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Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Electrical Systems

by
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FOREWORD

This research was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE) and the Office of the Assistant Chief of Engineers under various research, development, testing, and evaluation (RDTE) and reimbursable funding documents. Work began under RDTE in 1980 and continued in reimbursable projects during 1984 through 1989. The technical monitor for the RDTE part was Dr. Larry Schindler (CEMP-EC) and for the reimbursable part was Ms. Val Corbridge (DAEN-ZCF-R).

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). The Principal Investigators were Dr. Edgar Neely and Mr. Robert Neathammer (USACERL-FS). The primary contractor for much of the data development was the Department of Architectural Engineering, Pennsylvania State University. Dr. Michael O'Connor is Chief of USACERL-FS.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

CONTENTS

TABLES

FIGURES

BUILDING MAINTENANCE AND REPAIR DATA FOR LIFE-CYCLE COST ANALYSES: ELECTRICAL SYSTEMS

1 INTRODUCTION

Background

Maintenance* and repair (M&R) cost estimates are needed during planning, design, and operations/maintenance of Army facilities. During planning, life-cycle costs are needed to evaluate alternative ways of meeting requirements (e.g., lease, new construction, renovate existing facilities). During design, M&R requirements for various types of components, such as built-up or shingle roofs, are needed so that the total life-cycle cost of different designs can be minimized. Finally, once the facility has been constructed, outyear predictions of maintenance and repair costs are needed so that enough funds can be programmed to ensure that Army facilities are maintained properly and do not deteriorate due to lack of maintenance.

The Directorate of Engineering and Construction (EC), Headquarters, U.S. Army Corps of Engineers (HQUSACE),** asked the U.S. Army Construction Engineering Research Laboratory (USACERL) to coordinate the assembly of a single centralized maintenance and repair data base for use by Corps designers. This research was required because designers were not able to obtain reliable maintenance and repair data to support their life-cycle cost (LCC) analysis from installations or from the technical literature. One of the first tasks in the research effort was to determine if reliable data bases, which could be adapted for Corps use, existed in government or private industry. Comprehensive data bases of maintenance costs for government and private sector facilities did not exist. The little data available always depended on widely varying standards of maintenance used to maintain the facilities for which the data was collected and thus was unreliable for prediction purposes. Recognizing this, HQUSACE asked USACERL to develop a maintenance and repair cost data base. This data is for use by U.S. Army Corps of Engineers (USACE) designers in performing life-cycle cost analyses during the design of new facilities. Initial results were presented in several USACERL reports.[1]

Soon after this request, the Facilities Programming and Budgeting Branch of the Facilities Engineering Directorate asked USACERL to develop prediction models for outyear maintenance requirements of the Army facility inventory. The Programming Office of EC, responsible for Military Construction, Army (MCA) planning, also requested that USACERL provide methods and automated tools to help installations perform economic analyses. Part of the objective was to allow analysts to obtain future maintenance cost data.

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*Maintenance in this report means all work required to keep a facility in good operating condition; it includes all maintenance, repair, and replacement of components required over the life of a facility.

**At the time of this request, EC was part of the Office of the Chief of Engineers, which has since reorganized. In addition, EC has now become the Directorate of Military Programs.

[1] R.D. Neathammer, *Life-Cycle Cost Database Design and Sample Cost Data Development*, Interim Report P-120/ADA0997222 (U.S. Army Construction Engineering Research Laboratory [USACERL], February 1981); R.D. Neathammer, *Life-Cycle Cost Database: Vol I, Design*, and *Vol II, Sample Data Development*, Technical Report P-139/ADA126644 and ADA126645 (USACERL, January 1983), Appendices E through G.

In response to these requests, USACERL began a multiyear effort to develop a comprehensive maintenance and repair cost research program for buildings. This coordinated program is the key to all detailed estimation of future maintenance costs for Army facilities.

Research Performed and Reports Published

This is one of several interrelated reports addressing maintenance resource prediction in the facility life-cycle process. The total research effort is described in a USACERL Technical Report.[2]

The first research product was a data base containing maintenance tasks related to every building construction component. This data base provides labor, material, and equipment resource information. The frequency of task occurrence is also included. This information is published in a series of four USACERL Special Reports by engineering systems: (1) architectural, (2) heating, ventilating, and air-conditioning (HVAC), (3) plumbing, and (4) electrical. The title for the series is *Maintenance Task Data Base for Buildings*[3] Table 1 shows an example from this data base. This data is also available in electronic form. The data base is used in a personal computer (PC) system under the Disk Operating System (DOS). This computer program allows a facility to be defined by entering the components and component quantities comprising the facility. The tasks are used to determine the resources required annually to keep the facility maintained.

The second research product was a component resource summary for the first 25 years of a facility. The tasks for the component were scheduled and combined into one set of annual resource requirements. This annual resource information is published in a series of four USACERL Special Reports titled *Building Component Maintenance and Repair Data Base*.[4] An example from this data base is shown in Table 2. The data base is also available in electronic form. This data can be used to perform special economic analyses such as one for a 20-year life using a 10 percent discount rate.

The third research product was a set of 25-year present worth factor tables for use by designers in selecting components for discount rates of 7 and 10 percent. The annual component resource values were multiplied by the appropriate present worth factor and added for the 25 years to produce one set of resource values. This information is published in a series of four USACERL Special Reports titled

[2] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Resource Prediction in the Facility Life-Cycle Process*, Technical Report P-91/10 (USACERL, March 1991).

[3] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/21 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Plumbing Systems*, Special Report P-91/18 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Electrical Systems*, Special Report P-91/25 (USACERL, May 1991), and E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Architecutral Systems*, Special Report P-91/23 (USACERL, May 1991).

[4] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Architectural Systems*, Special Report P-91/27 (USACERL, May 1991); E. S. Neely, R. D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/22 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Plumbing Systems*, Special Report P-91/30 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Electrical Systems*, Special Report P-91/19 (USACERL, May 1991).

Table 1

Typical Task Data Form

Task Code: 1131411

Component: MERCURY VAPOR FIXT. 175W.   System: LIGHTING SYSTEM   Subsystem: LIGHTING FIXTURES

Task Description: M/R MAINTENANCE AND REPAIR

Unit of Measure: COUNT   Frequency of Occurence: H: 5.00 A: 10.00 L: 20.00
Once every (H, A, L) years

Persons per Team: 1   Task Duration: 0.6154 hours

Trade: ELECTRICAL, INT.   Task Classification: 0

Labor Resources

Subtask Description	Labor Hours
1. REMOVE AND REINSTALL LOUVER	0.004100
2. REMOVE AND REINSTALL 1 TUBE	0.071200
3. REMOVE OLD/REINSTALL BALLAST	0.384000
4. TEST FIXTURES	0.014100

Material Resources

Description	Quantity	Unit Cost
BALLAST	1	50.0000
		50.0000

SUMMARY

Resources UOM	Direct	Indirect	Total
Labor Hours	0.473400	0.142020	0.615420
Material Cost	50.000000		50.000000
Equipment Hours			0.615420

Table 2

CACES No.: 031134 - Roll Roofing				031135 - Shingles		
Labor Hours	Materials $	Equipment Hours	YR	Labor Hours	Materials $	Equipment Hours
0.0076	0.0165	0.0039	1	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	2	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	3	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	4	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	5	0.0032	0.0330	0.0017
0.0090	0.0165	0.0046	6	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	7	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	8	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	9	0.0026	0.0220	0.0014
0.0414	0.7496	0.0207	10	0.0032	0.0330	0.0017
0.0076	0.0165	0.0039	11	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	12	0.0026	0.0220	0.0014
0.0090	0.0165	0.0046	13	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	14	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	15	0.0034	0.0330	0.0018
0.0090	0.0165	0.0046	16	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	17	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	18	0.0026	0.0220	0.0014
0.0090	0.0165	0.0046	19	0.0024	0.0220	0.0013
0.0414	0.7496	0.0207	20	0.0332	0.4675	0.0167
0.0076	0.0165	0.0039	21	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	22	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	23	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	24	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	25	0.0032	0.0330	0.0017

All data is per fixture.

Building Maintenance and Repair Data for Life-Cycle Cost Analyses.[5] Table 3 shows an example from this data base. The data base is also available in electronic form. The first three resource columns provide data to allow designers to calculate the life-cycle costs at any location by multiplying by the correct labor rate, equipment rate, and material geographic factor. The multiplication and addition have been performed for the Military District of Washington, DC, and results are given in the fourth column of the table. The right section of the table is information that can be entered into computer systems that perform life-cycle cost analysis.

[5] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Architectural Systems*, Special Report P-91/17 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/20 (USACERL, May 1991), and E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Plumbing Systems*, Special Report P-91/24 (USACERL, May 1991).

Table 3

Life-Cycle Cost Analysis

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)													PAGE 97
COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d = 10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS							
		By Resources			Washington D.C. Total	Annual Maintenance and Repair			Replacement and High Costs Tasks				
	um	labor	material	equipment		labor	material	equipment	Yr	labor	material	equipment	
LIGHTING SYSTEM													
LIGHTING FIXTURES													
INCANDESCENT LIGHTING FIXT	CT	0.12489	2.99191	0.12489	6.20	0.01012	0.14063	0.01012	20	0.44850	16.96000	0.44850	
QUARTZ FIXTURE	CT	0.18095	21.69174	0.18095	26.33	0.01796	[illegible]	0.01796	20	0.44850	58.30000	0.44850	
FLOUR. LIGHTING FIXT. 80W.	CT	0.35366	14.22361	0.35366	23.30	[illegible]	0.87794	0.03731	20	0.74126	67.84000	0.74126	
MERCURY VAPOR FIXT. 175W	CT	0.27593	40.56016	0.27593	47.64	0.02905	3.46673	0.02905	20	0.58162	134.62000	0.58162	
METAL-HALIDE FIXT. 175W.	CT	0.31034	88.72582	0.31034	96.69	0.03626	9.17686	0.03626	20	0.43550	197.16000	0.43550	
EMERGENCY LIGHTING FIXT.	CT	0.71076	16.09790	0.71046	34.32	[illegible]	0.60201	0.04779	20	3.14782	100.70000	3.14782	
H.P. SODIUM FIXT. 250W.	CT	0.30038	167.06999	0.15019	174.29	0.03465	16.20810	0.01733	20	0.44850	436.72000	0.22425	
L.P. SODIUM FIXT. 200W.	CT	0.30038	99.54375	0.15019	106.77	0.03465	8.32916	0.01733	20	0.44850	341.32000	0.22425	

A fourth research product was a PC system that allows facilities to be modeled by entering the components that comprise the facility. Future years resource predictions are produced by applying the individual tasks and then forming resource summaries by subsystems, systems, facilities, installations, reporting installations, Major Commands (MACOMS) and Army. A summary level computer system was also developed for use by the Department of the Army (DA) and MACOMS. The summary level system applies the most basic data contained in the current facility real property inventory files: (1) current facility use, (2) floor area, and (3) construction date. Users and systems manuals will be published as USACERL ADP Reports.

Objective

The objective of this report is to describe the component summaries for electrical systems and give examples for using these tables in performing the component during the design process.

Approach

The first activity in the research was to survey the literature for available maintenance data. No comprehensive task resource data base was located. The Navy has developed a series of manuals dealing with labor hours required to perform several basic maintenance tasks. This work has been adopted by the Department of Defense (DOD) for tri-service use. A series of Technical Bulletins (TBs) under the general title *Engineered Performance Standards* has been published.

The next activity was to survey USACE District offices to solicit their input for a data base. A guiding committee composed of District personnel, installation representatives, and private sector consultants met and agreed upon a general data base design. More importantly, they recommended that the data base be developed using the Engineered Performance Standards rather than historical data.

Once the data base was developed, component summaries were created by summing all tasks for a component. These summaries were then input into a program that computed present worth values for each component.

The calculation procedures described in this report were performed and summarized for standard Army life-cycle analysis of 25 years with a 7 or 10 percent present worth factor. Final results are published in the USACERL Special report series *Building Maintenance and Repair Data Base for Life-Cycle Analyses*.

Scope

The 25 year component resources summary tables are for DOD designers and can also be used by those in the private sector.

Mode of Technology Transfer

The tables pertinent to designer use will be issued as a supplement to Technical Manual (TM) 5-802-1, *Economic Studies for Military Construction Design—Applications*.

2 PROBLEM DEFINITION

In the facility life-cycle process, costs are incurred in construction, operation, maintenance, and disposal of a facility. Past emphasis during the planning, design, and construction phases has been on estimating initial construction costs. The impact of operating and maintaining facilities has always been a secondary consideration. In many cases, the operation and maintenance (O&M) costs are far greater than initial construction costs. Building owners are concerned with the total ownership costs of facilities rather than just the initial construction costs.

The Army has realized the importance of performing total life-cycle cost analyses for facilities at the design stage of accurately forecasting these costs for funds programming. HQUSACE asked USACERL in 1980 to develop a method of estimating future maintenance costs for buildings. In 1982, the programming branch of the former Facilities Engineering Directorate asked USACERL to develop effective models for forecasting facility maintenance resource requirements based on the actual facility.

Life-cycle cost economic studies are an integral part of facility design in the MCA program. Requirements for performing these studies are given in:

- Statutes, Code of Federal Regulations and Executive Orders for performing analyses when energy is a key cost and for wastewater treatment plants
- USACE *Architectural and Engineering Instructions: Design Criteria*
- Army Regulation (AR) 11-28, *Economic Analysis and Program Evaluation for Resource Management* for general economic analyses
- TM 5-802-1, *Economic Studies for Military Construction Design--Applications*

The main purpose of these studies is to minimize the life-cycle costs of Army facilities.

To perform life-cycle cost analyses on facility designs, three categories of costs are needed: initial, operating, and maintenance. Initial costs are usually easy to estimate through existing cost estimating systems such as the Corps of Engineers Computer Assisted Cost Estimating System (CACES) and standard publications such as Means or Dodge. Operating costs can be estimated by using energy consumption models such as the Corps of Engineers Building Loads Analysis and System Thermodynamics (BLAST) program or the Trane Company's Trace program. However, accurate estimates of maintenance costs are not available.

There are no comprehensive data bases of maintenance costs for building components either in the private sector or State/Federal Governments. Some historical data is available from the Building Owners' and Managers' Association reports. Within the Army, the Integrated Facilities System (IFS) contains some historical data; however, it does not have a feature for retaining several types of a building component (e.g., having brick and wood exteriors or three types of floor covering). Moreover, the data in IFS has not been kept current. For example, at one installation several family housing units were shown as having wood siding when, in fact, they had been covered with aluminum siding several years earlier.

3 DATA BASE DEVELOPMENT

Introduction

Historical data within the Army and other agencies was reviewed to determine the availability of accurate resource data. The best source of labor resource data was the Engineered Performance Standards[6] adopted by DOD for use by all DOD agencies. The advisory committee decided to develop a maintenance task data base using the Engineered Performance Standards as the basis for the labor resources.

A typical building was subdivided into systems, sub-systems, and components. All maintenance, repair and replacement tasks were listed for each component. The resources required to perform each task were identified and the significance of the task resources discussed. Component summary tables listing resources by component age were developed by combining all tasks that were scheduled to be performed during each year. A summary of labor, material, and equipment requirements was given by component age. Life-cycle costs analysis tables were created by applying discount factors to the resources given in the component summary tables. The resulting tables can be used to perform life-cycle cost analysis.

Historical Data Review

Extensive research was performed during a 3-year period of reviewing the available historical data at several installations. This research revealed that a large portion of the component replacement tasks was not performed when replacement was required, due to lack of available funding, but was completed several years later. Most replacements performed by contract were not entered into the corporate data base. Most installations maintained few historical records because there was no Army regulation requiring such records to be kept. When component replacement dates were available, the comparable component installation or previous replacement dates were unknown, thus, accurate frequencies could not be established.

The task description fields given for the tasks performed were often blank or the descriptions given were very vague. Often several tasks were reported on one entry. Most entries gave a dollar cost but provided very little information about labor hours, materials, and equipment hours. Discussions with service personnel revealed that the data recorded on the forms may not actually relate to the resources required to perform the work.

In conclusion, all maintenance personnel interviewed stated clearly and emphatically that the current historical data cannot be used to develop accurate resource predictions. This data is erroneous, incomplete, and inaccurate.

Engineered Performance Standards

In 1955 the new use of maintenance management for public works and public utilities required that a greater portion of maintenance work be planned and estimated. The general absence, however, of

[6] Army Technical Bulletin 420-1 through 420-51.

adequate and reliable maintenance estimating data severely handicapped any increase in the number of estimates, and, more seriously, the production of accurate estimates. About this time, the Department of Defense directed that standards for work should be developed to the maximum feasible extent and applied throughout the military establishment. As a result of that directive, Engineered Performance Standards were developed.

The Navy undertook a large research program to perform time and motion studies of maintenance personnel as they performed their maintenance tasks. After several years of effort, the Navy published the results under the title "Engineered Performance Standards." Both Army and Air Force maintenance personnel reviewed this set of manuals and adopted it for official use. Today, the Engineered Performance Standards are used by all DOD agencies and are published as one set of reports carrying three different publication numbers for the Army, Navy, and Air Force.

Committee Reviews

At the beginning of this research project HQUSACE and USACERL formed an advisory committee composed of representatives from all offices involved in performing life-cycle cost analysis. The basic objective of the advisory committee was to involve as many appropriate and knowledgeable people as possible in deciding how to solve the M&R data base problem. The advisory committee reviewed the historical information research results and the Engineered Performance Standards research program and reports. After lengthy discussion of all possible alternatives, the advisory committee decided to develop a maintenance task data base using the Engineered Performance Standards as the basis for the labor resources. The advisory committee was active for the first two years of the project.

A second maintenance steering committee was formed that was composed of one representative from each HQDA office involved in maintenance resource programming and planning, six major commands, and ten installations. This maintenance steering committee had the same basic objective as the first advisory committee. In addition, the steering committee wanted to use the data developed to predict actual maintenance resource requirements at installations.

Building Subdivision

The UNIFORMAT method of dividing a building into systems, subsystems, and components was adopted because it is used by all Federal construction agencies and many private organizations. Systems requiring little maintenance such as foundations and superstructure were not considered.

The level of component detail was determined by the members of the maintenance steering committee. This level varied, depending on the facility classification and the costs versus the benefit of collecting and maintaining data. For example, in the typical building the steering committee voted to stop at the door level and not define hardware requirements because the hardware was not a costly item, but for historical family housing, where one hinge could cost two hundred dollars, all door hardware had to be defined.

Task Data Development

A task is defined as the work performed by a single trade. Each task is divided into the labor, material, and equipment resources required to perform the work. By separating the tasks in this manner the data can also be used to determine manpower staffing requirements and equipment requirements. The following procedures have been used to develop the tasks for this research project. Identical procedures can be applied to develop new tasks not currently covered in the task data base.

The task development procedures can be demonstrated by using the existing task number 1131411, MAINTENANCE AND REPAIR OF 175W MERCURY VAPOR LIGHT FIXTURE, shown in Table 1. This task involves: removing and reinstalling the louver, one tube, ballast and testing the fixture.

In order to repair most light fixtures, the electrician must first gain access to the fixture by removing the louver.

The first step is to obtain a copy of DA Pamphlet 25-30, *Consolidated Index of Army Publications and Blank Forms*. A list of the current TBs covering Engineered Performance Standards (EPS) is given in Appendix C. Review this list to determine which TBs seem to address the task to be developed. The TBs can be obtained from your library or from:

Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

Once the TBs are available, the second step is to review the Table of Contents of each to determine if tasks related to the component are covered in the bulletin. If the tasks to be developed are covered by the bulletin, review the tasks to determine if the data given can be applied to the task under development. When tasks related to the new component tasks under development are not covered by EPS, other sources such as estimating books and manuals, national standards, trade publications, and manufacturer data must be researched. It is important to provide a complete list of such materials. A reference librarian can provide resources addressing a specific component.

In order to repair most light fixtures, the worker must first gain access to the fixture by removing the louver. One reference to this subtask is TB 420-6(PG 175), Task GT -307, -308, -309, Subtask 1, remove and reinstall louver, as duplicated in Table 4. The labor rate is given as .00410/hr/fixture.

The next step "Remove plus reinstall one tube" can be found in TB 420-6(PG 175), Task GT -309, Subtask 2. If we assume that a ladder will be needed, the labor rate will be .07120/hr/fixture.

TB 420-6 (PG 175) Task GT-309, Subtask 3, Lists the labor rate to remove old and reinstall new ballast in florescent fixture as .03560, to remove and .34840 to reinstall. The total labor rate for subtask 3 would be .38400/hr/fixture.

The final task is to test the newly installed light fixture. TB 420-6(pg 175) Task GT -309 Subtask 4, shows the labor rate as .01410/hr/fixture.

The total direct labor hours to perform the entire job would be the sum of all subtasks, or .47340 hr/fixture. The indirect time or the time to plan the work, load the truck at the beginning of the day, unload the truck at the end of the day, personal time, delay time, and material handling time must be included to obtain the total onsite labor time. In EPS, this value is expressed as a percentage of the direct labor. When all factors have been considered, the direct labor should be increased by 30 percent or .14202 hr/fixture.

Table 4

Task GT-309*

No.	Reference	Work Unit Description	Hours	Units
1	PWG-18-VI	Remove and install louver, glass or plastic diffuser	.00410	Fixture
2	PWG-18-II	Remove and reinstall 1 tube, including 2 fiber locks, using ladder	.02330 .04790	Fixture Fixture
3	PWMU-1-8374	Remove old and reinstall new ballast in flourescent fixture	.03560 .34840	Fixture Fixture
4	PWMU-1-8383	Test fixture	.01410	Fixture

*GT-309 = .47340 Hrs Per Fixture

The steering committee wanted to apply the same material costs for all planning, programming, design, construction, and operations activities. For this research project, all material costs were developed using prices in the Washington, DC area. Material prices for exact locations throughout the world can be obtained by multiplying the Washington, D.C. area costs by the appropriate location adjustment factor published in a Programming, Administration, and Execution System (PAX) Newsletter under the title "Area Cost Factor Indexes." A copy of the 22 September 1988 indexes are given in Appendix D, Geographical Location Adjustment Factors. The *CACES Unit Price Book* for Region II dated July 1, 1985 has been used for all costs and can be obtained from the Corps District Cost Estimating Section.

In reviewing material prices, there will usually be many grades listed for the component in question. Since only one entry for the component task will be made for the maintenance data base, it is important to use the middle grade for pricing. This will produce an average material cost.

When materials are not given in the CACES manuals, other material pricing manuals, such as Means, should be used to determine the cost.

The material cost for ballast, $50/ballast, was taken from *Means Electrical Cost Data* (p 191). Since only one material is involved, the material cost for ballast equals total cost

The normal equipment cost is for a maintenance truck with all required tools such as ladders and hand tools. The cost for the truck and equipment is usually based on task duration.

Task frequency determination is the most subjective area in the data base. Most frequencies must be determined by the judgment of professional maintenance personnel with many years of experience in performing the maintenance tasks. Some task frequencies are suggested by the manufacturer or professional organizations. Some frequencies, such as for interior wall painting, are set by regulations. There is very little published information in this area.

The data base has been reviewed by ten installation Directorates of Engineering and Housing (DEHs) and has been determined to accurately represent the resources required to perform the tasks. This data base serves as the foundation for the tables published in this report. The complete data base is too large to be duplicated in this report, but is available in the USACERL Special Report series titled *Maintenance Task Data Base for Buildings.*

The maintenance steering committee asked Forts Leonard Wood and Bragg to use the tasks to produce resource estimates for the past 3 years and then compare the predictions with their actual expenditures on a facility-by-facility basis. After this comparison was performed by both installations, the results were presented to the steering committee. Both installations stated that they were not performing all the tasks that they should, such as annual gutter cleaning and annual roof inspection. For the total installation, the tasks predicted an 8 to 10 percent higher total expenditure than the actual expenditure. This difference was due to the difference between the tasks predicted and actually performed. When comparisons were made at the task level, the task resource predictions were found to be accurate.

Two additional reviews were performed by two independent organizations that had related research work in the Army. The first review was for a research project to determine the maintenance requirements for historical family housing within the Military District of Washington, DC. The second review was a research project which needed an estimate of all resource requirements for the entire Army. This effort is known as the RPLANS research project. Both organizations reviewed the data base in detail and approved the resource requirements stated in the tasks. In addition, both used the data base within their research projects.

Significance of the Task Data

The task data presented in the previous section is based on average resources. Actual resource values for a particular project will vary as discussed below.

The labor hours reported will vary, depending on factors such as the actual productivity of the workers, the weather conditions, and the working space available. The labor hours given in this report are based on the average obtained from performing time and motion studies as tasks were performed.

The Washington, DC, material costs will vary, depending on factors such as the grade of material actually used, the manufacturer, and the quantity of material actually purchased. The figures given are the averages for all material prices found in the unit price books.

Task frequencies are the most subjective feature in the data base. High, average, and low frequency values are given to emphasize the variances. Average frequencies are used in developing the life-cycle analysis tables presented in the following sections.

Component Summary Tables

A typical component summary is shown in Table 2 (Chapter 1). The development process is illustrated by using the labor resource for the Mercury Vapor 175W Light Fixture.

All tasks related to the mercury vapor component are listed individually in Table 5, with a task summary in Table 6. The task average frequency is used to project times of occurrence of M&R tasks for the first 25-year period as shown in Table 7.

The first task (Task 1 - 1131411 -Maintenance and Repair) has an average frequency (AVE FREQ in Table 5) of 10.00 years; thus, it would be performed once every ten years. The labor hours (.615420 in Table 5) are listed for every ten years of the 25 years in the second column of Table 7.

The second task (Task 2 - 1131412 - Replacement of Lamp) has an average frequency from Table 5 of ten years; thus, it would be performed once every ten years. The labor hours (.068640 in Table 5) are listed for the year 10 in the third column of Table 7.

The third task (Task 3 - 1131413 - Replacement of Fixture) has an average frequency of 20 years; thus it would be performed one time. (Note that tasks 1 and 2 would not be performed in year 20.) The labor hours (.581620 in Table 5) are listed for the twentieth year in the fourth column of Table 7.

The total column in Table 7 is formed by adding the labor hours for tasks one through three on a year-by-year basis. For example, during the tenth year, Tasks one and two, are performed. The total labor hours would be .615420 and .068640 which equals .684060.

The total column in Table 7 is shown in Table 2, Typical Component Summary for Fixtures--1131410. The material costs and equipment hours have been developed in the same manner as explained for the labor hours.

Table 5

Tasks for a 175W Mercury Vapor Fixture

TASK DATA FORM

Task Code: 1131611

Component: MERCURY VAPOR FIXT, 175W, System: LIGHTING SYSTEM Subsystem: LIGHTING FIXTURES
Task Description: M/R MAINTENANCE AND REPAIR
Unit of Measure: COUNT Frequency of Occurrence: N: 5.00 A: 10.00 L: 20.00
Persons per Team: 1 Task Duration: 0.6154 hours Once every (N,A,L) years
Trade: ELECTRICAL, INT. Task Classification: 0

Labor Resources

Subtask Description	Labor Hrs
1.REMOVE AND REINSTALL LOUVER	0.004100
2.REMOVE AND REINSTALL 1 TUBE	0.071200
3.REMOVE OLD/REINSTALL BALLAST	0.384000
4.TEST FIXTURES	0.014100

Material Resources

Description	Quantity	Unit Cost
BALLAST	1	50.0000
		50.0000

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.473400	0.142020	0.615420
Material	Cost $	50.000000		50.000000
Equipment	Hours			0.615420

Components In This Task: 1131410

Table 5 (Cont'd)

TASK DATA FORM

Task Code: 1131412

Component: MERCURY VAPOR FIXT. 175W. System: LIGHTING SYSTEM Subsystem: LIGHTING FIXTURES
Task Description: M/R REPLACE LAMP
Unit of Measure: COUNT Frequency of Occurrence: H: 5.00 A: 10.00 L: 15.00
Persons per Team: 1 Task Duration: 0.0686 hours Once every (H,A,L) years
Trade: ELECTRICAL, INT. Task Classification: 0

Labor Resources

Subtask Description	Labor Hrs
1.CHANGE LAMP IN FLUSH FIXTURE	0.052800

Material Resources

Description	Quantity	Unit Cost
LAMP	1	27.0000
		27.0000

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.052800	0.015840	0.068640
Material	Cost $	27.000000		27.000000
Equipment	Hours			0.068640

Components In This Task: 1131410

TASK DATA FORM

Task Code: 1131413

Component: MERCURY VAPOR FIXT. 175W. System: LIGHTING SYSTEM Subsystem: LIGHTING FIXTURES
Task Description: REPLACE REPLACE FIXTURE
Unit of Measure: COUNT Frequency of Occurrence: H: 10.00 A: 20.00 L: 40.00
Persons per Team: 1 Task Duration: 0.5816 hours Once every (H,A,L) years
Trade: ELECTRICAL, INT. Task Classification: 1

Labor Resources

Subtask Description	Labor Hrs
1.TURN BRANCH CIRCUIT OFF AND ON	0.014700
2.INSTALL OUTLET BOX COVER PLATE	0.012900
3.CUT LEADS IN BOX AND TAPE ENDS	0.016600
4.DISASSEMBLE/REMOVE FIXTURES	0.090700
5.REMOVE AND UNPACK PARTS	0.030200
6.INSTALL MOUNTING BRACKETS	0.064300
7.ASSEMBLE AND HANG REFLECTOR	0.218600

Material Resources

Description	Quantity	Unit Cost
FIXTURE	1	127.0000
		127.0000

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.447400	0.134220	0.581620
Material	Cost $	127.000000		127.000000
Equipment	Hours			0.581620

Components In This Task: 1131410

Table 6

Task Summary Data for a 175W Mercury Vapor Fixture

Caces	Description	UM	TRD	Class	High Freq	Ave Freq	Low Freq	Labor Hours	Material Costs	Equip. Hours
1131101	MAINTENANCE AND REPAIR	1	2	0	10.00	20.00	30.00	.390000	10.000000	.390000
1131102	REPLACE LAMP	1	2	0	2.00	5.00	8.00	.068640	.900000	.068640
1131103	REPLACE LIGHTING FIXTURE	1	2	1	10.00	20.00	40.00	.448500	16.000000	.448500
4 2	1131200 QUARTZ LIGHTING FIXTURE									
1131201	MAINTENANCE AND REPAIR	1	2	0	5.00	10.00	20.00	.390000	1.160000	.390000
1131202	REPLACE LAMP	1	2	0	5.00	10.00	15.00	.032760	45.000000	.032760
1131203	REPLACE FIXTURE	1	2	1	10.00	20.00	40.00	.448500	55.000000	.448500
4 3	1131300 FLUORESCENT LIGHTING FIXTURE									
1131301	MAINTENANCE AND REPAIR	1	2	0	5.00	10.00	20.00	.615420	50.000000	.615420
1131302	REPLACE LAMPS (2)	1	2	0	5.00	10.00	15.00	.045890	4.500000	.045890
1131303	REPLACE FIXTURE	1	2	1	10.00	20.00	40.00	.741260	64.000000	.741260
4 4	1131400 HID									
5 1	1131410 HID, MERCURY VAPOR FIXTURES, 175W									
1131411	MAINTENANCE AND REPAIR	1	2	0	5.00	10.00	20.00	.615420	5.000000	.615420
1131412	REPLACE LAMP	1	2	0	5.00	10.00	15.00	.068640	27.000000	.068640
1131413	REPLACE FIXTURE	1	2	1	10.00	20.00	40.00	.581620	127.000000	.581620
5 2	1131420 HID, METAL HALID FIXTURE, 250W									
1131421	MAINTENANCE AND REPAIR	1	2	0	5.00	10.00	20.00	.615420	65.000000	.615420
1131422	REPLACE LAMP	1	2	0	3.00	5.00	8.00	.068640	40.000000	.068640
1131423	REPLACE FIXTURE	1	2	1	10.00	20.00	40.00	.435500	186.000000	.435500

Army Wide Task/Basic Task Structure List   Tree id: BF   Group id: B5

UM = Unit of Measure   TRD = Trade Index   Class = Task Classification   TWPMTH = Task Work Performance Method

Table 7

175W Mercury Vapor Spreadsheet - Labor Hours

Year	Task 1 1131411	Task 2 1131412	Task 3 1131413	Total Labor Hrs	10% P.W.F.	P.W. Labor Hours
1				0.000000	0.7164	0.000000
2				0.000000	0.6512	0.000000
3				0.000000	0.5920	0.000000
4				0.000000	0.5382	0.000000
5				0.000000	0.4893	0.000000
6				0.000000	0.4448	0.000000
7				0.000000	0.4044	0.000000
8				0.000000	0.3676	0.000000
9				0.000000	0.3342	0.000000
10	0.615420	0.068640		0.684060	0.3038	0.207817
11				0.000000	0.2762	0.000000
12				0.000000	0.2511	0.000000
13				0.000000	0.2283	0.000000
14				0.000000	0.2075	0.000000
15				0.000000	0.1886	0.000000
16				0.000000	0.1715	0.000000
17				0.000000	0.1559	0.000000
18				0.000000	0.1417	0.000000
19				0.000000	0.1288	0.000000
20			0.581620	0.581620	0.1171	0.068108
21				0.000000	0.1065	0.000000
22				0.000000	0.0968	0.000000
23				0.000000	0.0880	0.000000
24				0.000000	0.0800	0.000000
25				0.000000	0.0727	0.000000
					TOTAL	0.275925

The component data base is not printed in this report because of its size. Component summary data tables are published in the USACERL Special Report series titled *Maintenance Component Data Base for Buildings.*

Life-Cycle Cost Analysis Tables

The main purpose of this report is to provide the designer with easy-to-use tables for the most common life-cycle cost analysis. USACE designers frequently perform life-cycle cost analysis for a 25-year period using a 7 or 10 percent discount rate shown in Tables 8 and 9. Two sets of summary tables have been generated for these cases and are given in Appendices A and B. Table 3 shows typical life-cycle cost analysis data.

Present Worth. The left four columns of Table 3, labeled "Present Worth of All 25-Year Maintenance and Repair Costs," were developed by multiplying the resources in Table 2 by the 7 or 10 percent present worth factors shown in Tables 8 and 9. The 25 individual year resource figures are totaled as shown for labor in Table 7.

The 1988 Washington, DC area labor and equipment rates were applied to this data to produce the totals shown in the column so titled. This column is given to provide one comparative cost figure for easy computation. This column can be used to quickly assess the ranking of various components' total 25-year LCC.

Annual and High Cost. The right section of Table 3 is provided as input data for current life-cycle cost analysis computer programs. Two types of input are usually required: (1) a uniform or annual maintenance figure and (2) high-cost and replacement tasks that occur in specific years.

The data listed under the heading "Annual Maintenance and Repair" was generated by subtracting the present worth of the replacement task, if its occurrence is 25 years or less, and any high-cost tasks from the present worth values given in the "Present Worth" section of the table. The remaining present worth figures for the low-cost task resources are divided by the cumulative 25-year present worth figure to arrive at the "uniform" or "annual" maintenance figures shown under the "Annual Maintenance and Repair" heading.

There are two types of tasks listed under the heading "Replacement and High-Cost Tasks." The first is the replacement task. The replacement task is shown on the same line as the component description. For example, the replacement task for 175 Mercury Vapor Fixture, shown in Table 3 would occur when the fixture is 20 years old. Replacement would require the expenditure of .58162 hours of labor unit, $134.62 of material per unit, and .58162 hours of equipment (maintenance truck) per unit. The second type of task is the high-cost task. Each high-cost task is listed on a separate line below the component description line. There is no example of this here. High cost tasks are figured in the same manner as replacement tasks.

Table 8

7 Percent Discount Factors From Date of Study*

Years from BOD		End of Year	Accumulated End of Year
1		0.9346	0.9346
2		0.8734	1.8080
3		0.8163	2.6243
4		0.7629	3.3872
5		0.7130	4.1002
6		0.6663	4.7665
7		0.6227	5.3893
8		0.5820	5.9713
9		0.5439	6.5152
10		0.5083	7.0236
11		0.4751	7.4987
12		0.4440	7.9427
13		0.4150	8.3576
14		0.3878	8.7455
15		0.3624	9.1079
16		0.3387	9.4466
17		0.3166	9.7632
18		0.2959	10.0591
19		0.2765	10.3356
20		0.2584	10.5940
21		0.2415	10.8355
22		0.2257	11.0612
23		0.2109	11.2722
24		0.1971	11.4693
25	(Retention value at end of 25th year)	0.1842	11.6536

*Date of Study (DOS) is the Beneficial Occupancy Date (BOD)

Table 9

10 Percent Discount Factors From Date of Study*

Year from BOD	Factors Mid-Year	Factors End of Year	Accumulated Mid-Year
-3	0.9535		0.0
-2	0.8668		0.0
-1	0.7880		0.0
BOD			
1	0.7164		0.7164
2	0.6512		1.3676
3	0.5920		1.9596
4	0.5382		2.4978
5	0.4893		2.9871
6	0.4448		3.4319
7	0.4044		3.8362
8	0.3676		4.2038
9	0.3342		4.5380
10	0.3038		4.8418
11	0.2762		5.1180
12	0.2511		5.3691
13	0.2283		5.5973
14	0.2075		5.8048
15	0.1886		5.9935
16	0.1715		6.1650
17	0.1559		6.3209
18	0.1417		6.4626
19	0.1288		6.5914
20	0.1171		6.7086
21	0.1065		6.8150
22	0.0968		6.9118
23	0.0880		6.9998
24	0.0800		7.0799
25	0.0727		7.1526
Retention Value at End of 25th Year		0.0693	

*Date of Study (DOS) exactly 3 years before the Beneficial Occupancy Date (BOD).

4 DATA BASE APPLICATION EXAMPLES

Introduction

This chapter is divided into two sections. The first section defines the terminology used in the report and information needed to apply the labor hour, material cost and equipment hour resource data in this report. The second section gives specific examples using both the 10 percent present worth tables given in Appendix B and the 7 percent present worth tables given in Appendix A.

Terminology

Economic Studies

Two basic types of economic studies are covered in this report: (1) general economic studies and (2) special energy-conservation studies.

General economic studies are conducted routinely as part of the design process for all military facilities. Such studies are normally performed for a 25-year period using a 10 percent discount rate and considering tasks to be performed mid-year. The Beneficial Occupancy Date (BOD) occurs approximately three years after the Date of Study (DOS) for most MILCON projects, and that assumed in the example.

Special economic studies for the design of energy-consuming portions of a building are required by statute. Such studies analyze the use of extraordinary energy-saving design initiatives to conserve energy in new Federal facilities. The studies are normally performed for a 25-year period using a 7 percent discount rate considering all tasks to be performed at the end of the year. The BOD is normally assumed to occur on the DOS, in accordance with the provisions of the design criteria.

Installation Labor Rates

To perform an accurate cost analysis, the current shop effective labor rates and equipment rates per hour must be obtained from the installation. This information can be obtained from the DEH. Telephone numbers for the DEH are listed in the "Director of Engineering and Housing/Facilities, Engineer Assignments Roster" published yearly by the Office of the Chief of Engineers. Most installations maintain this information within their IFS data base; it can be obtained from the IFS data base administrator within the Management Engineering and Systems Branch.

Initial Costs

The initial construction costs can be obtained from the CACES Regional Unit Cost Manuals. The manuals are available from the district cost estimating section. When this manual is not available the cost estimates can be taken from other publications such as Means and Dodge.

Geographical Location Adjustment Factors

The Washington, DC-based material costs in the summary tables can be adjusted to a specific installation through the application of a geographical location adjustment factor. The factors are published in AR 415-17 and updates are available through the PAX computer system (Area Cost Factor Newsletter) and through the Engineering Improvement Recommendation System (EIRS) Bulletin. The 1988 set of factors is given in Appendix D.

Inflation Factors

The material costs and Washington, DC, total costs presented in Appendices A and B are in July 1988 dollars. The costs need to be adjusted to the date of study by applying an approved inflation factor obtained from the District cost estimating office.

Timing of Costs

Figure 1 shows the relationship of DOS, BOD, and the end of the study (EOS) which is assumed to be a 25-year comparison period:

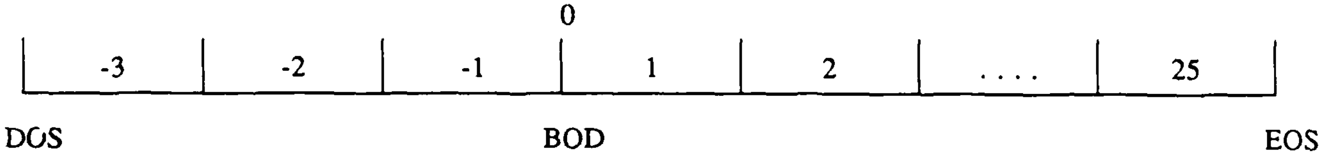

Figure 1. DOS, BOD, EOS relationship.

In Appendix B, costs are discounted 3 years from time of occurrence to DOS. M&R costs occur throughout a year and are costed at mid-year in accordance with established criteria for MILCON design. The basic present worth factor formula is:

$$PWF(BA) = \frac{1}{(1 + DR)^{(B + BA - C)}} \qquad \text{[Eq 1]}$$

where PWF = present worth factor
BA = building age
DR = discount rate
B = years from DOS to BOD
C = task placement, either .5 for mid-year, or 0 for end of year

The 10 percent present worth factor to bring costs from the mid-year of first year of occupancy to the DOS is $1/(1.1)^{3.5} = 0.7164$ which is the first value in Table 10. If the DOS is not 3 years before BOD, Appendix B data can be adjusted. For example, if there is only 1 year between BOD and DOS (two less than the 3 years in the appendices), multiply this data by $(1.1)^2$. If there are 5 years (2 years more than the 3 years in the appendices), divide by $(1.1)^2$.

In Appendix A, the DOS and BOD are identical. M&R costs are assumed to occur at the end of the year as stipulated by regulations. The basic formula is:

$$PWF(BA) = \frac{1}{(1 + DR)^{(BA)}} \qquad \text{[Eq 2]}$$

where PWF = present worth factor
BA = building age
DR = discount rate

Disposal Costs/Retention Value

When disposal costs/retention value is considered, it should be expressed as a percentage of the initial cost occurring at the end of the study period. The present worth of this value can be subtracted from the final net present worth.

Examples

Introduction

This section contains one example for each of the basic uses for this life-cycle cost data. The first example demonstrates the procedures for calculating LCC for construction and maintenance and repair data when the DOS is exactly 3 years before the BOD: the building is 25 years old at the end of the study and installation resource costs are available from the installation. The second example demonstrates the procedures for calculating LCC for construction and maintenance and repair data when resource costs are not available from the installation and Washington, DC, cost data is to be applied. Examples 3 and 4 show how to adjust data to cover the case for which BOD is not 3 years after DOS. Example 5 shows how to use the data to generate input for other computer programs. Example 6 demonstrates the use for a project containing an extraordinary energy-saving design initiative to conserve energy.

Each example is presented in five sections:

1. Statement of the problem.
2. Identification of all installation-related information.
3. Identification of all component-related information.
4. Description of the present worth calculations.
5. A typical calculation worksheet.

Example 1: BOD 3 Years After DOS--175W Mercury Vapor Fixture

Problem Statement. This example demonstrates all steps using a system of ten mercury vapor fixtures. An apartment building for family housing is under design at Fort Eustis, VA. The DOS is July 1989. The projected BOD is July 1992. A 25-year life-cycle cost analysis using a 10 percent discount rate is required.

Installation-Related Data.

Geographic Location Adjustment Factor. The geographic location adjustment factor (LAF) can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system, as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or Area Cost Factor [ACF] Index) is 0.96.

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the date of the study is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates. The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures the designer called the Fort Eustis DEH-ME branch. The July 1989 rates of $13.50 per hour for an electrician and $3.00 per hour for an electrician maintenance truck were obtained.

Component Information.

Size. The designer is considering a system of ten mercury vapor fixtures.

Initial Costs. The designer obtained a CACES unit price manual from the cost estimator. For the mercury vapor fixture component, a cost of $134.62 per unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual,* other books such as Means and Dodge can be used.)

Retention Value. The average life of a mercury vapor fixture is 20 years for the replacement task in Appendix B. At the end of the 25-year analysis period, the mercury vapor fixture would still have fifteen years of life remaining or 15/20 = 75 percent of its useful life. The retention value can be considered to be 75 percent of the initial cost of $134.62 per unit, or $100.965/per unit.

Present Worth Calculations. Three factors must be considered when performing a present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The average construction project would normally be completed in one year. The contractor normally receives progress payments for work completed throughout the construction period. The initial cost of $134.62/per unit is assumed to occur at the midpoint of construction during the year before BOD. The present worth factor at midyear for the year before BOD is given in Table 9 as 0.7880. The present worth of the initial cost would be the initial cost multiplied by the present worth factor at BOD or $134.62/unit x 0.7880 = $106.08/unit.

$$\$134.62 \times \$0.7880 = \$106.08/\text{unit} \qquad [\text{Eq } 2]$$

25-Year Maintenance Cost. The total 25-year maintenance cost is composed of three parts: labor, material, and equipment. Labor costs per unit are equal to the labor hours per unit obtained from Appendix B, multiplied by the installation labor hourly rate. This would be .27593 hr/unit multiplied by a labor rate of $13.50/hr, which is equal to $3.72506/unit.

$$\text{Labor} = .27593 \text{ hours/unit} \times \$13.50/\text{hr} = \$3.72506/\text{unit} \qquad [\text{Eq } 3]$$

Material costs per unit are equal to the material dollars in Washington, DC, base per unit obtained from Appendix B, multiplied by the geographic LAF from Appendix D and then multiplied by the inflation factor. This would be $40.56016 DC-based dollars per unit multiplied by a geographic LAF of 0.96 and a cost escalation factor (CEF) of 1.02 which is equal to $39.71651/unit.

$$\text{Material} = \$40.56016/\text{unit} \times 0.96 \times 1.02 = \$39.71651/\text{unit} \qquad [\text{Eq } 4]$$

Equipment costs per unit are equal to the equipment hours per unit obtained from Appendix B, multiplied by the installation equipment hourly rate. This would be .27593 hr/unit multiplied by an equipment rate of $3.00/hr which is equal to $.82779/unit.

Equipment = .27593 hr/unit x $3.00/hr = $.82779/unit [Eq 5]

The total maintenance cost per unit would be the labor cost ($3.72506/unit) plus the material cost ($39.71651/unit) plus the equipment cost ($.82779/unit) or $44.27/unit.

Total = $3.72506/unit+ $39.71651/unit + $.82779/unit = $44.27/unit [Eq 6]

This total has already been discounted to the DOS since all figures on the left side of the table in Appendix B are expressed in terms of the DOS.

Retention Value. The DOS present worth for the retention value would be the expected retention value of $100.965/unit multiplied by the end-of-year present worth factor for the end of study year (EOS) obtained from Table 9, 0.06930, which produces a cost of $7.00/unit.

Total Life Cycle Cost for Construction and Maintenance and Repair. The total life-cycle cost (LCC) per unit for the DOS is the sum of the present worth costs for the initial cost of $106.08/unit plus the 25-year maintenance cost of $44.26936/unit minus the retention value of $7.00/unit.

Total LCC = $106.08 + $44.27 - $7.00/unit = $143.35/unit [Eq 7]

The total dollar cost would be the LCC per unit of $143.35 multiplied by the 10 units producing a total cost of $1433.50.

Calculation Sheet. A typical calculation sheet is shown in Table 10.

Example 2: BOD 3 Years After DOS -- Washington, DC Rate Applied

Problem Statement. This example demonstrates all steps using a system of ten mercury vapor fixtures. An apartment building for family housing is under design at Fort Eustis, VA. The DOS is July 1989. The projected BOD is July 1992, three years after DOS. A 25-year life-cycle cost analysis using a 10 percent mid-year discount rate is required.

The designer wishes to perform a rougn cost estimate without calling the installation to obtain cost information. It should be understood that the installation's costs may vary significantly from the Washington, DC, costs and the rough calculations may be misleading. However, if the designer is going to compare several types of fixtures such as mercury vapor, metal halide, and flourescent all of which involve the identical trade such as an electrician—he comparisons may be quite accurate.

Installation-Related Data.

Geographic Location Adjustment Factor. The geographic LAF can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Table 10

Calculation Sheet - Example 1

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Cost	$134.62/unit			
PWF for BOD-1	x .7880			
Initial cost/unit			$106.08	
25-Year Maintenance Cost				
PW - Labor	.27593 hr/unit			
Labor Rate	x $13.50/hr			
Labor cost/unit		$3.73		
PW - Material	$40.56016/unit			
LAF	x .96			
CEF	x 1.02			
Material cost/unit		$39.72		
PW - Equipment	.27593 hr/unit			
Equipment Rate	x $3.00/hr			
Equipment cost/unit		$.83		
Maintenance cost/unit			$44.28	
Retention Value				
Initial Cost	$134.62/unit			
Remaining Life	x .75			
PWF for EOS	x .06930			
Retention Value cost/unit			-$7.00	
Life Cycle Cost/unit			$143.35	
Unit			x 10 unit	
Total Life Cycle Cost				$1433.50

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the DOS is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates. The designer wishes to perform a rough calculation using the Washington, DC, labor and equipment rates rather than calling the installation.

Component Information.

Size. The designer is considering a system of ten mercury vapor fixtures.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. For the mercury vapor fixture component, a cost figure of $134.62/unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a mercury vapor fixture unit is 20 years, as shown for the replacement task in Appendix B. At the end of the 25-year analysis period, the unit would still have 15 years of life remaining or 15/20 = 75 percent of its useful life. The retention value can be considered to be 75 percent of the initial cost of $134.62/per unit or $100.965/per unit.

Present Worth Calculations. Three factors need to be considered when performing a present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The average construction project would normally be completed in one year. The contractor normally receives progress payments for work completed throughout the construction period. The initial cost of $134.62/per unit is assumed to occur at the midpoint of construction during the year before BOD. The present worth factor at midyear for the year before BOD is given in Table 9 as 0.7880. The present worth of the initial cost would be the initial cost multiplied by the present worth factor at BOD or $134.62/unit x 0.7880 = $106.08/unit.

25-Year Maintenance Cost. The total 25-year maintenance cost for Fort Eustis can be calculated by taking the Washington, DC, total cost per unit, $47.64, and multiplying by the location adjustment factor (0.96) producing a cost of $45.73/unit.

Retention Value. The DOS present worth for the retention value would be the expected retention value of $100.965/ unit multiplied by the end of year present worth factor for the EOD obtained from Table 10, 0.06930, which produces a cost of $7.00/unit.

Total LCC for Construction and Maintenance and Repair. The total LCC per unit for the DOS is the sum of the present worth costs for the initial cost of $106.08/unit plus the 25-year maintenance cost of $45.73/unit minus the salvage value of $7.00/unit.

$$\text{Total LCC} = \$106.08/\text{unit} + \$45.73/\text{unit} - \$7.00/\text{unit} = \$144.81/\text{unit} \qquad \text{[Eq 13]}$$

The total dollar cost would be the LCC per unit, $144.81, multiplied by the number of units, 10, units, producing a total cost of $1448.10.

Calculation Sheet. A typical calculation sheet is shown in Table 11.

Example 3: DOS Less Than 3 Years Before BOD

Perform the calculations as shown in Examples 1 through 3. The answers are lower than the actual DOS answers. The calculated values must be adjusted by multiplying by the formula:

$$(1 + DR)^{(3-A)} \qquad \text{[Eq 14]}$$

where DR = discount rate
3 = years between DOS and BOD given in the tables
A = actual years between DOS and BOD

For example, using the answer of $1433.50 in Example 1 and assuming 1 year between BOD and DOS with discount rate = 10% (0.10), the formula would be $(1.10)^{(3-1)} = (1.1)^{(2)} = 1.21$. The correct answer would be $1433.50 x 1.21 = $1734.51

Example 4: DOS Greater Than 3 Years Before BOD

Perform the calculation as shown in Examples 1 and 2. The answers are larger than the actual DOS answers. The calculated values must be adjusted by dividing by the formula:

$$(1 + DR)^{(A-3)} \quad \text{[Eq 15]}$$

where DR = discount rate
3 = years between DOS and BOD given in the tables
A = actual years between DOS and BOD

For example, using the answer of $1433.50 in Example 1 and assuming 5 years between BOD and DOS with d = 10% (0.10), the formula would be $(1.10)^{(5-3)} = (1.10)^{(2)} = 1.21$. The correct answer would be $1433.50 ÷ 1.21 = $1184.71.

Table 11

Calculation Sheet - Example 2

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Cost	$134.62/unit			
PWF for BOD	x .7880			
Initial Cost/unit			$106.08/unit	
25-Year Maintenance Cost				
PW Total	$47.64/unit			
LAF	x .96			
Maintenance Cost/unit			$45.73/unit	
Retention Value				
Initial Cost	$134.62/unit			
Remaining Life	x .75			
PWF for EOS	x .06930			
Retention value/unit			-7.00/unit	
Life Cycle cost/unit			$144.81	
Units			x 10 units	
Total Life Cycle Cost				$1448.10

Example 5: Computer Input--BOD 3 Years After DOS Mercury Vapor

Problem Statement. This example demonstrates all steps using a system of ten mercury vapor fixtures. An apartment building for family housing is under design at Fort Eustis, VA. The BOD is July 1992. The DOS is 3 years before BOD or July 1989. A 25-year LCC analysis using a 10 percent discount rate is required. A computer program, such as the Corps' LCCID, that requires an annual maintenance figure and high cost tasks will be used.

Installation Related Data.

Geographic Location Adjustment Factor. The LAF can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the DOS is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all material costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates. The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures the designer called the Fort Eustis DEH-MES branch. The July 1989 rates of $13.50/hr for an electrician and $3.00/hr for a maintenance truck were obtained.

Component Information.

Size. The designer is considering a system of ten mercury vapors.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. By looking up the mercury vapors component, a cost of $134.62/per unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a mercury vapors is 20 years, as shown for the replacement table in Appendix B. At the end of the 25-year analysis period, the mercury vapor fixture would still have 15 years of life remaining or 15/20 = 75 percent of its useful life. The retention value can be considered to be 75 percent of the initial cost of $134.62/unit, or $100.97/unit.

Data Entry Calculations. Four factors need to be considered when performing a present worth calculation: initial cost, annual maintenance costs, high costs, and retention value. Each factor is discussed below.

Initial Costs. The initial cost of $134.62/unit is estimated from CACES as discussed above.

25-Year Maintenance Cost. The total annual 25-year maintenance cost is composed of three parts: labor, material, and equipment. Annual labor costs per unit is equal to the labor hours per units obtained from Appendix B, multiplied by the installation labor hourly rate. This would be .02905 hr/unit/yr multiplied by a labor rate of $13.50/hr, which is equal to $.39218/unit.

Labor = .02905 hr/unit/yr x $13.50/hr = $.39218/unit/yr [Eq 16]

Annual material costs per unit is equal to the material dollars in Washington, DC, base units obtained from Appendix B, multiplied by the geographic LAF from Appendix D, and then multiplied by the inflation factor. This would be $3.46673 DC-based dollars per unit multiplied by a geographic LAF of 0.96 and a CEF of 1.02, or $3.39462/per unit.

Material = $3.46673/unit/yr x 0.96 x 1.02 = $3.39/unit/yr [Eq 17]

Annual equipment costs per unit is equal to the equipment hours per unit obtained from Appendix B, multiplied by the installation equipment hourly rate. This would be .02905 hr/units multiplied by an equipment rate of $3.00/hr, which is equal to $.08715/units.

Equipment = .02905 hr/unit/yr x $3.00/hr = $.08715/unit/yr [Eq 18]

The total annual maintenance cost per unit would be the labor cost ($.39268/unit) plus the material cost ($3.39/unit), plus the equipment cost ($.08715/unit) or $3.88/unit

Total: $.39268/unit/yr + $3.39/unit/yr + $.08715/unit/yr = $3.88/unit/yr [Eq 19]

The total cost figure for the uniform maintenance cost for computer entry is obtained by multiplying the total of $3.88 by the ten units, resulting in an annual cost of $38.80.

Replacement/High Cost Tasks. There are no high-cost tasks for mercury vapor fixtures.

Replacement Task. The maintenance cost is composed of three parts: labor, material, and equipment. Labor costs per unit is equal to the labor hours per units obtained from Appendix B, multiplied by the installation labor hourly rate. This would be .58162 hr/unit/yr multiplied by a labor rate of $13.50/hr, which is equal to $7.85.

Labor = .58162 hr/unit/yr x $13.50/hr = $7.85/unit/yr [Eq 16]

Material costs per unit is equal to the material dollars in Washington, DC, base units obtained from Appendix B, multiplied by the geographic LAF from Appendix D, and then multiplied by the inflation factor. This would be $134.62000 DC-based dollars per unit multiplied by a geographic LAF of 0.96 and a CEF of 1.02, or $131.82 per unit.

Material = $134.62000/unit/yr x 0.96 x 1.02 = $131.82 [Eq 17]

Equipment costs per unit is equal to the equipment hours per unit obtained from Appendix B, multiplied by the installation equipment hourly rate. This would be .58162 hr/units multiplied by an equipment rate of $3.00/hr, which is equal to $1.74/units.

Equipment = .58162 hr/unit/yr x $3.00/hr = $1.74/unit/yr [Eq 18]

The replacement cost per unit would be the labor cost (7.85/unit) plus the material cost ($134.62/unit), plus the equipment cost ($1.74/unit) or $144.22/unit.

Total: $7.85/unit/yr + $134.62/unit/yr + $1.74/unit/yr = $144.22 [Eq 19]

Table 12

Calculation Sheet - Example 5

ANNUAL MAINTENANCE

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit
Initial Cost			
Initial Cost/unit	$134.62/unit		
Unit	x 10 unit		
Initial Cost			$1346.20
25-Year Annual Maintenance			
Labor hours/per unit	.02905 hr/unit		
Labor Rate	x $13.50/hr		
Labor cost/per unit		$.39218/unit	
Material/per unit	$3.46673/unit		
AF	x .96		
CEF	x 1.02		
Material cost/unit		3.39	
Equipment	.02905 hr/unit		
Equipment Rate	x $3.00/hr		
Equipment cost/unit		$.08715/unit	
Annual Maintenance/unit			$ 3.88
Units			x 10 units
TOTAL Annual Maintenance			$38.80
Replacement Task			
Labor hours/per unit	.58162 hr/unit		
Labor Rate	x $13.50/hr		
Labor cost/per unit		$7.85	
Material/per unit	134.62000		
AF	x .96		
CEF	x 1.02		
Material cost/unit		131.82	
Equipment	.58162 hr/unit		
Equipment Rate	x $3.00/hr		
Equipment cost/unit		$1.74	
Total Replacement/unit			$144.22
Units			x 10 units
TOTAL Replacement			$1442.20
Retention Value			
Initial Cost	$134.62/unit		
Remaining Life	x .75		
Retention Value		$100.97/unit	

Example 6: Extraordinary Energy-Saving Design Initiatives—Mercury Vapor Fixture

Problem Statement. This example demonstrates all steps involved in using the summary tables in Appendix A for the conventional mercury vapor fixture alternative. An apartment building for family housing is under design at Fort Eustis, VA. The designers are considering the use of a new-technology energy conserving, low maintenance unit. They will determine if it is more cost effective on the basis of a life-cycle cost analysis. The system contains ten mercury vapor units. The DOS is July 1989. The analysis period is 25 years. In accordance with established criteria for energy-conservation studies, the BOD is assumed to occur on the DOS (July 1989); all costs are assumed to occur at the end of the year in which they are projected to occur; and the discount rate for the present worth calculations is assumed to be seven percent.

Installation Related Data.

Geographic Location Adjustment Factor. The geographic LAF can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Inflation. The cost data in Appendix A is expressed in July 1988 dollars. Since the DOS is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates: The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures, the designer called the Fort Eustis DEH-MES branch. The July 1989 rates of $13.50 per hour for a electrician and $3.00 per hour for a maintenance truck were obtained.

Component Information.

Size. The designer is considering a system of ten mercury vapor fixtures.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. For the mercury vapor fixture component a cost figure of $134.62/unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a mercury vapor fixture is 20 years as shown for the replacement task in Appendix B. At the end of the 25-year analysis period, the mercury vapor fixture would still have 15 years of life remaining or 15/20 = 75 percent of its useful life. The retention value can be considered to be 75 percent of the initial cost of $134.62/unit or $100.965/unit.

Present Worth Calculations. The following factors are considered in performing the present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The initial cost of $134.62/unit is assumed to occur on the BOD/DOS in accordance with established criteria for energy conservation studies.

25-Year Maintenance Cost. The total 25-year maintenance cost is composed of three parts: labor, material, and equipment. Labor costs per unit is equal to the labor hours per units obtained from

Appendix A multiplied by the installation labor hourly rate. This would be .49800 hr/unit multiplied by a labor rate of \$13.50/hr which is equal to \$6.72/unit.

Labor = .49800 hours/units x \$13.50/hour = \$6.72/unit [Eq 24]

Material costs per unit are equal to the material dollars in Washington, DC, base per unit obtained from Appendix A multiplied by the geographic LAF from Appendix D and then multiplied by the inflation factor. This would be \$76.27325 DC-based dollars per unit multiplied by a geographic LAF of 0.96 and a CEF of 1.02, which is equal to \$74.69/unit.

Material = \$76.27325/unit x 0.96 x 1.02 = \$74.69/unit [Eq 25]

Equipment costs per unit are equal to the equipment hours per unit obtained from Appendix A multiplied by the installation equipment hourly rate. This would be .49800 hr/unit multiplied by an equipment rate of \$3.00/hr, which is equal to \$1.49/unit.

Equipment = .49800 hr/unit x \$3.00/hr = \$1.49/unit [Eq 26]

The total maintenance cost per unit would be the labor cost (\$6.72/unit) plus the material cost (\$74.69/unit) plus the equipment cost (\$1.49/unit) or \$82.90/unit.

Total = \$6.72/unit + \$74.69/unit + \$1.49/unit = \$82.90/unit [Eq 27]

This total has already been discounted to the date of study since all figures on the left side of the table in the Appendix are expressed in terms of the DOS.

Retention Value. The DOS present worth for the retention value would be the expected retention value of \$100.965/unit multiplied by the end of year present worth factor for the EOD of .1842 obtained from Table 9 which produces a cost of \$18.60/unit.

Total Life Cycle Cost for Construction and Maintenance and Repair. The total LCC per unit for the DOS is the sum of the present worth costs for the initial cost of \$134.62/unit plus the 25-year maintenance cost of \$82.90/unit minus the retention value of \$18.60/unit.

Total LCC = \$134.62/unit + \$82.90/unit - \$18.60/unit = \$198.92/unit [Eq 28]

The total dollar cost would be the LCC per unit of \$198.92 multiplied by the ten units producing a total cost of \$1989.20.

Calculation Sheet. A typical calculation sheet is shown in Table 13.

Table 13

Calculation Sheet - Example 6

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Cost			$134.62/unit	
25 Year Maintenance Cost				
PW - Labor	.49800 hr/unit			
Labor Rate	x $13.50/hr			
Labor cost/unit		$6.72/unit		
PW - Material	$76.27325/unit			
LAF	x .96			
CEF	x 1.02			
Material cost/unit		$74.69/unit		
PW - Equipment	.49800 hr/unit			
Equipment Rate	x $3.00/hr			
Equipment cost/unit		$1.49/unit		
Maintenance cost/unit		$82.90/unit		
Retention Value				
Initial Cost	$134.62/unit			
Remaining Life	x .75			
PWF for EOS	x .1842			
Retention value/unit			- 18.60/unit	
Life Cycle Cost/unit			$198.92/unit	
Units			x 10 unit	
TOTAL Life Cycle Cost				$1989.20

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LIST OF ACRONYMS

ACE	Assistant Chief of Engineers
AMS	Army Management System
APC	Account Processing Code
AR	Army Regulation
ARR	Annual Requirements Report
ASTM	American Society for Testing and Materials
BLAST	Building Loads Analysis and System Thermodynamics
BMAR	Backlog of Maintenance and Repair
CA	Commercial Activities
CACES	Computer-Assisted Cost Estimating System
CONUS	Continental United States
DA	Department of the Army
DEH	Directorate of Engineering and Housing
DOD	Department of Defense
EA	Economic Analysis
EPS	Engineered Performance Standards
HQ-IFS	Headquarters - Integrated Facilities System
HQDA	Headquarters Department of the Army
IFS	Integrated Facilities System
IJO	Individual Job Order
LCC	Life-Cycle Cost
LCCID	Life-Cycle Cost in Design
M&R	Maintenance and Repair
MACOM	Major Command

MCA	Military Construction, Army
MRPM	Maintenance Resource Prediction Model
OCE	Office of the Chief of Engineers
PAVER	Pavement Maintenance Management System
PC	Personal Computer
PM	Preventive Maintenance
R&D	Research and Development
RAM	Random Access Memory
RMF	Recurring Maintenance Factor
RPI	Real Property Inventory
RPLANS	Real Property Planning System
RPMS	Real Property Management System
SO	Service Order
STANFINS	Standard Army Financial System
TB	Technical Bulletin
URR	Unconstrained Requirements Report
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory
USAEHSC	U.S. Army Engineering and Housing Support Center

APPENDIX A:

LIFE-CYCLE COST ANALYSIS (7 PERCENT)

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d= 7%) By Resources labor	material	equipment	Washington D.C. Total	ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS Annual Maintenance and Repair labor	material	equipment	yr	Replacement and High Costs Tasks labor	material	equipment
ELECTRICAL												
SERVICE AND DIST.												
OVERHEAD SERVICE FEEDER												
OVERHEAD SERVICE, SPLICE	TF	6.17341	0.67957	6.17341	159.03	0.52974	0.05831	0.52974	30	21.91579	438.84000	10.95790
MAIN PROTECTION EQUIP.												
SWITCHGEAR, MAINFR.,1200a.	PC	21.22458	1478.10184	20.89701	2021.46	1.77913	97.60951	1.77913	20	1.90151	1318.11000	0.63384
FUSES	CT	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	50	0.40300	265.00000	0.40300
PRIMARY TRANSFORMERS												
TRANS.,LIQUID FILLED >600V	CT	11.95237	1450.67307	11.95237	1757.25	1.02564	124.48283	1.02564	30	15.99000	17307.68000	5.33000
TRANS.,DRY, > 15,000V.	CT	9.66892	9.60360	9.66892	257.61	0.82969	0.82409	0.82969	30	30.94000	20926.52000	10.31333
POWER PROTECTION EQUIP.												
SWITCHGEAR,INDOOR, < 600V.	PC	0.12611	2.64128	0.12611	5.88	0.01082	0.22665	0.01082	30	1.12476	122.69500	1.12476
SWITCHGEAR,INDOOR, > 600V.	PC	0.12611	6.70479	0.12611	9.94	0.01082	0.57534	0.01082	30	1.90151	177.28500	0.95076
SECONDARY TRANSFORMER												
TRANS.,LIQUID FILLED <600V	CT	15.38862	4.88130	15.38862	399.60	1.32050	0.41887	1.32050	50	2.62561	7645.78000	1.31281
TRANS.,DRY, < 15,000V.	CT	1.90566	60.95265	1.90566	109.83	0.16353	5.23037	0.16353	30	2.62561	4432.92000	1.31281
LIGHTING PROTECTION												
SWITCHGEAR,INDOOR, <600V.	PC	0.12611	2.64128	0.12611	5.88	0.01082	0.22665	0.01082	30	1.12424	122.69500	0.56212
SWITCHGEAR,INDOOR, > 600V.	PC	0.23123	10.15878	0.23123	16.09	0.01984	0.87173	0.01984	30	1.90151	177.28500	0.95076
POWER & LIGHTING DIST.												
CABLE,THRMPLST., <15,000V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	260	7.36281	76.32000	3.68141
CABLE,THRMSETT., <15,000V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	100	7.36268	108.12000	3.68134
CABLE,SHIELDED,<15,000V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	100	7.36281	343.44000	3.68141
CABLE,FLEX. METALIC <600V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	60	56.21200	595.72000	28.10600
BRANCH WIRING, < 600V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	50	10.35307	150.52000	5.17654
BRANCH WIRING, > 600V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	130	8.68608	50.88000	4.34304
BUSS DUCT	LF	0.13121	9.51816	0.08042	12.72	0.00451	0.00000	0.00353	20	0.30420	36.83500	0.15210
CONDUIT EMT	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	200	28.98259	1283.13000	14.49130
SPECIAL SYSTEMS												
METERS,DARS.,GALVANOMETER	CT	2.79334	680.07840	2.79334	751.73	0.21808	25.42896	0.21808	20	0.97500	1485.06000	0.97500
INVERTER	CT	116.08578	478.59042	87.66937	3365.26	9.91481	3.10938	7.49967	20	2.09950	1711.90000	1.04975
RECTIFIER, < 600V.	CT	74.79430	1071.26367	74.52304	2988.87	6.37158	77.35319	6.37158	20	2.09950	657.20000	1.04975
POWER SYSTEM												
SAFETY SWITCH												
SAFETY SWITCH, ENCLOSED	CT	9.75852	7.60897	9.70645	257.75	0.82845	0.00000	0.82845	25	0.56537	41.30820	0.28269
CIR. BKR.,M.C.< 599V 1P	CT	9.62426	0.00000	9.62426	246.86	0.82586	0.00000	0.82586	250	0.75049	212.00000	0.75049
CIR. BKR.,M.C.< 599V 2P	CT	9.62426	0.00000	9.62426	246.86	0.82586	0.00000	0.82586	250	0.75049	224.72000	0.75049
CIR. BKR.,M.C.<.599V 3P	CT	9.62426	0.00000	9.62426	246.86	0.82586	0.00000	0.82586	250	0.75049	73.14000	0.75049
CIR. BKR.,M.C.>\600V 1P	CT	15.69841	64.85362	15.69841	467.52	1.34709	5.56511	1.34709	200	0.97292	256.52000	0.97292
CIR. BKR.,M.C.> 600V 2P	CT	15.69841	64.85362	15.69841	467.52	1.34709	5.56511	1.34709	200	0.97292	572.40000	0.97292
CIR. BKR.,M.C.> 600V 3P	CT	15.69841	64.85362	15.69841	467.52	1.34709	5.56511	1.34709	200	0.97292	923.26000	0.97292
CIR. BKR.,FIXED <599V 1P	CT	4.69624	0.00000	4.69624	120.46	0.40299	0.00000	0.40299	250	0.75049	11.23600	0.75049
CIR. BKR.,FIXED <599V 2P	CT	4.69624	0.00000	4.69624	120.46	0.40299	0.00000	0.40299	250	0.75049	25.54600	0.75049
CIR. BKR.,FIXED <599V 3P	CT	4.69624	0.00000	4.69624	120.46	0.40299	0.00000	0.40299	250	0.75049	87.98000	0.75049
CIR. BKR.,FIXED >600V 1P	CT	18.01460	558.80179	18.01460	1020.88	1.49232	44.16060	1.49232	12	0.97292	68.90000	0.97292
CIR. BKR.,FIXED >600V 2P	CT	18.01460	679.08497	18.01460	1141.16	1.49232	44.16060	1.49232	12	0.97292	256.52000	0.97292
CIR. BKR.,FIXED >600V 3P	CT	18.06860	725.29546	18.06860	1188.76	1.49232	44.16060	1.49232	12	1.05716	328.60000	1.05716
SAFETY SWITCH, FUSED, 1P	CT	9.75852	2.92878	9.70645	253.07	0.82845	0.00000	0.82845	25	0.56537	15.90000	0.28269
SAFETY SWITCH, FUSED, 2P	CT	9.75852	8.20058	9.70645	258.34	0.82845	0.00000	0.82845	25	0.56537	44.52000	0.28269
SAFETY SWITCH, FUSED, 3P	CT	9.75852	18.54894	9.70645	268.69	0.82845	0.00000	0.82845	25	0.56537	100.70000	0.28269
LOW VOLTAGE CARTRIDGE	CT	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	50	0.06500	0.83740	0.06500
PLUG FUSE	CT	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	35	0.10400	0.31800	0.10400
MOTOR STARTER												
MOTOR STARTER, < 600V.	CT	18.51200	77.40421	18.51200	552.24	1.56724	4.08088	1.56724	18	0.83824	100.86960	0.83824
MOTOR STARTER,601-15,000V.	CT	51.71530	982.74307	51.58199	2308.81	4.41483	22.31793	4.41483	18	0.90103	2442.24000	0.45052
CONTACTORS AND RELAYS												
CONTACTORS AND RELAYS	CT	13.45261	111.61111	13.45261	456.67	1.13532	4.46359	1.13532	18	0.75049	201.40000	0.75049
RECEPTACLES AND PLUGS												

See NOTES on the last page of this table for Explanation of Column Headings

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d= 7%): By Resources labor	material	equipment	Washington D.C. Total	ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS: Annual Maintenance and Repair labor	material	equipment	yr	Replacement and High Costs Tasks labor	material	equipment
WIRING DEVICES, SWITCHES												
RECEPTACLES AND PLUGS	CT	0.51959	2.72600	0.51959	16.05	0.02974	0.09448	0.02974	15	0.47736	4.48380	0.47736
SWITCH, PULL CORD	CT	0.12335	1.52017	0.12335	4.68	0.00000	0.00000	0.00000	20	0.47736	5.88300	0.47736
	CT	1.00578	4.27053	1.00578	30.07	0.07146	0.22702	0.07146	15	0.47736	4.48380	0.47736
LIGHTING SYSTEM												
LIGHTING FIXTURES												
INCANDESCENT LIGHTING FIXT	CT	0.23724	6.06904	0.23724	12.15	0.01041	0.14473	0.01041	20	0.44850	16.96000	0.44850
QUARTZ FIXTURE	CT	0.33078	39.93564	0.33078	48.42	0.01844	2.13418	0.01844	20	0.44850	58.30000	0.44850
FLOUR. LIGHTING FIXT. 80W.	CT	0.63804	28.03642	0.63804	44.40	0.03831	0.90157	0.03831	20	0.74126	67.84000	0.74126
MERCURY VAPOR FIXT. 175W.	CT	0.49800	76.27325	0.49800	89.05	0.02984	3.56005	0.02984	20	0.58162	134.62000	0.58162
METAL-HALIDE FIXT. 175W.	CT	0.54670	160.92697	0.54670	174.95	0.03726	9.43750	0.03726	20	0.43550	197.16000	0.43550
EMERGENCY LIGHTING FIXT.	CT	1.37420	33.02878	1.37420	68.28	0.04812	0.60135	0.04812	20	3.14782	100.70000	3.14782
H.P. SODIUM FIXT. 250W.	CT	0.53060	306.81573	0.26530	319.58	0.03559	16.64441	0.01779	20	0.44850	436.72000	0.22425
L.P. SODIUM FIXT. 200W.	CT	0.53060	187.87472	0.26530	200.64	0.03559	8.55338	0.01779	20	0.44850	341.32000	0.22425
EXIT LIGHT	CT	0.23724	11.91146	0.23724	18.00	0.01041	0.72363	0.01041	20	0.44850	13.46200	0.44850
GROUNDING SYSTEM												
ELECTRICAL SERVICE GRD.												
ELECTRICAL SERVICE GROUND	TF	0.19430	0.43346	0.19430	5.42	0.01667	0.03720	0.01667	50	11.97118	320.33200	11.97118
BLDG. STRUCTURE GROUND												
BUILDING STRUCTURE GROUND	TF	1.32063	2.94621	1.32063	36.82	0.11332	0.25282	0.11332	150	11.97118	383.93200	11.97118
LIGHTNING PROTECTION												
LIGHTNING PROTECTION SYS.	TF	11.91446	178.57657	10.85286	480.79	0.84019	2.99733	0.84019	25	11.52658	779.84200	5.76329
LIGHTNING GR. ROD	CT	12.57665	45.77422	12.33719	367.60	1.03811	3.70339	1.03811	25	2.60000	14.20400	1.30000
COMPUTER GROUND SYSTEM												
COMPUTER GROUND SYSTEM	TF	0.68134	3.72380	0.68134	21.20	0.05847	0.31954	0.05847	60	7.03300	99.21600	7.03300
SPECIAL GROUND SYSTEM												
SPECIAL GROUND SYSTEM	TF	0.68134	3.72380	0.68134	21.20	0.05847	0.31954	0.05847	60	7.03300	99.21600	3.51650

See NOTES on the last page of this table for Explanation of Column Headings

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d= 7%): By Resources: labor	material	equipment	Washington D.C. Total	ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS: Annual Maintenance and Repair: labor	material	equipment	Replacement and High Costs Tasks: yr	labor	material	equipment
ELECTRICAL												
SOUND SYSTEM												
TELEPHONE SYSTEM												
4-PIN RECEPTACLE	CT	0.51356	1.18885	0.51356	14.36	0.02620	0.04161	0.02620	20	0.80600	2.72420	0.80600
TELEPHONE CABLE	TF	0.61613	0.49764	0.61613	16.30	0.05287	0.04270	0.05287	50	13.54730	299.45000	6.77365
DOOR BELL												
DOOR BELL	CT	5.29744	20.08573	5.29744	155.96	0.35351	0.50391	0.35351	15	3.25000	39.22000	3.25000
ALARM SYSTEM												
FIRE ALARM SYSTEM												
MANUAL PULL STATION	CT	0.46280	15.14801	0.46280	27.02	0.03090	0.04724	0.03090	15	0.28340	40.28000	0.28340
SMOKE DETECTOR	CT	2.71209	30.26178	2.71209	99.83	0.21983	0.15747	0.21983	15	0.41470	78.44000	0.41470
FIRE ALARM BELL	CT	0.07424	9.03883	0.07424	10.94	0.00000	0.00000	0.00000	20	0.28730	34.98000	0.28730
ANNUNCIATION PANEL	CT	13.06000	159.33655	13.06000	494.33	1.06591	3.78367	1.06591	15	1.76150	318.00000	1.76150
HEAT DETECTOR	CT	2.71209	10.60196	2.71209	80.17	0.21983	0.28345	0.21983	15	0.41470	20.14000	0.41470
FIRE ALARM CONT. PANEL	CT	13.06000	351.40855	13.06000	686.40	1.06591	3.78367	1.06591	15	1.76150	848.00000	1.76150
TELEVISION SYSTEM												
TELEVISION SYSTEM												
TV CABLE OUTLET	CT	0.51356	3.90872	0.51356	17.08	0.02620	0.04161	0.02620	20	0.80600	13.25000	0.80600
CONTROL SYSTEM												
CONTROL SYSTEM												
LIGHT DIMMING PANEL	CT	4.98708	157.7666	4.98708	285.69	0.37316	5.29713	0.37316	15	1.76150	265.00000	1.76150
TIME SYSTEMS												
CLOCK & PROGRAM SYSTEM												
TIME CONTROL CLOCK	CT	5.13510	31.72488	5.13510	163.44	0.39213	0.78736	0.39213	15	1.56000	62.22200	1.56000
ELECTIC HEATING SYSTEM												
BASEBOARD HEATING UNIT.												
BASEBOARD HEATING UNITS	CT	28.88241	61.35450	28.88241	802.19	2.42298	0.00000	2.42298	20	2.49990	237.44000	2.49990
WALL AND CEILING HEATERS												
WALL MTD./RECESS.,WITH FAN	CT	14.90168	101.19661	14.90168	483.42	1.22329	5.62823	1.22329	20	2.49990	137.80000	2.49990
RADIANT SUSPENDED, COMM.	CT	29.01712	96.03600	29.01712	840.33	2.41223	0.00000	2.41223	15	2.49990	265.00000	2.49990
INFARED SUSPENDED, COMM.	CT	32.52246	61.07890	32.52246	895.28	2.71302	0.00000	2.71302	15	2.49990	168.54000	2.49990
INDUSTRIAL HEATERS.												
STANDARD SUSPENDED HEATER	CT	29.01712	240.57760	29.01712	984.87	2.41223	12.40317	2.41223	15	2.49990	265.00000	2.49990
EXPLOSION PROOF INDUSTRIAL	CT	29.01712	481.15520	29.01712	1225.44	2.41223	24.80634	2.41223	15	2.49990	530.00000	2.49990
DUCT HEATER												
DUCT HEATER	CT	32.52246	699.44227	32.52246	1533.64	2.71302	51.35000	2.71302	15	2.49990	278.78000	2.49990
POWER GENERATION SYSTEM												
ENGINE GENERATOR SETS												
GEN. GASOLINE, 1000KW.	CT	161.61327	39050.40000	135.82343	43113.25	9.44203	0.00000	9.44203	25	280.02000	212000.00000	140.01000
GENERATOR, DIESEL, 1000KW.	CT	161.61327	39050.40000	122.92851	43071.99	9.44203	0.00000	9.44203	25	280.02000	212000.00000	70.00500
GEN., VAPOR GAS, 1000KW.	CT	161.61327	39050.40000	122.92851	43071.99	9.44203	0.00000	9.44203	25	280.02000	212000.00000	70.00500
GEN., STEAM TURBINE 1000KW	CT	147.05410	48813.00000	119.28872	52496.09	9.44203	0.00000	9.44203	25	200.98000	265000.00000	50.24500
GEN., GAS TURBINE, 1000KW.	CT	183.71543	48813.00000	146.87451	53407.41	9.44203	0.00000	9.44203	25	400.01000	265000.00000	200.00500
TRANSFER SWITCH	CT	9.61259	167.16921	9.61259	413.73	0.80581	2.44853	0.80581	18	0.75023	468.52000	0.75023
UNINTERRUPT.POWER SOURCE												
STATIC - CHARGER, BATTERY	CT	74.79430	282.98555	74.79430	2201.46	6.37158	11.05046	6.37158	20	2.09950	596.78000	2.09950
MOTOR - GENERATOR, BATTERY	CT	89.95580	747.87876	89.95580	3055.24	7.55339	58.53900	7.55339	15	5.33000	181.26000	5.33000
EMERGENCY BATTERY SYS.												
BATTERY, PRIMARY WET	CT	283.63804	203.17550	283.63804	7478.49	24.31283	0.00000	24.31283	10	0.39910	265.00000	0.39910
BATTERY, PRIMARY DRY	CT	58.62786	107.39390	58.62786	1611.20	4.96148	0.00000	4.96148	5	0.39910	53.00000	0.39910
BATTERY, SECONDARY WET	CT	283.63804	284.44570	283.63804	7559.76	24.31283	0.00000	24.31283	10	0.39910	371.00000	0.39910
BATTERY, SECONDARY DRY	CT	58.62786	214.78780	58.62786	1718.59	4.96148	0.00000	4.96148	5	0.39910	106.00000	0.39910

See NOTES on the last page of this table for Explanation of Column Headings

Notes

1. The resources listed in this table are as of the Date of Study (DOS) and have been calculated using a present worth discount factor (d) of 7 percent. The Date of Study (DOS) is the Beneficial Occupancy Date (BOD). All tasks are assumed to occur at the end of the year. All resources have been assumed to be constant with no differential escalation from year to year.

2. Component Description - This column contains an indented list of systems, subsystems, components, and high cost task descriptions.

3. Unit of Measure (UM) - This column contains a two-character code to indicate the measurement unit for the component. Units used in this column are as follows:

CT	Count
LF	Linear Foot
SF	Square Foot
TF	Thousands of Linear Feet

4. Labor - Labor resources can be used in one of two ways: (1) labor hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr labor rate.

5. Materials - Material resources are expressed in dollars per unit of measure in July 1988 dollars for the Washington, DC, area.

6. Equipment - Equipment resources can be used in one of two ways: (1) equipment hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr equipment rate.

7. Washington, DC, Total - The dollars per unit of measure figures were calculated by applying the Military District of Washington labor and equipment rates to the labor and equipment resources, then adding the labor, material, and equipment costs together to form one total cost figure.

8. Year (YR) - This column contains the average age of the component when the high cost task or replacement task would be performed.

9. Engineered Performance Standards (EPS) - Most labor and equipment resource data is based on the DOD series of Technical Bulletins as discussed in the body of the report.

APPENDIX B:

LIFE-CYCLE COST ANALYSIS (10 PERCENT)

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d=10%) By Resources labor	material	equipment	Washington D.C. Total	ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS Annual Maintenance and Repair labor	material	equipment	Replacement and High Costs Tasks yr	labor	material	equipment
ELECTRICAL												
SERVICE AND DIST.												
OVERHEAD SERVICE FEEDER												
OVERHEAD SERVICE, SPLICE	TF	3.26955	0.35097	3.26955	84.21	0.45711	0.04907	0.45711	30	21.91579	438.84000	10.95790
MAIN PROTECTION EQUIP.												
SWITCHGEAR, MAINFR.,1200a.	PC	12.77505	832.77273	12.62660	1159.98	1.75494	94.84971	1.75494	20	1.90151	1318.11000	0.63384
FUSES	CT	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	50	0.40300	265.00000	0.40300
PRIMARY TRANSFORMERS												
TRANS.,LIQUID FILLED >600V	CT	7.14243	796.38489	7.14243	979.59	0.99858	111.34201	0.99858	30	15.99000	17307.68000	5.33000
TRANS.,DRY, > 15,000V.	CT	5.86869	4.99790	5.86869	155.53	0.82050	0.69875	0.82050	30	30.94000	20926.52000	10.31333
POWER PROTECTION EQUIP.												
SWITCHGEAR,INDOOR, < 600V.	PC	0.07158	1.45000	0.07158	3.29	0.01001	0.20272	0.01001	30	1.12476	122.69500	1.12476
SWITCHGEAR,INDOOR, > 600V.	PC	0.07158	3.68077	0.07158	5.52	0.01001	0.51461	0.01001	30	1.90151	177.28500	0.95076
SECONDARY TRANSFORMER												
TRANS.,LIQUID FILLED <600V	CT	9.39289	1.92655	9.39289	242.85	1.31321	0.26935	1.31321	50	2.62561	7645.78000	1.31281
TRANS.,DRY, < 15,000V.	CT	1.10507	33.46155	1.10507	61.81	0.15450	4.67824	0.15450	30	2.62561	4432.92000	1.31281
LIGHTING PROTECTION												
SWITCHGEAR,INDOOR, <600V.	PC	0.07158	1.45000	0.07158	3.29	0.01001	0.20272	0.01001	30	1.12424	122.69500	0.56212
SWITCHGEAR,INDOOR, > 600V.	PC	0.13676	5.57693	0.13676	9.08	0.01912	0.77971	0.01912	30	1.90151	177.28500	0.95076
POWER & LIGHTING DIST.												
CABLE,THRMPLST., <15,000V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	260	7.36281	76.32000	3.68141
CABLE,THRMSETT., <15,000V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	100	7.36268	108.12000	3.68134
CABLE,SHIELDED,<15,000V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	100	7.36281	343.44000	3.68141
CABLE,FLEX. METALIC <600V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	60	56.21200	595.72000	28.10600
BRANCH WIRING, < 600V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	50	10.35307	150.52000	5.17654
BRANCH WIRING, > 600V.	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	130	8.68608	50.88000	4.34304
BUSS DUCT	LF	0.06762	4.31338	0.04296	5.97	0.00447	0.00000	0.00352	20	0.30420	36.83500	0.15210
CONDUIT EMT	TF	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	200	28.98259	1283.13000	14.49130
SPECIAL SYSTEMS												
METERS,DARS.,GALVANOMETER	CT	1.63311	351.01593	1.63311	392.91	0.21236	24.76238	0.21236	20	0.97500	1485.06000	0.97500
INVERTER	CT	71.58582	222.83638	54.08521	2003.01	9.97399	3.12794	7.54443	20	2.09950	1711.90000	1.04975
RECTIFIER, < 600V.	CT	46.06894	632.31989	45.94601	1813.59	6.40649	77.64474	6.40649	20	2.09950	657.20000	1.04975
POWER SYSTEM												
SAFETY SWITCH												
SAFETY SWITCH, ENCLOSED	CT	5.96532	3.00311	5.94477	155.95	0.82826	0.00000	0.82826	25	0.56537	41.30820	0.28269
CIR. BKR.,M.C.< 599V 1P	CT	5.87003	0.00000	5.87003	150.57	0.82069	0.00000	0.82069	250	0.75049	212.00000	0.75049
CIR. BKR.,M.C.< 599V 2P	CT	5.87003	0.00000	5.87003	150.57	0.82069	0.00000	0.82069	250	0.75049	224.72000	0.75049
CIR. BKR.,M.C.< 599V 3P	CT	5.87003	0.00000	5.87003	150.57	0.82069	0.00000	0.82069	250	0.75049	73.14000	0.75049
CIR. BKR.,M.C.> 600V 1P	CT	9.53117	35.60309	9.53117	280.08	1.33255	4.97764	1.33255	200	0.97292	256.52000	0.97292
CIR. BKR.,M.C.> 600V 2P	CT	9.53117	35.60309	9.53117	280.08	1.33255	4.97764	1.33255	200	0.97292	572.40000	0.97292
CIR. BKR.,M.C.> 600V 3P	CT	9.53117	35.60309	9.53117	280.08	1.33255	4.97764	1.33255	200	0.97292	923.26000	0.97292
CIR. BKR.,FIXED <599V 1P	CT	2.88250	0.00000	2.88250	73.94	0.40300	0.00000	0.40300	250	0.75049	11.23600	0.75049
CIR. BKR.,FIXED <599V 2P	CT	2.88250	0.00000	2.88250	73.94	0.40300	0.00000	0.40300	250	0.75049	25.54600	0.75049
CIR. BKR.,FIXED <599V 3P	CT	2.88250	0.00000	2.88250	73.94	0.40300	0.00000	0.40300	250	0.75049	87.98000	0.75049
CIR. BKR.,FIXED >600V 1P	CT	11.07697	339.32879	11.07697	623.45	1.50363	44.25188	1.50363	12	0.97292	68.90000	0.97292
CIR. BKR.,FIXED >600V 2P	CT	11.07697	401.44977	11.07697	685.57	1.50363	44.25188	1.50363	12	0.97292	256.52000	0.97292
CIR. BKR.,FIXED >600V 3P	CT	11.10486	425.31546	11.10486	710.16	1.50363	44.25188	1.50363	12	1.05716	328.60000	1.05716
SAFETY SWITCH, FUSED, 1P	CT	5.96532	1.15593	5.94477	154.10	0.82826	0.00000	0.82826	25	0.56537	15.90000	0.28269
SAFETY SWITCH, FUSED, 2P	CT	5.96532	3.23660	5.94477	156.18	0.82826	0.00000	0.82826	25	0.56537	44.52000	0.28269
SAFETY SWITCH, FUSED, 3P	CT	5.96532	7.32089	5.94477	160.27	0.82826	0.00000	0.82826	25	0.56537	100.70000	0.28269
LOW VOLTAGE CARTRIDGE	CT	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	50	0.06500	0.83740	0.06500
PLUG FUSE	CT	0.00000	0.00000	0.00000	0.00	0.00000	0.00000	0.00000	35	0.10400	0.31800	0.10400
MOTOR STARTER												
MOTOR STARTER, < 600V.	CT	11.31886	42.64027	11.31886	332.97	1.56588	3.96318	1.56588	18	0.83824	100.86960	0.83824
MOTOR STARTER,601-15,000V.	CT	31.73766	504.84281	31.67382	1318.71	4.41937	22.19856	4.41937	18	0.90103	2442.24000	0.45052
CONTACTORS AND RELAYS												
CONTACTORS AND RELAYS	CT	8.21560	60.29386	8.21560	271.02	1.13375	4.43971	1.13375	18	0.75049	201.40000	0.75049
RECEPTACLES AND PLUGS												

See NOTES on the last page of this table for Explanation of Column Headings

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)

COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d=10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS						
		By Resources			Washington	Annual Maintenance and Repair			Replacement and High Costs Tasks			
	um	labor	material	equipment	D.C. Total	labor	material	equipment	yr	labor	material	equipment
WIRING DEVICES, SWITCHES												
RECEPTACLES AND PLUGS	CT	0.27847	1.44428	0.27847	8.59	0.02635	0.08369	0.02635	15	0.47736	4.48380	0.47736
SWITCH, PULL CORD	CT	0.05590	0.68890	0.05590	2.12	0.00000	0.00000	0.00000	20	0.47736	5.88300	0.47736
	CT	0.58197	2.40846	0.58197	17.34	0.06878	0.21850	0.06878	15	0.47736	4.48380	0.47736
LIGHTING SYSTEM												
LIGHTING FIXTURES												
INCANDESCENT LIGHTING FIXT	CT	0.12489	2.99191	0.12489	6.20	0.01012	0.14063	0.01012	20	0.44850	16.96000	0.44850
QUARTZ FIXTURE	CT	0.18095	21.69174	0.18095	26.33	0.01796	2.07824	0.01796	20	0.44850	58.30000	0.44850
FLOUR. LIGHTING FIXT. 80W.	CT	0.35366	14.22361	0.35366	23.30	0.03731	0.87794	0.03731	20	0.74126	67.84000	0.74126
MERCURY VAPOR FIXT. 175W.	CT	0.27593	40.56016	0.27593	47.64	0.02905	3.46673	0.02905	20	0.58162	134.62000	0.58162
METAL-HALIDE FIXT. 175W.	CT	0.31034	88.72582	0.31034	96.69	0.03626	9.17686	0.03626	20	0.43550	197.16000	0.43550
EMERGENCY LIGHTING FIXT.	CT	0.71046	16.09790	0.71046	34.32	0.04779	0.60201	0.04779	20	3.14782	100.70000	3.14782
H.P. SODIUM FIXT. 250W.	CT	0.30038	167.06999	0.15019	174.29	0.03465	16.20810	0.01733	20	0.44850	436.72000	0.22425
L.P. SODIUM FIXT. 200W.	CT	0.30038	99.54375	0.15019	106.77	0.03465	8.32916	0.01733	20	0.44850	341.32000	0.22425
EXIT LIGHT	CT	0.12489	6.60589	0.12489	9.81	0.01012	0.70317	0.01012	20	0.44850	13.46200	0.44850
GROUNDING SYSTEM												
ELECTRICAL SERVICE GRD.												
ELECTRICAL SERVICE GROUND	TF	0.07669	0.17108	0.07669	2.14	0.01072	0.02392	0.01072	50	11.97118	320.33200	11.97118
BLDG. STRUCTURE GROUND												
BUILDING STRUCTURE GROUND	TF	0.75778	1.69054	0.75778	21.13	0.10595	0.23635	0.10595	150	11.97118	383.93200	11.97118
LIGHTNING PROTECTION												
LIGHTNING PROTECTION SYS.	TF	6.79255	77.93702	6.37356	250.83	0.83250	2.96990	0.83250	25	11.52658	779.84200	5.76329
LIGHTNING GR. ROD	CT	7.65704	27.67429	7.56253	223.77	1.04410	3.72475	1.04410	25	2.60000	14.20400	1.30000
COMPUTER GROUND SYSTEM												
COMPUTER GROUND SYSTEM	TF	0.40238	2.19916	0.40238	12.52	0.05626	0.30746	0.05626	60	7.03300	99.21600	7.03300
SPECIAL GROUND SYSTEM												
SPECIAL GROUND SYSTEM	TF	0.40238	2.19916	0.40238	12.52	0.05626	0.30746	0.05626	60	7.03300	99.21600	3.51650

See NOTES on the last page of this table for Explanation of Column Headings

COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d=10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS						
		By Resources			Washington	Annual Maintenance and Repair			Replacement and High Costs Tasks			
	um	labor	material	equipment	D.C. Total	labor	material	equipment	yr	labor	material	equipment
ELECTRICAL												
SOUND SYSTEM												
TELEPHONE SYSTEM												
4-PIN RECEPTACLE	CT	0.27684	0.60883	0.27684	7.71	0.02551	0.04052	0.02551	20	0.80600	2.72420	0.80600
TELEPHONE CABLE	TF	0.34125	0.27562	0.34125	9.03	0.04771	0.03853	0.04771	50	13.54730	299.45000	6.77365
DOOR BELL												
DOOR BELL	CT	3.12098	10.58961	3.12098	90.64	0.35065	0.44637	0.35065	15	3.25000	39.22000	3.25000
ALARM SYSTEM												
FIRE ALARM SYSTEM												
MANUAL PULL STATION	CT	0.24923	7.89613	0.24923	14.29	0.02737	0.04185	0.02737	15	0.28340	40.28000	0.28340
SMOKE DETECTOR	CT	1.63197	15.79151	1.63197	57.65	0.21723	0.13949	0.21723	15	0.41470	78.44000	0.41470
FIRE ALARM BELL	CT	0.03364	4.09616	0.03364	4.96	0.00000	0.00000	0.00000	20	0.28730	34.98000	0.28730
ANNUNCIATION PANEL	CT	7.97600	86.02165	7.97600	290.61	1.06867	3.64159	1.06867	15	1.76150	318.00000	1.76150
HEAT DETECTOR	CT	1.63197	5.59431	1.63197	47.45	0.21723	0.25108	0.21723	15	0.41470	20.14000	0.41470
FIRE ALARM CONT. PANEL	CT	7.97600	185.97965	7.97600	390.56	1.06867	3.64159	1.06867	15	1.76150	848.00000	1.76150
TELEVISION SYSTEM												
TELEVISION SYSTEM												
TV CABLE OUTLET	CT	0.27684	1.84140	0.27684	8.94	0.02551	0.04052	0.02551	20	0.80600	13.25000	0.80600
CONTROL SYSTEM												
CONTROL SYSTEM												
LIGHT DIMMING PANEL	CT	2.99674	86.44459	2.99674	163.31	0.37252	5.09823	0.37252	15	1.76150	265.00000	1.76150
TIME SYSTEMS												
CLOCK & PROGRAM SYSTEM												
TIME CONTROL CLOCK	CT	3.04697	16.72369	3.04697	94.88	0.38486	0.69746	0.38486	15	1.56000	62.22200	1.56000
ELECTRIC HEATING SYSTEM												
BASEBOARD HEATING UNIT.												
BASEBOARD HEATING UNITS	CT	17.72250	27.80422	17.72250	482.39	2.43684	0.00000	2.43684	20	2.49990	237.44000	2.49990
WALL AND CEILING HEATERS												
WALL MTD./RECESS.,WITH FAN	CT	9.05842	55.25462	9.05842	287.60	1.22552	5.46909	1.22552	20	2.49990	137.80000	2.49990
RADIANT SUSPENDED, COMM.	CT	17.78115	49.97900	17.78115	506.07	2.42005	0.00000	2.42005	15	2.49990	265.00000	2.49990
INFARED SUSPENDED, COMM.	CT	19.97207	31.78664	19.97207	544.07	2.72636	0.00000	2.72636	15	2.49990	168.54000	2.49990
INDUSTRIAL HEATERS.												
STANDARD SUSPENDED HEATER	CT	17.78115	137.85565	17.78115	593.94	2.42005	12.28597	2.42005	15	2.49990	265.00000	2.49990
EXPLOSION PROOF INDUSTRIAL	CT	17.78115	275.71130	17.78115	731.80	2.42005	24.57195	2.42005	15	2.49990	530.00000	2.49990
DUCT HEATER												
DUCT HEATER	CT	19.97207	421.66991	19.97207	933.95	2.72636	51.60249	2.72636	15	2.49990	278.78000	2.49990
POWER GENERATION SYSTEM												
ENGINE GENERATOR SETS												
GEN.,GASOLINE,1000KW.	CT	88.28201	15412.40000	78.10329	17644.26	9.49649	0.00000	9.49649	25	280.02000	212000.00000	140.01000
GENERATOR, DIESEL, 1000KW.	CT	88.28201	15412.40000	73.01392	17627.98	9.49649	0.00000	9.49649	25	280.02000	212000.00000	70.00500
GEN., VAPOR GAS, 1000KW.	CT	88.28201	15412.40000	73.01392	17627.98	9.49649	0.00000	9.49649	25	280.02000	212000.00000	70.00500
GEN., STEAM TURBINE,1000KW	CT	82.53581	19265.50000	71.57737	21347.48	9.49649	0.00000	9.49649	25	200.98000	265000.00000	50.24500
GEN., GAS TURBINE, 1000KW.	CT	97.00529	19265.50000	82.46492	21707.16	9.49649	0.00000	9.49649	25	400.01000	265000.00000	200.00500
TRANSFER SWITCH	CT	5.80406	83.39751	5.80406	232.27	0.79660	2.37791	0.79660	18	0.75023	468.52000	0.75023
UNINTERRUPT.POWER SOURCE												
STATIC - CHARGER, BATTERY	CT	46.06894	149.22033	46.06894	1330.89	6.40649	11.09211	6.40649	20	2.09950	596.78000	2.09950
MOTOR - GENERATOR, BATTERY	CT	55.29728	454.95052	55.29728	1873.33	7.59053	58.82684	7.59053	15	5.33000	181.26000	5.33000
EMERGENCY BATTERY SYS.												
BATTERY, PRIMARY WET	CT	175.36721	111.53850	175.36721	4609.71	24.49448	0.00000	24.49448	10	0.39910	265.00000	0.39910
BATTERY, PRIMARY DRY	CT	36.39003	62.08950	36.39003	995.49	5.02230	0.00000	5.02230	5	0.39910	53.00000	0.39910
BATTERY, SECONDARY WET	CT	175.36721	156.15390	175.36721	4654.32	24.49448	0.00000	24.49448	10	0.39910	371.00000	0.39910
BATTERY, SECONDARY DRY	CT	36.39003	124.17900	36.39003	1057.58	5.02230	0.00000	5.02230	5	0.39910	106.00000	0.39910

See NOTES on the last page of this table for Explanation of Column Headings

Notes

1. The resources listed in this table are as of the Date of Study (DOS) and have been calculated using a discount rate (d) of 10 percent. The Date of Study (DOS) is 3 years before the Beneficial Occupancy Date (BOD). All tasks are assumed to occur at mid-year. All resources have been assumed to be constant with no differential escalation from year to year.

2. Component Description - This column contains an indented list of systems, subsystems, components, and high cost task descriptions.

3. Unit of Measure (UM) - This column contains a two-character code to indicate the measurement unit for the component. Units used in this column are as follows:

CT	Count
LF	Linear Foot
SF	Square Foot
TF	Thousands of Linear Feet

4. Labor - Labor resources can be used in one of two ways: (1) labor hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr labor rate.

5. Materials - Material resources are expressed in dollars per unit of measure in July 1988 dollars for the Washington, DC, area.

6. Equipment - Equipment resources can be used in one of two ways: (1) equipment hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr equipment rate.

7. Washington, DC, Total - The dollars per unit of measure figures were calculated by applying the Military District of Washington labor and equipment rates to the labor and equipment resources, then adding the labor, material, and equipment costs together to form one total cost figure.

8. Year (YR) - This column contains the average age of the component when the high-cost task or replacement task would be performed.

9. Engineered Performance Standards (EPS) - Most labor and equipment resource data is based on the DOD series of Technical Bulletins as discussed in the body of the report.

APPENDIX C:

TECHNICAL BULLETIN INDEX FOR ENGINEERED PERFORMANCE STANDARDS

TB No.	Date	Title
TB 420-1	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Engineers Manual (NAVDOCKS P-700.0)
TB 420-2	5 Oct 72	Engineered Performance Standards Public Works Maintenance: General Handbook (NAVDOCKS P-701.0)
TB 420-3	5 Oct 72	Engineered Performance Standards Public Works Maintenance: General Formulas
TB 420-4	1 Mar 82	Tri-Service Coordination of the Carpentry Handbook
TB 420-5	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Carpentry Formulas
TB 420-6	1 Feb 82	Tri-Service Coordination of the Electric, Electronic Handbook
TB 420-7	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Electric, Electronic Formulas
TB 420-8	1 Feb 82	Tri-Service Coordination of the Heating, Cooling and Ventilating Handbook
TB 420-9	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Heating, Cooling, Ventilating Formulas
TB 420-10	1 Apr 81	Engineered Performance Standards Real Property Maintenance Activities Janitorial Handbook
TB 420-11	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Janitorial Formulas
TB 420-12	1 Apr 83	Engineered Performance Standards Real Property Maintenance Activities Machine Shop, Machine Repairs Handbook
TB 420-13	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Machine Shop and Repairs Formulas
TB 420-14	Sep 80	Engineered Performance Standards Real Property Maintenance Activities: Masonry Handbook
TB 420-15	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Masonry Formulas

TB 420-16	1 Apr 81	Engineered Performance Standards Real Property Maintenance Activities: Moving, Rigging Handbook
TB 420-17	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Moving, Rigging Formulas
TB 420-18	1 Nov 78	Engineered Performance Standards Real Property Maintenance Activities: Paint Handbook
TB 420-19	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Paint Formulas
TB 420-20	1 Aug 83	Engineered Performance Standards Real Property Maintenance Activities: Pipefitting, Plumbing Handbook
TB 420-21	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Pipefitting, Plumbing Formulas
TB 420-22	1 Sep 80	Engineered Performance Standards Public Works Maintenance: Roads, Grounds, Pest Control, Refuse Collection Handbook
TB 420-24	1 Mar 84	Engineered Performance Standards Real Property Maintenance Activities: Sheet Metal, Structural Iron and Welding Handbook
TB 420-25	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Sheet Metal, Structural Iron and Welding Handbook
TB 420-26	1 Nov 79	Engineered Performance Standards Real Property Maintenance Activities: Trackage Handbook
TB 420-27	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Trackage Formulas
TB 420-28	1 Nov 79	Engineered Performance Standards Real Property Maintenance Activities: Wharfbuilding Handbook
TB 420-29	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Wharfbuilding Formulas
TB 420-30	1 Aug 79	Engineered Performance Standards Real Property Maintenance Activities: Emergency/Service Handbook
TB 420-31	1 Dec 73	Engineered Performance Standards Real Property Maintenance Activities: Planner and Estimator's Workbook (Instructor's Manual) (S&I OCE)
TB 420-32	1 Mar 80	Engineered Performance Standards Real Property Maintenance Activities: Planner and Estimator's Workbook, Student's Manual

TB 420-33	1 Aug 83	Engineered Performance Standards Real Property Maintenance Activities: Unit Price Standards Handbook
TB 420-34	1 Mar 84	Engineered Performance Standards Real Property Maintenance Activities: Preventive/Recurring Maintenance Handbook
TB 420-35	1 Apr 81	Tri-Service Coordination of the Moving, Rigging Handbook
TB 420-51	30 Oct 73	Engineered Performance Standards Public Works Maintenance: Facilities Engineering Management of Maintenance Painting of Facilities

APPENDIX D:

GEOGRAPHICAL LOCATION ADJUSTMENT FACTORS

State	Location	ACF Index
Alabama	State Average	.86
	Birmingham	.96
	Mobile	.86
	Montgomery	.76
	Anniston Army Depot	.81
	Huntsville	.88
	Fort McClellan	.80
	Redstone Arsenal	.88
	Fort Rucker	.80
Alaska	State Average	2.25
	Anchorage	1.92
	Delta Junction	2.70
	Fairbanks	2.13
	Adak	3.88
	Aleutian Islands	3.86
	Anchorage NSGA	1.92
	Barrow	4.18
	Burnt Mtn.	6.86
	Clear	3.10
	Eielson AFB	2.13
	Elmendorf AFB	1.92
	Galena	3.73
	Fort Greely	2.70
	Fort Richardson	1.92
	Fort Wainwright	2.13
Arizona	State Average	1.02
	Flagstaff	1.02
	Phoenix	.99
	Tucson	1.05
	Fort Huachuca	1.22
	Yuma Proving Ground	1.31
	Yuma	1.31
Arkansas	State Average	.89
	Pinebluff	.93
	Little Rock	.83
	Fort Smith	.92
	Fort Chaffee	.92
	Pine Bluff Arsenal	.93
California	State Average	1.21
	Los Angeles	1.20
	San Diago	1.18
	San Francisco	1.25
	Beale	1.28
	Bridgeport NWTC	1.27
	Castle	1.13
	Centerville Beach	1.32
	Desert Area	1.18
	Edwards AFB	1.30

State	Location	ACF Index
California (Cont'd)	El Centro	1.27
	George AFB	1.31
	Fort Hunter Liggett	1.29
	Fort Irwin	1.20
	Le Moore NAS	1.20
	March AFB	1.18
	Mather AFB	1.17
	McClellan AFB	1.17
	Monterey Area	1.23
	Presidio of Monterey	1.23
	Norton AFB	1.16
	Oakland Army Base	1.33
	Fort Ord	1.24
	Port Huenema Area	1.20
	Riverside	1.18
	Sacramento	1.15
	Sacramento Army Depot	1.15
	Presidio of San Francisco	1.25
	San Nicholas Island	2.59
	Sharpe Army Depot	1.13
	Sierra Army Depot	1.33
	Stockton	1.15
	Travis AFB	1.27
	Vandenburg AFB	1.38
Colorado	State Average	.98
	Colorado Springs	.94
	Denver	1.04
	Pueblo	.96
	Fort Carson	1.01
	Fitzsimmons AMC	1.06
	Pueblo Army Depot	.96
	Peterson AFB	.94
	Rocky Mountain Arsenal	1.06
Connecticut	State Average	1.13
	Bridgeport	1.16
	Hartford	1.10
	New London	1.14
Delaware	State Average	.99
	Dover	1.04
	Lewes	.98
	Milford	.96
	Lewes NF	1.04
	Dover AFB	1.04
District of Columbia	Washington	1.03
	Fort McNair	1.03
	Walter Reed AMC	1.03
Florida	State Average	.89
	Miami	.95
	Panama City	.92
	Tampa	.79
	Cape Canaveral	.96
	Cape Kennedy	.96

State	Location	ACF Index
Florida (Cont'd)	Gulf Coast	.85
	Homestead AFB	.88
	Homestead	.88
	Jacksonville Area	.85
	Key West NAS	1.08
	Orlando	.80
	Pensacola Area	.85
	McDill AFB	.77
	Eglin AFB	.77
	Tyndall AFB	.92
Georgia	State Average	.80
	Albany	.82
	Atlanta	.87
	Macon	.70
	Athens	.90
	Atlanta-Marietta	.93
	Fort Benning	.71
	Columbus	.71
	Fort Gillem	.87
	Fort Gordon	.94
	Kings Bay	.93
	Fort McPherson	.87
	Fort Stewart	.84
Hawaii	State Average	1.28
	Hawaii	1.29
	Honolulu	1.27
	Maui	1.29
	Alimanu	1.27
	Barbers Point NAS	1.34
	Fort Debussy	1.27
	EWA Beach Area	1.34
	Helemano	1.34
	Hickam Army Air Field	1.27
	Kaneohe MCAS	1.34
	Moanalua	1.27
	Pearl City	1.27
	Pearl Harbor	1.27
	Pohakuloa	1.32
	Schofield Barracks	1.27
	Fort Shafter	1.27
	Tripler AMC	1.27
	Wheeler Army Air Field	1.34
Idaho	State Average	1.11
	Boise	1.05
	Idaho Falls	1.08
	Mountain Home	1.19
	Mountain Home AFB	1.20
Illinois	State Average	1.03
	Belleville	.96
	Chicago	1.09
	Rock Island	1.03
	Rock Island Arsenal	1.06

State	Location	ACF Index
Illinois (Cont'd)	St. Louis Support Ctr	.96
	Savannah Army Depot	1.05
	Scott AFB	1.03
	Fort Sheridan	1.10
Indiana	State Average	.99
	Indianapolis	1.03
	Logansport	.99
	Madison	.94
	Fort Benjamin Harrison	1.07
	Crane	1.10
	Crane AAP	1.10
	Grissom AFB	1.06
	Indiana AAP	1.02
	Jefferson Proving Ground	.94
Iowa	State Average	1.02
	Burlington	1.04
	Cedar Rapids	.98
	Des Moines	1.05
	Iowa AAP	1.06
Kansas	State Average	.94
	Manhattan	.97
	Topeka	.96
	Wichita	.88
	Kansas AAP	.94
	Fort Leavenworth	.94
	Fort Riley	.97
	Sunflower AAP	.97
Kentucky	State Average	.96
	Bowling Gree	.99
	Lexington	.96
	Louisville	.93
	Fort Campbell	.93
	Fort Knox	.99
	Lexington/Bluegrass Army Depot	1.06
	Louisville NAS	.93
Louisiana	State Average	.92
	Alexandria	.87
	New Orleans	.94
	Shreveport	.94
	Barksdale AFB	.94
	England AFB	.87
	Gulf Outport New Orleans	.94
	Louisiana AAP	.94
	Fort Polk	.94
Maine	State Average	.93
	Bangor	.85
	Caribou	.99
	Portland	.94
	Brunswick	.93
	Cutler	.98
	Northern Area	1.17
	Winter Harbor	.98

State	Location	ACF Index
Maryland	State Average	.97
	Baltimore	.95
	Fredrick	.94
	Lexington Park	1.01
	Aberdeen Proving Ground	.94
	Annapolis	1.03
	Fort Detrick	.94
	Harry Diamond Lab	1.00
	Fort Meade	.95
	Patuxent River Area	1.08
	Fort Ritchie	.90
Massachusetts	State Average	1.10
	Boston	1.13
	Fitchburg	1.08
	Springfield	1.08
	Army Mtls & Mech Research Ctr	1.13
	Fort Devens	1.15
	Natick Research & Development Ctr	1.13
	South Weymouth	1.13
Michigan	State Average	1.06
	Bay City	1.02
	Detroit	1.14
	Marquette	1.03
	Detroit Arsenal	1.14
	Northern Area	1.25
	Republic (Elfcom)	1.10
	Selfridge AFB	1.14
Minnesota	State Average	1.08
	Duluth	1.05
	Minneapolis	1.09
	St. Cloud	1.10
	Twin Cities AAP	1.09
Mississippi	State Average	.84
	Biloxi	.87
	Columbus	.81
	Jackson	.84
	Columbus AFB	.81
	Gulfport Area	.87
	Meridian	.92
Missouri	State Average	.92
	Kansas City	.92
	St. Louis	.99
	Rolla	.85
	Lake City AAP	.93
	Fort Leonard Wood	.91
Montana	State Average	1.15
	Billings	1.15
	Butte	1.18
	Great Falls	1.12
	Malmstrom AFB	1.12
Nebraska	State Average	1.03
	Grand Island	1.00

State	Location	ACF Index
Nebraska (Cont'd)	Lincoln	1.05
	Omaha	1.05
	Offutt AFB	1.05
Nevada	State Average	1.18
	Hawthorne	1.26
	Las Vegas	1.13
	Reno	1.15
	Fallon	1.28
	Hawthorne AAP	1.26
	Nellis AFB	1.13
New Hampshire	State Average	1.09
	Concord	1.06
	Nashua	1.06
	Portsmouth	1.14
	Cold Regions Lab	1.17
New Jersey	State Average	1.08
	Newark	1.11
	Red Bank	1.08
	Trenton	1.06
	Bayonne	1.10
	Bayonne Mil Ocean Term	1.09
	Fort Dix	1.03
	Earle	1.10
	Lakehurst	1.05
	Fort Monmouth	1.09
	Picatinny Arsenal	1.20
New Mexico	State Average	1.03
	Alamogordo	.99
	Albuquerque	1.03
	Gallup	1.06
	Holloman AFB	1.05
	Kirtland AFB	1.03
	White Sands Missile Range	1.09
	Fort Wingate	1.06
New York	State Average	1.12
	Albany	1.07
	New York City	1.24
	Syracuse	1.05
	Brooklyn	1.24
	Fort Drum	1.18
	Fort Hamilton	1.24
	Seneca Army Depot	1.15
	U.S. Military Academy	1.17
	Watervliet Arsenal	1.07
North Carolina	State Average	.76
	Fayetteville	.76
	Greensboro	.75
	Wilmington	.78
	Fort Bragg	.76
	Camp Lejeune Area	.86
	Cherry Point	.86
	Goldsboro	.77

State	Location	ACF Index
North Carolina (Cont'd)	Pope AFB	.82
	Seymour AFB	.77
	Sunny Point Mil Ocean Term	.78
North Dakota	State Average	1.03
	Bismarck	1.02
	Grand Forks	.98
	Minot	1.10
	Grand Forks AFB	.98
	Stanley R. Hicklesen CPX	1.03
	Minot AFB	1.12
Ohio	State Average	1.00
	Columbus	1.03
	Dayton	.98
	Youngstown	.99
	Cleveland	1.14
	Wright-Patterson AFB	.98
Oklahoma	State Average	.93
	Lawton	.90
	McAlester	.91
	Oklahoma City	.98
	Altus AFB	.94
	Enid	1.01
	McAlester AAP	.91
	Fort Sill	.90
Oregon	State Average	1.05
	Pendleton	1.08
	Portland	1.07
	Salem	.99
	Charleston	1.11
	Coos Head	1.08
	Umatilla Army Depot	1.18
Pennsylvania	State Average	1.00
	Harrisburg	.91
	Philadelphia	1.05
	Pittsburgh	1.04
	Carlisle Barracks	.93
	New Cumberland Army Depot	.91
	Fort Indiantown Gap	1.07
	Letterkenny Army Depot	1.07
	Mechanicsburg Area	.91
	Tobyhanna Army Depot	1.14
	Warminster Area	1.04
Rhode Island	State Average	1.11
	Bristol	1.13
	Newport	1.11
	Providence	1.10
	Davisville	1.17
South Carolina	State Average	.82
	Charleston	.81
	Columbia	.82
	Myrtle Beach	.84
	Beaufort Area	.89

State	Location	ACF Index
South Carolina (Cont'd)	Charleston AFB	.81
	Fort Jackson	.82
	Sumter	.80
South Dakota	State Average	.95
	Aberdeen	.95
	Sioux Falls	.94
	Rapid City	.96
	Ellsworth AFB	.98
Tennessee	State Average	.84
	Chattanooga	.86
	Kingsport	.72
	Memphis	.95
	Arnold AFB	.90
	Milan AAP	.98
	Holston AAP	.71
Texas	State Average	.85
	San Angelo	.76
	San Antonio	.86
	Fort Worth	.93
	Fort Bliss	.96
	Carswell AFB	.93
	Chase Field - Beeville	.97
	Corpus Christi Army Depot	.92
	Corpus Christi	.92
	Dallas	.93
	Dyess AFB	.94
	Fort Hood	.89
	Kingsville	.99
	Red River Army Depot	.78
	Fort Sam Houston	.86
	William Beaumont AMC	.96
	Bergstrom AFB	.95
	Brooks AFB	.86
	Randolph AFB	.86
	Kelly AFB	.86
	Lackland AFB	.86
Utah	State Average	1.03
	Ogden	1.05
	Salt Lake City	1.00
	Tooele	1.06
	Dugway Proving Ground	1.03
	Hill AFB	1.07
	Tooele Army Depot	1.05
Vermont	State Average	.99
	Burlington	1.00
	Montpelier	1.00
	Rutland	.96
Virginia	State Average	.95
	Norfolk	.95
	Radford	.95
	Richmond	.94
	Arlington	1.04

State	Location	ACF Index
Virginia (Cont'd)	Arlington Hall Station	1.04
	Arlington National Cemetery	1.04
	Fort Belvoir	1.04
	Cameron Station	1.04
	Dahlgren	1.10
	Fort Eustis	.96
	Humphreys Engineer Center	1.03
	Fort A. P. Hill	.92
	Fort Lee	.93
	Fort Monroe	.94
	Fort Myer	1.03
	Norfolk-Newport News Area	.95
	Fort Pickett	.98
	Quantico	1.03
	Nadford AAP	1.02
	Port Story	.95
	Vint Hill Farms Station	1.08
Washington	State Average	1.09
	Spokane	1.08
	Tacoma	1.07
	Yakima	1.11
	Fairchild AFB	1.13
	Jim Creek	1.34
	Fort Lewis	1.07
	Pacific Beach	1.27
	Puget Sound Area	1.15
	Seattle Area	1.12
	Widbey Island	1.12
	Yakima Firing Center	1.18
West Virginia	State Average	.95
	Bluefield	.92
	Clarksburg	.95
	Charleston	.99
	Sugar Grove	1.15
Wisconsin	State Average	1.06
	LaCrosse	1.04
	Madison	1.02
	Milwaukee	1.13
	Badger AAP	1.06
	Clam Lake	1.20
	Fort McCoy	1.11
Wyoming	State Average	1.08
	Casper	1.07
	Cheyenne	1.10
	Laramie	1.08
	F. E. Warren AFB	1.10

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