Epilogue
Grimmett the Man

Like most of us Grimmett was a complex person. Those that knew him talked about how kind and thoughtful he was, what an English gentleman he was and how much they liked him. On the other hand, there were those who could not get along with him and disliked him.

He came from a poor home in a working class section of London at a time when class distinction was deeply ingrained in English life. To get ahead in life, he had to do it on his own. Life was very competitive in his home with three brothers and no sisters; as the eldest he would have had to set the example. They were all musical and this would have increased the competitiveness. His education was only affordable because he obtained scholarships and took nighttime jobs. He worked hard to improve himself and be accepted. He became such a good pianist that for a short period of time he earned his living by playing the piano on steamship liners going to South America and for some months in South America. When he returned to England, he played for silent movies and theaters.

He was a precise and neat person and was determined that his work reflected who he was. His laboratory notebook is written in a clear legible hand, the diagrams beautifully drawn and the data entered in precise order. He required that any equipment that he designed and built or had built was not only functionally but also esthetically pleasing to look at. His reports on meetings, trips and conferences were well written leaving the impression that in reading them he had conveyed the essential facts of what had taken place. Without them much of what is in this book could not have been written.

He was a man of many interests, scriptwriter, flying, bookbinding, calligraphy, jewelry and a worker in precious metals besides his music. He was known to grow star sapphires and had a small workshop in his home in London and had a jewelry business on the side with his brother Rubin.

John Reed who probably knew him better than any of his contemporaries in England said that he, "…was kind, gentle, always soft spoken and quite imperturbable." He had compassion and as Reed put it could be, "…filled with

P. R. Almond, *Cobalt Blues*, DOI: 10.1007/978-1-4614-4924-9,

distress," at the sight of out-of-work musicians because he had played with them and who were out of work because of the "talkies" as he had been. John Read's obituary in the British Journal of Radiology, September 1951, recalls:

> Grimmett showed that with few initial advantages other than ability, courage and tenacity, he could be a twentieth-century pioneer and adventurer, yet without aggression or acquisitiveness, laying the foundations of an expanded application of physics in the cure of disease. [3]

Those that worked with him and for him were extremely loyal to him. The sketch presented to him when he left Paris sums it up; even the Eiffel Tower is in tears to see him go. Scientist and musician Dr. Grimmett was a unique personality. He was charming and delightful and enjoyed widespread admiration and respect.

J.E. Roberts who was a contemporary medical physicist in London and was at The Cancer Hospital (Free) from 1932 to 1937 and who along with Grimmett and others was a founding member of the Hospital Physicists' Association called him, "assuredly one of the characters of early medical physics."

He wrote of Grimmett:

> Although he made some valuable contributions to radiological physics, particularly in instrumentation, he would probably have claimed that his greatest contribution to human welfare and happiness was as a "pop" musician and particularly as a pianist. [203]

He may have played "pop" music when he performed in the theaters during his university days and for the passengers on the liners to South American, but he was also a classicist. In January 1951 Ann Holmes, the fine arts editor of the Houston Chronicle, interviewed him prior to the first, and as it turned out his only piano concert, he was to present in Houston. Her article appeared in the January 25 edition of the Chronicle under the headline, "Physicist Grimmett Is Successful Musician Also." She noted that he was a quiet man given to understatement. She reported that he had started playing very early in life and studied for many years in London and served as an accompanist for a number of leading singers and instrumentalists in London. It was with small chamber groups in the repertory theaters of Hampstead that she said he described as the 'arty' section of London which had had a special appeal to him. His program, she wrote, was of impressive dimensions and included Scarlatti sonatas, Schubert Impromptus, Chopin and Beethoven works. There was no "pop" music [204].

The concert he gave on January 30, 1950, at 8 p.m. in the Carter Recital Hall, advertised as "The finest studio auditorium in the southwest," was purely classical music. It was a private recital for the staff of the M.D. Anderson Hospital and their friends with the proceeds going to the hospital's patient welfare fund. He played four sonatas by Scarlatti, an Impromptu by Franz Schubert and a Sonata by Beethoven. After an intermission, he played Pictures at an Exhibition by Mussorgsky for which he wrote the program notes, and after another intermission, he finished the concert with two Preludes by Chopin and the Hungarian Rhapsody by Frantz Liszt [205]. No record has been found of the amount of money that was raised.

His hope had been that by coming to Houston he would be able to reestablish himself as a medical physicist to build up a name for himself and his department. But he did not have time.

Reed wrote for Grimmett's obituary in the British Journal of Radiology:

> Then in 1944 he disappeared from his usual scenes, reappearing briefly from time to time from Paris, or wherever his service for the British Council, UNESCO, and UNO had taken him. Finally it was reported that he had settled in Houston, Texas, where he was developing a radiobiological research laboratory in the really big way which suited his temperament [3].

But Grimmett could be stubborn and obstinate and very defensive about his work. Perhaps, the first instance of this was his disagreement with Mayneord over the report on Radium Beam Therapy Research 1934–1937. In reading the report, it is hard to understand why Mayneord was upset, but he was involved with Grimmett in the dosimetry of the radium teletherapy units and there was an agreement with the Royal Cancer Hospital that they would review manuscripts prior to publication. When Grimmett became aware of Mayneord's concerns, he did make a concerted effort to address them and suggested a follow-up publication, but when Mayneord was still not satisfied, Grimmett dug his heals in and cancelled the idea of a joint publication. Mayneord was not only a leading figure in British medical physics he was extremely well connected in London, and it could not have been too helpful to Grimmett's career to have crossed swords with him.

At times he was perhaps too disconnected from others to realize what their impression of him might be. This seems to be the case when he was let go from the Medical Research Council. Although he worked hard and often long hours, it was on his schedule and not other peoples' so when he was not around during their working hours, he was seen as lazy and uninterested. When this was pointed out to him, he seemed surprised and hurt and defensive. Perhaps, this meant that any relationship would eventually deteriorate.

This was true of Grimmett's relationship with Dr. Gilbert Fletcher during the time they worked together. In the memo that Grimmett sent to Fletcher on April 4, 1950, his annoyance and disgust with Fletcher clearly comes through. Fletcher could be very difficult to work with and provoked strong reactions from people, and the relationship between the two would never be restored. Grimmett was proud of his work, his accomplishments and his ability to solve problems that were presented to him. He knew what he had done and what he could do and he did not appreciate anyone taking credit or trying to take credit for what he had done. The M.D. Anderson Hospital position represented a chance to re-establish his medical physics career, an opportunity he stated repeatedly in his letters to his wife back in England before she joined him in the spring of 1949. His appointment as a Fellow in the Institute of Physics in 1946 he regarded as recognition of him as a physicist, and he made sure that a notation about it was put in his files at UNESCO.

But he did not have enough time to establish himself internationally. Although Grimmett came up with the concept of the cobalt-60 teletherapy unit, he died before his unit could be put into use. The Canadians who independently developed the concept and put it into clinical use received most of the credit. J.E. Roberts writing his memoirs in the late 1990s never mentions Grimmett's contribution to the cobalt-60 units. He ends his comments on Grimmett by writing, "He ended up as a physicist at the M.D. Anderson Hospital in Houston, Texas." [203] There is not even the recognition that Grimmett was the chairman of his own independent department at the hospital. Grimmett would have been disappointed.

Appendix A
Principles of Radiotherapy

The basis for radiotherapy is that ionizing radiation destroys cancer cells. Ionizing radiation has the ability, when it interacts with matter, to set free some of the electrons, associated with the atoms of the material, which allows them to move through the material being irradiated. The electrons have a negative electric charge leaving the remaining atoms with a positive charge, creating what is called an ion pair. Hence, the term “ionizing radiation.” As the electrons move through the material, they can create further ion pairs. It is these negative and positive ions that have a biological effect. For clinical purposes, the energy of the radiation must be greater than that of ultraviolet light, not only to have enough energy to create ion pairs but also to have enough energy to penetrate into the tissue. There are two sources of ionizing radiation, radioactive materials and radiation producing machines such as X-ray machines or linear accelerators. Radioactive materials emit ionizing radiation in the form of alpha rays, beta rays and gamma rays, and in general, it is the gamma rays that are used for treatment purposes because of their ability to penetrate into the tissue. X-rays and gamma rays are, from a physics viewpoint, identical, and they are both electromagnetic radiation. Gamma rays are emitted by radioactive materials, while X-rays are produced when high-energy electrons hit a target (in an X-ray tube) and are stopped. The energy of the X-rays can never exceed the energy of the electrons producing them, and because there is a range of X-ray energies produced, the average energy of the X-rays is approximately half that of the electron energy. Gamma rays have single energies.

To match the average energy of the X-rays to the gamma ray energy, the energy rating of the X-ray tube must be about twice the energy of the gamma rays. In the middle of the twentieth century, it was normal for electromagnetic radiation to be characterized by the wavelength of the radiation. The product of the radiations wavelength with its frequency gives the velocity of the radiation. Since all electromagnetic radiation (including X-rays and gamma rays) travels at the speed of light, which is constant, the shorter the wavelength, the higher the frequency, and since frequency is directly related to energy, the shorter the wavelength, the higher the energy. When Grimmett became a medical physicist in the 1920s, X-ray

P. R. Almond, *Cobalt Blues*, DOI: 10.1007/978-1-4614-4924-9,

energies were designated by their wavelength. Today, it is customary to express the energy of ionizing radiation directly in terms of electron volts (eV). For therapy X-rays with energies of thousands of electron volts (keV) or higher are required; gamma rays from radioactive materials have energies in the millions of electron volts (MeV). Grimmett understood that to match the 1.25 MeV gamma ray energy of cobalt-60 would require a 3 MeV X-ray tube.[1]

Radiotherapy was the term used for much of the twentieth century, and the doctors who practiced it were generally radiologists located in radiology departments in hospitals. Radiologist practiced both diagnostic and therapeutic radiology. If a doctor specialized in treatments only, they were called radiotherapists. In the twenty-first century they are more generally referred to as radiation oncologist and practice in departments of radiation oncology, separate from departments of diagnostic or imaging radiology.

The French physicists Pierre and Marie Curie at the end of the nineteenth century and the beginning of the twentieth century discovered radium which is radioactive. They soon noticed that the application of radium to the skin had a biological effect and radium was quickly made available to the medical profession to treat cancer. However, ionizing radiation also destroys normal human tissue cells, so that in treating cancer with radiation, care must be taken to get as much of the radiation to the cancer and as little a possible to normal tissues. Milligram amounts of radium were therefore put into small metal containers, about a millimeter in diameter and about a centimeter in length and made into tubes and needles. If cancer was in or near a body cavity, the tubes would be put into the cavity. For other anatomical sites, needles could be inserted directly into the tumor. For skin cancer the radium was put into plaques that had been molded over the skin and designed to hold the radium close to the lesion. In this way the radiation dose to the cancer was maximized, and the dose to surrounding normal tissue was kept to a minimum. In general, one or two applications of the radium were made and in many cases were successful in curing the patient or controlling the disease. Radon, the radioactive gas emitted by radium, was also put into small capsules and used for therapy. This approach was not without its hazards, however. The doctor had to handle the radium when inserting it into the patient and over time could receive a significant radiation dose that could and often did result in damage to the physicians' fingers and the development of cancer. The needles and tubes of radium could also leak radiation if not handled properly, which could cause radiation contamination in the hospital. This type of cancer treatment was called by many names such as radium interstitial therapy, mold therapy, intracavitary therapy or more generally radium therapy. The overall term that came to be used to describe them all was brachytherapy, meaning therapy at a short

---

[1] With the development of linear accelerators in particular, it became possible to build X-ray generators in the multi- megavolt range, and by the end of the twentieth century, linear accelerator x-ray machines had all but replaced the cobalt-60 units.

distance since the radium was placed next to, in contact with, or at a short distance from the cancer. Because interstitial radium therapy required placing needles in the patient under anesthesia, surgeons often practiced this kind of radiotherapy.

At the same time that radium was discovered, Wilhelm Roentgen discovered X-rays in Würsburg, Germany. The biological effects of X-rays were also noted right away, and doctors started treating cancer with X-rays. Because of the size of the X-ray tubes, the patient was placed some distance from the X-ray source and the X-rays were directed to the site on the patient that needed treatment. It too had its hazards and in the early days, the operators of the X-ray equipment also received large amounts of radiation. It was soon realized that the X-ray tubes had to be adequately shielded and the X-rays had to be restricted, by collimation, to a beam just large enough to irradiate the cancer and avoid as much normal tissue as possible. This type of treatment became known as external beam treatment, X-ray treatment or more generally as teletherapy, meaning treatment at a distance. Its major benefit over brachytherapy was that it required no surgical intervention.

Although brachytherapy was generally given in one or two treatment sessions, each lasting hours or sometimes days, it was determined that teletherapy was best given on a daily basis with treatment times of a few minutes each day and the course of treatments lasting several weeks. This type of treatment became known as fractionated treatment. The break between each daily treatment gave time for the normal tissues to recover better, and the accumulated dose of radiation to the cancer could be increased to high enough levels to kill all the cancer cells.

One of the questions in the first half of the twentieth century for radiotherapy was the following: Could the benefits of external treatments be realized using radium as the source of the external radiation? Since the gamma rays from the radium and the X-rays from the X-ray tube were known to be identical from a physics viewpoint (they are both electromagnetic radiation) differing only in energy, could the X-ray tube be replaced by a sufficient amount of radium to give treatments at a distance? If it could, then high-voltage electrical equipment, in the range of hundreds of kilovolts, and its associated electrical hazards could be eliminated. There would also be no need to replace costly X-ray tubes that had finite lifetimes. The half-life of radium is long, 1,600 years, so that its output was considered constant with time and would never need replacing. There was also a belief among some radiologists that gamma rays from radium were medically superior to X-rays because of their shorter wavelength, and therefore higher energy. Gamma rays from radium have energies up to 1–2 MeV. To match this would require an X-ray tube of 3 MeV, and to build and operate such an X-ray tube did not appear feasible at the time. There were good reasons, therefore, to see whether radium could be used to replace X-ray tubes. But there were serious problems. It required a large amount of radium, which was very expensive (approximately $750 per milligram in today's dollars), and it was generally considered that 4 g of radium was the minimal amount needed (i.e., a $3 million investment). Only a few places could consider this kind of expense. The use of such large amounts of radium meant that the apparatus holding the radium source had to provide an adequate degree of protection for the people unsung the equipment. The containers therefore had thick walls of dense metal to absorb the radiation, and an aperture to allow the exit of the beam of gamma rays for the treatment. Because of their shape, size and the fact they were made of metal, they were often called radium bombs. Single sources of 4 g of radium were not easy to come by, and the sources in the radium bombs consisted of multiple sources of lower amounts. For example, twenty tubes of 200 mg each might be used. This meant that the size of the radium source in the radium bomb was quite large and considerable self-absorption of the gamma rays in the source itself took place, making the source strength effectively much less. Even with 4 g, the radiation output of these units was not high, and in order to give the treatments, the source had to be close to the patient surface. In most cases between 5 and 10 cm (compared with 75 cm for X-ray treatments), even so the treatment could last up to 30 min or longer. But a 5–10 cm treatment distance counteracted the very characteristic for which radium might be used in the first place.

For external beam treatments, the radiation must pass through the skin of the patient to reach the cancer below the surface. The essential problem of radiotherapy at the time therefore was to deliver, at depth in tissue, as high a percentage as possible of the dose received by the skin. The reason being that the skin reaction was the limiting factor as to how much dose could be given. The radiation would produce a sunburn-like reaction, and there are limits in the amount of radiation to the skin beyond which permanent damage would be done.

All other factors being equal the penetration of the radiation into the body is determined by the energy of the radiation and the distance of the source of radiation from the skin surface (called the treatment distance). The higher the energy, the more the radiation penetrates, but it is also dependent upon the inverse square law, the intensity drops off as one over the square of the distance from the source. If the distance from the source is doubled, the intensity is decreased by a factor of four, for example. If the treatment distance is short, of the order of the depth into the body to which the radiation needs to penetrate, the inverse square law predominates and the energy has little effect. On the other hand, if the treatment distance is long compared to the depth of interest, the energy of the radiation predominates.

For radium bombs that had a treatment distance of 5–10 cm, the penetration of the radiation into the body (to depths of say 10 cm) would be almost identical to that of a kilovoltage X-rays at the same treatment distance and there would be no physical advantage to using the radium with its higher-energy radiation, except if there was a biological advantage to the higher-energy radiation as some radiologist believed.

Figure A.1 shows the measured depth doses of 200 kv. X-rays at a 50 cm. focus-skin distance (curve B), the depth dose calculated for a hypothetical radium unit utilizing the same focus-skin distance (curve A) and the depth dose for an existing 4 g unit in which the focus-skin distance was 8.0 cm (curve C) [47]. Comparison of the curves A and C shows the gain that would have been achieved

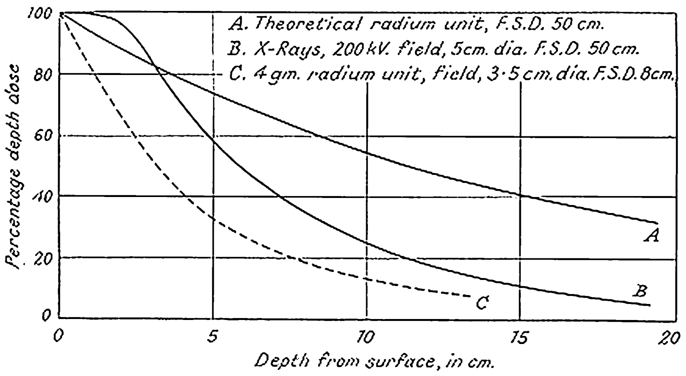


Fig. A.1 Comparison of the depth doses from (*A*) a theoretical radium unit having 50 cm F.S.D., (*B*) 200 kv. X-rays, 50 cm. F.S.D., (*C*) an actual radium unit, 8 cm. F.S.D. [47]

if such a unit could have been built and how much better it would have been compared to the X-rays (curve B)

But with the focus-skin distance at 50 cm compared to 8.0 cm, the intensity of the radiation at the surface would be reduced by almost a factor of 40. To achieve the same dose rates therefore with the longer treatment distance machine as with the shorter treatment distance machine (whose treatment times of 30 min or so were too long and not ideal) would require approximately 160 g of radium, which was not possible from a cost, safety or even availability considerations. It would seem that the radium teletherapy units were stuck at treatment distances of 10 cm or less.

X-ray units did not have this problem. Even at the extended treatment distances of 50–75 cm, the output was high enough that treatment times of a few minutes were possible.

The other factor that came into play was the penumbra of the beam, that is, the fall off of the dose, at the edge of the beam. This is dependent upon the geometry of the treatment machine. With short treatment distances and large source sizes, the penumbra is large, which was the case with radium units and was not desirable to radiation treatments. For X-ray units at longer treatment distances and very small source size, penumbra becomes almost nonexistent, which is a large advantage for X-rays.

It is surprising therefore that with these three major disadvantages, poor depth of penetration, poor penumbra and low output that radium teletherapy showed any promise at all. It succeeded to the extent that it did because the main area in which it was tried was for head and neck cancer where penetration is not a big issue, a large penumbra can be tolerated and immobilization of the patients head can be used to minimize the effect of the long treatment times.

Appendix B
Principles of Reactor Production of Cobalt-60

The story of the completion of MDAH/ORINS cobalt-60 unit is the story of two nuclear reactors, the Oak Ridge graphite reactor in Oak Ridge Tennessee and the Canadian heavy water reactor at Chalk River in Ontario Canada.

Cobalt exists naturally only as non-radioactive cobalt-59 with 27 protons and 32 neutrons in its nucleus. The addition of one extra neutron in the nucleus creates radioactive cobalt-60, but does not change the chemical characteristics of cobalt. Placing cobalt-59 into an intense field of slow or low-energy neutrons such as found in the interior of a nuclear reactor can produce cobalt-60.

In a reactor the fission of uranium-235 is initiated when it captures a slow (low energy) neutron. In the process heat and a number of high-energy neutrons are released. The coolant carries off the heat. The high-energy neutrons are slowed down by the moderator and can then be captured by other atoms of uranium-235, causing further fission.

As the process repeats itself, a chain reaction is produced. Control rods of boron or cadmium, which are proficient at absorbing the neutrons, can be inserted into or removed from the reactor in order to adjust the power level or to shut the reactor down. Samples, such as cobalt-59, can be inserted into the reactor to be activated as long as they do not absorb too many neutrons and reduce the power of the reactor to unacceptable levels.

The Oak Ridge reactor was a 1,000 kW, carbon-moderated, air-cooled reactor built in 1942–1943 as a pilot plant, to demonstrate the feasibility of producing plutonium from uranium in large-scale production units, and partly to provide plutonium that was badly needed for experimental purposes. It was considered the first milestone in the creation of the atomic bomb that ended World War II. The moderator was a cube of graphite, 7.3 m (24 ft) on each side, as the moderator with tubes containing the uranium fuel in a horizontal matrix running through the moderator. Vertical boron steel control rods could be moved in and out of the moderator to control the reactor. There were a number of horizontal channels, at right angles to the fuel elements, in the moderator, into which long graphite holders or stringers could be inserted. The stringers contained cylindrical holes

P. R. Almond, *Cobalt Blues*, DOI: 10.1007/978-1-4614-4924-9,

into which gas-tight aluminum casings could be inserted. Normally uranium would be put into the casings for plutonium production, but the same type of system was used to place isotopes to be activated. For nearly 20 years, it was one of the world's foremost sources of radioisotopes for medicine, agriculture, industry and research. In the early 1950s, however, the top priority was for defense work, and the production of radioactive isotopes for non-military purposes came second. There was always a trade-off between the number of samples that could be put into the reactor and the power level of the reactor; too many samples would absorb too many neutrons, and the power level would drop (Fig. B.1).

Although quite a few cobalt-59 samples were placed in and around the Oak Ridge reactor, they were generally in areas of low neutron flux, so that it took a long time to activate the samples to acceptable levels of activity. The Oak Ridge reactor was, therefore, not ideal for activating kilocuries of cobalt-60 to high specific activities. It was into this reactor, however, that the initial cobalt sources for the ORINS/MDAH cobalt unit were placed.

Decommissioned in 1963, the Graphite Reactor is now a National Historic Landmark.

The reactor at Chalk River, Ontario, Canada, on the other hand provided a neutron flux many times greater (approximately 100 times greater than the Oak Ridge reactor) than any other reactor at the time. Called the NRX it was a heavy water-moderated, light water-cooled reactor. NRX was for a time the world's most powerful research reactor. It was a cooperative effort between Britain, the United States and Canada during World War II. NRX was a multipurpose research reactor used to develop new isotopes, test materials and fuels and produce beams of neutrons.

In a heavy water-moderated reactor either inserting the control rods or removing the heavy water moderator can stop the reaction.

The NRX reactor incorporated a sealed vertical aluminum cylindrical vessel which held 14,000 L of heavy water and helium gas and about 175 six centimeter diameter vertical tubes in a hexagonal lattice. The level of water in the reactor could be adjusted to help set the power level. Sitting in the vertical tubes and surrounded by air were uranium fuel elements or experimental items, cooled by light water.

Twelve of the vertical tubes contained control rods made of boron powder inside steel tubes. These could be raised and lowered to control the reaction, with seven inserted being enough to absorb sufficient neutrons that no chain reaction could happen. The reactor began operation on July 22, 1947, under the National Research Council of Canada and was taken over by Atomic Energy of Canada Limited (AECL) in late 1952. It operated for 45 years, being shut down permanently in 1992.

Because of its higher neutron flux and the number of tubes available for samples to be activated, the NRX was far superior to the Oak Ridge reactor for producing large curie amounts of radioactive cobalt-60 with high specific activity.

The activation of a sample depends upon the neutron flux in the reactor, the probability of the target nucleus absorbing the neutron (known as the cross section

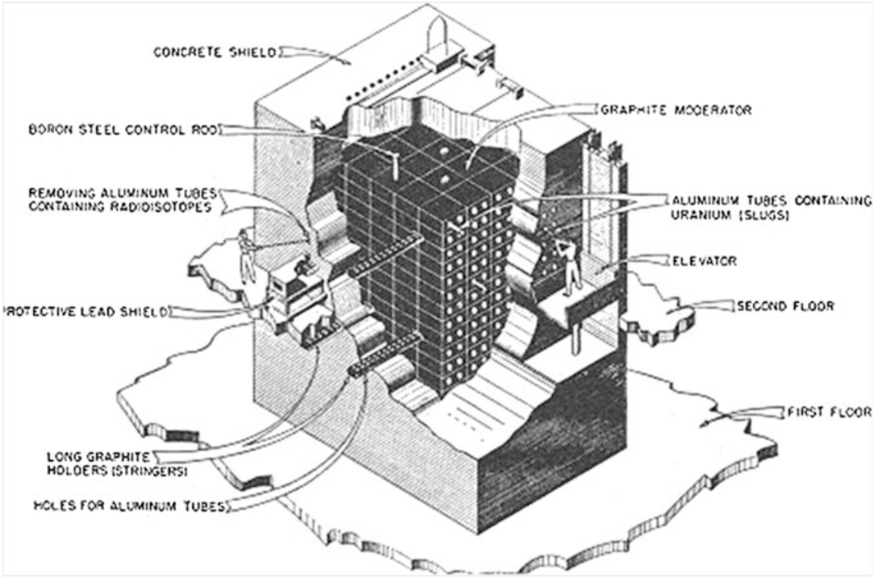


Fig. B.1 Cut-away view of the Oak Ridge reactor [206]

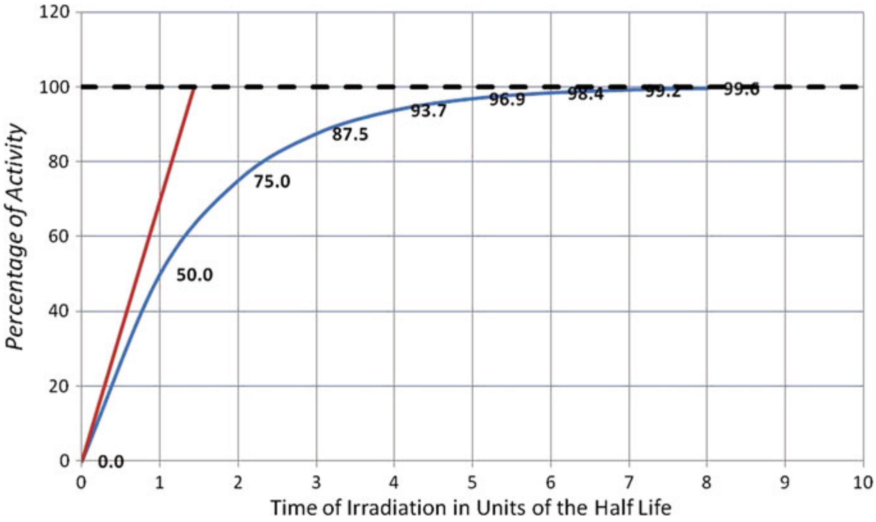


Fig. B.2 Percentage buildup of activity in a reactor versus the irradiation time in units of half-life

for the interaction), the half-life of the isotope being produced and the amount of the sample being activated but not the shape of the sample. The ORINS/MDAH source consisted of four plaques of cobalt, 2 x 2 x 0.25 cm. Since a total activity of 1,250 Ci of cobalt-60 was needed, each source had to be activated to 312.5 Ci.

In the Oak Ridge reactor, it would have taken nearly 7 years to reach that level. In the Chalk River reactor with a hundred times higher neutron flux, it would take 10 months (Fig. B.2).

The sources for the ORINS/MDAH cobalt irradiator were eventually removed, therefore, from the Oak Ridge reactor and placed in the Chalk River reactor in order to get the desired activity [206].

Appendix C
Grimmett's Suggested References on Cobalt-60

The following is an excerpt from Grimmett's letter to Jasper Richardson, April 26, 1951:

> In response to an earlier request of yours for some references touching on our Cobalt-60 program, you will find the following of some help:-
>
> C.W. WILSON, 'Radium Therapy', Chapman &Hall, London, 1945 (this excellent little book will give you a general orientation as regards gamma-ray therapy of cancer.)
>
> COLIEZ, Robert, Journal de radiologie et d'Electrologie XXX, p. 518, 1949 (An early paper outlying the possibilities of Co-60.)
>
> MORTON, and MYERS, Am. J. Roent., Vol. 60, p. 816, Dec '48 (new ideas about Co-60 as a substitute for *Ra needles*).
>
> H.F. FREUNDLICH, Acta Rad., XXXIV, p. 115, Jul-Aug '50 (Review of some gamma-active isotopes suitable for therapy, with details of an Iridium Irradiator.)
>
> H. MILLER, Brit. J. Rad., XXIII, p. 731, Dec '50 (2-Mev X-Ray Generator.-Techniques for measuring electronic build-up in water, etc. useful model for our experiments.)
>
> MAYNEORD, Supplement No.11, Brit. J. rad., 1950(I believe I already mentioned this work to you? It is an excellent summary, but don't take his pessimistic remarks about large Co-60 sources too seriously!)
>
> C.A.P. WOOD, and J.W. BOAG, 'Researches on the radiotherapy of Oral Cancer', Report No. 267, H.M. Stationary Office, London, 1950(Most of the physics in this is my work, although you wouldn't think so from the scanty acknowledgements! You will find some ideas here on measurements in general which can be applied to our cobalt program.)
>
> J. R. GREENING, Brit. J. Rad., XXIV, p.204, April '51 'Effective' wavelength in irradiated water.
>
> This reading will keep you busy for a bit. It is not exhaustive or comprehensive, but I haven't the leisure just now to look out all the pertinent references. I will do so at the earliest opportunity, however. [135]

Perhaps, it was not intentionable but Grimmett still seemed to be upset by what had happened in 1944 at the Radiotherapeutic Research Unit at Hammersmith Hospital with Jack Boag and Paul Howard Flanders. The "scanty" acknowledgement to him in the reference above is very limited, and if it was mainly his work, he had reason to be upset.

P. R. Almond, *Cobalt Blues*, DOI: 10.1007/978-1-4614-4924-9,

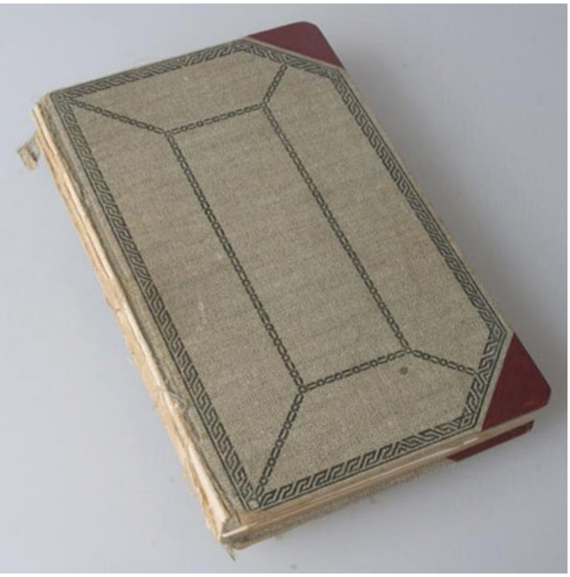
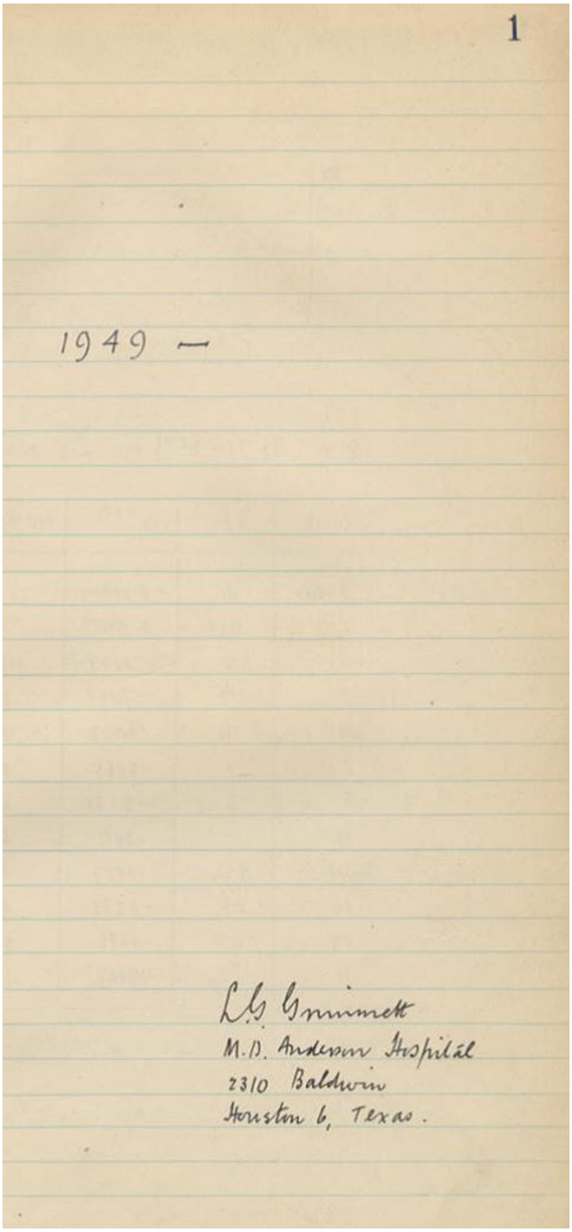


Fig. C.1 Grimmett's notebook [140]

He may still have been outdone with Mayneord over the dispute concerning the output of the radium units just prior to the war, telling Richardson not to take too seriously his pessimistic views about the availability of large Co-60 sources. In fact, Freundlich makes a similar comment in his paper, which Grimmett does not mention, and which led Freundlich and the Cambridge group to go with Iridium-191 instead. With the comparatively small neutron capture, cross section of cobalt-59 and the long life of cobalt-60 and the relatively low neutron flux in the British reactor iridium seemed a better choice. It was therefore reasonable to think that large cobalt-60 sources would not be available. The exterior and flysheet of Grimmett's notebook are shown in Figs. C.1 and C.2, respectively.

Fig. C.2 Fly sheet of Grimmett's notebook [141]



1

1949 –

L.G. Grimmett
M.D. Anderson Hospital
2310 Baldwin
Houston 6, Texas.

References

1. Leonard Grimmett. portrait. 1949. Historical Resources Center Image Collection, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center. Illustration used by permission.
2. Going critical: 50 years of nuclear energy. *Journal of Nuclear Medicine* 33(12):16N, 29N. Dec 1992
3. Read, J. 1951. Obituary L.G. Grimmett. *British Journal of Radiology* 24(285):522.
4. Grimmett, L.G. 1948. Letter of resignation to Dr. Auger. August 21, 1948. UNESCO archives Paris.
5. Logo of the United States Atomic Energy Commission. 1946–1974. *United States Atomic Energy Commission*.
6. Baker Estate. 1950. Historical resources center image collection, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center. Illustration used by permission.
7. Texas State Hospital Underway. 1942. *JAMA* 120(4):298.
8. Bates, W.B. 1956. History and development of the Texas medical center. *Texas Gulf Coast Historical Society*.
9. Fletcher, G.H. 1979. The early days at M. D. Anderson. *The Cancer Bulletin* 31(2):S8.
10. *The Starkville* (*Miss.*) *News*, Friday, April 25, 1947, Society Section.
11. *The Starkville* (*Miss.*) *News*, Friday, May 2, 1947, Society Section.
12. Macon, N.D. 1976. *Clark and the Anderson: A personal profile*, 188. Houston: The Texas Medical Center Houston.
13. Mayneord, W.V., and J. Cipriani. 1947. The absorption of gamma-rays from Co-60. *Canadian Journal of Research* 25(6):303.
14. Excerpt from Dr. Leonard's Grimmett Diary, 1948, Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
15. *The Starkville* (*Miss.*) *News*, Friday, February 20, 1948, Society Section.
16. Cobalt for cancer tested. *The Science News-Letter* 53(18):275. 1948.
17. Medical and Scientific Director of the American Cancer Society, Inc. Memo to the Divisions of the American Cancer Society, Inc. re: Radioactive Cobalt. April 30, 1948. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
18. Fletcher, G.H. Memo to R. Lee Clark re: Radioactive Cobalt. [ca. 1948]. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.

P. R. Almond, *Cobalt Blues*, DOI: 10.1007/978-1-4614-4924-9,

19. Clark, R.L. Letter to Shields Warren. February 5, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
20. Clark, R.L. 1949. Letter to Albert Thomas. May 18, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
21. Cancer Work in Peril City May Lose Atomic Center. 1949. *Headline—The Houston Post.*
22. Atomic Cancer Treatment. 1949. *Editorials—The Houston Post.*
23. *The first twenty years of the University of Texas M. D. Anderson Hospital and Tumor Institute*, 62. The University of Texas M.D. Anderson Hospital and Tumor Institute, Houston, Texas, 1964.
24. Macon, N.D. 1976. *Clark and the Anderson: A personal profile*, 189. Houston, TX: The Texas Medical Center Houston.
25. Grimmett, L.G. Letter to Norah Grimmett. February 8, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
26. Grimmett, L,G. Letter to Richardson. September 23, 1921. University of Texas Archives & Institute of Physics. Richardson Archives.
27. Grimmett, L.G. Letter to Richardson. July 11, 1927. University of Texas Archives & Institute of Physics. Richardson Archives.
28. Grimmett LG. Letter to Richardson. December 22, 1929. University of Texas Archives & Institute of Physics. Richardson Archives.
29. Richardson, O.W., and L.G. Grimmett. 1930. The emission of electrons under the influence of chemical action at lower gas pressures. *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character.* 130(812):217–238.
30. Grimmett, L.G. Letter to Richardson. May 18,1932. University of Texas Archives & Institute of Physics. Richardson Archives.
31. Read, J. 1951. Obituary notices. *The Proceedings of the Physical Society* 64(Section A): 1143–1144.
32. Flint, H.T., and L.G. Grimmett. 1930. Measurement of the distribution of gamma rays around a four-gram mass of Radium. *British Medical Journal* 2(3628):98–99.
33. Flint, H.T., L.G. Grimmett, E.R. Carling, and S. Cade. 1934. Radium teletherapy: Latest modification of the westminster apparatus and its use. *The British Medical Journal.* 1(3823):653–655.
34. Spear, F.G., and L.G. Grimmett. 1933. The biological response to gamma rays of Radium as a function of the intensity of radiation. *British Journal of Radiology* 6(67): 387 (1 July 1933).
35. The Empire Cancer Campaign. *The Times of London*, April 11, 1934.
36. Spear, F.G., and L.G. Grimmett. 1935. Supplementary note on "the biological response to gamma rays of radium as a function of the intensity of radiation". *British Journal of Radiology* 8(88):231–234 (1 Apr 1935).
37. Grimmett, L.G. Letter to Richardson. May 20, 1932. University of Texas Archives & Institute of Physics. Richardson Archives.
38. Grimmett, L.G. 1932. A direct-reading γ-ray electroscope. *Proceedings of the Physical Society* 44(4):445–450.
39. Grimmett, L.G. 1933. A sensitivity-control for the Lindemann electrometer. *Proceedings of the Physical Society* 45(1):117–119.
40. Wellcome library archives in London. Dr. Constance Annie Wood archives.
41. Annual Report to the Board of Regents and the Chancellor of the University of Texas. 1951. Houston: University of Texas M.D. Anderson Hospital for Cancer Research.
42. Email from Professor Anders Brahme of Karolinska Institute to Peter Almond. 2004.

43. Wood, C.A.P., L.G. Grimmett, and T.A. Green. 1938. Medical Research Council—special report series, no. 231. Report on radium beam therapy research 1934–1937, 69. Grimmett's copy from MDACC archives.
44. Sievert, R.M. 1933. The new apparatus for teleradium treatment used at radiumhemmet. *Acta Radiologica* 14:197–206.
45. Grimmett, L.G. 1937. A five-gramme radium unit, with pneumatic transference of radium. *British Journal of Radiology* 10(110):105–117 (1 Feb 1937).
46. Wood, C.A.P., L.G. Grimmett, and T.A. Green. 1938. Medical Research Council—special report series, no. 231. Report on radium beam therapy research 1934–1937, 73. Grimmett's copy from MD Anderson archives.
47. Wilson, C.W. 1948. *Radium therapy. Its physical aspects*, 168. London: Chapman and Hall.
48. Grimmett, L.G., and J. Read. 1935. An application of a new dense tungsten alloy in teleradium therapy. *British Journal of Radiology* 8(94):661–665 (1 Oct 1935).
49. Grimmett, L.G., and J. Read. 1936. Protection problems associated with the use of a 5-GM. Radium unit. *British Journal of Radiology* 9(107):712–731 (1 Nov 1936).
50. Wilson, C.W. 1948. *Radium therapy. Its physical aspects*, 71. London: Chapman and Hall.
51. Grimmett, L.G. Postcard to Norah Grimmett. August 31, 1937. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
52. Grimmett, L.G. Postcard to Norah Grimmett. September 13, 1937. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
53. Eve, A.S., and L.G. Grimmett. 1937. Radium beam therapy and high-voltage X-rays. *Nature* 139(3506): 52–55.
54. Grimmett, L.G. 1938. Nuclear physics and medicine. *Nature* 141(3564):311–314.
55. Wood, C.A.P., L.G. Grimmett, and T.A. Green. Medical Research Council—special report series, no. 231. Report on radium beam therapy research 1934–1937. 1938. 70. Grimmett's copy from the MDACC archives. Illustration used by permission.
56. Letter from D. W. Kerst to Grimmett on May 13, 1942 from University of Illinois University Archives.
57. Letter from Grimmett to Kerst. 1942. University of Illinois University Archives.
58. History of Hospital Physicists' Association 1943–1983: Hospital Physicists' Association. 1983. 6–9.
59. Grimmett, N. Letter to Leonard Grimmett. February 9, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
60. Grimmett, L.G. Letter to Norah Grimmett. February 10, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
61. Grimmett, L.G. Letter to Sir Owen Richardson. June 29, 1943. University of Texas Archives—The Institute of physics. Richardson Collection.
62. Declaration Attested by Supervising Teacher, 1943. Signed by Grimmett and Richardson. From University of Texas Archives—The Institute of physics. Richardson Collection.
63. History of Hospital Physicists' Association 1943–1983: Hospital Physicists' Association. 1983. 101.
64. Grimmett's Transcript. King's College University of London Archives.
65. U.K. National Archives. Ref.: FD113386. Kew, England.
66. Shalek RJ. Personal Communication.
67. Grimmett, N. Letter to Leonard Grimmett. [ca. February 13, 1949]. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center

68. Joseph Neeham, F.R.S. Farewell Dinner Menu, n.d., Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
69. Excerpt from Dr. Leonard's Grimmett Diary, 1947, Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center.
70. "Pavlovaelev, Radiologfru" newsclipping, Dagens Nyheter, July 16, 1948, Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center.
71. "To Dr. L.E. Grimmett From the National Sciences Department. UNESCO." pastel print, undated, Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center. Illustration used by permission.
72. Fermi, E., E. Amaldi, O. D'Agostino, F. Rasetti, and E. Segre. 1934. Artificial radioactivity produced by neutron bombardment. *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character* 146(857):483–500.
73. McLennan, J.C., L.G. Grimmett, and J. Read. 1935a. Artificial radioactivity produced by neutrons. *Nature* 135(3404):147.
74. McLennan, J.C., L.G. Grimmett, and J. Read. 1935b. Production of radioactivity by neutrons. *Nature* 135:505.
75. Lawrence, E.O. 1934. Radioactive Sodium produced by deuton bombardment. *Physical Review* 46(8):746.
76. Brucer, M. 1990. *A Chronology of Nuclear Medicine*, 292.
77. Rotblat, J. 1935. Induced radioactivity of Nickel and Cobalt. *Nature* 136:515.
78. Sampson, M.B., L.N. Ridenour, and W. Bleakney. 1936. The isotopes of Cobalt and their radioactivity. *Physical Review* 50(4):382.
79. Risser, J.R. 1937. Neutron-induced radioactivity of long life in Cobalt. *Physical Review* 52(8):768–772.
80. Livingood, J.J., and G.T. Seaborg. 1941. Radioactive isotopes of Cobalt. *Physical Review* 60(12):913.
81. Nelson, M.E., M.L. Pool, and J.D. Kurbatov. 1942. The characteristic radiations of Co-60. *Physical Review* 62(1–2):1–3.
82. Mitchell, J.S. 1946. Applications of recent advances in nuclear physics to medicine. *British Journal of Radiology* 19(228):481–487.
83. Grimmett LG. Letter to Norah Grimmett. February 9, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
84. *The first twenty years of the University of Texas M. D. Anderson Hospital and Tumor Institute*, 24–27, 53. The University bof Texas M.D. Anderson Hospital and Tumor Institute, Houston, Texas, 1964. Illustration used by permission.
85. Notes on Grimmett from discussion with Harriet Awapara. Private communication.
86. Grimmett, L.G. Letter to Norah Grimmett. February 23, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
87. Grimmett, L.G. Letter to Norah Grimmett. March 16, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
88. Grimmett, L.G. Letter to Norah Grimmett. March 8, 1949. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center
89. Almond P. Personal Communication.
90. Grimmett, L.G. Memo entitled "Provisional 1949 Work Plan for Physics Section", February 15, 1949, Research, radiotherapy, radiation physics, proposed program, 1946–1951, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The

President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.

91. Grimmett, L.G. Memo to Clark re: additional help for physics workshop on January 23,1950, Physics Department, 1949–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
92. Physics staff department. photograph. 1950. Historical Resources Center Image Collection, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center; 1950. Illustration used by permission.
93. Cartoon from the Houston Post. April 2, 1949. Illustration used by permission.
94. Grimmett, L.G. Memo entitled "Proposals for the use of Cobalt-60 in Radiotherapy", August 12, 1949, Research, radiotherapy, radiation physics, proposed programs, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
95. Painter, T.S. Letter to William G. Pollard. June 23, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
96. Brucer, M. Letter to Clark. July 6, 1949. Grimmett, Leonard G. (Ph.D.) physicist, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library.
97. Brucer, M. Letter to Leonard Grimmett. August 12, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
98. Lough, S.A. Letter to R. Lee Clark. August 18, 1949, Research, radiotherapy, radiation physics, proposed programs, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
99. Grimmett, L.G. 1949. Composite of Grimmett's design of Cobalt-60 unit, research, radiotherapy, radiation physics, proposed program, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center. Illustration used by permission.
100. Grimmett, L.G. Notes, "A Cobalt-60 Irradiator for Cancer Treatment", February 4, 1950, Research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
101. Grimmett, L.G. Grimmett's drawing of a loading Cobalt-60 machine, research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center. Illustration used by permission.
102. Grimmett, L.G., H.D. Kerman, M. Brucer, G.H. Fletcher, and J.E. Richardson. 1952. Design and construction of multicurie Cobalt teletherapy unit. A preliminary report. *Radiology* 59:19–29.
103. Clark, R.L. Letter to Marshall Brucer. September 21, 1949, Archives, Research—radiotherapy—Cobalt 60 project—MDA and Oak Ridge, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library

104. Brucer, M. Letter to R. Lee Clark. November 8, 1949. Directors Office Records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's Office Records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
105. Clark, R.L. Letter to Marshall Brucer. November 18, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
106. Brucer, M. Letter to A. H. Holland, Jr. December 2, 1949. Archives, Research—radiotherapy—Cobalt 60 project—MDA and Oak Ridge, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library
107. Brucer, M. Letter to Paul C. Aebersold. December 2, 1949. Research—radiotherapy—Cobalt 60 project—MDA and Oak Ridge, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library
108. Brucer, M. Letter to Leonard Grimmett. December 2, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
109. Report of meeting held December 20, 1949, Concerning muticurie Cobalt 60 sources. December 20, 1949. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
110. Joint proposal to the Atomic Energy Commission by the Medical Division of the Oak Ridge Institute of Nuclear Studies and the University of Texas Postgraduate School of Medicine M. D. Anderson Hospital for Cancer Research. 1950. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
111. Grimmett, L.G. Memo to Clark re: estimated cost of materials required for the fabrication of the head of the Cobalt-60 irradiator (excluding suspension mechanism and control panel) on January 25, 1950. MDACC Archives.
112. *The first twenty years of the University of Texas M. D. Anderson Hospital and Tumor Institute*, 24. The University of Texas M.D. Anderson Hospital and Tumor Institute, Houston, Texas, 1964.
113. Fletcher, G., and L.G. Grimmett. Report on a mission to Washington, D.C. to attend a meeting on Cobalt-60, called by the Atomic Energy Commission. February 12–14, 1950. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
114. Attendants Roster for a meeting on multicurie Cobalt 60 teletherapy sources. February 13, 1950. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
115. Grimmett, L.G. Notes on a Meeting Called by the U.S. Atomic Energy Commission, Oak Ridge National Laboratory for the discussion of a Cobalt-60 irradiator. February 13, 1950. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
116. Grimmett, L.G. Effects of Washington meeting on the design for Cobalt-60 unit. 1950. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.

117. Macon, N.D. 1976. *Clark and the Anderson: A personal profile*, 195. Houston, TX: The Texas Medical Center Houston.
118. Grimmett, L.G. 1950. The use of Cobalt-60 in medicine. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
119. Photo of mockup. 1950. MDACC Archives.
120. Grimmett, L.G. 1950. 1000-Curie Cobalt-60 irradiator. *Texas Reports on Biology and Medicine* Winter Issue (Oct–Dec).
121. Grimmett, L.G., and G.H. Fletcher. 1953. A 1000-Curie Cobalt-60 irradiator. *Acta Union Internationale Contre Le Cancer* IX(1):43–47.
122. Grimmett, L.G. Letter to W. Binks. August 9, 1949. Radiation Physics Departmental Archives, The University of Texs M. D. Anderson Cancer Center
123. Contract agreement between Oak Ridge Institute of Nuclear Studies and the University of Texas. July 1950. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
124. *The first twenty years of the University of Texas M. D. Anderson Hospital and Tumor Institute*, 66. The University of Texas M.D. Anderson Hospital and Tumor Institute, Houston, Texas, 1964.
125. *The first twenty years of the University of Texas M. D. Anderson Hospital and Tumor Institute*, 67. The University of Texas M.D. Anderson Hospital and Tumor Institute, Houston, Texas, 1964.
126. The University of Texas M.D. Anderson groundbreaking. photograph. 1950. Historical Resources Center Image Collection, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center. Illustration used by permission.
127. General Electronic X-Ray Corporation. Letter to Leonard Grimmett. March 27, 1951. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
128. Grimmett, L.G. Report on mission to Milwaukee, Chicago and Binghamton. 4–9 April 1951. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center 1951.
129. Figure 7. Photograph of the Control Cabinet. Oak Ridge Institute of Nuclear Studies. Quarterly Report (July 1–Sept 30, 1953). 1953.
130. Kerman, H. 1994. Personal communication. 25th Annual radiation oncology clinical research seminar. Early history of the development of Cobalt teletherapy units.
131. Freundlich, H.F., J.L. Haybittle, and R.S. Quick. 1950. Radio-Iridium teletherapy. *Acta Radiologica* 34:115–134.
132. Freundlich, H.F., and J.L. Haybittle. 1953. An improved Iridium-192 teletherapy unit. *Acta Radiologica* 39:231–241.
133. Grimmett, L.G. Letter to Dr. Jasper Richardson on January 25, 1951. From MDACC Radiation Physics Departmental Archives.
134. Grimmett, L.G. Letter to Dr. Jasper Richardson on March 19, 1951. From MDACC Radiation Physics Departmental Archives.
135. Grimmett, L.G. Letter to Dr. Jasper Richardson on April 26, 1951. From MDACC Radiation Physics Departmental Archives.
136. Cobalt 60 therapy.*Newsweek*, May 28, 1951.
137. Doctor Grimmett, Cancer expert, dies suddenly. *Houston Chronicle*, May 28, 1951.

138. Trout, E.D. Letter to R. Lee Clark. June 20, 1951. Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
139. Cobalt-60 unit. photograph. undated. Historical Resources Center Image Collection, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
140. Grimmett's notebook cover. Peter R. Almond private collection.
141. Grimmett's notebook, flysheet. Peter R. Almond private collection.
142. Grimmett, L.G. Memo entitled "Proposals for the Educational Programme of the Physics Department". August 9, 1949. Research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
143. Grimmett, L.G. Memo to Clark. June 7, 1950. Physics Department, 1949–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
144. Grimmett, L.G. Memo entitled "Proposals for Construction of an Automatic Dose Contour Plotting Machine", August 12, 1949, Research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
145. Grimmett, L.G. Memo to Clark re: Mr. Rasmussen of Kelley-Koett Mfg. Co., September 21, 1949, Research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
146. Clark, R.L. Letter to Mr. Rasmussen, September 28, 1949, Research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
147. Grimmett, L.G. Memo to Clark re: Physicist-technician for isotope work, May 22, 1951, Physics Department, 1949–1956, Directors Office Records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's Office Records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
148. Grimmett, L.G. Memo to Clark in December 1950 and reply from Clark to Grimmett from MDACC archives radiotherapy—radiation physics (proposed programs)—research 1950–1951; 1948–1949, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library
149. Grimmett, L.G. 1950. Report on some measurements made on a westinghouse "Autoflex" diagnostic set. From MDACC Radiation Physics Department Archives.
150. Scintillation detector and ovoids. photograph. undated. Historical Resources Center Image Collection, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center. Illustration used by permission.
151. Grimmett, L.G. Memo to Clark re: money for developing a wavelength independent film, July 6, 1950, Research, radiotherapy, radiation physics, proposed program, 1946–1951, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.

152. Fricke, H., and S. Morse. 1927. The chemical action of Roentgen rays on dilute ferrous sulfate solutions as a measure of dose. *American Journal of Roentgenology* 18:430–432.
153. Shalek, R.J., and C.E. Smith. 1969. Chemical dosimetry for the measurement of high energy photons and electrons. *Annals of the New York Academy of Sciences* 161(1):44–62.
154. Oddie, T.H. 1950. Results of uptake and excretion tests with radio-iodine. *British Journal of Radiology* 23(270):348–354.
155. van Roojen, J. 1937. Radiating surfaces. *British Journal of Radiology* 10(117): 650–676 (1 Sept 1937).
156. Grimmett, L.G. Memo to Clark re: Substandard weekly calibration of the x-ray machines, June 21, 1949, Radiation therapy, Department 1948–1956, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library.
157. Grimmett, L.G. Letter to Scheer of Instrumentfirma Gustaf Rose on May 2, 1949. From MDACC Radiation Physics Department Archives.
158. Grimmett, L.G. Letter to Lauriston S. Taylor at the National Bureau of Standards on July 13, 1949. From MDACC Radiation Physics Department Archives.
159. Grimmett, L.G. Letter to Binks at the National Physical Laboratory on August 9, 1949. From MDACC Radiation Physics Department Archives.
160. Notes on Conference with Dr. Fletcher, January 20,1951, Radiation therapy, Department 1948–1956, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library.
161. Fletcher, G. Memo to Grimmett re: Calibration of therapy machines on April 4, 1950. From MDACC Radiation Physics Department Archives.
162. Grimmett, L.G. Memo to Fletcher re: Calibration of X-ray machines on April 5, 1950. From MDACC Radiation Physics Department Archives.
163. Heflebower, R.C. Memo to Fletcher re: responsibilities and roles of radiotherapy and physics, September 15, 1950, Research, radiotherapy, radiation physics, proposed program, 1946–1951, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
164. Fletcher, G. Memo to Grimmett re: Metal Ovoids, April 26, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956 6, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
165. Fletcher, G. Memo to Grimmett re: Treatment Chair and Adjustment of Light Localizer, May 2, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956 6, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
166. Fletcher, G. Memo to Grimmett re: Justification of the use of the share of the Institutional Grant of the American Cancer Society given to combined projects—radiology and physics, May 3, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
167. Fletcher, G. Memo to Heflebower re: Checking of the light localizer of maxitron 250, May 7, 1951, Research, radiotherapy, radiation physics, proposed program, 1949, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.

168. Grimmett, L.G. Handwritten note to Mrs. Rita Hendley, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's Office Records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
169. Fletcher, G. Memo to Grimmett re: Weekly calibration of the Maxitron, May 14, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
170. Fletcher, G. Memo to Clark re: Maxitron, May 15, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956 6, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
171. Shepley, T. Private Communication.
172. Grimmett, L.G. Memo to Fletcher re: 250 KV Maxitron, May 15, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
173. Fletcher, G. Memo to Clark re: Chronological order of events on Maxitron Light Localizer, May 15, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
174. Fletcher, G. Memo to Clark re: Standard procedures in the new therapy machines, May 16, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
175. Welman, G.A. Letter to Fletcher, May 16, 1951, Radiation therapy, Department 1948–1956, John P. McGovern Historical Collections and Research Center, Houston Academy of Medicine-Texas Medical Center Library.
176. Fletcher, G. Memo to Clark re: 250 KV Maxitron, May 21, 1951, Radiology Department (diagnostic radiology and radiotherapy), 1948–1956, Directors office records: Ernst Bertner and R. Lee Clark, 1941–1975, The President's office records, 1941–1975, Historical Resources Center, Research Medical Library, The University of Texas M. D. Anderson Cancer Center.
177. Grimmett, L.G., G.H. Fletcher, and E.B. Moore. 1954. An improved light localizer for X-ray therapy. *Radiology* 62(4):589–593.
178. Grigg, E.R.N. 1965. *The trail of the invisible light*, 302. Springfield, IL: Charles C Thomas
179. Cormack, D., and P. Munro. 1999. Cobalt-60: A Canadian perspective part 1: The development of kilocurie sources. *Canadian Medical Physics Newsletter* 45(1):10–14.
180. Ibid. 1999. Part 2: The saskatoon story. *Canadian Medical Physics Newsletter* 45(2): 38–41.
181. Munro, P. 1999. Cobalt-60: A Canadian perspective part 3: London, Ontario and the "peacetime bomb". *Canadian Medical Physics Newsletter* 45(3):64–69.
182. Litt, P. 2000. *Isotopes and innovation MDS Nordion's first fifty years, 1946–1996*. Montreal: McGill-Queens University Press.
183. Neil, R.H., W.E. Costolow, and O.N. Meland. 1953. Design and construction of a simple applicator for 1000 Curies of Cobalt 60. *Radiology* 61:408–410.
184. Grigg, E.R.N. 1965. *The trail of the invisible light*, 307–308. Springfield: Charles C Thomas.
185. Heppenheimer, T.A. 2006. How to detect an atomic bomb. *American Heritage of Invention and Technology* 21:44–51.

186. The Lewis L Strauss Page. http://www.smokershistory.com/Strauss.htm.
187. Livingood, J.J., and G.T. Seaborg. 1938. Long-lived radio Cobalt isotopes. Letters to the editor. *Physical Review* 53(10):847–848.
188. P.R. Almond's personal recollection of Fletcher's remarks at his retirement dinner 1984.
189. Johns, H.E., L.M. Bates, E.R. Epp, et al. 1951. 1,000-Curie Cobalt-60 units for radiation therapy. *Nature* 168(4285):1035–1036.
190. Kerman, H.D, and J.T. Ling. 1955. Supervoltage radiation therapy: The University of Lousiville-Louisville General Hospital Cobalt-60 unit. *The Journal of the Kentucky State Medical Association* 1061–1065.
191. Grigg, E.R.N. 1965. *The trail of the invisible light*, 307. Springfield, IL:Charles C Thomas
192. Grigg, E.R.N. 1965. *The trail of the invisible light*, 313. Springfield, IL:Charles C Thomas.
193. Fletcher, G.H. 1980. *Textbook of radiotherapy*, 3rd ed. Philadelphia: Lea and Febiger.
194. Chairman of the Medical Division, Oak Ridge Institute of Nuclear Studies Under contract with the United States Atomic Energy Commission. 1954. A standard Cobalt 60 teletherapy source capsule. *British Journal of Radiology* 27(319):410–412.
195. Cohen, L., T.E. Schultheiss, and R.C. Kennaugh. 1995. A radiation overdose incident: Initial data. *International Journal of Radiation Oncology Biology Physics* 33(1):217–224.
196. Ministerio de Energia y Minas. Comsion Nacional de Seguridad Nuclear y Salvaguardias. Accidente de contaminacion con 60Co. CNSN-IT-001. Mexico 1984.
197. Dr. Leonard Grimmett's Diary, 1947, Leonard Grimmett papers, 1923, 1945–1950, 1944, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center.
198. United Nations Scientific Committee on the Effects if Atomic Radiation (UNSCEAR). Survey of Medical Usage and Exposures. Radiotherapy Equipment worldwide (1991–1996).
199. Private Communication from P. Grochowska, International Atomic Energy Agency, Vienna. Directory of Radiotherapy Centers (DIRAC), 2012.
200. Morton, J.L., A.C. Barnes, G.W. Callendine Jr, and W.G. Myers. 1951. Individualized interstitial irradiation of cancer of the uterine cervix using Cobalt 60 in needles, inserted through a lucite template; a progress report. *American Journal of Roentgenology and Radium Therapy* 65(5):737–748.
201. Yordy, J.S., P.R. Almond, and L. Delclos. 2012. Development of the M. D. Anderson Cancer Center gynecologic applicators for the treatment of cervical cancer: historical analysis. *International Journal of Radiation Oncology Biology Physics* 82(4):1445–1453 (Mar 15).
202. Almond, P.R., P.J. Biggs, B.M. Coursey, et al. 1999. AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams. *Medical Physics* 26(9):1847–1870.
203. Roberts, J.E. 1999. *Meandering in medical physics: A personal account of hospital physics*, 16. Bristol, Pa.: Institute of Physics Pub.
204. Physicist Grimmett is successful musician also. *Houston Chronicle*, 1951.
205. "A Private Recital of Piano Music Presented by Leonard G. Grimmett", January 30, 1951. Leonard Grimmett papers, 1923, 1945–1950, 1964, Historical Resources Center, The University of Texas M.D. Anderson Cancer Center; 1951.
206. Glasstone, S. 1956. Sourcebook on Atomic Energy. St. Martin's Street, London: Macmillan and Co. Limited.

Index

P. R. Almond, *Cobalt Blues*, DOI: 10.1007/978-1-4614-4924-9,