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FIELD ENGINEERING APPLICATIONS OF EQUIPMENT REPLACEMENT ANALYSIS BY INCREMENTAL DISCOUNTED CASH FLOW RATE OF RETURN

by

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ABSTRACT

A large number of analytical techniques have been developed to determine when industrial equipment should be replaced. However, many corporations which would be interested in these methods have failed to use them for two reasons. First, company personnel have found that the underlying assumptions of various equipment replacement techniques are too restrictive for many applications. Second, all too often equipment replacement algorithms take an excessive amount of time and effort to be used on a periodic basis.

In an attempt to rectify this situation, a computer program, which can be found beginning on page 76 in the appendix, has been written to solve equipment replacement problems by incremental discounted cash flow rate of return. Further, an additional program has been designed to solve equipment replacement problems on any programmable Hewlett-Packard calculator. The listing of the Hewlett-Packard program can be found by contacting the author. The programs have been written to give on-line engineers, plant managers, and interested staff personnel an initial indication whether a machine should be replaced, or if it should be kept for another year.

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CHAPTER 1

AN INTRODUCTION TO EQUIPMENT REPLACEMENT ANALYSIS

Equipment replacement decisions are one of the crucial problems that the management of any mining, manufacturing, or processing company faces. Ultimately, if equipment is not replaced on a timely basis, capital-intensive corporations will face bankruptcy because competitors have invested in machinery with significantly lower production costs. Due to these lower costs, the firms with more efficient equipment replacement policies, in a perfectly competitive market, will undersell organizations that have neglected capital replacement.

Although the initial investment for a new machine may seem prohibitive, managers must be continually aware of the long term benefits of purchasing equipment that has lower operating and maintenance costs. Unfortunately, the management of some industries has failed to replace equipment in an appropriate fashion. For example, many American steel companies have neglected to replace blast furnaces, rolling mills, and other major equipment on a periodic basis; this has led to the present situation in which Japanese steel producers, who have replaced equipment properly, can undersell their United States competitors because of less costly processing technology.

Although company management is continually scanning contemporary market developments for potential investment opportunities, it is odd that equipment replacement decisions are often overlooked. George Terborgh, one of the most respected equipment replacement theorists, has said:[1]

> That American industry, devoted to the ideal of "scientific" management, should have nothing better than these ancient conventions to test the replaceability of its equipment is astonishing to say the least. There is something quite out of character in the continued acceptance and use of such primitive expedients, especially in an area as important as equipment replacement policy. Indeed, when we consider the advanced techniques employed in other areas of business management, we may well wonder if equipment policy is not, in general, the most backward sector of all. We are inclined to think it is.

There are a number of reasons that equipment replacement has been neglected by companies. First, and perhaps most important, equipment replacement has been overlooked because of its intractability. The complexity of equipment replacement is due to the large number of variables that can influence it. Not only are quantities internal to equipment, such as machine operating and maintenance costs, important, but economic factors outside of the machine, such as inflation and general market conditions, drastically influence a replacement decision. Because of the degree of complexity, no one equipment replacement technique is, at all times, valid. Many firms, therefore, have decided to use hunches and guesswork in the replacement of equipment.

As Gentry and Johnson[2] mention:

> Many organizations do not have a formal equipment replacement policy, and some do not even have a standard approach to equipment replacement decisions. This is understandable since a strict economic analysis is dependent upon rather subjective determinations of future operating costs, cash flows and other factors.

Equipment replacement problems are further complicated because accounting techniques have arbitrarily stipulated the service life, or replacement cycle, of particular machines. Using this technique for income tax purposes is perfectly valid; however, equipment should not be replaced because of depreciation techniques enacted by the Internal Revenue Service and used by company tax accountants. In other words, many companies assume that the most profitable operations of their machines are after they have been fully depreciated. In reality, nothing could be further from the truth because the minimum of the total cost curve, as shown in Figure 1, has often been passed after a machine has been fully depreciated.

In addition to replacing equipment on the basis of its depreciation period, many companies and individuals view machine replacement as an exercise in thrift. At first glance, this may seem a plausible consideration; further thought, however, shows a number of inconsistencies. The most glaring of these is that beyond some period of time the repair, operating, and opportunity costs of the old machine are far more expensive than the initial costs of purchasing equipment.

Another fallacious rule of thumb which has developed is the concept of present equipment's profitability level. In other words, managers often claim that present equipment should not be replaced because it is already operating profitably. The answer that must be determine, in this case, is how much operating profitability is limited by unprofitable procedures in equipment operation. For instance, if the present machines' maintenance costs are too high, the long-term profit margin of the firm can be increased if more efficient machines are purchased.

Any equipment replacement analysis must consider the effects of capital budgeting. Two schools of thought exist concerning the relationship of capital budgeting to equipment replacement. The first of these schools is represented by Stermole's comments:[3]

> ..Financial and intangible considerations often get entangled with the economics of the replacement of satisfactory equipment, sometimes resulting in a manager's decisions statement to the effect that it is not economical to replace at this time. What the manager probably means is that from an economic viewpoint the replacement should be

> made now, but because of financial and intangible considerations, the replacement will be deferred.

Stermole's view, which is shared by a number of analysts, is that the economic evaluation of equipment dictates its replacement regardless of capital budgeting constraints, managerial whims, or other economic forces. Although Stermole's opinion must be considered, many individuals feel it is unrealistic.

The second viewpoint is that the capital budget defines the replacement of equipment. In other words, if there is not enough money in the capital budget to buy replacement pumps, for example, the pumps should not be purchased regardless of the results of equipment replacement analysis.

As far as the equipment replacement analyst is concerned, the question of capital budgeting constraints is often a moot point. For instance, a field engineer engaged in an equipment replacement project will determine the economic criteria of buying a new machine. The actual decision to purchase the new machine, however, is a managerial consideration that is beyond the scope of pure equipment replacement techniques.

One of the simplest ways to visualize the trade off of buying a new piece of equipment versus holding on to the original item is by studying the following graph which

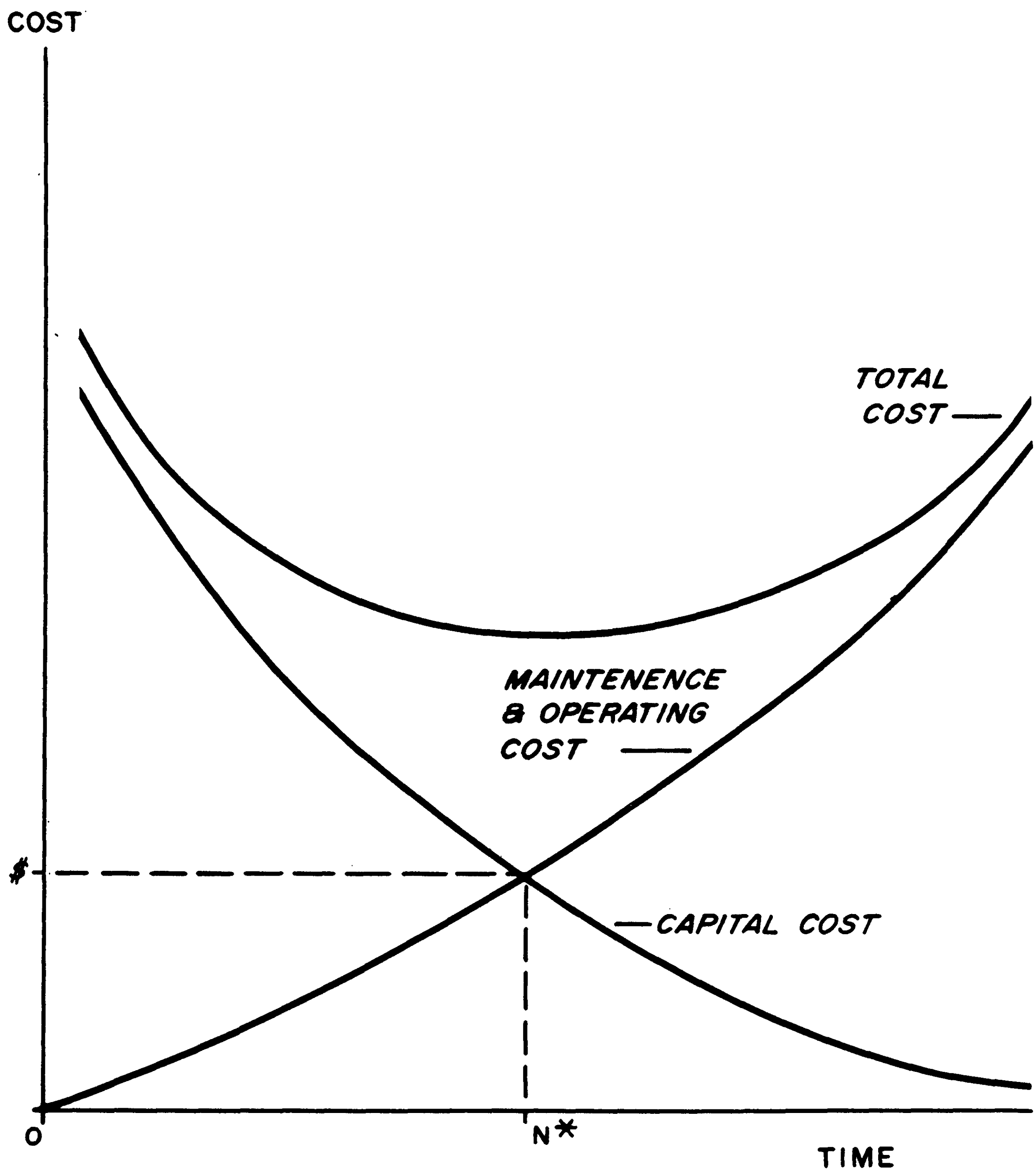


Figure 1. Typical Equipment Cost Curves

shows three curves representing the ultimate cost pattern of nearly any machine.

The graph shows that as the age of a machine increases, its capital cost approaches zero and its maintenance and operating costs increase without bound. The third curve, labeled total cost, is the sum of the capital cost and maintenance and operating cost curves. It can be seen that the optimum time to replace any machine is indicated by n*; in other words, a particular line of equipment should be replaced at the time the slope of its total cost curve changes sign. If equipment is replaced before n*, capital costs are too expensive. If equipment is replaced after n*, maintenance and operating costs are too high.

Although a myriad of techniques have been developed to solve equipment replacement problems, all of them in some way determine the value of n*. Authors have proposed methods from Markov Chains[4] to Dynamic Programming[5]. However, the most basic of these techniques is Minimum Annual Total Cost. The method calculates the average total cost of a machine on a year-by-year basis. The time period that a new machine is purchased is determined by the year in which average total cost is a minimum. This is simply a numerical solution of the three curves presented in Figure 1. Various modifications can be performed on this kind of analysis to account for inflation and uncertainty[6,7].

Replacement analysis by calculating a machine's average minimum cost is simple to perform. All the analyst needs is the expected life of the equipment, its annual operating and maintenance costs, and its initial costs as well as its annual trade-in value. After this information has been found, yearly costs are calculated as shown in Table 1 on the following page.

The calculation of minimum annual cost is not particularly realistic because the equipment replacement analyst is usually more concerned about the savings that can be achieved by the purchase of a new machine. The minimum annual cost method can be modified to account for the comparison of a new machine, often called the challenger, to the existing or incumbent machine which is generally called the defender. By comparing the annual cost of the defender to the annual cost of the challenger over the expected life of the challenger, it can be seen, as shown in Figure 2, that an annual savings is generated by using the challenger. The method of replacing the incumbent or defending equipment by the challenging machine when the average annual savings differential is a maximum between the two is called Classic Equipment Replacement Theory.

Although the costs used in Figure 2 are for an ideal

Year	Purchase Price	Trade-In Value	Replacement Cost	Yearly Operating Expense	Total Operating Expense	Total Expense	Average Cost
1	$20,000	$17,500	$ 2,500	$1,000	$ 1,000	$ 3,500	$3,500.00
2	$20,000	$16,000	$ 4,000	$1,500	$ 2,500	$ 6,800	$3,250.00
3	$20,000	$14,500	$ 5,500	$2,000	$ 4,500	$10,000	$3,333.33
4	$20,000	$10,000	$10,000	$2,750	$ 7,250	$17,250	$4,312.50
5	$20,000	0	$20,000	$5,000	$12,250	$32,250	$6,450.00

Table 1: Example showing the calculation of minimum average annual cost

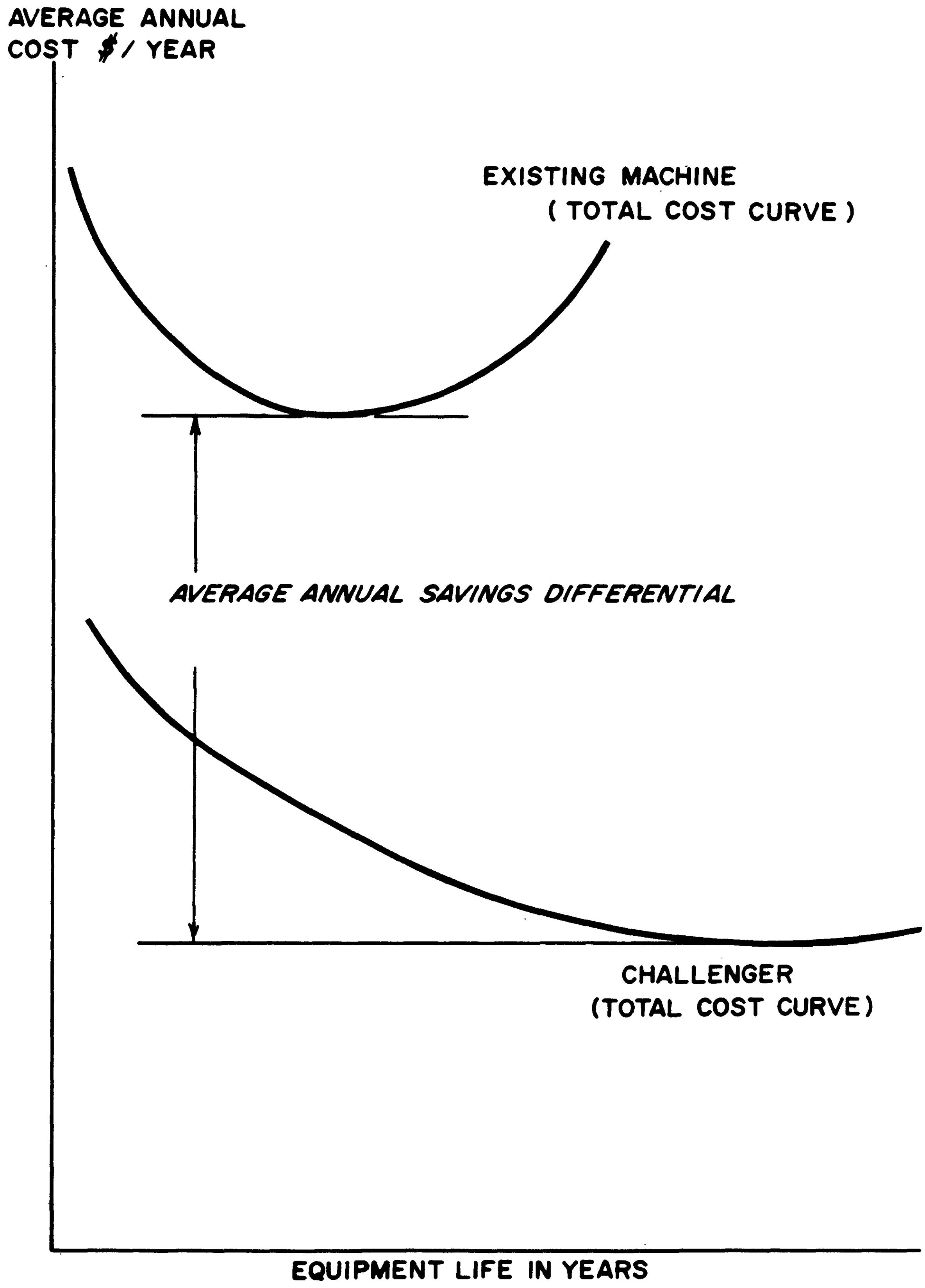


Figure 2. Annual Savings from Using a Challenging Machine

defender-challenger comparison, any time that a challenger presents a lower minimum annual total cost curve than does the defender, it is possible that the challenging machine should replace the defending machine. However, if the equipment replacement analyst only considers the fact that the total annual cost of the challenger is lower than the total annual cost of the defender, the defender may be replaced prematurely. The problem of possible premature defender replacement can best be explained graphically. See Figure 3 on the following page. It can be seen in Figure 3 that the maximum savings is represented by the vertical line labeled "A." If the challenger replaces the defender in year five rather than year six, which is the optimum year for replacement, an annual savings of B is generated. If the replacement of the defender occurs in year 4, a savings of C results and so on. Further observation of Figure 3 shows that any replacement of the defender before year 6 incurs a lower than optimum annual savings.

The problem of premature defender replacement can be further clarified by an example. Table 2 shows the operating maintenance and capital costs of a challenging bulldozer as well as the defending bulldozer.

The arrows indicate the year in which the annual total cost is a minimum. The annual savings are determined by

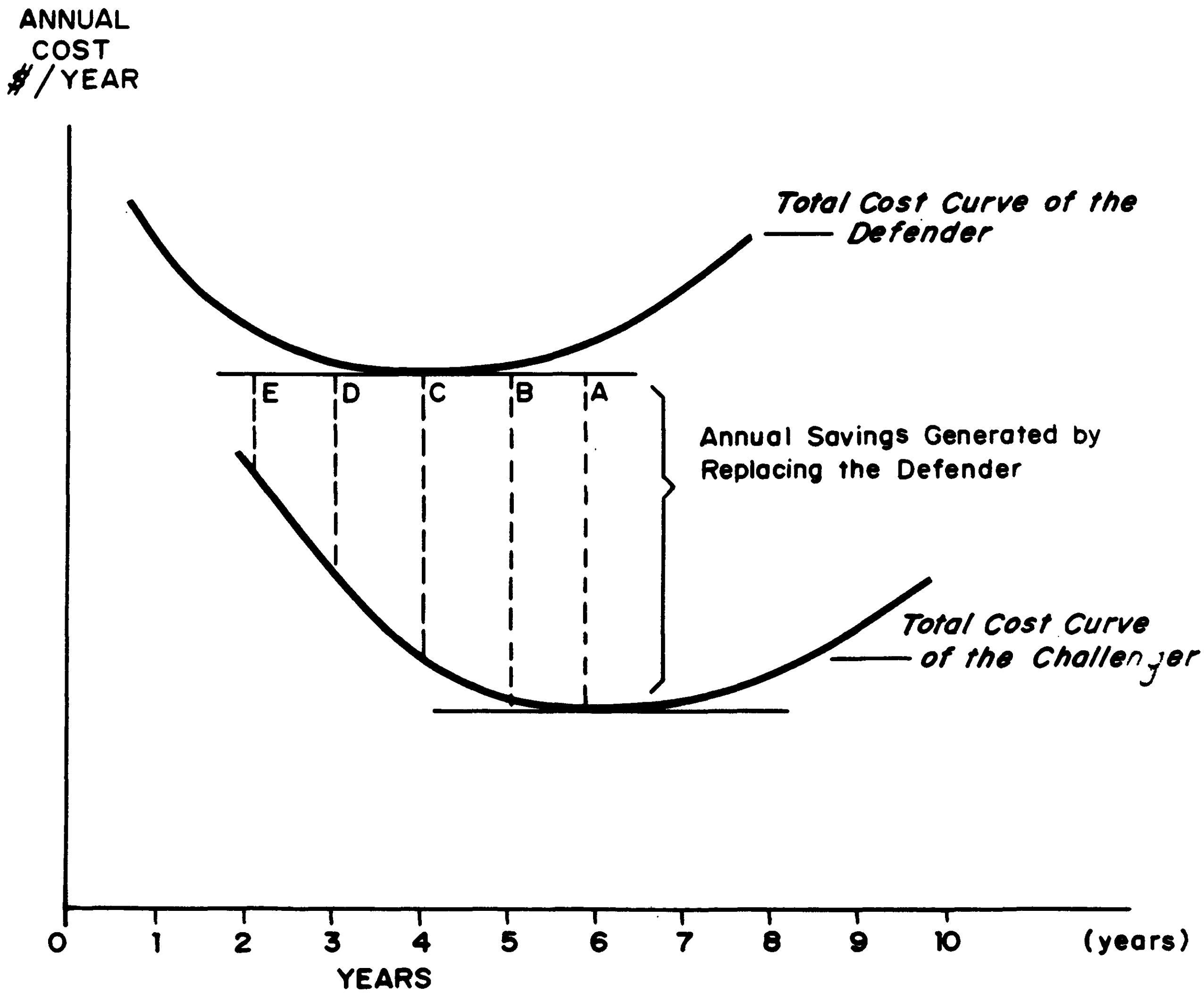


Figure 3. Illustration Showing the Origins of Premature Replacement of a Defending Machine.

Challenger:

Year	Capital Cost	Operating and Maintenance Costs	Annual Total Cost
1	$20,000	$ 5,000	$25,000
2	$15,000	$12,000	$27,000
3	$10,000	$14,000	$24,000
4	$ 5,000	$18,000	$23,000 ←
5	0	$25,000	$25,000

Defender:

Year	Capital Cost	Operating and Maintenance Costs	Annual Total Cost
1	$50,000	$ 7,000	$57,000
2	$40,000	$10,000	$50,000
3	$30,000	$11,000	$41,000
4	$20,000	$12,000	$32,000
5	$10,000	$20,000	$30,000 ←

Table 2: Premature defender replacement by minimum annual total cost

taking the difference between the minimum annual cost of the defender, which is $30,000, from the minimum annual total costs for the challenger as shown below.

Year			Annual Savings
1	$30,000-$25,000	=	$5,000
2	$30,000-$27,000	=	$3,000
3	$30,000-$24,000	=	$6,000
4	$30,000-$23,000	=	$7,000 ←
5	$30,000-$25,000	=	$5,000

It can be seen the maximum annual savings occurs in year 4, and any replacement that occurs before year 4 is premature because the annual savings generated in that year are less than $7,000.

Therefore, the problem with Classic Equipment Replacement Theory is that the annual savings that were originally calculated are based on the assumption that the defender is kept for the entirety of its expected life. If the defender is not kept its expected life, a lesser amount of annual savings will result because of premature equipment replacement. Hence, equipment replacement analysts must be continually aware of the minimization of annual savings by the premature replacement of a defending machine.

In recent years, three new equipment replacement techniques have been developed which attempt to overcome some of the difficulties found in Classic Equipment Replacement Theory. G. A. Rathbun, Jr. in his article "Equipment Replacement Evaluation by Return on Investment"[9] considers equipment replacement as an investment evaluation. His method entails determining the discounted rate of return of various machines from an opportunity cost standpoint of keeping a machine one more year. The methodology that Rathbun presents is ultimately no different than classic equipment replacement theory because most of his calculations are based on a total cost curve as shown in Figure 1.

Another method, the Kennecott Equipment Replacement Guide[10] develops various concepts such as Forecasted Yearly Total Cost Per Unit of Work and Average Total Cost Per Unit of Work to determine the optimum replacement cycle of a machine. However, like the Rathbun method, the Kennecott Equipment Replacement Guide is variation of classic equipment replacement theory because of its basis in the total cost curve of Figure 1.

The equipment replacement technique developed by Gentry and Johnson in their article "An Investment Policy for Equipment Replacement" is one of the most valid and useful methods that have been developed. Their method is based on the Profitability Index, which is the present value of costs divided by the present value of potential benefits, of the existing and challenging machines. The method eliminates the requirements of keeping machines for the entirety of their expected lives, hence eliminating the problem of replacing the defender prematurely, as well as permitting the evaluation of two machines with unequal lives.

The major drawback of the Profitability Index Method is that incomes from the challenger and defender must be determined. This difficulty is due to the fact that it is nearly impossible to associate incomes with a particular piece of processing, manufacturing, or mining equipment. For example, the difficulties that a maintenance manager in an oil refinery faces in determining the incomes associated with an individual charge pump are nearly insurmountable. This is because over a certain time period a number of different feedstocks will pass through the pump. To further complicate the situation, each of these feedstocks will produce varying amounts of income, none of which is exactly known to the maintenance manager.

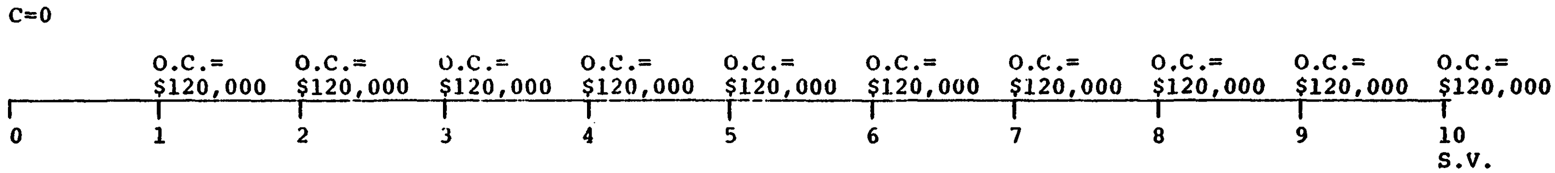
An equipment replacement technique which can circumvent the problems of premature defender replacement, determination of incomes associated with machines, and optimum economic life determination, is the method of incremental discounted cash flow rate of return. The following chapter is devoted to the discussion of the methods, assumptions, and limitations of equipment replacement by incremental discounted cash flow rate of return.

CHAPTER TWO

ANALYSIS AND DISCUSSION OF EQUIPMENT REPLACEMENT BY INCREMENTAL DISCOUNTED CASH FLOW RATE OF RETURN

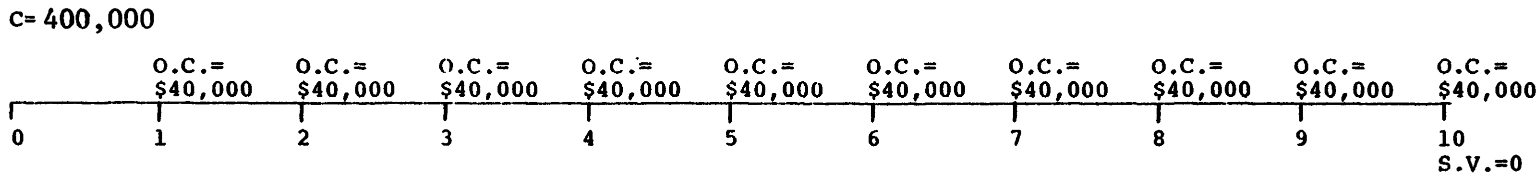
The method of incremental discounted cash flow rate of return, in its most general terms, is the rate of return of the difference between the costs of the defender and the costs of the challenger. Cash flows can be derived from costs because the challenger's costs are not as high as the defender's. The savings that result from the cheaper alternative can be considered cash flows after the appropriate calculations have been performed.

The following example shows how a cash flow can be generated from two projects that only have costs associated with them. In addition, other features of incremental discounted cash flow are discussed. The three time diagrams on the following page give the annual costs of a defending gas compressor, the annual costs of a challenging gas compressor, and the annual difference between these two costs for each of the 10 operating years of the challenging compressor. The first diagram shows the costs of the defending compressor. The second time diagram gives the operating costs of the challenger. The third time diagram, Figure 6,



O.C. = operating cost
C = initial cost
S.V. = salvage value

Figure 4: Time diagram of the defending compressor



O.C. = operating costs
C = initial cost of the challenger
S.V. = salvage value

Figure 5: Time diagram of the challenging compressor

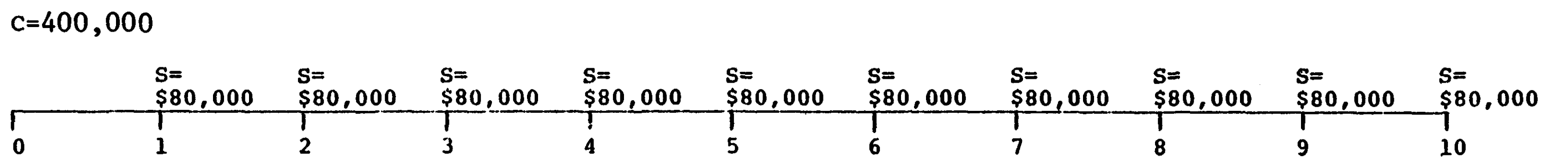


Figure 6: Time diagram showing the savings generated from the challenging compressor.

gives the savings generated by subtracting the challenger's costs from the defender's costs.

The cash flows for each of the 10 operating years is generated on the basis of the $80,000 annual savings as shown as follows for years 1 through 10.

Savings	$80,000
- Depreciation*	60,000
Income before tax	$20,000
- Tax @ 50%	10,000
Income after tax	$10,000
+ Depreciation	60,000
Cash Flow	$70,000

Figure 7: Example of a cash flow calculation using the savings generated from the challenging compressor

The time diagram for the cash flow is generated on the following page.

Figure 8 is the final result of the series of calculations to determine the cash flow of the defender-challenger compressor comparison. It is incremental because the operating costs of the two machines are subtracted from each

*Depreciation is straight line over an operating life of 10 years of $\frac{\$600,000}{10}$ = $60,000/year.

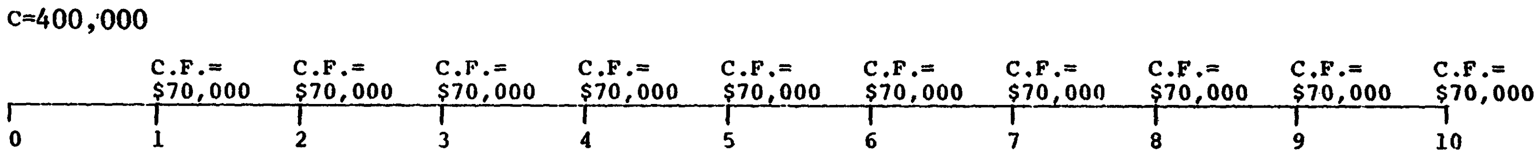


Figure 8: Cash flow time diagram for the defender-challenger compressor comparison

other. The cash flow is generated because the savings are taxed and adjusted with the challenger's annual depreciation. The rate of return is determined by the following equation.

$$400{,}000 = 70{,}000\ (P/A_{i,10})$$

The $P/A_{i,10}$ notation is a kind of discount factors used to represent the present value of an annuity and is a function of interest rate, i, as described by F.J. Stermole in <u>Economic Evaluation and Investment Decision Methods</u>. The \$400,000 is the challenger's capital cost and the \$70,000 is the annual cash flow as previously shown. By replacing the defender with the challenger, a savings is incurred by operating the new machine which is based on the challenger's lower total cost. After the incremental cash flow is calculated from the defender-challenger comparison, the final rate of return is determined, which in this case is approximately 11.5%.

Since any investment evaluation technique is inevitably based on future cash flows, costs that have been incurred in the past have no bearing on the evaluation. All too often, however, equipment replacement practitioners consider sunk costs. As F.J. Stermole mentions, on page 223 of his book Economic Evaluation and Investment Decision Methods:

> Sunk costs must not be considered in evaluating expected future costs of one alternative versus another. Only tax considerations that remain to be realized from sunk costs should have an effect on economic analysis involving sunk costs. This means that actual value should be used in economic analysis rather than book value, whenever actual values can be obtained.

In addition to sunk cost considerations, the defender's trade-in value must be handled correctly. As a case in point, many automobile dealership salesmen offer artificially inflated trade-in values to car buyers to insure that the purchases are made through them. In any economic evaluation, trade-in values must be in real terms and not some figure that has been escalated for sales purposes.

As well as the problems involved with sunk costs and trade-in values, the operating maintenance costs of the defending and challenging machine are often difficult to determine. In fact, with machines that have been recently developed, it is not infrequent that operating and maintenance costs have not been determined until appropriate field tests are implemented.

Statistics can be used to give equipment analysts some idea of the range of a machine's operating and maintenance costs. There are, however, two related difficulties in the use of statistics. First, the field engineer or plant manager that wants to determine if a machine should be replaced rarely has enough time to generate the data needed to run a statistical analysis. Second, even if the data are determined, it is not known what kind of distribution the data should be based on, unless a prohibitive amount of information is gathered. For example, the analyst does not know if the confidence intervals should be based on a normal, log normal, or hypergeometric distribution. Therefore techniques such as Monte Carlo Simulation have to be used sparingly because of the questionability of the probability distribution. Sensitivity analysis, however, can be run on any cost data, and this can be done with the computer program contained in the appendix.

With the exception of test data from equipment manufacturers, the costs used to calculate incremental discounted cash flow rate of return are estimates. This is due to the two sources of cost data which are readily available to the engineer and other interested parties. First, many in-house records exist such as past electric bills, machine fuel costs, and lubrication schedules, all of which can be used to determine the operating costs of a particular machine. Second, maintenance costs can be found from past purchase orders of maintenance items such as bearings, seals, and replacement parts.

After these costs have been found, they can be extrapolated over the expected life of the challenger. In other words, if future costs of the incumbent machine are unknown, they can be estimated by the extrapolation of the present costs of a similar machine. In the same manner, the future costs of the challenger can be estimated by extrapolating the costs of a similar machine.

There are two major problems with the extrapolation approach. First, the rate at which the defender and challenger costs change over the expected life of the challenger is, at best, difficult to estimate. Second, the determination of the challenger's expected life can often lead to problems. The second of these two points will be discussed in the following pages. The first of these, the problem with the rate at which the defender and challenger costs change, can be ameliorated by a number of techniques. For example, if the defending machine is in its fifth operating year, and the equipment replacement analyst wants to compare it to a challenging machine for the next five years, the analyst can estimate the fifth through tenth year costs of the defender by comparing the present machine with the costs of similar machines over an analogous period of time. The same procedure can be performed for the challenger if the challenger's technology hasn't changed significantly. If the challenger's technology has changed, it is unwise to attempt to extrapolate its cost from a similar machine because of the dissimilar technology and hence different operating costs.

One of the easiest ways to determine operating cost of machines with different technologies is through communications with the appropriate equipment manufacturers. For example, if the United Pump Corporation has placed a new pump on the market, the field engineer can determine operating and maintenance cost through discussions with representatives from United Pump. There may be some problems with this procedure if the equipment manufacturer has not run the appropriate field tests on their newly developed equipment. If this is the case, two courses of action may be taken. First, the field engineer can wait until the data from the field tests have been gathered. Second, he or she can estimate costs from another pump that has the same degree of technology.

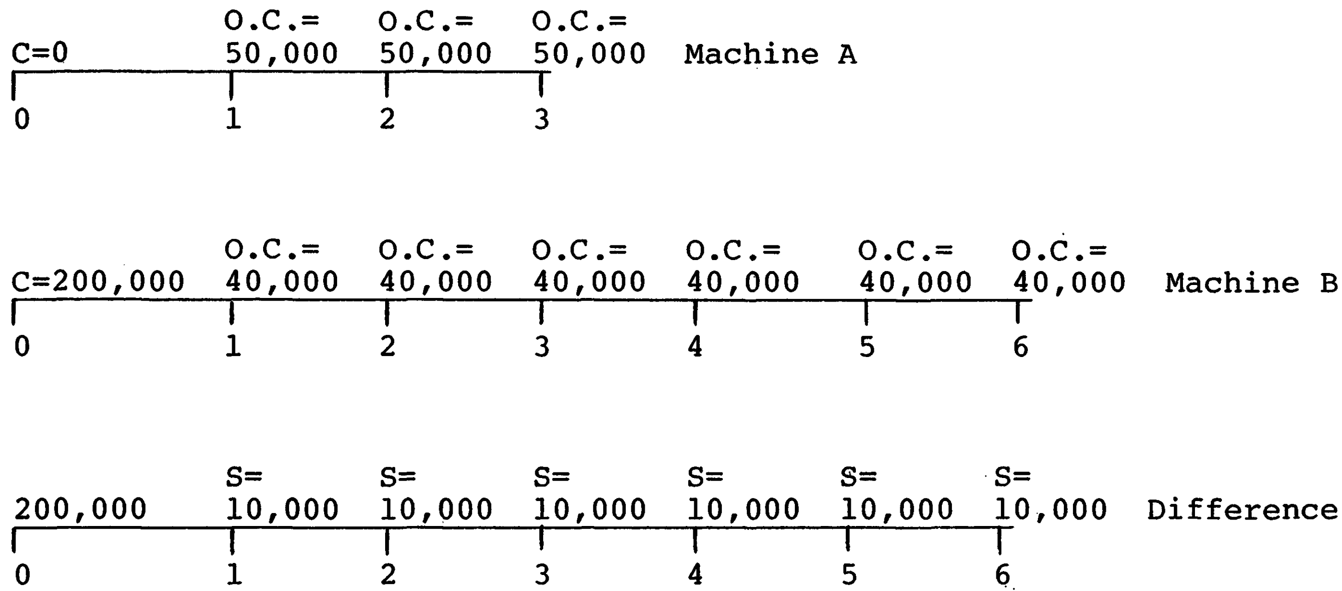
Although a machine's costs can often times be estimated by comparing it to a similar piece of equipment, the operating and maintenance costs of an individual machine may not be representative of its equipment line. The automobile industry is a classic example in which one car, a "lemon," does not give a representative picture of the operating and maintenance costs of other units.

After appropriate cost data have been found, the equipment replacement analyst will follow a sequence of operations to determine the incremental discounted cash flow rate of return of a challenger-defender comparison. Before this is done, however, the expected life of the challenger, the remaining life of the defender, and the length of time of the defender-challenger comparison must be determined. Generally, the expected life of the challenger and the remaining life of the defender are not difficult to ascertain. The length of time of the defender-challenger comparison, however, presents a number of difficulties. This is because there are a large number of variables which influence the comparison period between two projects of unequal length. In other words, if project A has a life of 5 years and project B has a life of 10 years, the study period or comparison period is between 5 and 10 years, but other than the determination of these two limits, it is extremely difficult to determine the value of the study period.

Although a number of problems exist in the calculation of the study period between two machines, methods have been developed to calculate the length of time of the defender-challenger comparison which give reasonably accurate results. There are two ways to determine the study period for two projects of unequal lives. In the first method, the life of the shorter project is extended to coincide with the expected life of the longer lived alternative. In other words, if machine A has a life of 3 years and machine B has a life of 6 years, the project life of machine A is extended to 6 years. This extension is done by extrapolating the maintenance and repair costs of the defender over the remaining time period of the challenger. For example, the time diagrams on the following page show the life of machine A, the life of machine B and the study period of the two machines based on method one.

To determine the savings in the first three years, the operating and maintenance costs of project B is subtracted from those of project B. The savings in years 4, 5, and 6 are found by extrapolating the costs of machine A, which is the defender, for years 4 through 6, and extrapolating these costs from the costs of project B. There are errors induced by the extrapolating of project A's costs; the equipment replacement analyst must realize these errors whenever method one is used.

In the second method, the life of the longer-lived



C = capital cost
O.C. = operating cost
S = savings

Figure 9: Means of extrapolating future costs by method one

machine is contracted to equal the life of the shorter-lived machine. For example, if the machine with the shorter life is expected to operate for 4 years and the challenger has a life of 8 years, the study period in which the two machines is compared is 4 years.

The contraction of the challenger's life is done in the same manner that the expansion of the defender is done. In other words, costs are interpolated over the years where the challenger's life is unequal to the defender's.

Both of these methods present a number of problems because of the difficulty of estimating the costs of the two machines over the calculated study period. For instance, if the operating and maintenance costs of a pick-up truck are known for a span of 3 years, it can become extremely difficult to extrapolate these costs for a period of 6 years. Further, in equipment replacement analysis, it is often unrealistic to use the method of determining the study period by the shortest-lived equipment. This technique would permit an extremely high equipment turnover rate, and most company management would consider this to be uneconomical. Ultimately, the high turnover rate is due to the remaining life of the defender, which is rarely more than two or three years. In fact, if the remaining life of the defender is greater than two or three years, the work involved with equipment replacement analysis is usually uncalled for.

As an example of Method Two, an existing pipeline has a projected remaining life of one year; the challenging pipeline has an expected life of 15 years. Method Two requires that the life of the challenging pipeline be constricted to one year. More importantly, the method requires that the challenger be replaced with a new pipeline at the end of one year.

Method One is much more realistic. When this technique is used, the remaining life of the defending machine is extrapolated to the expected life of the challenger. If the previous example is used, the one year life of the defending pipeline would be extrapolated to the 15 year life of the challenger. In terms of industrial applications, Method One appears to be much more reasonable than Method Two, and it will be the only technique recommended for use in this thesis.

However, the computer program listed in the following appendix is flexible enough so that either of the two methods can be used. This is because the program operator enters the expected life of the challenger to initiate the calculation. If it is desired, the operator can enter the remaining life of the defender, and have the computer calculations based on the defender's life.

Although the problem of unequal lives must be dealt with whenever incremental discounted cash flow rate of return is used, the technique has enough attributes to justify its application for industrial users. With the aid of the enclosed computer program, incremental discounted rate of return, offers a range of calculational flexibility that is unknown to many other equipment replacement methods.

It has been mentioned that the operation of the incremental discounted cash flow rate of return computer program can be done with either the challenger's expected life or the defender's remaining life. The importance of this kind of flexibility is that the potential to vary the defender-challenger study period gives the equipment replacement analyst some insight into the results of a premature replacement of the defender. In other words, incremental discounted cash flow rate of return equipment replacement faces the same kind of difficulties that classic equipment replacement theory does. The crux of the problem lies in the assumption that the challenging machine must be used for all of its expected life; if it isn't used for its entire expected life, lesser amounts of annual savings will result as shown in Figure 3 on page 12.

If the equipment replacement analyst feels that the challenger will be replaced prematurely, he or she can vary the expected life of the challenger to the point where the premature replacement will occur. In doing this, a valid rate of return can be calculated.

CHAPTER THREE

IMPLEMENTATION OF INCREMENTAL DISCOUNTED CASH FLOW EQUIPMENT REPLACEMENT ANALYSIS

After the operating, maintenance costs and salvage values of the defender and challenger are found as well as the capital cost of the challenger, the equipment replacement analyst will generally follow the sequence of operations listed below to determine incremental discounted cash flow rate of return of the defender-challenger comparison.

1. Determine the expected life of the challenger.
2. Choose either the Decsystem - 1091 computer program or the Hewlett-Packard calculator program.
3. If the Decsystem - 1091 program is used, enter the operating, maintenance, capital costs, and salvage value of the challenger and defender.
4. If the Hewlett-Packard program is used, enter the incremental savings for the defender-challenger comparison. Examples of incremental savings calculations have been given in previous pages.
5. After the Decsystem - 1091 program has given a rate of return, determine whether a sensitivity analysis or inflation rate calculation on the original rate of return is to be done. Net Present

Value at a given interest rate can be determined also.

6. Enter the incremental savings of the challenger-defender comparison.
7. If additional equipment replacement problems are to be solved, go to Step 1.

Two programs have been developed for several reasons. First, the Decsystem - 1091 program was written to give the analyst more insight and flexibility in equipment replacement problems than is possible in the program written for the hand-held calculator. The increased insight and flexibility is due to modified sensitivity analysis, inflation, and net present value algorithms. Second, the Decsystem - 1091 program was written to supplement the rates of return determined by Hewlett-Packard program. Third, the Hewlett-Packard program is designed for preliminary applications of equipment replacement calculations in which the analyst wants to initially determine if a machine should be replaced. Additionally, this program was designed for interested users who didn't have an access to a large-scale computer.

Because two different computer programs have been developed to solve equipment replacement programs, two different input techniques have to be used. First, if the equipment replacement analyst needs to use the program for a Hewlett-Packard, the operator has to calculate the incremental savings of the challenger-defender study period by hand, because the program for the calculator program could not be made sophisticated enough to calculate incremental savings internally. The following example shows what calculations have to be performed by hand each time an incremental discounted cash flow rate of return is desired. Additionally, the example shows what data has to be entered into the calculator as well as the results the calculator will yield.

In this example, the challenger has a 3-year operating life with an initial cost of $50,000 and annual operating costs of $2,000, $2,000, and $4,000. The defender has annual operating costs of $15,000, $16,000, and $24,000.

Challenger:	Cost= $50,000	Operating Cost= $2,000	Operating Cost= $2,000	Operating Cost= $4,000
	0	1	2	3
Defender:		Operating Cost= $15,000	Operating Cost= $16,000	Operating Cost= $24,000
	0	1	2	3

Figure 10: Required calculations for the hand-held calculator application

In addition to the defender's operating costs, a repair and maintenance cost of \$5,000 is incurred in year 2 of the defender's remaining life, and in year 3 of the defender's life a maintenance cost of \$15,000 is incurred.

The operator calculates by hand the savings of the challenger by subtracting the operating cost of the defender from the operating cost of the challenger. Therefore, the incremental cash flow diagram will appear as follows.

C=50,000	S=13,000	S=19,000	S=20,000
0	1	2	3

Figure 11: Incremental cash flow time diagram

A present worth equation of the above incremental cash flow can be shown to be

$$50{,}000 = 13{,}000\ (P/F_{i,1}) + 19{,}000\ (P/F_{i,2}) + 20{,}000\ (P/F_{i,3})$$

The $P/F_{i,n}$ notation, which is called "the single payment present-worth factor," calculates a present single sum, P, that is equivalent to a single future sum, F.

The values of \$50,000, \$13,000, \$19,000, and \$20,000 are entered into the appropriate storage slots of the calculator. After the capital cost of the challenger as well as the savings generated by the incremental cash flow have been entered into the calculator, the calculator will indicate the incremental discounted cash flow rate of return through either its diode registers or a paper printout. Further explanations of the operating procedure of the Hewlett-Packard calculator as well as a listing of the program can be obtained by contacting the author.

If the operator wants to use the larger program, cash flow calculations are not required because they are generated by the program itself; however, the operating and maintenance costs of both the defender and challenger must be properly entered.

The computer program, which was designed to run on the Colorado School of Mines Computing Center Decsystem - 1091 computer, was written to be as "conversational" as possible. In other words, as the program is operating, it will print out a question which the replacement analyst has to answer. For example, the program will ask the operator how long the expected life of the challenger is. After this question has been answered, other questions will be asked concerning the operating and maintenance costs of the defender and challenger, the depreciation technique that the operator wants to have used, the other questions concerning the replacement of a defending machine.

A listing of the Decsystem - 1091 program is given in the appendix. Also, four examples showing the input procedures for the computer program as well as the corresponding output is listed in the following chapter.

1. Capital Cost of the Challenger
2. Salvage Value of the Challenger
3. Salvage Value of the Defender
4. Operating Cost of the Challenger
5. Maintenance Cost of the Challenger
6. Operating Cost of the Defender
7. Maintenance Cost of the Defender

In addition, various inflation rates can be entered into the computer program to determine how the discounted cash flow rate of return varies with a change in the inflation rate.

Lastly, the following examples given in the next chapter and the appendix show what values have to be entered into the program as well as the corresponding output. The user of the program must follow the input format as shown for each of the computer generated questions.

CHAPTER FOUR

CASE STUDY OF THE USE OF INCREMENTAL DISCOUNTED CASH FLOW RATE OF RETURN EQUIPMENT REPLACEMENT ANALYSIS

Typically, on-line management or support personnel will be aware that particular machines have the potential to be replaced. When it's possible that equipment has to be replaced, the two programs discussed in this thesis can give management some kind of rate of return criteria for replacement analysis.

The following four examples show how the defender and challenger operating and maintenance costs have to be entered into the Decsystem - 1091 computer program. Additionally, the corresponding outputs follow each example. The first example demonstrates how the incremental cash flow rate of return is determined for a challenging gas chromatograph. The second example shows how incremental rates of return are calculated from pre-determined cash flows. Example three implements the sensitivity, inflation, and net present value algorithms. Example four illustrates the use of double declining balance depreciation.

A much more extensive explanation of the various economic evaluation techniques for equipment replacement analysis can be found in a number of engineering economics textbooks such as F.J. Stermole's <u>Economic Evaluation and Investment Decision Methods</u>.

Example One:

In a chemical plant, gas chromatographs are often used to measure the concentration of feedstocks and products in a refining or other processing operation. In this example, new gas chromatographs are being considered to replace older equipment. Figure 12 shows the operating costs of the defending and challenging chromatographs.

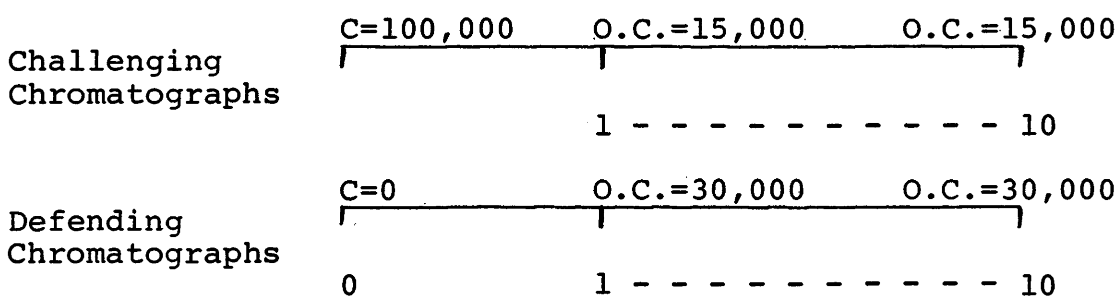


Figure 12: Operating and initial cost time diagram for the defending and challenging gas chromatographs

The equipment replacement analyst has to determine if the initial cost of $100,000 for the new chromatographs will provide sufficient savings in operating costs, which in this case decrease from $30,000 per year to $15,000 per year. By spending the $100,000, $15,000 per year is saved in operating costs. The initial investment of $100,000 can be depreciated by one of three depreciation techniques. For this example, straight-line depreciation will be used; however, if the operator desired, he or she could have picked either the double declining balance or the switch-over techniques.

The tax calculation that follows is also calculated by the computer program as shown on page 45.

Annual Savings	$15,000
- Depreciation	-10,000
Taxable Savings	5,000
- Tax at 50%	- 2,500
Net Profit	2,500
+ Depreciation	10,000
Cash Flow	$12,500

C=100,000 Cash Flow=$12,500/hr.

0 1 10

Figure 13: After-tax time diagram of defending-challenging gas chromatograph cash flows

The present worth equation would appear as follows:

$$100{,}000 = 12{,}500\ (P/A_{1,\ 10})$$

where the $P/A_{1,\ 10}$ notation is used to represent the Uniform Series Present Worth Factor which is used to give the present value of future annual costs at the interest rate, i, for the 10-year life of the chromatographs.

To operate the Decsystem - 1091 program, the user must log into the computer and call the program. If the user has logged in properly, the computer will respond by typing out a number of statements. After this is done, the computer will ask the user to enter the expected life of the challenger. This is done by entering the years of the expected life of the challenger immediately after the carriage return. Next, the computer will "ask" a series of questions about the defender's and challenger's operating, maintenance, capital costs, and salvage values. These values should be entered by the same method the computer operator entered the challenger's expected life. If there is no value to be entered, enter zero. After the program has calculated the incremental discounted cash flow rate of return, it will "ask" the user if he wants a sensitivity analysis or an inflated DCFROR. Also, the computer will determine if the user wants a Net Present Value analysis. If all of the responses are no, the program will answer if the user wants to run another equipment replacement problem. Finally, the next several pages show the gas chromatograph example as it was entered into the Decsystem - 1091 computer as well as the corresponding output.

```
 EX DCF.FOR
[2:53:14]
LINK:   Loading
[LNKXCT DCF execution]

ENTER THE MINIMUM RATE OF RETURN
AS A %.  FOR EXAMPLE, ENTER 45 FOR 45%.

45

UNLESS OTHERWISE NOTED,ALL OF THE COSTS
THAT YOU INPUT SHOULD BE IN THOUSANDS OF DOLLARS.
FOR EXAMPLE,IF THE OPERATING COST OF THE CHALLENGER
IS 10000 DOLLARS PER YEAR,ENTER 10.

ENTER THE EXPECTED LIFE OF THE CHALLENGER.
THE MAXIMUM ALLOWABLE LIFE OF THE CHALLENGER
IS 25 YEARS.

10

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  1

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  2

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  3

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  4

15.

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  5

15
```

```
ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  6

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  7

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  8

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  9

15

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR 10

15

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  2

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  3

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  4

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  5
```

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR 6

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR 7

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR 8

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR 9

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR 10

0

ENTER THE SALVAGE VALUE OF THE CHALLENGER.

0

ENTER THE CAPITAL COST OF THE CHALLENGER.

100

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR 1

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR 2

30

```
ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  3

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  4

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  5

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  6

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  7

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  8

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  9

30

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR 10

30

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  2
```

```
0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  3

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  4

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  5

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  6

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  7

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  8

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  9

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR 10

0

ENTER THE SALVAGE VALUE OF THE DEFENDER.

0
```

```
ENTER THE INVESTMENT TAX CREDIT.
ENTER AS A %.  FOR EXAMPLE, IF THE TAX CREDIT IS 10
%, ENTER 10.

0

ENTER THE INCOME TAX RATE.
ENTER THE TAX RATE AS A %.  FOR EXAMPLE,
IF THE TAX RATE IS 46%, ENTER 46.

50

ENTER THE NUMBER OF YEARS OF DEPRECIATION
LEFT IN THE DEFENDER.

0

ENTER THE YEARLY AMOUNT OF DEPRECI-
ATION LEFT IN THE DEFENDER.  IN OTHER WORDS,
IF THERE ARE 500 DOLLARS PER
YEAR LEFT IN THE DEFENDER, ENTER .5

0

ENTER THE DEPRECIATION TECHNIQUE FOR THE
CHALLENGER.  ENTER THE NUMBER "1" FOR DOUBLE
DECLINING BALANCE.  ENTER THE NUMBER "2" FOR
STRAIGHT LINE DEPRECIATION.  ENTER THE
NUMBER "3" FOR SWITCHOVER FROM DOUBLE DECLINING
BALANCE TO STRAIGHT LINE WHEN IT IS APPROPRIATE.
ENTER THE NUMBER "4" IF THERE IS NO DEPRECIATION
TO BE TAKEN.  ONE OF THE FOUR OPTIONS MUST BE
USED BY THE OPERATOR.

2

DCFROR=    4.30%
MINIMUM RATE OF RETURN=  45.00%
THE EXPECTED LIFE OF THE CHALLENGER=    10

PLEASE NOTE THAT IN THE FOLLOWING STATEMENTS (CR)
MEANS CARRIAGE RETURN.

DO YOU WANT THE DCFROR WITH INFLATED
DOLLARS.  IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

N
```

```
DO YOU WANT TO RUN A NET PRESENT VALUE ANALYSIS
OF THE DEFENDER-CHALLENGER COMPARISON, BECAUSE OF THE
POSSIBIBLITY OF DUAL RATES OF RETURN? IF YES, ENTER THE
NUMBER "1",(CR). IF NO, ENTER THE NUMBER "2",(CR).

2

DO YOU WANT TO CONTINUE THE PROGRAM?
IF YES, ENTER Y,(CR). IF NO, ENTER N,(CR).

N

STOP

End of Execution
CPU Time: 0.51 Elapsed time: 4:8.75
EXIT

.
```

Example Two:

This example shows how the computer program can be used with only cash flows rather than the usual defender's and challenger's operating and maintenance cost. To do this, the operator simply enters the cash flow for each year into either the annual defender's maintenance or operating costs' slot. For instance, if a 4 year study period is used with annual cash flows of $5,000, $3,725, $3,125, and $3,125, the operator would enter these values for either the annual defender's operating or maintenance costs, and the entries for the challenger's maintenance and operating costs would all be zero. Additionally, all of the other questions such as the income tax rate, investment credit rate, and other cash flow criteria are answered with a zero, which means they will not be calculated. In doing this, the operator circumvents all of the means by which a cash flow is usually calculated from a defender's and challenger's operating costs.

```
ENTER THE MINIMUM RATE OF RETURN
AS A %.  FOR EXAMPLE, ENTER 45 FOR 45%.

45

UNLESS OTHERWISE NOTED,ALL OF THE COSTS
THAT YOU INPUT SHOULD BE IN THOUSANDS OF DOLLARS.
FOR EXAMPLE,IF THE OPERATING COST OF THE CHALLENGER
IS 10000 DOLLARS PER YEAR,ENTER 10.

ENTER THE EXPECTED LIFE OF THE CHALLENGER.
THE MAXIMUM ALLOWABLE LIFE OF THE CHALLENGER
IS 25 YEARS.

4

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  1

0

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  2

0

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  3

0

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  4

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  2

0
```

```
ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  3

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  4

0

ENTER THE SALVAGE VALUE OF THE CHALLENGER.

0

ENTER THE CAPITAL COST OF THE CHALLENGER.

10

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  1

5

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  2

3.75

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  3

3.125

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  4

3.125

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  2

0
```

```
ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  3

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  4

0

ENTER THE SALVAGE VALUE OF THE DEFENDER.

0

ENTER THE INVESTMENT TAX CREDIT.
ENTER AS A %.  FOR EXAMPLE, IF THE TAX CREDIT IS 10
%, ENTER 10.

0

ENTER THE INCOME TAX RATE.
ENTER THE TAX RATE AS A %.  FOR EXAMPLE,
IF THE TAX RATE IS 46%, ENTER 46.

0

ENTER THE NUMBER OF YEARS OF DEPRECIATION
LEFT IN THE DEFENDER.

0

ENTER THE YEARLY AMOUNT OF DEPRECI-
ATION LEFT IN THE DEFENDER.  IN OTHER WORDS,
IF THERE ARE 500 DOLLARS PER
YEAR LEFT IN THE DEFENDER, ENTER .5

0

ENTER THE DEPRECIATION TECHNIQUE FOR THE
CHALLENGER.  ENTER THE NUMBER "1" FOR DOUBLE
DECLINING BALANCE.  ENTER THE NUMBER "2" FOR
STRAIGHT LINE DEPRECIATION.  ENTER THE
NUMBER "3" FOR SWITCHOVER FROM DOUBLE DECLINING
BALANCE TO STRAIGHT LINE WHEN IT IS APPROPRIATE.
ENTER THE NUMBER "4" IF THERE IS NO DEPRECIATION
TO BE TAKEN.  ONE OF THE FOUR OPTIONS MUST BE
USED BY THE OPERATOR.
```

```
4

DCFROR=  20.60%
MINIMUM RATE OF RETURN=  45.00%
THE EXPECTED LIFE OF THE CHALLENGER=     4

PLEASE NOTE THAT IN THE FOLLOWING STATEMENTS (CR)
MEANS CARRIAGE RETURN.

DO YOU WANT THE DCFROR WITH INFLATED
DOLLARS.  IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

N

DO YOU WANT TO RUN A NET PRESENT VALUE ANALYSIS
OF THE DEFENDER-CHALLENGER COMPARISON, BECAUSE OF THE
POSSIBIBLITY OF DUAL RATES OF RETURN?  IF YES, ENTER THE
NUMBER "1",(CR).  IF NO, ENTER THE NUMBER "2",(CR).

2

DO YOU WANT TO CONTINUE THE PROGRAM?
IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

N

STOP

End of Execution
CPU Time: 0.32  Elapsed time: 3:20.53
EXIT

.
```

Example Three:

This example is used to show how the sensitivity, inflation, and net present value algorithms are used as well as the results they generate. The operating and capital costs for the challenging and defending machines are shown below.

Challenger:

C=$60K	O.C.=$10K	O.C.=$12K	O.C.=$14K	O.C.=$16K
o	1	2	3	4

Defender:

C=0	O.C.=$40K	O.C.=$42K	O.C.=$44K	O.C.=$46K
0	1	2	3	4

C = challenger capital cost
O.C. = operating cost
K = 1000 i.e., 10K = 10,000

Figure 14: Operating and capital costs for the defender and challenger used in example 3 of the case study

After the operating costs and capital cost of the two machines are entered in the program in the usual fashion of responding to the appropriate questions generated by the computer, a net present value of the challenger-defender incremental cash flow for discount rates of 10 and 20% are calculated. After this has been done, the challenger-defender rate of return of 20.3% is varied for inflation rates of 10 and 20%. Finally, a sensitivity analysis is performed on the initial challenger-defender rate of return by increasing the challenger's capital cost by $10,000 and $15,000.

The discount rates used in this example for net present value, the inflation rates, and the $10,000 and $15,000 capital cost variation are arbitrary. The equipment analyst can choose almost any value for the net present value, inflation rate, and sensitivity analysis algorithms. However, some variations may generate a zero or negative rate of return. Additionally, if the program operator does not care to use any of the three algorithms, he or she only has to give an answer of no after the program has asked if the user wants a particular algorithm. Pages 59 through 65, the computer printout for this example.

```
ENTER THE MINIMUM RATE OF RETURN
AS A %.  FOR EXAMPLE, ENTER 45 FOR 45%.

45

UNLESS OTHERWISE NOTED,ALL OF THE COSTS
THAT YOU INPUT SHOULD BE IN THOUSANDS OF DOLLARS.
FOR EXAMPLE,IF THE OPERATING COST OF THE CHALLENGER
IS 10000 DOLLARS PER YEAR,ENTER 10.

ENTER THE EXPECTED LIFE OF THE CHALLENGER.
THE MAXIMUM ALLOWABLE LIFE OF THE CHALLENGER
IS 25 YEARS.

4

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  1

10

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  2

12

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  3

14

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  4

16

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  2

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  3
```

```
0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  4

0

ENTER THE SALVAGE VALUE OF THE CHALLENGER.

0

ENTER THE CAPITAL COST OF THE CHALLENGER.

60

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  1

40

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  2

42

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  3

44

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  4

46

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  2

0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  3
```

```
0

ENTER THE MAINTENANCE COSTS OF THE DEFENDER
DEFENDER FOR YEAR  4

0

ENTER THE SALVAGE VALUE OF THE DEFENDER.

0

ENTER THE INVESTMENT TAX CREDIT.
ENTER AS A %.  FOR EXAMPLE, IF THE TAX CREDIT IS 10
%, ENTER 10.

3.333

ENTER THE INCOME TAX RATE.
ENTER THE TAX RATE AS A %.  FOR EXAMPLE,
IF THE TAX RATE IS 46%, ENTER 46.

50

ENTER THE NUMBER OF YEARS OF DEPRECIATION
LEFT IN THE DEFENDER.

0

ENTER THE YEARLY AMOUNT OF DEPRECI-
ATION LEFT IN THE DEFENDER.  IN OTHER WORDS,
IF THERE ARE 500 DOLLARS PER
YEAR LEFT IN THE DEFENDER, ENTER .5

0

ENTER THE DEPRECIATION TECHNIQUE FOR THE
CHALLENGER.  ENTER THE NUMBER "1" FOR DOUBLE
DECLINING BALANCE.  ENTER THE NUMBER "2" FOR
STRAIGHT LINE DEPRECIATION.  ENTER THE
NUMBER "3" FOR SWITCHOVER FROM DOUBLE DECLINING
BALANCE TO STRAIGHT LINE WHEN IT IS APPROPRIATE.
ENTER THE NUMBER "4" IF THERE IS NO DEPRECIATION
TO BE TAKEN.  ONE OF THE FOUR OPTIONS MUST BE
USED BY THE OPERATOR.

2
```

```
DCFROR=  20.30%
MINIMUM RATE OF RETURN=  45.00%
THE EXPECTED LIFE OF THE CHALLENGER=     4

PLEASE NOTE THAT IN THE FOLLOWING STATEMENTS (CR)
MEANS CARRIAGE RETURN.

DO YOU WANT THE DCFROR WITH INFLATED
DOLLARS.  IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

Y

ENTER THE DESIRED INFLATION RATE.  IF
THE INFLATION RATE IS 10%, ENTER 10.

10

THE INFLATED RATE OF RETURN IS   29.00%

DO YOU WANT TO RUN AN INFLATED DCFROR
AGAIN?  IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

Y

ENTER THE DESIRED INFLATION RATE.  IF
THE INFLATION RATE IS 10%, ENTER 10.

20

THE INFLATED RATE OF RETURN IS   39.00%

DO YOU WANT TO RUN AN INFLATED DCFROR
AGAIN?  IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

N

DO YOU WANT TO RUN A NET PRESENT VALUE ANALYSIS
OF THE DEFENDER-CHALLENGER COMPARISON, BECAUSE OF THE
POSSIBIBLITY OF DUAL RATES OF RETURN?  IF YES, ENTER THE
NUMBER "1",(CR).  IF NO, ENTER THE NUMBER "2",(CR).

1

PLEASE ENTER THE DISCOUNT RATE THAT THE
NET PRESENT VALUE IS TO BE CALCULATED WITH.
FOR EXAMPLE, IF THE N.P.V. IS TO BE CALCULATED AT
10 PERCENT. ENTER 10.

10
```

```
THE NET PRESENT VALUE AT THE GIVEN DISCOUNT RATE
IN THOUSANDS OF DOLLARS IS   13.30

DO YOU WANT TO RUN A N.P.V. ANALYSIS AGAIN
IF YES, ENTER THE NUMBER "1",(CR).  IF NO, ENTER
THE NUMBER "2",(CR).

1

PLEASE ENTER THE DISCOUNT RATE THAT THE
NET PRESENT VALUE IS TO BE CALCULATED WITH.
FOR EXAMPLE, IF THE N.P.V. IS TO BE CALCULATED AT
10 PERCENT, ENTER 10.

20

THE NET PRESENT VALUE AT THE GIVEN DISCOUNT RATE
IN THOUSANDS OF DOLLARS IS    0.23

DO YOU WANT TO RUN A N.P.V. ANALYSIS AGAIN
IF YES, ENTER THE NUMBER "1",(CR).  IF NO, ENTER
THE NUMBER "2",(CR).

2

DO YOU WANT A SENSITIVITY ANLYSIS
RUN ON THE COMPUTED DCFROR?  IF YES, ENTER Y,(CR)
IF NO, ENTER N,(CR).

Y

NOTE THAT ONLY ONE OF THE FOLLOWING
CAN BE VARIED TO DETERMINE THE SENSITIVITY
OF THE COMPUTED DCFROR.
        1. CAPITAL COST OF THE CHALLENGER
        2. SALVAGE VALUE OF THE CHALLENGER
        3. SALVAGE VALUE OF THE DEFENDER
        4. OPERATING COST OF THE CHALLNEGER
        5. MAINTENANCE COST OF THE CHALLENGER
        6. OPERATING COST OF THE DEFENDER
        7. MAINTENANCE COST OF THE DEFENDER
```

IF THE USER WANTS TO VARY THE CAPITAL COST
OF THE CHALLENGER, OR THE SALVAGE VALUE OF THE CHALLEN-
GER, OR THE SALVAGE VALUE OF THE DEFENDER,
FOLLOW THE DIRECTIONS AS SHOWN. ENTER THE NUMBER
"1" FOR A CHANGE IN THE CAPITAL COST OF THE
CHALLENGER, ENTER THE NUMBER "2" FOR A CHANGE IN
THE SALVAGE VALUE OF THE CHALLENGER, OR
ENTER THE NUMBER "3" FOR A CHANGE IN THE SALVAGE VALUE
OF THE DEFENDER. THE AMOUNT THAT THE VALUE CHANGES WILL
BE DETERMINED IN THE NEXT SERIES OF STATEMENTS. PLEASE
USE THE CARRIAGE RETURN AFTER EACH NUMBER IS ENTERED.
IF THE USER WANTS TO VARY A VALUE OTHER THAN THOSE
PREVIOUSLY MENTIONED, ENTER 4,(CR).

1

AFTER ENTERING THE APPROPRIATE
NUMBER FOR THE CAPITAL COST OF THE
CHALLENGER, OR THE SALVAGE VALUE OF THE CHALLENGER
OR THE SALVAGE VALUE OF THE DEFENDER,
ENTER THE AMOUNT BY WHICH ONE OF THESE
THREE VALUES CHANGE IN THOUSANDS OF DOLLARS. FOR
EXAMPLE, IF THE CAPITAL COST OF THE CHALLENGER INCREASED
BY 10000 DOLLARS, ENTER 10. NOTE THAT THE PERIOD IS
FOR PUNCTUATION ONLY.

THE SENSITIVITY ANALYSIS ROR IS 12.50%

DO YOU WANT TO RUN THE SENSITIVITY ANALYSIS
AGAIN? IF YES, ENTER Y,(CR). IF NO, ENTER N,
(CR).

Y

WHAT CASH FLOW COMPONENTS DO YOU WANT TO
VARY? IF YOU WANT TO CHANGE THE CAPITAL COST OF THE
CHALLENGER, OR THE SALVAGE VALUE OF THE CHALLENGER, OR
THE SALVAGE VALUE OF THE DEFENDER, ENTER THE NUMBER
"1". IF YOU WANT TO VARY EITHER THE
OPERATING COST OF THE CHALLENGER, OR THE MAINTENANCE
COST OF THE CHALLENGER, OR THE OPERATING COST OF THE
DEFENDER, OR THE MAINTENANCE COST OF THE DEFENDER, ENTER
THE NUMBER "2".

1

```
ENTER THE NUMBER OF THE CASH FLOW COMPO-
NENT THAT YOU WANT TO VARY IN THE DCFROR SEN-
SITIVITY ANALYSIS.  ENTER "1" TO VARY THE CAP-
ITAL COST OF THE CHALLENGER.  ENTER "2" TO VARY THE
SALVAGE VALUE OF THE CHALLENGER.  ENTER THE NUMBER
"3" TO VARY THE SALVAGE VALUE OF THE DEFENDER.

1

ENTER THE AMOUNT THAT THE DESIRED
CASH FLOW COMPONENT IS TO BE VARIED FOR THE
DCFROR SENSITIVITY ANALYSIS.

15

THE SENSITIVITY ANALYSIS ROR IS     9.30%

DO YOU WANT TO RUN THE SENSITIVITY ANALYSIS
AGAIN?  IF YES, ENTER Y,(CR).  IF NO, ENTER N,
(CR).

N

DO YOU WANT TO CONTINUE THE PROGRAM?
IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

N

STOP

End of Execution
CPU Time: 1.03  Elapsed time: 10:24.02
EXIT

.
```

Example Four:

In this example, double declining balance is used as a depreciation technique. The same procedure as in the previous examples is followed in the conversational part of the program with the exception that the user has to enter the number "1" rather than the number "2" after the computer asks for the kind of depreciation technique to be used.

The following time diagram gives the operating costs of a defender-challenger replacement project with an expected life of 3 years.

Defender:

	O.C.=45,000	O.C.=45,000	O.C.=45,000
0	1	2	3

Challenger:

C=45,000	O.C.=10,000	O.C.=10,000	O.C.=10,000
0	1	2	3

Figure 15: Defender and challenger operating and maintenance costs for example 4 of the case study

By techniques that have been previously discussed, yearly savings are generated as shown in Figure 16.

C=45,000	Savings=35,000	S=35,000	S=35,000
0	1	2	3

Figure 16: Savings generated by the challenger in example 4 of the case study

If double declining balance is used as a depreciation technique, the following annual cash flows are generated as shown below:

	Year 1	Year 2	Year 3
Annual Savings	35K	35K	35K
- Depreciation	20K	13.33K	8.89K
Taxable Savings	15K	21.67K	26.11K
- Tax @ 50%	7.5K	10.835K	13.055K
Net Profit	7.5K	10.835K	13.055K
+ Depreciation	20K	13.333K	8.889K
Cash Flow	27.5K	24.168K	21.944K

These cash flows generate the following present worth equation

$$45{,}000 = 27{,}500\ (P/F_{i,1}) + 24{,}168\ (P/F_{i,1}) + 21{,}944\ (P/F_{i,3})$$

where $P/F_{i,n}$ is the Single Payment Present Worth Factor as previous discussed. The rate of return for the present worth equation is 33.6%.

```
.EX DCF.G\G\FOR
[22:44:18]
LINK:   Loading
[LNKXCT DCF execution]

ENTER THE MINIMUM RATE OF RETURN
AS A %.  FOR EXAMPLE, ENTER 45 FOR 45%.

45

UNLESS OTHERWISE NOTED,ALL OF THE COSTS
THAT YOU INPUT SHOULD BE IN THOUSANDS OF DOLLARS.
FOR EXAMPLE, IF THE OPERATING
COST OF THE CHALLENGER
IS 10000 DOLLARS PER YEAR,ENTER 10.

ENTER THE EXPECTED LIFE OF THE CHALLENGER.
THE MAXIMUM ALLOWABLE LIFE OF THE CHALLENGER
IS 25 YEARS.

3

ENTER THE OPERATING COSTS
OF THE CHALLENGER FOR YEAR  1

10

ENTER THE OPERATING COSTS
OF THE CHALLENGER FOR YEAR  2

10

ENTER THE OPERATING COSTS
OF THE CHALLENGER FOR YEAR  3

10

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  1

0

ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  2

0
```

```
ENTER THE MAINTENANCE COSTS OF THE
CHALLENGER FOR YEAR  3

0

ENTER THE SALVAGE VALUE
OF THE CHALLENGER.

0

ENTER THE CAPITAL COST
OF THE CHALLENGER.

45

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  1

45

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  2

45

ENTER THE OPERATING COST OF THE
DEFENDER FOR YEAR  3

45

ENTER THE MAINTNENANCE
COSTS OF THE DEFENDER
FOR YEAR  1

0

ENTER THE MAINTNENANCE
COSTS OF THE DEFENDER
FOR YEAR  2

0

ENTER THE MAINTNENANCE
COSTS OF THE DEFENDER
FOR YEAR  3
```

0

ENTER THE SALVAGE
VALUE OF THE DEFENDER.

0

ENTER THE INVESTMENT TAX CREDIT.
ENTER AS A %. FOR EXAMPLE,
IF THE TAX CREDIT IS 10
%, ENTER 10.

0

ENTER THE INCOME TAX RATE.
ENTER THE TAX RATE AS A %. FOR EXAMPLE,
IF THE TAX RATE IS 46%, ENTER 46.

50

ENTER THE NUMBER
OF YEARS OF DEPRECIATION
LEFT IN THE DEFENDER.

0

ENTER THE YEARLY AMOUNT OF DEPRECI-
ATION LEFT IN THE DEFENDER. IN OTHER WORDS,
IF THERE ARE 500 DOLLARS PER
YEAR LEFT IN THE DEFENDER, ENTER .5

0

ENTER THE DEPRECIATION
TECHNIQUE FOR THE CHALLENGER.
ENTER THE NUMBER "1" FOR DOUBLE
DECLINING BALANCE. ENTER THE
NUMBER "2" FOR STRAIGHT LINE
DEPRECIATION. ENTER THE NUMBER
"3" FOR SWITCHOVER FROM DOUBLE
DECLINING BALANCE TO STRAIGHT LINE
WHEN IT IS APPROPRIATE. ENTER THE
NUMBER "4" IF THERE IS NO DEPRECIATION
TO BE TAKEN. ONE OF THE FOUR OPTIONS
MUST BE USED BY THE OPERATOR.

1

```
DCFROR=  33.60%
MINIMUM RATE OF RETURN=  45.00%
THE EXPECTED LIFE OF THE CHALLENGER=     3

PLEASE NOTE THAT IN
THE FOLLOWING STATEMENTS (CR)
MEANS CARRIAGE RETURN.

DO YOU WANT THE DCFROR WITH INFLATED
DOLLARS.  IF YES, ENTER Y,(CR).
IF NO, ENTER,(CR).

N

DO YOU WANT TO RUN
A NET PRESENT VALUE ANALYSIS
OF THE DEFENDER-CHALLNEGER
COMPARISON, BECAUSE OF THE
POSSIBILITY OF DUAL
RATES OF RETURN?  IF YES, ENTER THE
NUMBER "1",(CR).  IF
NO, ENTER THE NUMBER "2",(CR).

2

DO YOU WANT TO CONTINUE THE PROGRAM?
IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).

N

STOP
```

CONCLUSION AND RECOMMENDATIONS

Despite the imposing theoretical and empirical difficulties of equipment replacement, companies must develop some kind of long-run equipment replacement policy or stand the chance of losing large sums of money through excessive operating, maintenance, and repair costs. A number of different approaches to solve the problem of economical machine replacement have been developed. All of these techniques, however, have theoretical constraints. The minimum annual total cost method, for example, fails to take into account the expected lives of previous machines.

Although the technique of incremental discounted cash flow rate of return is a variation of the classical theory of equipment replacement analysis, it is flexible enough to minimize some of the difficulties associated with the classical theory. There are two reasons for this. First, since the rate of return technique only considers future costs, the minimum annual total costs of previous machines do not have to be considered. Second, the problem of replacement of the challenger before its expected life is over can be eliminated because the computer operator can vary the expected life of the challenger to his or her liking; hence, by the variation of these parameters, a valid rate of return can be calculated.

The user of incremental discounted cash flow rate of return equipment analysis must be continually aware of its shortcomings. The most important limitation is the softness of the input data. Additionally, the assumed expected life of the challenger may be incorrect. Nonetheless, as an initial indication of machine replacement, incremental discounted cash flow rate of return should prove to be a welcome and useful tool for industrial users.

APPENDIX

The appendix contains a copy of the Decsystem - 1091 computer program which can solve various equipment replacement problems through incremental discounted cash flow rate of return.

In addition to the enclosed computer program, an example print out of the Decsystem - 1091 program is given to show the potential user what can happen if incorrect response is given such as entering a "T" rather than a "Y," for example, the program will generally stop, and the user will have to run it again to generate the desired answers.

If an investment tax credit is to be calculated for the challenger's capital cost, the computer operator must be sure that all of the standards set by his company and the Internal Revenue Service are followed. Finally, pollution control equipment can be rapidly amortized through a special method as shown in a number of Federal government documents such as the Internal Revenue Service's publication #334.

DECSYSTEM - 1091 COMPUTER PROGRAM

```
C       THIS PROGRAM IS DESIGNED TO SOLVE EQUIPMENT REPLACE-
C       MENT PROBLEMS BY INCREMENTAL DISCOUNTED CASH FLOW
C       RATE OF RETURN.
C
C
C       THE FOLLOWING DIMENSION STATEMENTS ARE USED TO STORE
C       THE VARIOUS COMPONENTS OF CASH FLOW SUCH AS DEPRECI-
C       ATION AND SALVAGE VALUE.
C
C
        DIMENSION COC(26),CMC(26),CCC(26),CSV(1)
        DIMENSION ZITC(1),DOC(26),DMC(26)
        DIMENSION BTAX(26),ATAX(26),DEP(26),CASF(26)
        DIMENSION PF(3000),FV(26),F(26)
        DIMENSION DEPD(26),STL(26),CCOT(26),DDOT(26),SAV(26)
        DIMENSION ADBA(26),DSV(1),DCF1(3000)
        DIMENSION CASF2(26),BTAX2(26),ATAX2(26)
        DIMENSION SAV2(26),DDOT2(26),CCOT2(26),PF2(3000)
        DIMENSION F2(26),DCF12(3000)
        DIMENSION FV2(26),ZV(26)
C
C
        SEN=1HF
        AAA=1HF
        AGA=1HF
        NIP=1HF
        ANS=1HF
        TR=0.0
        M=0
        N=0
        DEP(I)=0.
        K=0
        J=0
        L=0
 20     WRITE(4,25)
 25     FORMAT(1X,'ENTER THE MINIMUM RATE OF RETURN'/,
      1    1X,'AS A %.  FOR EXAMPLE, ENTER 45 FOR 45%.'/)
        READ(4,40)ZMINRO
 40     FORMAT(F)
C
C
C       THE FOLLOWING STATEMENTS ARE USED TO INPUT THE VARIOUS
C       CASH FLOW COMPONENTS.
C
C
        WRITE(4,45)
 45     FORMAT(1X,'UNLESS OTHERWISE NOTED,ALL OF THE COSTS'/,
      1    1X,'THAT YOU INPUT SHOULD BE IN THOUSANDS OF DOLLARS.'/,
      2    1X,'FOR EXAMPLE, IF THE OPERATING'/,
      3    1X,'COST OF THE CHALLENGER'/,
      3    1X,'IS 10000 DOLLARS PER YEAR,ENTER 10.'/)
```

```
      WRITE(4,50)
50    FORMAT(1X,'ENTER THE EXPECTED LIFE OF THE CHALLENGER.'/,
     1   1X,'THE MAXIMUM ALLOWABLE LIFE OF THE CHALLENGER'/,
     2   1X,'IS 25 YEARS.'/)
      READ(4,100) N
100   FORMAT(I2)
      DO 150 I=1,N
110   WRITE(4,125)I
125   FORMAT(1X,'ENTER THE OPERATING COSTS'/,
     1     1X,'OF THE CHALLENGER FOR YEAR',I3,/)
      READ(4,130)COC(I)
130   FORMAT(F)
150   CONTINUE
      DO 250 I=1,N
      WRITE(4,225)I
225   FORMAT(1X,'ENTER THE MAINTENANCE COSTS OF THE'/,
     1     1X,'CHALLENGER FOR YEAR',I3,/)
      READ(4,230)CMC(I)
230   FORMAT(F)
250   CONTINUE
      WRITE(4,450)
450   FORMAT(' ENTER THE SALVAGE VALUE'/,
     1     1X,'OF THE CHALLENGER.'/)
      READ(4,500) CSV(1)
500   FORMAT(F)
      WRITE(4,550)
550   FORMAT(' ENTER THE CAPITAL COST'/,
     1     1X,'OF THE CHALLENGER.'/)
      READ(4,600)CCC(1)
600   FORMAT(F)
      DO 700 I=1,N
      WRITE(4,650)I
650   FORMAT(1X,'ENTER THE OPERATING COST OF THE'/,
     1     1X,'DEFENDER FOR YEAR',I3,/)
      READ(4,675)DOC(I)
675   FORMAT(F)
700   CONTINUE
      DO 750 I=1,N
      WRITE(4,725)I
725   FORMAT(1X,'ENTER THE MAINTNENANCE'/,
     1     1X,'COSTS OF THE DEFENDER'/,
     2     1X,'FOR YEAR',I3,/)
      READ(4,730)DMC(I)
730   FORMAT(F)
750   CONTINUE
      WRITE(4,760)
760   FORMAT(1X,'ENTER THE SALVAGE'/,
     1     1X,'VALUE OF THE DEFENDER.'/)
      READ(4,1000)DSV(1)
1000  FORMAT(F)
      WRITE(4,1050)
```

```
1050 FORMAT(1X,'ENTER THE INVESTMENT TAX CREDIT.'/,
    1    1X,'ENTER AS A %.  FOR EXAMPLE,'/,
    2    1X,'IF THE TAX CREDIT IS 10'/,
    2    1X,'%, ENTER 10.'/)
     READ(4,1100)ZITC(1)
1100 FORMAT(F)
     WRITE(4,1125)
1125 FORMAT(1X,'ENTER THE INCOME TAX RATE.'/,
    1    1X,'ENTER THE TAX RATE AS A %.  FOR EXAMPLE,'/,
    2    1X,'IF THE TAX RATE IS 46%, ENTER 46.'/)
     READ(4,1130)TR
1130 FORMAT(F)
     WRITE(4,1150)
1150 FORMAT(1X,'ENTER THE NUMBER'/,
    1    1X,'OF YEARS OF DEPRECIATION'/,
    1    1X,'LEFT IN THE DEFENDER.'/)
     READ(4,1200)M
1200 FORMAT(I)
     WRITE(4,1210)
1210 FORMAT(1X,'ENTER THE YEARLY AMOUNT OF DEPRECI-'/,
    1    1X,'ATION LEFT IN THE DEFENDER.  IN OTHER WORDS,'/,
    2    1X,'IF THERE ARE 500 DOLLARS PER'/,
    3    1X,'YEAR LEFT IN THE DEFENDER, ENTER .5'/)
     READ(4,1220)DEPD(I)
1220 FORMAT(F)
C
C
C     THE FOLLOWING STATEMENTS INPUT THE DEPRECIATION
C     TECHNIQUE FOR THE CHALLENGER.
C
C
1225 WRITE(4,1250)
1250 FORMAT(1X,'ENTER THE DEPRECIATION'/,
    1    1X,'TECHNIQUE FOR THE CHALLENGER.'/,
    2    1X,'ENTER THE NUMBER "1" FOR DOUBLE'/,
    3    1X,'DECLINING BALANCE.  ENTER THE'/,
    4    1X,'NUMBER "2" FOR STRAIGHT LINE'/,
    5    1X,'DEPRECIATION.  ENTER THE NUMBER'/,
    6    1X,'"3" FOR SWITCHOVER FROM DOUBLE '/,
    7    1X,'DECLINING BALANCE TO STRAIGHT LINE'/,
    8    1X,'WHEN IT IS APPROPRIATE.  ENTER THE'/,
    9    1X,'NUMBER "4" IF THERE IS NO DEPRECIATION'/,
    10   1X,'TO BE TAKEN.  ONE OF THE FOUR OPTIONS'/,
    1    1X,'MUST BE USED BY THE OPERATOR.'/)
     READ(4,1300) IZAP
1300 FORMAT(I)
       IF(IZAP.NE.1.AND.IZAP.NE.2.AND.
    1    IZAP.NE.3.AND.IZAP.NE.4) GO TO 1225
     IF(IZAP.EQ.1) GO TO 5500
     IF(IZAP.EQ.2) CALL SL(N,CCC,CSV,DEPD,M,DEP)
     IF(IZAP.EQ.3) CALL SWO(DEPD,N,M,CCC,CSV,DEP)
```

```
      IF(IZAP.EQ.4) DEP(I)=0
C
C
C     THE FOLLOWING STATEMENTS CALCULATE THE
C     INCREMENTAL CASH FLOW FOR THE DEFENDER-CHALLENGER
C     COMPARISON.
C
C
C     (THE DO LOOP STARTING WITH
C     STATEMENT NUMBER 1325 DETERMINES
C     THE APPARENT SAVINGS OF USING THE CHALLENGER.)
C
C
      SEN=1HF
 1325 DO 1350 I=1,N
      CCOT(I)=COC(I)+CMC(I)
      DDOT(I)=DOC(I)+DMC(I)
      SAV(I)=DDOT(I)-CCOT(I)
 1350   CONTINUE
      TR1=TR/100
      RISV=CSV(1)-DSV(1)
      TZITC=ZITC(1)/100
C
C
C     THE FOLLOWING DO LOOP CALCULATES
C     THE INCREMENTAL CASH FLOW
C
C
      DO 1400 I=1,N
      BTAX(I)=SAV(I)-DEP(I)
      IF(BTAX(I).LE.0)TR1=0
      ATAX(I)=BTAX(I)-TR1*BTAX(I)
      ZITQQ=TZITC*CCC(1)
      CASF(I)=ATAX(I)+DEP(I)
      IF(I.EQ.N)CASF(I)=ATAX(I)+DEP(I)+RISV
 1400   CONTINUE
      DCF=0
      SUM=0
C
C
C     THE FOLLOWING NESTED DO LOOPS
C     CALCULATE THE DISCOUNTED INCRE-
C     MENTAL CASH FLOW FOR EACH YEAR
C     OF THE LIFE OF THE CHALLENGER-
C     DEFENDER COMPARISON AS GIVEN BY THE OPERATOR.
C
C
      DO 1600 J=1,30000
      DCF=DCF+.001
      DCF1(J)=DCF-.001
      DO 1500 I=1,N
```

```
      PF(I)=1/((1+DCF1(J))**I)
      FV(I)=CASF(I)*PF(I)
      SUM=SUM+FV(I)
 1500   CONTINUE
      ZNPV=SUM-CCC(1)+ZITQQ
      IF(ZNPV.LE.0) GO TO 1700
      SUM=0.
 1600   CONTINUE
 1700 DCF=DCF1(J)*100
      IF(SEN.NE.1HF) SROR=DCF
      IF(SEN.NE.1HF) GO TO 1975
      IF(ZNPV.LE.0.AND.J.EQ.1) GO TO 1805
      WRITE(4,1750)DCF,ZMINRU,N
 1750 FORMAT(1X,'DCFROR= ',F6.2,'%'/,
     1    1X,'MINIMUM RATE OF RETURN= ',F6.2,'%'/,
     2    1X,'THE EXPECTED LIFE OF THE CHALLENGER=',I6/)
      GO TO 1890
 1805 WRITE(4,1825)
 1825 FORMAT(1X,'THE DCFROR IS NEGATIVE OR ZERO.')
      WRITE(4,1850)ZMINRU,N
 1850 FORMAT(1X,'THE MINIMUM RATE OF RETURN=',F6.2,'%'/,
     1    1X,'THE EXPECTED LIFE OF THE CHALLENGER=',I6/)
C
C
C     THE FOLLOWING STATEMENTS DETERMINES IF THE USER WANTS
C     TO RUN A SENSITIVITY ANALYSIS ON THE COMPUTED DCFROR.
C
C
 1890 WRITE(4,1895)
 1895 FORMAT(1X,'PLEASE NOTE THAT IN'/,
     1    1X,'THE FOLLOWING STATEMENTS (CR)'/,
     1    1X,'MEANS CARRIAGE RETURN.'/)
      GO TO 2200
 1897 WRITE(4,1900)
 1900 FORMAT(1X,'DO YOU WANT A SENSITIVITY ANLYSIS'/,
     1  1X,'RUN ON THE COMPUTED DCFROR?  IF YES, ENTER Y,(CR)'/,
     2    1X,'IF NO, ENTER N,(CR).'/)
      READ(4,1907) SEN
 1907 FORMAT(A3)
      IF(SEN.EQ.1HN) GO TO 3000
      IF(AGA.EQ.1HN) GO TO 3000
 1915 WRITE(4,1920)
 1920 FORMAT(1X'NOTE THAT ONLY ONE OF THE FOLLOWING'/,
     1  1X,'CAN BE VARIED TO DETERMINE THE SENSITIVITY'/,
     2    1X,'OF THE COMPUTED DCFROR.'/,
     3    9X,'1. CAPITAL COST OF THE CHALLENGER'/,
     4    9X,'2. SALVAGE VALUE OF THE CHALLENGER'/,
     5    9X,'3. SALVAGE VALUE OF THE DEFENDER'/,
     5    9X,'4. OPERATING COST OF THE CHALLNEGER'/,
     6    9X,'5. MAINTENANCE COST OF THE CHALLENGER'/,
     7    9X,'6. OPERATING COST OF THE DEFENDER'/,
```

```
8    9X,'7. MAINTENANCE COST OF THE DEFENDER'/)
     A=0
     C=0
     NUT=2
     GRAD=0
     SEN=1HY
     WRITE(4,1930)
1930 FORMAT(1X,'IF THE USER WANTS TO VARY THE CAPITAL COST'/,
1        1X,'OF THE CHALLENGER, OR THE'/,
1        1X,'SALVAGE VALUE OF THE CHALLEN-'/,
2        1X,'GER, OR THE SALVAGE VALUE OF THE DEFENDER,'/,
3        1X,'FOLLOW THE DIRECTIONS AS SHOWN.'/,
4        1X,'ENTER THE NUMBER "1" FOR A CHANGE'/,
5        1X,'IN THE CAPITAL COST OF THE'/,
4        1X,'CHALLENGER, ENTER THE NUMBER "2" FOR A CHANGE IN'/,
5        1X,'THE SALVAGE VALUE OF THE CHALLENGER, OR'/,
6        1X,'ENTER THE NUMBER "3" FOR'/,
6        1X,'A CHANGE IN THE SALVAGE VALUE'/,
7        1X,'OF THE DEFENDER.  THE AMOUNT'/,
7        1X,'THAT THE VALUE CHANGES WILL'/,
8        1X,'BE DETERMINED IN THE NEXT'/,
8        1X,'SERIES OF STATEMENTS.  PLEASE'/,
9        1X,'USE THE CARRIAGE RETURN'/,
9        1X,'AFTER EACH NUMBER IS ENTERED.'/,
B        1X,'IF THE USER WANTS TO'/,
B        1X,'VARY A VALUE OTHER THAN THOSE'/,
C        1X,'PREVIOUSLY MENTIONED, ENTER 4,(CR).'/)
1935 READ(4,1940)C
1940 FORMAT(F)
     IF(C.EQ.4) GO TO 1957
     WRITE(4,1945)
1945 FORMAT(1X,'AFTER ENTERING THE APPROPRIATE'/,
1        1X,'NUMBER FOR THE CAPITAL COST OF THE '/,
1        1X,'CHALLENGER, OR THE SALVAGE VALUE OF THE CHALLENGER'/,
2        1X,'OR THE SALVAGE VALUE OF THE DEFENDER,'/,
A        1X,'ENTER THE AMOUNT BY WHICH ONE OF THESE'/,
3        1X,'THREE VALUES CHANGE IN THOUSANDS OF DOLLARS.  FOR'/,
4        1X,'EXAMPLE, IF THE CAPITAL'/,
4        1X,'COST OF THE CHALLENGER INCREASED'/,
5        1X,'BY 10000 DOLLARS, ENTER 10. NOTE THAT THE PERIOD IS'/,
6        1X,'FOR PUNCTUATION ONLY.'/)
     READ(4,1955)A
1955 FORMAT(F)
     IF(C.NE.0.AND.A.NE.0) GO TO 3225
1957 WRITE(4,1960)
1960 FORMAT(1X,'IF THE CHALLENGER OPERATING COST IS TO BE'/,
1        1X,'CHANGED, ENTER 4.  IF THE CHALLENGER MAINTENANCE'/,
2        1X,'COST IS TO BE CHANGED, ENTER 5.  IF THE DEFENDER'/,
3        1X,'OPERATING COST IS TO BE CHANGED, ENTER 6.  IF THE'/,
4        1X,'DEFENDER MAINTENANCE COST'/,
4        1X,'IS TO BE CHANGED, ENTER 7.'/)
```

```
      READ(4,1965)C
1965  FORMAT(F)
      WRITE(4,1967)
1967  FORMAT(1X,'ENTER THE RATE AT WHICH THE OPERATING AND/OR'/,
     1      1X,'MAINTENANCE COSTS OF THE DEFENDER OR CHALLENGER'/,
     2      1X,'CHANGE.  FOR EXAMPLE, IF'/,
     2      1X,'THE OPERATING COST OF THE DE-'/,
     3      1X,'FENDER INCREASES 50 PERCENT PER YEAR, ENTER 50.'/)
      READ(4,1968) GRAD
1968  FORMAT(F)
      GO TO 3225
1975  IF(ZNPV.LT.0.AND.J.EQ.1) GO TO 1995
      WRITE(4,1990) SROR
1990  FORMAT(1X,'THE SENSITIVITY ANALYSIS ROR IS',F6.2'%'/)
      GO TO 1999
1995  WRITE(4,1997)
1997  FORMAT(1X,'THE SENSITIVITY ANALYSIS IS NEGATIVE'/,
     1      1X,'OR ZERO.'/)
1999  WRITE(4,2000)
2000  FORMAT(1X,'DO YOU WANT TO RUN THE SENSITIVITY ANALYSIS'/,
     1      1X,'AGAIN?  IF YES, ENTER Y,(CR).  IF NO, ENTER N,'/,
     2      1X,'(CR).'/)
      READ(4,2100) AGA
2100  FORMAT(A3)
      IF(AGA.EQ.1HN) GO TO 3000
2101  NUT=3
      GO TO 3227
2102  WRITE(4,2105)
2105  FORMAT(1X,'WHAT CASH FLOW COM-'/,
     1      1X,'PONENTS DO YOU WANT TO'/,
     1      1X,'VARY?  IF YOU WANT TO'/,
     2      1X,'CHANGE THE CAPITAL COST OF THE'/,
     2      1X,'CHALLENGER, OR THE SALVAGE'/,
     2      1X,'VALUE OF THE CHALLENGER, OR'/,
     3      1X,'THE SALVAGE VALUE OF THE'/,
     3      1X,'DEFENDER, ENTER THE NUMBER'/,
     4      1X,'"1".  IF YOU WANT TO VARY EITHER THE '/,
     5      1X,'OPERATING COST OF THE CHALLENGER'/,
     5      1X,'OR THE MAINTNANCE'/,
     6      1X,'COST OF THE CHALLNEGER,'/,
     6      1X,'OR THE OPERATING COST OF THE'/,
     7      1X,'DEFENDER, OR THE MAINTNENANCE'/,
     7      1X,'COST OF THE DEFENDER, ENTER'/,
     8      1X,'THE NUMBER "2".'/)
      READ(4,2110) NUT
2110  FORMAT(I)
      IF(NUT.EQ.1) GO TO 2115
      IF(NUT.EQ.2) GO TO 2140
2115  WRITE(4,2120)
2120  FORMAT(1X,'ENTER THE NUMBER OF THE CASH FLOW COMPO-'/,
     1      1X,'NENT THAT YOU WANT TO VARY IN THE DCFROR SEN-'/,
```

```
     2    1X,'SITIVITY ANALYSIS.  ENTER "1" TO VARY THE CAP-'/,
     1    1X,'ITAL COST OF THE CHALLENGER.  ENTER "2" TO VARY THE'/,
     2    1X,'SALVAGE VALUE OF THE'/,
     2    1X,'CHALLENGER.  ENTER THE NUMBER'/,
     3    1X,'"3" TO VARY THE'/,
     3    1X,'SALVAGE VALUE OF THE DEFENDER.'/)
      READ(4,2125) C
 2125 FORMAT(F)
      WRITE(4,2130)
 2130 FORMAT(1X,'ENTER THE AMOUNT THAT THE DESIRED'/,
     1    1X,'CASH FLOW COMPONENT IS TO BE VARIED FOR THE'/,
     2    1X,'DCFROR SENSITIVITY ANALYSIS.'/)
      READ(4,2135) A
 2135 FORMAT(F)
      GO TO 3225
 2140 WRITE(4,2145)
 2145 FORMAT(1X,'ENTER THE NUMBER OF THE CASH FLOW COM-'/,
     1    1X,'PONENT THAT IS TO BE'/,
     1    1X,'VARIED.  YOU MUST ENTER EITHER 4,'/,
     2    1X,'5,6,OR 7'/)
      READ(4,2150) C
 2150 FORMAT(F)
      WRITE(4,2155)
 2155 FORMAT(1X,'ENTER THE PERCENTAGE'/,
     1    1X,'BY WHICH THIS CASH FLOW'/,
     1    1X,'COMPONENT CHANGES.  FOR EXAMPLE,'/,
     1    1X,'IF THE OPERATING COST'/,
     2    1X,'OF THE CHALLENGER CHANGES'/,
     2    1X,'BY 10 PERCENT PER YEAR, ENTER 10.'/)
      READ(4,2160) GRAD
 2160 FORMAT(F)
      GO TO 3225
C
C
C     THE FOLLOWING STATEMENTS ARE USED TO DETERMINE IF THE
C     USER OF THE PROGRAM WANTS TO RUN AN INFLATED DCFROR.
C
C
 2200 WRITE(4,2300)
 2300 FORMAT(1X,'DO YOU WANT THE DCFROR WITH INFLATED'/,
     1    1X,'DOLLARS.  IF YES, ENTER Y,(CR).'/,
     1    1X,'IF NO, ENTER,(CR).'/)
      READ(4,2400)AAA
 2400 FORMAT(A3)
      IF(AAA.EQ.1HY) GO TO 2450
      IF(AAA.EQ.1HN) GO TO 2885
 2450 WRITE(4,2500)
 2500 FORMAT(1X,'ENTER THE DESIRED INFLATION RATE.  IF'/,
     1    1X,'THE INFLATION RATE IS 10%, ENTER 10.'/)
 2525 READ(4,2600) RINF
 2600 FORMAT(F)
```

```
2625 GO TO 3205
2629 WRITE(4,2650) DCF2
2650 FORMAT(1X,'THE INFLATED RATE OF RETURN IS',F8.2,'%'/)
     GO TO 2795
2700 WRITE(4,2750)
2750 FORMAT(1X,'THE INFLATED DCFROR IS NEGATIVE OR ZERO.'/)
2795 WRITE(4,2880)
2880 FORMAT(1X,'DO YOU WANT TO RUN AN INFLATED DCFROR'/,
    1   1X,'AGAIN?  IF YES, ENTER Y, (CR).'/,
    1   1X,'IF NO, ENTER N, (CR).'/)
     READ(4,2800) NIP
2800 FORMAT(A3)
     IF(NIP.EQ.1HY) GO TO 2450
     IF(NIP.EQ.1HN) GO TO 2885
C
C
C     THE FOLLOWING STATEMENTS
C     DETERMINE IF THE OPERATOR WANTS
C     TO RUN A NET PRESENT VALUE ANALYSIS OF THE
C     DEFENDER-CHALLENGER COMPARISON BECAUSE OF DUAL RATES
C     OF RETURN.
C
C
     SUM=0.
2885 WRITE(4,2890)
2890 FORMAT(1X,'DO YOU WANT TO RUN'/,
    1   1X,'A NET PRESENT VALUE ANALYSIS'/,
    1   1X,'OF THE DEFENDER-CHALLNEGER'/,
    2   1X,'COMPARISON, BECAUSE OF THE'/,
    2   1X,'POSSIBILITY OF DUAL'/,
    2   1X,'RATES OF RETURN?  IF YES, ENTER THE'/,
    3   1X,'NUMBER "1",(CR).  IF'/,
    3   1X,'NO, ENTER THE NUMBER "2",(CR).'/)
     READ(4,2895) TRT
2895 FORMAT(F)
     IF(TRT.EQ.1.) GO TO 3290
3000 WRITE(4,3100)
3100 FORMAT(1X,'DO YOU WANT TO CONTINUE THE PROGRAM?'/,
    1   1X,'IF YES, ENTER Y,(CR).  IF NO, ENTER N,(CR).'/)
     READ(4,3200) ANS
3200 FORMAT(A3)
     IF(ANS.EQ.1HY) GO TO 20
     GO TO 7050
C
C
C     THE FOLLOWING STATEMENTS DETERMINE HOW THE SPECIFIED
C     INFLATION RATE AFFECTS THE DCFROR.
C
C
3205 ZINR=RINF/100
     DCF2=0.
```

```
      SUM2=0.
      DO 3207 I=1,N
      F2(I)=EXP(ZINR*I)
      CCOT2(I)=COC(I)*F2(I)+CMC(I)*F2(I)
      DDOT2(I)=DOC(I)*F2(I)+DMC(I)*F2(I)
      SAV2(I)=DDOT2(I)-CCOT2(I)
 3207 CONTINUE
      TR12=TR/100
      RISV2=CSV(1)-DSV(1)
      DO 3209 I=1,N
      BTAX2(I)=SAV2(I)-DEP(I)
      IF(BTAX2(I).LE.0.) TR12=0.
      TZITC2=(ZITC(1))/100
      ATAX2(I)=BTAX2(I)-TR12*BTAX2(I)
      ZITQQ2=TZITC2*CCC(1)
      CASF2(I)=ATAX2(I)+DEP(I)
      IF(I.EQ.N) CASF2(I)=ATAX2(I)+DEP(I)+RISV2
 3209 CONTINUE
      SUM2=0.
      DO 3215 J=1,3000
      DCF2=DCF2+.01
      DCF12(J)=DCF2-.01
      DO 3210 I=1,N
      PF2(I)=1/((1+DCF12(J))**I)
      FV2(I)=CASF2(I)*PF2(I)
      SUM2=SUM2+FV2(I)
 3210 CONTINUE
      ZNPV2=SUM2-CCC(1)+ZITQQ2
      SUM2=0.
      IF(ZNPV2.LE.0.AND.J.EQ.1) GO TO 2700
      IF(ZNPV2.LE.0) GO TO 3220
 3215 CONTINUE
 3220 DCF2=DCF12(J)*100
      GO TO 2629
C
C
C     THE QUANITIES THAT ARE
C     NUMBERED BELOW CAN BE VARIED
C     AS THE OPERATOR DICTATES FOR THE SENSITIVITY
C     ANALYSIS OF THE DCFROR.
C    1. CHALLENGER'S CAPITAL COST
C    2. CHALLENGER'S SALVAGE VALUE
C    3. DEFENDER'S SALVAGE VALUE
C    4. CHALLENGER'S OPERATING COST
C    5. CHALLENGER'S MAINTENANCE COST
C    6. DEFENDER'S OPERATING COST
C    7. DEFENDER'S MAINTENANCE COST
C
C
 3225 GRAD=GRAD/100
 3227 IF(NUT.EQ.3) A=-A
```

```
      IF(NUT.EQ.1.OR.NUT.EQ.2) A=A
      IF(NUT.EQ.1.OR.NUT.EQ.2) GRAD=GRAD
      IF(C.EQ.1)CCC(1)=CCC(1)+A
        IF(C.EQ.2)CSV(1)=CSV(1)+A
        IF(C.EQ.3)DSV(1)=DSV(1)+A
      IF(NUT.EQ.2.AND.C.EQ.4) GO TO 3230
      IF(NUT.EQ.3.AND.C.EQ.4) GO TO 4100
      IF(NUT.EQ.2.AND.C.EQ.5) GO TO 3245
      IF(NUT.EQ.3.AND.C.EQ.5) GO TO 4200
      IF(NUT.EQ.2.AND.C.EQ.6) GO TO 3260
      IF(NUT.EQ.3.AND.C.EQ.6) GO TO 4300
      IF(NUT.EQ.2.AND.C.EQ.7) GO TO 3280
      IF(NUT.EQ.3.AND.C.EQ.7) GO TO 4400
 3230 DO 3240 I=1,N
      COC(I)=COC(I)*(EXP(I*GRAD))
 3240 CONTINUE
 3245 DO 3250 I=1,N
      CMC(I)=CMC(I)*(EXP(I*GRAD))
 3250 CONTINUE
 3260 DO 3270 I=1,N
      DOC(I)=DOC(I)*(EXP(I*GRAD))
 3270 CONTINUE
 3280 DO 3285 I=1,N
      DMC(I)=DMC(I)*(EXP(I*GRAD))
 3285 CONTINUE
      IF(NUT.EQ.3) GO TO 2102
      GO TO 1325
C
C
C     THE FOLLOWING STATEMENTS
C     CALCULATE THE NET PRESENT
C     VALUE OF THE DEFENDER-CHALLENGER COMPARISON
C     FOR WHATEVER DISCOUNT RATE THE USER DESIRES.
C
C
 3290 WRITE(4,3291)
      SUM=0.0
 3291 FORMAT(1X,'PLEASE ENTER THE DISCOUNT RATE THAT THE'/,
     1    1X,'NET PRESENT VALUE IS TO BE CALCULATED WITH.'/,
     2    1X,'FOR EXAMPLE, IF THE'/,
     2    1X,'N.P.V. IS TO BE CALCULATED AT'/,
     3    1X,'10 PERCENT, ENTER 10.'/)
      READ(4,3292) ZZINT
 3292 FORMAT(F)
      RZZINT=ZZINT/(100)
      DO 3295 I=1,N
      PF(I)=1/((1+RZZINT)**I)
      ZV(I)=CASF(I)*PF(I)
      SUM=SUM+ZV(I)
 3295 CONTINUE
      XNPV=SUM-CCC(1)+ZITQQ
```

```
      WRITE(4,3297) XNPV
 3297 FORMAT(1X,'THE NET PRESENT VALUE'/,
     1    1X,'AT THE GIVEN DISCOUNT RATE'/,
     1    1X,'IN THOUSANDS OF DOLLARS IS',F8.2/)
      WRITE(4,3298)
 3298 FORMAT(1X,'DO YOU WANT TO'/,
     1    1X,'RUN A N.P.V. ANALYSIS AGAIN'/,
     1    1X,'IF YES, ENTER THE NUMBER'/,
     1    1X,'"1",(CR).  IF NO, ENTER'/,
     2    1X,'THE NUMBER "2",(CR).'/)
      READ(4,3299) XXX
 3299 FORMAT(F)
      IF(XXX.EQ.1) GO TO 3290
      IF(XXX.EQ.2) GO TO 1897
 4100 DO 4150 I=1,N
      COC(I)=COC(I)*(1/((1+GRAD)**I))
 4150 CONTINUE
      GO TO 2102
 4200 DO 4250 I=1,N
      CMC(I)=CMC(I)*(1/((1+GRAD)**I))
 4250 CONTINUE
      GO TO 2102
 4300 DO 4350 I=1,N
      DOC(I)=DOC(I)*(1/((1+GRAD)**I))
 4350 CONTINUE
      GO TO 2102
 4400 DO 4450 I=1,N
      DMC(I)=DMC(I)*(1/((1+GRAD)**I))
 4450 CONTINUE
      GO TO 2102
C
C
C     THE FOLLOWING STATEMENTS
C     DETERMINE THE DOUBLE DECLINING
C     BALANCE OF THE CHALLENGER.
C
C
 5500 IF(M.EQ.0) GO TO 6000
      IF(M.NE.0) GO TO 6050
 6000 DO 6010 I=1,N
      L=I-1
      K=I
      DEP(I)=(2/FLOAT(N))*(CCC(1))*((1-2/FLOAT(N)))**L
      ADBA(I)=(CCC(1))*((1-2/N))**K
      IF(ADBA(I).LE.CSV(1)) DEP(I)=0
 6010   CONTINUE
      GO TO 7000
 6050   DO 6075 I=1,M
      L=I-1
      DEP(I)=(2/FLOAT(N))*(CCC(1))*((1-2/FLOAT(N)))**L
     1    -(DEPD(I))
```

```
      IF(ADBA(I).LE.CSV(1)) DEP(I)=0
 6075 CONTINUE
      J=M+1
      DO 6090 I=J,N
      DEP(I)=(2/FLOAT(N))*(CCC(1))*((1-2/FLOAT(N)))**L
      IF(ADBA(I).LE.CSV(1)) DEP(I)=0
 6090 CONTINUE
 7000 GO TO 1325
 7050 STOP
      END
C
C
C     THE FOLLOWING SUBROUTINE CALCULATES THE STRAIGHT LINE
C     DEPRECIATION OF THE CHALLENGER.
C
C
```

```
      SUBROUTINE SL(N,CCC,CSV,DEPD,M,DEP)
      DIMENSION DEP(26),CCC(1),CSV(1),DEPD(26)
      IF(M.EQ.0) GO TO 2000
      IF(M.NE.0) GO TO 3000
 2000 DO 2500 I=1,N
      DEP(I)=(CCC(1)-CSV(1))/(FLOAT(N))
 2500 CONTINUE
      GO TO 4500
 3000 DO 3500 I=1,M
      DEP(I)=(CCC(1)-CSV(1))/(FLOAT(N))-(DEPD(I))
 3500 CONTINUE
      J=M+1
      DO 4000 I=J,N
      DEP(I)=(CCC(1)-CSV(1))/(FLOAT(N))
 4000 CONTINUE
 4500 RETURN
      END
C
C
C     THE FOLLOWING SUBROUTINE CALCULATES  THE SWITCH-
C     OVER DEPRECIATION TECHNIQUE FOR THE CHALLENGER.
C
C
```

```
      SUBROUTINE SWO(DEPD,N,M,CCC,CSV,DEP)
      DIMENSION DEP(26),ADBA(26),STL(26)
      DIMENSION CCC(1),CSV(1),DEPD(26)
      IF(M.EQ.0) GO TO 800
      IF(M.NE.0) GO TO 870
800   DO 850 I=1,N
      L=I-1
      K=I
      DEP(I)=(2./FLOAT(N))*(CCC(1))*((1-2./FLOAT(N)))**L
      ADBA(I)=(CCC(1))*((1-2/N))**K
      STL(I)=(CCC(1)-CSV(1))/(N)
      IF(DEP(I).LE.STL(I)) DEP(I)=STL(I)
      IF(ADBA(I).LE.CSV(1))DEP(I)=0
      IF(ADBA(I).LE.CSV(1))STL(I)=0
850   CONTINUE
      GO TO 910
870   DO 890 I=1,M
      L=I-1
      K=I
      DEP(I)=(2./FLOAT(N))*(CCC(1))*((1-2./FLOAT(N)))**L
     1   -DEPD(I)
      ADBA(I)=CCC(I)*((1-2/N))**K
      STL(I)=(CCC(1)-CSV(1))/FLOAT(N)
      IF(DEP(I).LE.STL(I)) DEP(I)=STL(I)
      IF(ADBA(I).LE.CSV(1)) DEP(I)=0
      IF(ADBA(I).LE.CSV(1))STL(I)=0
890   CONTINUE
      J=M+1
      DO 900 I=J,N
      L=I-1
      K=I
      DEP(I)=(2./FLOAT(N))*(CCC(1))*((1-2./FLOAT(N)))**L
      ADBA(I)=(CCC(1))*((1-2/N))**K
      STL(I)=(CCC(1)-CSV(1))/FLOAT(N)
      IF(DEP(I).LE.STL(I)) DEP(I)=STL(I)
      IF(ADBA(I).LE.CSV(1))DEP(I)=0
      IF(ADBA(I).LE.CSV(I))STL(I)=0
900   CONTINUE
910   RETURN
      END
```

EXAMPLE OF THE COMPUTER PROGRAM'S RESPONSE TO ERRONEOUS INPUT

```
ENTER THE MINIMUM RATE OF RETURN
AS A %.  FOR EXAMPLE, ENTER 45 FOR 45%.

45

UNLESS OTHERWISE NOTED,ALL OF THE COSTS
THAT YOU INPUT SHOULD BE IN THOUSANDS OF DOLLARS.
FOR EXAMPLE,IF THE OPERATING COST OF THE CHALLENGER
IS 10000 DOLLARS PER YEAR,ENTER 10.

ENTER THE EXPECTED LIFE OF THE CHALLENGER.
THE MAXIMUM ALLOWABLE LIFE OF THE CHALLENGER
IS 25 YEARS.

3

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  1

10\0\1

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  2

12

ENTER THE OPERATING COSTS OF THE CHALLENGER
FOR YEAR  3

AS

%FRSDAT Illegal character in data [ A ]
Unit=4 TTY:/ACCESS=SEQINOU/MODE=ASCII
(F)
AS


Name     (Loc)     <<---  Caller  (Loc)    <#Args> [Arg Types]
IOLST.   (404116) <<---   MAIN.+47(120423)       <#0>    []

? Job aborted

End of Execution
CPU Time: 0.08  Elapsed time: 35.95
EXIT

.
```

REFERENCES CITED

1. Terborgh, George, Dynamic Equipment Policy, McGraw-Hill Book Co., 1949, pp. 215-16.

2. Gentry, D. W., Johnson, T. B., "An Investment Policy for Equipment Replacement," Colorado School of Mines Mineral Industries Bulletin, v. 17, number 1, Jan., 1974, p. 1.

3. Stermole, F. J., Economic Evaluation and Investment Decision Methods, Investment Evaluations Corp., 1974, p. 221.

4. Kolesar, P., "Minimum-Cost Replacement under Markovian Deterioration," Management Science, 12, 1966, pp. 694-706.

5. Beenhakker, H. L., "Approaches to Dynamic Transport Planning," Transportation, v. 2, No. 3 Oct., 1973, pp. 245-281.

6. Ross, R. C., "Uncertainty Analysis Helps in Making Business Decisions," Chemical Engineering, v. 78, No. 21, Sept. 20, 1971, pp. 149-154.

7. Davidson, L.B., "Investment Evaluation Under Conditions of Inflation," Journal of Petroleum Technology, v. 27, Oct, 1975, pp. 1183-1189.

8. Gentry, D. W., Johnson, T. B., "An Investment Policy for Equipment Replacement," Colorado School of Mines Mineral Industries Bulletin, v. 17, number 1, Jan., 1974, p. 1.

9. Rathbun, G. A., Jr., "Equipment Replacement-Evaluation by Return on Investment," 15 pgs., U.S. Steel Corp., Pittsburgh, PA, 1970.

10. Kearns, J. L., Buckley, R. E., et al., "Taking the Guesswork Out of Equipment Replacement Decisions," Society of Mining Engineers of A.I.M.E., preprint number 79-6, 1979.