility 3. The growth rate describes the rate at which the function increases between these two values.

1. Enter the maximum value of the function along with its growth rate and y-intercept separated by commas.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION
A VALUE OF $      .00, $ 45000.00 FOR THE MAXIMUM
VALUE ADDED, AND  1.45 FOR THE GROWTH RATE.


DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the annual equivalent capital equipment cost-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the annual equivalent capital equipment cost at each of the three levels of producibility defined by PPEM.

B.3.5 Enter the hourly machine rate

1. Enter 5 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, hourly machine rate, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, THE
HOURLY RATE FOR MACHINE TIME.  IN THE PPEM PROGRAM THE
THE HOURLY RATE FOR MACHINE TIME IS RELATED TO THE
PRODUCT'S LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (HOURLY RATE FOR MACHINE TIME) IS THE
GROWTH FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*x))+b
FOR THIS RELATIONSHIP THE THREE PARAMETERS ARE:
c - THE MAXIMUM VALUE ADDED TO b,
r - THE GROWTH RATE,
b - THE y-INTERCEPT.


ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE
MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)
(e.g.,  35.50, 40.00, 1.45 )
```

The hourly machine rate incorporates the cost of operating and maintaining the production equipment required to produce the product. The y-intercept is the hourly rate charged for equipment used to produce the product at Level of Producibility 1. The maximum value to be added is an estimate of the additional cost that would be incurred for production equipment used to produce the product at Level of Producibility 3. The growth rate describes the rate at which the function increases between these two values.

1. Enter the maximum value of the function along with its growth rate and y-intercept separated by commas.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION
A VALUE OF $ 35.50, $ 40.00 FOR THE MAXIMUM VALUE
ADDED, AND  1.45 FOR THE GROWTH RATE.


DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the hourly machine rate-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the hourly machine rate at each of the three levels of producibility defined by PPEM.

B.3.6 Enter the direct material cost

1. Enter 6 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, direct material cost, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, THE
DIRECT MATERIAL COST FOR AN UNIT.  IN THE PPEM PROGRAM
THE DIRECT MATERIAL IS IS RELATED TO THE PRODUCT'S
LEVEL OF PRODUCIBILITY.

YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.

THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (DIRECT MATERIAL COST) IS THE
DECAY FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = c(e(-r*x))
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
c - THE MAXIMUM VALUE OF THE FUNCTION (y-INTERCEPT),
r - THE DECAY RATE.

ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH ITS
DECAY RATE.  (SEPERATED BY A COMMA.)
(e.g.,  75.50, .40 )
```

The direct material cost of the product includes the cost of all materials required in the production of a unit of the product. The y-intercept represents the direct material cost of a unit of the product at Level of Producibility 1. The direct material cost of the product at the higher levels of producibility would be estimated using the decay rate parameter.

1. Enter the maximum value of the function along with its decay rate separated by a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION
A VALUE OF $    75.50 AND A VALUE OF    .40 FOR THE
FUNCTION'S DECAY RATE.


DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the direct material cost-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the direct material cost at each of the three levels of producibility defined by PPEM.

B.3.7 Enter the slope parameter of manufacturing progress function

1. Enter 7 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, slope parameter of the manufacturing function, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, SLOPE
PARAMETER OF MANUFACTURING PROGRESS FUNCTION.  IN THE
PPEM PROGRAM THE SLOPE PARAMETER OF THE MPF. IS RELATED
TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (SLOPE PARAMETER) IS A GROWTH FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*t))+b
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
c - THE MAXIMUM VALUE ADDED TO b,
r - THE GROWTH RATE,
b - THE y-INTERCEPT.


ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE
MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)
(e.g.,  .75, .20. 1.55 )
```

The slope parameter of the manufacturing progress function describes the amount of manufacturing improvement as a percentage reduction of the direct labor required on doubled production quantities of the product. This and the number of direct labor hours required (1st unit) are used to calculate the average number of direct labor hours required to produce the required number of units. The y-intercept is the slope parameter (0.0 < = slope parameter < = 1.0) for the product at Level of Producibility 1. The maximum value to be added is an estimate of the difference between the slope parameter for the product at Level of Producibility 1 and Level of Producibility 3. The growth rate describes the rate at which the function increases between these two values.

1. Enter the maximum value of the function along with its growth rate and y-intercept separated by commas.

In the event the equation parameters entered above describe an non-positive slope parameter the following message will appear.

```
               !!!!! WARNING !!!!!

AN NONPOSITIVE VALUE FOR THE SLOPE PARAMETER OF THE
MANUFACTURING PROGRESS FUNCTION HAS BEEN COMPUTED.
AN EXECUTION ERROR WOULD BE THE RESULT IF USED !!!
```

Upon a valid entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION
A VALUE OF    .75,   .20 FOR THE MAXIMUM VALUE
ADDED, AND  1.55 FOR THE GROWTH RATE.



DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the slope parameter of the manufacturing function-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the slope parameter of the manufacturing function at each of the three levels of producibility defined by PPEM.

B.3.8 Enter the design life of the product

1. Enter 8 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, design life of the product, is presented.

```
ENTER THE DESIGN LIFE OF THE PRODUCT BEING (RE)DESIGNED.
IT IS ASSUMED THAT THE PRODUCT, NO MATTER WHICH LEVEL OF
PRODUCIBILITY IT IS DESIGNED FOR, WILL BE DESIGNED WITH
THIS LIFE (MEASURED IN YEARS) IN MIND.  NOTE: THE NUMBER
ENTERED WILL BE READ AS AN INTEGER VALUE.
```

Upon a valid entry, the values will be presented for verification.

```
YOU HAVE ENTERED A VALUE OF  7 FOR THE DESIGN LIFE OF
THE PRODUCT.  DO YOU WISH TO ALTER THIS?  ENTER "Y" FOR
YES, "N" FOR NO.
```

Upon approving the value entered for design life of the product the PPEM Design Dependent Parameters menu screen will appear.

B.3.9 Enter the MTBF and MTTR profiles of the base-line product

1. Enter 9 from the PPEM Design Dependent menu screen.

If the design life of the product has not yet been defined the following message will be presented.

```
THE YEAR TO WHICH THIS CHANGE APPLIES IS GREATER THAN THE
PRESENT VALUE ENTERED FOR THE DESIGN LIFE OF THE PRODUCT.
```

If the design life of the product was previously defined a description of the design dependent parameters, MTBF and MTTR profiles of the base-line product, is presented.

```
ENTER THE MEAN TIME BETWEEN FAILURE (MTBF) AND MEAN TIME TO
REAPAIR (MTTR) PROFILE FOR THE BASE-LINE PRODUCT.  YOU WILL
BE PROMPTED FOR THE MTBF AND MTTR VALUES OF THE PRODUCT
BY AGE COHORT.  FOR EACH YEAR ENTER THE TWO VALUES SEPERATED
BY A COMMA.  (e.g., 1.234, .234 )  NOTE: THESE VALUES ARE
MEASURED IN YEARS.
```

```
ENTER THE MTBF AND MTTR FOR AGE COHORT  0 -  1 YEARS
```

The base-line product refers to the product at Level of Producibility 1. These profiles entered by age cohort are adjusted by the MTBF and MTTR multipliers (yet to entered) to achieve the desired profiles for each of the three levels of producibility considered by PPEM. Following the entry of each age cohort's MTBF and MTTR, the values will be presented for verification.

```
************       ******       ******
 AGE COHORT         MTBF         MTTR
************       ******       ******

    0 -  1         1.234         .234

    1 -  2         1.234         .234

    2 -  3         1.234         .234

    3 -  4         1.234         .234

    4 -  5         1.234         .234

    5 -  6         1.234         .234

    6 -  7         1.234         .234
```

```
DO YOU WISH TO CHANGE THE MTBF OR MTTR FOR ANY GIVEN
AGE COHORT.  ENTER "Y" FOR YES, "N" FOR NO.
```

If you entered "Y" or "y" you will prompted to reenter the values by age cohort.

```
ENTER THE YEAR TO WHICH THE CHANGE APPLIES FOLLOWED BY THE
NEW MTBF AND MTTR VALUES (SEPERATED BY COMMAS).
(e.g., 5, 1.234, .234 )  NOTE: THE YEAR NUMBER 5 REFERS TO
AGE COHORT 4 - 5.
```

Upon approving all values entered for the MTBF and MTTR profiles for the base-line product (Level of Producibility 1) the PPEM Design Dependent Parameters menu screen will appear.

B.3.10 Enter the MTBF multiplier

1. Enter 10 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, MTBF multiplier, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, MTBF
MULTIPLIER.  IN THE PPEM PROGRAM THE MTBF MULTIPLIER IS
RELATED TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (MTBF MULTIPLIER) IS A GROWTH FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = (c(1-(e(-r*x))))+1
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
c - THE MAXIMUM VALUE ADDED TO 1,
r - THE GROWTH RATE.


ENTER THE MAXIMUM VALUE ADDED ALONG WITH THE GROWTH
RATE OF THE FUNCTION.  (SEPERATED BY A COMMA.)
(e.g.,  .09, 1.75 )
```

The MTBF multiplier is used to adjust the MTBF profile of the base-line case (Level of Producibility 1). The desired MTBF profiles for each of three levels of producibility considered by PPEM are found by multipling the previously defined MTBF value for each age cohort within the base-line profile by this multiplication factor. The MTBF profile of the base-line product was entered as a separate PPEM design dependent parameter. Therefore, the MTBF multiplier for

Level of Producibility 1 must be 1.0. The maximum value added is an estimate of the percent increase in MTBF realized by the product at Level of Producibility 3. The growth rate describes the rate at which the function increases between these two values.

1. Enter the maximum value of the function along with its growth rate separated a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE MAXIMUM VALUE ADDED A
VALUE OF  .09 AND VALUE OF 1.75 FOR THE
FUNCTION'S GROWTH RATE.



DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the MTBF multiplier-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the MTBF multiplier at each of the three levels of producibility defined by PPEM.

B.3.11 Enter the MTTR multiplier

1. Enter 11 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, MTTR multiplier, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, MTTR
MULTIPLIER.  IN THE PPEM PROGRAM THE MTTR MULTIPLIER IS
RELATED TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (MTTR MULTIPLIER) IS A GROWTH FUNCTION.
THE GENERAL FORM OF THE EQUATION IS y = (c(1-(e(-r*x))))+1
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
c - THE MAXIMUM VALUE ADDED TO 1,
r - THE GROWTH RATE.


ENTER THE MAXIMUM VALUE ADDED ALONG WITH THE GROWTH
RATE OF THE FUNCTION.  (SEPERATED BY A COMMA.)
(e.g.,  .05, 1.75 )
```

The MTTR multiplier is used to adjust the MTTR profile of the base-line case (Level of Producibility 1). The desired MTTR profiles for each of three levels of producibility considered by PPEM are found by multipling the previously defined MTTR value for each age cohort within the base-line profile by this multiplication factor. The MTTR profile of the base-line product was entered as a separate PPEM design dependent parameter. Therefore, the MTTR multiplier for Level of Producibility 1 must be 1.0. The maximum value added is an estimate of the percent increase in MTTR realized by the product at Level of Producibility 3. The growth rate describes the rate at which the function increases between these two values.

1. Enter the maximum value of the function along with its growth rate separated a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE MAXIMUM VALUE ADDED A
VALUE OF  .05 AND VALUE OF 1.75 FOR THE
FUNCTION'S GROWTH RATE.


DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the MTTR multiplier-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the MTTR multiplier at each of the three levels of producibility defined by PPEM.

B.3.12 Enter the salvage value

1. Enter 12 from the PPEM Design Dependent menu screen.

A description of the design dependent parameter, salvage value of the product, is presented.

```
YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER,
SALVAGE VALUE.  IN THE PPEM PROGRAM SALVAGE VALUE IS
RELATED TO THE PRODUCT'S LEVEL OF PRODUCIBILITY.


YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH
MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE
RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE
PARAMETERS OF THE EQUATION.


THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN
DEPENDENT PARAMETER (SALVAGE VALUE) IS A STRAIGHT LINE.
THE GENERAL FORM OF THE EQUATION IS y = (m*x)+b
FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:
m - THE SLOPE OF THE LINE
b - THE y-INTERCEPT (SALVAGE VALUE OF THE BASE-LINE PRODUCT)


ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH ITS
SLOPE.  (SEPERATED BY A COMMA.)
(i.e.,  500, 0.0 )
```

The usefulness or value of the materials or parts which make up the product at the time of its retirement determine the product's salvage value. The y-intercept is the estimated value of the product (Level of Producibility 1) at the end of its design life. The salvage value of the product if designed to achieve the higher levels of producibility would then estimated and the slope parameter of the linear function described above would be used to include these values.

1. Enter the y-intercept and slope of the function separated by a comma.

Upon entry, the values will be presented for verification.

```
YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION
A VALUE OF $   500.00 AND VALUE OF   .000 FOR THE
FUNCTION'S SLOPE.



DO YOU WISH TO CHANGE EITHER VALUE?  ENTER "Y" FOR YES,
"N" FOR NO.
```

Upon approving the equation parameter values for the salvage value-level of producibility relationship you may view a graph of the function just defined. Also included with the graph are the values that will be used for the salvage value of the product at each of the three levels of producibility defined by PPEM.

B.4 Run the PPEM program

From the PPEM Main Menu you may select function 3 to run the PPEM program.

1. Enter 3 from the PPEM Main Menu.

A check is made to see if all PPEM design independent and PPEM design dependent parameters have been defined. If any PPEM design parameters have not been defined a message as follows will appear.

```
THE FOLLOWING PPEM INDEPENDENT PARAMETER(S) HAVE NOT BEEN
ENTERED !!!

PPEM INDEPENDENT PARAMETER NUMBER 1
PPEM INDEPENDENT PARAMETER NUMBER 2
PPEM INDEPENDENT PARAMETER NUMBER 3
PPEM INDEPENDENT PARAMETER NUMBER 4
```

Following an appropriate response the PPEM Design Independent Parameter or the PPEM Design Dependent Parameter menu screen will appear. The undefined design parameter must be entered before calculations can be made.

If all PPEM design independent and dependent parameters have been defined the following message will appear.

```
********  SEARCH FOR THE OPTIMUM HAS BEGUN  ********
```

B.4.1 Possible warning messages

During the calculation of expected annual equivalent total system life-cycle cost the following warning messages may appear:

1.

```
          !!!! WARNING !!!!

THE NUMBER OF UNITS TO BE PRODUCED AND
DEPLOYED HAS REACHED A VALUE OF 33.
COMPUTATIONS FOR LEVEL OF PRODUCIBILITY 1
WILL STOP AT THIS POINT !!
```

Due to the computational limits of the personal computer population sizes greater than 33 are not allowed.

2.

```
            !!!! WARNING !!!!

THE SALVAGE VALUE FOR THE PRODUCT DEFINED
FOR LEVEL OF PRODUCIBILITY 1IS GREATER
THAN THE DERIVED VALUE FOR ITS FIRST COST.
AN EXECUTION ERROR WILL RESULT !!
```

If the salvage value defined for a product was allowed to be greater than its first cost an infinite number of units would be deployed.

B.5 PPEM Output Report

Following a successful PPEM run an output report is automatically generated and printed to screen. The output report provided by PPEM is organized into three sections, PPEM Results Summary, PPEM Input Summary and PPEM Output Summary. The first section, PPEM Results Summary, presents the outcome of the PPEM calculations. Included are the expected annual equivalent total system life-cycle costs of each of the three design alternatives considered by PPEM and the selection of the optimal design alternative based solely upon these life-cycle costs.

The second section, PPEM Input Summary, presents PPEM design independent parameter data followed by the PPEM design dependent data. The PPEM design independent data is simply a "dump" of the values entered via the PPEM Design Independent Parameters menu screen prior to execution. The PPEM design dependent parameter data presented is the result of the user specified equation parameters defining the design dependent parameters' relationship to each level of producibility considered by PPEM. The resulting values for each design dependent parameter are presented grouped by Level of Producibility.

The third section of the PPEM Output Report, PPEM Output Summary, presents derived information for each level of producibility considered by PPEM. This includes the average number of direct labor hours required per unit, average first cost of an unit, components of the expected annual equivalent total system life-cycle cost calculation, expected number of units short of demand, probability of one or more units short of demand, and the optimum values for the system design variables.

The output may be viewed with the benefit of screen lock statements if desired.

If a printout of the PPEM Output Report is desired strike [Ctrl][P] prior to viewing the on-screen report. Note: The printer must be online or an execution error will occur. Strike [Ctrl][P] after printing has stopped.

The PPEM Output Report may be viewed again if desired.

```
WOULD YOU CARE TO VIEW THE PPEM OUTPUT REPORT
AGAIN?  ENTER "Y" FOR YES, "N" FOR NO.
```

B.6 Save current PPEM design parameter data

From the PPEM Main Menu you may select function 4 to save current PPEM design parameter data.

1. Enter 4 from the PPEM Main Menu.

Any valid PC/MS DOS filename may be used. The file name consists of one to eight characters. The following character are invalid filename characters: . / \ | | : < > + = ; , The filename extension consists of a period followed by one to three characters. The following characters are invalid filename extension characters: . / \ [ ] : < > + = ; ,

If an error occurs while saving the file the following message will appear.

```
!!!! I/O ERROR !!!!
```

B.7 Retrieve PPEM design parameter data file

From the PPEM Main Menu you may select function 5 to retrieve previously stored PPEM design parameters.

1. Enter 5 from the PPEM Main Menu.

The file must exist for it to be retrieved. If an incorrect filename is specified or the file does not exist on disk the following message will appear.

```
!!!! I/O ERROR !!!!
   FILE NOT FOUND
```

If the file exists but an error occurs while retrieving the file the following message will appear.

```
!!!! I/O ERROR !!!!
```

B.8 Exit to DOS

From the PPEM Main Menu you may select function 6 to exit the PPEM program. At any time you may strike [Ctrl][Break] to exit. Note: if the [Ctrl][Break] method is used all current data is lost.

Upon selecting function 6 from the PPEM Main Menu you will prompted to save all current PPEM design parameter data.

```
DO YOU WISH TO SAVE THE CURRENT PPEM DESIGN PARAMETER
DATA BEFORE EXISTING.  ENTER "Y" FOR YES, "N" FOR NO.
```

Appendix C. PPEM SOURCE CODE

```
C
C      PROGRAM PPEM.FOR
C
C      PRODUCT PRODUCIBILITY EVALUATION MODEL (PPEM)
C
C      WRITTEN IN FORTRAN 77
C
C      SCREEN OUTPUT FORMAT
C

C
C       MAIN PROGRAM
C

C    *** REAL VARIABLE DICTIONARY ***

C    AECEC - array containing Annual Equivalent Capital Equipment Cost
C    AVGLAB - array containing AVG. no. of direct LABor hrs. (1st unit)
C    BMTBF - array containing Base-line Mean Time Between Failure
C    BMTTR - array containing Base-line Mean Time To Repair
C    DCOST - array containing Design COST
C    DIRMAT - array containing DIRect MATerial cost
C    DLH1 - array containing Direct Labor Hours (1st unit)
C    DP#PS - design Dependent Parameter #, parametic eq. parameter $
C    ES1 - maintains current best Expected number of units Short
C    ESSTAR - array containing optimum Expected number of unit Short
C    FACT - array containing FACTorials
C    FCOST - array containing unit First COST
C    FCST - equated specific unit First CoST
C    FLAG - array containing data entry FLAG
C    FRFC - annual equivalent Fixed Repair Facility Cost
C    GA - General and Administrative rate
C    IC1 - maintains current best Item Cost
C    ICSTAR - array containing optimum Item Cost
C    INT - annual INTerest rate
C    LABRT - direct LABor RaTe
C    MACHR - array containing MAChine HouRs required
C    MACHRT - array containing MACHine RaTe
C    MTBF - array containing resulting Mean Time Between Failure profil
C    MTBFM - array containing Mean Time Between Failure Multiplier
C    MTTR - array containing resulting Mean Time To Repair profile
C    MTTRM - array containing Mean Time To Repair Multiplier
C    OH - OverHead rate
C    OPT - array containing OPTimum e[aetslcc]
C    ORFC - annual equivalent Operating Repair Facility Cost
C    PHI - array containing manuf. progress fn. slope parameter (PHI)
C    PROFIT - PROFIT rate
C    PSHORT1 - maintains current best Probability of one or more SHORT
C    PSSTAR - array containing optimum Prob. of one or more units Short
C    RC1 - maintains current best Repair facility Cost
C    RCSTAR - array containing optimum Repair facility Cost
C    SALV - equated specific SALVage value
C    SALVAG - array containing SALVAGe value
C    SC1 - maintains current best Shortage penalty Cost
C    SCSTAR - array containing optimum Shortage Cost
C    SHORT - SHORTage penalty cost
C    TCLOW - maintains ann. equiv. Total syst. life cycle Cost (LOWest)

C    *** INTEGER VARIABLE DICTIONARY ***

C    DAGE - Design life or AGE of the product
C    DEMAND - stated DEMAND or need of the system
C    M1 - maintains current best number of repair facilites
```

```
C    MSTAR - array containing optimum number of repair facilities
C    N1 - maintains current best number of units (population size)
C    NHORZ - duration of demand
C    NSTAR - array containing optimum number of units (population size)
C    NN1 - maintains current best economic retirement age
C    NNSTAR - array containing optimum economic retirement age

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &MACHR(3), DIRMAT(3), DLH1(3), PHI(3), BMTBF(20), BMTTR(20),
     &MTBFM(3), MTTRM(3), DCOST(3), SALVAG(3), SALV, TCLOW,
     &ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &FCOST(3), FCST, ICSTAR(3), SCSTAR(3), RCSTAR(3),
     &OPT(3), ESSTAR(3), PSSTAR(3), RC1, SC1, IC1, AVGLAB(3),
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2, AECEC(3)

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, NN1, N1, M1, DAGE, NNSTAR(3), NSTAR(3), MSTAR(3),
     &NHORZ

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1

C    *** DOUBLE PRECISION DECLARATIONS ***

      DOUBLE PRECISION FACT(35)

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /CBLK/ DLH1, PHI

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      COMMON /GBLK/ FACT

      COMMON /HBLK/ NNSTAR, NSTAR, MSTAR, OPT, ESSTAR, PSSTAR,
     &ICSTAR, SCSTAR, RCSTAR, AVGLAB

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      DAGE = 0

      DO 5 I = 1,21
      FLAG(I) = 0
5     CONTINUE
```

```
C     WRITE PPEM MAIN MENU SCREEN

15    WRITE(*,16)
16    FORMAT(/,
     &/,' ************************************************************',
     &/,' *                                                          *',
     &/,' *                    PPEM MAIN MENU                        *',
     &/,' *                                                          *',
     &/,' *  1  ENTER PPEM DESIGN INDEPENDENT PARAMETERS             *',
     &/,' *  2  ENTER PPEM DESIGN DEPENDENT PARAMETERS               *',
     &/,' *  3  RUN THE PPEM PROGRAM (OPTIMIZE UPON SYSTEM           *',
     &/,' *     DESIGN VARIABLES AND VIEW RESULTS)                   *',
     &/,' *  4  SAVE CURRENT PPEM DESIGN PARAMETER DATA              *',
     &/,' *  5  RETRIEVE PPEM DESIGN PARAMETER DATA FILE             *',
     &/,' *  6  EXIT TO DOS                                          *',
     &/,' *                                                          *',
     &/,' *  ENTER THE NUMBER (1,2,3,4,5,OR 6) OF THE FUNCTION YOU   *',
     &/,' *  WISH TO PERFORM.                                        *',
     &/,' *                                                          *',
     &/,' ************************************************************',
     &//)

      READ(*,*,ERR=15) NUM

      IF(NUM.EQ.1) GO TO 30
      IF(NUM.EQ.2) GO TO 50
      IF(NUM.EQ.3) GO TO 700
      IF(NUM.EQ.4) GO TO 925
      IF(NUM.EQ.5) GO TO 950
      IF(NUM.EQ.6) GO TO 975
25    GO TO 15

C     WRITE PPEM DESIGN INDEPENDENT PARAMETER MENU SCREEN

30    WRITE(*,31)
31    FORMAT(//,1X,60('*'),
     &/,' *                                                          *',
     &/,' *           PPEM DESIGN INDEPENDENT PARAMETERS             *',
     &/,' *                                                          *',
     &/,' * 1  MAGNITUDE AND DURATION OF DEMAND ON THE SYSTEM        *',
     &/,' * 2  THE TIME VALUE OF MONEY                               *',
     &/,' * 3  ANNUAL EQUIVALENT FIXED REPARIR FACILITY COST         *',
     &/,' * 4  ANNUAL EQUIVALENT OPERATING REPAIR FACILITY COST      *',
     &/,' * 5  SHORTAGE PENALTY COST                                 *',
     &/,' * 6  HOURLY LABOR RATE                                     *',
     &/,' * 7  OVERHEAD RATE                                         *',
     &/,' * 8  GENERAL AND ADMINISTRATIVE RATE                       *',
     &/,' * 9  PROFIT RATE                                           *',
     &/,' * 10 RETURN TO TO PPEM MENU                                *',
     &/,' *                                                          *',
     &/,' *  ENTER THE NUMBER OF THE DESIGN INDEPENDENT PARAMETER    *',
     &/,' *  YOU WISH TO DEFINE OR RETURN TO PPEM MAIN MENU.         *',
     &/,' *                                                          *',
     &/,1X,60('*'),//)

      READ(*,*,ERR=30) NUM

C     A DATA ENTRY SUBROUTINE EXISTS FOR EACH DESIGN INDEP. PARAMETER

      IF(NUM.EQ.1) THEN
       CALL IP1SUB
       GO TO 30
```

```
      END IF

      IF(NUM.EQ.2) THEN
       CALL IP2SUB
       GO TO 30
      END IF

      IF(NUM.EQ.3) THEN
       CALL IP3SUB
       GO TO 30
      END IF

      IF(NUM.EQ.4) THEN
       CALL IP4SUB
       GO TO 30
      END IF

      IF(NUM.EQ.5) THEN
       CALL IP5SUB
       GO TO 30
      END IF

      IF(NUM.EQ.6) THEN
       CALL IP6SUB
       GO TO 30
      END IF

      IF(NUM.EQ.7) THEN
       CALL IP7SUB
       GO TO 30
      END IF

      IF(NUM.EQ.8) THEN
       CALL IP8SUB
       GO TO 30
      END IF

      IF(NUM.EQ.9) THEN
       CALL IP9SUB
       GO TO 30
      END IF

      IF(NUM.EQ.10) GO TO 15

45    GO TO 30

C     WRITE PPEM DESIGN DEPENDENT PARAMETER MENU SCREEN

50    WRITE(*,51)
51    FORMAT(//,1X,60('*'),/,1X,'*',58X,'*',
     &/,' *            PPEM DESIGN DEPENDENT PARAMETERS            *',
     &/,' *                                                        *',
     &/,' * 1  COST OF DESIGN (REDESIGN OF BASE-LINE PRODUCT)      *',
     &/,' * 2  NUMBER OF DIRECT LABOR HOURS REQUIRED FOR FIRST UNIT *',
     &/,' * 3  NUMBER OF DIRECT MACHINE HOURS REQUIRED             *',
     &/,' * 4  ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST            *',
     &/,' * 5  HOURLY MACHINE RATE                                 *',
     &/,' * 6  DIRECT MATERIAL COST                                *',
     &/,' * 7  SLOPE PARAMETER OF THE MANUFACTURING PROGRESS FN.   *',
     &/,' * 8  DESIGN LIFE OF THE PRODUCT                          *',
     &/,' * 9  MTBF AND MTTR PROFILE OF THE BASE-LINE PRODUCT      *',
     &/,' * 10 MTBF MULTIPLIER                                     *',
     &/,' * 11 MTTR MULTIPLIER                                     *',
```

```
     &/,' * 12 SALVAGE VALUE                                   *',
     &/,' * 13 RETURN TO PPEM MAIN MENU                        *',
     &/,' *                                                    *',
     &/,' *  ENTER THE NUMBER OF THE DESIGN DEPENDENT PARAMETER *',
     &/,' *  YOU WISH TO DEFINE OR RETURN TO PPEM MAIN MENU.   *',
     &/,' *',58X,'*',/,1X,60('*'),//)

      READ(*,*,ERR=50) NUM

C     A DATA ENTRY SUBROUTINE EXISTS FOR EACH DESIGN DEP. PARAMETER

      IF(NUM.EQ.1) THEN
       CALL DP1SUB
       GO TO 50
      END IF

      IF(NUM.EQ.2) THEN
       CALL DP2SUB
       GO TO 50
      END IF

      IF(NUM.EQ.3) THEN
       CALL DP3SUB
       GO TO 50
      END IF

      IF(NUM.EQ.4) THEN
       CALL DP4SUB
       GO TO 50
      END IF

      IF(NUM.EQ.5) THEN
       CALL DP5SUB
       GO TO 50
      END IF

      IF(NUM.EQ.6) THEN
       CALL DP6SUB
       GO TO 50
      END IF

      IF(NUM.EQ.7) THEN
       CALL DP7SUB
       GO TO 50
      END IF

      IF(NUM.EQ.8) THEN
       CALL DP8SUB
       GO TO 50
      END IF

      IF(NUM.EQ.9) THEN
       CALL DP9SUB
       GO TO 50
      END IF

      IF(NUM.EQ.10) THEN
       CALL DP10SB
       GO TO 50
      END IF

      IF(NUM.EQ.11) THEN
       CALL DP11SB
```

```
      GO TO 50
     END IF

     IF(NUM.EQ.12) THEN
      CALL DP12SB
      GO TO 50
     END IF

     IF(NUM.EQ.13) GO TO 15

500  GO TO 50

C    BEFORE E[EATSLCC] CALCULATIONS ARE MADE CHECK TO SEE IF ALL
C    DESIGN INDEPENDENT PARAMETERS HAVE BEEN ENTERED

700  DO 710 I = 1,9
     IF(FLAG(I).EQ.0) GO TO 750
710  CONTINUE
     GO TO 800

C    PRINT ANY DESIGN INDEPENDENT PARAMETERS WHICH HAVE NOT BEEN
C    ENTERED

750  WRITE(*,751)
751  FORMAT(/,
    &/,' THE FOLLOWING PPEM INDEPENDENT PARAMETER(S) HAVE NOT BEEN ',
    &/,' ENTERED !!! ',/)
760  DO 780 I = 1,9
     IF(FLAG(I).EQ.0) THEN
       WRITE(*,770) I
770    FORMAT(' PPEM INDEPENDENT PARAMETER NUMBER ',I1)
     END IF
780  CONTINUE

790  WRITE(*,791)
791  FORMAT(/,
    &/,' STRIKE ANY KEY  <R>  TO CONTINUE ',//)

     READ(*,'(A)',ERR=30) C
     GO TO 30

C    BEFORE E[EATSLCC] CALCULATIONS ARE MADE CHECK TO SEE IF ALL
C    DESIGN DEPENDENT PARAMETERS HAVE BEEN ENTERED

800  DO 810 I = 10,21
     IF(FLAG(I).EQ.0) GO TO 850
810  CONTINUE
     GO TO 900

C    PRINT ANY DESIGN DEPENDENT PARAMETERS WHICH HAVE NOT BEEN
C    ENTERED

850  WRITE(*,851)
851  FORMAT(/,
    &/,' THE FOLLOWING PPEM DEPENDENT PARAMETER(S) HAVE NOT BEEN ',
    &/,' ENTERED !!! ',/)
860  DO 880 I = 10,21
     IF(FLAG(I).EQ.0) THEN
       INUM = I-9
       WRITE(*,870) INUM
870    FORMAT(' PPEM DEPENDENT PARAMETER NUMBER ',I2)
     END IF
880  CONTINUE
```

```
890  WRITE(*,891)
891  FORMAT(/,
    &/,' STRIKE ANY KEY <R> TO CONTINUE ',//)

     READ(*,'(A)',ERR=50) C
     GO TO 50

C    SUBROUTINE PPEMCL PERFORMS E[AETSLCC] CALCULATIONS
C    SUBROUTINE OUTP PRINTS OUTPUT REPORT TO SCREEN

900  CALL PPEMCL
     CALL OUTP
     GO TO 15

C    SUBROUTINE SAVE SAVES DESIGN PARAMETER DATA TO DISK

925  CALL SAVE
     GO TO 15

C    SUBROUTINE RETRV RETRIEVES DESIGN PARAMETER DATA FROM DISK

950  CALL RETRV
     GO TO 15

975  WRITE(*,976)
976  FORMAT(/,
    &/,' DO YOU WISH TO SAVE THE CURRENT PPEM DESIGN PARAMETER      ',
    &/,' DATA BEFORE EXISTING.  ENTER 'Y' FOR YES, 'N' FOR NO.    ',//)

     READ(*,'(A)',ERR=975) YN

     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') CALL SAVE

999  STOP
     END

C    ++++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE IP1SUB

C    *** REAL VARIABLE DICTIONARY ***

C    FLAG - array containing data entry FLAG

C    *** INTEGER VARIABLE DICTIONARY ***

C    DEMAND - stated DEMAND or need of the system

C    *** REAL DECLARATIONS ***

     REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
    &FLAG(21)

C    *** INTEGER DECLARATIONS ***

     INTEGER DEMAND

C    *** CHARACTER DECLARATIONS ***

     CHARACTER YN*1
```

```
C     *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

C     CHECK TO SEE IF THIS DESIGN INDEPENDENT PARAMETER HAS PREVIOUSLY
C     BEEM ENTERED IF SO PRESENT THE VALUE

      IF(FLAG(1).EQ.1) GO TO 30

C     THE FIRST TIME THROUGH PRESENT THE USER WITH FULL EXPLANATION
C     OF INPUT REQUIREMENTS

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE DEMAND OR NEED ON THE SYSTEM FOLLOWED BY THE    ',
     &/,' DURATION OF THIS NEED SEPERATED BY A COMMA (E.G., 15,10). ',
     &/,' THE VALUES ENTERED WILL BE READ AS INTEGER NUMBERS AND    ',
     &/,' ARE ASSUMED TO BE DETERMINISTIC AND TIME INVARIANT.       ',
     &/,' NOTE: DUE TO COMPUTATIONAL LIMITATIONS OF PERSONAL        ',
     &/,' COMPUTERS, THE DEMAND OF THE SYSTEM AND THE SUBSEQUENT    ',
     &/,' NUMBER OF UNITS TO DEPLOY CAN NOT EXCEED 33.  THEREFORE   ',
     &/,' A MAXIMUM DEMAND OF APPROXIMATELY 25 IS SUGGUSTED.        ',
     &//)

      READ(*,*,ERR=20) DEMAND, NHORZ

C     THE DEMAND ON THE SYSTEM CAN NOT EXCEED 33

      IF(DEMAND.GT.33) GO TO 20

C     PRINT INPUT DATA

30    WRITE(*,31) DEMAND, NHORZ
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF ',I2,' FOR THE DEMAND AND     ',
     &/,' ',I2,' FOR THE DURATION OF THIS NEED.                     ',
     &/,' DO YOU WISH TO ALTER THIS.  ENTER "Y" FOR YES,            ',
     &/,' "N" FOR NO.',//)

C     THE USER MAY CHANGE THE INPUT IF DESIRED

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

C     INDICATE THAT THIS DESIGN INDEPENDENT PARAMETER HAS BEEN ENTERED

999   FLAG(1) = 1

C     RETURN TO THE PPEM DESIGN INDEPENDENT PARAMETER MENU SCREEN

      RETURN
      END

C     +++++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE IP2SUB
```

```
C    *** REAL VARIABLE DICTIONARY ***

C    FLAG - array containing data entry FLAG
C    INT - annual INTerst rate (decimal)
C    INTRST - annual INTeRST rate (percentage)

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21), INTRST

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      IF(FLAG(2).EQ.1) THEN
        INTRST = INT*100.0
        GO TO 30
      END IF

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE TIME VALUE OF MONEY TO BE USED OVER THE LIFE     ',
     &/,' OF THE SYSTEM UNDER STUDY.  THIS VALUE IS TO BE ENTERED    ',
     &/,' AS AN ANNUAL INTEREST RATE.                                ',
     &/,' NOTE: AN INTEREST RATE OF NINE AND ONE QUARTER PERCENT     ',
     &/,' SHOULD BE ENTERED AS 9.25.  ',//)

      READ(*,*,ERR=20) INTRST

30    WRITE(*,31) INTRST
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF ',F5.2,'
     &/,' INTEREST RATE.  DO YOU WISH TO ALTER THIS.  ENTER "Y" FOR ',
     &/,' YES, "N" FOR NO.',//)

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   INT = INTRST / 100.0

      FLAG(2) = 1

      RETURN
      END

C    + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +

      SUBROUTINE IP3SUB
```

```
C    *** REAL VARIABLE DICTIONARY ***

C    FLAG - array containing data entry FLAG
C    FRFC - annual equivalent Fixed Repair Facility Cost

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21)

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      IF(FLAG(3).EQ.1) GO TO 30

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE ANNUAL EQUIVALENT FIXED COST FOR A REPAIR       ',
     &/,' FACILITY.  THIS A PRECALCULATED VALUE WHICH INCLUDES      ',
     &/,' SUCH FACTORS AS LAND, BUILDINGS, CAPITAL EQUIPMENT,       ',
     &/,' ETC.  IT IS ASSUMED THAT EACH REPAIR FACILITY IS          ',
     &/,' IDENTICAL AND NO LIMITATIONS AS TO THE NUMBER OF REPAIR   ',
     &/,' FACILITIES EXIST.      ',//)

      READ(*,*,ERR=20) FRFC

30    WRITE(*,31) FRFC
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF $',F8.2,' FOR THE ANNUAL      ',
     &/,' EQUIVALENT FIXED REPAIR FACILITY COST.  DO YOU WISH TO    ',
     &/,' ALTER THIS.  ENTER "Y" FOR YES, "N" FOR NO. ',//)

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   FLAG(3) = 1

      RETURN
      END

C    ++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE IP4SUB

C    *** REAL VARIABLE DICTIONARY ***
```

```
C    FLAG - array containing data entry FLAG
C    ORFC - annual equivalent Operating Repair Facility Cost

C     *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21)

C     *** INTEGER DECLARATIONS ***

      INTEGER DEMAND

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1

C     *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      IF(FLAG(4).EQ.1) GO TO 30

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE ANNUAL EQUIVALENT OPERATING COST FOR A REPAIR    ',
     &/,' FACILITY.  THIS IS A PRECALCULATED VALUE WHICH INCLUDES    ',
     &/,' SUCH FACTORS AS LABOR, ENERGY, SMALL TEST EQUIPMENT, ETC.  ',
     &/,' IT IS ASSUMED THAT EACH REPAIR FACILITY''S REQUIREMENTS    ',
     &/,' ARE IDENTICAL.          ',//)

      READ(*,*,ERR=20) ORFC

30    WRITE(*,31) ORFC
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF $',F8.2,' FOR THE ANNUAL       ',
     &/,' EQUIVALENT OPERATING REPAIR FACILITY COST.  DO YOU         ',
     &/,' WISH TO ALTER THIS.  ENTER "Y" FOR YES, "N" FOR NO. ',//)

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   FLAG(4) = 1

      RETURN
      END

C     + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +

      SUBROUTINE IP5SUB

C     *** REAL VARIABLE DICTIONARY ***

C    FLAG - array containing data entry FLAG
C    SHORT - SHORTage penalty cost

C     *** REAL DECLARATIONS ***
```

```
      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21)

C     *** INTEGER DECLARATIONS ***

      INTEGER DEMAND

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1

C     *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      IF(FLAG(5).EQ.1) GO TO 30

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE SHORTAGE PENALTY COST.  THIS IS AN ANNUAL        ',
     &/,' DOLLAR AMOUNT REPRESENTING AN INCOME LOST, OPPORTUNITY     ',
     &/,' LOST OR PENALTY COST INCURRED, PER UNIT SHORT PER YEAR,    ',
     &/,' OF THE SPECIFIED SYSTEM DEMAND.     ',//)

      READ(*,*,ERR=20) SHORT

30    WRITE(*,31) SHORT
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF $',F9.2,' FOR THE SHORTAGE    ',
     &/,' PENALTY COST.  DO YOU WISH TO ALTER THIS.                 ',
     &/,' ENTER "Y" FOR YES, "N" FOR NO. ',//)

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   FLAG(5) = 1

      RETURN
      END

C     +++++++++++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE IP6SUB

C     *** REAL DICTIONARY ***

C     FLAG - array containing data entry FLAG
C     LABRT - direct LABor RaTe

C     *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21)

C     *** INTEGER DECLARATIONS ***

      INTEGER DEMAND
```

```
C    *** CHARACTER DECLARATIONS ***

     CHARACTER YN*1

C    *** LABELED COMMON BLOCKS ***

     COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
    &OH, GA, PROFIT, NHORZ

     COMMON /FBLK/ FLAG

     IF(FLAG(6).EQ.1) GO TO 30

20   WRITE(*,21)
21   FORMAT(/,
    &/,' ENTER THE LABOR RATE FOR HUMAN LABOR.  THE VALUE          ',
    &/,' SHOULD BE ENTERED AS A DOLLAR AMOUNT.  DO NOT INCLUDE      ',
    &/,' A "$" SIGN.  IT IS ASSUMED THAT THERE IS ONLY ONE LEVEL    ',
    &/,' OF SKILLED WORKER.  THEREFORE, ANY HUMAN LABOR WILL BE     ',
    &/,' PERFORMED AT THIS DOLLAR/HR RATE.   ',//)

     READ(*,*,ERR=20) LABRT

30   WRITE(*,31) LABRT
31   FORMAT(/,
    &/,' YOU HAVE ENTERED A VALUE OF $',F6.2,' FOR THE LABOR       ',
    &/,' RATE.  DO YOU WISH TO ALTER THIS.  ENTER "Y" FOR YES,     ',
    &/,' "N" FOR NO.',//)

     READ(*,'(A)',ERR=30) YN

     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
     GO TO 30

999  FLAG(6) = 1

     RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE IP7SUB

C    *** REAL VARIABLE DICTIONARY ***

C    FLAG - array containing data entry FLAG
C    OH - OverHead rate (decimal)
C    OHXX - OverHead rate (percentage)

C    *** REAL DECLARATIONS ***

     REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
    &FLAG(21), OHXX

C    *** INTEGER DECLARATIONS ***

     INTEGER DEMAND

C    *** CHARACTER DECLARATIONS ***

     CHARACTER YN*1
```

```
C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      IF(FLAG(7).EQ.1) THEN
        OHXX = OH*100.0
        GO TO 30
      END IF

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE OVERHEAD RATE TO BE APPLIED TO HUMAN LABOR.      ',
     &/,' THE OVERHEAD RATE IS ADDED TO HUMAN LABOR TO ACCOUNT       ',
     &/,' FOR VACATION, SICK LEAVE, OTHER EMPLOYEE BENEFITS, ETC.    ',
     &/,' NOTE: AN OVERHEAD RATE OF SIXTY FIVE AND ONE HALF PERCENT  ',
     &/,' SHOULD BE ENTERED AS 65.5                                   ',
     &//)

      READ(*,*,ERR=20) OHXX

30    WRITE(*,31) OHXX
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF ',F6.2,'
     &/,' RATE.  DO YOU WISH TO ALTER THIS.  ENTER "Y" FOR YES,      ',
     &/,' "N" FOR NO.',//)

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   OH = OHXX / 100.0

      FLAG(7) = 1

      RETURN
      END

C    +++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE IP8SUB

C    *** REAL VARIABLE DICTIONARY ***

C    FLAG - array containing data entry FLAG
C    GA - General and Administrative rate (decimal)
C    GAXX - General and Administrative rate (percentage)

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21), GAXX

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND

C    *** CHARACTER DECLARATIONS ***
```

```
      CHARACTER YN*1

C     *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      IF(FLAG(8).EQ.1) THEN
       GAXX = GA*100.0
       GO TO 30
      END IF

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE GENERAL AND ADMINISTRATIVE RATE TO BE USED.         ',
     &/,' THE GENERAL AND ADMINISTRATIVE RATE IS ADDED TO               ',
     &/,' ACCOUNT FOR SUPERVISORY AND ADMINISTRATIVE PERSONNEL.         ',
     &/,' NOTE: A GENERAL AND ADMINISTRATIVE RATE OF FIFTEEN AND        ',
     &/,' AND A QUARTER PERCENT SHOULD BE ENTERED AS 15.25 ',//)

      READ(*,*,ERR=20) GAXX

30    WRITE(*,31) GAXX
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF ',F6.2,' FOR THE GENERAL
     &/,' AND ADMINISTRATIVE RATE.  DO YOU WISH TO ALTER THIS.         ',
     &/,' ENTER "Y" FOR YES, "N" FOR NO.',//)

      READ(*,'(A)',ERR=30) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   GA = GAXX / 100.0

      FLAG(8) = 1

      RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE IP9SUB

C     *** REAL VARIABLE DICTIONARY ***

C     FLAG - array containing data entry FLAG
C     PROFIT - PROFIT rate (decimal)
C     PRXX - PRofit rate (percentage)

C     *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21), PRXX

C     *** INTEGER DECLARATIONS ***

      INTEGER DEMAND
```

```
C    *** CHARACTER DECLARATIONS ***

     CHARACTER YN*1

C    *** LABELED COMMON BLOCKS ***

     COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
    &OH, GA, PROFIT, NHORZ

     COMMON /FBLK/ FLAG

     IF(FLAG(9).EQ.1) THEN
       PRXX = PROFIT*100.0
       GO TO 30
     END IF

20   WRITE(*,21)
21   FORMAT(/,
    &/,' ENTER THE PROFIT RATE TO BE USED.                    ',
    &/,' NOTE: A PROFIT RATE OF TEN AND ONE HALF PERCENT SHOULD     ',
    &/,' BE ENTERED AS 10.5 ',//)

     READ(*,*,ERR=20) PRXX

30   WRITE(*,31) PRXX
31   FORMAT(/,
    &/,' YOU HAVE ENTERED A VALUE OF ',F6.2,'
    &/,' RATE.  DO YOU WISH TO ALTER THIS.  ENTER "Y" FOR YES,     ',
    &/,' "N" FOR NO.',//)

     READ(*,'(A)',ERR=30) YN

     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
     GO TO 30

999  PROFIT = PRXX / 100.0

     FLAG(9) = 1

     RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE DP1SUB

C    *** REAL VARIABLE DICTIONARY ***

C    DCOST - array containing Design COST
C    DP1P1 - design Depend. Para. 1, eq. Para. 1 - slope of line
C    DP1P2 - design Depend. Para. 1, eq. Para. 2 - y intercept
C    DP1X - array containing LOP values - x axis
C    DP1Y - array containing resulting design cost values - y axis
C    FLAG - array containing data entry FLAG

C    *** REAL DECLARATIONS ***

     REAL BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
    &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, FLAG(21),
    &DP1X(21), DP1Y(21), RC1, SC1, IC1, FCST,
    &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
    &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
```

```
      &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
      &DP12P1, DP12P2

C     *** INTEGER DECLARATIONS ***

      INTEGER NN1, N1, M1

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C     *** LABELED COMMON BLOCKS ***

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
      &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
      &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
      &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

C     CHECK TO SEE IF THIS DESIGN DEPENDENT PARAMENTER HAS PREVIOUSLY
C     BEEN ENTERED IF SO PRESENT THE VALUES

      IF(FLAG(10).EQ.1) GO TO 140

C     THE FIRST TIME THROUGH PRESENT THE USER WITH FULL EXPLANATION
C     INPUT REQUIREMENTS

50    WRITE(*,51)
51    FORMAT(/,
      &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER,       ',
      &/,' DESIGN COST.  IN THE PPEM PROGRAM DESIGN COST IS         ',
      &/,' RELATED TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.    ')
60    WRITE(*,61)
61    FORMAT(/,
      &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH ',
      &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE ',
      &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE      ',
      &/,' PARAMETERS OF THE EQUATION.                          ')
70    WRITE(*,71)
71    FORMAT(/,
      &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
      &/,' DEPENDENT PARAMETER (DESIGN COST) IS A STRAIGHT LINE.    ',
      &/,' THE GENERAL FORM OF THE EQUATION IS y = (m*x)+b       ',
      &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:          ',
      &/,' m - THE SLOPE OF THE LINE                          ',
      &/,' b - THE y-INTERCEPT (DESIGN COST OF THE BASE-LINE PRODUCT) ')
100   WRITE(*,101)
101   FORMAT(/,
      &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C

C     PROMPT THE USER FOR INPUT

120   WRITE(*,121)
121   FORMAT(/,
      &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH ITS   ',
      &/,' SLOPE.  (SEPERATED BY A COMMA.)                   ',
      &/,' (e.g.,  45000, 15000 )                         ',//)
```

```
130  READ(*,*,ERR=120) DP1P2, DP1P1

C    PRINT INPUT DATA

140  WRITE(*,141) DP1P2, DP1P1
141  FORMAT(/,
    &/,' YOU HAVE ENTERED FOR THE y-INTETCEPT (DESIGN COST OF   ',
    &/,' BASE-LINE PRODUCT) A VAULE OF $',F9.2,' AND A VALUE    ',
    &/,' OF ',F8.2,' FOR THE SLOPE OF THE FUNCTION.  ',//)

C    THE USER MAY CHANGE THE INPUT DATA

150  WRITE(*,151)
151  FORMAT(/,
    &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
    &/,' "N" FOR NO.      ',//)

C    IF THE USER WISHES TO MAKE A CHANGE PROMPT THE USER FOR NEW INPUT

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

C    ONCE INPUT DATA IS APPROVED CALCULATE THE VALUES FROM THE
C    EQUATION RELATING THE DESIGN DEPENDENT PARAMETER TO THE LEVELS OF
C    PRODUCIBILITY

160  DO 170 I = 1,21
     DP1X(I) = FLOAT(I-1)*.1
     DP1Y(I) = (DP1P1*DP1X(I)) + DP1P2
170  CONTINUE

C    THE THREE DESIGN DEPENDENT PARAMETER VALUES TO BE USED (FOR LEVELS
C    OF PRODUCIBILITY 1,2 AND 3) COME FROM THE EQUATION FOR X = 0,1,2

     DCOST(1) = DP1Y(1)
     DCOST(2) = DP1Y(11)
     DCOST(3) = DP1Y(21)

C    THE USER MAY VIEW A GRAPH OF THE EQUATION DEFINED FOR THE DESIGN
C    DEPENDENT PARAMETER AND THE RESULTING VALUES FOR THE PRODUCT'S
C    THREE LEVELS OF PRODUCIBILITY

180  WRITE(*,181)
181  FORMAT(/,
    &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
    &/,' FOR THE DESIGN DEPENDENT PARAMETER (DESIGN COST) AND      ',
    &/,' THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS OF   ',
    &/,' PRODUCIBILITY.  ENTER "Y" FOR YES, "N" FOR NO.     ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = '            DESIGN COST            '

C    SUBROUTINE PLOT GRAPHS THE DEFINED EQUATION

     CALL PLOT(DP1X,DP1Y,DCOST,NAME)
```

```
C    INDICATE THAT VALUES FOR THIS DESIGN DEPENDENT PARAMETER
C    HAVE BEEN ENTERED

998  FLAG(10) = 1

C    RETURN TO THE PPEM DESIGN DEPENDENT PARAMETER MENU SCREEN

999  RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE DP2SUB

C    *** REAL VARIABLE DICTIONARY ***

C    DLH1 - array containing Direct Lahor Hours required (1st unit)
C    DP2P1 - design Depend. Para. 2, eq. Para. 1 - decay rate
C    DP2P2 - design Depend. Para. 2, eq. Para. 2 - maximum value
C    DP2X - array containing LOP values - x axis
C    DP2Y - array containing resulting direct lab. hours - y axis
C    FLAG - array containing data entry FLAG

C    *** REAL DECLARATIONS ***

     REAL DLH1(3), PHI(3), DP2X(21), DP2Y(21), FLAG(21),
    &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
    &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
    &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
    &DP12P1, DP12P2

C    *** CHARACTER DECLARATIONS ***

     CHARACTER YN*1, C*1, NAME*40

C    *** LABELED COMMON BLOCKS ***

     COMMON /CBLK/ DLH1, PHI

     COMMON /FBLK/ FLAG

     COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
    &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
    &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

     IF(FLAG(11).EQ.1) GO TO 140

50   WRITE(*,51)
51   FORMAT(/,
    &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, THE    ',
    &/,' NUMBER OF DIRECT LABOR HOURS REQUIRED TO PRODUCT THE      ',
    &/,' FIRST UNIT.  IN THE PPEM PROGRAM THE NUMBER OF DIRECT     ',
    &/,' LABOR HOURS (1ST UNIT) IS RELATED TO THE PRODUCT''S       ',
    &/,' LEVEL OF PRODUCTIBILITY.   ')
60   WRITE(*,61)
61   FORMAT(/,
    &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH ',
    &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE ',
    &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
    &/,' PARAMETERS OF THE EQUATION.                               ')
70   WRITE(*,71)
71   FORMAT(/,
    &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
```

```
     &/,' DEPENDENT PARAMETER (DIRECT LABOR HOURS (1ST UNIT)) IS      ',
     &/,' THE DECAY FUNCTION.                                 ',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = c(e(-r*x))       ',
     &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:           ',
     &/,' c - THE MAXIMUM VALUE OF THE FUNCTION (y-INTERCEPT).      ',
     &/,' r - THE DECAY RATE.                                  ')
100  WRITE(*,101)
101  FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

     READ(*,'(A)',ERR=120) C

120  WRITE(*,121)
121  FORMAT(/,
     &/,' ENTER THE MAXIMUM VALUE OF THE FUNCTION ALONG WITH ITS ',
     &/,' DECAY RATE.  (SEPERATED BY A COMMA.)                 ',
     &/,' (e.g.,  25.50, .90 )                    ',//)

130  READ(*,*,ERR=120) DP2P2, DP2P1

140  WRITE(*,141) DP2P2, DP2P1
141  FORMAT(/,
     &/,' YOU HAVE ENTERED FOR THE MAXIMUM VALUE OF THE FUNCTION   ',
     &/,' A VALUE OF ',F6.2,' HOURS AND VALUE OF ',F5.2,' FOR THE  ',
     &/,' FUNCTION''S DECAY RATE.                        ',//)

150  WRITE(*,151)
151  FORMAT(/,
     &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
     &/,' "N" FOR NO.      ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP2X(I) = FLOAT(I-1)*.1
     DP2Y(I) = (DP2P2*(EXP(-(DP2P1*DP2X(I)))))
170  CONTINUE

     DLH1(1) = DP2Y(1)
     DLH1(2) = DP2Y(11)
     DLH1(3) = DP2Y(21)

180  WRITE(*,181)
181  FORMAT(/,
     &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
     &/,' FOR THE DESIGN DEPENDENT PARAMETER (DIRECT LABOR HOURS    ',
     &/,' REQUIED TO PRODUCT THE FIRST UNIT) AND THE RESULTING      ',
     &/,' VALUES FOR THE PRODUCT''S THREE LEVELS OF PRODUCIBILITY. ',
     &/,' ENTER "Y" FOR YES, "N" FOR NO.    ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = '      DIRECT LABOR HOURS (1ST UNIT)      '

     CALL PLOT(DP2X,DP2Y,DLH1,NAME)

998  FLAG(11) = 1
```

```
999  RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE DP3SUB

C    *** REAL VARIABLE DICTIONARY ***

C    DP3P1 - design Depend. Para. 3, eq. Para. 1 - growth rate
C    DP3P2 - design Depend. Para. 3, eq. Para. 2 - max. value added
C    DP3P3 - design Depend. Para. 3, eq. Para. 3 - y intercept
C    DP3X - array containing LOP values - x axis
C    DP3Y - array containing resulting machine hrs. - y axis
C    FLAG - array containing data entry FLAG
C    MACHR - array containing MAChine HouRs required

C    *** REAL DECLARATIONS ***

     REAL MACHR(3), DIRMAT(3), FLAG(21), DP3X(21), DP3Y(21),
    &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
    &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
    &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
    &DP12P1, DP12P2, AECEC(3)

C    *** CHARACTER DECLARATIONS ***

     CHARACTER YN*1, C*1, NAME*40

C    *** LABELED COMMON BLOCKS ***

     COMMON /BBLK/ MACHR, DIRMAT, AECEC

     COMMON /FBLK/ FLAG

     COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
    &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
    &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

     IF(FLAG(12).EQ.1) GO TO 140

50   WRITE(*,51)
51   FORMAT(/,
    &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, NUMBER ',
    &/,' OF MACHINE HOURS REQUIRED.  IN THE PPEM PROGRAM THE       ',
    &/,' NUMBER OF MACHINE HOURS REQUIRED TO PRODUCE A PRODUCT IS  ',
    &/,' RELATED TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.    ')
60   WRITE(*,61)
61   FORMAT(/,
    &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH  ',
    &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE  ',
    &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
    &/,' PARAMETERS OF THE EQUATION.                               ')
70   WRITE(*,71)
71   FORMAT(/,
    &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
    &/,' DEPENDENT PARAMETER (MACHINE HOURS) IS A GROWTH FUNCTION. ',
    &/,' THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*x))+b   ',
    &/,' FOR THIS RELATIONSHIP THE THREE PARAMETERS ARE:          ',
    &/,' c - THE MAXIMUM VALUE ADDED TO b,                        ',
    &/,' r - THE GROWTH RATE,                      ',
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```
      &/,' b - THE y-INTERCEPT.                              ')
100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C

120   WRITE(*,121)
121   FORMAT(/,
     &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE    ',
     &/,' MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)',
     &/,' (e.g.,  15.50, 12.00, 1.45 )                  ',//)

130   READ(*,*,ERR=120) DP3P3, DP3P2, DP3P1

140   WRITE(*,141) DP3P3, DP3P2, DP3P1
141   FORMAT(/,
     &/,' YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION      ',
     &/,' A VALUE OF ',F6.2,' HOURS, ',F6.2,' HOURS FOR THE MAXIMUM ',
     &/,' VALUE ADDED, AND ',F5.2,' FOR THE GROWTH RATE.    ',//)

150   WRITE(*,151)
151   FORMAT(/,
     &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
     &/,' "N" FOR NO.     ',//)

      READ(*,'(A)',ERR=150) YN
      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
      GO TO 140

160   DO 170 I = 1,21
      DP3X(I) = FLOAT(I-1)*.1
      DP3Y(I) = (DP3P2*(1-(EXP(-DP3P1*DP3X(I)))))+DP3P3
170   CONTINUE

      MACHR(1) = DP3Y(1)
      MACHR(2) = DP3Y(11)
      MACHR(3) = DP3Y(21)

180   WRITE(*,181)
181   FORMAT(/,
     &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
     &/,' FOR THE DESIGN DEPENDENT PARAMETER (MACHINE HOURS) AND    ',
     &/,' THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS OF   ',
     &/,' PRODUCIBILITY.  ENTER "Y" FOR YES, "N" FOR NO.    ',//)

      READ(*,'(A)',ERR=180) YN
      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
      GO TO 180

200   NAME = '    NUMBER OF MACHINE HOURS REQUIRED    '

      CALL PLOT(DP3X,DP3Y,MACHR,NAME)

998   FLAG(12) = 1

999   RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++++++
```

```
      SUBROUTINE DP4SUB

C     *** REAL VARIABLE DICTIONARY ***

C     AECEC - array containing Annual Equivalent Capital Equip. Cost
C     DP4P1 - design Depend. Para. 4, eq. Para. 1 - growth rate
C     DP4P2 - design Depend. Para. 4, eq. Para. 2 - max. value added
C     DP4P3 - design Depend. Para. 4, eq. Para. 3 - y intercept
C     DP4X - array containing LOP values - x axis
C     DP4Y - array containing resulting AECEC values - y axis
C     FLAG - array containing data entry FLAG

C     *** REAL DECLARATIONS ***

      REAL MACHR(3), DIRMAT(3), FLAG(21), DP4X(21), DP4Y(21),
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2, AECEC(3)

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C     *** LABELED COMMON BLOCKS ***

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(13).EQ.1) GO TO 140

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, ANNUAL ',
     &/,' EQUIV. CAPITAL EQUIP. COST.  IN THE PPEM PROGRAM THE      ',
     &/,' ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST FOR A PRODUCT IS ',
     &/,' RELATED TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.    ')
60    WRITE(*,61)
61    FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH  ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE  ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
     &/,' PARAMETERS OF THE EQUATION.                    ')
70    WRITE(*,71)
71    FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN    ',
     &/,' DEPENDENT PARAMETER (MACHINE HOURS) IS A GROWTH FUNCTION.  ',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*x))+b   ',
     &/,' FOR THIS RELATIONSHIP THE THREE PARAMETERS ARE:          ',
     &/,' c - THE MAXIMUM VALUE ADDED TO b,                  ',
     &/,' r - THE GROWTH RATE,                         ',
     &/,' b - THE y-INTERCEPT.                     ')
100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C
```

```
120  WRITE(*,121)
121  FORMAT(/,
   &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE    ',
   &/,' MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)',
   &/,' (e.g.,  0.00, 45000, 1.45 )                         ',//)

130  READ(*,*,ERR=120) DP4P3, DP4P2, DP4P1

140  WRITE(*,141) DP4P3, DP4P2, DP4P1
141  FORMAT(/,
   &/,' YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION      ',
   &/,' A VALUE OF $',F9.2,', $',F9.2,' FOR THE MAXIMUM          ',
   &/,' VALUE ADDED, AND ',F5.2,' FOR THE GROWTH RATE.     ',//)

150  WRITE(*,151)
151  FORMAT(/,
   &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
   &/,' "N" FOR NO.     ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP4X(I) = FLOAT(I-1)*.1
     DP4Y(I) = (DP4P2*(1-(EXP(-DP4P1*DP4X(I)))))+DP4P3
170  CONTINUE

     AECEC(1) = DP4Y(1)
     AECEC(2) = DP4Y(11)
     AECEC(3) = DP4Y(21)

180  WRITE(*,181)
181  FORMAT(/,
   &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED ',
   &/,' FOR THE DESIGN DEPENDENT PARAMETER (ANNUAL EQUIV. CAPITAL  ',
   &/,' EQUIPMENT COST) AND THE RESULTING VALUES FOR THE PRODUCT''S',
   &/,' THREE LEVELS OF PRODUCIBILITY.  ENTER "Y" FOR YES,         ',
   &/,' "N" FOR NO.    ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = 'ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST'

     CALL PLOT(DP4X,DP4Y,AECEC,NAME)

998  FLAG(13) = 1

999  RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE DP5SUB

C    *** REAL VARIABLE DICTIONARY ***

C    DP5P1 - design Depend. Para. 5, eq. Para. 1 - growth rate
C    DP5P2 - design Depend. Para. 5, eq. Para. 2 - max. value added
```

```
C     DP5P3 - design Depend. Para. 5, eq. Para. 3 - y intercept
C     DP5X - array containing LOP values - x axis
C     DP5Y - array containing resulting machine rate - y axis
C     FLAG - array containing data entry FLAG
C     MACHRT - array containing MACHine RaTe

C     *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &FLAG(21), DP5X(21), DP5Y(21),
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2

C     *** INTEGER DECLARATIONS ***

      INTEGER DEMAND

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C     *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(14).EQ.1) GO TO 140

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, THE    ',
     &/,' HOURLY RATE FOR MACHINE TIME.  IN THE PPEM PROGRAM THE    ',
     &/,' THE HOURLY RATE FOR MACHINE TIME IS RELATED TO THE        ',
     &/,' PRODUCT''S LEVEL OF PRODUCIBILITY. ')
60    WRITE(*,61)
61    FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH  ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE  ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
     &/,' PARAMETERS OF THE EQUATION.                               ')
70    WRITE(*,71)
71    FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
     &/,' DEPENDENT PARAMETER (HOURLY RATE FOR MACHINE TIME) IS THE ',
     &/,' GROWTH FUNCTION.                                          ',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*x))+b    ',
     &/,' FOR THIS RELATIONSHIP THE THREE PARAMETERS ARE:           ',
     &/,' c - THE MAXIMUM VALUE ADDED TO b,                         ',
     &/,' r - THE GROWTH RATE,                                      ',
     &/,' b - THE y-INTERCEPT.                                      ')
100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C
```

```
120  WRITE(*,121)
121  FORMAT(/,
    &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE    ',
    &/,' MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)',
    &/,' (e.g., 35.50, 40.00, 1.45 )                  ',//)

130  READ(*,*,ERR=120) DP5P3, DP5P2, DP5P1

140  WRITE(*,141) DP5P3, DP5P2, DP5P1
141  FORMAT(/,
    &/,' YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION      ',
    &/,' A VALUE OF $',F6.2,', $',F6.2,' FOR THE MAXIMUM VALUE     ',
    &/,' ADDED, AND ',F5.2,' FOR THE GROWTH RATE.          ',//)

150  WRITE(*,151)
151  FORMAT(/,
    &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
    &/,' "N" FOR NO.    ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP5X(I) = FLOAT(I-1)*.1
     DP5Y(I) = (DP5P2*(1-(EXP(-DP5P1*DP5X(I)))))+DP5P3
170  CONTINUE

     MACHRT(1) = DP5Y(1)
     MACHRT(2) = DP5Y(11)
     MACHRT(3) = DP5Y(21)

180  WRITE(*,181)
181  FORMAT(/,
    &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
    &/,' FOR THE DESIGN DEPENDENT PARAMETER (HOURLY RATE FOR      ',
    &/,' MACHINE TIME) AND THE RESULTING VALUES FOR THE PRODUCT''S ',
    &/,' THREE LEVELS OF PRODUCIBILITY.  ENTER "Y" FOR YES,       ',
    &/,' "N" FOR NO.   ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = '     HOURLY RATE FOR MACHINE TIME      '

     CALL PLOT(DP5X,DP5Y,MACHRT,NAME)

998  FLAG(14) = 1

999  RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE DP6SUB

C    *** REAL VARIABLE DICTIONARY ***
```

```
C    DIRMAT - array containing DIRect MATerial cost
C    DP6P1 - design Depend. Para. 6, eq. Para. 1 - decay rate
C    DP6P2 - design Depend. Para. 6, eq. Para. 2 - maximum value
C    DP6X - array containing LOP values - x axis
C    DP6Y - array containing resulting direct material cost - y axis
C    FLAG - array containing data entry FLAG

C    *** REAL DECLARATIONS ***

      REAL MACHR(3), DIRMAT(3), FLAG(21), DP6X(21), DP6Y(21),
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2, AECEC(3)

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C    *** LABELED COMMON BLOCKS ***

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(15).EQ.1) GO TO 140

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, THE   ',
     &/,' DIRECT MATERIAL COST FOR AN UNIT.  IN THE PPEM PROGRAM   ',
     &/,' THE DIRECT MATERIAL IS IS RELATED TO THE PRODUCT''S      ',
     &/,' LEVEL OF PRODUCTIBILITY.   ')
60    WRITE(*,61)
61    FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE      ',
     &/,' PARAMETERS OF THE EQUATION.                         ')
70    WRITE(*,71)
71    FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
     &/,' DEPENDENT PARAMETER (DIRECT MATERIAL COST) IS THE         ',
     &/,' DECAY FUNCTION.                                 ',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = c(e(-r*x))       ',
     &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:            ',
     &/,' c - THE MAXIMUM VALUE OF THE FUNCTION (y-INTERCEPT),      ',
     &/,' r - THE DECAY RATE.                              ')
100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C

120   WRITE(*,121)
121   FORMAT(/,
     &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH ITS     ',
     &/,' DECAY RATE.  (SEPERATED BY A COMMA.)                 ',
     &/,' (e.g.,  75.50, .40 )                        ',//)
```

```
130  READ(*,*,ERR=120) DP6P2, DP6P1

140  WRITE(*,141) DP6P2, DP6P1
141  FORMAT(/,
    &/,' YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION      ',
    &/,' A VALUE OF $',F8.2,' AND A VALUE OF ',F5.2,' FOR THE      ',
    &/,' FUNCTION''S DECAY RATE.                              ',//)

150  WRITE(*,151)
151  FORMAT(/,
    &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
    &/,' "N" FOR NO.      ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP6X(I) = FLOAT(I-1)*.1
     DP6Y(I) = (DP6P2*(EXP(-(DP6P1*DP6X(I)))))
170  CONTINUE

     DIRMAT(1) = DP6Y(1)
     DIRMAT(2) = DP6Y(11)
     DIRMAT(3) = DP6Y(21)

180  WRITE(*,181)
181  FORMAT(/,
    &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
    &/,' FOR THE DESIGN DEPENDENT PARAMETER (DIRECT MATERIAL COST) ',
    &/,' AND THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS  ',
    &/,' OF PRODUCIBILITY.  ENTER "Y" FOR YES, "N" FOR NO.  ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = '         DIRECT MATERIAL COST          '

     CALL PLOT(DP6X,DP6Y,DIRMAT,NAME)

998  FLAG(15) = 1

999  RETURN
     END

C    + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +

     SUBROUTINE DP7SUB

C    *** REAL VARIABLE DICTIONARY ***

C    DP7P1 - design Depend. Para. 7, eq. Para. 1 - growth rate
C    DP7P2 - design Depend. Para. 7, eq. Para. 2 - max. value added
C    DP7P3 - design Depend. Para. 7, eq. Para. 3 - y intercept
C    DP7X - array containing LOP values - x axis
C    DP7Y - array containing resulting PHI values - y axis
C    FLAG - array containing data entry FLAG
C    PHI - array containing maufacturing progress fn. slope para. (PHI)
```

```
C    *** REAL DECLARATIONS ***

      REAL DLH1(3), PHI(3), FLAG(21), DP7X(21), DP7Y(21),
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C    *** LABELED COMMON BLOCKS ***

      COMMON /CBLK/ DLH1, PHI

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(16).EQ.1) GO TO 140

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, SLOPE  ',
     &/,' PARAMETER OF MANUFACTURING PROGRESS FUNCTION.  IN THE     ',
     &/,' PPEM PROGRAM THE SLOPE PARAMETER OF THE MPF. IS RELATED   ',
     &/,' TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.   ')
60    WRITE(*,61)
61    FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH  ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE  ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
     &/,' PARAMETERS OF THE EQUATION.                               ')
70    WRITE(*,71)
71    FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
     &/,' DEPENDENT PARAMETER (SLOPE PARAMETER) IS A GROWTH FUNCTION.',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = c(1-e(-r*t))+b    ',
     &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:             ',
     &/,' c - THE MAXIMUM VALUE ADDED TO b,                         ',
     &/,' r - THE GROWTH RATE,                                      ',
     &/,' b - THE y-INTERCEPT.                                      ')
100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C

120   WRITE(*,121)
121   FORMAT(/,
     &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH THE     ',
     &/,' MAXIMUM VALUE ADDED AND GROWTH RATE (SEPERATED BY COMMAS.)',
     &/,' (e.g.,  .75, .20. 1.55 )              ',//)

130   READ(*,*,ERR=120) DP7P3, DP7P2, DP7P1

140   WRITE(*,141) DP7P3, DP7P2, DP7P1
141   FORMAT(/,
     &/,' YOU HAVE ENTERED FOR THE y-INTERCEPT OF THE FUNCTION      ',
     &/,' A VALUE OF ',F6.2,',' ,F6.2,' FOR THE MAXIMUM VALUE       ',
```

```
     &/,' ADDED, AND ',F5.2,' FOR THE GROWTH RATE.          ',//)

150  WRITE(*,151)
151  FORMAT(/,
     &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
     &/,' "N" FOR NO.     ',//)

      READ(*,'(A)',ERR=150) YN
      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
      GO TO 140

160  DO 170 I = 1,21
      DP7X(I) = FLOAT(I-1)*.1
      DP7Y(I) = (DP7P2*(1-(EXP(-DP7P1*DP7X(I)))))+DP7P3
170  CONTINUE

      PHI(1) = DP7Y(1)
      PHI(2) = DP7Y(11)
      PHI(3) = DP7Y(21)

C    CHECK TO SEE IF ANY NONPOSTIVE VALUES OF PHI HAVE BEEN INPUT
C    THIS WOULD CAUSE AN EXECUTION ERROR

      IF(PHI(1).LT.0.OR.PHI(2).LT.0.OR.PHI(3).LT.0) THEN
       WRITE(*,175)
175    FORMAT(/,
     & /,'              !!!!! WARNING !!!!!           ',
     & /,
     & /,' AN NONPOSTIVE VALUE FOR THE SLOPE PARAMETER OF THE     ',
     & /,' MANUFACTURING PROGRESS FUNCTION HAS BEEN COMPUTED.     ',
     & /,' AN EXECUTION ERROR WOULD BE THE RESULT IF USED !!!     ',
     & /,
     & /,'        STRIKE ANY KEY <R> TO CONTINUE.         ',//)

       READ(*,*,ERR=120) C
       GO TO 120
      END IF

180  WRITE(*,181)
181  FORMAT(/,
     &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED ',
     &/,' FOR THE DESIGN DEPENDENT PARAMETER (SLOPE PARAMETER OF MPF) ',
     &/,' AND THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS OF ',
     &/,' PRODUCIBILITY.  ENTER "Y" FOR YES, "N" FOR NO.    ',//)

      READ(*,'(A)',ERR=180) YN
      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
      GO TO 180

200  NAME = '      SLOPE PARAMETER OF M.P.F.        '

      CALL PLOT(DP7X,DP7Y,PHI,NAME)

998  FLAG(16) = 1

999  RETURN
      END

C    ++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE DP8SUB
```

```
C     *** REAL VARIABLE DICTIONARY ***

C     FLAG - array containing data entry FLAG

C     *** INTEGER VARIABLE DICTIONARY ***

C     DAGE - Design life or AGE of the product

C     *** REAL DECLARATIONS ***

      REAL BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &FCST, RC1, SC1, IC1

C     *** INTEGER DECLARATIONS ***

      INTEGER NN1, N1, M1, DAGE

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1

C     *** LABELED COMMON BLOCKS ***

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      IF(FLAG(17).EQ.1) GO TO 30

20    WRITE(*,21)
21    FORMAT(/,
     &/,' ENTER THE DESIGN LIFE OF THE PRODUCT BEING (RE)DESIGNED.   ',
     &/,' IT IS ASSUMED THAT THE PRODUCT, NO MATTER WHICH LEVEL OF   ',
     &/,' PRODUCIBILITY IT IS DESIGNED FOR, WILL BE DESIGNED WITH    ',
     &/,' THIS LIFE (MEASURED IN YEARS) IN MIND.  NOTE: THE NUMBER   ',
     &/,' ENTERED WILL BE READ AS AN INTEGER VALUE.     ',//)

      READ(*,*,ERR=20) DAGE

30    WRITE(*,31) DAGE
31    FORMAT(/,
     &/,' YOU HAVE ENTERED A VALUE OF ',I2,' FOR THE DESIGN LIFE OF  ',
     &/,' THE PRODUCT.  DO YOU WISH TO ALTER THIS.  ENTER "Y" FOR    ',
     &/,' YES, "N" FOR NO.',//)

      READ(*,'(A)') YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 20
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 30

999   FLAG(17) = 1

      RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++++++
```

```
      SUBROUTINE DP9SUB

C     *** REAL VARIABLE DICTIONARY ***

C     BMTBF - array containing Base-line Mean Time Between Failures
C     BMTTR - array containing Base-line Mean Time To Repair
C     FLAG - array containing data entry FLAG

C     *** INTEGER VARIABLE DICTIONARY ***

C     DAGE - Design life or AGE of the product

C     *** REAL DECLARATIONS ***

      REAL BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &FCST, RC1, IC1, SC1

C     *** INTEGER DECLARATIONS ***

      INTEGER NN1, N1, M1, DAGE

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1

C     *** LABELED COMMON BLOCKS ***

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

C     THE DESIGN LIFE OF THE PRODUCT MUST HAVE BEEN ENTERED BEFORE
C     THE MTBF AND MTTR PROFILES CAN BE ENTERED

      IF(DAGE.EQ.0) THEN
20      WRITE(*,21)
21      FORMAT(//,1X,60('*'),/,
     &/,' BEFORE THE MTBF AND MTTR PROFILES FOR THE BASE-LINE PRODUCT',
     &/,' CAN BE ENTERED, THE DESIGN LIFE OF THE PRODUCT MUST BE     ',
     &/,' DEFINED.                                                    ',
     &/,'                                                             ',
     &/,'            STRIKE ANY KEY <R> TO CONTINUE',//,1X,60('*'),//)

        READ(*,'(A)',ERR=999) C

C     RETURN TO PPEM DESIGN DEPENDENT PARAMETER MENU SCREEN

        GO TO 999
      END IF

C     CHECK TO SEE IF MTBF AND MTTR VALUES WERE PREVIOUSLY ENTERED
C     IF SO PRESENT THE VALUES

      IF(FLAG(18).EQ.1) GO TO 80

30    WRITE(*,31)
31    FORMAT(/,
     &/,' ENTER THE MEAN TIME BETWEEN FAILURE (MTBF) AND MEAN TIME TO',
     &/,' REAPAIR (MTTR) PROFILE FOR THE BASE-LINE PRODUCT.  YOU WILL',
```

```
     &/,' BE PROMPTED FOR THE MTBF AND MTTR VALUES OF THE PRODUCT    ',
     &/,' BY AGE COHORT.  FOR EACH YEAR ENTER THE TWO VALUES SEPERATED',
     &/,' BY A COMMA.  (e.g., 1.234, .234 )  NOTE: THESE VALUES ARE ',
     &/,' MEASURED IN YEARS.  ',//)

C    FOR EACH AGE COHORT PROMPT THE USER FOR INPUT

      DO 70 I = 1,DAGE
      IA = I - 1
      IB = I

60    WRITE(*,61) IA, IB
61    FORMAT(/,' ENTER THE MTBF AND MTTR FOR',
     &' AGE COHORT ',I2,' - ',I2,' YEARS',/)

      READ(*,*,ERR=60) BMTBF(I), BMTTR(I)
70    CONTINUE

C    PRINT A TABLE OF THE MTBF AND MTTR VALUES

80    WRITE(*,81)
81    FORMAT(/,
     &/,' YOU HAVE ENTERED THE FOLLOWING MTBF AND MTTR PROFILE FOR',
     &/,' THE PRODUCT.',//)

90    WRITE(*,91)
91    FORMAT(5X,12('*'),5X,6('*'),5X,6('*'),
     &/,5X,' AGE COHORT ',5X,' MTBF ',5X,' MTTR ',
     &/,5X,12('*'),5X,6('*'),5X,6('*'),/)

      DO 140 I = 1,DAGE
      IA = I - 1
      IB = I

      WRITE(*,130) IA, IB, BMTBF(I), BMTTR(I)
130   FORMAT(8X,I2,' - ',I2,7X,F6.3,5X,F6.3,/)
140   CONTINUE

C    THE USER MAY CHANGE THE VALUES ENTERED FOR ANY YEAR

150   WRITE(*,151)
151   FORMAT(/,
     &/,' DO YOU WISH TO CHANGE THE MTBF OR MTTR FOR ANY GIVEN ',
     &/,' AGE COHORT.  ENTER "Y" FOR YES, "N" FOR NO.',//)

      READ(*,'(A)',ERR=150) YN
      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 160
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
      GO TO 150

160   WRITE(*,161)
161   FORMAT(/,
     &/,' ENTER THE YEAR TO WHICH THE CHANGE APPLIES FOLLOWED BY THE',
     &/,' NEW MTBF AND MTTR VALUES (SEPERATED BY COMMAS).          ',
     &/,' (e.g., 5, 1.234, .234 )  NOTE: THE YEAR NUMBER 5 REFERS TO',
     &/,' AGE COHORT 4 - 5. ',//)

      READ(*,*,ERR=160) I, BMTBF(I), BMTTR(I)

C    CHECK TO SEE IF THE YEAR TO WHICH THE CHANGE IS TO APPLY FALLS
C    WITHIN THE PREVIOUSLY DEFINED DESIGN LIFE OF THE PRODUCT
```

```
      IF(I.GT.DAGE) THEN
170     WRITE(*,171)
171     FORMAT(//,1X,60('*'),/,
     &/,' THE YEAR TO WHICH THIS CHANGE APPLIES IS GREATER THAN THE   ',
     &/,' PRESENT VALUE ENTERED FOR THE DESIGN LIFE OF THE PRODUCT.   ',
     &/,'                                                             ',
     &/,'             STRIKE ANY KEY <R> TO CONTINUE',//,1X,60('*'),//)

        READ(*,'(A)',ERR=80) C
        GO TO 80

      END IF

C     IF THE REQUESTED CHANGE WAS VALID PRESENT THE REVISED TABLE
C     OF MTBF AND MTTR VALUES

      GO TO 80

C     INDICATE THAT VALUES FOR THIS DESIGN DEPENDENT PARAMETER
C     HAVE BEEN ENTERED

998   FLAG(18) = 1

C     RETURN TO PPEM DESIGN DEPENDENT PARAMETER MENU SCREEN

999   RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE DP10SB

C     *** REAL VARIABLE DICTIONARY ***

C     BMTBF - array containing Base-line Mean Time Between Failure
C     BMTTR - array containing Base-line Mean Time To Repair
C     DP10P1 - design Depend. Para. 10, eq. Para. 1 - growth rate
C     DP10P2 - design Depend. Para. 10, eq. Para. 2 - max. value added
C     DP10X - array containing LOP values - x axis
C     DP10Y - array containing resulting MTBFM values - y axis
C     FLAG - array containing data entry FLAG
C     MTBFM - array containing Mean Time Between Failure Multiplier

C     *** INTEGER VARIABLE DICTIONARY ***

C     DAGE - Design life or AGE of the product

C     *** REAL DECLARATIONS ***

      REAL BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &DP10X(21), DP10Y(21), RC1, SC1, IC1, FCST,
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2

C     *** INTEGER DECLARATIONS ***

      INTEGER NN1, N1, M1, DAGE

C     *** CHARACTER DECLARATIONS ***
```

```
      CHARACTER YN*1, C*1, NAME*40

C     *** LABELED COMMON BLOCKS ***

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(19).EQ.1) GO TO 140

C     CHECK TO SEE IF THE DESIGN LIFE OF THE PRODUCT HAS PREVIOUSLY
C     BEEN ENTERED  THIS MUST BE DONE FIRST

      IF(DAGE.EQ.0) THEN
20      WRITE(*,21)
21      FORMAT(//,1X,60('*'),/,
     &/,' BEFORE THE MTBF OR MTTR MULTIPLIERS CAN BE ENTERED, THE    ',
     &/,' DESIGN LIFE OF THE PRODUCT MUST BE DEFINED.                ',
     &/,'                                                            ',
     &/,'           STRIKE ANY KEY <R> TO CONTINUE',//,1X,60('*'),//)

C       RETURN TO PPEM DESIGN DEPENDENT PARAMETER MENU SCREEN

        READ(*,'(A)',ERR=999) C
        GO TO 999

      END IF

C     CHECK TO SEE IF FOR EVERY YEAR OF THE PRODUCT'S DESIGN LIFE
C     MTBF AND MTTR INFORMATION IS AVAILABLE

      DO 40 I = 1, DAGE

      IF(BMTBF(I).EQ.0 .OR. BMTTR(I).EQ.0) THEN
30      WRITE(*,31)
31      FORMAT(//,1X,60('*'),/,
     &/,' BEFORE THE MTBF OR MTTR MULTIPLIERS CAN BE ENTERED, THE    ',
     &/,' MTBF AND MTTR PROFILES OF THE BASE-LINE PRODUCT MUST BE    ',
     &/,' FULLY DEFINED.                                             ',
     &/,'                                                            ',
     &/,'           STRIKE ANY KEY <R> TO CONTINUE',//,1X,60('*'),//)

C       RETURN THE PPEM DESIGN DEPENDENT PARAMETER MENU SCREEN

        READ(*,'(A)',ERR=999) C
        GO TO 999

      END IF

40    CONTINUE

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, MTBF    ',
     &/,' MULTIPLIER.  IN THE PPEM PROGRAM THE MTBF MULTIPLIER IS    ',
```

```
     &/,' RELATED TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.    ')
60   WRITE(*,61)
61   FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH  ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE  ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
     &/,' PARAMETERS OF THE EQUATION.                               ')
70   WRITE(*,71)
71   FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
     &/,' DEPENDENT PARAMETER (MTBF MULTIPLIER) IS A GROWTH FUNCTION.',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = (c(1-(e(-r*x))))+1 ',
     &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:             ',
     &/,' c - THE MAXIMUM VALUE ADDED TO 1,                         ',
     &/,' r - THE GROWTH RATE.                                      ')
100  WRITE(*,101)
101  FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

     READ(*,'(A)',ERR=120) C

120  WRITE(*,121)
121  FORMAT(/,
     &/,' ENTER THE MAXIMUM VALUE ADDED ALONG WITH THE GROWTH    ',
     &/,' RATE OF THE FUNCTION.  (SEPERATED BY A COMMA.)         ',
     &/,' (e.g.,  .09, 1.75 )                       ',//)

130  READ(*,*,ERR=120) DP10P2, DP10P1

140  WRITE(*,141) DP10P2, DP10P1
141  FORMAT(/,
     &/,' YOU HAVE ENTERED FOR THE MAXIMUM VALUE ADDED A         ',
     &/,' VALUE OF ',F4.2,' AND VALUE OF ',F4.2,' FOR THE        ',
     &/,' FUNCTION''S GROWTH RATE.                  ',//)

150  WRITE(*,151)
151  FORMAT(/,
     &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER 'Y' FOR YES, ',
     &/,' 'N' FOR NO.     ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP10X(I) = FLOAT(I-1)*.1
     DP10Y(I) = (DP10P2*(1-(EXP(-(DP10P1*DP10X(I))))))+1
170  CONTINUE

     MTBFM(1) = DP10Y(1)
     MTBFM(2) = DP10Y(11)
     MTBFM(3) = DP10Y(21)

180  WRITE(*,181)
181  FORMAT(/,
     &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
     &/,' FOR THE DESIGN DEPENDENT PARAMETER (MTBF MULTIPLIER) AND  ',
     &/,' THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS OF   ',
     &/,' PRODUCIBILITY.  ENTER 'Y' FOR YES, 'N' FOR NO.    ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
```

```
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
      GO TO 180

200   NAME = '          MTBF MULTIPLIER              '

      CALL PLOT(DP10X,DP10Y,MTBFM,NAME)

998   FLAG(19) = 1

999   RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE DP11SB

C     *** REAL VARIABLE DICTIONARY ***

C     BMTBF - array containing Base-line Mean Time Between Failure
C     BMTTR - array containing Base-line Mean Time To Repair
C     DP11P1 - design Depend. Para. 11, eq. Para. 1 - growth rate
C     DP11P2 - design Depend. Para. 11, eq. Para. 2 - max. value added
C     DP11X - array containing LOP values - x axis
C     DP11Y - array containing resulting MTTRM values - y axis
C     FLAG - array containing data entry FLAG
C     MTTRM - array containing Mean Time To Repair Multiplier

C     *** INTEGER VARIABLE DICTIONARY ***

C     DAGE - Design life or AGE of the product

C     *** REAL DECLARATIONS ***

      REAL BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &DP11X(21), DP11Y(21), RC1, SC1, IC1, FCST,
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2

C     *** INTEGER DECLARATIONS ***

      INTEGER NN1, N1, M1, DAGE

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C     *** LABELED COMMON BLOCKS ***

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(20).EQ.1) GO TO 140
```

```
      IF(DAGE.EQ.0) THEN
20       WRITE(*,21)
21       FORMAT(//,1X,60('*'),/,
     &/,' BEFORE THE MTBF OR MTTR MULTIPLIERS CAN BE ENTERED, THE    ',
     &/,' DESIGN LIFE OF THE PRODUCT MUST BE DEFINED.                ',
     &/,'                                                            ',
     &/,'           STRIKE ANY KEY <R> TO CONTINUE',//,1X,60('*'),//)

         READ(*,'(A)',ERR=999) C
         GO TO 999

      END IF

      DO 40 I = 1, DAGE

      IF(BMTBF(I).EQ.0 .OR. BMTTR(I).EQ.0) THEN
30       WRITE(*,31)
31       FORMAT(//,1X,60('*'),/,
     &/,' BEFORE THE MTBF OR MTTR MULTIPLIERS CAN BE ENTERED, THE    ',
     &/,' MTBF AND MTTR PROFILES OF THE BASE-LINE PRODUCT MUST BE    ',
     &/,' FULLY DEFINED.                                             ',
     &/,'                                                            ',
     &/,'           STRIKE ANY KEY <R> TO CONTINUE',//,1X,60('*'),//)

         READ(*,'(A)',ERR=999) C
         GO TO 999

      END IF

40    CONTINUE

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER, MTTR   ',
     &/,' MULTIPLIER.  IN THE PPEM PROGRAM THE MTTR MULTIPLIER IS   ',
     &/,' RELATED TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.   ')
60    WRITE(*,61)
61    FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH  ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE  ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
     &/,' PARAMETERS OF THE EQUATION.                    ')
70    WRITE(*,71)
71    FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
     &/,' DEPENDENT PARAMETER (MTTR MULTIPLIER) IS A GROWTH FUNCTION.',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = (c(1-(e(-r*x))))+1 ',
     &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:             ',
     &/,' c - THE MAXIMUM VALUE ADDED TO 1,                         ',
     &/,' r - THE GROWTH RATE.                           ')

100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C

120   WRITE(*,121)
121   FORMAT(/,
     &/,' ENTER THE MAXIMUM VALUE ADDED ALONG WITH THE GROWTH     ',
     &/,' RATE OF THE FUNCTION.  (SEPERATED BY A COMMA.)          ',
     &/,' (e.g.,  .05, 1.75 )                          ',//)
```

```
130  READ(*,*,ERR=120) DP11P2, DP11P1

140  WRITE(*,141) DP11P2, DP11P1
141  FORMAT(/,
   &/,' YOU HAVE ENTERED FOR THE MAXIMUM VALUE ADDED A         ',
   &/,' VALUE OF ',F4.2,' AND VALUE OF ',F4.2,' FOR THE        ',
   &/,' FUNCTION''S GROWTH RATE.                          ',//)

150  WRITE(*,151)
151  FORMAT(/,
   &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER "Y" FOR YES, ',
   &/,' "N" FOR NO.     ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP11X(I) = FLOAT(I-1)*.1
     DP11Y(I) = (DP11P2*(1-(EXP(-(DP11P1*DP11X(I))))))+1
170  CONTINUE

     MTTRM(1) = DP11Y(1)
     MTTRM(2) = DP11Y(11)
     MTTRM(3) = DP11Y(21)

180  WRITE(*,181)
181  FORMAT(/,
   &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
   &/,' FOR THE DESIGN DEPENDENT PARAMETER (MTTR MULTIPLIER) AND  ',
   &/,' THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS OF   ',
   &/,' PRODUCIBILITY.  ENTER "Y" FOR YES, "N" FOR NO.     ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = '           MTTR MULTIPLIER            '

     CALL PLOT(DP11X,DP11Y,MTTRM,NAME)

998  FLAG(20) = 1

999  RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE DP12SB

C    *** REAL VARIABLE DICTIONARY ***

C    DP12P1 - design Depend. Para. 12, eq. Para. 1 - slope of line
C    DP12P2 - design Depend. Para. 12, eq. Para. 2 - y intercept
C    DP12X - array containing LOP values - x axis
C    DP12Y - array containing resulting salvage values - y axis
C    FLAG - array containing data entry FLAG
C    SALVAG - array containing SALVAGe value

C    *** REAL DECLARATIONS ***
```

```
      REAL BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, FLAG(21),
     &DP12X(21), DP12Y(21), RC1, SC1, IC1, FCST,
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2

C     *** INTEGER DECLARATIONS ***

      INTEGER NN1, N1, M1

C     *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, NAME*40

C     *** LABELED COMMON BLOCKS ***

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /FBLK/ FLAG

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

      IF(FLAG(21).EQ.1) GO TO 140

50    WRITE(*,51)
51    FORMAT(/,
     &/,' YOU WILL NOW ENTER THE DESIGN DEPENDENT PARAMETER,       ',
     &/,' SALVAGE VALUE.  IN THE PPEM PROGRAM SALVAGE VALUE IS     ',
     &/,' RELATED TO THE PRODUCT''S LEVEL OF PRODUCTIBILITY.    ')
60    WRITE(*,61)
61    FORMAT(/,
     &/,' YOU WILL BE GIVEN THE GENERAL FORM OF THE EQUATION WHICH ',
     &/,' MUST BE USED.  YOU MAY INFLUENCE THE ACTUAL SHAPE OF THE ',
     &/,' RESULTING CURVE BY ASSIGNING SPECIFIC VALUES TO THE       ',
     &/,' PARAMETERS OF THE EQUATION.                               ')
70    WRITE(*,71)
71    FORMAT(/,
     &/,' THE FORM OF THE RELATIONSHIP TO BE USED FOR THIS DESIGN   ',
     &/,' DEPENDENT PARAMETER (SALVAGE VALUE) IS A STRAIGHT LINE.   ',
     &/,' THE GENERAL FORM OF THE EQUATION IS y = (m*x)+b        ',
     &/,' FOR THIS RELATIONSHIP THE TWO PARAMETERS ARE:             ',
     &/,' m - THE SLOPE OF THE LINE                            ',
     &/,' b - THE y-INTERCEPT (SALVAGE VALUE OF THE BASE-LINE PRODUCT)')
100   WRITE(*,101)
101   FORMAT(/,
     &/,' STRIKE ANY KEY <R> TO CONTINUE ',/)

      READ(*,'(A)',ERR=120) C

120   WRITE(*,121)
121   FORMAT(/,
     &/,' ENTER THE y-INTERCEPT OF THE FUNCTION ALONG WITH ITS    ',
     &/,' SLOPE.  (SEPERATED BY A COMMA.)                        ',
     &/,' (i.e.,  500, 0.0 )                         ',//)

130   READ(*,*,ERR=120) DP12P2, DP12P1
```

```
140  WRITE(*,141) DP12P2, DP12P1
141  FORMAT(/,
   &/,' YOU HAVE ENTERED FOR THE y-INTERCEPT 0F THE FUNCTION   ',
   &/,' A VALUE OF $',F9.2,' AND VALUE OF ',F6.3,' FOR THE     ',
   &/,' FUNCTION''S SLOPE.                    ',//)

150  WRITE(*,151)
151  FORMAT(/,
   &/,' DO YOU WISH TO CHANGE EITHER VALUE.  ENTER 'Y' FOR YES, ',
   &/,' 'N' FOR NO.     ',//)

     READ(*,'(A)',ERR=150) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 120
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 160
     GO TO 140

160  DO 170 I = 1,21
     DP12X(I) = FLOAT(I-1)*.1
     DP12Y(I) = (DP12P1*DP12X(I)) + DP12P2
170  CONTINUE

     SALVAG(1) = DP12Y(1)
     SALVAG(2) = DP12Y(11)
     SALVAG(3) = DP12Y(21)

180  WRITE(*,181)
181  FORMAT(/,
   &/,' WOULD YOU CARE TO VIEW A GRAPH OF THE RELATIONSHIP DEFINED',
   &/,' FOR THE DESIGN DEPENDENT PARAMETER (SALVAGE VALUE) AND    ',
   &/,' THE RESULTING VALUES FOR THE PRODUCT''S THREE LEVELS OF   ',
   &/,' PRODUCIBILITY.  ENTER 'Y' FOR YES, 'N' FOR NO.    ',//)

     READ(*,'(A)',ERR=180) YN
     IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 200
     IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 998
     GO TO 180

200  NAME = '           SALVAGE VALUE             '

     CALL PLOT(DP12X,DP12Y,SALVAG,NAME)

998  FLAG(21) = 1

999  RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE PLOT(X,Y,DPLOP,NAME)

C    *** REAL VARIABLE DICTIONARY ***

C    X - array containing x axis values
C    Y - array containing y axis values
C    DPLOP - array containing the 3 design depend. para. values
C    YMIN - the minimum value in the array Y
C    YMAX - the maximum value in the array Y
C    RANGEY - the difference in the mimimum and maximum Y values

C    *** INTEGER VARIABLE DICTIONARY ***

C    STRCOL - the column number to position the star for this line
C    ILOP - a counter for the x axis scale
```

```
C    *** REAL DECLARATIONS ***

     REAL X(21), Y(21), DPLOP(3)

C    *** INTEGER DECLARATIONS ***

     INTEGER STRCOL

C    *** CHARACTER DECLARATIONS ***

     CHARACTER*1 LINE(61), BLANK, STAR, NAME*40, C

     BLANK = ' '
     STAR = '*'

C    CLEAR OUT THE CURRENT LINE

     DO 5 I = 0,60
     LINE(I) = BLANK
5    CONTINUE

C    FIND THE MIMIMUM AND MAXIMUM OF THE ARRAY Y

     YMIN = MIN(Y(1),Y(21))
     YMAX = MAX(Y(1),Y(21))

     RANGEY = YMAX-YMIN

C    IF THE RANGE ON THE Y AXIS IS 0 THIS PLOT ROUTINE WILL NOT WORK

     IF(RANGEY.EQ.0) GO TO 65

C    PRINT THE PLOT TITLE AND THE Y AXIS SCALE

     WRITE(*,10) NAME
10   FORMAT(/,17X,A40)

     WRITE(*,20)(YMIN+(RANGEY/3.0*I), I=0,3)
20   FORMAT(/,3X,F8.2,3(12X,F8.2),/,
    &7X,'+',3(19X,'+'),/,6X,63('*'))

C    PRINT THE X AXIS SCALE AND A * IN THE APPROPRIATE COLUMN

     ILOP = 1

     DO 50 ISTEP = 1,21
     STRCOL = (Y(ISTEP)-YMIN)/RANGEY*60.0
     LINE(STRCOL) = STAR
     IF(((ISTEP-1)/10*10).EQ.(ISTEP-1)) THEN
      WRITE(*,30) ILOP, (LINE(K), K=0,60)
30    FORMAT(' LOP ',I2,61A1,'*')
      ILOP = ILOP + 1
     ELSE
      WRITE(*,40) (LINE(K), K=0,60)
40    FORMAT(6X,'*',61A1,'*')
     END IF

C    CLEAR OUT THE CURRENT LINE

     LINE(STRCOL) = BLANK

50   CONTINUE
```

```
60  WRITE(*,61)
61  FORMAT(6X,63('*'))
    GO TO 70

C   IF THIS WAS A HORIZONTAL LINE GRAPH PRINT A MESSAGE

65  WRITE(*,66) DPLOP(1)
66  FORMAT(/,
   &/,12X,' YOU HAVE DEFINED A STRAIGHT LINE FUNCTION WITH        ',
   &/,12X,' ALL VALUES EQUAL TO ',F10.3,' (i.e., UNIFORM DIST.)',/)

C   PRINT THE DESIGN DEPENDENT PARAMETER VALUES TO BE USED
C   FOR THE THREE LEVELS OF PRODUCIBILITY

70  WRITE(*,71) NAME, DPLOP(1), DPLOP(2), DPLOP(3)
71  FORMAT(/,17X,A40,/,
   &/,'             LEVEL OF PRODUCIBILITY  1 ',4X,F10.2,
   &/,'             LEVEL OF PRODUCIBILITY  2 ',4X,F10.2,
   &/,'             LEVEL OF PRODUCIBILITY  3 ',4X,F10.2)

80  WRITE(*,81)
81  FORMAT(/,
   &'               STRIKE ANY KEY <R> TO CONTINUE ',//)

    READ(*,'(A)',ERR=999) C

999 RETURN
    END

C   ++++++++++++++++++++++++++++++++++++++++++++++

    SUBROUTINE PPEMCL

C   *** REAL VARIABLE DICTIONARY ***

C   AECEC - array containing Annual Equivalent Capital Equipment Cost
C   AVGLAB - array containing optimum AVGerage direct LABor hrs.
C   BMTBF - array containing Base-line Mean Time Between Failure
C   BMTTR - array containing Base-line Mean Time To Repair
C   DCOST - array containing Design COST
C   DIRLAB - average DIRect LAB hours required to product an unit
C   ES1 - maintains current best Expected number of units Short
C   ESSTAR - array containing optimum Expected number of unit Short
C   FACT - array containing FACTorials
C   FCOST - array containing unit First COST
C   FCST - equated specific unit First CoST
C   IC1 - maintains current best Item Cost
C   ICSTAR - array containing optimum Item Cost
C   MTBF - array containing resulting Mean Time Between Failure profil
C   MTBFM - array containing Mean Time Between Failure Multiplier
C   MTTR - array containing resulting Mean Time To Repair profile
C   MTTRM - array containing Mean Time To Repair Multiplier
C   OPT - array containing OPTimum e[aetslcc]
C   PCOST - average Production COST of an unit
C   PSHORT1 - maintains current best Probability of one or more SHORT
C   PSSTAR - array containing optimum Prob. of one or more units Short
C   RC1 - maintains current best Repair facility Cost
C   RCSTAR - array containing optimum Repair facility Cost
C   SALV - equated specific SALVage value
C   SALVAG - array containing SALVAGe value
C   SC1 - maintains current best Shortage penalty Cost
C   SCSTAR - array containing optimum Shortage Cost
```

```
C    SUBOPT - current best e[aetslcc]
C    TCLOW - maintains ann. equiv. Total syst. life cycle Cost (LOWest)
C    TRY - best e[aetslcc] for a given population size

C    *** INTEGER VARIABLE DICTIONARY ***

C    DEMAND - stated DEMAND or need of the system
C    LOP - current Level Of Producibility
C    M1 - maintains current best number of repair facilites
C    MSTAR - array containing optimum number of repair facilities
C    N - current population size
C    N1 - maintains current best number of units (population size)
C    NHORZ - duration of demand
C    NSTAR - array containing optimum number of units (population size)
C    NN1 - maintains current best economic retirement age
C    NNSTAR - array containing optimum economic retirement age

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, MTBF(20), MTTR(20),
     &OPT(3), ESSTAR(3), PSSTAR(3), FCST, ICSTAR(3), SCSTAR(3),
     &RCSTAR(3), RC1, SC1, IC1, AVGLAB(3), MACHR(3), DIRMAT(3), AECEC(3)

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, DAGE, LOP, N, NNSTAR(3), NSTAR(3), MSTAR(3)

C    *** CHARACTER DECLARATIONS ***

      CHARACTER C*1

C    *** DOUBLE PRECISION DECLARATIONS ***

      DOUBLE PRECISION FACT(35)

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     $OH, GA, PROFIT, NHORZ

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM,
     &DCOST, FCOST, FCST, SALVAG, SALV, TCLOW,
     &NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /GBLK/ FACT

      COMMON /HBLK/ NNSTAR, NSTAR, MSTAR, OPT, ESSTAR, PSSTAR,
     &ICSTAR, SCSTAR, RCSTAR, AVGLAB

C    PRE-CALCULATE THE NECESSARY FACTORIALS

      FACT(0) = 1.D+00
      DO 10 I=1,33
      FACT(I) = FACT(I-1)*FLOAT(I)
10    CONTINUE
```

```
      WRITE(*,20)
20    FORMAT(/,
     &/,' ********  SEARCH FOR THE OPTIMUM HAS BEGUN  ********')

C     THE OUTER MOST LOOP STARTS HERE   LOOP ON LOP

      DO 100 LOP = 1,3

C     ASSIGN TCLOW A VERY LARGE NUMBER

      TCLOW = 1E12

c     write(*,21) lop, mtbfm(lop), lop, mttrm(lop)
21    format(/,' mtbfm(',i1,') = ',f5.2,' mttrm(',i1,') = ',f5.2,/)

C     CALCULATE THE RESULTING MTBF AND MTTR FOR THIS LOP

      DO 22 I=1,DAGE
      MTBF(I) = BMTBF(I) * MTBFM(LOP)
      MTTR(I) = BMTTR(I) * MTTRM(LOP)

C     WRITE(*,*) MTBF(I), MTTR(I)

22    CONTINUE

      SALV = SALVAG(LOP)

C     THE SEARCH FOR THE OPTIMUM E[AETSLCC] BEGINS HERE
C     THE LOOP WILL BE ON N (THE NUMBER OF UNITS TO DEPLOY)
C     ASSIGN N THE STATED DEMAND AS AN INITIAL VALUE

      N = DEMAND

C     SUBROUNTINE OPTNN WILL FIND THE BEST VALUE OF NN (THE RETIREMENT
C     AGE OF THE EQUIPMENT) GIVEN N AND RETURN THE CORRESPONDING
C     E[AETSLCC]

      CALL OPTNN(LOP,N,TRY,TRYFC,TRYDL)

25    SUBOPT = TRY
      FCOST(LOP) = TRYFC
      AVGLAB(LOP) = TRYDL

C     INCREMENT N AND FIND THE BEST E[AETSLCC] FOR THIS VALUE OF N

      N = N+1

C     CHECK TO MAKE SURE N IS NOT GREATER THAN 33

      IF(N.GE.34) THEN
30      WRITE(*,31) LOP
31      FORMAT(/,
     & /,'          !!!! WARNING !!!!                ',
     & /,
     & /,' THE NUMBER OF UNITS TO BE PRODUCED AND     ',
     & /,' DEPLOYED HAS REACHED A VALUE OF 33.        ',
     & /,' COMPUTATIONS FOR LEVEL OF PRODUCIBILITY ',I1,
     & /,' WILL STOP AT THIS POINT !!                 ',
     & /,
     & /,'    STRIKE ANY KEY <R> TO CONTINUE   ',//)

        READ(*,'(A)',ERR=100) C
        GO TO 100
```

```
      END IF

      CALL OPTNN(LOP,N,TRY,TRYFC,TRYDL)

c     write(*,48)n,try
48    format(///,3x,'N = ',i2,3x,'TRY = ',f10.2,///)

C     THE SEARCH WILL CONTINUE AS LONG AS THE INCREASE IN N PROVIDES
C     BETTER E[AETSLCC]S

      IF(TRY.LE.SUBOPT) GO TO 25

C     IF IT DOES NOT THE OPTIMUM HAS BEEN FOUND
C     SET THE ARRAYS MAINTAINING THE OPTIMUMS FOR THIS LOP TO THE
C     APPROPRIATE VALUES

50    OPT(LOP) = SUBOPT
      NNSTAR(LOP) = NN1
      NSTAR(LOP) = N1
      MSTAR(LOP) = M1
      ESSTAR(LOP) = ES1
      PSSTAR(LOP) = PSHRT1
      ICSTAR(LOP) = IC1
      SCSTAR(LOP) = SC1
      RCSTAR(LOP) = RC1

C     WRITE(*,75) OPT(LOP)
75    FORMAT(//,'OPTIMUM EXP. ANN. EQIVAL. TOTAL SYS. COST = $',F12.2)
C     write(*,*) NN1,N1,M1,TCLOW
C     write(*,*) LOP,es1, pshrt1

100   CONTINUE

C     WHEN THE OPTIMUMS FOR ALL THREE LOPS HAVE BEEN FOUND RETURN

      RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE OPTNN(LOP,N,TRY,TRYFC,TRYDL)

C     *** REAL VARIABLE DICTIONARY ***

C     MOPT - the best e[aetslcc] for the given pop. size and retire. age
C     TRY - the current best e[aetslcc]

C     *** INTEGER VARIABLE DICTIONARY ***

C     NN - the current retirement age of the product
C     DAGE - the Design life or AGE of the product

C     *** REAL DECLARATIONS ***

      REAL MOPT, MTBF(20), MTTR(20), DCOST(3), AECEC(3), SALVAG(3),
     &MACHRT(3), MACHR(3), DIRMAT(3), BMTBF(20), BMTTR(20), MTBFM(3),
     &MTTRM(3), FCOST(3), FCST, SALV, TCLOW, ES1, PSHRT1, RC1, SC1, IC1

C     *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, DAGE, NHORZ

C     *** LABELED COMMON BLOCKS ***
```

```
      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

C     ASSIGN NN THE VALUE OF THE DESIGN AGE OF THE EQUIPMENT  THIS WILL
C     BE DECREASED TOWARD ZERO  (THIS COULD ALSO BE ACCOMPLISHED BY
C     ASSIGNING AN INTITAL VALUE OF ZERO AND INCREASING TOWARD DAGE)

C     NN = DAGE
      NN = 1

      REPLRT = REAL(N)/REAL(NN)
      NRPLRT = REPLRT
      IF(REPLRT.GT.REAL(NRPLRT)) THEN
       NRPLRT = NRPLRT + 1
      END IF

      NTOTAL = (NHORZ * NRPLRT) + N

C     SUBROUTINE MPF EMPLOYS THE MANUFACTURING PROGRESS FUNCTION TO
C     CALCULATE THE AVERAGE NUMBER OF DIRECT LABOR HOURS ARE REQUIRED
C     GIVEN THE NUMBER OF UNITS N

      CALL MPF(LOP,NTOTAL,DIRLAB)

C     WRITE(*,*) NTOTAL, DIRLAB

C     SUBROUTINE UPC CALCULATES THE UNIT PRODUCTION COST

      CALL UPC(LOP,DIRLAB,PCOST)

C     WRITE(*,*) PCOST

C     ADD TO THE UNIT PRODUCTION COST AN EQUALLY PROPORTIONED AMOUNT OF
C     THE DESIGN COST AND ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST

      FCST = (DCOST(LOP)/NTOTAL) + (AECEC(LOP)/NTOTAL) + PCOST

C     WRITE(*,*) FCST

C     IF THE FIRST COST OF AN UNIT IS LESS THAN THE SALVAGE VALUE PRINT
C     A MESSAGE  AN INFINITE NUMBER OF UNITS WILL BE DEPLOYED

      IF(FCST.LE.SALVAG(LOP)) THEN
10      WRITE(*,11) LOP
11      FORMAT(/,
     & /,'            !!!! WARNING !!!!              ',
     & /,
     & /,' THE SALVAGE VALUE FOR THE PRODUCT DEFINED    ',
     & /,' FOR LEVEL OF PRODUCIBILITY ',I1, 'IS GREATER ',
     & /,' THAN THE DERIVED VALUE FOR ITS FIRST COST.   ',
     & /,' AN EXECUTION ERROR WILL RESULT !!            ',
     & /,
     & /,'     STRIKE ANY KEY <R> TO CONTINUE  ',//)

       READ(*,'(A)',ERR=25) C
```

```
       GO TO 25
      END IF

C     SUBROUTINE OPTM WILL SEARCH FOR THE BEST VALUE OF M (THE NUMBER
C     OF REPAIR CHANNELS) AND RETURN E[AETSLCC] FOR THE GIVEN VALUES OF
C     NN AND N

      CALL OPTM(NN,N,MOPT)

c     write(*,19)n,nn,mopt
19    format(/,15x,'N = ',i2,3x,'NN = ',i2,3x,'MOPT = ',f10.2,//)

20    TRY = MOPT
      TRYFC = FCST
      TRYDL = DIRLAB

C     DECREASE NN AND FIND THE BEST E[AETSLCC] FOR THIS VALUE OF NN
C     AND N

C     NN = NN-1
      NN = NN+1

C     NN SHOULD NOT REACH ZERO

C     IF(NN.LE.0) GO TO 25
      IF(NN.GT.DAGE) GO TO 25

      REPLRT = REAL(N)/REAL(NN)
      NRPLRT = REPLRT
      IF(REPLRT.GT.REAL(NRPLRT)) THEN
       NRPLRT = NRPLRT + 1
      END IF

      NTOTAL = (NHORZ * NRPLRT) + N

      CALL MPF(LOP,NTOTAL,DIRLAB)

      CALL UPC(LOP,DIRLAB,PCOST)

      FCST = (DCOST(LOP)/NTOTAL) + (AECEC(LOP)/NTOTAL) + PCOST

      CALL OPTM(NN,N,MOPT)

c     write(*,23)n,nn,mopt
23    format(/,15x,'N = ',i2,3x,'NN = ',i2,3x,'MOPT = ',f10.2,//)

C     THE SEARCH WILL CONTINUE AS LONG AS THE CHANGE IN NN PROVIDES
C     BETTER E[AETSLCC]S

      IF(MOPT.LE.TRY) GO TO 20

25    RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE OPTM(NN,N,MOPT)

C     *** REAL VARIABLE DICTIONARY ***

C     MOPT - the current best e[aetslcc]
C     TC - the e[aetslcc] for the given M N NN
```

```
C    *** INTEGER VARIABLE DICTIONARY ***

C    M - the current number of repair channels
C    N - the current population size
C    NN - the current retirement age

C    *** REAL DECLARATIONS ***

     REAL MOPT

C    ASSIGN M THE VALUE OF 1

     M = 1

C    SUBROUTINE CALCUL WILL CALCULATE E[AETSLCC] BASED UPON THE STATED
C    DESIGN INDEPENDENT AND DEPENDENT DATA SETS AND THE GIVEN VALUES OF
C    M N AND NN

     CALL CALCUL(NN,N,M,TC)

20   MOPT = TC

C    INCREMENT THE VALUE OF M.

     M = M+1

C    THE VALUE OF M SHOULD NOT EXCEED THE VALUE OF N

     IF(M.GT.N) GO TO 30

     CALL CALCUL(NN,N,M,TC)

c    write(*,23)nn,n,m,tc
23   format(25x,'NN =',i2,3x,'N =',i2,3x,'M =',i2,3x,'TC =',f10.2)

C    THE SEARCH WILL CONTINUE AS LONG AS THE INCREASE IN M PROVIDES
C    BETTER E[AETSLCC]S

     IF(TC.LE.MOPT) GO TO 20

30   RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE CALCUL(NN,N,M,TC)

C    Subroutine CALCUL calculates the E[AETSLCC] for the provided set
C    of design independent and dependent data and the given values of
C    NN, N and M. These calculations follow those set forth in Chapter
C    10 of Procurement and Inventory Analysis, by Banks and Fabrycky.
C    Comments include text equation numbers where possible.

C    *** REAL VARIABLE DICTIONARY ***

C    AEIC - Annual Equivalent Item Cost per unit
C    AERCC - Annual Equivlent Repair Channel Cost per channel
C    B - Book value
C    ES1 - maintains current best Expected number of units Short
C    ES - Expected number of items Short
C    FACT - array containing factorials
C    FCST - equated specific unit First CoST
C    GM - the failure rate divided by the repair rate
```

```
C    IC1 - maintains current best Item Cost
C    IC - annual equivalent Item Cost
C    INT - annual INTerst rate
C    P - array containing Probability of n units short of demand
C    PSHRT1 - maintains current best Prob. of units SHoRT
C    PSHRT - accumulates the Probability of unit SHoRT
C    RC1 - maintains current best Repair facility Cost
C    RC - annual equivalent Repair Cost
C    SALV - equated specific unit SALVage value
C    SC1 - maintains current best Shortage Cost
C    SC - annual Shortage Cost
C    TC - expected [annual equivalent Total system life-cycle Cost]
C    TCLOW - maintains current best e[aeTslcC] (LOWest)
C    XBARF - average MTBF
C    XBARR - average MTTR
C    XF - accumulates the design's MTBF
C    XR - accumulates the design's MTTR

C    *** INTEGER VARIABLE DICTIONARY ***

C    DAGE - Design life or AGE of the product
C    DEMAND - stated DEMAND or need on the system
C    M1 - maintains current best number of repair facilities
C    M - current number of repair facilities
C    N1 - maintains current best population size
C    N - current population size
C    NN1 - maintains current best retirement age
C    NN - current retirement age

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &BMTBF(20), BMTTR(20), MTBFM(3), MTTRM(3), DCOST(3), FCOST(3),
     &SALVAG(3), SALV, TCLOW, ES1, PSHRT1, MTBF(20), MTTR(20), IC,
     &P(35), FCST, RC1, SC1, IC1

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, DAGE, N1, M1, NN1

C    *** DOUBLE PRECISION DECLARATIONS ***

      DOUBLE PRECISION FACT(35), C(35), XX

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     $OH, GA, PROFIT, NHORZ

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /GBLK/ FACT

C    equ. (10.9)

      B = FCST-FLOAT(NN)*((FCST-SALV)/DAGE)

c     write(*,*) b

C    equ. (10.8)
```

```
      AAA = INT*((1.0+INT)**FLOAT(NN))
      BBB = ((1.0+INT)**FLOAT(NN))-1.0
      AEIC = FCST*(AAA/BBB)-B*(INT/BBB)

      IC = AEIC*FLOAT(N)

c     write(*,*) ic

      AERCC = FRFC + ORFC

      RC = AERCC*FLOAT(M)

c     write(*,*) rc

      XF = 0
      XR = 0

      DO 25 I=1,NN
      XF = XF+MTBF(I)
      XR = XR+MTTR(I)
25    CONTINUE

C     equ. (10.10 and 10.11)

      XBARF = XF/FLOAT(NN)
      XBARR = XR/FLOAT(NN)
c     write(*,27) xbarf, xbarr
27    format(/,' xbarf = ',f7.4,' xbarr = ',f7.4)

      GM = XBARR/XBARF

C     PERFORM equ. (10.14)

      DO 50 J=1,M
      C(J) = (FACT(N)/(FACT(N-J)*FACT(J)))*(GM**J)
50    CONTINUE

      DO 75 K=M+1,N

      XX = FLOAT(M)**(K-M)
      C(K) = (FACT(N)/(FACT(N-K)*FACT(M)*XX))*(GM**K)

75    CONTINUE

C     CALCULATE THE SUM OF THE ARRAY C JUST FOUND
C     C(0) = 1.0  THE SUMMATION WILL START AT 1.0

      SUMC = 1.0

      DO 100 II=1,N
      SUMC = SUMC+C(II)
100   CONTINUE

C     equ. (10.13)

      P0 = 1.0/SUMC

C     COMPUTE THE ARRAY P

      DO 125 JJ=1,N
      P(JJ) = P0*C(JJ)
125   CONTINUE
```

```
C   COMPUTE THE PROBABILITY OF UNITS SHORT OF DEMAND

    PSHRT = 0

    DO 130 IJK = 1,DEMAND
    NK = N - DEMAND + IJK
    PSHRT = PSHRT + P(NK)

130  CONTINUE

C   COMPUTE THE EXPECTED NUMBER OF UNITS SHORT OF DEMAND
C   equ. (10.15)

    ES = 0

    DO 150 JK=1,DEMAND
    ES = ES+(JK*P(N-DEMAND+JK))
150  CONTINUE

C   equ. (10.16)

    SC = SHORT*ES

C   equ. (10.1)

    TC = IC+RC+SC

c   write(*,200)n,nn,m,ic,rc,sc,oc,tc
200  format(/,1x,'N =',1x,i2,5x,'NN =',1x,i2,5x,'M =',1x,i2,/,
   &' IC =',f10.2,5x,'RC =',f10.2,5x,'SC =',f10.2,5x,'OC =',f10.2,/,
   &' TC =',f10.2)

    IF(TC.LE.TCLOW) THEN
     TCLOW = TC
     NN1 = NN
     N1 = N
     M1 = M
     ES1 = ES
     PSHRT1 = PSHRT
     IC1 = IC
     RC1 = RC
     SC1 = SC
    END IF

    RETURN
    END

C   +++++++++++++++++++++++++++++++++++++++++++

    SUBROUTINE MPF(LOP,N,DIRLAB)

C   *** REAL VARIABLE DICTIONARY ***

C   DLH1 - array containing Direct Labor Hour (1st unit)
C   PHI - array containing slope parameter (PHI) of mpf
C   DIRLAB - average no. of DIRect LAB hrs.

C   *** INTEGER VARIABLE DICTIONARY ***

C   LOP - Level Of Producibility
C   N - Number of units to be produced
```

```
C    *** REAL DECLARATIONS ***

     REAL DLH1(3), PHI(3), DIRLAB

C    *** INTEGER DECLARATIONS ***

     INTEGER LOP, N

C    *** LABELED COMMON BLOCKS ***

     COMMON /CBLK/ DLH1, PHI

     Z = LOG(PHI(LOP))/LOG(2.0)

     DLHTOT = 0

     DO 50 I = 1,N

     DLH = DLH1(LOP) * (FLOAT(I)**Z)

     DLHTOT = DLHTOT + DLH

50   CONTINUE

     DIRLAB = DLHTOT/FLOAT(N)

     RETURN
     END

C    ++++++++++++++++++++++++++++++++++++++++

     SUBROUTINE UPC(LOP,DIRLAB,PCOST)

C    *** REAL VARIABLE DICTIONARY ***

C    LABRT - direct LABor RaTe
C    MACHRT - array containing MACHine RaTe
C    OH - OverHead rate applied to direct labor cost
C    GA - General and Administrative rate
C    PROFIT - PROFIT rate
C    MACHR - array containing MAChine HouRs required
C    DIRMAT - array containing DIRect MATerial cost
C    DIRLAB - average no. of DIRect LAB hrs.
C    PCOST - unit Production COST
C    AECEC - array containing Annual Equivalent Capital Equip. Cost

C    *** INTEGER VARIABLE DICTIONARY ***

C    LOP - Level Of Producibility

C    *** REAL DECLARATIONS ***

     REAL LABRT, MACHRT(3), OH, GA, PROFIT, MACHR(3), DIRMAT(3),
    &DIRLAB, PCOST, AECEC(3)

C    *** INTEGER DECLARATIONS ***

     INTEGER LOP

C    *** LABELED COMMON BLOCKS ***

     COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT, OH,
    &GA, PROFIT, NHORZ
```

```
      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      DLC = DIRLAB * LABRT

C     WRITE(*,10) DLC, DIRLAB, LABRT
10    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2)

      DMCHC = MACHR(LOP) * MACHRT(LOP)

C     WRITE(*,20) DMCHC, MACHR(LOP), MACHRT(LOP)
20    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2)

      DMATC = DIRMAT(LOP)

C     WRITE(*,30) DMATC
30    FORMAT(/,1X,F8.2)

      TDC = DLC + DMCHC + DMATC

C     WRITE(*,40) TDC, DLC, DMCHC, DMATC
40    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2,4X,F8.2)

      TIC = DLC * OH

C     WRITE(*,50) TIC, DLC, OH
50    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2)

      UC = TDC + TIC

C     WRITE(*,60) UC, TDC, TIC
60    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2)

      SUB = UC * (1.0+GA)

C     WRITE(*,70) SUB, UC, GA
70    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2)

      PCOST = SUB * (1.0+PROFIT)

C     WRITE(*,80) PCOST, SUB, PROFIT
80    FORMAT(/,1X,F8.2,4X,F8.2,4X,F8.2)

      RETURN
      END

C     ++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE OUTP

C     *** REAL VARIABLE DICTIONARY ***


C     AECEC - array containing Annual Equivalent Capital Equipment Cost
C     AVGLAB - array containing AVG. no. of direct LABor hrs. (1st unit)
C     BMTBF - array containing Base-line Mean Time Between Failure
C     BMTTR - array containing Base-line Mean Time To Repair
C     DCOST - array containing Design COST
C     DIRMAT - array containing DIRect MATerial cost
C     DLH1 - array containing Direct Labor Hours (1st unit)
C     ESSTAR - array containing optimum Expected number of unit Short
C     FCOST - array containing unit First COST
C     FCST - equated specific unit First CoST
```

```
C    FRFC - annual equivalent Fixed Repair Facility Cost
C    GA - General and Administrative rate
C    ICSTAR - array containing optimum Item Cost
C    INT - annual INTerest rate
C    LABRT - direct LABor RaTe
C    MACHR - array containing MAChine HouRs required
C    MACHRT - array containing MACHine RaTe
C    MTBF - array containing resulting Mean Time Between Failure profil
C    MTTR - array containing resulting Mean Time To Repair profile
C    OH - OverHead rate
C    OPT - array containing OPTimum e[aetslcc]
C    ORFC - annual equivalent Operating Repair Facility Cost
C    PHI - array containing manuf. progress fn. slope parameter (PHI)
C    PROFIT - PROFIT rate
C    PSHORT1 - maintains current best Probability of one or more SHORT
C    PSSTAR - array containing optimum Prob. of one or more units Short
C    RCSTAR - array containing optimum Repair facility Cost
C    SALVAG - array containing SALVAGe value
C    SCSTAR - array containing optimum Shortage Cost
C    SHORT - SHORTage penalty cost

C    *** INTEGER VARIABLE DICTIONARY ***

C    DAGE - Design life or AGE of the product
C    DEMAND - stated DEMAND or need of the system
C    MSTAR - array containing optimum number of repair facilities
C    NHORZ - duration of demand
C    NSTAR - array containing optimum number of units (population size)
C    NNSTAR - array containing optimum economic retirement age

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &MACHR(3), DIRMAT(3), DLH1(3), PHI(3), BMTBF(20), BMTTR(20),
     &MTBFM(3), MTTRM(3), DCOST(3), SALVAG(3), SALV, TCLOW,
     &ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &FCOST(3), FCST, ICSTAR(3), SCSTAR(3), RCSTAR(3),
     &OPT(3), ESSTAR(3), PSSTAR(3), RC1, SC1, IC1, AVGLAB(3), AECEC(3)

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, NN1, N1, M1, DAGE, NNSTAR(3), NSTAR(3), MSTAR(3),
     &NHORZ

C    *** CHARACTER DECLARATIONS ***

      CHARACTER C*1, PRNTYN*1, YN*1

C    *** DOUBLE PRECISION DECLARATIONS ***

      DOUBLE PRECISION FACT(35)

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /CBLK/ DLH1, PHI

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1
```

```
      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      COMMON /GBLK/ FACT

      COMMON /HBLK/ NNSTAR, NSTAR, MSTAR, OPT, ESSTAR, PSSTAR,
     &ICSTAR, SCSTAR, RCSTAR, AVGLAB

10    WRITE(*,11)
11    FORMAT(/,
     &/,' DO YOU WISH TO USE SCREEN LOCK STATEMENTS INORDER TO STOP ',
     &/,' OUTPUT FLOW AND FACILIATE THE ON SCREEN READING OF THE    ',
     &/,' OUTPUT REPORT ?                                            ',
     &/,' ENTER "Y" FOR YES, "N" FOR NO.            ',//)

      READ(*,'(A)',ERR=10) PRNTYN

      IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') GO TO 12
      IF(PRNTYN.EQ.'N'.OR. PRNTYN.EQ.'n') GO TO 12
      GO TO 10


12    WRITE(*,13)
13    FORMAT(//,1X,60('*'),/,1X,60('*'),
     &/,' **                                                       **',
     &/,' **               PPEM RESULTS SUMMARY                    **',
     &/,' **                                                       **',
     &/,1X,60('*'),/,1X,60('*'))

      WRITE(*,15) OPT(1), OPT(2), OPT(3)
15    FORMAT(//,
     &/,'  E[AETSLCC] LEVEL OF PRODUCIBILITY 1 = $',F9.2,/,
     &/,'  E[AETSLCC] LEVEL OF PRODUCIBILITY 2 = $',F9.2,/,
     &/,'  E[AETSLCC] LEVEL OF PRODUCIBILITY 3 = $',F9.2,
     &//)

      X = MIN(OPT(1),OPT(2),OPT(3))
      DO 17 I =3,1,-1
      IF(X.EQ.OPT(I)) IAA = I
17    CONTINUE

18    WRITE(*,19) IAA
19    FORMAT(//,1X,60('*'),/,1X,60('*'),
     &/,' **                                                       **',
     &/,' **  THE OPTIMAL DESIGN FOR THIS PRODUCT WAS FOUND TO      **',
     &/,' **  EXIST AT A PRODUCIBILITY LEVEL OF ',I1,' (AS DEFINED',
     &'       **',
     &/,' **  BY PPEM).                                            **',
     &/,' **                                                       **',
     &/,1X,60('*'),/,1X,60('*'))

      IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') THEN
191     WRITE(*,192)
192     FORMAT(/,
     &/,'             STRIKE ANY KEY <R> TO CONTINUE        ',//)
        READ(*,'(A)',ERR=999) C
      END IF

20    WRITE(*,21)
21    FORMAT(10(/),1X,60('*'),/,1X,60('*'),
     &/,' **                                                       **',
```

```
&/,' **                 PPEM INPUT SUMMARY                 **',
&/,' **                                               **',
&/,1X,60('*'),/,1X,60('*'))

 XINT = INT * 100.0
 XOH = OH * 100.0
 XGA = GA * 100.0
 XPROFT = PROFIT * 100.0

30  WRITE(*,31) DEMAND, NHORZ, XINT, FRFC, ORFC, SHORT, LABRT,
   &XOH, XGA, XPROFT
31  FORMAT(/,
   &/,'          PPEM DESIGN INDEPENDENT PARAMETERS   ',/,
   &/,
   &/,' DEMAND = ',I2,' UNITS     DURATION OF DEMAND = ',I2,' YEARS',
   &/,
   &/,' ANNUAL INTEREST RATE = ',F5.2,'
   &/,
   &/,' ANNUAL EQUIVALENT FIXED REPAIR FACILITY COST = $',F9.2,
   &/,
   &/,' ANNUAL EQUIVALENT OPERATING REPAIR FACILITY COST = $',F9.2,
   &/,
   &/,' SHORTAGE PENALTY COST = $',F9.2,' HR. LABOR RATE = $',F5.2,
   &/,
   &/,' OVERGHENERRA RBEA DMIN2,RATE = ',F5.2,
   &'       ',/,
   &/,' PRO/)IT RATE = ',F5.2,'


 IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') THEN
35   WRITE(*,36)
36   FORMAT(/,
   &/,'          STRIKE ANY KEY <R> TO CONTINUE        ',//)
  READ(*,'(A)',ERR=38) C
 END IF

38  DO 100 LOP = 1,3

40  WRITE(*,41) LOP
41  FORMAT(1X,60('*'),//,
   &/,'          PPEM DESIGN DEPENDENT PARAMETERS   ',
   &/,
   &/,'             LEVEL OF PRODUCIBILITY ',I1,
   &/,'             -----------------------      ')

50  WRITE(*,51) DCOST(LOP), DAGE, AECEC(LOP), DLH1(LOP), MACHR(LOP),
   &MACHRT(LOP), DIRMAT(LOP), PHI(LOP), MTBFM(LOP), MTTRM(LOP)
51  FORMAT(/,
   &/,' COST OF DESIGN = $',F9.2,'   DESIGN LIFE = ',I2,' YEARS',
   &/,
   &/,' ANNUAL EQUIVALENT CAPITAL EQUIPMENT COST = $',F9.2,
   &/,
   &/,' DIRECT LABOR HOURS REQUIRED (1ST UNIT) = ',F6.2,
   &/,
   &/,' DIRECT MACHINE HOURS REQUIRED = ',F6.2,
   &/,
   &/,' MACHINE HOURLY RATE = $',F6.2,' DIRECT MATERIAL COST = $',
   &F8.2,/,
   &/,' SLOPE PARAMETER (MPF) = ',F3.2,
   &/,
   &/,' MTBF MULTIPLIER = ',F5.2,'  MTTR MULTIPLIER = ',F5.2)
```

```
      IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') THEN
52      WRITE(*,53)
53      FORMAT(/,
     &/,'              STRIKE ANY KEY <R> TO CONTINUE         ',//)
       READ(*,'(A)',ERR=55) C
      END IF

55    WRITE(*,56)
56    FORMAT(/,
     &/,'           RESULTING MTBF AND MTTR PROFILES    ',
     &/,
     &/,'         AGE COHORT       MTBF (YR)    MTTR (YR)',/)

      DO 70 I = 1,DAGE
      IA = I - 1
      IB = I

      MTBF(I) = BMTBF(I) * MTBFM(LOP)
      MTTR(I) = BMTTR(I) * MTTRM(LOP)

60    WRITE(*,61) IA, IB, MTBF(I), MTTR(I)
61    FORMAT(12X,I2,' - ',I2,8X,F6.3,7X,F6.3)

70    CONTINUE

80    WRITE(*,81) SALVAG(LOP)
81    FORMAT(/,' SALVAGE VALUE = $',F8.2,//)

      IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') THEN
90      WRITE(*,91)
91      FORMAT(/,
     &'              STRIKE ANY KEY <R> TO CONTINUE         ',//)
       READ(*,'(A)',ERR=100) C
      END IF

100   CONTINUE

200   WRITE(*,201)
201   FORMAT(/,1X,60('*'),/,1X,60('*'),
     &/,' **                                                      **',
     &/,' **               PPEM OUTPUT SUMMARY                    **',
     &/,' **                                                      **',
     &/,1X,60('*'),/,1X,60('*'))

      DO 299 LOP = 1,3

210   WRITE(*,211) LOP
211   FORMAT(/,
     &/,'               LEVEL OF PRODUCIBILITY ',I1,
     &/,'               -----------------------     ')

220   WRITE(*,221) AVGLAB(LOP), FCOST(LOP), ICSTAR(LOP), RCSTAR(LOP),
     &SCSTAR(LOP), OPT(LOP), ESSTAR(LOP), PSSTAR(LOP)
221   FORMAT(/,
     &/,' AVG. NO. OF DIRECT LABOR HOURS REQUIRED PER UNIT = ',F6.2,
     &/,
     &/,' AVERAGE FIRST COST OF A UNIT = $',F8.2,
     &/,
     &/,' ANNUAL EQUIVALENT UNIT COST                  = $',F9.2,
     &/,' ANNUAL EQUIVALENT REPAIR FACILITY COST       = $',F9.2,
     &/,' ANNUAL EQUIVALENT SHORTAGE COST              = $',F9.2,
     &/,'                                          --------- ',
     &/,' EXPECTED ANNUAL EQUIVALENT TOTAL SYSTEM LCC  = $',F9.2,
```

```
     &//,
     &/,' EXPECTED NUMBER OF UNITS SHORT OF DEMAND = ',F5.2,
     &/,
     &/,' PROBABILITY OF ONE OR MORE UNITS SHORT = ',F5.2)

      IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') THEN
225     WRITE(*,226)
226     FORMAT(/,
     &/,'               STRIKE ANY KEY <R> TO CONTINUE       ',//)
       READ(*,'(A)',ERR=230) C
      END IF

230  WRITE(*,231) NSTAR(LOP), NNSTAR(LOP), MSTAR(LOP)
231  FORMAT(/,
     &/,'               PPEM SYSTEM DESIGN VARIABLES         ',
     &/,
     &/,' NUMBER OF UNITS DEPLOYED = ',I2,
     &/,
     &/,' NUMBER OF REPAIR FACILITIES = ',I2,
     &/,
     &/,' RETIREMENT AGE = ',I2,
     &/)

      IF(PRNTYN.EQ.'Y'.OR. PRNTYN.EQ.'y') THEN
240     WRITE(*,241)
241     FORMAT(/,
     &/,'               STRIKE ANY KEY <R> TO CONTINUE       ',//)
       READ(*,'(A)',ERR=245) C
      END IF

245  IF(LOP.LE.2) THEN
      WRITE(*,250)
250   FORMAT(/,1X,60('*'))
      END IF

299  CONTINUE

500  WRITE(*,501)
501  FORMAT(/,
     &/,' WOULD YOU CARE TO VIEW THE PPEM OUTPUT REPORT   ',
     &/,' AGAIN?  ENTER 'Y' FOR YES, 'N' FOR NO.          ',//)

      READ(*,'(A)',ERR=500) YN

      IF(YN.EQ.'Y'.OR. YN.EQ.'y') GO TO 10
      IF(YN.EQ.'N'.OR. YN.EQ.'n') GO TO 999
      GO TO 500

999  RETURN
      END

C    ++++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE SAVE

C    *** REAL VARIABLE DICTIONARY ***

C    BMTBF - array containing Base-line Mean Time Between Failure
C    BMTTR - array containing Base-line Mean Time To Repair
C    DP#P$ - design Dependent Parameter #, parametic eq. parameter $
C    FLAG - array containing data entry FLAG
C    FRFC - annual equivalent Fixed Repair Facility Cost
C    GA - General and Administrative rate
```

```
C    INT - annual INTerest rate
C    LABRT - direct LABor RaTe
C    MTBF - array containing resulting Mean Time Between Failure profil
C    MTTR - array containing resulting Mean Time To Repair profile
C    OH - OverHead rate
C    ORFC - annual equivalent Operating Repair Facility Cost
C    PROFIT - PROFIT rate
C    SHORT - SHORTage penalty cost

C    *** INTEGER VARIABLE DICTIONARY ***

C    DAGE - Design life or AGE of the product
C    DEMAND - stated DEMAND or need of the system
C    NHORZ - duration of demand

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &MACHR(3), DIRMAT(3), DLH1(3), PHI(3), BMTBF(20), BMTTR(20),
     &MTBFM(3), MTTRM(3), DCOST(3), SALVAG(3), SALV, TCLOW,
     &ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &FCOST(3), FCST, ICSTAR(3), SCSTAR(3), RCSTAR(3),
     &OPT(3), ESSTAR(3), PSSTAR(3), RC1, SC1, IC1,
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2, AVGLAB(3), AECEC(3)

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, NN1, N1, M1, DAGE, NNSTAR(3), NSTAR(3), MSTAR(3),
     &NHORZ

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, FNAME*12

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /CBLK/ DLH1, PHI

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      COMMON /HBLK/ NNSTAR, NSTAR, MSTAR, OPT, ESSTAR, PSSTAR,
     &ICSTAR, SCSTAR, RCSTAR, AVGLAB

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2

50    WRITE(*,51)
51    FORMAT(/,
     &/,' ENTER THE FILENAME(.EXT) TO BE USED.  THE FILENAME MAY    ',
```

```
      &/,' CONSIST OF ONE TO EIGHT CHARACTERS.  THE FILENAME EXTENSION',
      &/,' IF INCLUDED MAY CONSIST OF A PERIOD FOLLOWED BY ONE TO      ',
      &/,' THREE CHARACTERS.  ENTER "Q" TO QUIT WITHOUT SAVING.  ',//)

70    READ(*,'(A)',ERR=50) FNAME
      IF(FNAME.EQ.'Q'.OR. FNAME.EQ.'q') GO TO 999

      OPEN(4,ERR=500,FILE=FNAME,STATUS='NEW')

      WRITE(4,81,ERR=500) DEMAND, INT, FRFC, ORFC, SHORT, LABRT,
      &(MACHRT(I),I=1,3), OH, GA, PROFIT, NHORZ,
      &(MACHR(I),I=1,3),(DIRMAT(I),I=1,3),
      &(DLH1(I),I=1,3),(PHI(I),I=1,3),
      &(BMTBF(I),I=1,10),
      &(BMTBF(I),I=11,20),
      &(BMTTR(I),I=1,10),
      &(BMTTR(I),I=11,20),
      &(MTBFM(I),I=1,3),(MTTRM(I),I=1,3),(DCOST(I),I=1,3),
      &(FCOST(I),I=1,3),(SALVAG(I),I=1,3),
      &DAGE, (AECEC(I),I=1,3),
      &(FLAG(I),I=1,21),
      &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
      &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
      &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2


81    FORMAT(I2,F5.4,F9.2,F9.2,F9.2,F5.2,/,
      &3F6.2,F5.4,F5.4,F5.4,I2,/,
      &3F6.2,3F9.2,/,
      &3F6.2,3F3.2,/,
      &10F5.2,/,
      &10F5.2,/,
      &10F5.2,/,
      &10F5.2,/,
      &3F5.2,3F5.2,3F9.2,/,
      &3F9.2,3F9.2,/,
      &I2,3F9.2,/,
      &21F3.1,/,
      &7F9.2,/,
      &9F9.2,/,
      &8F9.2)

      GO TO 999

500   WRITE(*,501)
501   FORMAT(/,
      &/,'      !!!! I/O ERROR  !!!! ',//,
      &/,' STRIKE ANY KEY <R> TO CONTINUE ',//)

      READ(*,'(A)',ERR=999) C

999   CLOSE(4)
      RETURN
      END

C     +++++++++++++++++++++++++++++++++++++++++++++++

      SUBROUTINE RETRV

C     *** REAL VARIABLE DICTIONARY ***

C     BMTBF - array containing Base-line Mean Time Between Failure
C     BMTTR - array containing Base-line Mean Time To Repair
```

```
C    DP#P$ - design Dependent Parameter #, parametic eq. parameter $
C    FLAG - array containing data entry FLAG
C    FRFC - annual equivalent Fixed Repair Facility Cost
C    GA - General and Administrative rate
C    INT - annual INTerest rate
C    LABRT - direct LABor RaTe
C    MTBF - array containing resulting Mean Time Between Failure profil
C    MTTR - array containing resulting Mean Time To Repair profile
C    OH - OverHead rate
C    ORFC - annual equivalent Operating Repair Facility Cost
C    PROFIT - PROFIT rate
C    SHORT - SHORTage penalty cost

C    *** INTEGER VARIABLE DICTIONARY ***

C    DAGE - Design life or AGE of the product
C    DEMAND - stated DEMAND or need of the system
C    NHORZ - duration of demand

C    *** REAL DECLARATIONS ***

      REAL INT, FRFC, ORFC, SHORT, LABRT, MACHRT(3), OH, GA, PROFIT,
     &MACHR(3), DIRMAT(3), DLH1(3), PHI(3), BMTBF(20), BMTTR(20),
     &MTBFM(3), MTTRM(3), DCOST(3), SALVAG(3), SALV, TCLOW,
     &ES1, PSHRT1, MTBF(20), MTTR(20), FLAG(21),
     &FCOST(3), FCST, ICSTAR(3), SCSTAR(3), RCSTAR(3),
     &OPT(3), ESSTAR(3), PSSTAR(3), RC1, SC1, IC1,
     &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2,
     &DP7P1, DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2,
     &DP12P1, DP12P2, AVGLAB(3), AECEC(3)

C    *** INTEGER DECLARATIONS ***

      INTEGER DEMAND, NN1, N1, M1, DAGE, NNSTAR(3), NSTAR(3), MSTAR(3),
     &NHORZ

C    *** CHARACTER DECLARATIONS ***

      CHARACTER YN*1, C*1, FNAME*12

C    *** LABELED COMMON BLOCKS ***

      COMMON /ABLK/ DEMAND, INT, FRFC, ORFC, SHORT, LABRT, MACHRT,
     &OH, GA, PROFIT, NHORZ

      COMMON /BBLK/ MACHR, DIRMAT, AECEC

      COMMON /CBLK/ DLH1, PHI

      COMMON /DBLK/ BMTBF, BMTTR, MTBFM, MTTRM, DCOST, FCOST, FCST,
     &SALVAG, SALV, TCLOW, NN1, N1, M1, ES1, PSHRT1, RC1, SC1, IC1

      COMMON /EBLK/ DAGE, MTBF, MTTR

      COMMON /FBLK/ FLAG

      COMMON /HBLK/ NNSTAR, NSTAR, MSTAR, OPT, ESSTAR, PSSTAR,
     &ICSTAR, SCSTAR, RCSTAR, AVGLAB

      COMMON /IBLK/ DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
     &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
     &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2
```

```
50   WRITE(*,51)
51   FORMAT(/,
    &/,' ENTER THE FILENAME(.EXT) OF THE FILE TO BE RETRIEVED,     ',
    &/,' OR ENTER 'Q' TO QUIT.  ',//)

70   READ(*,'(A)',ERR=50) FNAME

     IF(FNAME.EQ.'Q'.OR. FNAME.EQ.'q') GO TO 999

     OPEN(4,ERR=400,FILE=FNAME,STATUS='OLD')

     READ(4,81,ERR=500) DEMAND, INT, FRFC, ORFC, SHORT, LABRT,
    &(MACHRT(I),I=1,3), OH, GA, PROFIT, NHORZ,
    &(MACHR(I),I=1,3),(DIRMAT(I),I=1,3),
    &(DLH1(I),I=1,3),(PHI(I),I=1,3),
    &(BMTBF(I),I=1,10),
    &(BMTBF(I),I=11,20),
    &(BMTTR(I),I=1,10),
    &(BMTTR(I),I=11,20),
    &(MTBFM(I),I=1,3),(MTTRM(I),I=1,3),(DCOST(I),I=1,3),
    &(FCOST(I),I=1,3),(SALVAG(I),I=1,3),
    &DAGE, (AECEC(I),I=1,3),
    &(FLAG(I),I=1,21),
    &DP1P1, DP1P2, DP2P1, DP2P2, DP3P1, DP3P2, DP3P3,
    &DP4P1, DP4P2, DP4P3, DP5P1, DP5P2, DP5P3, DP6P1, DP6P2, DP7P1,
    &DP7P2, DP7P3, DP10P1, DP10P2, DP11P1, DP11P2, DP12P1, DP12P2


81   FORMAT(I2,F5.4,F9.2,F9.2,F9.2,F5.2,/,
    &3F6.2,F5.4,F5.4,F5.4,I2,/,
    &3F6.2,3F9.2,/,
    &3F6.2,3F3.2,/,
    &10F5.2,/,
    &10F5.2,/,
    &10F5.2,/,
    &10F5.2,/,
    &3F5.2,3F5.2,3F9.2,/,
    &3F9.2,3F9.2,/,
    &I2,3F9.2,/,
    &21F3.1,/,
    &7F9.2,/,
    &9F9.2,/,
    &8F9.2)

     GO TO 999

400  WRITE(*,401)
401  FORMAT(/,
    &/,'    !!!! I/O ERROR  !!!! ',/,
    &/,'        FILE NOT FOUND      ',/,
    &/,' STRIKE ANY KEY <R> TO CONTINUE ',//)

     READ(*,'(A)',ERR=999) C
     GO TO 999

500  WRITE(*,501)
501  FORMAT(/,
    &/,'    !!!! I/O ERROR  !!!! ',//,
    &/,' STRIKE ANY KEY <R> TO CONTINUE ',//)

     READ(*,'(A)',ERR=999) C
```

```
999  CLOSE(4)
     RETURN
     END
```

VITA

James Loyd Sowder was born in Lynchburg, Virginia where he attended and graduated from Heritage High School.

Mr. Sowder enrolled at Virginia Polytechnic Institute and State University in 1980 and received a Bachelor of Science degree in Industrial Engineering and Operations Research in 1983. While employed with Technology Applications, Inc., in Alexandria, Va., Mr. Sowder attended graduate courses offered at VPI&SU's Northern Virginia Graduate Center within the Systems Engineering department. In the fall of 1986 Mr. Sowder returned to VPI&SU's Blacksburg, Va. campus to complete the requirements of a Master of Science degree in Industrial Engineering and Operations Research.

Mr. Sowder is now employed by TRW in Fairfax, Va.