Medical Equipment Service Manual

FRANK BILOON

Theory and Maintenance Procedures

Sterilizer
The Instrument Boiler
The Bedpan Sterilizer
Steam Pressure Sterilizer
Dry Sterilizer
Ultrasound Machine
Lamp
Therapeutic Lamp
Electrocardiograph
Electrocardioscope Machine
Electrocardioscope Recorder
Monitorscope
Pulse-Rate Meter
Temperature Meter
Defibrillator and Synchronizer
The X-ray Tube Filament Circuit
The High-Voltage Circuit
The Timing Circuit
The Rotating-Anode X-ray Tube
Potter-Bucky Diaphragm
Mechanical Timer
Electronic Timer
X-ray Machine
Autotransformer
X-ray Generator

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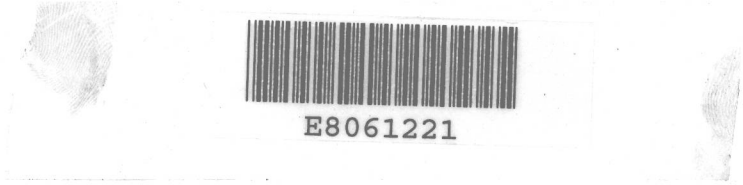

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To my wife, Lillien,
and to my medical equipment manufacturing associates
without whose help this work could not have been accomplished

Foreword

We have been witnessing an amazing transition in modern medicine. Thirty years ago the average general hospital may have utilized an electrocardiograph and an x-ray machine; that same hospital today would have many additional technical devices, for example, phonocardiographs, scintillation imaging computers, electroencephalographs, and cardiac stress testing apparatus. Moreover, intensive-care wards usually employ a full assortment of monitoring equipment each with 10 to 30 or more bedside stations, and, as often as not, a fully complemented central nurses' station. The influence of modern science on health care equipment has similarly expanded in the departments of clinical laboratories, physical therapy, and even into the private physicians' offices. Moreover, the great demand for the new tools of modern medicine has created a new profession of clinical engineering technology.

This accelerating demand in clinical engineering has only recently been appreciated. In the 1950s, medical equipment manufacturers could easily cope with demands for periodic overhauling of their products, while routine

maintenance of their units within the medical facilities was usually satisfactorily accomplished by hospital technicians. But by the early 1960s, the volume of service and the scope of technical knowledge required for satisfactory performance began to exceed the capacity or willingness of the equipment manufacturers to meet the need. Inevitably, physicians and hospital administrators became increasingly dissatisfied with the deteriorating quality of service provided by manufacturers' field service organizations. Hospital maintenance personnel lacked the necessary training to fill the gap. In the early 1970s the users abruptly realized that special skills were required and the labor pool with these skills simply did not exist! Very little foresight was required to see a continually growing need for clinical engineering technicians. Indeed, clinical engineering would soon become an indispensible staff requirement for every hospital. Some of the administrators who attempted to assemble such a staff at a moment's notice were shocked to find that about the only training programs available anywhere were limited to a military source and a few cursory reviews offered by manufacturers.

More as a public service than for any other reason, the author decided to leave a successful 30-year career in military electronics to help fill some of the needs for technical assistance in the medical community of northern California. From 1964 this has been his career. Starting with extensive reading and home study, plus technical courses taken at several prominent medical equipment manufacturing plants, he thoroughly analyzed the operation and maintenance of a wide variety of health care devices. As time went on, hundreds of satisfied customers among the hospital personnel and physicians in the area could attest to his record for prompt and competent service in consulting, maintenance, and repair of medical devices.

In the years that I have known him, Frank has become well-known as a pioneer in the new profession of clinical engineering. He has received invitations to deliver papers before technical societies, to lecture at local universities, and to participate as an instructor at in-service training for a number of general hospitals. When the need became apparent for a textbook in the area of medical equipment maintenance, he volunteered to prepare such a manual from a broad fund of knowledge and experience developed over many years.

This *Medical Equipment Service Manual* is that result. I believe that it will help solve many maintenance problems faced by clinical technicians and engineers. It will also encourage the reader to appreciate the complexity of medical equipment maintenance and its role in improving the quality of patient care.

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Preface

The *Medical Equipment Service Manual* is specifically written for key hospital personnel such as doctors, nurses, and medical administrators, as well as medical equipment repairmen, biomedical equipment technicians, and clinical engineers. It is comprehensive in that a great many of the most important equipment areas are covered. You will notice that its "cookbook" style of preparation lends itself both to the textbook training of students and to instant use in hospital laboratories, repair shops, and even the smallest of doctors' offices. The format is particularly suited to the quick, effective repair of equipment malfunctions.

Throughout the text the language and numbered procedures are selected to supplement the abilities of any conscientious technician regardless of his previous level or precise discipline of study. Wherever possible, a description of the equipment is followed by diagrammatic description and numbered check lists for service. Also included are photographs and schematics of equipment currently in use. These are meant to supplement the file of technical books the user should have received with his instrument purchases.

There are questions and answers for frequently encountered problems and a general bibliography which should make the reader's understanding more complete in the entire field of clinical engineering as it has in the author's experience.

It has been observed by the author that the persons with the greatest aptitude for clinical engineering functions are those with engineering degrees, baccalaureate or associate, well-trained electronic technicians, those trained by the military in medical equipment maintenance, and instrument and electronic repair experts formerly employed at high levels in major defense industry. Of particular background value is the thoughtful comprehensive attitude developed by those in positions of responsibility. Foremen, laboratory supervisors, and technical service department heads are examples. Amateur radio experience is valuable where skill in equipment construction has been demonstrated. Such personnel should study this text as a means of preparing themselves for the many private and public employment openings soon to be in demand throughout the world.

Others engaged in the various branches of health care delivery, such as doctors, nurses, and administrators, will find this book of great value for the understanding and description of many of their equipment problems. Its use will aid them in coping with many of the day-to-day problems associated with the technical devices in daily use. Every office should contain a copy to provide personnel with a better understanding of the use of their own instrumentations as well as the occasional emergency repair.

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B.E.E.
C.B.E.T.
C.C.E.
P.E.

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Contents

1 Electrical Safety

Categories of Electrical Safety

In the hospital or other clinical environment, electrical safety is generally considered to fall into two categories: safety to the patient and safety to operating and attending personnel. These two major subdivisions will be discussed herein and a review of the fundamental aspects will be made. Furthermore, it is pointed out that the clinical equipment operator or electronic technician and engineer are exposed more to the dangers of electrocution than all other personnel combined. You will notice as you progress through the chapters of this manual that the dangers of self-electrocution to service personnel are reiterated repeatedly due to the seriousness of the problem. Be skeptical of equipment safety. Never rely on built-in safety precautions, and do not take electrical safety for granted.

General Electrical Safety

Electrical safety is a technical problem with which all of us in the medical profession are attempting to contend to the best of our abilities and in accordance with certain minimum specifications. In fact employees of all businesses throughout the United States are legally protected by federal regulations for

safety imposed upon all employers by OSHA, the Williams-Steiger. Occupational Safety and Health Act of 1971. Hospitals in many states are legally constrained to provide for the safety of both patients and personnel through state and municipality ordinances. As a general rule, these laws adopt in their entirety the National Electric Code (NEC) of the National Fire Protection Association. The NEC therefore becomes the "bible," for electrical safety in the health care facility where installation of wiring, the performance of wiring and equipment, its specifications for performance, and the reporting of inspections must be made according to the code. Although some states and areas within certain states are not so legally bound, it is sincerely hoped that they find themselves at least morally constrained by the requirements of the National Electric Code. Those health care facilities which are hospitals subscribing to the Joint Commission on the Accreditation of Hospitals (JCAH) now must institute semiannual electrical safety inspections, and the recording thereof, according to the JCAH 1976 requirements. In isolated instances where the laws and the regulations of governing bodies do not apply, the facility, whether it be a small clinical laboratory, or simply a doctor's office, should feel the *moral* obligation to institute at least minimum standards of safety and corrections of safety hazard deficiencies. Not the least of the incentives to create safer electrical conditions is the rising cost of malpractice insurance for physicians and other health care professionals. There can be no doubt that increasing the health care safety criteria and the implementation of safety measures will rapidly decrease the incidence of legal actions by patients sustaining injury. This in turn will tend to lower the hospital and physician insurance rates. No doubt there will continue to be lawsuits by patients claiming negligence against a hospital or physician. It is conceivable that improper electrical facilities and improper design or maintenance of technical equipment may constitute the basis for personal damages. Within the hospital there is no question but that the hospital has the obligation to insure that its medical equipment is properly selected, purchased, employed, and maintained. The hospital is responsible for its physical plant and for employing capable, qualified, well-trained employees. Supervision and record-keeping of plant, equipment, and personnel on a sufficiently regular and comprehensive basis are its responsibilities as well. Also, the physicians, as independent contractors to the hospital and as licensed practitioners elsewhere, have parallel responsibilities. Manufacturers of equipment and their agents can be held legally responsible for the failure or the improper design of equipment items. For these reasons, the knowledge of electrical safety requirements, its routine employment, and conscientious record keeping must be a continuous and repetitive function for health care delivery personnel. Electrical hazards in hospitals and elsewhere are *real.* Accidents *do* occur and it is the *duty* of all personnel to be alert to possible dangerous conditions. While the manufacturer must design and construct safe equipment, this does not remove the requirement for user management to provide both a safe operational environment and a continuing safety maintenance and testing program.

Technician Safety

It has been said that probably more technicians are killed by electrocution than all other personnel combined. This is so because of the obvious reason that engineers and technicians are employed to test, calibrate, and service

electronic and electrical equipment. The procedure most often involves removing the equipment cover and then testing and investigating inside the unit where the accidental exposure to electrical dangers is greater. There is yet another reason not quite so obvious. Although these skilled personnel are expected to be more aware of shock hazards through their training and daily work, when such exposure becomes commonplace it is an easy matter for the technician to forget or become negligent concerning the dangers present. Therefore, before proceeding with the accomplishment of his function, we caution technical personnel to:

1. Periodically check the safety of your work environment.
2. Ascertain the integrity of the grounding system for the electrical wiring in the work area.
3. Be certain your test equipment is in operating condition and within the established period of calibration.
4. Adhere to the normal precautions spelled out in this text as well as in the instruction books for technical equipment upon which service is being performed. Always remove the power cord from the wall socket before taking off the equipment cover for access to the internal components. With the possible exception of some solid-state circuitry, as cautioned in its accompanying service instructions, always "short-out" each exposed voltage terminal to chassis ground by means of a grounding rod or an insulated-handle screwdriver. Included will be capacitor terminals, power supply terminals, tube plate caps, junction boards, and other exposed wiring. From this point the procedures will progress in accordance with the methods explained in subsequent chapters.

Basic Physical Laws and Definitions

Many of the readers of this manual will have been educated in disciplines other than engineering or physics. For those to whom electrical basic principles are well known, please bear with the author. This is, after all, a chapter on safety, and every reader should understand the fundamentals. Sometimes people refuse to learn the basics and this in itself is a safety hazard. The author recalls an incident where the chief maintenance engineer of a 500-bed general hospital, with 18 subordinate employees in the department, related to him proudly: "I don't know Ohm's Law and don't really believe it to be necessary!" And so we will commence with a definition of Ohm's Law. Readers sufficiently familiar with basic electrical principles may skip this section if they wish.

Ohm's Law. The electromotive force across an electrical circuit is proportional to the current flow therein.

$$E = kI$$

where k is a mathematical constant of proportionality. Ohm's Law is generally expressed as:

$E = IR$ for the direct-current (dc) case.