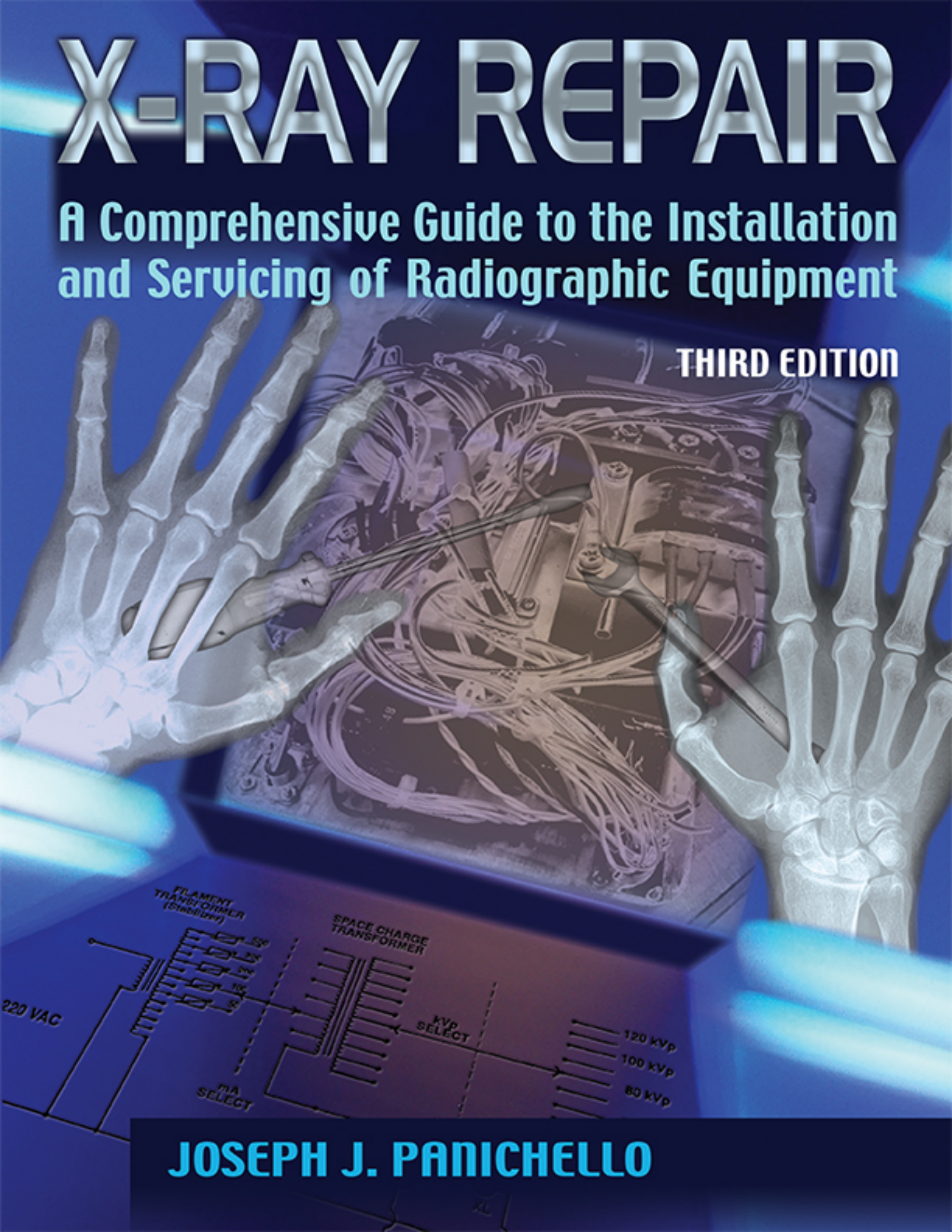
X-RAY REPAIR

A Comprehensive Guide to the Installation and Servicing of Radiographic Equipment

THIRD EDITION



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X-RAY REPAIR

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Joseph J. Panichello earned his B.S. degree in Biology from Pfeiffer University, an A.A.S. degree in Biomedical Equipment Technology from Stanly Technical College, and is AAMI certified. He has worked for over 30 years in x-ray servicing, both as an in-house BMET and as an x-ray field service engineer. He lives in Medford, New Jersey with his wife and daughter.

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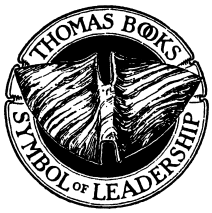
By

JOSEPH J. PANICHELLO, CBET



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For Emily

PREFACE

It has been 20 years since the publication of the first edition of *X-ray Repair*. In that time, the field of Radiology has advanced in ways that would have been difficult to predict. The most notable change relates to the way images are recorded and stored. Film and film processing, which had been used in this field since the very beginning, are becoming a thing of the past. Since the second edition of *X-ray Repair* (2005), radiography has progressed from using x-ray film as the primary means of recording images, to using computed radiography (CR), and, finally, to digital radiography (DR). Within a few years of this writing, x-ray film and CR technology will no longer be used for medical imaging. Sadly, new students of radiographic technology will never know the art of x-ray filming. This third edition of *X-ray Repair* will focus on the transition to digital technology.

Fortunately for those who install and repair x-ray equipment–the x-ray service engineers–the basics of x-ray production still apply to the field of radiography. The x-ray generator, tube support, radiographic table, and wall stand are still needed to obtain an x-ray image. With digital imaging, most of the changes apply to image capture and post-processing.

Another change to healthcare, in general, relates to an aging population, which has changed the way we test, diagnose, and treat patients. Rather than traveling to the hospital, patients can travel shorter distances to smaller satellite medical facilities for their examinations. They can also go to urgent care centers located within their communities. This trend has led to a demand for compact, yet high-powered, x-ray units to perform the exams in these smaller facilities. But there are many older patients, or patients with disabilities, who cannot travel outside the home for their examinations. These “non-ambulatory” patients must be examined in their private residences, or at nursing

homes and retirement facilities. In response, mobile x-ray has become a growing industry. Mobile x-ray machines are light and compact. When paired with a digital receptor, these units produce high-quality images for many of the exams commonly performed in hospitals and clinics. The images acquired in the home are transmitted instantly to secured servers where they can be accessed by radiologist for interpretation and diagnosis. This lighting speed technology is the way of the future. For this edition, I have expanded the chapter on mobile x-ray units to include the latest trends in mobile x-ray services.

A goal of *X-ray Repair* has always been to prepare the student who wishes to enter the x-ray servicing profession. This new edition has been completely rewritten and updated to focus on equipment currently in use, and to address the latest in digital imaging. With new illustrations and a revised chapter order, the book is more approachable to students. Discussions on film and film processing remain because it is important to understand the challenges that faced medical imaging in those early days, and to understand how digital technology developed. I have included calibration procedures as well as troubleshooting guidelines for digital equipment. With 33-plus years servicing x-ray equipment, I have witnessed many types of equipment failures. Included are some troubleshooting tips to help service engineers quickly narrow down the cause of an x-ray failure. Also, working directly in the mobile x-ray industry has allowed me to provide valuable insight into troubleshooting and repairing those "portable" units.

I hope this new edition will be of great help to students as well all the biomeds and service engineers currently working in the field. The goal of writing *X-ray Repair* has always been to shed light on this highly technical field.

JOE PANICHELLO

ACKNOWLEDGMENTS

I would like to thank Michael Payne Thomas and Charles C Thomas Publisher, LTD for publishing this book on x-ray servicing. It has been a pleasure working with Mr. Thomas over the past 20 years. I am grateful for the opportunity to write this third edition.

I would like to thank my wife, Caroline, for her patience and understanding while I was working on this edition–mostly on nights and weekends. This edition is dedicated to my daughter, Emily, who is graduating from college this year and will now embark on her own professional career.

THE LAWS OF X-RAY SERVICE

This book is intended to be used as a reference manual for field service engineers and in-house biomedical engineers when servicing radiographic equipment. It is also written to prepare the student of x-ray servicing for all the specific duties involved for the safe and proper maintenance of radiographic equipment. The goal is to provide standard servicing practices.

To be successful in this career, the engineer should always adhere to the "laws" listed below when servicing radiographic equipment.

THE LAWS

I. When radiographic equipment is installed properly, it will perform optimally and more reliably. When a failure does occur, it is more easily repaired.
II. If PMs are performed properly and at regular intervals, equipment failure rate will be reduced and the equipment will operate well beyond its predicted life expectancy.
III. When servicing equipment, if a problem is correctly diagnosed, properly repaired, and thoroughly tested after the repair, there will be no service recall.

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THE DISCOVERY OF X-RAYS

The use of x-rays is so prevalent today that it is difficult to imagine how many industries, especially the medical profession, could function without their daily use. Indeed, most people have had some contact with x-rays in their lifetime and are aware of their importance. Doctors, structural engineers, research scientists, and airline security agents all use x-rays routinely in their respective careers. Hardly anyone would argue that the discovery of x-rays was one of the most important discoveries of our time. Mankind has certainly benefited from their use.

Because of their widespread use, it is difficult to imagine that x-rays were discovered a little over a century ago. And though there have been many advancements in radiographic equipment design since that time, most of the devices used today in general radiography very closely resemble those early units. The service engineer can gain a much better understanding of general x-ray theory by learning just how x-rays were first discovered and by following the development of the x-ray tube and radiographic system.

The discovery of x-rays, like many other important discoveries, occurred accidentally while scientists were experimenting with glass vacuum tubes. These vacuum tubes were made of thin-walled glass that contained two metal electrodes. They were partially evacuated by a mercury pump and then filled with a specific gas to create a visual effect. When a high-tension discharge from an induction coil was applied to the vacuum tube, beautifully-colored streams of light were produced between the two electrodes of the tube. These streams of light mostly were a source of fascination and curiosity for the scientists at that time. After further experimentation with improved vacuum tubes, scientists began to learn more about the streams of light. They deter-

mined that the stream of light originated at the negative "cathode" electrode within the tube and flowed to the positive "anode" electrode. In addition, as the tube's vacuum level was increased, the streams would likewise change in color and character, until they finally became invisible.

These "rays" were labeled cathode rays by William Crookes in 1878, who was the first to observe their directional properties while experimenting with vacuum tubes.[1]

During his experiments performed in the dark, Crookes noticed that the cathode rays appeared outside of the glass tube as a bluish glow. He later modified the glass tubes by placing an aluminum window in the tube so that the cathode rays could pass through more easily. These modified tubes then became known as Crookes Tubes and were commonly used for experimentation.

The cathode rays could easily pass through the aluminum window of the tube and would produce luminescent effects on phosphor materials. They would also affect photographic plates. These rays, however, were of very low energy and, consequently, would be absorbed in only a few centimeters of air. Unfortunately, Crookes had not realized that what he was actually observing were low energy x-rays.

Seventeen years later, scientists were still experimenting with the Crookes Tubes. Philip Lenard demonstrated that the cathode rays scattered in all directions at the point where they exited the aluminum window. He also made shadow pictures, termed "sciagraphs" on photographic plates. After performing many experiments, he concluded that there was another unidentified component to the cathode rays.

The person credited with the discovery of "x-rays" was a German physicist by the name of Wilhelm Conrad Roentgen. Roentgen was born in Lennep, Germany, in 1845. By the age of 24, he had already published many scientific papers on the properties of gasses. During his career as professor and scientist, he published more than 40 papers on scientific phenomena and was highly respected by his fellow scientists.

It wasn't until June of 1894, at age 49, however, that Roentgen began to experiment with vacuum tubes. Roentgen began his own experiments with the Crookes Tubes and made several important observa-

1. The cathode ray phenomenon was commonly used in early video monitors which used a CRT (cathode ray tube).

tions. He noticed that he obtained better results when the tubes were highly evacuated, and he would often spend days evacuating a tube for his experiments. Also, he felt that if more current was applied to the tubes, cathode ray production would increase. Incidentally, he damaged many tubes during his experiments and thus began using heavier walled tubes.

While experimenting with the modified tubes in the fall of 1894, he noticed a faint glow appearing in the room that precisely coincided with the discharge of the Crookes Tube. To be certain that the light was not coming from the tube or from the induction coil, he completely covered the Crookes Tube with cardboard so that no light could escape. He also covered the induction coil completely to eliminate any light caused by arcing within the machine. To his amazement, the glow still appeared in the darkened room.

The source of the glow turned out to be a screen made of a photographic material (barium platinocyanide) that was located several feet away from the tube. Some heretofore unknown invisible energy was being emitted from the vacuum tube and was traveling across the room, exciting the photographic screen. This was a highly significant observation since cathode rays had never been known to travel more than a few inches from the tube.

Roentgen experimented with the "new kind of ray" for nearly a year before he published his findings. On November 8 of 1895, at age 50, he presented his paper "The First Communication," announcing his discovery.[2]

He called the mysterious rays "x-rays," using the letter "x" (the mathematics symbol) to represent the "unknown" energy. Along with his paper he included several fascinating photographs that he had obtained by using the x-rays. These x-ray photographs included a metal compass, a box containing scientific weights, a double-barreled shotgun, and various types of metals.

Of all the published photographs, however, the one that immediately caught the attention of the media and of the public was the x-ray photograph of the hand of Bertha Roentgen, his wife. This famous photograph, showing all the bones in her hand including the two rings on her finger, was to change the course of medicine forever.

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2. Coincidentally, I was writing the first edition of this book on November 8, 1995, marking the 100-year anniversary of this great discovery.