AD-A220 456

(2)

REPORT DOCUMENTATION PAGE

DTIC FILE COPY

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
N/A

1b. RESTRICTIVE MARKINGS
N/A

2a. SECURITY CLASSIFICATION AUTHORITY
N/A

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE
N/A

3. DISTRIBUTION/AVAILABILITY OF REPORT
Unclassified/Unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
106-89

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
Gen. Leonard Wood Army Comm Hosp

6b. OFFICE SYMBOL (If applicable)
N/A

7a. NAME OF MONITORING ORGANIZATION
US Army-Baylor University Graduate Program in Health Care Administration

6c. ADDRESS (City, State, and ZIP Code)
Ft. Leonard Wood, MO

7b. ADDRESS (City, State, and ZIP Code)
AHS
San Antonio, TX 78234-6100

8a. NAME OF FUNDING/SPONSORING ORGANIZATION
N/A

8b. OFFICE SYMBOL (If applicable)
N/A

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
N/A

8c. ADDRESS (City, State, and ZIP Code)
N/A

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification) A STUDY TO IDENTIFY THE OPTIMUM METHOD OF PROVIDING BIOMEDICAL ENGINEERING/MAINTENANCE SUPPORT OF RADIOLOGIC EQUIPMENT AT GENERAL LEONARD WOOD ARMY COMMUNITY HOSPITAL

12. PERSONAL AUTHOR(S)
CRAIG, MARY PAT

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM 7/87 TO 7/88	88/1	75

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
General Leonard Wood Army Community Hospital (GLWACH), Biomedical Equipment Technicians (BMET); Mission Essential Repair Parts (MERP). (EDC)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This study was ~~done~~ (GLWACH), to determine the optimum method of providing biomedical engineering/maintenance support of diagnostic radiologic equipment at General Leonard Wood Army Community Hospital. The study concluded that the optimum method of providing biomedical engineering/maintenance support of diagnostic radiology equipment at ~~General Leonard Wood Army Community Hospital~~ GLWACH was through in-house/biomedical maintenance personnel. Keywords: Radiographic equipment maintenance; Ultrasonic/Diagnostic equipment; Nuclear medicine equipment; Maintenance management; Cost effectiveness; -

DTIC ELECTE APR 06 1990 S D E

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
N/A

22a. NAME OF RESPONSIBLE INDIVIDUAL
Major Leahy

22b. TELEPHONE (Include Area Code)
(512) 221-2324/6345

22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

A STUDY TO IDENTIFY THE OPTIMUM METHOD OF PROVIDING BIOMEDICAL ENGINEERING/MAINTENANCE SUPPORT OF RADIOLOGIC EQUIPMENT AT GENERAL LEONARD WOOD ARMY COMMUNITY HOSPITAL

A Graduate Research Project

Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the

Requirement for the Degree

of

Master of Health Administration

by

Major Mary Pat Craig, ANC

January 1988

X

A-1

88 04 ... 018

ACKNOWLEDGMENTS

Many thanks are due to the personnel in the Comptroller Division, Radiology Department and Medical Maintenance Branch for their help in gathering the wealth of information used in the analysis.

I owe a great debt of gratitude to Colonel James E. Contrell, MSC, Deputy Commander for Administration and my Preceptor. His professionalism and administrative expertise was an inspiration, and his guidance and faith in my abilities were a bulwark for my professional development and performance on this Graduate Research Project and throughout the residency year.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I
INTRODUCTION
Background

The advances in medicine since World War II have been astounding. The basis for many of these advances have been technological discoveries and improvements resulting in the physician's right hand progressing from the stethoscope and reflex hammer to microcomputers and autoanalyzers. Biomedical maintenance concerns for these innovations have progressed from episodic repairs to preventive maintenance service to quality assurance performance checks. Another key factor is the interdependence of all areas of patient care; the physician depends on many diagnostic specialties. Considering the exploding technologies, litigious climate and emphasis on quality assurance, and importance of coordinated, integrated patient care, the services of the biomedical maintenance department is a key element in the provision of quality health care today.

The Radiology Department at General Leonard Wood Army Community Hospital (GLWACH) is just such a high technology, quality patient care area whose services impact on the majority of patients seen in the hospital. The department has the following state-of-the-art radiologic equipment:

eight radiographic/fluoroscopic units;

two portable radiographic units;

two radiographic units;

two ultrasound units;

one mammography unit;

one Computerized Axial Tomography (CAT) scanner;

one image intensifier; and

three nuclear medicine units.

All units were installed between 1975 and 1986. There is concern within the Radiology Department that all units are experiencing increasing malfunctions and downtime. Since normal life span and required dollar amount for maintenance, as set by the Army, have not been exceeded, new equipment cannot be ordered. The health care providers desire the minimum repair time to insure maximum service time. What is the best way to satisfy all these requirements?

Problem Statement

To determine the optimum method of providing biomedical engineering/maintenance support of diagnostic radiologic equipment at GLWACH.

Objectives

The objectives of this study are:

1. Conduct a literature review to determine industry standards of technical expertise, provisions of service, equipment life span and maintenance problems.

2. Evaluate data from October 1985 to February 1986 to document medical maintenance services to Radiology and determine impact of equipment downtime.

3. Establish the availability of manufacturer service contracts or third party alternatives.

4. Compare the dollar costs of in-house maintenance and those of available civilian contracts.

5. Compare medical maintenance support of Keller Army Community Hospital (KACH) and GLWACH.

Criteria

The overriding criteria is for the solution to effect the most efficient delivery of medical maintenance support resulting in optimum patient care time at the least dollar expense. An analysis of the "costs" of each alternative then will include response time, repair time, dollar costs and impact on the queue for services.

Limitations

This research will be constrained by the following factors:

1. Evaluation of productivity in Radiology and Medical Maintenance support is limited to the period October 1985 to February 1986.

2. Projected costs from the civilian contractor will be an estimate only.

3. Those pieces of equipment with partial or full contracts will not be considered in the study, for simplicity and recognizing that their advanced technology often dictates the maintenance procedures.

Review of Literature

A. General Overview

A review of the literature concerning civilian biomedical engineering, especially of radiology equipment, is reflective of the overall concerns of modern medicine - rapid growth and change, technological improvements, quality assurance, and cost containment in the civilian sector. The clinical engineer and Biomedical Equipment Technician (BMET) are relatively new roles, developed in the middle to late '60's. Several widely publicized fatal accidents during that decade increased the awareness of the need for a coordinated program for monitoring operating function and safety. By 1979, the Joint Commission on Accreditation of Hospitals required scheduled and documented inspections of all medical equipment.[1]

As medical equipment advanced from vacuum tubes to transistors to integrated circuits to microprocessors, over the last forty years, equipment maintenance has progressed from a focus on repair to preventive maintenance of quality assurance. The role of the BMET has evolved from the hospital handy man to degreed clinical engineers, and a prediction for a biomedical equipment systems technician. Micro- processor circuits are leading towards decreasing "troubleshooting" during repairs to simple board substitution for a "fast fix". This minimizes the need for repair capabilities and points the systems technician to the role of assuring overall device function and safety, plus training for operator personnel.[2]

The technological improvements also present stumbling blocks for facilities anxious to establish biomedical engineering, but concerned with cost containment. To maintain state-of-the-art capabilities, facilities purchase new systems which pose challenges for in-house or contract services.

In-house departments must consider the expenses for training, repair parts (microprocessor boards can easily range from $30,000 - $50,000) and specialized test equipment. The industry standard for contract services however, is 10% of the acquisition costs.[4] Normally, service contracts do not include coverage for damage from operator error. The cost of service contracts is prohibitive for some facilities.

The epitome of these challenges can be seen in an effective program for the radiology department, where change, technological advancements and quality assurance are pronounced. The biggest challenge appears to be present for the smaller, rural hospital where cost containment is crucial, skilled personnel may be scarce, and equipment backup minimal. One applicable solution from the literature suggests a combined system of in-house and contract with two key points. First, the establishment of a resident radiology engineer -- dedicated personnel. Second, a modified contract allowing in-house completion of most preventive maintenance checks and initial triage of repair problems, referring to the contract personnel for necessary calibrations, and saving diagnostic time once the representative is on-site.[6]

This same approach was recommended in a study published in 1984, of a medium-sized university hospital -- "...a comprehensive maintenance program based upon a balanced blending of existing in-house service capabilities, with needed support provided by the equipment manufacturer's service organization."[7] One of their key elements was the inclusion of the maintenance personnel within the radiology department for increased communication and cooperation. The radiology department consisted of: diagnostic x-ray, ultrasound, nuclear medicine, and radiation therapy. For the purposes of this study, information pertaining to diagnostic x-ray is of interest.

The in-house service personnel consisted of two electronic service engineers; a certified medical physicist, as supervisor; with assistance from one radiological technologist on routine quality assurance, and one staff photographer on the film processors. These three individuals have electronic knowledge, with "extensive additional training on our specific equipment provided through various factory training programs."[8] It is important to recognize the stability of this workforce, their commitment to continuing education, and their sole assignment to the radiology department.

Table 1 is an extract from the article comparing estimated service costs and actual service expense, demonstrating the significant cost containment available with in-house capabilities and modified contracts. They averaged less than one percent downtime, not including time needed for preventive maintenance or the service time incurred for minor repairs or calibration. The system described reduces the real cost of maintenance by increasing the useful life of the equipment through technical problem solving, defect detection, and process control.

TABLE 1

ANNUAL EQUIPMENT MAINTENANCE EXPENDITURE

EQUIPMENT CATEGORY (C)	ESTIMATED SERVICE COST (B) (in Unit of $1,000)	ACTUAL SERVICE EXPENSE (in Unit of $1,000)
Radiography (A)	139	15
Radiography/Fluoroscopy	167	40
Mobile Units	29	18
	325	73

A = Including mammography

B = Estimated service costs are obtained by assuming placing all equipment under manufacturer's service agreement, plus cost incurred by obtaining all consumable items.

C = Including glassware, service contract, billed service labor/parts but no personnel salaries or benefits.

Source: Wei-Kom Chu, Ph.D., "Comprehensive Radiological Equipment Management Program," Journal of Clinical Engineering, Vol. 9, No. 4, (October - December 1984): 285.

In their final analysis, including costs for maintenance, personnel expenses, and test equipment, the in-house system was still 41 percent below the projected contract cost. Response time could be within minutes, instead of hours or days. And their conclusion was, "It is our belief that an in-house service organization, like the one described herein, not only increases overall equipment up-time, but also reduces overall equipment maintenance cost on a long term basis."[9]

B. Education and Training

Biomedical engineering/maintenance has been a concern for the US Army Medical Department since World War II. Maintenance and repair of technical equipment were by warranty or one time manufacturer contracts before 1940, but the dramatic increase in the number of items, plus their dispersion, especially overseas, made this existing system inadequate. It was recognized that on-site, trained personnel were required for effective preventive maintenance and accurate inspection of depot repair and exchange items. Accordingly, the Surgeon General directed that three month maintenance training courses be established and conducted starting in February 1942. The training has continued ever since.[10]

Presently the Army Medical Equipment and Optical School (USAMEOS) is located at Fitzsimons Army Medical Center, Colorado. The school conducts a 19 week basic course, granting the 35G (Biomedical Equipment Specialist, Basic) MOS. Through an affiliation with Regis College in 1974, the advanced course graduates, who complete ten additional hours in non-engineering subjects, are awarded an Associates Degree.

The Army Medical Department is planning to expand the current program to 38 weeks basic and 25 weeks advanced.[11]

The courses at USAMEOS provide a combination of electronic subjects, coupled with the theory, use, and repair of medical equipment.[12] The basic course covers periodic scheduled services and repair of equipment employing mechanical pneumatic high and low pressure gas and steam, hydraulic, electrical and optical principles. The advanced course expands this to include electronic, solid state, digital, logic and radiologic principles.[13] The training is based on concepts, as it is impossible to cover each individual manufacturer's equipment.[14] Equipment purchases throughout the Army Medical Department are nonstandardized. Each facility purchases equipment based on facility needs, practitioner preferences, and salesman expertise -- so it is possible to have like equipment from a different manufacturer in each facility.

In contrast, the civilian sector established the first official training programs in 1967. The Technical Education Research Centers, a nonprofit organization designed to explore career opportunities in emerging technical fields, conducted a study of biomedical engineering training in 1975. It documented five programs, besides the military, in 1967, which had expanded to only seventeen by 1973. The other significant finding, however, was that most of the graduates were <u>not</u> employed by hospitals, but by manufacturers, primarily due to the low salaries hospitals were willing to pay for medical maintenance personnel, at that time.[15] Clearly, the US Army Medical Department has been at the forefront of the biomedical engineering field, providing comprehensive training and guidance in biomedical engineering. The next section presents current guidance pertaining to biomedical engineering in the military.

Health Services Command Guidance

The role of Health Services Command (HSC) is similar to the parent corporation of a multi-institutional system. Within the Continental United States, it provides funds and guidance for all the Army medical treatment facilities. The Medical Maintenance Branch is a section within the Logistics Division of HSC. The effective functioning of the facility Medical Maintenance Branch is monitored monthly by HSC through required reports. Requests for major service contracts are also submitted to HSC. Several information papers disseminated from the Medical Maintenance Branch provide background information for understanding and analyzing biomedical engineering support within Army facilities.

An important focus of the Command guidance is the necessity of coordination between the medical Maintenance Branch and the user/operator and supervisor. BMET personnel follow a schedule of systematically checking, adjusting, doing repairs, and providing training for user/operator maintenance as needed.[16] The user/operator is responsible for the most important preventive maintenance on medical equipment - daily cleaning, adjusting, and reporting of malfunctions. "A major cause of equipment failure is improper use and care by operators."[17] The user/operator supervisor must insure that all elements of their organization, human and materiel, are ready to provide the best possible patient care. They are the most important link between medical maintenance and the successful daily operation of equipment: monitoring user/operator skill and performance, as well as daily preventive maintenance within the section, and submitting timely work requests, with follow-ups. The Medical Maintenance Branch is not solely responsible for effective functioning medical equipment in a facility.[18]

Another key aspect to an effective maintenance program is the need for a balanced approach. Medical equipment is defined as items used in the diagnosis and treatment of patients, and represents thousands of pieces of equipment, even in a small facility.[19] The preventive maintenance needs vary depending on regulations and manufacturer recommendations. Emphasis on a single maintenance area could create a significant problem in the overall condition and availability of medical equipment. For example, deferring preventive maintenance on critical equipment while repairing noncritical items on a *priority basis* will eventually cause the premature failure of the critical equipment. All tasks must be evaluated and prioritized, and portions accomplished to avoid unwarranted backlogs in any one area.[20] This approach is crucial for clinicians to understand.

Even before Gramm-Rudman and FY 86 budget cuts, the need for cost containment on contract maintenance service was well documented. From figures available in February 1985, contractual maintenance costs had significantly increased from slightly over $5 million in FY 81 to a projected $13.3 million in FY 85. "Contract maintenance costs associated with medical equipment maintenance can be contained if an in-house maintenance capability is developed to replace the reliance on the manufacturer or other contract sources."[21] Implied in the success of this guidance however is first, the stability of assigned personnel and a command commitment to continuing education and training so the expertise and familiarization is present, and second, standardized purchase of equipment from the same manufacturer.

Another aspect of cost containment, on a daily basis, is the cost of repair parts inventory. One key element of this supply system, which has a great impact on radiologic repairs, is the local stock of Mission Essential Repair Parts (MERP). MERP is a nondemand supported repair parts supply that is closely regulated because of expense. Many are essential because they ensure the functioning of life saving equipment.[22] When the line for repair parts lengthens, especially in isolated locations, there is an inclination to expand the MERP stock, as this significantly shortens the repair time. However, these stock levels are reviewed annually be the local command and HSC, which causes unexpected fluctuations to availability of MERP and directly affects response/repair time.

In personal interviews with the previous and current Chief of the Medical Maintenance Branch of HSC, CW4 William Robertson[23] and CW3(P) James Silvey,[24] the question of in-house versus contract maintenance was classified as perennial and academic. The consensus of opinion is that full contract maintenance is cost prohibitive, and eliminates experience and training required for mobilization, the experienced skills of active duty 35U and 35G personnel necessary in wartime to effect needed repairs. Although anecdotal in nature, it is also true that many times the service representatives are often moonlighting military personnel. They strongly support in-house capabilities and believe the service rendered has been timely and appropriate. Recognizing their inherent prejudice, from position and years of experience, their defense of the abilities of the BMET personnel can also be supported considering the fact the Army leads in training and maintaining a vital biomedical engineering program.

However, as stated, modern medicine is in the throes of dramatic change - technological improvements, quality assurance initiatives, risk management concerns, and cost containment initiatives. Biomedical engineering/maintenance is a dynamic field for the civilian and military sectors necessitating constant reevaluations of existing programs.

Research Methodology

This study was conducted utilizing historical data collection and analysis, and personal interviews for management input and analysis.

Historical data collected from October 1985 through February 1986, in both departments, Medical Maintenance and Radiology, yielded information on personnel staffing, dollar costs and productivity (number of weighted procedures and manhours). An examination of personnel staffing gave a basis for evaluating productivity -- were increases in maintenance time or decreases in patient procedures due to staffing levels? The actual expenditures were documented for cost comparisons with contract service projections. To analyze the premise that increasing medical maintenance requests were directly affecting patient care procedures, productivity statistics were compared. The relationships between variables were explored to determine if there was an independent or dependent association. This association was examined using the Spearman rank correlation coefficient test.

The Spearman test is a nonparametric analysis, making no assump- tions about the distribution of the sample, which is the basic assumption necessary for a parametric test. This test establishes the existence of an association between variables and then gives an indication of the strength and direction of the relationship. The relationship between medical maintenance and patient care procedures is the key factor in this study.

The following directions for the Spearman rank correlation coefficient test are from Daniel's Applied Nonparametric Statistics:[25]

Assumptions

A. The data consists of a random sample of n pairs of numeric observations. Each pair of observations represents two measurements taken on the same object, called the unit of association.
B. If the data consists of observations from a bivariate population, we designate the n pairs of observations $(X_1 Y_1)$, $(X_2 Y_2)$, ..., $(X_n Y_n)$.

C. Each X is ranked relative to all other observed values of X, from smallest to largest in order of magnitude.
D. Each Y is ranked relative to all other observed values of Y, from smallest to largest in order of magnitude.
E. If ties occur among the X's or among the Y's, each tied value is assigned the mean of the rank position for which it is tied.

The hypothesis to be tested states:
H_0: X and Y are independent.
H_1: There is a direct, or inverse, relationship between X and Y.

The Test equation is:

$$r_s = 1 - \frac{6(\Sigma d_i^2)}{n(n^2-1)}$$

The decision rule will be: Reject H_0 at the .95 alpha level if the computed value of r is greater than the tabulated value correspond- ing to 1-alpha.

Drawing from Table A.19, and considering our sample size of 5 months, the following values will be used to examine each outcome:

n	.001	.005	.010	.025	.05	.10
5	-	-	.9000	.9000	.8000	.7000

Data from Keller Army Community Hospital was examined. Direct comparisons were not accomplished due to the major differences between the two facilities. However, several conclusions were applicable from a management standpoint, as they have justified a full service contract for medical maintenance of radiology equipment.

Personal interviews revealed background information that directed some of the study and set parameters for the evaluation of findings. Especially important was information relating to the nonmonetary element of "costs", specifically relating to repair and patient care delays. A delay in repairs, if directly attributable to delays in providing patient care, would be a significant cost to be evaluated considering risk management and quality assurance concerns.

The results of the above analyses were evaluated utilizing the Churchman-Ackoff method of decision matrix. The Churchman-Ackoff technique allows for comparison and evaluation of nonquantifiable issues. The alternatives were: (1) in-house, and (2) civilian contract. The criteria included: (1) economic feasibility, (2) response time, (3) repair time, and (4) patient care costs. The matrix was a minimization problem, with weights determined equal, except for consideration of dollar costs. Considering the cost containment imperatives in health care today, this is certainly the most important criteria and was thus given a double weight.

CHAPTER I
FOOTNOTES

1 Seymour Ben-Zvi, "Development of Preventive Maintenance Procedures," Journal of Clinical Engineering 9 (April - June 1984): 104.

2 Marvin D. Shepard, "Does the in-Hospital BMET Face Obsolescence?" Journal of Clinical Engineering 5 (October - December 1980): 342.

3 Ibid., p. 343.

4 Ernest Guignon, "Setting Up a Clinical Engineering Department," Journal of Clinical Engineering 5 (January - March 1980): 71.

5 Duane H. Blienke, "Maintenance Cost Control of High Technology Hospital Equipment," Radiology Management 6, No.1 (1983): 2.

6 Joseph Herman, "Radiology Equipment Maintenance in a smaller Hospital," Applied Radiology (July - August 1984): 80.

7 Wei-Kom Chu; Charles A. Dobry; Thomas J. Imray; and Ted K. Taylor, "Comprehensive Radiological Equipment Management Program," Journal of Clinical Engineering 9 (October - December): 281.

8 Ibid., p. 283.

9 Ibid., p. 289.

10 Colonel Robert S. Anderson, M.C., ed., Medical Supply in World War II. Office of the Surgeon General. (Washington D.C.: Department of the Army, 1968), pp. 101-105.

11 Interview with Fred Walker, Education Specialist, US Army Medical Equipment and Obtical School, Fitzsimons Army Medical Center, Colorado, 24 June 1986.

12 USAHSC Information Paper, Subject: Medical Equipment Maintenance, dated February 1985.

13 US Department of the Army Medical Department. Army Regulation 611-201. Washington, D.C.: Department of the Army, June 1984.

14 Interview with Fred Waslker, Education Specialist, US Army Medical Equipment and Optical School, Fitzsimons Army Medical Center, Colorado, 24 June 1986.

15 Ibid., 24 June 1986.

16 USAHSC Information Paper, Subject: Preventive Maintenance, dated June 1985.

17 USAHSC Information Paper, Subject: Importance of User/Operator Maintenance - Supervisor Responsibility, dated June 1985.

18 USAHSC Information Paper, Subject: Preventive Maintenance, dated June 1985.

19 USAHSC Information Paper, Subject: Maintenance of Medical Equipment, dated September 1985.

20 USAHSC Information Paper, Subject: Maintenance of Medical Equipment, dated March 1986.

21 USAHSC Information Paper, Subject: Contract Maintenance Service, dated February 1985.

22 USAHSC Information Letter, Subject: Maintenance Shop Stock Procedures, dated January 1986.

23 Interview with CW4 John Robertson, Chief, Medical Maintenance Branch, US Army Health Services Command, San Antonio, Texas, 4 June 1985.

24 Interview with CW3(P) James Silvey, Chief, Medical Maintenance Branch, US Army Health Services Command, San Antonio, Texas, 6 June 1986.

25 Wayne W. Daniel, Applied Nonparametric Statistics (Boston: Houghton Miffin Company, 1978), pp. 298-306.

CHAPTER II

DISCUSSION
MEDICAL MAINTENANCE BRANCH

The primary objective of the Medical Maintenance Branch is to support biomedical equipment necessary to sustain the high standards of health care, providing effective maintenance, electrical safety testing and calibration of equipment. The Branch at GLWACH services over 3,000 line items, with approximately 6,000 additional categorical items such as stretchers and IV poles.[1] The staff is comprised of one warrant officer, MOS 202A; nine enlisted - two 35G's and seven 35U's; three Wage Grade 4805, GS-11 Medical Equipment Repairers; one job orders/control clerk; and one tool and parts attendant. Table 2 depicts the manpower accounting, which indicates the Branch is short one full time equivalent.

TABLE 2

MEDICAL MAINTENANCE MANPOWER

MILITARY			CIVILIAN		
REQUIRED	AUTHORIZED	ASSIGNED	REQUIRED	AUTHORIZED	ASSIGNED
11	11	10	7	5	5

Source: Manpower Survey and TDA 0486

This study examined the support to diagnostic radiology equipment, excluding the ultrasound units, CAT scanner, and nuclear medicine units, which are presently under contract, partial or full. The remaining equipment is detailed in Table 3 by room number, Medical Materiel Control Number (MMCN), and nomenclature. It is important to recognize the duplication of equipment and capabilities. Three units have been refurbished (rebuilt) and given new MMCN numbers within the last five months. Both numbers are given, as reference to each maintenance record was appropriate.

TABLE 3

Room Number	MMCN#	Nomenclature
1	2111-D1299	X-Ray Appar Radio/Fluoro 1000M
2	2110	X-Ray Appar Radio/Fluoro 800M
3	2109-D1095	X-Ray Appar Radio/Fluoro 1000M
4	2125	X-Ray Appar Radio 500M
	2108	X-Ray Appar Radio/Fluoro 1200M
5	2004	X-Ray Appar Radio 500MA
6	2113	X-Ray Appar Radio/Fluoro 1000M
7	1900	X-Ray Appar Radio/Fluoro 600M
8	3313	X-Ray Appar Radio/Fluoro 1000M
Mammography	2118	X-Ray Appar Mammography
Portable 1	2050	X-Ray Appar Radio Mobile 100M
Portable 2	2051-D1843	X-Ray Appar Radio Mobile 100M

Source: PCN RPB-8F1, Maintenance Record

The central aspect of the study was to examine medical maintenance support to diagnostic radiology equipment. Table 4 delineates scheduled and unscheduled services, in manhours. Scheduled services are comprised of preventive maintenance, calibrations and safety testing and accounted for more than 50% of the services in four of the five months. As stated earlier, the importance of scheduled services is widely recognized and used by many facilities as the basis for a medical maintenance branch requirement. The graph at Appendix A depicts this important relationship.

TABLE 4
MEDICAL MAINTENANCE SUPPORT TO DIAGNOSTIC RADIOLOGY

	OCT	NOV	DEC	JAN	FEB
Scheduled	136.5	79.5	66.6	133.3	33.0
Unscheduled	53.	113.1	4.5	73.	27.5
Total	189.5	192.6	71.1	206.3	60.5
Scheduled/Total	72%	41.3%	93.7%	64.6%	54.5%

Source: PCN RPB-8F1 Maintenance Record

Services to the diagnostic radiology equipment is just one small aspect of the total requirements of the hospital. The table of unscheduled services work orders at Appendix B shows that the total Radiology requests only average 7.2 percent of total facility requests. For the five month study period the average manhours for support were 144, not quite one Full-Time-Equivalent (FTE). This information is important for evaluating projected contract services and appreciating the wide range of expertise expected of each BMET.

In interviews with the Chief[2] and Noncommissioned Officer-in-Charge (NCOIC)[3] of the Branch, they identified three factors involved with repair delays. In order: 1) delay in receipt of repair parts, 2) rotation of military personnel through radiology for effective training, and 3) lack of user preventive maintenance. A small proportion of repair parts are maintained in stock due to expense and nondemand. As stated earlier, the MERP, or nondemand stockage is tightly controlled. Consequently many items must be ordered through the supply system, which necessitates anywhere from one day to three months for processing and receipt. The immediate priority items, with receipt in one to three days, also are tightly controlled with approval authority by the Chief of Logistics. It is a system delay inherent to the military.

For medical readiness and personnel development, the military personnel informally "assigned" to support radiology equipment are rotated every four to six months. Consequently, some repair delays may be experienced until the new individual is "up to speed" on the equipment. The civilian repairer is informally assigned for several years, the latest having worked on radiology equipment for over five years. This is in congruence with the civilian sector's trend toward stability and maximum familiarity with the equipment. A commitment to continuing education is essential however, as equipment is replaced/refurbished and training is not authorized to be included in the purchase price out of Operation and Maintenance, Army (OMA) funds.

Finally, HSC guidance supports the assumption that lack of user/operator maintenance causes significant downtime. From the tables in Appendix C, user/operator failure was identified in 21.6 percent of requests for unscheduled maintenance at GLWACH.

Radiology Department

The Radiology Department is an integral part of the hospital services providing an average of 31,616.2 total radiology and 20,560.4 diagnostic radiology weighted procedures, per month, for the five month study period (Appendix D). The total radiology weighted procedures include ultrasound, CAT scan and nuclear medicine services, in addition to diagnostic radiology. The department is very well staffed, to accomplish this workload, as depicted in Table 5.

TABLE 5
RADIOLOGY DEPARTMENT MANPOWER
(including nuclear medicine)

	Military			Civilian		
	Req	Auth	Assg	Req	Auth	Assg
Officers	4	3	4	18	15	16
Enlisted	13	11	10	12	10	10

(Technicians only)

Source: Manpower Survey - TDA 0486

In interviews with the Officer-in-Charge (OIC)[4] and NCOIC[5] of radiology, the main premise for the impetus for the study, that increasing medical maintenance repair times were impacting negatively on patient care capabilities, was reiterated. The study was focused to examine this possible correlation, drawing on medical maintenance records, quality control information and Uniform Chart of Accounts (UCA) productivity data, in retrospect. For a complete analysis, it is now apparent that daily documentation of department adjustments was necessary, albeit extremely time consuming, and therefore possibly not implemented even if it had been recognized. Due to the duplication of capabilities, alternate rooms were able to take up the slack for deadlined rooms. The wealth of information contained in stacks of computer printout, however, was a matter of composite reporting, and it was impossible to get a daily, by room, analysis. Although restricted, some valuable conclusions can still be drawn.

The graphs contained in Appendix E depict exposure counts, a different measure from weighted procedures, by room, linked with maintenance work orders. The most important conclusion is that the units still operated for the majority of time workorders were open. This is reflective of the versatility of the units - other procedures can be accomplished while waiting for a specific function to be repaired. In those instances when the room/unit was completely down, exposure count also declined. The other fact that can be drawn from these graphs is that the longest open time for a work order during the study was 95 days, but in cases where the unit was actually inoperable, the repair time averaged 6.7 days.

ANALYSIS OF VARIABLES

The next step is to evaluate the data collected. The graphs in Appendix D depict the productivity of Radiology over the five month period. It is important to remember that the diagnostic radiology weighted procedures are a factor in the total weighted procedures. The next observation is that although diagnostic procedures varied significantly, the pattern of the total procedures followed an expected seasonal trend, due to the holidays. Also, the same three physicians are responsible for all the procedures, so the dip in October for diagnostic procedures is most certainly related to the peak during the month for total procedures, they were just busy doing other procedures. Since the two samples are not independent, no statistical test can be used to establish direct correlations.

The table in Appendix F delineates the possible variables to be considered. By utilizing a nonparametric test of association, it is possible to establish a dependence or independence. An alpha level of .95, the normal statistical significance level, was set a priori. Statistical tests are detailed in Appendix G.

The first two variables evaluated were total diagnostic procedures and medical maintenance manhours. If medical maintenance delays were directly responsible for decreases in patient care procedures, it would be expected that the amount of medical maintenance time would have an inverse relationship with the number of procedures: increase the time, decrease the number of procedures. The statistical analysis shows no association - that the two samples are independent. This is where the factor of equipment duplication is crucial however -- it is possible that flexibility of equipment capabilities compensated for downtime. This is an important factor.

If the number of weighted procedures was not directly related to medical maintenance manhours, the next logical choice was patient population. In fact, there was a strong direct relationship between the number of inpatient procedures and average daily beds occupied, and, an association that would have been accepted at alpha = 0.9, for the outpatient procedures and average daily clinic visits. What these analyses demonstrate is an association of various factors which impact on diagnostic radiology performance. Logically, medical maintenance repair time would have some impact, which is demonstrated by the graphs is Appendix E, but do not appear to have a significant impact on overall performance. This is contrary to the basic premise held by the Radiology Department.

Civilian Contract

Another aspect of the study was to establish the availability and cost estimate of a civilian contract. Ten of the eleven units which provide diagnostic radiology services were manufactured by General Electric (GE). An interview with the local service representative for GE revealed a definite interest for providing contract services.[6] He felt that the repairman providing service for the CAT scanner could also accommodate a program for the diagnostic radiology equipment, with response time estimated at within 24 hours, subject to delays for evening or weekend problems. In contrast, the Medical Maintenance Branch maintains a call roster for emergency workorders, with response time guaranteed within an hour for life threatening malfunctions. The civilian contract estimate for repair times was from one to three days, depending on availability of parts. During the five month study, repair was accomplished within 72 hours only 38 percent of the time (Appendix C). The cost of the contract was figured at ten percent of purchase price for all equipment installed in 1977 or before, and eight percent for all other units. This estimate comes to $152,333.58 per year, or $63,472.33 for the five month study (Appendix H). In contrast, the medical maintenance services for October 1985 to February 1986 cost $23,972.45, a difference of $39,499.88, excluding only costs for testing and calibration equipment which is on-site, and one time purchase (Appendix I). So the civilian contract would offer better service, but at a much higher price.

KELLER ARMY COMMUNITY HOSPITAL

Keller Army Community Hospital is a facility where this cost has been justified. It is a 65 bed facility with three units in the Radiology Department providing diagnostic capabilities. A direct comparison was not possible due to the difference in unit capabilities, and disparity between workload, as seen in Table 6. Some general inferences are appropriate however.

TABLE 6
TOTAL RADIOLOGY WEIGHTED PROCEDURES

	OCT	NOV	DEC	JAN	FEB
GLWACH	34,428	31,634	29,225	30,761	32,033
KACH	8,749	6,513	5,424	6,483	6,261

Source: Comptroller Division Review and Analysis Data

7

In talking with the medical maintenance officer at KACH, several factors were identified in the decision to have a civilian contract for radiology equipment. First, the medical maintenance branch is comprised of two military BMETs, so the required familiarity and expertise with radiographic equipment may be absent, as military personnel rotate assignments. The second key factor is the lack of backup, or duplication of capabilities already mentioned. The impact of downtime is much greater in a small department. In this instance, the decrease in repair time available through contract services is often imperative. The capability of the service representative to simply substitute an entire board, which is then sent to the company for repair, is the main timesaver as compared to the facility BMET who must troubleshoot down to the offending circuit. Consequently, the repair times for radiologic equipment at KACH averages 24-48 hours. The main drawback is night and weekend malfunctions, as emergency calls are not covered in the contract, and monies for this support are closely monitored. The experience for this facility demonstrates a definite relationship though between repair time and patient procedures.

PATIENT CARE COSTS

The final element of the study to be examined is patient care costs: those elements of "costs" that are not monetary, but reflective of service and the delivery of quality patient care. One indication of the delivery of satisfactory patient care is the Patient Representative Program.[8] During the five month study, the Patient Representative Officer received only three complaints from Radiology patients - two related to delays in having x-rays taken, unrelated to downed equipment; one related to the receptionist's behavior and none with the inability to schedule an exam. It appears that equipment downtime did not affect quality patient care from the patients' viewpoint. As stated earlier, a daily log of patients might have documented some patient delays due to downed equipment, but his was not accomplished.

The other factor of patient care costs - the delivery of quality care, is of concern. Although there is duplication of capabilities, there are likely some rooms that are better organized, more familiar, or better located, that encourage a better quality exam. This has long been an assumption made by the clinicians in support of immediate repair of the ideal equipment. The increased emphasis on quality assurance and risk management lend weight to the claims, but also demand equal performance from second choice equipment. An in-house program has the greatest familiarity with clinicians and equipment, and can help insure standardization of quality control. Considering the nebulous aspects of patient care costs, and incomplete documentation of these factors over the five month study period, this criteria will not be used in the decision matrix.

DECISION MATRIX

An analysis of medical maintenance support of diagnostic radiology equipment has been accomplished. The decision matrix is the final step. The alternatives and criteria have been discussed, and the matrix is constructed in Table 7. The advantage is given to the alternative with the lowest value for each criteria, and the criteria of economic feasibility is given a double weight, as previously discussed. Given these factors, the alternative of in-house medical maintenance support is chosen.

TABLE 7
DECISION MATRIX

Alternative / Criteria	In-House	Contract
Economic Feasibility (x2)	+ + $23,972	- - $63,472
Response Time	+ within one hour	- within 24-72 hours
Repair Time	- Ave minimum 6.7 days	+ Ave 1-3 days
	3 + /1 -	1 + / 3 -

CHAPTER II
FOOTNOTES

[1] Interview with CW2 Owen Raysor, Chief, Medical Maintenance Branch, GLWACH, Fort Leonard Wood, Missouri, 20 May 1986.

[2] Ibid., 28 August 1985.

[3] Interview with SFC Samuel Gunther, NCOIC, Medical Maintenance Branch, GLWACH. Fort Leonard Wood, Missouri, 6 May 1986.

[4] Interview with Major Paul Meunier, MC, OIC, Radiology Department, GLWACH, Fort Leonard Wood, Missouri, 9 September 1985.

[5] Interview with SFC Don McCormick, NCOIC, Radiology Department, GLWACH, Fort Leonard Wood, Missouri, 18 February 1986.

[6] Interview with Craig Blackhall, General Electric Service Representative, Springfield, Missouri, 16 June 1986.

[7] Interview with CW2 William Smith, Chief, Medical Maintenance Branch, Keller Army Community Hospital, West Point, New York, 21 May 1986.

[8] Interview with Wilma Oursbourne, Patient Representative Officer, GLWACH, Fort Leonard Wood, Missouri, 10 March 1986.

CHAPTER III

CONCLUSION/RECOMMENDATION

Based on evidence provided in this study, the optimum method of providing biomedical engineering/maintenance support of diagnostic radiology equipment at General Leonard Wood Army Community Hospital is through in-house personnel. This finding is in congruence with current industry trends and Army Medical Department doctrine. It is cost effective; restricting contract expenditures to the unavoidable manufacturer repairs or technology imperatives. Immediate response time is insured, as well as continued familiarization of BMET personnel with equipment which will require on-site support in a wartime scenario. Although the repair time is extended, the system is available for expeditious parts acquisition and repair, if the patient care situation requires it.

This question of who should provide support has been posed often in the past -- with the same answer a majority of the time. The fast paced changes in modern health care lend a sense of justification to periodic reappraisal. However, a more appropriate study might examine the in-house support system to improve service and decrease the frequency of the question being asked in the first place. Technological change and sophistication of radiologic units has an impact on the effectiveness of the system. A study of the whole process, including shop stock procedures, the emphasis and impact of continuing education, and the determination of repair priorities might yield valuable answers.

The field of biomedical engineering/maintenance, military and civilian, continues to develop to meet the challenges of technological improvements, quality assurance, and cost containment.

APPENDIX A

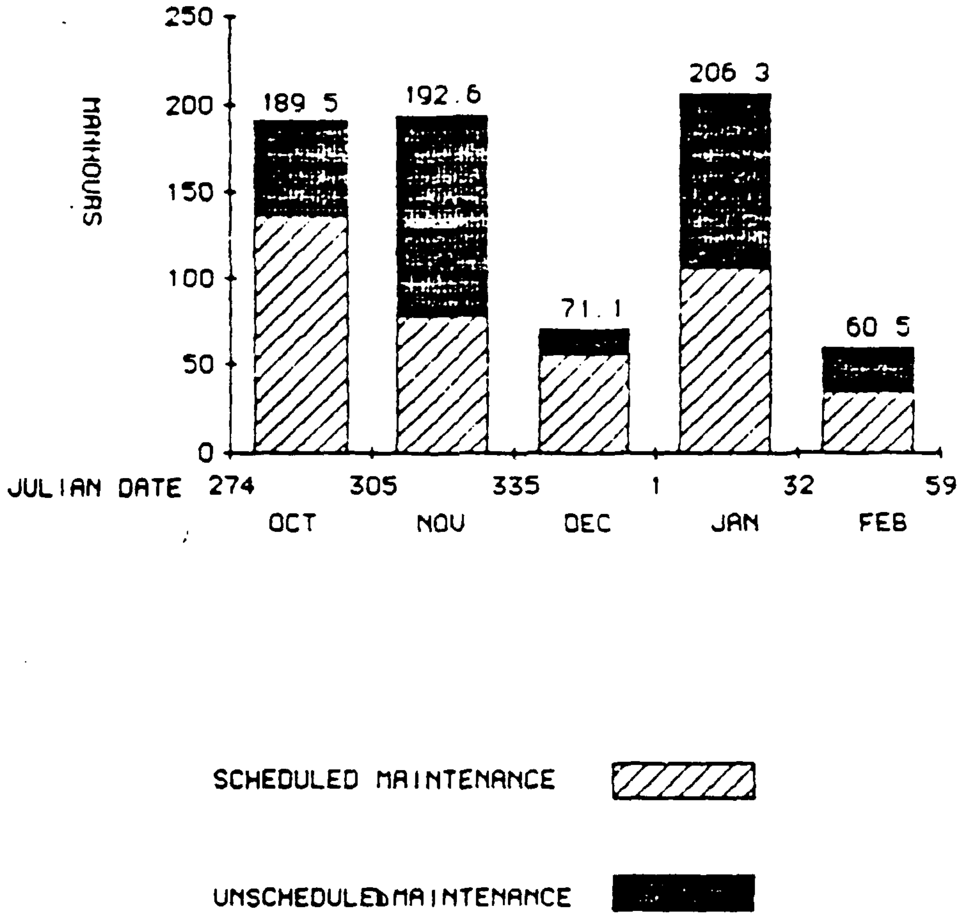
MEDICAL MAINTENANCE SUPPORT TO THE
DIAGNOSTIC RADIOLOGY DEPARTMENT

MEDICAL MAINTENANCE

by

MANHOURS TO RADIOLOGY

OCT 85 TO FEB 86



Source: PCN RPB-8F1 Maintenance Record

APPENDIX B

UNSCHEDULED MAINTENANCE REQUESTS

UNSCHEDULED SERVICES WORK ORDERS

	ON HAND	RECEIVED	RADIOLOGY / TOTAL	COMPLETED	BALANCE
OCTOBER 85					
Radiology	8	25	9.6%	18	15
Total	161	261		247	175
NOVEMBER 85					
Radiology	15	20	6.5%	12	23
Total	175	306		166	314
DECEMBER 85					
Radiology	23	14	5.4%	22	15
Total	314	257		366	205
JANUARY 86					
Radiology	15	33	9.9%	35	13
Total	205	334		404	136
FEBRUARY 86					
Radiology	13	14	4.5%	20	7
Total	136	308		240	204

SOURCE: PCN RPB - 8C1 MONTHLY MAINTENANCE PERFORMANCE REPORT (RECAP)

APPENDIX C

MAINTENANCE REQUESTS FROM

DIAGNOSTIC RADIOLOGY

MAINTENANCE REQUESTS FROM DIAGNOSTIC RADIOLOGY

OCTOBER (Julian dates 274 - 304)

MCN # (RM#)	WORK ORDER OPEN	PM/CL/RE HOURS	PARTS $
2111 - D1299(1)	5224-5319	17.0(PM)	-
2118(M)	5214-5283	2.5(RE)	0
2118(M)	5291-6010	1.5(RE)	$4,740.00
2004(5)	5240-5310	10.0(RC)	$ 700.00(MH)
2004(5)	5240-5311	1.0(RE)	0
2113(6)	5274-5303	28.0(PM)	-
2113(6)	5280-5282	5.0(RE)	0
2113(6)	5283-5284	2.5(RE)	0
2113(6)	5240-5310	10.0(RC)	$ 700.00(MH)
2113(6)	5240-5311	2.0(RE)	0
2113(6)	5289-5316	12.0(RE)	$ 36.00
1900(7)	5240-5310	10.0(RC)	$ 700.00
1900(7)	5240-5310	2.5(RE)	0
3313(8)	5274-5303	76.5(PC)	-
3313(8)	5280-5280	1.5(RE)	0
2050(P1)	5274-5303	15.0(PM)	-
D1843(P2)	5281-5320	22.5(RE)	$1,200.00
2109(3)	5280-5288	10.0(RE)	0

KEY

PM = Preventive Maintenance
CL = Calibration
RE = Repair
AA = PM, CL, and Safety Check
RC = Contract Repair
PS = PM and Safety

SOURCE: PCN RPB-8F1, MAINTENANCE RECORD

MAINTENANCE REQUESTS FROM DIAGNOSTIC RADIOLOGY

NOVEMBER (Julian dates 305 - 334)

MMCN # (RM#)	WORK ORDER OPEN	PM/CL/RE HOURS	PARTS $
*2118(M)	5311-5351	0.5(RE)	0
2004(5)	5305-5331	16.0(CL)	-
2113(6)	5312-5312	1.5(RE)	0
1900(7)	5305-5331	33.0(PM)	-
1900(7)	5339-5351	0.5(RE)	-
3313(8)	5302-5322	13.0(RC)	$1,026.00
3313(8)	5302-5338	78.5(RE)	744.20
2111 - D1299(1)	5305-5324	30.5(PM)	-
*2111 - D1299(1)	5319-5337	1.0(RE)	-
2110(2)	5323-5323	10.0(RE)	-
2004(5)	5335-5340	21.1(RE)	-

* User/Operator Caused Failure

KEY

PM = Preventive Maintenance
CL = Calibration
RE = Repair
AA = PM, CL, and Safety Check
RC - Contract Repair
PS = PM and Safety

SOURCE: PCN RPB-8F1, MAINTENANCE RECORD

MAINTENANCE REQUESTS FOR DIAGNOSTIC RADIOLOGY

DECEMBER (Julian dates 335 - 365)

MMCN # (RM#)	WORK ORDER OPEN	PM/CL/RE HOURS	PARTS $
2108(4)	5335-5352	24.0(PM)	-
2004(5)	5335-5340	21.1(PS)	-
1906(7)	5354-5357	2.5(RE)	0
3313(8)	5346-6010	6.5(RC)	$536.45
3313(8)	5346-6010	2.0(RE)	0
D1843(P2)	5335-5347	0.5(PM)	-
2110(2)	5335-5344	21.0(PM)	-

KEY

PM = Preventive Maintenance
CL = Calibration
RE = Repair
AA = PM, CL, and Safety Check
RC = Contract Repair
PS = PM and Safety

SOURCE: PCN RPB-8F1, MAINTENANCE RECORD

MAINTENANCE REQUESTS FROM DIAGNOSTIC RADIOLOGY

JANUARY (Julian dates 1 - 31)

MMCN #(RM#)	WORK ORDER OPEN	PM/CL/RE HOURS	PARTS $
2118(MM)	6010-6010	2.0(RE)	$ 541.00
*2118(M)	6013-6013	0.5(RE)	0
2113(6)	6001-6031	48.0(AA)	-
*2004(5)	6006-6007	1.5(RE)	0
*2004(5)	6017-6021	0.5(RE)	0
2004(5)	6021-6051	1.0(RC)	$ 75.00(MH)
2004(5)	6021-6057	2.5(RE)	0
*2113(6)	6013-6013	1.0(RE)	-
*2113(6)	6017-6042	1.0(RE)	7.00
3313(8)	6001-6028	40.8(PS)	-
3313(8)	6006-6010	13.5(RE)	0
3313(8)	6014-6021	13.5(RE)	0
3313(8)	6027-6036	1.5(RE)	-
3313(8)	6021-6066	36.0(RC)	$2,664.00
3313(8)	6021-6066	29.8(RE)	-
2050(P1)	6001-6029	15.5(PS)	-
2050(P1)	6028-6030	29.0(CL)	-
2050(P1)	6013-6014	1.0(RE)	0
D1843(P2)	6008-6009	1.0(RE)	0
*2110(2)	6006-6007	0.5(RE)	0
2110(2)	6014-6014	0.7(RE)	0
2110(2)	6017-6021	1.0(RE)	0
2110(2)	6027-6036	1.0(RE)	0

*User/Operator Caused Failure

KEY

PM = Preventive Maintenance
CL = Calibration
RE = Repair
AA = PM, CL, and Safety Check
RC = Contract Repair
PS = PM and Safety

SOURCE: PCN RPB-8F1, MAINTENANCE RECORD

MAINTENANCE REQUESTS FROM DIAGNOSTIC RADIOLOGY

FEBRUARY (Julian dates 32 - 59)

MMCN #(RM#)	WORK ORDER OPEN	PM/CL/RE HOURS	PARTS $
2004(5)	6041-6042	1.0(RE)	$ 7.00
*2004(5)	6052-6052	0.5(RE)	0
*2113(6)	6038-6042	1.0(RE)	0
2113(6)	6051-6056	4.0(RE)	0
1900(7)	6032-6057	23.0(PS)	-
*1900(7)	6037-6042	1.0(RE)	0
1900(7)	6043-6044	3.0(RE)	0
1900(7)	6035-6051	2.0(RE)	0
D1843(P2)	6032-6057	10.0(CL)	-
2110(2)	6045-6050	15.0(RE)	0

*User/Operator Caused Failure

KEY

PM = Preventive Maintenance
CL = Calibration
RE = Repair
AA = PM, Cl, and Safety Check
RC = Contract Repair
PS = PM and Safety

SOURCE: PCN RPB-8F1, MAINTENANCE RECORD

APPENDIX D

WORKLOAD DATA FOR THE

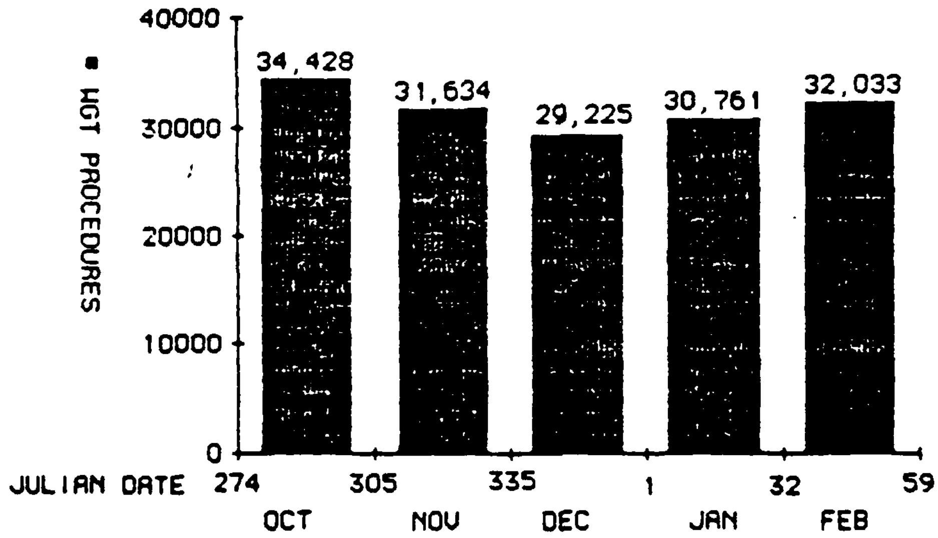
RADIOLOGY DEPARTMENT AND THE

DIAGNOSTIC RADIOLOGY SECTION

TOTAL RADIOLOGY

WEIGHTED PROCEDURES

FOR OCT 85 TO FEB 86

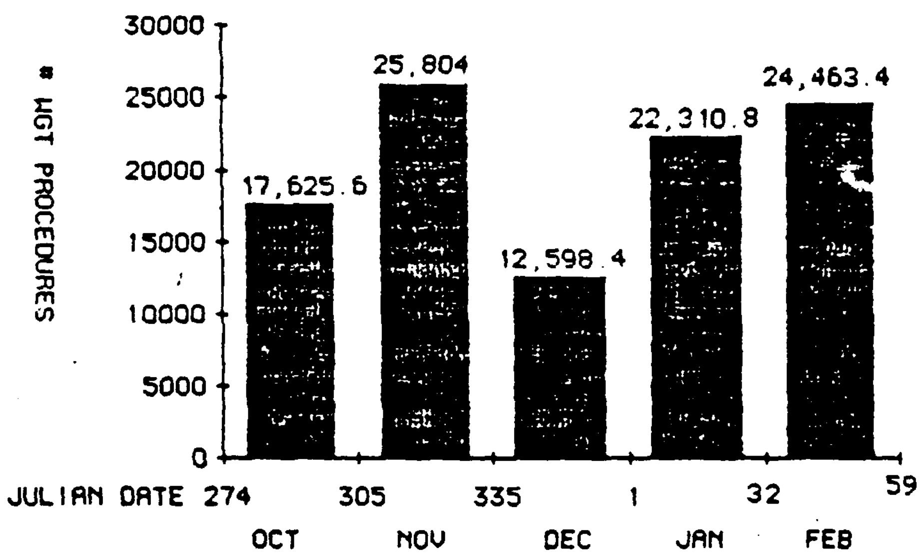


Source: Uniform Chart of Accounts Data

DIAGNOSTIC RADIOLOGY

WEIGHTED PROCEDURES

FOR OCT 85 TO FEB 86



Source: Uniform Chart of Accounts Data

APPENDIX E

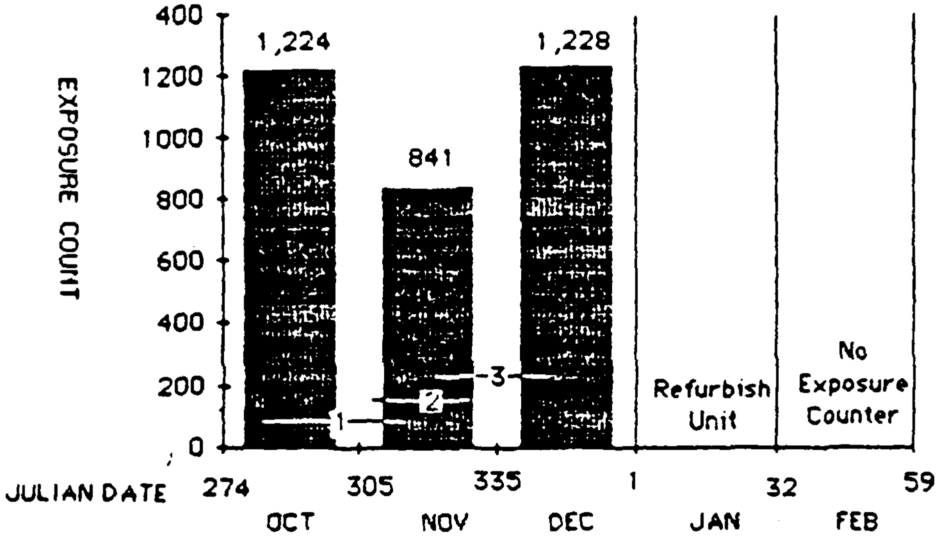
WORKLOAD AND MAINTENANCE REQUEST,

PER DIAGNOSTIC RADIOLOGY UNIT

MMCN# 2111-0199

ROOM 1

X RAY APPAR RADIO/ FLUORO



1-WORK ORDER OPEN FROM JULIAN DATES 224-319. MAINT. REPAIR/ PM TIME = 17.0 HRS.

2-WORK ORDER 305- 324. TIME = 30.5 HRS

3-WORK ORDER 319-337. TIME = 1.0 HRS

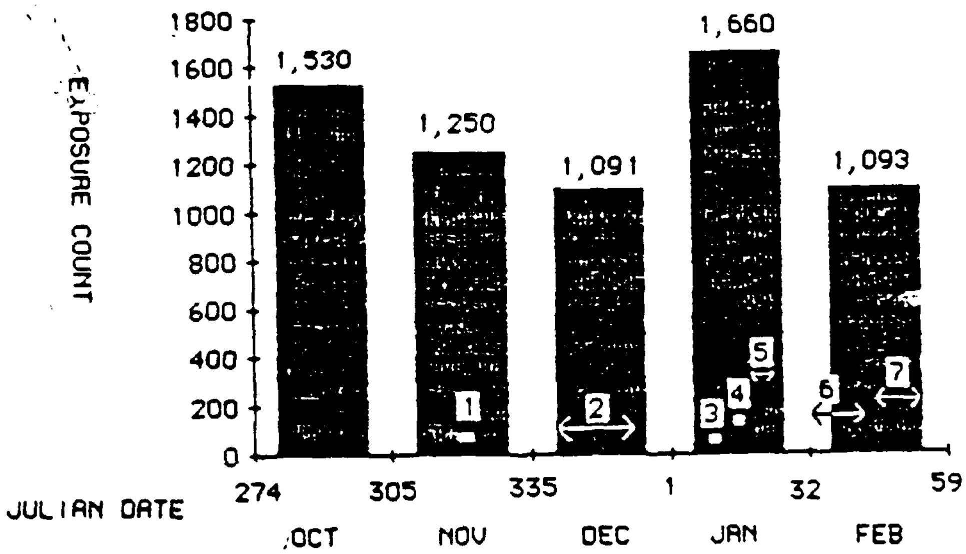
Source: PCN RPB-8F1 Maintenance Record, Radiology Quality Control Data

MMCN * 2110

ROOM 2

X RAY APPAR RADIO/ FLUORD

800M



1-Work order 323-323. Time 10.0 hours.

* 2-Work order 335-344. Time 21.0 hours.

3-Work order 006-007. Time 0.5 hours.

4-Work order 014-014. Time 0.7 hours.

5-Work order 017-021. Time 1.0 hours.

6-Work order 027-036 Time 1.0 hours.

*7-Work order 045-050. Time 15.0 hours

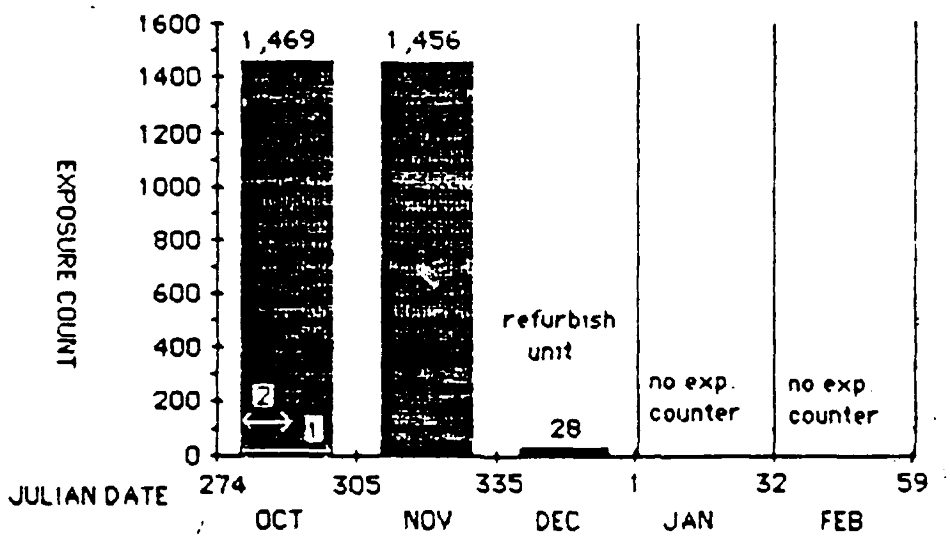
* Unit actually inoperable.

Source: *PCNRPB-8F1 Maintenance Record, Radiology Quality Control Data*

MMCN * 2109-01095

ROOM 3

XRAY APPAR RADIO-FLUORO 10



1- WORK ORDER 274-305. TIME 0. HOURS.

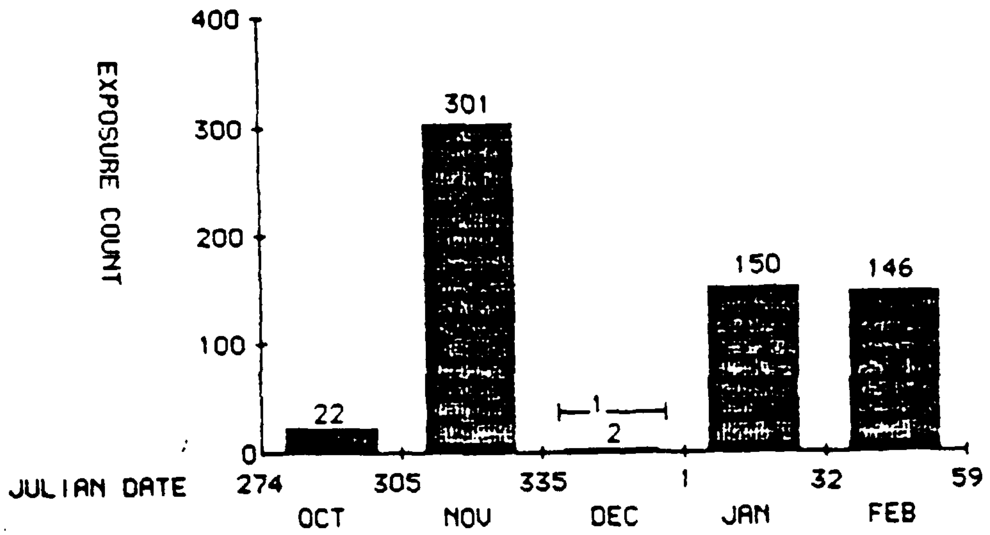
2- WORK ORDER 280-288. TIME 10.0 HOURS.

Source: PCN RPB-8F1 Maintenance Record, Radiology Quality Control Data

MMCN * 2125/2108

ROOM 4

X RAY APPAR RADIO/FLUORO 1200M



* 1- WORK ORDER 335-354 TIME 24.0 HOURS.

* MMCN 2108 UNIT ACTUALLY INOPERABLE.

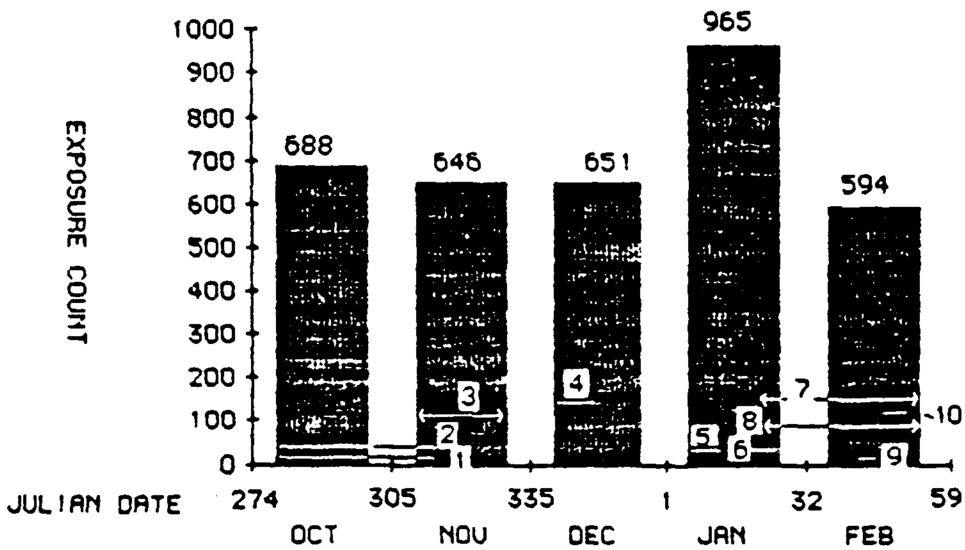
Source: PCN RPB-8F1 Maintenance Record, Radiology Quality Control Data

MMCN * 2004

ROOM 5

X RAY APPAR RADIO

500 MA



1- WORK ORDER 240-310 TIME 1.0 HOUR.

2- WORK ORDER 240-311. TIME 1.0 HOUR

3- WORK ORDER 305-331. TIME 16.0 HOURS

4- WORK ORDER 335-340. TIME 21.0 HOURS

* 5- WORK ORDER 006-007. TIME 2.0 HOURS.

6- WORK ORDER 017-021. TIME 0.5 HOUR.

7- WORK ORDER 021-051. TIME 1.0 HOUR.

8- WORK ORDER 041-042. TIME 1.0 HOUR.

* 9- WORK ORDER 021- 057. TIME 2.5 HOURS

* 10- WORK ORDER 052-052. TIME 0.5 HOUR.

* UNIT ACTUALLY INOPERABLE.

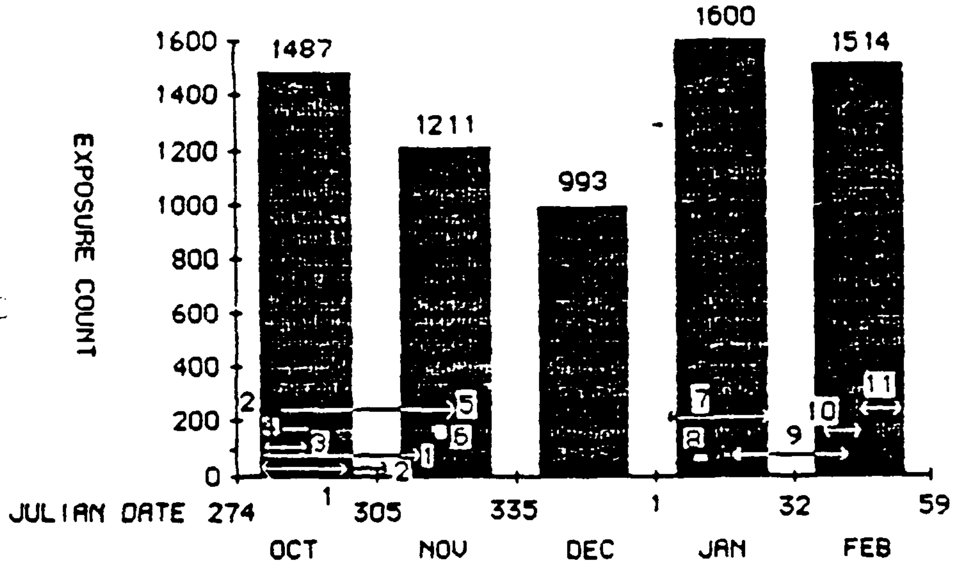
Source: PCN RPB-8F1 Maintenance Record, Radiology Quality Control Data

MMCN # 2113

ROOM 6

X RAY RADIO/FLUORO

1000M



1- WORK ORDER 240-311. TIME 12.0 HOURS.

2- WORK ORDER 274-303. TIME 28.0 HOURS.

* 3-WORK ORDER 280-282. TIME 5 HOURS.

* 4- WORK ORDER 283-284. TIME 2.5 HOURS.

5- WORK ORDER 289-316 TIME 12.0 HOURS

6- WORK ORDER 312-312. TIME 1.5 HOURS.

7- WORK ORDER 001-031. TIME 48.0 HOURS.

8- WORK ORDER 013-013. TIME 1.0 HOUR.

9- WORK ORDER 017-042. TIME 1.0 HOUR.

* 10- WORK ORDER 038-042. TIME 1 0 HOUR.

11- WORK ORDER 051-056 TIME 4.0 HOURS.

* UNIT ACTUALLY INOPERABLE.

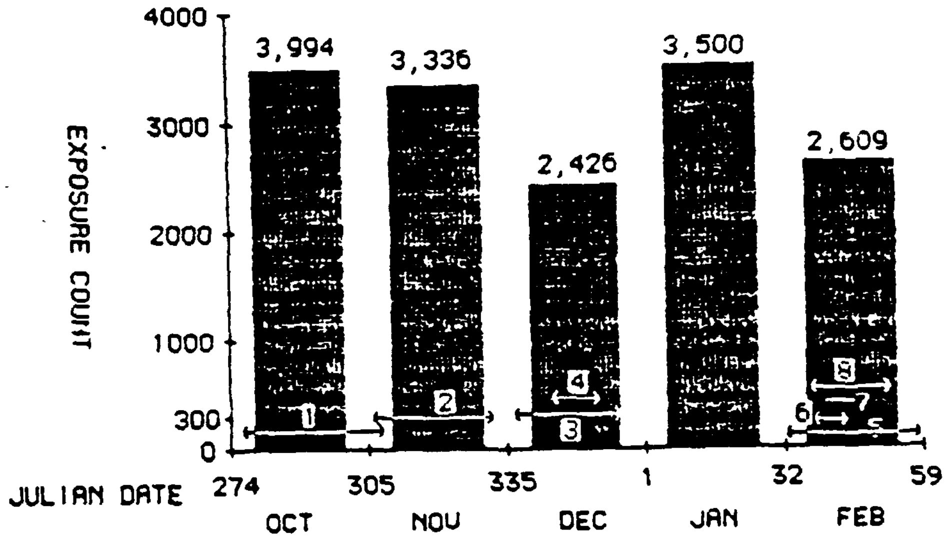
Source: PCN RPB-8F1 Maintanance Record,
Radiology Quality Control Data

MMCN * 1900

ROOM 7

XRAY APPAR RADIO/ FIUORO

600M



1- WORK ORDER 240-311. TIME 12.5 HOURS.

2- WORK ORDER 305- 331. TIME 33.0 HOURS.

3- WORK ORDER 339- 351. TIME 0.5 HOUR.

* 4- WORK ORDER 354-357. TIME 2.5 HOURS.

5- WORK ORDER 032-057. TIME 23.0 HOURS.

*6- WORK ORDER 037-042. TIME 1.0 HOUR

7- WORK ORDER 043-044. TIME 3.0 HOURS.

8- WORK ORDER 035-051. TIME 2.0 HOURS

* UNIT ACTUALLY INOPERABLE.

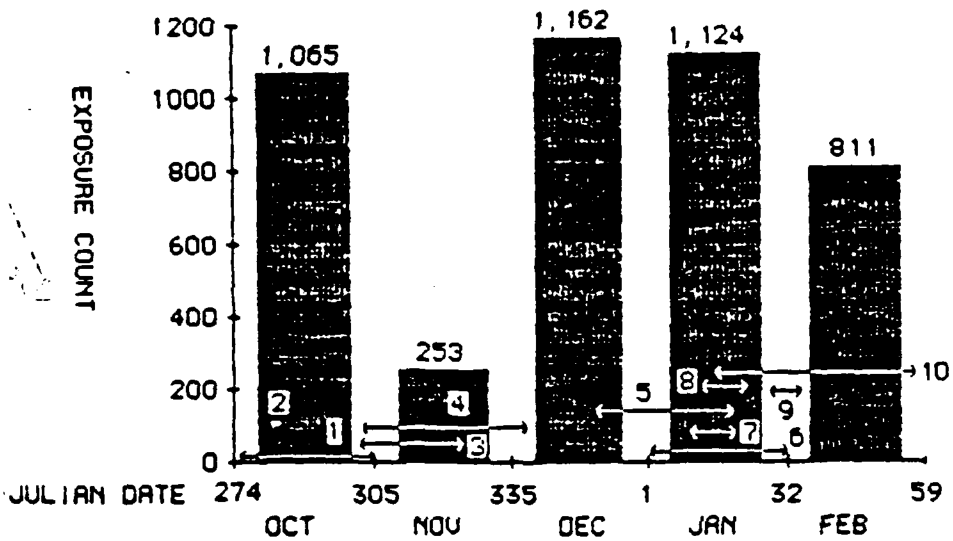
Source: PCN RPB-8F1 Maintenance Record,
Radiology Quality Control Data

MMCN # 3313

ROOM 8

XRAY APPAR RADIO/FLUORO

1,000 M



1- WORK ORDER OPEN 275-303. TIME 76.5 HOURS.

2- WORK ORDER 280-280. TIME 1.5 HOURS.

3- WORK ORDER 303-322. TIME 13.0 HOURS.

* 4- WORK ORDER 302-328. TIME 78.5 HOURS.

5- WORK ORDER 346-010. TIME 8.5 HOURS.

6- WORK ORDER 001-028. TIME 40.8 HOURS.

* 7- WORK ORDER 006-010. TIME 13.5 HOURS.

8- WORK ORDER 014-021. TIME 13.5 HOURS.

* 9- WORK ORDER 027-036. TIME 1.5 HOURS.

10- WORK ORDER 021-066. TIME 65.8 HOURS.

* UNIT ACTUALLY INOPERABLE

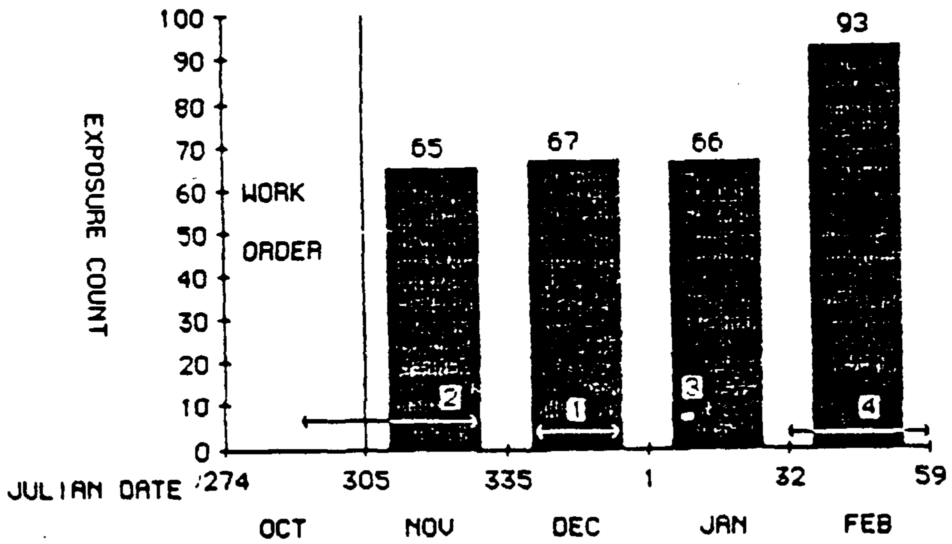
Source: PCN RPB-8F1 Maintenance Record, Radiology Quality Control Data

MMCN * 2051-D 1843

PORTABLE

XRAY APPAR RADIO MOBILE

100 M



1- WORK ORDER 5335-5347. TIME 0.5 HOUR.

2- WORK ORDER 5281-5320. TIME 22.5 HOURS.

* 3- WORK ORDER 6008- 6009. TIME 1.0 HOUR.

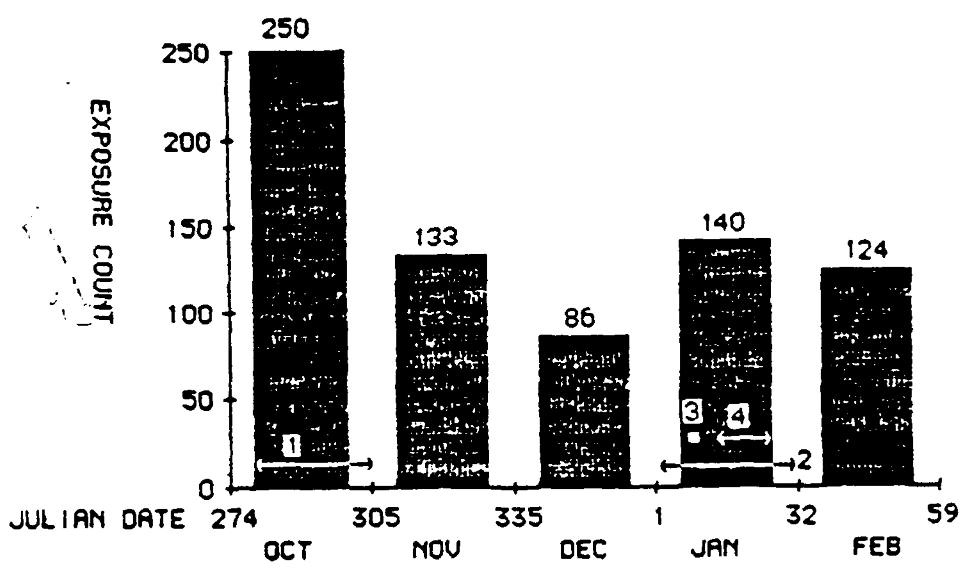
4- WORK ORDER 6032-6057. TIME 10.0 HOURS.

* UNIT ACTUALLY INOPERABLE.

Source: PCN RPB-8F1 Maintenance Record,
Radiology Quality Control Data

MMCN # 2050 PORTABLE

XRAY APPAR RADIO MOBILE 100



1- WORK ORDER 275-303. TIME 15.0 HOURS.

2- WORK ORDER 001-029. TIME 15.5 HOURS.

* 3- WORK ORDER 013-014. TIME 1.0 HOUR.

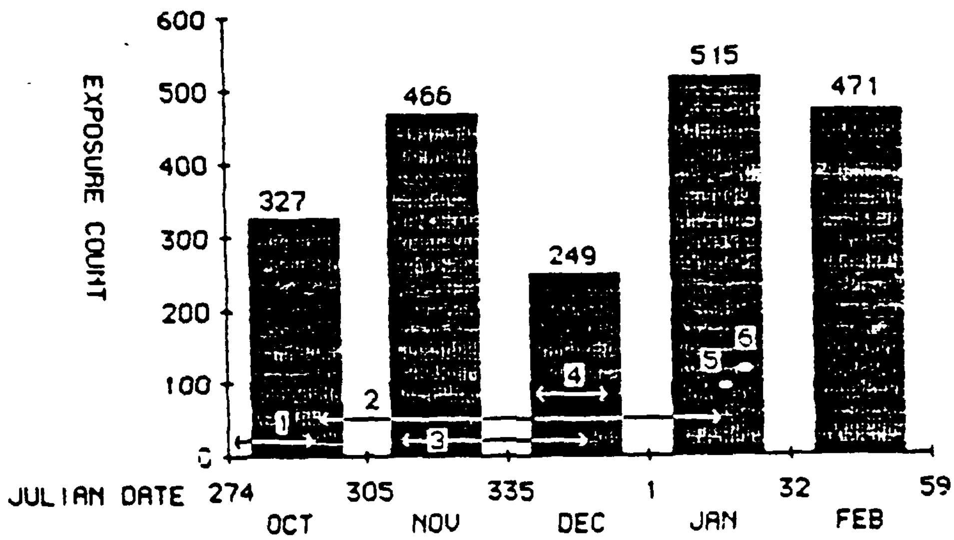
* 4- WORK ORDER 028-030. TIME 29.0 HOUIRS.

* UNIT ACTUALLY INOPERABLE.

Source: PCN RPB-8F1 Maintenance Record,
Radiology Quality Control Data

MMCN # 2118

MAMMOGRAPHY UNIT



1- WORK ORDER 214-283. TIME 2.5 HOURS.

2- WORK ORDER 291-010. TIME 1.5 HOURS.

3- WORK ORDER 311-351. TIME 0.5 HOUR.

4- WORK ORDER 335-346. TIME 0.5 HOUR.

*5- WORK ORDER 010-010. TIME 2.5 HOURS.

6- WORK ORDER 013-013. TIME 0.5 HOUR.

* UNIT ACTUALLY INOPERABLE

Source: PCN RPB-8F1 Maintenance Record, Radiology Quality Control Data

APPENDIX F

WORKLOAD DATA

WORKLOAD DATA

	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY
Total Radiology Weighted Procedures	34,428	31,634	29,225	30,761	32,033
Total Diagnostic Radiology Weighted Procedures	17,626	25,804	12,598	22,311	24,463
Total Medical Maintenance Manhours To Radiology	189.5	192.6	71.1	206.3	60.5
Total (DX RAD) Inpatient Weighted Procedures	2,195	4,095	1,492	2,418	2,475
Average Daily Beds Occupied	124.3	133.5	89.6	124.3	161.1
Total (DX RAD) Outpatient Weighted Procedures	15,431	21,709	11,106	19,893	21,988
Average Daily Clinic Visits	473	423.3	408	487.4	489.4

Source: UCA Radiology Logging System, Maintenance Records, and Comptroller Review and Analysis Data

APPENDIX G

STATISTICAL ANALYSIS OF ASSOCIATION

SPEARMAN RANK CORRELATION COEFFICIENT TEST

H_o : The number of diagnostic radiology weighted procedures and medical maintenance manhours to diagnostic radiology equipment are independent.

H_A : There is a direct, inverse relationship between the number of diagnostic radiology weighted procedures and medical maintenance manhours to diagnostic radiology equipment.

Test statistic $r_s = 1 - \frac{6(\Sigma d_i^2)}{n(n^2-1)}$

Data

n	# PROCEDURES (Xi)	# MANHOURS (Yi)	R(Xi)	R(Yi)	di(Xi-Yi)	di^2
OCT	17,626	189.5	2	3	-1	1
NOV	25,804	192.6	5	4	1	1
DEC	12,598	71.1	1	2	-1	1
JAN	22,311	206.3	3	5	-2	4
FEB	24,463	60.5	4	1	-3	9

$di^2 = 16$

$$r_s = 1 - \frac{6(16)}{5(5^2-1)} = 0.2$$

n	.001	.005	.010	.025	.05	.10
5	-	-	.9000	.9000	.8000	.7000

∴ Accept H_o. The two variables are independent.

SPEARMAN RANK CORRELATION COEFFICIENT TEST

H_0 : The number of inpatient diagnostic radiology weighted procedures and the average daily beds occupied, per month, are independent.

H_A : There is a direct relationship between the number of inpatient diagnostic radiology weighted procedures and the average daily beds occupied, per month.

Test statistic $$r_s = 1 - \frac{6(\Sigma d_i^2)}{n(n^2-1)}$$

Data

n	# INPT PROC (Xi)	# AVE BEDS (Yi)	R(Xi)	R(Yi)	di(Xi-Yi)	di^2
OCT	2,195	124.3	2	2.5	-.5	.25
NOV	4,095	133.5	5	4	1	1
DEC	1,492	89.6	1	1	0	0
JAN	2,418	124.3	3	2.5	.5	.25
FEB	2,475	161.1	4	5	-1	1

$di^2 = 2.5$

$$r_s = 1 - \frac{6(2.5)}{5(5^2-1)} = 0.875$$

n	.001	.005	.010	.025	.05	.10
5	-	-	.9000	.9000	.8000	.7000

$.025 < p < .05$

∴ Reject H_0. At the .05 level of significance, there is a direct relationship between the two variables.

SPEARMAN RANK CORRELATION COEFFICIENT TEST

H_o : The number of outpatient diagnostic radiology weighted procedures and the average daily clinic visits per month are independent.

H_A : There is a direct relationship between the number of outpatient diagnostic radiology weighted procedures and the average daily clinic visits, per month.

Test statistic $r_s = 1 - \frac{6(\Sigma d_i^2)}{n(n^2-1)}$

Data

n	# OUTPT PROC Xi	# VISITS Yi	R(Xi)	R(Yi)	di(Xi -Yi)	di^2
OCT	15,431	473	2	3	-1	1
NOV	21,709	423.3	4	2	2	4
DEC	11.106	408	1	1	0	0
JAN	19,893	487.4	3	4	-1	1
FEB	21,988	489.4	5	5	0	0
					di^2 =	6

$$r_A = 1 - \frac{6(6)}{5(5^2 -1)} = 0.7$$

n	.001	.005	.010	.025	.05	.10
5	-	-	.9000	.9000	.8000	.7000

p = .10

$\therefore$ Accept H_o. The two variables are independent.

APPENDIX H

CIVILIAN CONTRACT ESTIMATE

CIVILIAN CONTRACT ESTIMATE

MMCN/RM	PURCHASE PRICE	YEAR IN-SERVICE	PERCENT	CONTRACT PRICE
D1299/1	$110,993	1986	.08	$ 8,879.44
2110/2	403,713	1977	.10	40,371.30
D1095/3	270,657	1985	.08	21,652.56
2125/4	28,683	1977	.10	2,868.30
2108/4	321,977	1977	.10	32,197.70
2004/5	28,683	1972	.10	2,868.30
2113/6	133,629	1977	.10	13,362.90
1900/7	115,285	1979	.08	9,222.80
3313/8	143,203	1980	.08	11,456.24
2050/P1	34,469	1982	.08	2,757.52
D1843/P2	34,469	1985	.08	2,757.52
2118/M	39,390	1977	.10	3,939.00
				$152,333.58

$152,333.58 ÷ 12 = $12,694.47 per month

$63,472.33 for five month period.

Source: PCN RPB-8F1, Maintenance Record

APPENDIX I

MEDICAL MAINTENANCE COSTS
OCTOBER 1985 - FEBRUARY 1986

ANALYSIS OF DOLLAR COSTS - MEDICAL MAINTENANCE SUPPORT
TO DIAGNOSTIC RADIOLOGY

OCTOBER

Labor	$4,282.70	(189.5 hours x $22.60)
Parts	5,976.00	
Contract	2,100.00	
	$6,382.70	

NOVEMBER

Labor	$4,352.76	(192.6 hours x $22.60)
Parts	744.00	
Contract	1,026.00	
	$6,122.76	

DECEMBER

Labor	$1,606.86	(71.1 hours x $22.60)
Parts	0	
Contract	536.45	
	$2,143.31	

JANUARY

Labor	$4,662.38	(206.3 hours x $22.60)
Parts	548.00	
Contract	2,739.00	
	$7,949.38	

FEBRUARY

Labor	$1,367.30	(60.5 hours x $22.60)
Parts	7.00	
Contract	0	
	$1,374.30	

SELECTED BIBLIOGRAPHY

Government Publications

U.S. Civil Service Commission. Bureau of Policies and Standards. Job Grading Standard for Medical Equipment Repairer, WG 4805. Washington, D.C.: Bureau of Policies and Standards, June, 1974.

U.S. Department of the Army. Health Service Command. Logistics Operating Instructions. HSC Regulation 11-5. Ft. Sam Houston, TX.: Health Services Command, August 10, 1984.

U.S. Department of the Army. Health Services Command. Maintenance of Supplies and Equipment Condition Coding and Maintenance Expenditure Limits. HSC Regulation 750-2. Ft. Sam Houston, TX.: Health Services Command, December 6, 1984.

U.S. Department of the Army. Medical Department. Army Medical Department Property Accounting System User's Manual. ADSM 18-HL3-RPB-IBM-UM Vols. 1 and 2. Washington, D.C.: Department of the Army, March 1, 1982.

U.S. Department of the Army. Medical Department. Medical Logistics Policies and Procedures. Army Regulation 40-61. Washington, D.C.: Department of the Army, September 27, 1984.

U.S. Department of the Army. Medical Department. Medical Supply in World War II. Office of the Surgeon General. Washington, D.C.: Department of the Army, 1968.

U.S. Department of the Army. Medical Department. Preventive Maintenance Procedures and Serviceability Standards for Medical Equipment. Technical Manual No. 8-605. Washington, D.C.: Department of the Army, May, 1977.

Books

American Hospital Association. American Society for Hospital Engineering. Medical Equipment Management in Hospitals. AHA Publication No. 190105. Chicago: American Hospital Association, 1982.

Daniel, Wayne W. Applied Nonparametric Statistics. Boston: Houghton Miffin Company, 1978.

Joint Commission on the Accreditation of Hospitals. Accreditation Manual for Hospitals. 1986 ed. Chicago: Author, 1985.

Periodicals

Ben-Zvi, Seymour. "Development of Preventive Maintenance Procedures." Journal of Clinical Engineering 9 (April-June, 1984): pp. 103-112.

Bluemke, Duane H. "Maintenance Cost Control of High Technology Hospital Equipment." Radiology Management 6, no. 1 (1983): pp. 2-3.

Chu, Wei-Kom; Dobry, Charles A.; Imray, Thomas J.; and Taylor, Ted K. "Comprehensive Radiological Equipment Management Program." Journal of Clinical Engineering 9 (October-December 1984): pp. 281-289.

Guignon, Ernest. "Setting up a Clinical Engineering Department." Journal of Clinical Engineering 5 (January-March 1980): pp. 69-75.

Herman, Joseph. "Radiology Equipment Maintenance in a Smaller Hospital." Applied Radiology, (July-August 1984): pp. 79-86.

McNair, Gerald; Brown, C.E.; and Wolbarsht, Roz. "Analysis and Recommendations for a Medical Engineering Department." Journal of Clinical Engineering 6 (October-December 1981): pp. 293-299.

Shepard, Marvin D. "Does the In-Hospital BMET Face Obsolescence?" Journal of Clinical Engineering 5 (October-December 1980): pp. 341-343.

Interviews

Blackball, Craig. General Electric Service Representative, Springfield, Missouri. Interview, 16 June 1986.

Gunther, Samuel J., SFC. NCOIC, Medical Maintenance Branch, GLWACH, Ft. Leonard Wood, Missouri. Interview, 6 May 1986.

McCormick, Don, SFC. NCOIC, Radiology Department, GLWACH, Ft. Leonard Wood, Missouri. Interview, 18 February 1986.

Meunier, Paul, Major. OIC, Radiology Department, GLWACH, Ft. Leonard Wood, Missouri. Interview, 9 September 1985.

Oursbourne, Wilma. Patient Representative Officer, GLWACH, Ft. Leonard Wood, Missouri. Interview, 10 March 1986.

Plumley, Ronald, CW2. Instructor, Medical Maintenance and Facility Branch, Academy of Health Sciences, San Antonio, Texas. Interview, 28 October 1985.

Raysor, Owen, CW2. OIC, Medical Maintenance Branch, GLWACH, Ft. Leonard Wood, Missouri. Interview, 28 August 1985 and 20 May 1986.

Riley, Randall, Commercial Activities Officer, US Army Health Services Command, San Antonio, Texas. Interview, 29 October 1985.

Robertson, John, CW4. Chief, Medical Maintenance Branch, US Army Health Services Command, San Antonio, Texas. Interview, 4 June 1985.

Silvey, James, CW3(P). Chief, Medical Maintenance Branch, US Army Health Services Command, San Antonio, Texas. Interview, 6 June 1986.

Smith, William, CW2. Chief, Medical Maitenance Branch, Keller Army Community Hospital, West Point, New York. Interview, 12 November 1985 and 21 May 1986.

Walker, Fred. Education Specialist, US Army Medical Equipment and Optical School, Fitzsimmons Army Medical Center, Denver, Colorado. Interview, 24 June 1986.